NASA/RSA Joint Specifications Standards Document for the ISS Russian Segment

International Space Station Program

June 30, 2009
Revision B

National Aeronautics and
Space Administration
International Space Station Program
Johnson Space Center

Houston, Texas

~~Russian Space Agency~~Roscosmos

Moscow, Russia

REVISION AND HISTORY PAGE

REV.	DESCRIPTION	PUB. DATE
-	Initial Release (Reference per SSCD 000300, EFF. 6/8/96	03-06-98
A	Revision A per SSCD 003349 Eff. 07/21/00 TIM #20 Revision, July 1997 Update Sections 3.2, 9.9.1.1.9, 9.9.1.1.11, 9.9.1.1.12, 9.9.1.2.1.4, 9.9.1.3.1.5, 9.9.1.3.1.6, 9.9.1.3.1.10, 9.9.1.3.2.4 (TIM #21 Protocol) Replace Sections 6.6.1.1.1, 6.6.1.1.2, and 6.6.1.1.3 (NDC-001A) Delete TBRs from section 6.4.5.3 (NDC-004) Update Sections 9.9.1.2.1.6 and 9.9.1.3.2.9 to remove TBRs (NDC-005) Revise Section 3.3.3 to reflect External Contamination team Protocol (NDC-006) Correct Editorial Errors in Sections 6.5.1.1 and 6.5.1.2 (NDC-007) Change Section 3.1 to Reserved since requirements exist in Section 3.2.6.1.1, Thermal Environment, Russian Segment Specification, SSP 41163 (NDC-008) Update Sections 7.1.4.5.3 and 7.1.4.8.4 to reflect TIM #22 Team 8A.1 Protocol (NDC-009) Modify Sections 6.6.2 to reflect new ISSP Common Standards SSP 50313 (NDC-010B) Update Section 6.4.7.4.9 to reflect Protocol by EVA Working Group Mini-TIM (NDC-012) To reflect TIM #23 Protocol by Flight Crew Support Team Sections 6.4.7 and 6.4.7.2.3 (NDC-013) Remove TBR to reflect status change of SSP50253 Section 6.4.7.2.3 (NDC-016) Clean-Up translation path requirements Section 6.3.1.1 (NDC-018) Replace TBD in Section 6.5.3 with Crew Radiation Safety requirements (NDC-014) Update Thermal Control System Fluid Standards Section 4.2.3 (NDC-017) Add new Corona Requirement Section 3.4.9 (NDC-003) To add TBR in Section 13 (NDC-025)	08-08-00
B	Revision B per SSCD XXXXXX Eff. xx/xx/09 This revision incorporates the following NDCs: NDC-020, NDC-021, NDC-022, NDC-023, NDC-026, NDC-027, NDC-028, NDC-030. and NDC-031.	TBD

INTERNATIONAL SPACE STATION ~~ALPHA~~ PROGRAM
NASA/RSA JOINT SPECIFICATIONS/STANDARDS DOCUMENT FOR THE ISS~~A~~ RUSSIAN SEGMENT
June 30, 2009

PREFACE

SSP 50094 (NASA/RSA Joint Specifications/Standards Document for the ISSA Russian Segment) applies to the Russian Segment of the ISSA. This document is under control of the Space Station Control Board (SSCB) with the concurrence of the respective International Partners. Any changes or revision requires approval by the SSCB and RSA.

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INTERNATIONAL SPACE STATION ~~ALPHA~~ PROGRAM
NASA/RSA JOINT SPECIFICATIONS/STANDARDS DOCUMENT FOR THE ISS~~A~~ RUSSIAN SEGMENT

June 30, 2009

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INTERNATIONAL SPACE STATION PROGRAM

NASA/RSA JOINT SPECIFICATIONS

STANDARS DOCUMENT FOR THE ISS RUSSIAN SEGMENT

JUNE 30, 2009

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INTERNATIONAL SPACE STATION PROGRAM
NASA/RSA JOINT SPECIFICATIONS/STANDARDS DOCUMENT FOR THE ISSA RUSSIAN SEGMENT

LIST OF CHANGES

June 30, 2009

All changes to paragraphs, tables, and figures in this document are shown below:

SSCB ENTRY DATE PARAGRAPH TITLE

NDC	Date	Paragraph	TITLE
020	6/30/2009	7.1.4.8.4	TRANSMISSIBILITY REQUIREMENTS FOR IR & UV
021		3.4	ELECTROMAGNETIC COMPATIBILITY AND POWER
		3.4.1.2.3	PULSE INTERFERENCE
		3.4.1.3	CHARACTERISTICS OF DISTRIBUTED 28 VOLT POWER
		3.4.1.3.1	VOLTAGE RANGE
		3.4.1.3.2	OUTLET CURRENT CAPABILITIES (RATINGS)
		3.4.1.3.3	RIPPLE AND NOISE
		3.4.1.3.4	TRANSIENTS
		3.4.1.3.5	GROUNDING AND ISOLATION
		3.4.1.3.6	OVERCURRENT PROTECTION, WILL TRIP LIMITS
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		3.4.1.3.8	SYSTEM SOURCE IMPEDANCE AT OUTLET INTERFACE
		3.4.1.4	CONSTRAINTS ON ELECTRICAL LOADS
		3.4.1.4.1	STEADY STATE INPUT CURRENT
		3.4.1.4.2	INRUSH AND SURGE CURRENTS
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		3.4.1.5.3	INPUT POWER CONNECTIONS BETWEEN LOADS AND CABLES
023		10.1.2	NITROGEN TETROXIDE
026		6.4.7.2	IVA LABELING
		6.4.7.2.1	DESIGN REQUIREMENTS
		6.4.7.2.1.1	COMPONENTS OF LABELING
027		3.3.3.2	MOLECULAR DEPOSITION
028		3.4.1.1.1	LOW-FREQUENCY CONDUCTIVE INTERFERENCE
		3.4.1.1.2	CONDUCTIVE RADIO FREQUENCY INTERFERENCE
		3.4.1.1.3	INTENSITY OF THE ELECTRICAL FIELD OF RADIATED RADIO FREQUENCY INTERFERENCE
		3.4.1.2.1	LOW-FREQUENCY CONDUCTED INTERFERENCE
		3.4.1.2.2	CONDUCTIVE RADIO FREQUENCY

NDC	Date	Appendix	TITLE
031		D	PARALLEL INJECTION TEST SET-UP FOR EQUIPMENT USING THE USOS PRIMARY OR SECONDARY POWER

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1 INTRODUCTION

1.1 PURPOSE ~~&~~AND SCOPE

The purpose of this document is to define the minimum set of specifications and standards to be used by Russian Space Agency (RSA) on the Russian Segment (RS) of the International Space Station ~~Alpha~~ (ISS~~A~~). The scope of the document includes those specifications and standards that were agreed to by National Aeronautics and Space Administration (NASA) and RSA.

1.2 APPLICABILITY

RSA shall apply these requirements to the ~~Russian Segment~~RS of the ISS~~A~~ and is responsible for flowing the requirements down to the lowest level necessary.

1.3 PRECEDENCE

In the event of conflict between the contents of this document (SSP 50094, NASA/RSA Joint Specifications/Standards Document for the ISS~~A~~ ~~Russian Segment~~RS) and SSP 41163, Russian Segment Specification, the requirements in SSP 41163 shall take precedence.

2 APPLICABLE DOCUMENTS ~~LIST~~

2.1 ~~STATE~~ SPECIFICATIONS AND STANDARDS

2.1.1 RUSSIAN STANDARDS

2.1.1.1 STATE STANDARDS

GOST 9.005-72	Unified System for Corrosion and Aging Protection (USCAP). Machines, instruments and other technical articles. Allowable and not allowable contacts for metals. General requirements.
GOST 9.048-89	Unified System for Corrosion and Aging Protection (USCAP). Technical articles. Methods of Laboratory Testing for resistance to Molding Fungi exposure.
GOST 9.049-91	Unified System for Corrosion and Aging Protection (USCAP). Polymer Materials. Methods of Laboratory Testing for resistance to Molding Fungi exposure.
GOST 9.050-75	Unified System for Corrosion and Aging Protection (USCAP). Lacquers and Paints Coatings. Methods of Laboratory Testing for resistance to Molding Fungi exposure.
GOST 9.303-84	Unified System for Corrosion and Aging Protection (USCAP). Metallic and Nonmetallic Inorganic Coatings. General Requirements for Selection.
GOST 9.305-84	Unified System for Corrosion and Aging Protection (USCAP). Metallic and Nonmetallic Inorganic Coatings. Technological Process for Obtaining Those Coatings.
GOST 12.020-72	Plastics, Methods to Test Plastics' Resistance to Chemical Substances.
GOST 12.1.027-80	Occupational Safety Standards System (OSSS). Noise. Determination of noise sources characteristics in reverberative premises. Technical method.
GOST 12.2.052-81	Occupational Safety Standards System (OSSS). Equipment Operating with Gaseous Oxygen. General Safety Requirements.
GOST 12.4.026-76	System of Labor Safety Standards (SLSS). Warning colors and safety signs.
GOST 19.102-77	Unified System for Program Documentation (USPD). Stages of Development.

GOST 19.301-79 Unified System for Program Documentation (USPD). Program and Methods of Testing. Requirements for Contents and Form of Presentation.

GOST 25.602-80 Calculations and strength tests. Methods of Mechanical Testing of Composite Materials with Polymer Matrix. Compression Testing at Normal, Elevated, and Low Temperatures.

GOST 26.008-85 Typefaces for engraved signs.

GOST 977-88 Steel Castings, General Specifications.

GOST 2930-62 Typefaces and signs.

GOST 3057-90 Disk springs. General technical requirements.

GOST 7512-82 Nondestructive Control of Welded Joints - Radiographic Method.

GOST 9389-75 Steel carbon spring wire. Technical requirements.

GOST 10316-78 Foiled laminated insulation and fibreglass laminate. Technical requirements.

GOST 15130-86 Optical Quartz Glass. General Technical Requirements.

GOST 18353-79 Nondestructive Testing. Classification of types and methods.

GOST 20415-82 Nondestructive Control - Acoustic Methods, General Statement

GOST 21105-87 Nondestructive Testing. Magnetic Particles Testing Method.

GOST 23751-86 Printed Circuit Boards. Main parameters. Design.

GOST 23752-79 Printed Circuit Boards. General technical requirements.

GOST 25645.115-84 Upper Earth Atmosphere. Density model for ballistic support of artificial Earth satellites flights.

GOST 25645.302-83 Ballistic calculations for artificial Earth satellites. Solar activity index calculation procedure.

GOST 27265-87 Titanium and Titanium Alloys Welding Wire.

GOST B 22027-82 Complexes….Failure investigation procedures and accomplishment organization method.

GOST B 28146-89 Semiconductor units. General technical requirements.

GOST R 50109-92 Non-metallic Materials. Method of Testing for Loss of Mass and Content of Volatile Condensable Materials in a Vacuum-Thermal Environment.

2.1.1.2 INDUSTRY STANDARDS

OST 4G0.033.200-86 Soldering fluxes and solders. Brands, composition, characteristics and field of application.

OST 92-0019-78 Methods and modes of drying the items before pressure testing.

OST 92-0021-87 Procedure for working out and application of technological process Documentation. Industrial System of Technological Preparation of Production.

OST 92-0286-80 Electric assembling process in the radio-electronic equipment fabrication. General technological requirements.

OST 92-0300-92 Industrial cleanliness. General requirements.

OST 92-0320-68 Cables. General technical requirements.

OST 92-0912-69 Parts of High Strength Carbon Steels, Alloyed and High Alloy Steels, General Requirements for Design, Manufacturing, and Corrosion Protection.

OST 92-0919-85 Ferrous Metals and Alloys Allowed for Use.

OST 92-0920-85 Nonferrous Metals and Alloys Allowed for Use.

OST 92-0948-74 Glues, Selection and Applications. Technical Requirements.

OST 92-0949-74 Glues, Typical Materials Adhesive Bonding Process.

OST 92-0966-75 Titanium Alloys, Stampings and Forgings. Technical Requirements.

OST 92-1010-77 Metals, Alloys, Metallic and Nonmetallic Inorganic coatings. Duty terms.

OST 92-1019-81 Parts of Aluminum and Magnesium Alloys. Technical Requirements.

OST 92-1020-89	Procedure for Selecting and Using Materials and Manufactured Items.
OST 92-1025-82	Steel and Heat Resistant Alloy Forgings and Stampings. Technical Requirements.
OST 92-1042-82	Radio-electronic equipment and devices. Technical and safety requirements for standard technological blocks and units assembly operations on PCBs.
OST 92-1107-79	Rules for Welders Certification.
OST 92-1114-80	Welded Assemblies. General Technical Requirements.
OST 92-1126-76	Welding Production. General Technical Requirements.
OST 92-1152-75	Welding and Brazing, Preparation of the Surface for Welding and Brazing, Treatment of Assembling Units after Brazing and Welding.
OST 92-1165-75	Castings of Aluminum Alloys Technical Requirements.
OST 92-1166-86	Castings Made from Wax Models. Technical Requirements.
OST 92-1173-87	Welded assembles. Ultrasonic Inspection methods.
OST 92-1186-81	Metal and Alloy Parts Arc Welding in Protective Inert Gasses Environment.
OST 92-1190-88	Metallic and Ceramic Braze Joints, Typical Technological Process of Brazing.
OST 92-1311-77	Parts of Steels and Alloys, Technical Requirements and Heat Treatment.
OST 92-1347-83	Electrical Discharge Machining, Process Recommendations for EDM.
OST 92-1443-87	Finishes, Metallic and Nonmetallic Inorganic, Requirements for Structural Materials.
OST 92-1467-90	Metallic and Nonmetallic Inorganic Finishes, Typical Processes of Their Application.
OST 92-1468-90	Varnish-and-paint coatings. Electronic equipment units moisture protection and electrical insulation. Standard technological processing.

OST 92-1481-79 Lacquer and Paint Finishes for Metallic Surfaces, Typical Processes.

OST 92-1611-74 Control by Exposure to Rays of Welded and Brazed Joints, Methods of Control.

OST 92-4272-86 Nondestructive Dye Penetrate Control - Methods of Control.

OST 92-4556-85 Solid Lubricant Coatings, Technical Requirements.

OST 92-5051-88 Lubricant Grades Allowed for Use in the Field of Aerospace.

OST 92-5100-89 Ground and on-board equipment. General Technical Requirements.

OST 92-5168-93 Vacuum-Shield Thermal Insulation of Rocket/Space Equipment, General Requirements for Protection from Static Electricity.

OST 92-8584-74 Cables. Mounting ~~&~~and harness fabrication, crimping and wire wrap.

OST 92-8593-74 Cables. Marking.

OST 92-8730-82 On-Board Cable Mounting Requirements.

OST 92-8768-76 Piping and containers. Color-coded identification labeling.

OST 92-8847-77 Coiled springs. Technical requirements.

OST 92-9388-80 Electronic elements pin forming to install on electronic equipment PCBs. Designing.

OST 92-9389-80 Electronic elements installation on electronic equipment PCBs Technical requirements.

OST 92-9465-81 Parts of Titanium Alloys. Technical Requirements.

OST 92-9501-81 Metallic and Nonmetallic Inorganic Finishes for Manufacturing of Instruments. Requirements for Selection.

OST 92-9661-89 Parts of Welded Assemblies of Corrosion Resistant Steels. General Requirements for Corrosion Resistance.

OST B11 073.012-87 Special integrated circuits. General technical requirements. Restriction list.

OST B11 0398-87 Integrated circuits. General technical requirements.

OST1 90060-92 Titanium Alloy Castings, Technical Requirements.

OST1 90073-85 Aluminum Alloy, Stampings and Forgings. Technical Requirements.

OST1 90122-74 Plastics, Testing for Shear Strength of the Honeycomb Core Material.

OST1 90147-74 Plastics the Testing for Modulus of Elasticity at the Shear of the Honeycomb Core.

OST1 90150-74 Plastics Strength Testing at the Tension of the Honeycomb Core.

OST1 90248-77 Castings of Magnesium, Technical Requirements.

2.1.1.3 ENTERPRISE STANDARDS AND OTHER TECHNICAL REGULATIONS

33Y.0211.003 Specification for Electrical Bonding and Grounding.

33Y.0211.005 Specification for Electrical Bonding and Grounding of Screen Vacuum Thermal Insulation.

33Y.0220.006 Pneumo-Hydraulic Systems

33Y.0221.003 Pressure Vessels. Technical requirements.

33Y.0242.010 Technical requirements for manufacturing, testing and acceptance of on-board cables.

33Y.0247.010 Technical requirements for design, manufacturing and formatting of design documentation for single-sided and double-sided Printed Circuit Boards (PCB).

33Y.0303.001 Life of Non Metallic Materials and Finishes. Technical requirements.

33Y.0336.028 Methodology of Assessment, Limit Concentration of Oxygen during Combustion of Polymeric Materials.

33Y.0342.026 Technical requirements for encapsulant 51-Г-23 usage to attach electro-radio articles (ЭРИ).

M117-472-89 Methods of Control of Semi-finished Parts and Assemblies and Eddy Current Portable Detectors

P 11760-083	Regulation on the Organization of Work to Ensure the Safety of Non-metallic Materials Usage and Procedure of Documentation of the Certificate Allowing Their Use as Components of the Products.
P 17375-082	Baseline Data for the Selection of Nonmetallic Materials Used in Habitable Pressurized Module Compartments of Products Based on their Hazard Factors. Restriction list.
STP 33-32-75	Fasteners for Main Production. Restriction List.
STP 304.408-89	Complex System for Product Quality Control (CSPQC). Failures investigations procedures at the facility.
STP 351-54-86	Organization and Implementation of Nondestructive Control at the Enterprise.
STP 351-92-80	Complex System for Product Quality Control (CSPQC). Ground equipment cable items. Restriction list.
STP 351-100-80	Complex System for Product Quality Control (CSPQC). On-board equipment and networks cable items. Restriction list.
STP 351-115-82	Complex System for Product Quality Control (CSPQC) Radio Electronic Parts for Ground Equipment. Restriction List.
STP 351-119-82	CSPQC. Radio Electronic Parts of On-board Equipment. Restriction list.
STP 351-125-85	Factory Standard - Nonmetallic Material Test Procedure. Safe application index estimation table.
STP 351-134-84	Special technical rubber sealing parts. Procedure for development and application.
STP 371-77-87	Non-metallic materials warranty documentation issue and format.
AAO.339.190 TY	"OS" index semiconductor instruments. Special addendum to General Technical Requirements GOST B28146-89.
No Doc. Number	Materials for Sanitary-Chemical and Toxicological Investigation of Nonmetallic Materials with an Evaluation of the Possibility of their Use in Hermetically Sealed Enclosures for odor and toxic off-gassing (Section 4.3.4.2.1)

2.1.2 US STANDARDS

D684-10056-1	~~ISSA~~ISS Prime Contractor Software Standards and Procedures Specification.
~~SSP 41163~~	~~Russian Segment Specification~~
~~SSP 50128~~	~~Specification of Technical Requirements for FGB~~
SSP 50253	OPS Data File Standard

2.2 REFERENCE DOCUMENTS

SSP 30219	Space Station Reference Coordinate System
SSP 30425	Space Station Program Natural Environment Definition for Design
SSP 41163	Russian Segment Specification
SSP 50005	International Space Station Flight Crew Integration Standard (NASA-STD-3000/T)
SSP 50128	Specification of Technical Requirements for FGB

2.3~~1~~ ORDER OF PRECEDENCE

In the event of a conflict between the text of this specification and the references cited herein, the text of this specification (SSP 50094) takes precedence.

3 ENVIRONMENTS

3.1 RESERVED

3.2 NEUTRAL ATMOSPHERE AND SOLAR ACTIVITY

3.2.1 SOLAR ACTIVITY

Since the beginning date of a solar cycle cannot be predicted with certainty, the ~~ISSA~~ISS will consider three start dates (solar minimum dates) for cycle 23:

July 1995	(early minimum)
August 1996	(most likely minimum)
September 1997	(late minimum)

The start date for cycle 24 is assumed to be August of 2007, 11 years after the "most likely" start date for cycle 23. These dates will be revised by mutual agreement as additional data becomes available.

3.2.1.1 RSC-ENERGIA MODEL

At the present time, the 22nd cycle of the solar activity is coming to an end. The prediction of the parameters for the next cycle at the time when the previous cycle is coming to an end is an “ultralong-term prediction” and such a prediction does not allow the use of reliable methods with high verification scores. For ultralong-term predictions of solar cycle 23, the methods of Ohl and Schovier are used. They are based on the superposition hypothesis and represent the extrapolation of the sum of components of the detected periods of solar activity into the next cycle. These periods are determined by analysis of Zurick series Wolf numbers (w) starting from the year 1749, by analysis of flux rate measurements of the solar radio radiation at the wavelength of 10.7 cm (F10.7) (starting from the year 1947) and by analysis of the geomagnetic disturbance indices - Ap (starting from the year 1932). These periods include centennial cycle (80-90 years), super centennial (600 years) and 22-year solar activity cycles. Also, the Ohl's method uses the relationship between the next cycle Wolf numbers and the average value of delay time between the maximum geomagnetic disturbance and the Wolf number maximum of the previous cycle. Such methods of ultralong-term prediction allow one to derive only the main (general) parameters of the next cycle, such as epoch, the maximum Wolf number (wm), the duration of the cycle, and the duration of its growth and decay phases. To calculate the solar activity maximum in the 23rd cycle, the smoothed value of the solar activity maximum during four 11-year cycles, including the 22nd cycle, was combined with the curve of the current centennial period and this curve was extrapolated into the 23rd cycle. During this extrapolation, the results of the centennial period curve analysis, which allows the assumption that cycle 23 will be located on the decay branch of centennial period, were considered. In accordance with extrapolation data for the decay branch of centennial period, the maximum value of Wolf number for the 23rd cycle is w_m=100 -140 or $F_{10.7}$ = 150 - 200 flux units. The relation between rate of flux of the solar radio noise at the wave length of 10.7 cm and Wolf number was taken in the form of:

$$F_{10.7} = 0.895w + 61.17.$$

The changes of the solar activity during the predicted cycle are derived based on the data of ultralong-term prediction and using methods of long-term and average-term predictions. The method of Waldmeier, which is recommended for predicting Wolf numbers within an 11-year cycle by GOST 25645.302-83 (The Calculations of Earth Ballistics Artificial Satellites. Calculation Method of Solar Activity Indices), and the regression method of Ohl were used. Besides this, to improve the quality of prediction using these methods, the following assumptions were made:

- For temporal series which have the tendency of cyclic change (for example, Wolf numbers, $F_{10.7}$ and Ap indices), the estimation of any future value, in the first approximation, is represented by the mean value of all the previous values for the same cycle phase.
- To improve the estimation quality the initial series data should be reduced to the same amplitude - to the predicted value of Wolf number maximum in the predicted cycle.

To predict the magnitude of the geomagnetic disturbance index inside the 23rd solar activity cycle, the same method as was used for solar radio noise flux rate prediction was utilized. The mean annual values of Ap index beginning from the year 1964 were used as initial data.

The extrapolation of solar activity to cycle 24 gives a lower estimate of maximum Wolf number in that cycle than in cycle 23. For preliminary long term planning of space station flight, it is suggested to accept the values of $F_{10.7}$ and Ap for cycle 24 which are analogous to the values of cycle 23 with most likely beginning in August of 1996.

3.2.1.2 NASA MODEL

Thirteen month smoothed values of the 10.7 cm solar radio noise flux (F10.7) and the Ap geomagnetic index are provided for use as input parameters to the atmosphere models in design applications where estimates of long term average thermospheric densities are needed. Reference SSP 30425, Section 4 for a discussion of thermosphere models and their inputs. Only the "maximum" profile representing a very active solar cycle is provided here, Tables 3.2.1.2-1 and -2, Figures 3.2.1.2-1 through -4. (SSP 30425 also provides "mean", and "minimum" profiles for other applications).

This profile was obtained by converting 13-month smoothed sunspot numbers from 1755 to 1947 to equivalent 10.7 cm solar radio noise flux (F10.7) using Equation 1. These data were combined with 13-month smoothed values of the measured daily F10.7 flux made since 1947 to form a continuous record through 1986 (end of cycle 21).

$$F10.7 = 49.4 + 0.97\,R_Z + 17.6\,\exp(-0.035\,R_Z) \qquad (1)$$

The duration of each solar cycle, minimum to minimum, was normalized to 11 years and divided into 132 equal intervals, each representing one month. The 21 values (one for each cycle) at each of the 132 intervals were ranked by magnitude and the highest value for each interval is the "maximum" value as listed on Table 3.2.1.2-1. The Ap profile was derived in similar fashion using a data record going back to 1932. Table 3.2.1.2-1 gives the F10.7 and Ap values for Solar Cycle 23 with each of the three start dates given in Paragraph 3.2.1. Table 3.2.1.2-2 gives the equivalent data for cycle 24 assuming a start date of August 2007, 11 years after the ~~"most likely"~~ start of cycle 23.

3.2.2 ATMOSPHERE DENSITY MODELS

Because the NASA model (~~MET~~Marshall Engineering Thermosphere model) and the Russian model (GOST 25645.115-84) concur with each other quite well, either of these models may be used for design calculations, long term planning, and ballistic calculations. Rocket Space Corporation-Energia (RSC-E) will use for its calculations the atmosphere density model from GOST 25645.115-84 at all design phases- "Density Model for Ballistics Support of Artificial Earth Satellite Flights". This standard consists of the density model, the calculation method and parameter magnitudes of Earth atmosphere density in the altitude range of 120 to 1500 km for different levels of solar activity. Also, it includes a description and text of the FORTRAN language program.

The Earth's upper atmosphere density model was built (designed) according to the data on Artificial Earth Satellites (AES) deceleration in the period from 1964 until 1982 and this model is presented in analytical form.

Atmosphere density r, (kg/m^3), is calculated by the formula:

$$r = r_n K_0 K_1 K_2 K_3 K_4$$

where:

r_n = night atmosphere density, kg/m^3
K_0 = a factor, which characterizes atmosphere density variation associated with the deviation of F_{135} from F_0;
K_1 = a factor, which takes in consideration the diurnal effect in density distribution;
K_2 = a factor, which takes in consideration the semi-annual (half year) effect;
K_3 = a factor, which characterizes the density variation associated with the deviation of F from F_{135};
K_4 = a factor, which considers the relationship between atmosphere density and geomagnetic activity.~~;~~

The coefficients of the atmosphere density model are derived based on fixed values of solar activity indices. The tables of factors were compiled for six fixed solar activity levels:

F_0 = 75, 100, 125, 150, 200, 250, (10^{-22} W/(m^2 ∑ Hz)

When atmospheric density is calculated, the magnitudes of the model coefficients for F_0 closest to F_{135} are used.

F_0 - fixed solar activity level during the study time period,
F - average diurnal value of $F_{10.7}$ index;
F_{135} - average value of $F_{10.7}$ for 135 days preceding the calculation time.
$F_{10.7}$ - solar average index equal to the Sun's radio emission flux density at wavelength 10.7 cm (on frequency 2800 MHz) expressed in solar flux units, 10^{-22} W/(m^2 ∑ Hz).

When data on solar activity indices are absent, the atmosphere density should be calculated by using predicted values of these indices or by using data averaged for the previous period. In the latter case (data averaged for the previous period) the average value of $F_{10.7}$ for the previous 30 - 50 days can be used as F, average value for the previous 135 days as F_{135}, and the value closest to F_{135} for which model coefficients exist is taken as F_0. During this, it is necessary to use prediction tables of parameter $F_{10.7}$, from paragraph 3.2.1.1 or 3.2.1.2.

Table 3.2.1.1-1 _RSC-E Feb-96 Design Atmosphere for Solar Cycle 23

		F10.7			Ap	
	Min	Nom	Max	Min	Nom	Max
Jan-96	69.87	74.25	78.83	10.75	14.55	19.10
Feb-96	70.10	73.92	78.70	9.85	12.90	17.30
Mar-96	69.95	73.99	78.30	8.73	12.25	17.35
Apr-96	69.87	74.22	77.94	8.77	12.02	16.85
May-96	70.10	74.39	76.11	8.93	11.92	16.45
Jun-96	69.95	74.30	75.71	9.23	11.50	14.43
Jul-96	70.45	73.93	75.87	9.00	11.28	13.82
Aug-96	70.84	73.30	75.72	8.33	10.44	12.95
Sep-96	70.99	73.44	75.90	7.10	9.30	11.57
Oct-96	70.55	73.55	76.10	7.00	9.64	12.88
Nov-96	70.61	73.75	75.63	7.25	9.73	12.75
Dec-96	71.01	73.92	75.88	7.68	10.08	13.53
Jan-97	71.24	74.08	75.75	7.57	10.47	14.85
Feb-97	71.69	74.13	76.83	7.07	10.69	16.05
Mar-97	71.93	74.10	77.97	6.93	11.02	17.10
Apr-97	72.04	73.99	79.62	7.30	11.68	17.35
May-97	72.48	74.85	81.13	8.27	12.45	18.08
Jun-97	72.07	75.84	82.83	8.15	11.81	16.48
Jul-97	71.99	77.20	84.67	7.70	11.12	15.45
Aug-97	72.62	78.40	87.40	7.35	10.58	15.23
Sep-97	73.52	79.93	90.01	6.78	10.02	13.75
Oct-97	74.64	81.38	92.65	7.15	10.07	13.55
Nov-97	75.52	83.55	95.40	8.63	11.26	14.13
Dec-97	76.93	85.61	99.71	10.30	12.37	14.20
Jan-98	78.00	87.71	103.87	7.40	10.73	15.60
Feb-98	79.59	90.11	109.58	7.70	9.59	13.20
Mar-98	81.12	93.52	114.70	7.26	9.50	13.30
Apr-98	82.66	96.81	120.86	7.29	9.52	12.68
May-98	84.82	101.34	125.43	6.86	10.54	13.80
Jun-98	87.33	105.39	129.89	7.22	11.31	13.90
Jul-98	89.76	110.26	133.84	8.20	11.88	13.49
Aug-98	93.09	113.88	139.10	8.16	12.18	15.47
Sep-98	96.08	117.41	144.08	9.06	12.47	16.22
Oct-98	99.67	120.54	149.38	9.22	12.91	16.95
Nov-98	102.34	124.71	155.36	9.72	13.82	18.47
Dec-98	104.93	128.65	160.76	10.73	15.33	19.07
Jan-99	107.24	132.84	164.55	11.00	15.93	20.49
Feb-99	110.31	137.57	169.12	10.52	15.80	21.39
Mar-99	113.21	141.85	171.68	9.77	14.79	20.15
Apr-99	116.30	144.85	176.06	10.07	14.37	20.65
May-99	119.79	148.47	177.86	10.25	13.69	19.10
Jun-99	122.94	150.50	181.92	10.35	13.12	17.15
Jul-99	125.15	153.97	185.13	10.35	13.96	19.32
Aug-99	127.82	155.39	188.02	9.85	13.27	17.22
Sep-99	129.31	158.60	191.25	9.35	13.74	17.35
		~~F10.7~~			~~Ap~~	
	~~Min~~	~~Nom~~	~~Max~~	~~Min~~	~~Nom~~	~~Max~~
Nov-99	132.92	163.43	190.89	11.23	17.25	19.66
Dec-99	135.28	165.99	189.20	11.45	18.75	21.70
Jan-00	137.16	165.77	190.97	11.61	18.32	21.02
Feb-00	138.85	165.71	190.89	11.93	18.52	21.48

	F10.7 Min	F10.7 Nom	F10.7 Max	Ap Min	Ap Nom	Ap Max
Mar-00	140.73	164.37	189.20	11.28	15.16	18.51
Apr-00	138.16	162.50	186.84	11.56	14.88	18.26
May-00	138.06	162.36	186.67	12.35	16.87	24.54
Jun-00	138.20	162.56	186.92	12.00	16.66	23.53
Jul-00	139.53	164.37	189.20	11.57	17.58	25.08
Aug-00	139.14	163.83	188.53	10.68	16.73	24.35
Sep-00	138.64	163.16	187.67	9.85	14.68	18.11
Oct-00	138.35	162.76	187.18	10.05	16.13	21.92
Nov-00	137.05	160.99	184.94	9.50	16.56	23.23
Dec-00	137.01	160.94	184.87	9.35	16.87	22.42
Jan-01	136.92	160.82	184.72	9.27	16.91	22.36
Feb-01	137.67	161.84	186.01	9.82	15.96	19.68
Mar-01	139.26	164.00	188.74	10.68	15.72	19.66
Apr-01	139.58	164.43	189.28	11.05	15.50	19.42
May-01	139.66	164.54	189.42	10.52	14.94	19.68
Jun-01	139.96	164.94	189.93	9.20	14.08	18.69
Jul-01	139.95	164.93	189.91	8.45	12.52	15.86
Aug-01	140.61	165.83	191.05	9.20	11.95	16.02
Sep-01	141.89	167.57	193.24	9.38	11.56	15.59
Oct-01	142.69	168.52	194.45	9.88	11.99	17.80
Nov-01	141.71	169.35	195.50	9.57	14.07	19.42
Dec-01	142.47	168.34	194.22	8.18	14.96	21.94
Jan-02	141.72	168.65	194.45	7.70	16.15	22.98
Feb-02	140.19	167.32	195.50	8.10	17.87	21.19
Mar-02	137.99	168.36	194.22	10.30	19.12	23.69
Apr-02	134.76	167.33	194.61	10.75	19.69	21.97
May-02	131.17	165.25	192.94	11.68	20.17	23.26
Jun-02	128.33	162.27	194.24	13.43	20.51	24.76
Jul-02	124.88	157.89	192.95	12.88	19.91	22.70
Aug-02	123.16	153.02	190.32	13.13	18.65	22.62
Sep-02	120.68	149.16	186.55	13.48	17.79	20.47
Oct-02	118.68	144.47	181.02	11.82	17.73	22.79
Nov-02	114.23	142.15	174.86	10.70	16.28	21.94
Dec-02	111.18	138.78	169.99	11.27	18.24	27.23
Jan-03	109.10	136.07	164.07	11.30	19.25	28.49
Feb-03	107.84	130.03	161.13	11.17	17.72	25.72
Mar-03	107.80	125.88	156.88	12.70	18.60	28.69
Apr-03	107.25	123.06	153.45	12.98	17.35	23.61
May-03	106.15	121.35	145.83	12.32	18.40	27.28
Jun-03	105.82	121.29	140.59	11.40	18.87	29.93
Jul-03	104.72	120.56	137.02	9.85	19.05	30.54
Aug-03	103.41	119.07	134.87	9.68	19.25	31.07
Sep-03	101.70	118.62	134.79	10.27	17.35	26.02
Oct-03	100.93	117.12	133.86	11.00	17.03	24.59
	~~Min~~	~~F10.7 Nom~~	~~Max~~	~~Min~~	~~Ap Nom~~	~~Max~~
Nov-03	100.68	115.35	131.98	11.30	16.74	22.26
Dec-03	99.91	113.03	131.41	11.23	16.63	22.38
Jan-04	99.21	111.98	129.52	10.80	16.71	23.98
Feb-04	97.49	111.64	127.28	11.18	15.68	21.23
Mar-04	96.02	110.59	124.35	11.40	14.85	21.60
Apr-04	94.88	109.64	123.03	10.75	13.60	19.68
May-04	93.41	107.30	122.60	11.38	13.47	17.78
Jun-04	91.79	105.31	121.27	10.27	13.56	18.18

	F10.7			Ap		
	Min	Nom	Max	Min	Nom	Max
Jul-04	90.07	103.76	120.07	10.02	14.29	18.05
Aug-04	88.58	101.77	117.12	10.77	14.67	17.65
Sep-04	87.16	99.57	114.61	9.29	14.08	17.38
Oct-04	85.65	97.24	112.65	10.01	15.12	17.25
Nov-04	83.93	95.21	110.14	9.66	14.77	16.48
Dec-04	82.49	93.28	107.36	9.96	16.61	19.38
Jan-05	81.17	91.24	104.41	10.00	18.02	21.08
Feb-05	79.81	88.90	101.85	9.98	17.71	23.25
Mar-05	78.92	86.95	99.41	11.07	18.09	25.42
Apr-05	77.93	85.16	96.82	11.54	16.43	23.09
May-05	77.50	83.31	93.88	14.16	16.63	23.94
Jun-05	77.29	82.11	91.41	14.48	17.55	23.46
Jul-05	77.04	80.76	89.14	14.30	16.97	21.19
Aug-05	77.26	80.18	86.82	13.82	17.09	21.40
Sep-05	76.52	79.89	85.30	12.37	16.27	20.10
Oct-05	76.45	79.55	83.59	11.50	14.40	18.02
Nov-05	77.02	79.86	82.85	10.47	13.44	15.70
Dec-05	77.46	78.86	82.50	9.60	13.59	16.52
Jan-06	77.45	78.75	82.06	8.85	13.34	15.98
Feb-06	77.24	79.53	82.45	9.57	13.63	17.77
Mar-06	76.95	80.12	81.19	10.74	14.27	20.25
Apr-06	76.24	80.10	81.06	11.32	13.69	19.42
May-06	76.09	79.82	82.04	12.39	14.49	22.39
Jun-06	76.12	79.43	82.78	13.12	15.20	22.71
Jul-06	75.70	78.56	82.76	13.10	15.12	22.24
Aug-06	75.73	78.37	82.41	12.66	15.23	23.59
Sep-06	75.64	78.42	81.91	12.41	15.19	22.95
Oct-06	75.70	77.86	80.88	11.89	15.79	23.85
Nov-06	75.73	77.92	80.65	11.91	15.81	22.88
Dec-06	75.64	77.83	80.72	11.07	15.43	20.92

Table 3.2.1.2-1 NASA Design Profiles for Solar Cycle- 23

Date	Early F10.7	Ap	–Most Likely F10.7	Ap	Late F10.7	Ap
Jul-1995	73.3	11.5				
Aug-1995	73.4	11.7				
Sep-1995	74.0	11.8				
Oct-1995	74.5	11.9				
Nov-1995	74.9	11.9				
Dec-1995	76.2	12.2				
Jan-1996	78.4	12.5				
Feb-1996	79.8	12.9				
Mar-1996	81.5	13.3				
Apr-1996	84.1	14.1				
May-1996	87.7	15.1				
Jun-1996	93.4	15.7				
Jul-1996	97.9	15.9				
Aug-1996	101.7	16.4	73.3	11.5		
Sep-1996	107.7	17.4	73.4	11.7		
Oct-1996	114.5	18.4	74.0	11.8		
Nov-1996	121.1	18.7	74.5	11.9		
Dec-1996	129.1	18.8	74.9	11.9		
Jan-1997	137.6	18.6	76.2	12.2		
Feb-1997	143.4	18.3	78.4	12.5		
Mar-1997	147.6	18.1	79.8	12.9		
Apr-1997	151.7	18.4	81.5	13.3		
May-1997	155.7	18.4	84.1	14.1		
Jun-1997	160.1	17.6	87.7	15.1		
Jul-1997	164.8	17.1	93.4	15.7		
Aug-1997	169.1	17.4	97.9	15.9		
Sep-1997	173.0	17.4	101.7	16.4	73.3	11.5
Oct-1997	177.1	18.5	107.7	17.4	73.4	11.7
Nov-1997	186.1	19.9	114.5	18.4	74.0	11.8
Dec-1997	191.5	19.9	121.1	18.7	74.5	11.9
Jan-1998	194.3	19.9	129.1	18.8	74.9	11.9
Feb-1998	196.9	20.1	137.6	18.6	76.2	12.2
Mar-1998	199.6	20.4	143.4	18.3	78.4	12.5
Apr-1998	204.2	20.8	147.6	18.1	79.8	12.9
May-1998	210.6	20.9	151.7	18.4	81.5	13.3
Jun-1998	214.8	21.0	155.7	18.4	84.1	14.1
Jul-1998	217.2	21.2	160.1	17.6	87.7	15.1
Oct-1998	229.9	22.2	173.0	17.4	101.7	16.4
Nov-1998	231.7	21.0	177.1	18.5	107.7	17.4
Dec-1998	233.7	20.1	186.1	19.9	114.5	18.4
Jan-1999	235.6	19.8	191.5	19.9	121.1	18.7
Feb-1999	238.8	19.3	194.3	19.9	129.1	18.8
Mar-1999	242.8	19.2	196.9	20.1	137.6	18.6
	~~Early~~		~~–Most Likely~~		~~Late~~	
~~Date~~	~~F10.7~~	~~Ap~~	~~F10.7~~	~~Ap~~	~~F10.7~~	~~Ap~~

Date	Early F10.7	Ap	–Most Likely F10.7	Ap	Late F10.7	Ap
Jun-1999	243.3	18.6	210.6	20.9	151.7	18.4
Jul-1999	244.7	18.6	214.8	21.0	155.7	18.4
Aug-1999	245.7	18.3	217.2	21.2	160.1	17.6
Sep-1999	243.3	18.2	221.6	21.6	164.8	17.1
Oct-1999	239.4	18.7	226.9	22.1	169.1	17.4
Nov-1999	235.0	19.2	229.9	22.2	173.0	17.4
Dec-1999	232.9	19.6	231.7	21.0	177.1	18.5
Jan-2000	233.3	20.3	233.7	20.1	186.1	19.9
Feb-2000	233.1	21.0	235.6	19.8	191.5	19.9
Mar-2000	231.2	21.4	238.8	19.3	194.3	19.9
Apr-2000	229.1	21.2	242.8	19.2	196.9	20.1
May-2000	228.1	20.4	245.2	19.0	199.6	20.4
Jun-2000	227.6	20.7	244.5	18.8	204.2	20.8
Jul-2000	226.7	21.9	243.3	18.6	210.6	20.9
Aug-2000	225.6	22.7	244.7	18.6	214.8	21.0
Sep-2000	223.0	22.7	245.7	18.3	217.2	21.2
Oct-2000	218.6	22.3	243.3	18.2	221.6	21.6
Nov-2000	215.2	21.7	239.4	18.7	226.9	22.1
Dec-2000	212.0	21.5	235.0	19.2	229.9	22.2
Jan-2001	206.9	22.1	232.9	19.6	231.7	21.0
Feb-2001	204.0	23.1	233.3	20.3	233.7	20.1
Mar-2001	203.6	23.5	233.1	21.0	235.6	19.8
Apr-2001	200.4	23.4	231.2	21.4	238.8	19.3
May-2001	196.8	23.3	229.1	21.2	242.8	19.2
Jun-2001	195.7	23.1	228.1	20.4	245.2	19.0
Jul-2001	194.8	22.2	227.6	20.7	244.5	18.8
Aug-2001	191.5	22.1	226.7	21.9	243.3	18.6
Sep-2001	187.4	22.2	225.6	22.7	244.7	18.6
Oct-2001	182.9	22.5	223.0	22.7	245.7	18.3
Nov-2001	178.6	22.6	218.6	22.3	243.3	18.2
Dec-2001	176.3	22.5	215.2	21.7	239.4	18.7
Jan-2002	174.9	21.6	212.0	21.5	235.0	19.2
Apr-2002	158.1	21.6	203.6	23.5	233.1	21.0
May-2002	154.4	22.2	200.4	23.4	231.2	21.4
Jun-2002	152.7	22.0	196.8	23.3	229.1	21.2
Jul-2002	150.8	22.0	195.7	23.1	228.1	20.4
Aug-2002	148.1	22.2	194.8	22.2	227.6	20.7
Sep-2002	145.0	22.5	191.5	22.1	226.7	21.9
Oct-2002	141.1	22.8	187.4	22.2	225.6	22.7
Nov-2002	137.0	23.5	182.9	22.5	223.0	22.7
Dec-2002	132.4	24.2	178.6	22.6	218.6	22.3
Jan-2003	125.4	24.7	176.3	22.5	215.2	21.7
Feb-2003	119.5	25.0	174.9	21.6	212.0	21.5
Mar-2003	118.4	24.9	171.1	21.0	206.9	22.1
Apr-2003	118.7	24.5	164.5	21.1	204.0	23.1
May-2003	119.4	23.6	158.1	21.6	203.6	23.5
	~~Early~~		~~–Most Likely~~		~~Late~~	
~~Date~~	~~F10.7~~	~~Ap~~	~~F10.7~~	~~Ap~~	~~F10.7~~	~~Ap~~

Date	Early F10.7	Ap	–Most Likely F10.7	Ap	Late F10.7	Ap
Aug-2003	117.7	21.8	150.8	22.0	195.7	23.1
Sep-2003	116.4	21.4	148.1	22.2	194.8	22.2
Oct-2003	114.6	21.1	145.0	22.5	191.5	22.1
Nov-2003	110.8	20.5	141.1	22.8	187.4	22.2
Dec-2003	105.4	19.7	137.0	23.5	182.9	22.5
Jan-2004	103.2	19.7	132.4	24.2	178.6	22.6
Feb-2004	102.0	19.8	125.4	24.7	176.3	22.5
Mar-2004	100.4	19.5	119.5	25.0	174.9	21.6
Apr-2004	98.2	19.1	118.4	24.9	171.1	21.0
May-2004	96.6	18.6	118.7	24.5	164.5	21.1
Jun-2004	94.6	17.9	119.4	23.6	158.1	21.6
Jul-2004	93.8	17.0	119.8	22.8	154.4	22.2
Aug-2004	92.7	16.5	119.0	22.1	152.7	22.0
Sep-2004	92.0	16.7	117.7	21.8	150.8	22.0
Oct-2004	91.8	16.9	116.4	21.4	148.1	22.2
Nov-2004	91.4	17.1	114.6	21.1	145.0	22.5
Dec-2004	90.8	17.4	110.8	20.5	141.1	22.8
Jan-2005	90.1	17.7	105.4	19.7	137.0	23.5
Feb-2005	89.1	17.6	103.2	19.7	132.4	24.2
Mar-2005	88.2	17.4	102.0	19.8	125.4	24.7
Apr-2005	87.0	16.9	100.4	19.5	119.5	25.0
May-2005	85.4	16.1	98.2	19.1	118.4	24.9
Jun-2005	83.2	14.7	96.6	18.6	118.7	24.5
Jul-2005	80.5	13.6	94.6	17.9	119.4	23.6
Oct-2005	77.1	13.0	92.0	16.7	117.7	21.8
Nov-2005	76.9	12.7	91.8	16.9	116.4	21.4
Dec-2005	76.7	12.4	91.4	17.1	114.6	21.1
Jan-2006	76.5	11.7	90.8	17.4	110.8	20.5
Feb-2006	76.2	11.2	90.1	17.7	105.4	19.7
Mar-2006	75.2	11.0	89.1	17.6	103.2	19.7
Apr-2006	74.2	10.9	88.2	17.4	102.0	19.8
May-2006	74.0	11.1	87.0	16.9	100.4	19.5
Jun-2006	73.5	11.4	85.4	16.1	98.2	19.1
Jul-2006			83.2	14.7	96.6	18.6
Aug-2006			80.5	13.6	94.6	17.9
Sep-2006			78.5	13.7	93.8	17.0
Oct-2006			77.6	13.4	92.7	16.5
Nov-2006			77.1	13.0	92.0	16.7
Dec-2006			76.9	12.7	91.8	16.9
Jan-2007			76.7	12.4	91.4	17.1
Feb-2007			76.5	11.7	90.8	17.4
Mar-2007			76.2	11.2	90.1	17.7
Apr-2007			75.2	11.0	89.1	17.6
May-2007			74.2	10.9	88.2	17.4
Jun-2007			74.0	11.1	87.0	16.9
Jul-2007			73.5	11.4	85.4	16.1
	~~Early~~		~~–Most Likely~~		~~Late~~	
~~Date~~	~~F10.7~~	~~Ap~~	~~F10.7~~	~~Ap~~	~~F10.7~~	~~Ap~~

Date	Early F10.7	Ap	–Most Likely F10.7	Ap	Late F10.7	Ap
Oct-2007					78.5	13.7
Nov-2007					77.6	13.4
Dec-2007					77.1	13.0
Jan-2008					76.9	12.7
Feb-2008					76.7	12.4
Mar-2008					76.5	11.7
Apr-2008					76.2	11.2
May-2008					75.2	11.0
Jun-2008					74.2	10.9
Jul-2008					74.0	11.1
Aug-2008					73.5	11.4

Table 3.2.1.2-2 NASA- Design -Profiles for Solar Cycle- 24

Date	F10.7	Ap
Aug-2007	73.3	11.5
Sep-2007	73.4	11.7
Oct-2007	74.0	11.8
Nov-2007	74.5	11.9
Dec-2007	74.9	11.9
Jan-2008	76.2	12.2
Feb-2008	78.4	12.5
Mar-2008	79.8	12.9
Apr-2008	81.5	13.3
May-2008	84.1	14.1
Jun-2008	87.7	15.1
Jul-2008	93.4	15.7
Aug-2008	97.9	15.9
Sep-2008	101.7	16.4
Oct-2008	107.7	17.4
Nov-2008	114.5	18.4
Dec-2008	121.1	18.7
Jan-2009	129.1	18.8
Feb-2009	137.6	18.6
Mar-2009	143.4	18.3
Apr-2009	147.6	18.1
May-2009	151.7	18.4
Jun-2009	155.7	18.4
Jul-2009	160.1	17.6
Aug-2009	164.8	17.1
Sep-2009	169.1	17.4
Oct-2009	173.0	17.4
Nov-2009	177.1	18.5
Dec-2009	186.1	19.9
Jan-2010	191.5	19.9
Feb-2010	194.3	19.9
Mar-2010	196.9	20.1
Apr-2010	199.6	20.4
May-2010	204.2	20.8
Jun-2010	210.6	20.9
Jul-2010	214.8	21.0
Aug-2010	217.2	21.2
Sep-2010	221.6	21.6
Oct-2010	226.9	22.1
Dec-2010	231.7	21.0
Jan-2011	233.7	20.1
Feb-2011	235.6	19.8
Mar-2011	238.8	19.3
Apr-2011	242.8	19.2
May-2011	245.2	19.0
Date	F10.7	Ap

Date	F10.7	Ap
Jul-2011	243.3	18.6
Aug-2011	244.7	18.6
Sep-2011	245.7	18.3
Oct-2011	243.3	18.2
Nov-2011	239.4	18.7
Dec-2011	235.0	19.2
Jan-2012	232.9	19.6
Feb-2012	233.3	20.3
Mar-2012	233.1	21.0
Apr-2012	231.2	21.4
May-2012	229.1	21.2
Jun-2012	228.1	20.4
Jul-2012	227.6	20.7
Aug-2012	226.7	21.9
Sep-2012	225.6	22.7
Oct-2012	223.0	22.7
Nov-2012	218.6	22.3
Dec-2012	215.2	21.7
Jan-2013	212.0	21.5
Feb-2013	206.9	22.1
Mar-2013	204.0	23.1
Apr-2013	203.6	23.5
May-2013	200.4	23.4
Jun-2013	196.8	23.3
Jul-2013	195.7	23.1
Aug-2013	194.8	22.2
Sep-2013	191.5	22.1
Oct-2013	187.4	22.2
Nov-2013	182.9	22.5
Dec-2013	178.6	22.6
Jan-2014	176.3	22.5
Feb-2014	174.9	21.6
Mar-2014	171.1	21.0
Apr-2014	164.5	21.1
May-2014	158.1	21.6
Jul-2014	152.7	22.0
Aug-2014	150.8	22.0
Sep-2014	148.1	22.2
Oct-2014	145.0	22.5
Nov-2014	141.1	22.8
Dec-2014	137.0	23.5
Jan-2015	132.4	24.2
Feb-2015	125.4	24.7
Mar-2015	119.5	25.0
Apr-2015	118.4	24.9
May-2015	118.7	24.5
Jun-2015	119.4	23.6
Jul-2015	119.8	22.8
~~Date~~	~~F10.7~~	~~Ap~~
Sep-2015	117.7	21.8

Date	F10.7	Ap
Oct-2015	116.4	21.4
Nov-2015	114.6	21.1
Dec-2015	110.8	20.5
Jan-2016	105.4	19.7
Feb-2016	103.2	19.7
Mar-2016	102.0	19.8
Apr-2016	100.4	19.5
May-2016	98.2	19.1
Jun-2016	96.6	18.6
Jul-2016	94.6	17.9
Aug-2016	93.8	17.0
Sep-2016	92.7	16.5
Oct-2016	92.0	16.7
Nov-2016	91.8	16.9
Dec-2016	91.4	17.1
Jan-2017	90.8	17.4
Feb-2017	90.1	17.7
Mar-2017	89.1	17.6
Apr-2017	88.2	17.4
May-2017	87.0	16.9
Jun-2017	85.4	16.1
Jul-2017	83.2	14.7
Aug-2017	80.5	13.6
Sep-2017	78.5	13.7
Oct-2017	77.6	13.4
Nov-2017	77.1	13.0
Dec-2017	76.9	12.7
Jan-2018	76.7	12.4
Feb-2018	76.5	11.7
Mar-2018	76.2	11.2
Apr-2018	75.2	11.0
May-2018	74.2	10.9
Jun-2018	74.0	11.1
Jul-2018	73.5	11.4

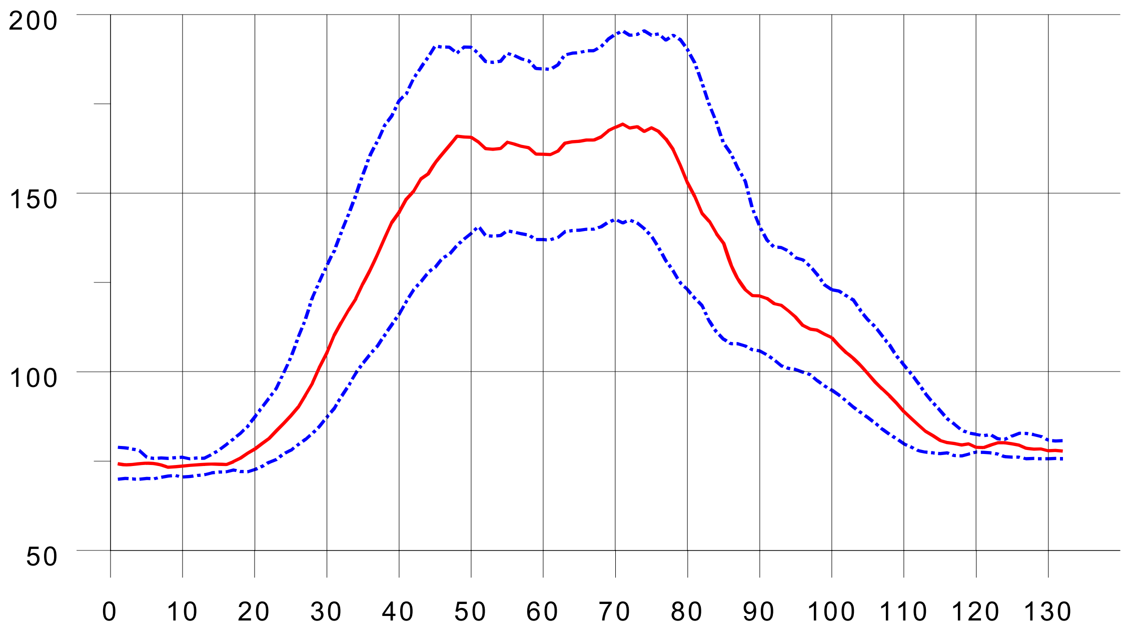

Figure 3.2.1.1-1 _RSA Feb-96 Design Atmosphere Profile for Solar Cycle 23: 13 Month Smoothed F10.7.

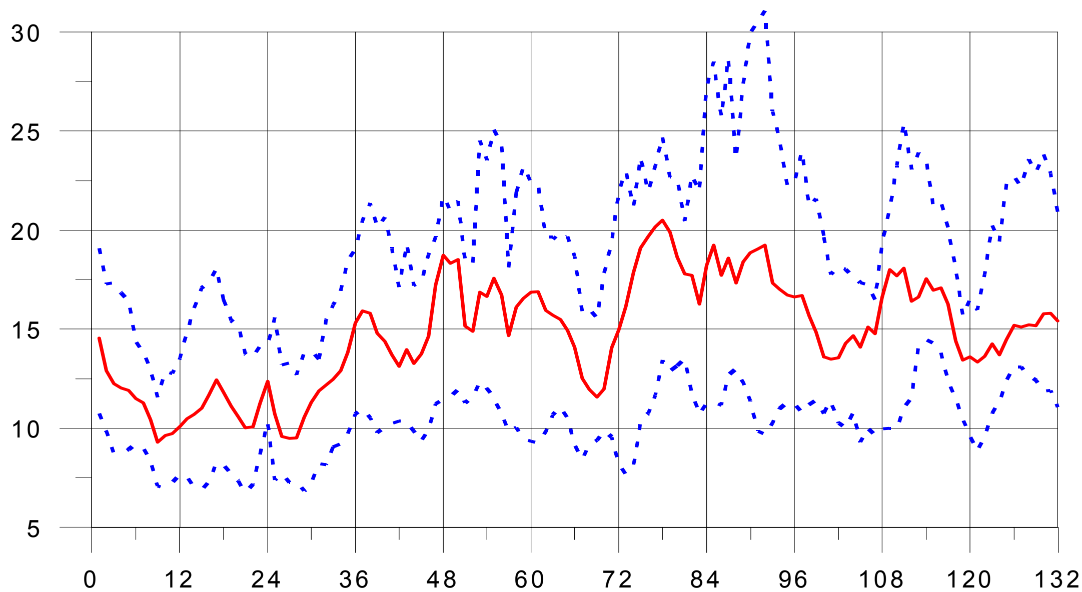

Figure 3.2.1.1-2: _RSA Feb-96 Design Atmosphere Profile for Solar Cycle 23: Geomagnetic Index

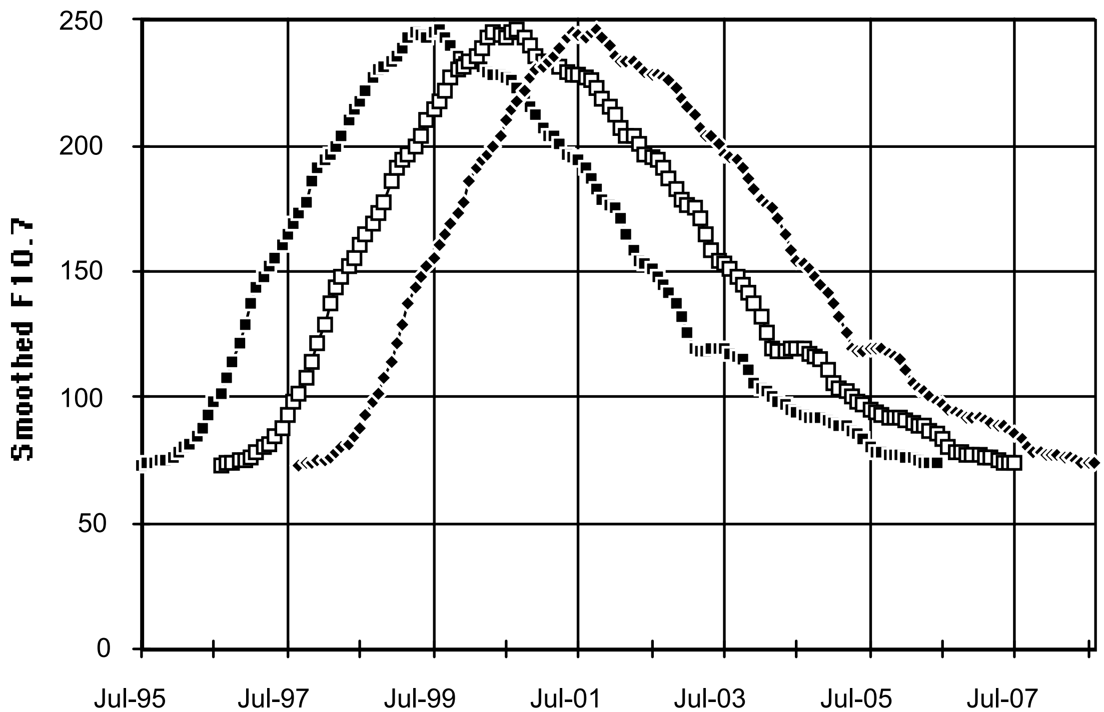

Figure ~~Figure~~ 3.2.1.2-1 _NASA Design Profiles for Solar Cycle 23; F10.7 Assuming Early, Most Likely, and Late Start Dates

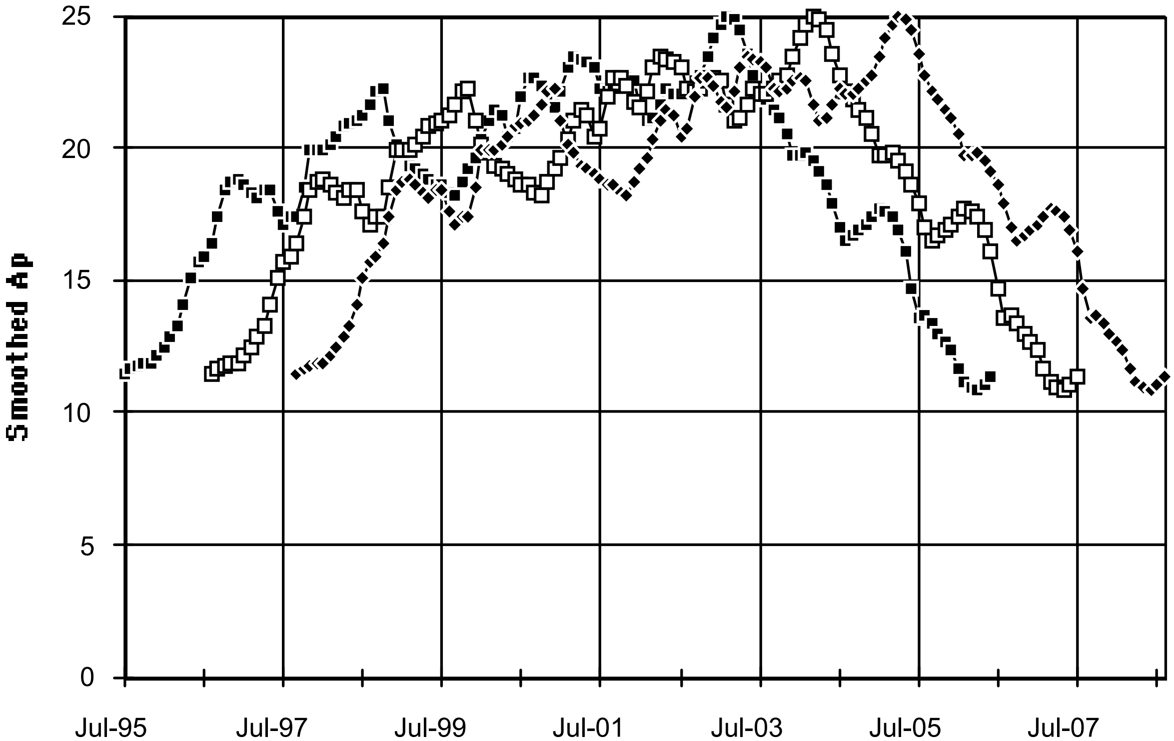

Figure 3.2.1.2-2 _NASA Design Profiles for Solar Cycle 23; Geomagnetic Index, Ap, Assuming Early, Most Likely, and Late Start Dates

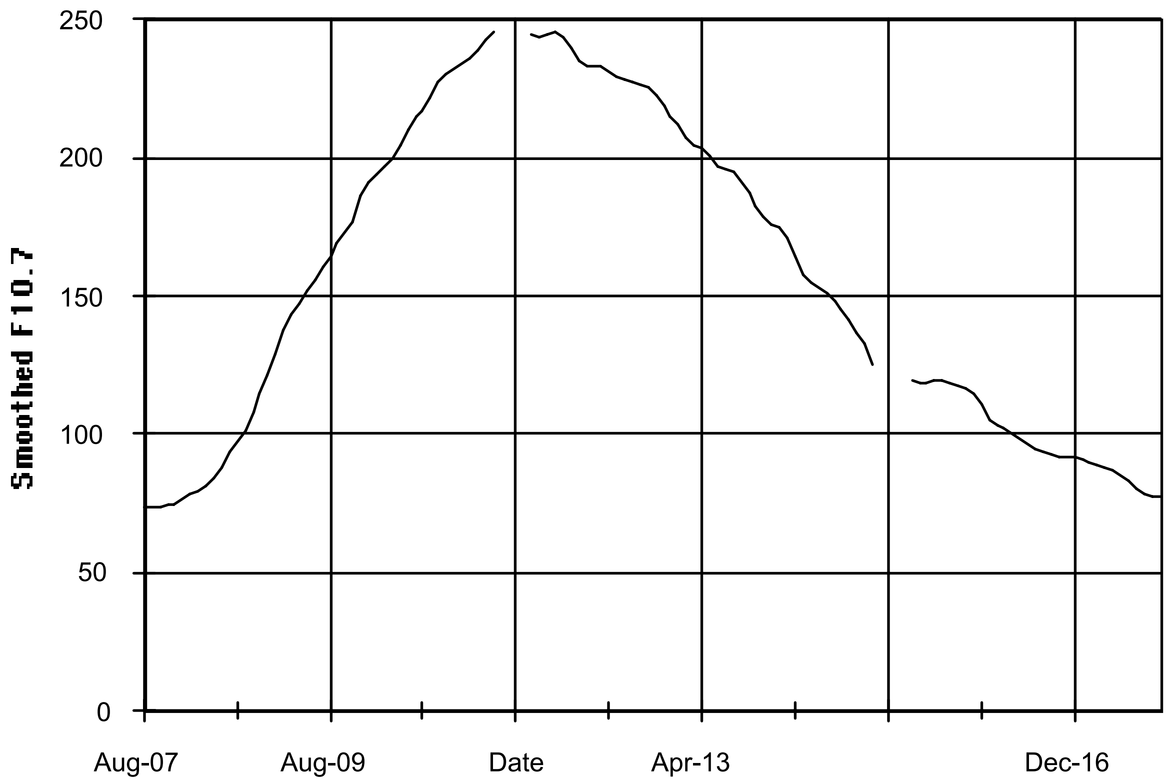

Figure 3.2.1.2-3 _NASA Design Profile for Solar Cycle 24; F10.7 Assuming a Most Likely Start Date of August 2007

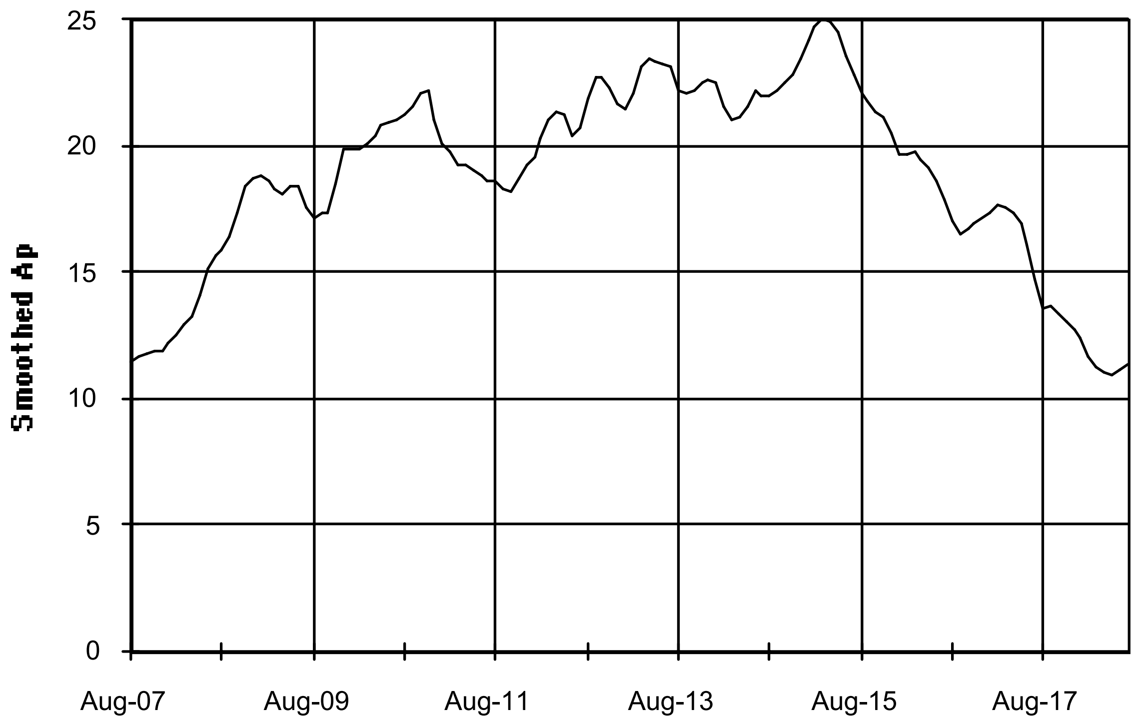

Figure 3.2.1.2-4 NASA Design Profile for Solar Cycle 24; Geomagnetic Index, Ap, Assuming a Most Likely Start Date of August, 2007

3.3 EXTERNAL CONTAMINATION

3.3.1 AMBIENT/SURFACE INTERACTIONS

As the Space Station moves through the Earth's rarefied environment, a ram-wake effect is created, i.e., density build-up preceding forward facing surfaces and a density decrease on aft facing surfaces. Build-up on surfaces that have some exposure to ram can be as high as approximately 60 times the ambient density. Instrument and Space Station hardware which are sensitive to such density shall be carefully located relative to large surfaces to preclude interferences. A change in the composition of the surface local environment can be expected due to either reaction with the surface or recombination occurring on or near these surfaces.

3.3.2 THERMAL/CHEMICAL REQUIREMENTS

In cases where molecular contamination condenses on surfaces with temperature which vary considerably, particularly below 300K, calculations for surface deposition shall take into account the entire orbital temperature cycle, characteristics of the deposit, and effects of the environmental factors on the deposits. Specifically, the balance of the re-evaporation/sublimation (cleaning), and deposition during each time step of the orbital temperature cycle shall be calculated and averaged over time. Additionally, removal of deposits by atomic oxygen shall be calculated for deposits that are reactive. Ultraviolet fixing effects on deposits which may enhance the deposition rate and potentially the sticking characteristics of the contaminants on the surface shall also be taken into account.

3.3.3 QUIESCENT PERIODS

3.3.3.1 MOLECULAR COLUMN DENSITY

Reserved

3.3.3.2 MOLECULAR DEPOSITION

External materials that have surface areas greater than 3 square meters shall be tested for their quasi-stationary outgassing rate characteristics. The test shall be long duration (minimum 5 days) in nature. The sample temperature shall be the working temperature of the material. The testing procedure for measuring the material outgassing rates shall be the Russian equivalent to U.S. ASTM E 1559.

~~The effective outgassing rates for the FGB shall not exceed the values given in Table 3.3.3.2-1. The effective rates for the Service Module shall not exceed the values given in Table 3.3.3.2-2. The effective outgassing rates shall be based upon the actual external (vacuum exposed) materials, their area usage and working temperatures.~~The condensable outgassing rates for each Russian element shall not exceed the values given in Tables 3.3.3.2-1 through 3.3.3.2-6. The condensable outgassing rates shall be based upon the actual external (vacuum exposed) materials, their area usage and working temperatures.

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Table 3.3.3.2-1 Effective Outgassing Rates: FGB

Material	Condensable Outgassing Rate (gm/cm^2/sec)	Sample/Receiver Temperature (°C)	Area Ratio (Area of Material/ Total Surface Area)	Effective Condensable Outgassing Rate (gm/cm^2/sec)
AK-573	5.0•10^{-13}	+35/-42	$\frac{20}{137.4^*} = 0.15$	7.3•10^{-14}
BF-4 Impregnated Mesh	1.8•10^{-14} **	+50/-50	$\frac{137.4}{137.4^*} = 1.0$	1.8•10^{-14}
KO-5191	2.5•10^{-11}	+30/-43	$\frac{5}{152} = 0.033$	8.2•10^{-13}
PArML Cable Wrap	9.6•10^{-14} **	+50/-50	$\frac{61}{152} = 0.4$	3.9•10^{-14}
AK-512	3.0•10^{-14}	+75/-40	$\frac{162}{152} = 1.07$	3.2•10^{-14}
EP-140	2.0•10^{-13}	+50/-40	$\frac{11.5}{152} = 0.076$	1.5•10^{-14}

* Note: 137.4 m^2 is the area of the solar arrays.
** Note: BF-4 impregnated mesh and PArML outgassing rates are 2.5 year projections based on Russian test data.

Table 3.3.3.2-2 Effective Outgassing Rates: Service Module

Material	Condensable Outgassing Rate (gm/cm^2/sec)	Sample/Receiver Temperature (°C)	Area Ratio (Area of Material/ Total Surface Area)	Effective Condensable Outgassing Rate (gm/cm^2/sec)
AK-573	5.0•10^{-13}	+35/-42	$\frac{20}{184^*} = 0.11$	5.4•10^{-14}
BF-4	2.3•10^{-14} **	+50/-50	$\frac{184}{184^*} = 1.0$	2.3•10^{-14}
KO-5191	2.5•10^{-11}	+30/-43	$\frac{2.5}{150} = 0.017$	4.2•10^{-13}
EP-140	2.0•10^{-13}	+50/-40	$\frac{11.1}{150} = 0.074$	1.5•10^{-14}
AK-512	3.0•10^{-14}	+75/-40	$\frac{63}{150} = 0.42$	1.3•10^{-14}

* Note: 184 m^2 is the area of the solar arrays.
** Note: BF-4 impregnated mesh outgassing rate is a 2 year projection based on Russian test data.

Table 3.3.3.2-3 Condensable Outgassing Rates: Progress

Material	Condensable Outgassing Rate (gm/cm^2/sec)	Sample/Receiver Test Temperature (°C)	Surface Area (m^2)
TCOH Black Glass Fabric and EVTI MLI	1.0×10^{-14}	+75/-10	53
Cables (Teflon coated glass fabric over LT-19 tape wrap)	2.0×10^{-11} 2.0×10^{-13} 1.0×10^{-14} 4.0×10^{-13} 5.0×10^{-14}	+50/-42 +50/-10 +50/+25 +25/-40 +25/-10	30
AK-512 (Cargo Module)	5.0×10^{-14}	+75/-20	14.66
KO-5191 (Instrument Module)	3.8×10^{-12} (1) 4.4×10^{-14} (1)	+30/-43 +31/-10	0.44
TP-CO-3 (Instrument Module)	$<1.0 \times 10^{-14}$	+75/-10	9.3
Kirza Fabric	TBD	TBD	3
VE-30 Paint	TBD	TBD	3.65
E3-100 Glass Fabric	1.0×10^{-14}	+75/-10	64
Metallized Glass Cloth	$<1.00 \times 10^{-13}$ 4.87×10^{-12} 1.45×10^{-12}	+50/+20 +50/-10 +50/-40	10
AK-512 (Solar Array Frames)	5.0×10^{-14}	+75/-20	10.4 (4 m^2 on cell side, 6 m^2 on mesh side)
BF-4 impregnated mesh (Solar Array - Cell Support)	3.3×10^{-13} (2)	+70/-43	11
Solar cells	2.0×10^{-14}	Note (3)	11

Notes:

(1) KO-5151 outgassing rate is an annual average based on a 6 month on-orbit residence time. This projection is based on U.S. test data.

(2) BF-4 impregnated mesh outgassing rate is an annual average based on a 6 month on-orbit residence time. This projection is based on Russian test data.

(3) Not tested, assumed similar to U.S. cells

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Table 3.3.3.2-4 Condensable Outgassing Rates: Soyuz

Material	Condensable Outgassing Rate (gm/cm²/sec)	Sample/Receiver Test Temperature (°C)	Surface Area (m²)
TCOH Black Glass Fabric and EVTI MLI	$1.0x10^{-14}$	+75/-10	36.3
Cables (Teflon coated glass fabric over LT-19 tape wrap)	$2.0x10^{-11}$ $2.0x10^{-13}$ $1.0x10^{-14}$ $4.0x10^{-13}$ $5.0x10^{-14}$	+50/-42 +50/-10 +50/+25 +25/-40 +25/-10	30
AK-512 (Orbital Module)	$5.0x10^{-14}$	+75/-20	2.9
FT Ablative Layer Location: sides (Descent Module)	$3.97x10^{-13}$ $3.31x10^{-13}$	+50/-40 +50/-10	8
TSP-F Ablative Layer Location: sides (Descent Module)	$1.32x10^{-12}$ $1.13x10^{-12}$	+50/-40 +50/-10	2
PKT-PK-FL Ablative Layer Location: bottom (Descent Module)	$6.22x10^{-13}$ $4.98x10^{-13}$	+50/-40 +50/-10	3.8
T-13 Fabric for multi-layer insulation (Descent Module)	$7.40x10^{-12}$ $1.28x10^{-12}$ $1.00x10^{-13}$	+50/-40 +50/-10 +50/+20	30
KO-5191 (Instrument Module)	$3.8x10^{-12}$ (1) $4.4x10^{-14}$ (1)	+30/-43 +31/-10	0.44
TP-CO-3 (Instrument Module)	$\leq 1.0x10^{-14}$	+75/-10	8.8
E3-100 Glass Fabric	$1.0x10^{-14}$	+75/-10	6
Metallized Glass Cloth	$1.45x10^{-12}$ $4.87x10^{-12}$ $\leq 1.00x10^{-13}$	+50/-40 +50/-10 +50/+20	10
Kir-A Black Cotton Fabric (cut during Descent Module Separation)	TBD	TBD	3
VE 30 Paint (applied to mounting brackets)	TBD	TBD	3.2
AK-512 (Solar Array Frames)	$5.0x10^{-14}$	+75/-20	10.4 (4 m² on cell side, 6 m² on mesh side)
BF-4 impregnated mesh (Solar Array - Cell Support)	$3.3x10^{-13}$ (2)	+70/-43	11
Solar cells	$2.0x10^{-14}$	Note (3)	11

Notes:

(1) KO-5151 outgassing rate is an annual average based on a 6 month on-orbit residence time. This projection is based on U.S. test data.

(2) BF-4 impregnated mesh outgassing rate is an annual average based on a 6 month on-orbit residence time. This projection is based on Russian test data.

(3) Not tested, assumed similar to U.S. cells

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Table 3.3.3.2-5 Condensable Outgassing Rates: Docking Compartment 1

Material	Condensable Outgassing Rate (gm/cm²/sec)	Sample/Receiver Test Temperature (°C)	Surface Area (m²)
TCOH White Glass Fabric	$1.0x10^{-14}$	+75/-10	22
EVTI MLI (Mylar/Kapton)	$1.0x10^{-14}$	+75/-10	23.5
E3-100 Glass Fabric	$1.0x10^{-14}$	+75/-10	69
KT-11 Silicate Fabric (baked at 600º C)	Estimated at $\leq 1.0x10^{-14}$	Note (1)	3.5
Cables (Teflon coated glass fabric over LT-19 tape wrap)	$2.0x10^{-11}$ $2.0x10^{-13}$ $1.0x10^{-14}$ $4.0x10^{-13}$ $5.0x10^{-14}$	+50/-42 +50/-10 +50/+25 +25/-40 +25/-10	6.5
Anodized coating on handrails	$< 1.0x10^{-14}$	+75/-10	6.17

Notes:
(1) Not tested

Table 3.3.3.2-6 Condensable Outgassing Rates: Service Module Conformal Shield

Material	Condensable Outgassing Rate (gm/cm²/sec)	Sample/Receiver Test Temperature (°C)	Surface Area (m²)
KACT-B glass fabric reinforced composite	$2.86x10^{-11}$ (120 hrs.) $6.14x10^{-12}$ (120 hrs.) $2.00x10^{-14}$ (120 hrs.)	+50/-40 +50/-10 +50/+20	4.8 (1)
8353/11-98 synthetic fabric	$2.63x10^{-11}$ (120 hrs.) $5.71x10^{-12}$ (120 hrs.) $2.00x10^{-14}$ (120 hrs.)	+50/-40 +50/-10 +50/+20	25.6 (1)

Notes:
(1) 23 conformal shield panels, each with 23 layers of 8353 fabric.

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3.3.4 NONQUIESCENT PERIODS

3.3.4.1 MOLECULAR COLUMN DENSITY

Reserved

3.3.4.2 MOLECULAR DEPOSITION

Reserved

3.3.5 VACUUM AND VENTING

3.3.5.1 MATERIALS

All materials used on external surfaces or used in hardware which will be exposed to space vacuum shall have low outgassing characteristics as defined by GOST-R-50109-92. All materials used in airlocks and laboratory vacuum chambers that will be vented to space shall be selected on the basis of low outgassing rates defined above.

3.3.5.2 VENTING AND DUMPING

All vents that are venting and dumping from this exterior of the RS shall have mass flux rates less than $6.45 \times 10^{-4} \sqrt{MT}$ (grams/sec) where M is the molecular weight and T is the temperature in Kelvin for continuously operating venting.

Note: This paragraph is not applicable to the Functional Cargo Block (FGB).

3.4 ELECTROMAGNETIC COMPATIBILITY AND POWER

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Compatibility shall be demonstrated between system/subsystems within the ~~Russian segment~~RS and across the functional interfaces with the required safety margin.

3.4.1 REQUIREMENTS FOR EQUIPMENT USING THE RUSSIAN ORBITAL SEGMENT 28V POWER SUPPLY

3.4.1.1 REQUIREMENTS FOR ELECTROMAGNETIC INTERFERENCE PRODUCED BY EQUIPMENT

Radio-electronic, electronic, electrical, and electromechanical equipment and electrical power sources shall not produce electromagnetic interference in excess of the requirements contained in this section with respect to the voltage of periodic interference in supply circuits, and also the intensity of the electrical field.:

3.4.1.1.1 LOW-FREQUENCY CONDUCTIVE INTERFERENCE

A. The ~~effective~~ peak values of the voltage of low-frequency interference in ±28V supply circuits shall not exceed the values given in Figure 3.4.1.1.1-1. Interference measurements should be carried out following the model shown in Figure 3.4.1.1.1-2, using the equivalent network or Line Impedance Stabilization Network (LISN) shown in Figure 3.4.1.1.1-3.

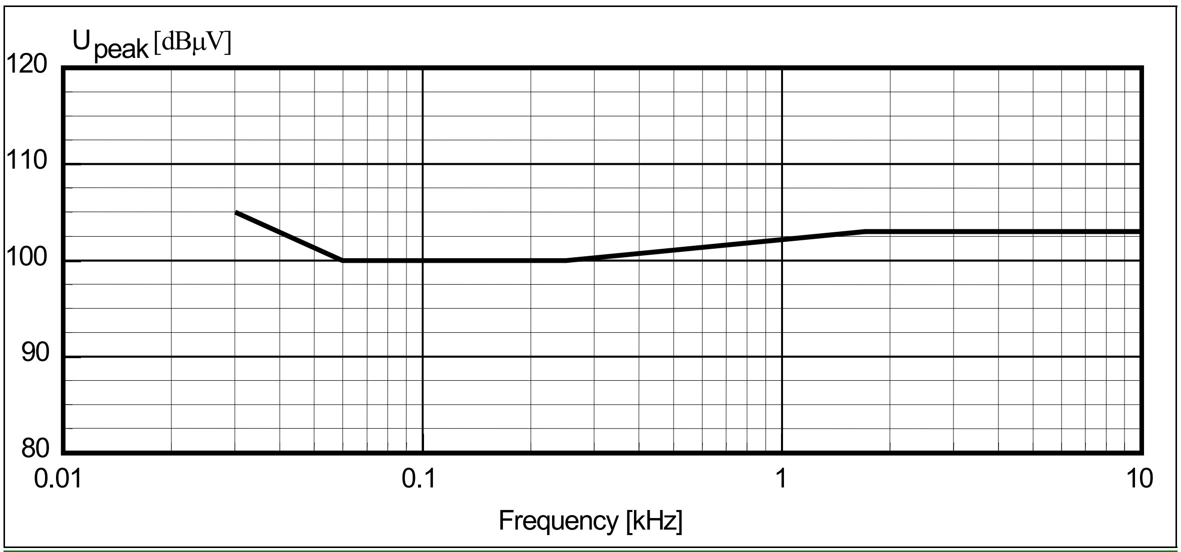
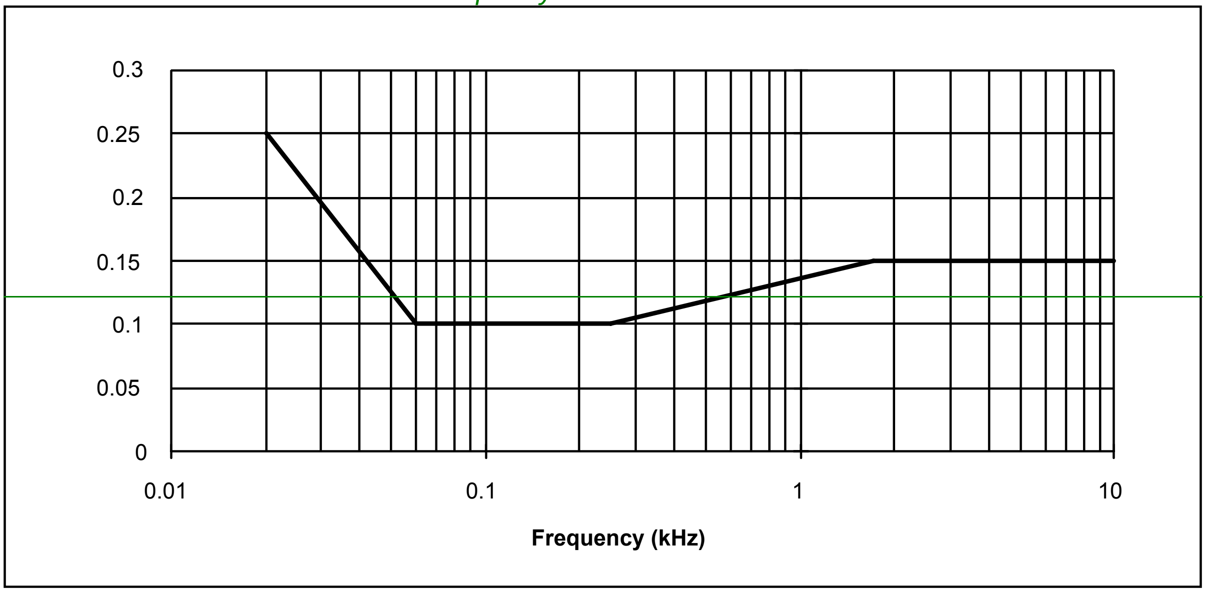


FIGURE 3.4.1.1.1-1 REQUIREMENTS FOR INTERFERENCE PRODUCED BY EQUIPMENT (LOW-FREQUENCY CONDUCTIVE INTERFERENCE)

NDC 028

~~Requirements for interference produced by equipment~~

~~*Low-Frequency conductive interference*~~



~~Figure 3.4.1.1.1-1~~

The values given in Figure 3.4.1.1.1.-1 are calculated according to the following formulae:

- in the frequency band from ~~0.02~~ 0.03 through 0.06 kHz

  ~~U_{eff} = 0.25 - 0.31 lg(f/0.02)[V]~~, U_{peak} = 105 - 16.77 lg(f/0.03) [dBμV],

- in the frequency band from 0.06 through 0.25 kHz

  ~~U_{eff} = 0.1[V]~~, U_{peak} = 105 - 16.77 lg(f/0.03) [dBμV],

- in the frequency band from 0.25 through 1.7 kHz

  ~~U_{eff} = 0.1 + 0.06 lg(f/0.25)[V]~~, U_{peak} = 100 + 3.6 lg(f/0.25)[dBμV],

- in the frequency band from 1.7 through 10 kHz

  ~~U_{eff} = 0.15[V]~~, U_{peak} = 103 [dBμV],

where f is the frequency in [kHz].

~~Note:~~

~~1. The measurement band should be no narrower than 5 percent of the measured frequency.~~

~~2. If the necessary measuring equipment is not available then measurements may be started at 30 Hz.~~

Note: The measurement bandwidth should be no narrower than:

10 Hz in the 30 Hz – 1 kHz range,

100 Hz in the 1 – 10 kHz range,

3B. –Matching devices may be used at low frequencies between the measurement device and the equipment under test to ensure a differential measurement. Matching devices schematics shall be presented in the appropriate measurement procedure program (PP).

The peak voltage of low-frequency interference in ±28V supply circuits from avionics, measured in a broad band of frequencies, shall not exceed 0.7V.

The conductive interference in ±28 V power circuits measured by the oscilloscope with frequency bandwidth of no less than 50 MHz shall not exceed 1.4 V peak to peak.

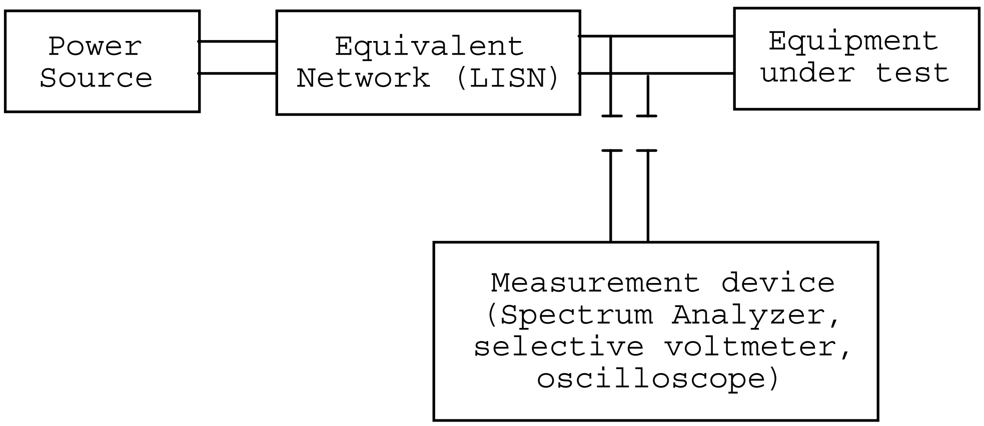


Figure 3.4.1.1.1-2 Model for measurement of interference in 28V supply circuits

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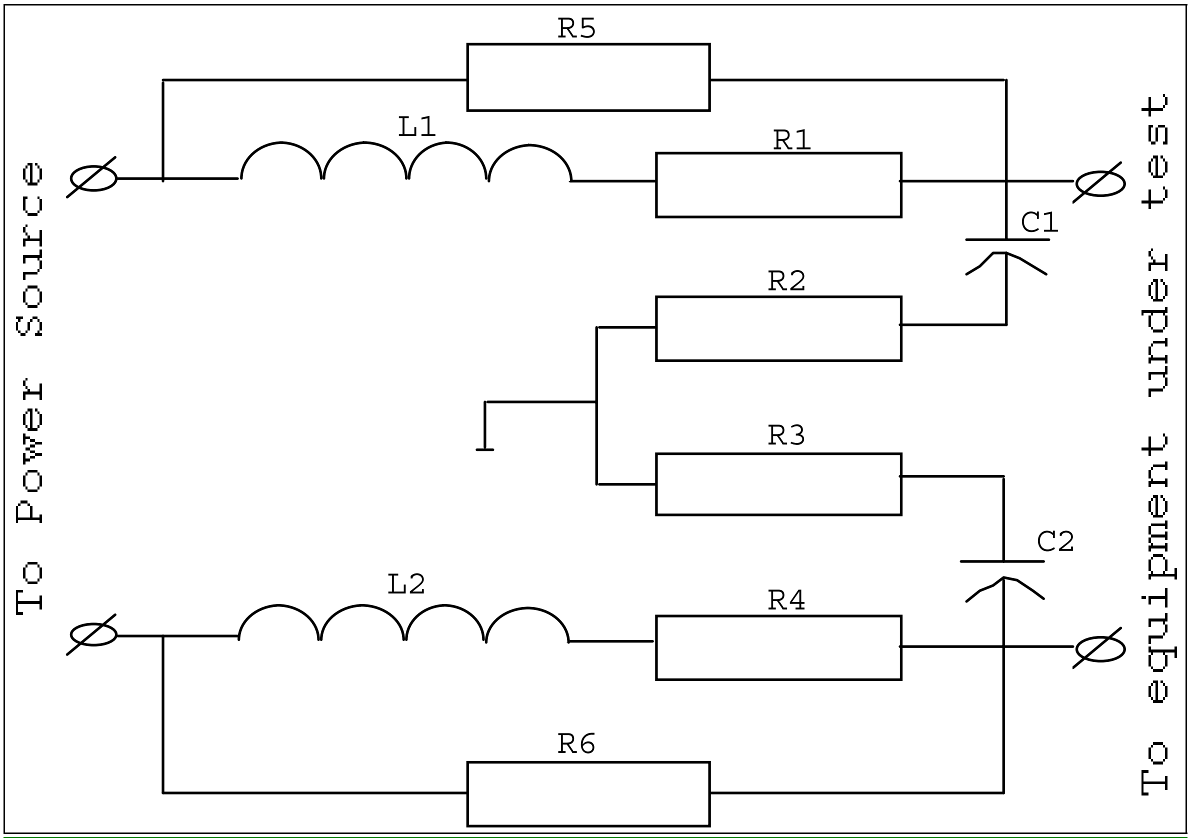
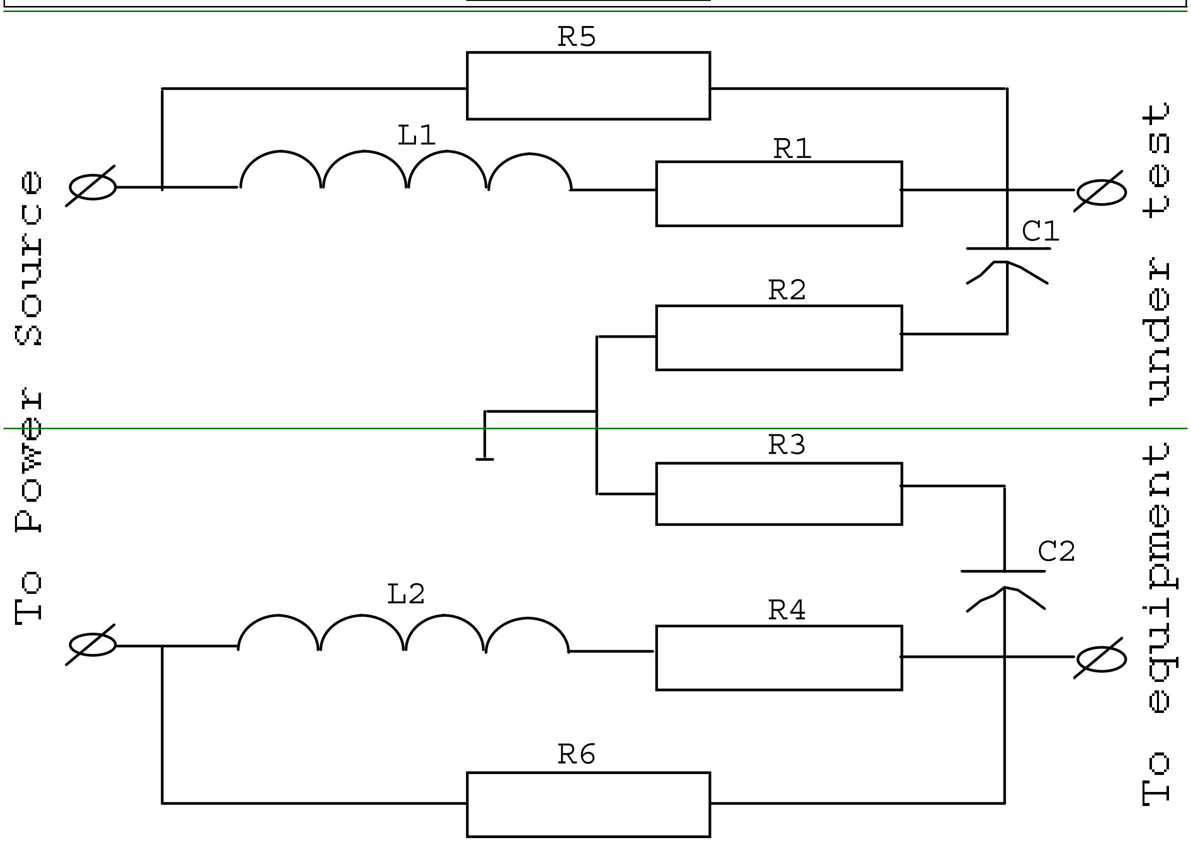

R5
L1
R1
C1
R2
R3
C2
L2
R4
R6
To Power Source
To equipment under test


R5
L1
R1
C1
R2
R3
C2
L2
R4
R6
To Power Source
To equipment under test

C1, C2 = 0.5 microF L1, L2 = 20 MicroH R2, R3 = 510 kohm
R1, R4 = 1/I[ohm] 0.05 ohm for I > 6 A R5, R6 = 1 kohm

= 0.15 ohm for I≤6A, where I[A] is the consumed current
R5, R6 = 1 kohm
For Automated Transfer Vehicle (ATV) L1, L2 = 10 MicroH

Figure 3.4.1.1.1-3 Equivalent network (LISN)

3.4.1.1.2 CONDUCTIVE RADIO FREQUENCY INTERFERENCE

Quasi-pPeak values of radio frequency interference voltage shall not exceed the values given in Figure 3.4.1.1.2-1. Interference measurements should be carried out following the model given in Figure 3.4.1.1.1-2, using the equivalent network (LISN) given in Figure 3.4.1.1.1-3.

Requirements for interference produced by equipment
Conductive radio frequency interference

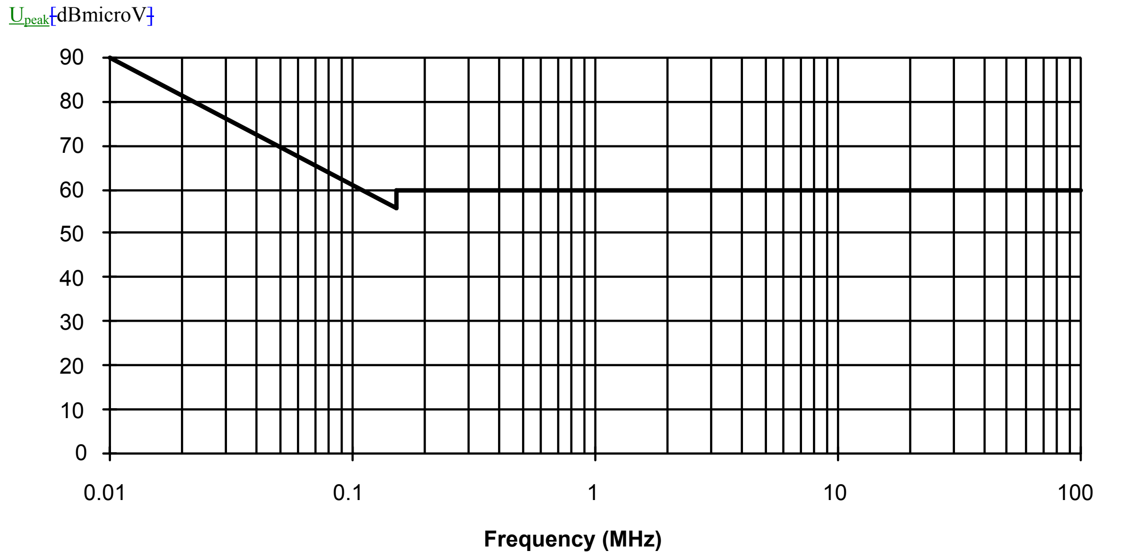


Figure 3.4.1.1.2-1 REQUIREMENTS FOR INTERFERENCE PRODUCED BY EQUIPMENT (CONDUCTIVE RADIO FREQUENCY INTERFERENCE)

The values given in Figure 3.4.1.1.2-1 are calculated according to the following formulae:

- in the frequency band from 0.009 through 0.15 MHz

$U_{QP} = 90 - 28.9 \lg(f/0.01)$ [dBmicroV]

- in the frequency band from 0.15 through 100 MHz

$U_{QP} = 60$ [dBmicroV],

where f is the frequency in [MHz].

Note: The measurement band should be no narrower than:
- 0.2 kHz in the 0.01 - 0.15 MHz range;
- 9.0 kHz in the 0.15 - 30.0 MHz range;
- 120 kHz in the 30 - 100 MHz range.

The values given in Figure 3.4.1.1.2-1 are calculated according to the following formulae:

- in the frequency band from 0.009 through 0.15 MHz

UPEAK = 90 - 28.9 lg(f/0.01) [dBmicroV]

- in the frequency band from 0.15 through 100 MHz

UPEAK = 60 [dBmicroV],

where f is the frequency in [MHz].

Note: The measurement band should be no narrower than:
- 1 kHz in the 0.01 - 0.15 MHz range;
- 10 kHz in the 0.15 - 30.0 MHz range;
- 100 kHz in the 30 - 100 MHz range.

3.4.1.1.3 INTENSITY OF THE ELECTRICAL FIELD OF RADIATED RADIO FREQUENCY INTERFERENCE

Equipment installed in the Russian segmentRS shall not produce interference in excess of the limits given in Figure 3.4.1.1.3-1. Above 30 MHz, adherence to the limits must be ensured for both horizontally and vertically polarized waves. Measurements should be taken with the detector in the quasi-peak (or peak) mode. The distance between the measuring antenna and equipment must be 1m.

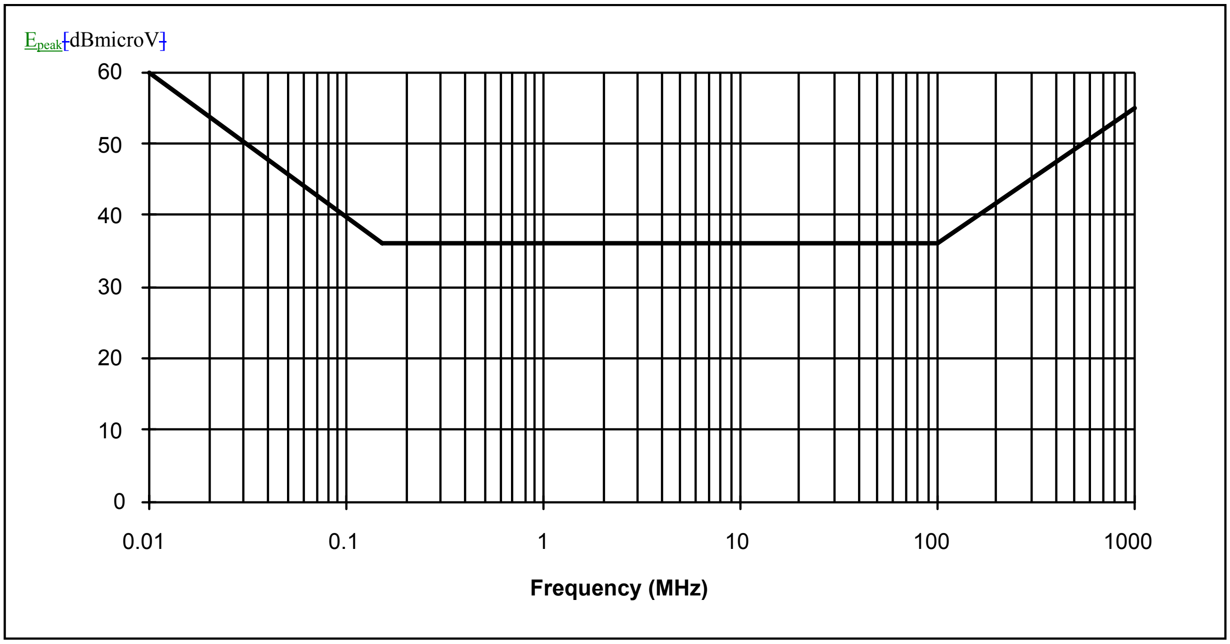


Figure 3.4.1.1.3-1 REQUIREMENTS FOR INTERFERENCE PRODUCED BY EQUIPMENT (INTENSITY OF ELECTRICAL FIELD)

The values given in Figure 3.4.1.1.3-1 are calculated according to the following formulae:

- in the frequency band from 0.01 through 0.15 MHz
  EPEAK = 60 - 20.4 lg(f/0.01) [dBmicroV/m],
- in the frequency band from 0.15 through 100 MHz
  EPEAK = 36 [dBmicroV/m]
- in the frequency band from 100 through 1000 MHz
  EPEAK = 36 + 19 lg(f/100) [dBmicroV/m],
  where f is the frequency in [MHz].

Note: 1. The measurement band should be no narrower than:
- 1 kHz in the 0.01 - 0.15 MHz range;
- 10 kHz in the 0.15 - 30.0 MHz range;
- 100 kHz in the 30 - 1000 MHz range.

2. The given requirements do not apply to radio frequency interference produced by emissions of radio transmitter output channels.

The following requirements will be verified with US provided hardware:
- in the frequency range from 1 GHz through 10 GHz
  EPEAK = 55 + 17 lg(f) [dBmicroV/m]
  where f is the frequency in GHz.
- in the frequency range from 13.5-15.5 GHz
  EPEAK = 76 dBmicroV/m

The bandwidth shall be no narrower than 1MHz in the frequency range more than 1000 MHz. The equipment externally mounted on the RS shall not produce radiated emission above the following frequency dependant limits as shown in Table 3.4.1.1.3-1.:

Table 3.4.1.1.3-1 E_{min} levels for determining RS maximum radiated emission levels

Frequency Band, MHz	E_{min}, dBμV/m	Name of Affected System
121 – 122	20	TTC
130 – 131	20	TTC
143 – 144	20	TTC
230 – 234	20	TM Orlan-Б
246 – 250	20	TM Orlan-Б
272 – 273	20	TTC
449 – 450	20	GTS
767 – 774	23	Regul
2202 – 2208	34	Intermodule Radio Link
3229 – 3245	45	Kurs-A
3294 – 3299	45	Kurs-П
13511 – 13545	45	Lira

Minimum Emin levels are tabulated. The levels may be changed for each specific device depending on its location on the ISS.

ATV equipment shall meet the requirements as identified in this paragraph. for ATV/Service Module (SM) interface excluding the requirements indicated in Figure 3.4.1.1.3-1. Radiated emissions in the frequency band from 0.01 to 1000 MHz shall not exceed 60 dBμV/m.

3.4.1.2 REQUIREMENTS FOR EQUIPMENT ELECTROMAGNETIC INTERFERENCE IMMUNITY

Radio-electronic, electronic, electrical, and electromechanical equipment and electric power sources shall function normally under the conditions of an electromagnetic environment, described in this section, with respect to the voltage of periodic and pulse interference in supply circuits, as well as the intensity of magnetic and electric fields outside and inside a module.

3.4.1.2.1 LOW-FREQUENCY CONDUCTED INTERFERENCE

~~Effective~~ Peak values of the voltage of low-frequency interference in ±28V supply circuits outside and inside a module are given in Figure 3.4.1.2.1-1. Tests should be performed following the model given in Figure 3.4.1.2.1-2, using the equivalent network shown in Figure 3.4.1.1.1-3.

Equipment immunity requirements

Low-frequency conductive interference

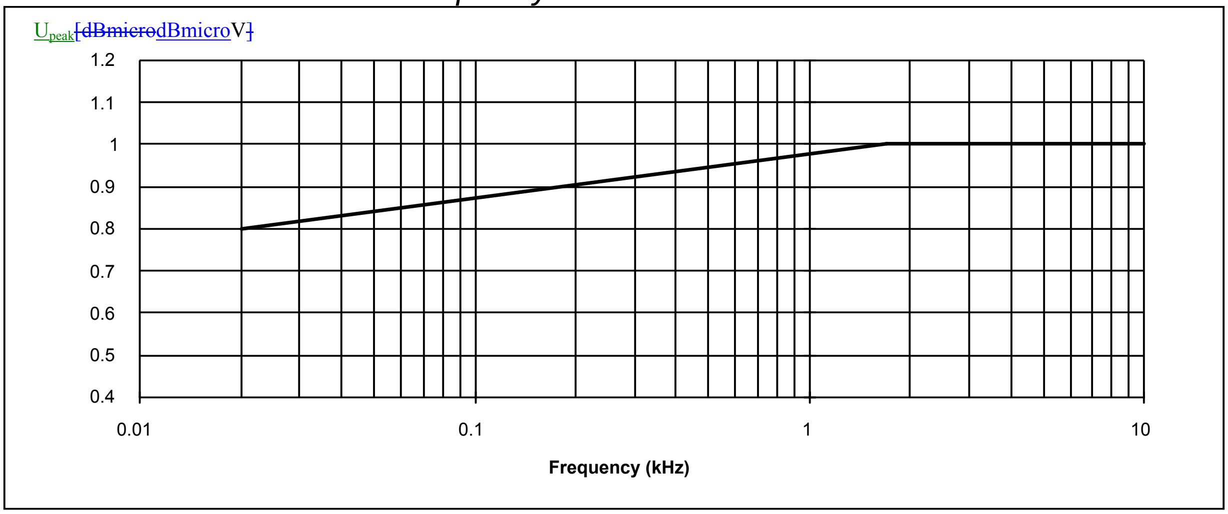


Figure 3.4.1.2.1-1 EQUIPMENT IMMUNITY REQUIREMENTS (LOW-FREQUENCY CONDUCTIVE INTERFERENCE)

~~The values given in Figure 3.4.1.2.1-1 are calculated according to the following formulae:~~

~~- in the frequency band from 0.25 through 1.7 kHz~~

~~U_{eff} = 0.8 + 0.1 lg(f/0.02)[V],~~

~~- in the frequency band from 1.7 through 10 kHz~~

~~U_{eff} = 1.0[V],~~

~~where f is the frequency in [kHz].~~

~~Note: Matching devices may be used at low frequency~~

The values given in Figure 3.4.1.2.1-1 are calculated according to the following formulae:

- in the frequency band from 0.25 through 1.7 kHz

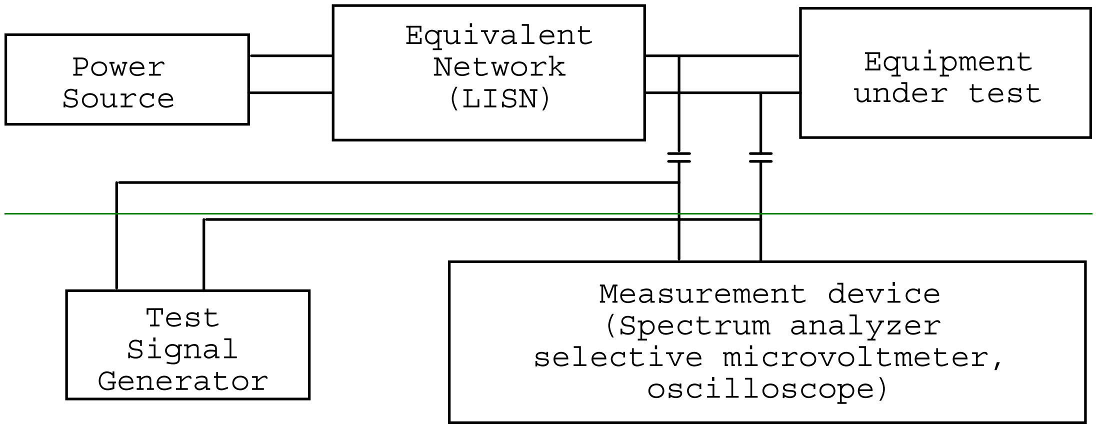
U_{peak} = 0.8 + 0.1 lg(f/0.02)[V],

- in the frequency band from 1.7 through 10 kHz

U_{peak} = 1.0[V],

where f is the frequency in [kHz].

Note: Matching devices may be used at low frequency



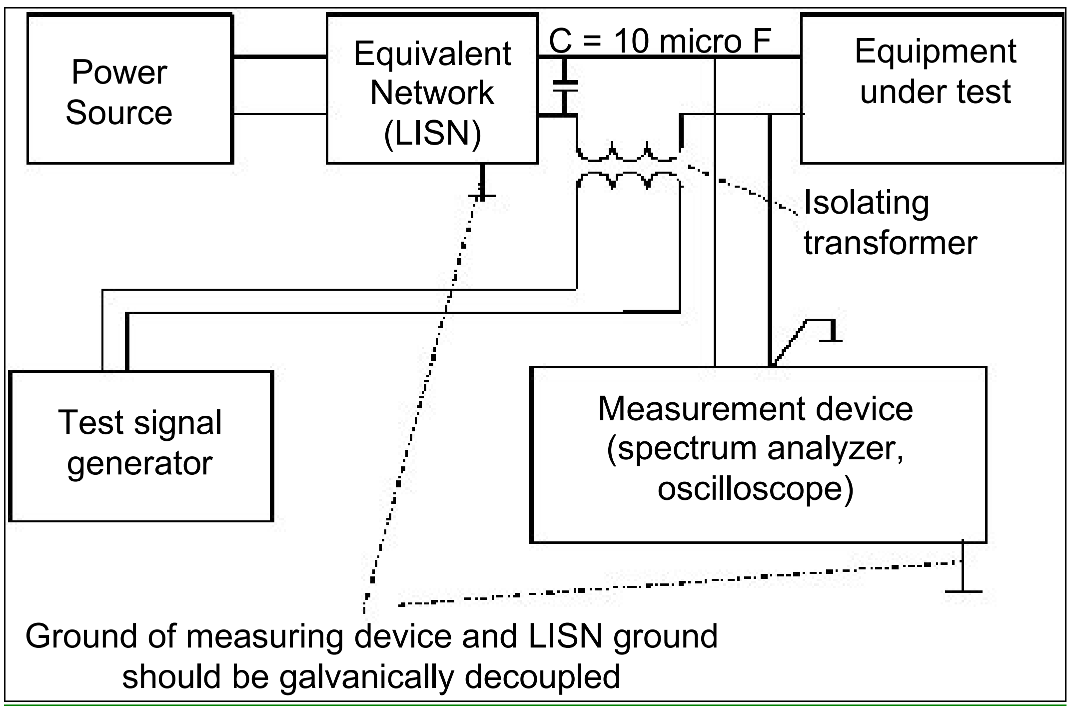


Figure 3.4.1.2.1-2. Model for testing of equipment for conducted interference immunity

The requirement is also met, if the generator producing the required voltage shown in Figure 3.4.1.2.1-1 in a 0.5 Ohm load cannot produce the required voltage within the test setup shown in Figure 3.4.1.2.1-2, and equipment under test is operating as specified.

3.4.1.2.2 CONDUCTIVE RADIO FREQUENCY INTERFERENCE

Quasi-peak (or pPeak) values of voltage of industrial radio frequency interference in +28V supply circuits outside and inside a module are given in Figure 3.4.1.2.2-1. Tests should be performed following the model shown in Figure 3.4.1.2.1-23.4.1.2.2-2, using the equivalent network shown in Figure 3.4.1.1.1-3.

Equipment immunity requirements

Conductive radio frequency interference

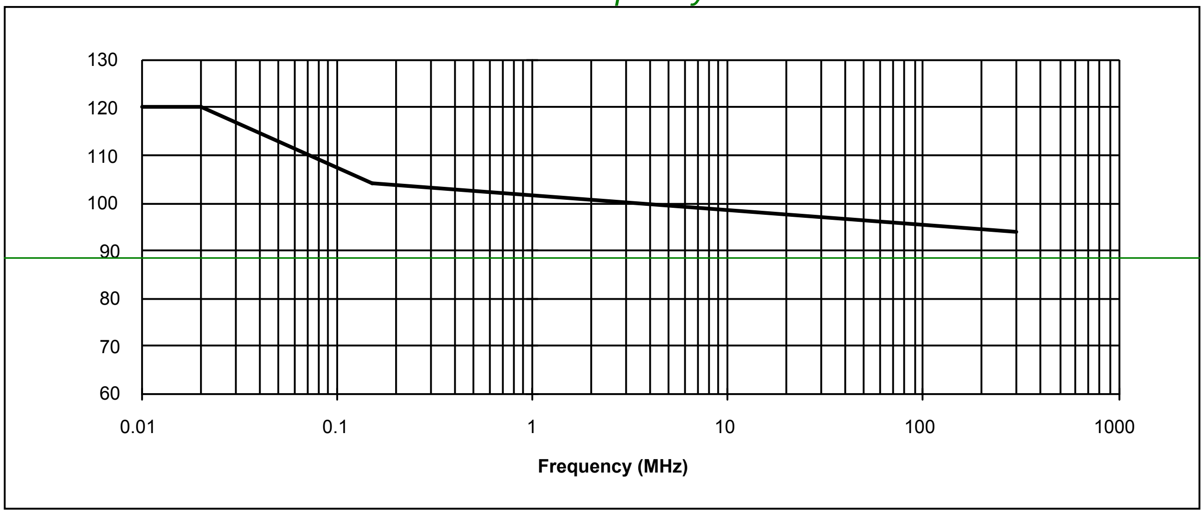


Figure 3.4.1.2.2-1

The values given in Figure 3.4.1.2.2-1 are calculated according to the following formulae:

- in the frequency band from 0.01 through 0.02 MHz

$U_{QP} = 120$ [dB microV],

- in the frequency band from 0.02 through 0.15 MHz

$U_{QP} = 120 - 18.3 \lg(f/0.02)$ [dB microV],

- in the frequency band from 0.15 through 300 MHz

$U_{QP} = 104 - 3 \lg(f/0.15)$ [dB microV],

where f is the frequency in [MHz].

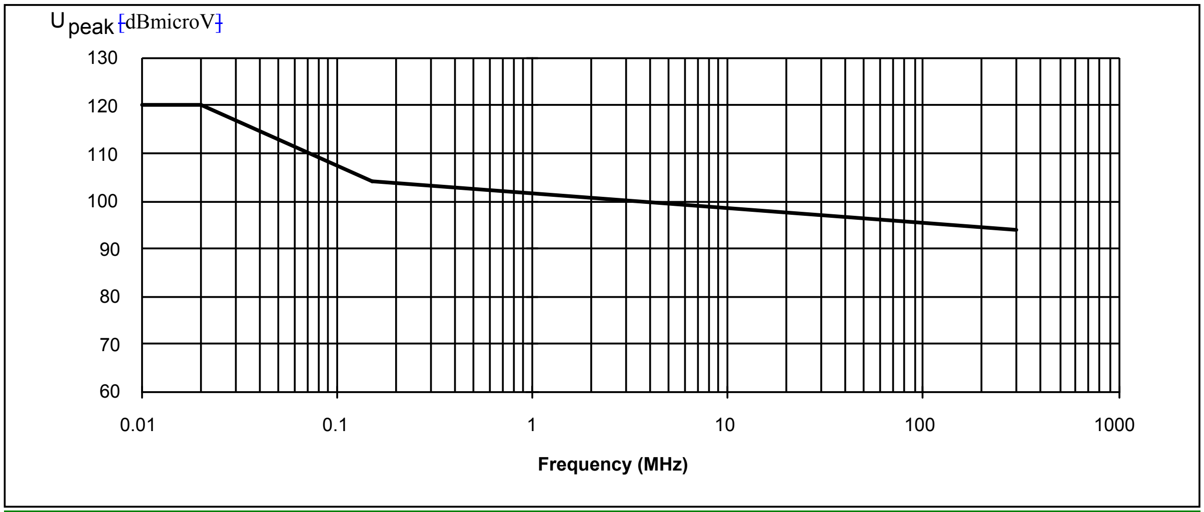


Figure 3.4.1.2.2-1 . EQUIPMENT IMMUNITY REQUIREMENTS (CONDUCTIVE RADIO FREQUENCY INTERFERENCE)

The values given in Figure 3.4.1.2.2-1 are calculated according to the following formulae:

- in the frequency band from 0.01 through 0.02 MHz

  $U_{PEAK} = 120$ [dB microV],

- in the frequency band from 0.02 through 0.15 MHz

  $U_{PEAK} = 120 - 18.3 \lg(f/0.02)$ [dB microV],

- in the frequency band from 0.15 through 300 MHz

  $U_{PEAK} = 104 - 3 \lg(f/0.15)$ [dB microV],

where f is the frequency in [MHz].

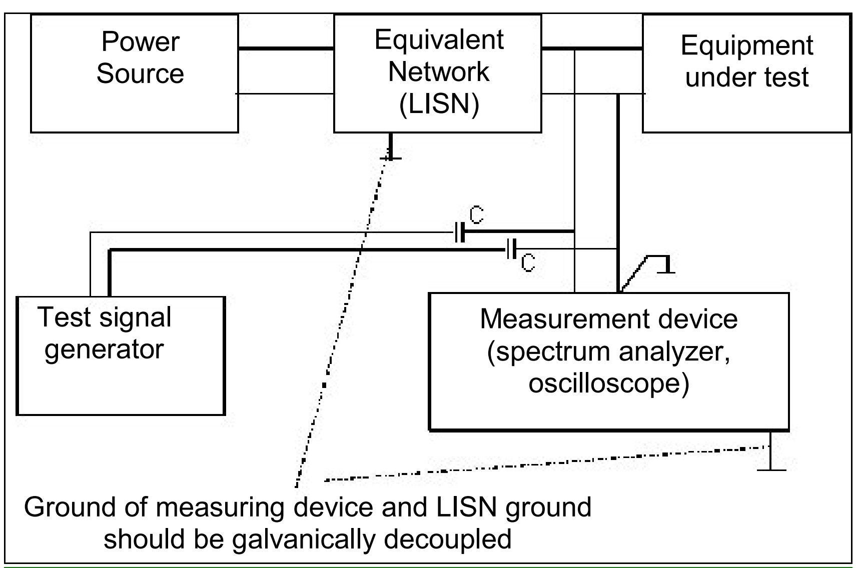


Figure 3.4.1.2.2-2 Equipment Test Set-up for Interference Immunity in Power Lines

The requirement is also met, if the generator producing the required voltage shown in Figure 3.4.1.2.2-1 in a 50 Ohm load cannot produce the required voltage within the test setup shown in Figure 3.4.1.2.2-2, and equipment under test is operating as specified.

NDC ~~027 and~~ 028

3.4.1.2.3 PULSE INTERFERENCE

Equipment shall function normally under the conditions of pulse interference in supply circuits as described in this section:

- ~~the voltage amplitude of single positive and negative pulses between ±28V power buses outside and inside a module is equal to 10V with a duration of 100±5 microsec, with the leading edge lasting no more than 5 microsec; internal resistance of the interference source is equal to 1 ohm (the amplitude of the test pulse should be set under no-load conditions);~~

- ~~the voltage amplitude of single positive and negative pulses between each of the ±28V power buses and the chassis outside and inside a module is 35V, with a duration of 100±5 microsec, with the leading edge lasting no more than 5 microsec; internal resistance of the interference source is equal to 500 ohms (the amplitude of the test pulse should be set under no-load conditions);~~

NDC 028~~7~~

- ~~the amplitude of a change in voltage (surges and dips) between ±28V power buses when the load is switched (connected, disconnected) and the load current is greater than 100A, is 1.5V, with a duration of up to 30 ms.~~

NDC 021 and 028~~7~~

The amplitudes and test pulse durations are given in Tables 3.4.1.2.3-1 and 3.4.1.2.3-2;
The front edge duration is no more than 5% of the pulse duration;
The recurrence frequency is 1 Hz for 1 min (or at a specified timeframe as required for the evaluation of the equipment under test);

Table 3.4.1.2.3-1 Characteristics of Pulse Interference between Power Buses (Diff. Mode)

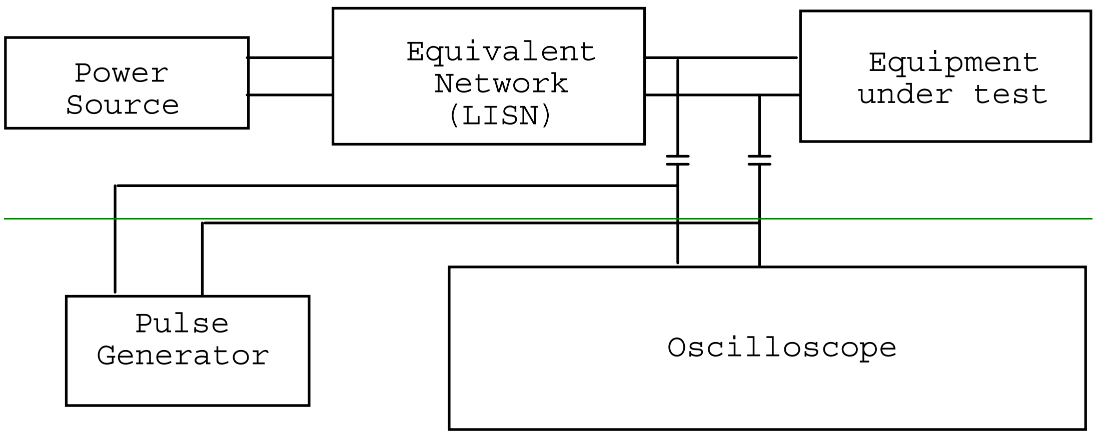
Pulse Time, microsec	50	100	300	500
Pulse Amplitude, V	±15	±15	±15	±10

NDC 028

Table 3.4.1.2.3-2 Characteristics of Pulse Interference between Each of Power Buses and Chassis (Common Mode)

Pulse Time, microsec	50	100	200	300
Pulse Amplitude, V	5	5	0	0

Tests should be performed following the model shown in Figure 3.4.1.2.3-1, using the equivalent network shown in Figure 3.4.1.1.1-3.



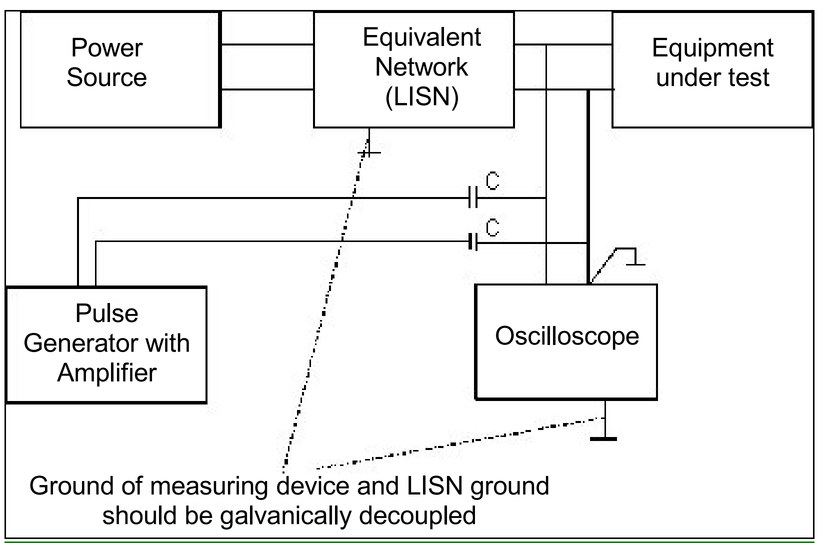


Figure 3.4.1.2.3-1. Model for testing of equipment for conducted pulse interference immunity

~~When testing equipment for pulse conductive interference immunity, a pulse generator with output resistance of 1 ohm and a pulse generator with output resistance of 500 ohms should be used. The pulse amplitude should be set under no-load generator conditions (Figure 3.4.1.2.3-2).~~

It is necessary to calibrate the pulse generator before testing in accordance with figure 3.4.1.2.3-2 following the below sequence. Set up pulse parameters at 1 Ohm load in accordance with table 3.4.1.2.3-1 and fix the amplitude setting of the generator. Set up pulse parameters at 500 Ohm load in accordance with table 3.4.1.2.3-2 and fix the amplitude setting of the generator. When performing testing in accordance with figure 3.4.1.2.3-1 the amplitude setting of the generator shall not exceed the setting set up during calibration. If the required pulse amplitude cannot be reached when doing the above and the equipment under test is operating as specified the requirement is also met.

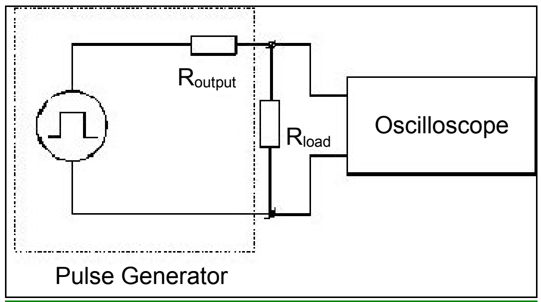


FIGURE 3.4.1.2.3-2 - CALIBRATION OF PULSE GENERATOR

NDC 028

3.4.1.2.4 RADIATED RADIO FREQUENCY INTERFERENCE INSIDE A MODULE

Quasi-peak (or peak)Peak values for the intensity of the magnetic field inside a module are given in Figure 3.4.1.2.4-1.

Equipment immunity requirements
Intensity of the magnetic field inside a module

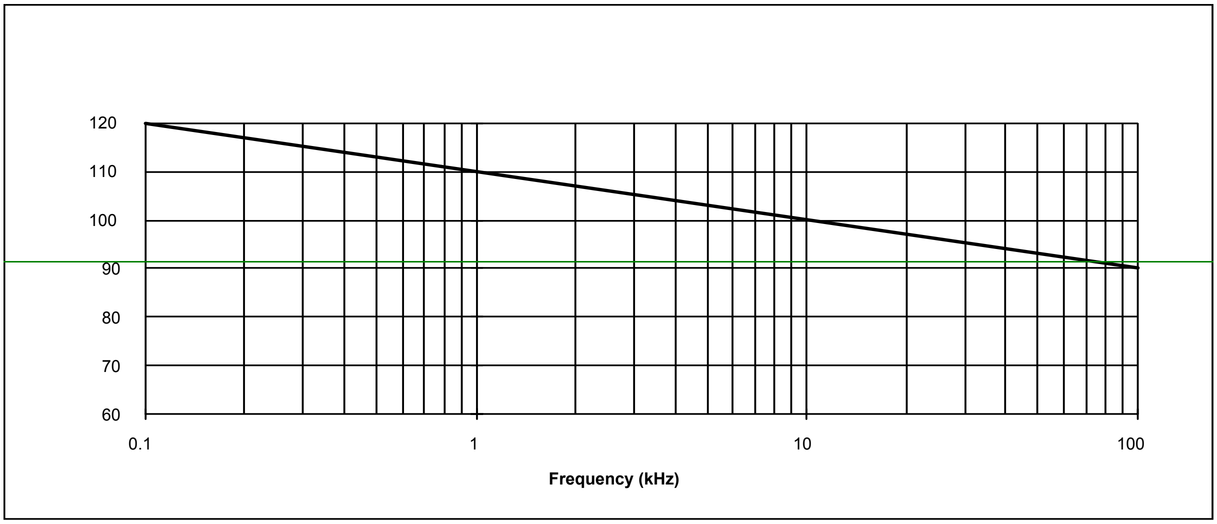


Figure 3.4.1.2.4-1.

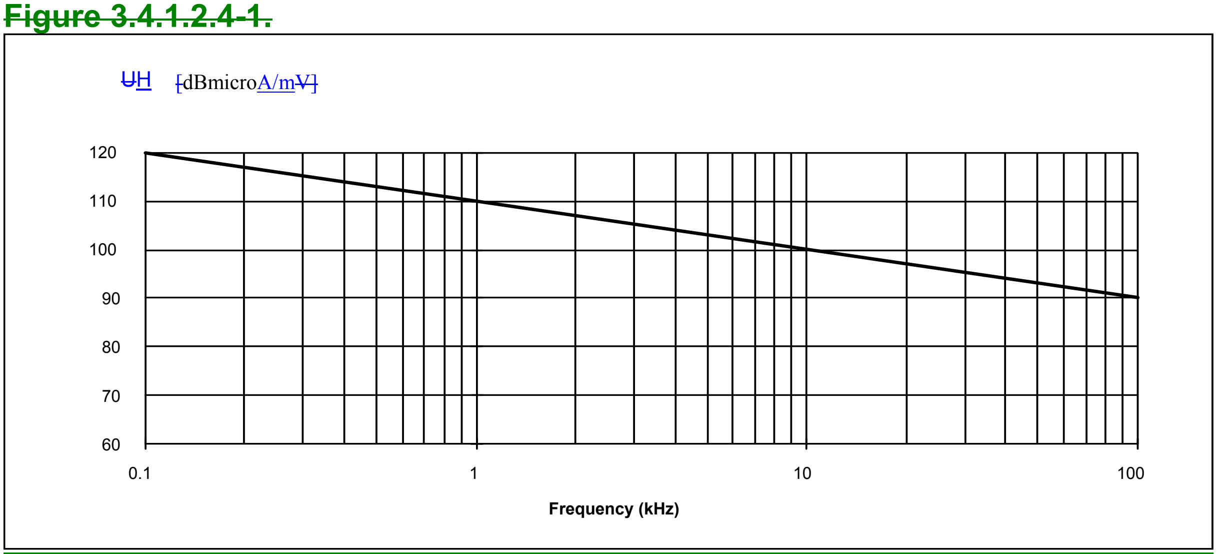


FIGURE 3.4.1.2.4-1. EQUIPMENT IMMUNITY REQUIREMENTS (INTENSITY OF THE MAGNETIC FIELD INSIDE A MODULE)

The values given in Figure 3.4.1.2.4-1 are calculated according to the following formulae:

- in the frequency band from 0.1 through 100 kHz

H = 120 - 10 lg(f/0.1) [dBmicroA/m],

where f is the frequency in [kHz].

Quasi-peak (or peak)Peak values of the intensity of an electrical field inside a module are given in Figure 3.4.1.2.4-2.

Equipment immunity requirements

Intensity of the electrical field inside an object

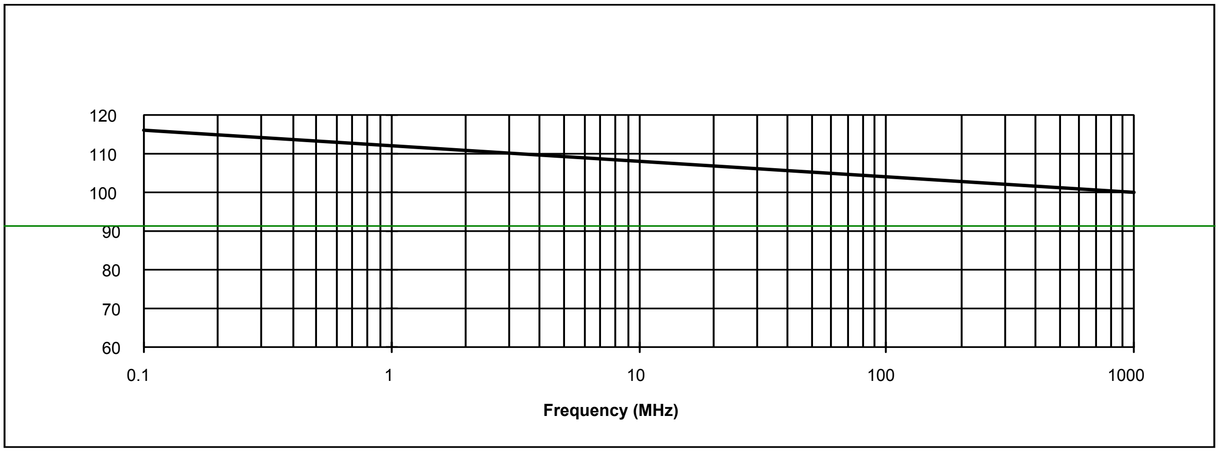


Figure 3.4.1.2.4-2

The values given in Figure 3.4.1.2.4-2 are calculated according to the following formulae:

- in the frequency band from 0.1 through 1000 MHz

E_{QP} = 116 - 4 lg(f/0.1) [dBmicroV/m],

where f is the frequency in [MHz].

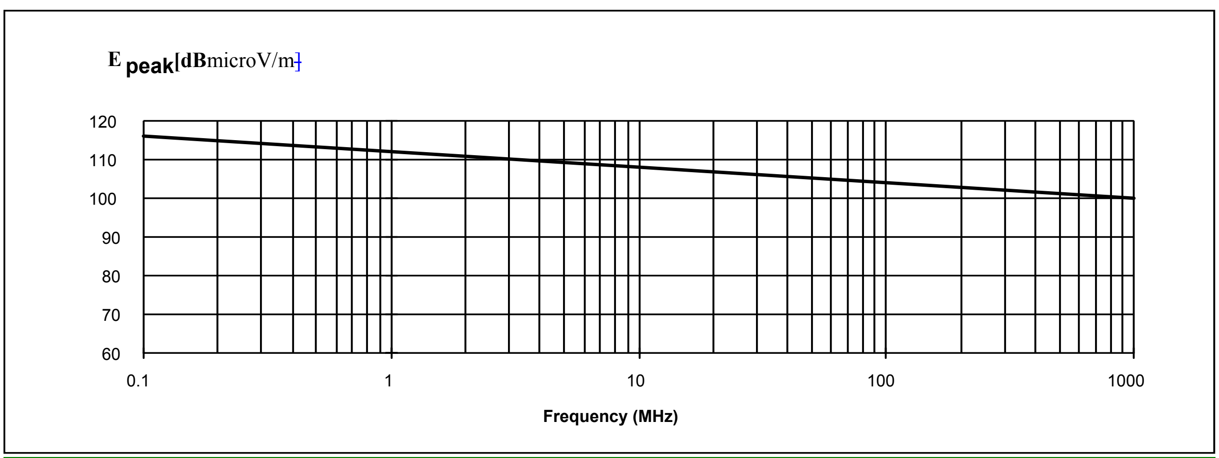


Figure 3.4.1.2.4-2. EQUIPMENT IMMUNITY REQUIREMENTS (INTENSITY OF THE ELECTRICAL FIELD INSIDE AN OBJECT)

The values given in Figure 3.4.1.2.4-2 are calculated according to the following formulae:

- in the frequency band from 0.1 through 1000 MHz

E_{PEAK} = 116 - 4 lg(f/0.1) [dBmicroV/m], where f is the frequency in [MHz].

In addition, the internal equipment shall satisfy the requirements in Paragraph 3.4.1.2.5 for resistance to radiation for all equipment and subsystems between 14 kHz and 20 GHz. At frequencies higher than 1 GHz, this requirement applies only to specific frequencies and amplitudes currently known for the Space Station. At frequencies below 1 GHz, this requirement shall be increased only for specific frequencies and amplitudes currently known for the ISS. The module shielding efficiency can be used to limit applied levels.

The peak values of the intensity of an electrical field inside the ATV are:
1 V/m in the frequency range from 0.01 through 1000 MHz;
5 V/m in the frequency range from 1 through 20 GHz;
and additionally:
10 V/m at frequencies from 2.2 through 2.3 GHz;
6 V/m at frequencies from 0.2 through 8 GHZ;
8 V/m at frequency of 8.5 GHz;
20 V/m at frequencies from 13.7 through 15.2 GHz.

3.4.1.2.5 RADIATED RADIO FREQUENCY INTERFERENCE OUTSIDE A MODULE

The effective value of the intensity of a constant magnetic field is 50 A/m.

The effective value of the intensity of a magnetic field is 1 A/m in a frequency range between 5 and 10 Hz.

Quasi-peak (or peak)Peak values of the intensity of the electrical field outside a module are given in Figure 3.4.1.2.5-1.

Equipment immunity requirements

Intensity of the electrical field outside an object

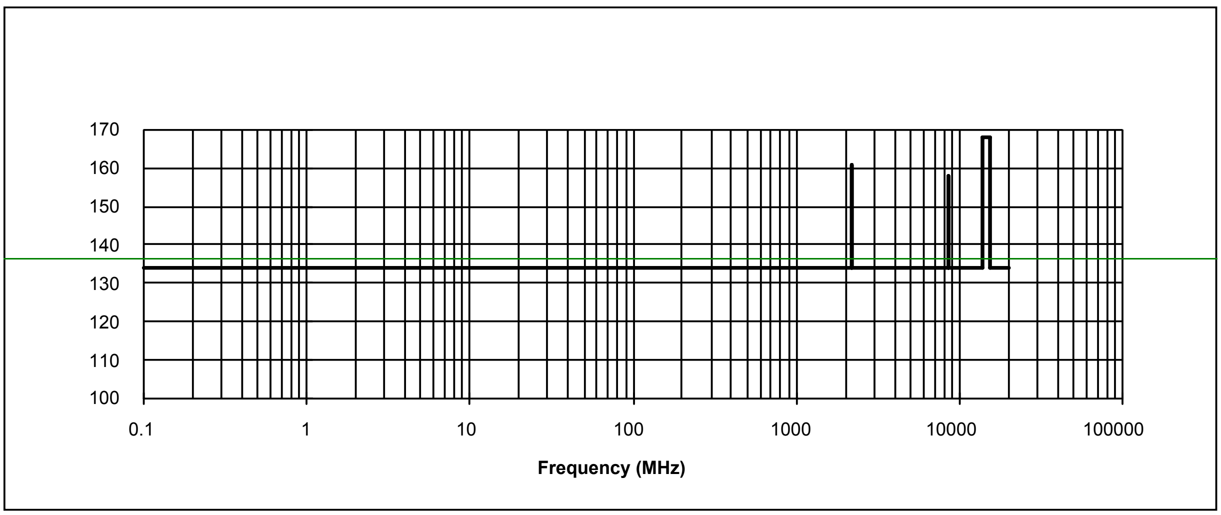


Figure 3.4.1.2.5-1

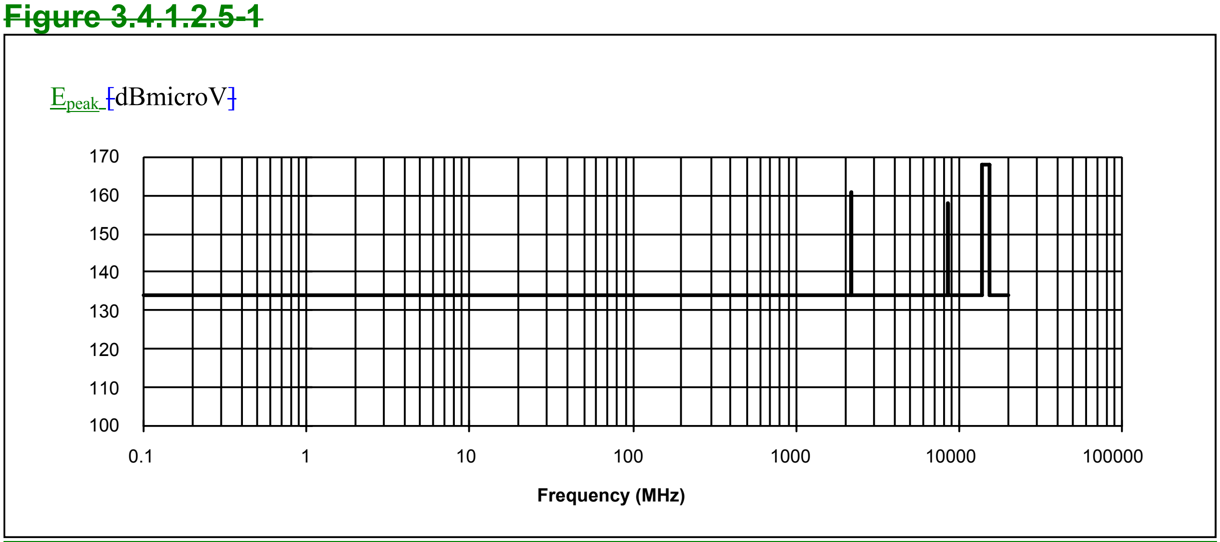


FIGURE 3.4.1.2.5-1. EQUIPMENT IMMUNITY REQUIREMENTS (INTENSITY OF THE ELECTRICAL FIELD OUTSIDE AN OBJECT)

The values given in Figure 3.4.1.2.5-1 are calculated according to the following formulae:

- in the frequency band from 0.1 through 20,000 MHz

E_{QP} = 134 [dBmicroV/m],

- At 2.2 GHz

E_{QP} = 164 [dBmicroV/m].

- At 8.5 GHz

E_{QP} = 158 [dBmicroV/m].

- At 13.7 GHz to 15.2 GHz

E_{QP} = 168 [dBmicroV/m].

The values given in Figure 3.4.1.2.5-1 are calculated according to the following formulae:

- in the frequency band from 0.1 through 20,000 MHz

E_{PEAK} = 134 [dBmicroV/m],

- At 2.2 GHz

E_{PEAK} = 164 [dBmicroV/m].

- At 8.5 GHz

E_{PEAK} = 158 [dBmicroV/m].

- At 13.7 GHz to 15.2 GHz

E_{PEAK} = 168 [dBmicroV/m].

Field intensity shall be 134 dBmicroV/m up to the specified magnitude depending on the location of hardware. If required, eExact values of electromagnetic fields and ranges will be clarified in the U.S. analysis for spacebased transmitterswill be calculated by NASA based on the real ISS configuration.

For the above levels, the radiated signal shall be 50 percent amplitude modulated with a 1 kHz signal

Also, the hardware shall meet impulse radiation from .2 GHz to 8 GHz with an amplitude of 60 V/m, a pulse train of 1000 pulses per second pulse, and a 10 microsecond pulse width. A minimum of three test frequencies per decade shall be used to verify this requirement.

Peak values of the intensity of the electric field outside ATV are:
5 V/m in the frequency range from 100 KHz through 20 GHz;
and additionally:
100 V/m at frequencies from 2.2 through 2.3 GHz;
60 V/m at frequencies from 0.2 through 8 GHz;
20 V/m at frequencies from 8 through 10 GHz;

80 V/m at frequency of 8.5 GHz;
180 V/m at frequencies from 13.7 through 15.2 GHZ.

NDC 0287

3.4.1.2.6 INTENTIONALLY RADIATED RADIO FREQUENCY INSIDE THE ~~RUSSIAN SEGMENT~~RS PRESSURIZED VEHICLE

Table 3.4.1.2.6-1 NEW INTENTIONAL TRANSMITTER LEVEL REQUIREMENT

Frequency (MHz)	Field Intensity (V/m)
850-1000	5
2350-2500	5
5725-5875	5

The internal radiated field level of the SM has been established at 5 V/m due to crew protection

NDC 030

3.4.1.3 CHARACTERISTICS OF DISTRIBUTED 28 VOLT POWER

This section defines the quality of electrical power that will be provided to portable loads within the ~~Russian Segment~~RS under normal system operating conditions. Connected loads should provide performance prescribed in their own equipment specifications under these system operating conditions.

3.4.1.3.1 VOLTAGE RANGE

a) Steady State voltage delivered by the Electric Power System (EPS) to the RS Power Distribution System is between 28.0 and 29.0 volts.

b) Steady State voltage provided by the ~~Russian Segment~~RS at Standard Outlets is between 25.0 and 29.0 volts for load currents between zero and the maximum outlet rating.

c) Voltage drop in cables from the RS outlets to electrical loads interface shall not exceed 2.0 volts at the maximum steady state load current.

3.4.1.3.2 OUTLET CURRENT CAPABILITIES (RATINGS)

Standard Outlets for portable loads have ratings of 3, 5, 10, or 20 amperes. Additional outlets with non-standard current ratings are possible.

3.4.1.3.3 RIPPLE AND NOISE

See paragraph 3.4.1.2.1

NDC 021

3.4.1.3.4 TRANSIENTS

The characteristics of power delivered from the ~~Electric Power System (~~EPS~~)~~ to the RS Power Distribution System during transients caused by connecting or disconnecting loads of up to 100 A are as follows:

a. Peak voltage transients do not exceed +/- 1.5 volts from the steady state voltage

b. Leading edge transition time is no less than 0.1 milliseconds.

c. Duration, measured at the half-amplitude points, is no more than 30 milliseconds.

3.4.1.3.5 GROUNDING AND ISOLATION

The ~~Russian Segment~~RS 28 Volt power systems are two-wire, essentially ground-isolated systems. Requirements on the isolation resistance of electrical loads drawing from this system are specified in paragraphs 3.4.1.5.1 and 3.4.1.5.2.

NDC 021

3.4.1.3.6 OVERCURRENT PROTECTION, WILL TRIP LIMITS

Power is automatically removed when load currents exceed: TBR

3.4.1.3.7 OVERCURRENT PROTECTION, NO TRIP LIMITS

Power is not removed when load currents remain below: TBR

3.4.1.3.8 SYSTEM SOURCE IMPEDANCE AT OUTLET INTERFACE

TBR.

3.4.1.4 CONSTRAINTS ON ELECTRICAL LOADS

This section defines loading constraints that shall be met by portable loads to be compatible with power characteristics available from standard outlets in the ~~Russian Segment~~RS.

3.4.1.4.1 Steady State input current

Maximum steady state load current shall not exceed the limits stated in the specification for the electrical load.

3.4.1.4.2 INRUSH AND SURGE CURRENTS

Peak inrush and surge currents shall not exceed 5.0 times the outlet rating. Duration of inrush and surge currents shall not exceed 20 milliseconds.

3.4.1.5 DESIGN REQUIREMENTS FOR ELECTRICAL LOADS

This section defines portable equipment design requirements that shall be met to be compatible with power characteristics available from standard outlets in the ~~Russian Segment~~RS.

3.4.1.5.1 ELECTRICAL INSULATION RESISTANCE

The resistance of the insulation between the body of any equipment and the primary power circuits (both positive and negative) shall be no less than 1 Meg-Ohm with an atmospheric relative humidity of 95% ± 3% at an atmospheric temperature of 20 ± 5 degrees Centigrade. This requirement is considered to be satisfied if the resistance is not less than 20 Meg-Ohms with an atmospheric relative humidity of 45 to 80% at an atmospheric temperature of 15 to 35 degrees Centigrade.

NDC 021

3.4.1.5.2 ELECTRICAL ISOLATION STRENGTH

The resistance of the insulation between the body of any equipment and the primary power circuits (both positive and negative leads), and also between any electrically separated circuits must satisfy paragraph 3.4.1.5.1 following the effect of a ±100V direct current (DC) test voltage on these circuits. The magnitude of the test voltage should not exceed the allowable magnitude for components used in the equipment.

3.4.1.5.3 INPUT POWER CONNECTIONS BETWEEN LOADS AND CABLES

Loads should preferably be designed to accept input power and ground connections from connecting cables through a dedicated input connector.

NDC 021

3.4.2 REQUIREMENTS FOR EQUIPMENT PROVIDING THE U.S. ON-ORBIT SEGMENT POWER SUPPLY

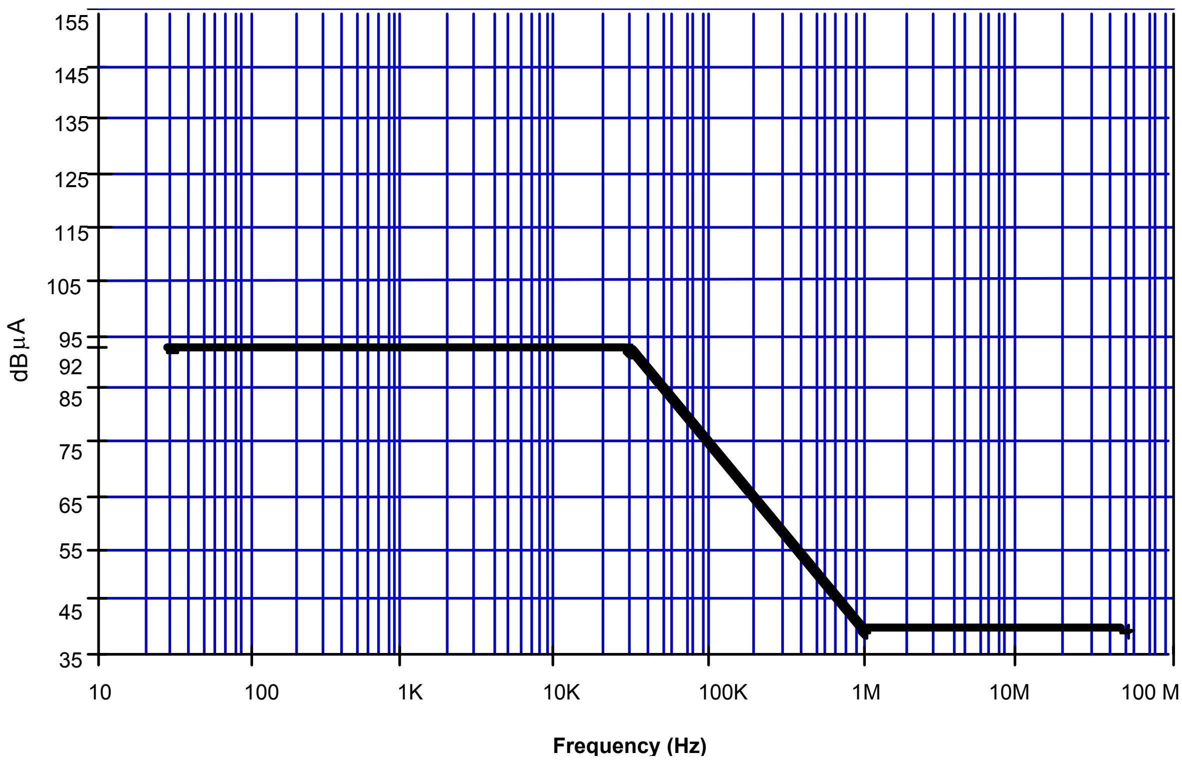
3.4.2.1 REQUIREMENTS FOR ELECTROMAGNETIC INTERFERENCE PRODUCED BY EQUIPMENT

Radio-electronic, electronic, electrical, and electromechanical equipment and electric power sources shall not produce electromagnetic interference in excess of the requirements described in this section with respect to the voltage of periodic conductive interference, as well as the intensity of the electrical field.

3.4.2.1.1 CE01/CE03 CONDUCTED EMISSIONS

The output power ports of the equipment shall not emit conducted emissions (CE) greater than the limit shown in Figure 3.4.2.1.1-1, when tested per the test set-up shown in Figure 3.4.2.1.1-2. The secondary bus impedance simulator is characterized in Figure 3.4.2.1.1-3 and the equivalent network (LISN) is shown in Figure 3.4.2.1.1-4. The functionality of the equipment must be exercised during these measurements.

~~**Figure 3.4.2.1.1-1 Conducted Emissions Limit (CE01/CE03) for Equipment Providing Power to USOS**~~



Note: 0 dBµA = 1 micro ampere root mean square (rms)

Figure 3.4.2.1.1-1 Conducted Emissions Limit (CE01/CE03) for Equipment Providing Power to USOS

Editorial formatting

~~**Figure 3.4.2.1.1-2 Conducted emissions Test Set-up for Equipment Providing 120V Secondary Power**~~

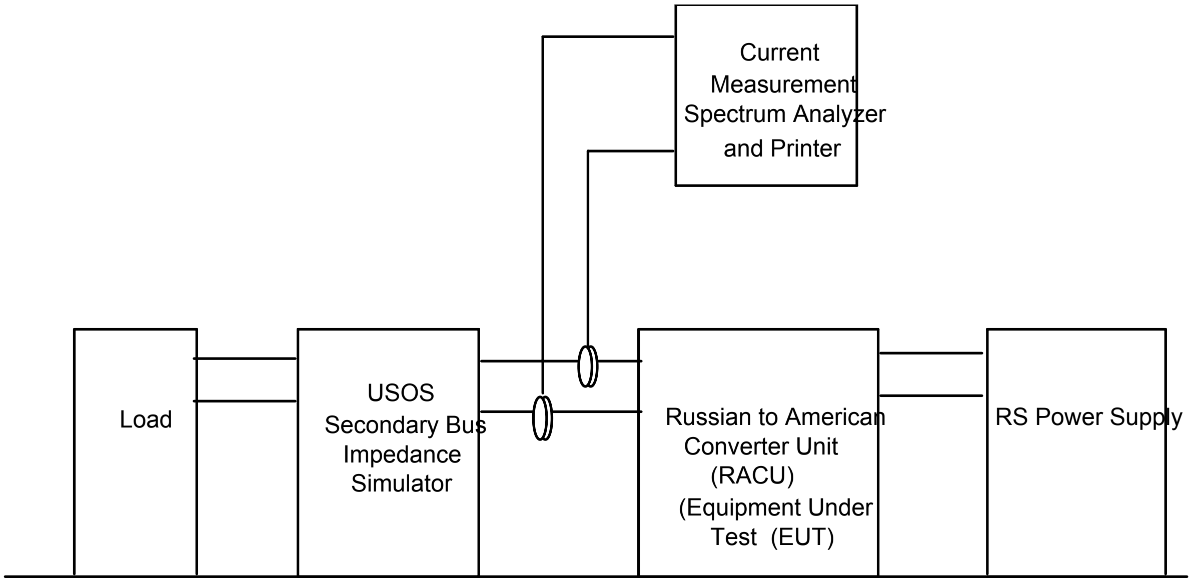


Figure 3.4.2.1.1-2 Conducted emissions Test Set-up for Equipment Providing 120V Secondary Power

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~~**Figure 3.4.2.1.1-3 Secondary Bus Load Impedance**~~

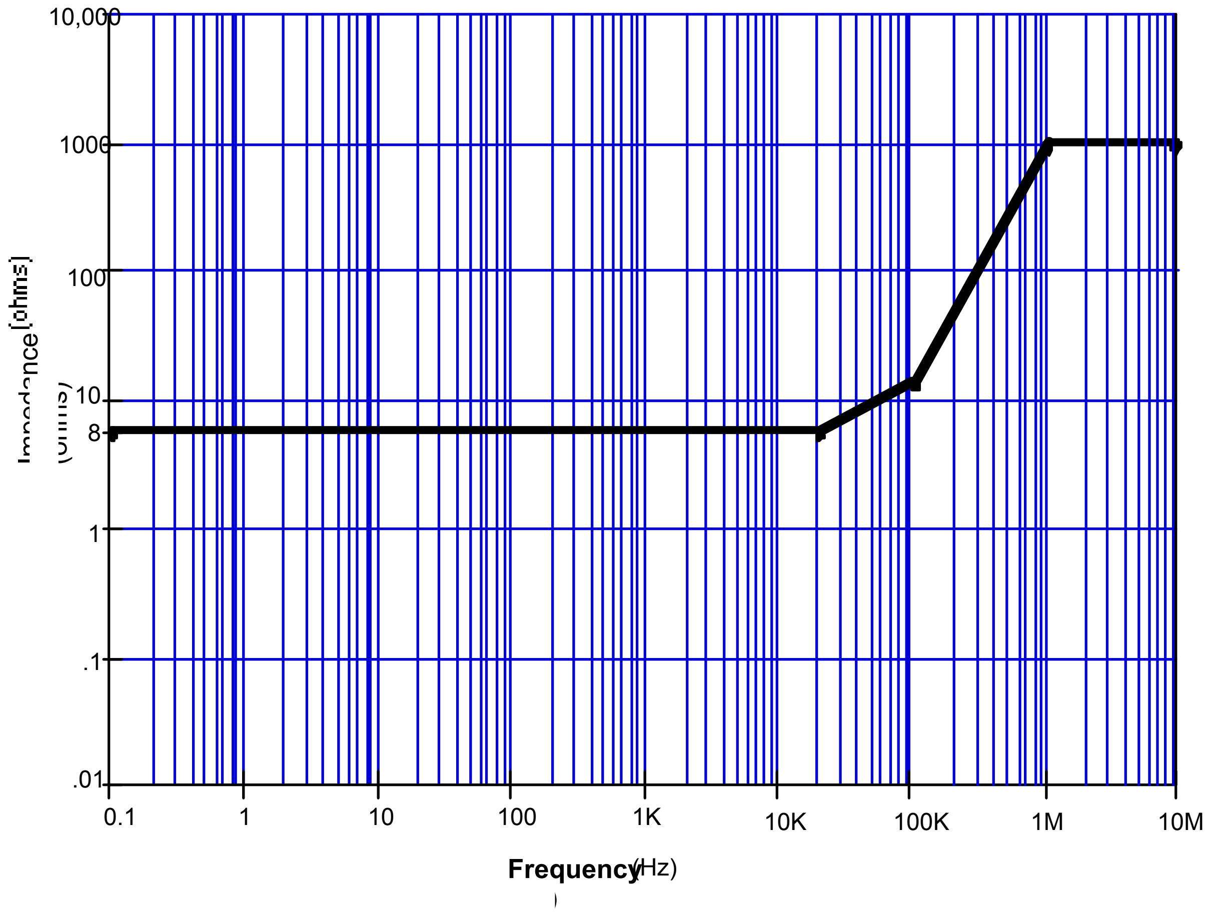

Figure 3.4.2.1.1-3 Secondary Bus Load Impedance

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Figure 3.4.2.1.1-4 Secondary Bus Load Impedance Equivalent Network

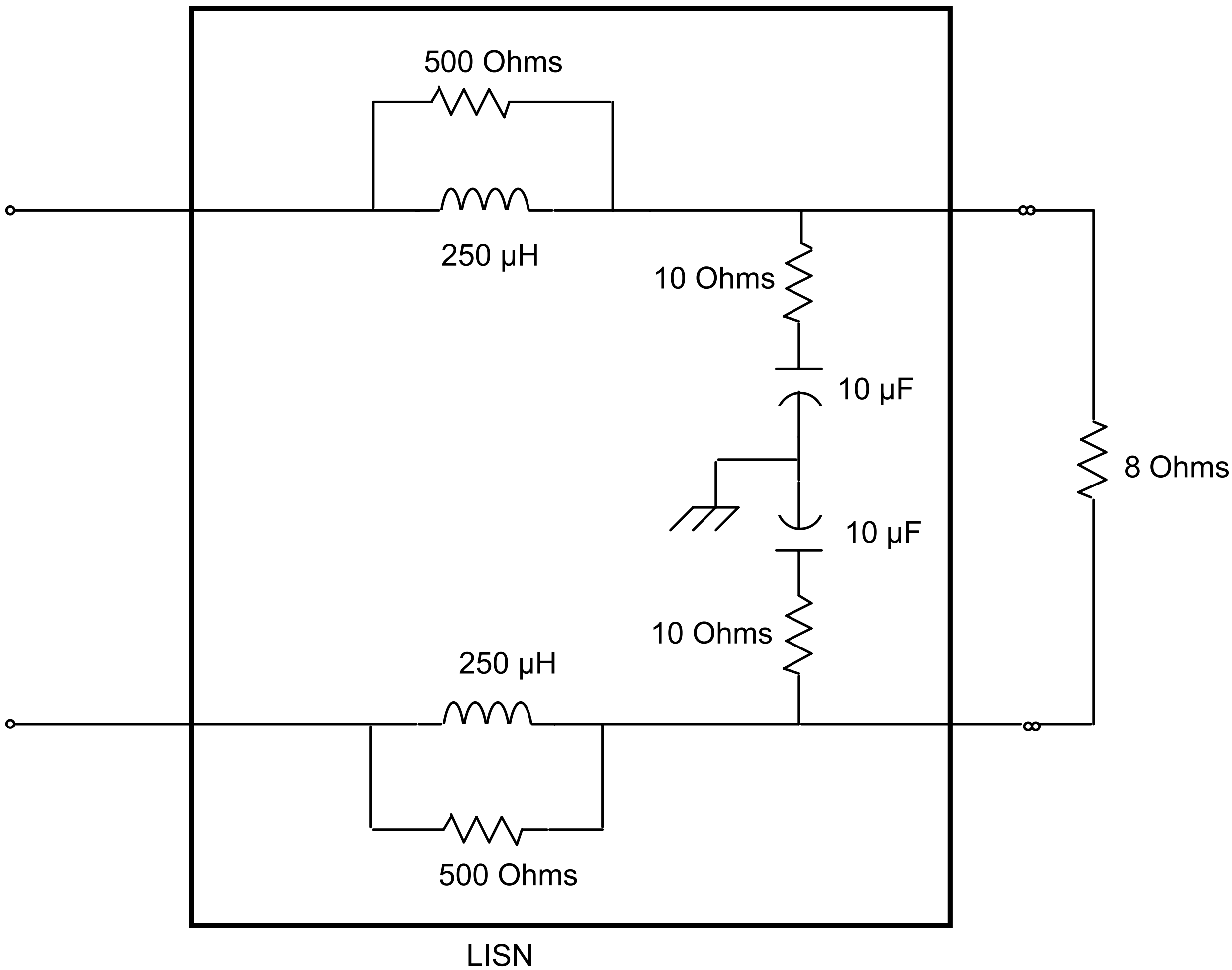


Figure 3.4.2.1.1-4 Secondary Bus Load Impedance Equivalent Network

Editorial formatting

3.4.2.1.1.1 OUTPUT VOLTAGE RIPPLE LIMITS FOR 2.0 KW DC/DC POWER CONVERTER (TIME DOMAIN)

The output power lines of 2.0 kW DC/DC power converter shall not emit voltage ripple in excess of 3 volts from peak to peak, under all load conditions for a bandwidth measurement of 20 Hz to 20 MHz (see Figure 3.4.2.1.1.1-1). The secondary bus impedance simulator shown in Figure 3.4.2.1.1.1-1 is characterized in Figure 3.4.2.1.1-3 and the equivalent network (LISN) is shown in Figure 3.4.2.1.1-4.

~~Figure 3.4.2.1.1.1-1 120 V Secondary Power Source Voltage Ripple Test Set-Up~~

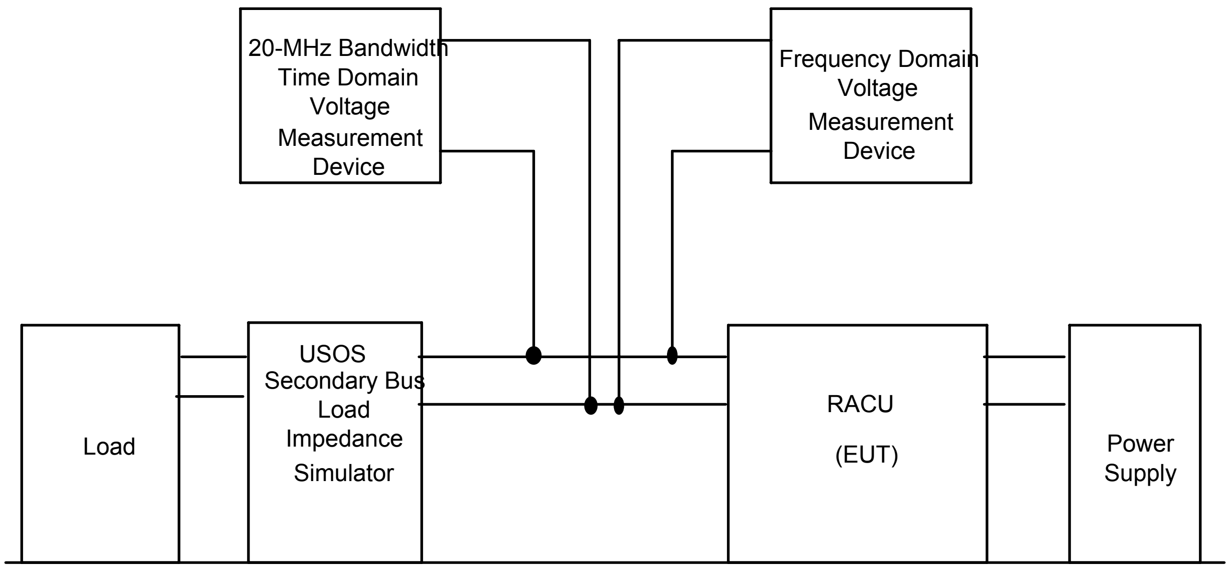


Figure 3.4.2.1.1.1-1 120 V Secondary Power Source Voltage Ripple Test Set-Up

Editorial formatting

3.4.2.1.1.2 OUTPUT VOLTAGE RIPPLE LIMITS FOR 2.0 KW DC/DC POWER CONVERTER (FREQUENCY DOMAIN)

The output power lines of a 2.0 kW DC/DC power converter shall not emit voltage ripple in excess of the limits shown in Figure 3.4.2.1.1.2-1 when measured as shown in Figure 3.4.2.1.1.1-1. The secondary bus load impedance simulator shown in Figure 3.4.2.1.1.1-1 is characterized in Figure 3.4.2.1.1-3 and the equivalent network (LISN) is shown in Figure 3.4.2.1.1-4.

Input power lines of a 2.0 kW DC/DC power converter shall not produce interference that exceeds the limits specified in items 3.4.1.1.1 and 3.4.1.1.2 and in Figures 3.4.1.1.1-1 and 3.4.1.1.2-1 when measurements are carried out following the model given in Figure 3.4.1.1.1-2, using the equivalent network shown in Figure 3.4.1.1.1-3.

~~Figure 3.4.2.1.1.2-1 120 V Secondary Bus Maximum Voltage Ripple Limits (Voltage Spectral Components)~~

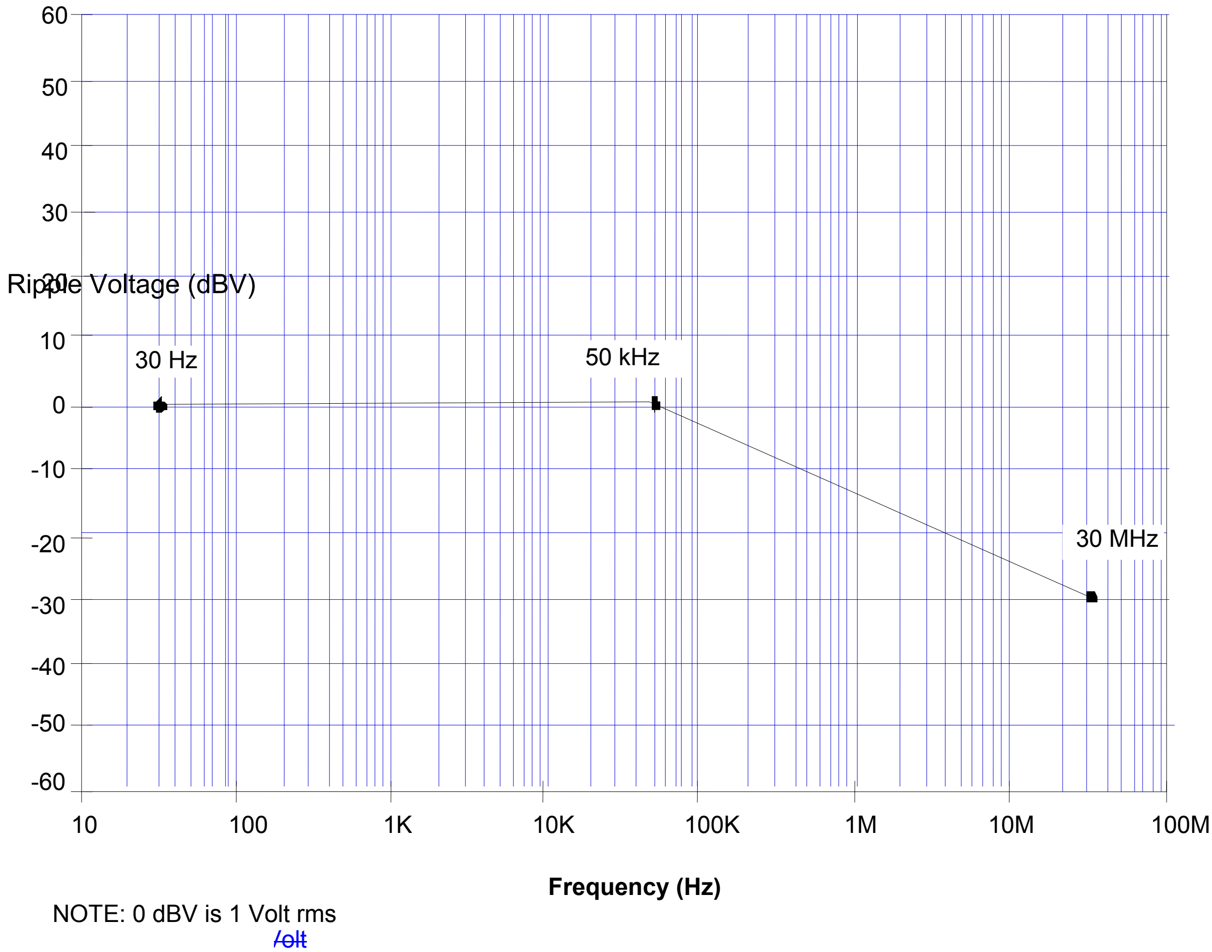


Figure 3.4.2.1.1.2-1 120 V Secondary Bus Maximum Voltage Ripple Limits (Voltage Spectral Components)

Editorial formatting

3.4.2.1.2 INTENSITY OF THE ELECTRICAL FIELD OF RADIATED RADIO FREQUENCY INTERFERENCE

Equipment installed on the ~~Russian Segment~~RS shall not produce interference that exceeds the limits given in Figure 3.4.1.1.3-1. Above 30 MHz, adherence to the limits must be ensured for both horizontally and vertically polarized waves. Measurements should be taken with the detector in quasi-peak (or peak) mode. The distance between the measuring antenna and equipment must be 1m.

3.4.2.2 REQUIREMENTS FOR EQUIPMENT ELECTROMAGNETIC INTERFERENCE IMMUNITY

Radio-electronic, electronic, electrical, and electromechanical equipment and electric power sources shall function normally under the conditions of an electromagnetic environment described in this section with respect to the voltage of periodic and pulse interference in supply circuits, and also the intensity of the magnetic and electrical fields outside and inside a module.

3.4.2.2.1 CS01 CONDUCTED SUSCEPTIBILITY

Equipment shall not exhibit any malfunction, degradation in performance, or deviations from specified indications beyond the tolerances indicated in the individual equipment or subsystem specification when subjected to electromagnetic energy injected onto its output and input power leads less than or equal to the values described below. The electromagnetic energy injected on the output leads shall be equal to the values indicated below (see the Table) in Table 3.4.2.2.1-1, when the testing is performed as indicated in Figure 3.4.2.2.2-1. The electromagnetic energy injected on the input leads shall be less than or equal to the values specified in items 3.4.1.2.1 and 3.4.1.2.2 and shown in Figures 3.4.1.2.1-1 and 3.4.1.2.2-1, when the testing is performed following the model shown in Figure 3.4.1.2.1-2, using the equivalent network shown in Figure 3.4.1.1.1-3.

~~Figure~~ Table 3.4.2.2.1-1 - Conducted Susceptibility (CS01) Limit for Equipment Providing USOS Secondary Power

Frequency	Voltage
30 Hz - 2 kHz	5V rms or 10% of supply voltage, whichever is less
2 kHz - 50 kHz	Declines linearly in a logarithmic scale from 5V rms or 10% of supply voltage, whichever is less, to 1V rms or 1% of supply voltage, whichever is less

Editorial correction

3.4.2.2.2 CS01 ALTERNATE LIMITS

The requirement is also met when the amplifier, shown in Figure 3.4.2.2.2-1, adjusted to dissipate 50 Watts (W) in a 0.5 ohm load, cannot develop the required voltage at the power output terminals, and the equipment is not susceptible to the output of the signal source.

~~**Figure 3.4.2.2.2-1 Conducted Susceptibility (CS01) Test Set-up for Equipment Providing Power for the USOS**~~

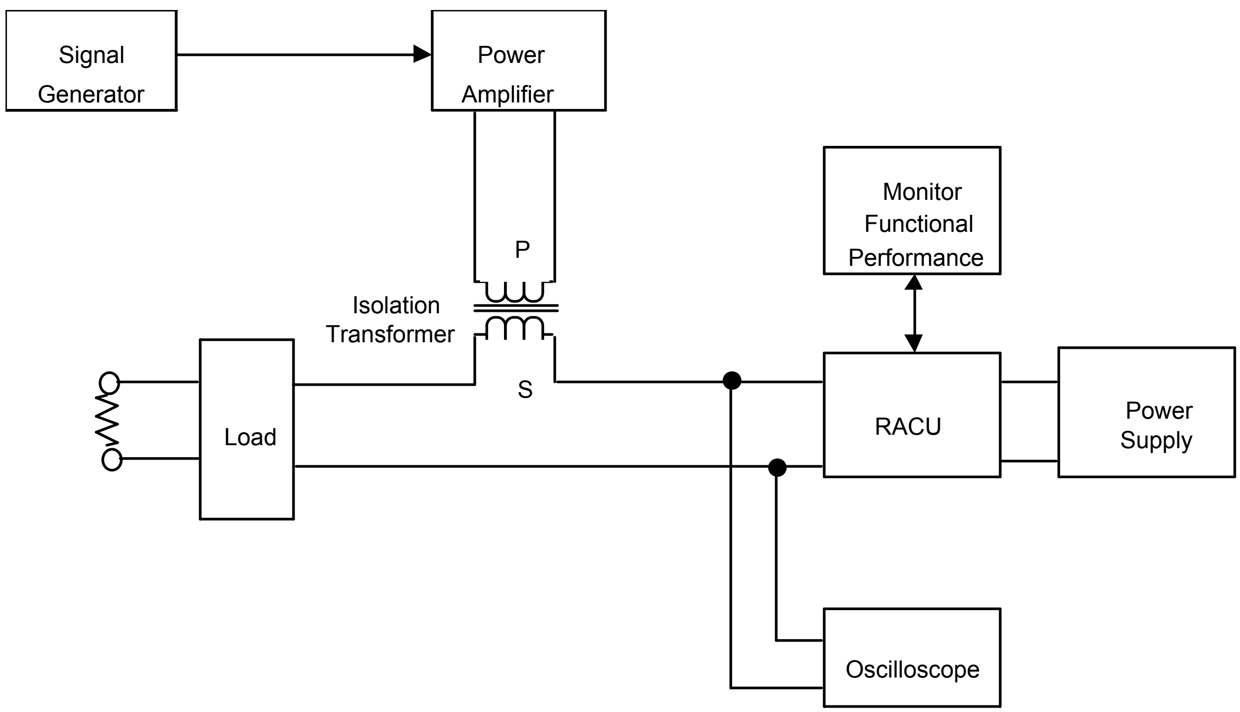


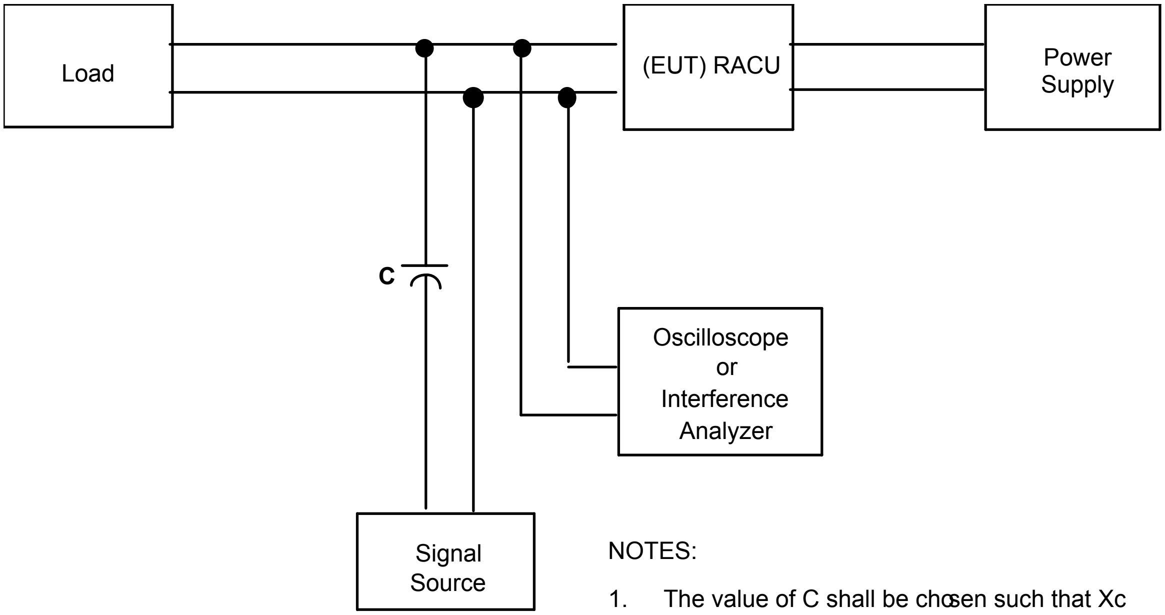
Figure 3.4.2.2.2-1 Conducted Susceptibility (CS01) Test Set-up for Equipment Providing Power for the USOS

Editorial formatting

3.4.2.2.3 CS02 CONDUCTED SUSCEPTIBILITY

This requirement is applicable to DC output power leads, including power returns which are not grounded internally to the equipment. Equipment shall not exhibit any malfunction, degradation in performance, or deviation from specified indications beyond the tolerances indicated in the individual equipment or subsystem specification subjected to 1V rms from a 50 ohm source across a frequency range of 50 kHz to 50 MHz. The test signal shall be applied to the equipment power line near the equipment output terminals. The requirement is also met under the following conditions: a 1 W source with 50 ohm impedance cannot develop the required voltage at the equipment output terminals, and the equipment is not susceptible to the output of the signal source. The required CS02 test set-up is shown in Figure 3.4.2.2.3-1.

~~**Figure 3.4.2.2.3-1 Conducted Susceptibility (CS02) Test Set-up for Equipment Providing USOS Power**~~



NOTES:

1. The value of C shall be chosen such that Xc <5 ohms over the test frequencies.

2. Connect the coupling capacitor and the Oscilloscope, or Interference Analyzer within 5 cm of the termination to the EUT.

Figure 3.4.2.2.3-1 Conducted Susceptibility (CS02) Test Set-up for Equipment Providing USOS Power

Editorial formatting

3.4.2.2.4 CS06 CONDUCTED SUSCEPTIBILITY (SPIKES)

CS06 is applicable to equipment and subsystem DC power leads, including grounds and returns which are not grounded internally to the equipment or subsystem. Equipment should not exhibit any malfunction, degradation in performance, or deviation from specified indications beyond the tolerances indicated in the individual equipment or subsystem specification when the test spikes, each having the waveform shown in Figure 3.4.2.2.4-1, are applied sequentially to the DC power output leads. The values of E and t are given below. Each spike shall be superimposed on the power line voltage waveform.

- Spike 1 E = ± twice the nominal line voltage, with t = 10 microsec ± 20%

- Spike 2 E = ± twice the nominal line voltage, with t = 0.15 microsec ± 20%.

Acceptable test set-ups for CS06 qualification are shown in Figures 3.4.2.2.4-2 and 3.4.2.2.4-3.

~~**Figure 3.4.2.2.4-1 Conducted Spike Susceptibility (CS06) Limit for Equipment Providing Power to the USOS**~~

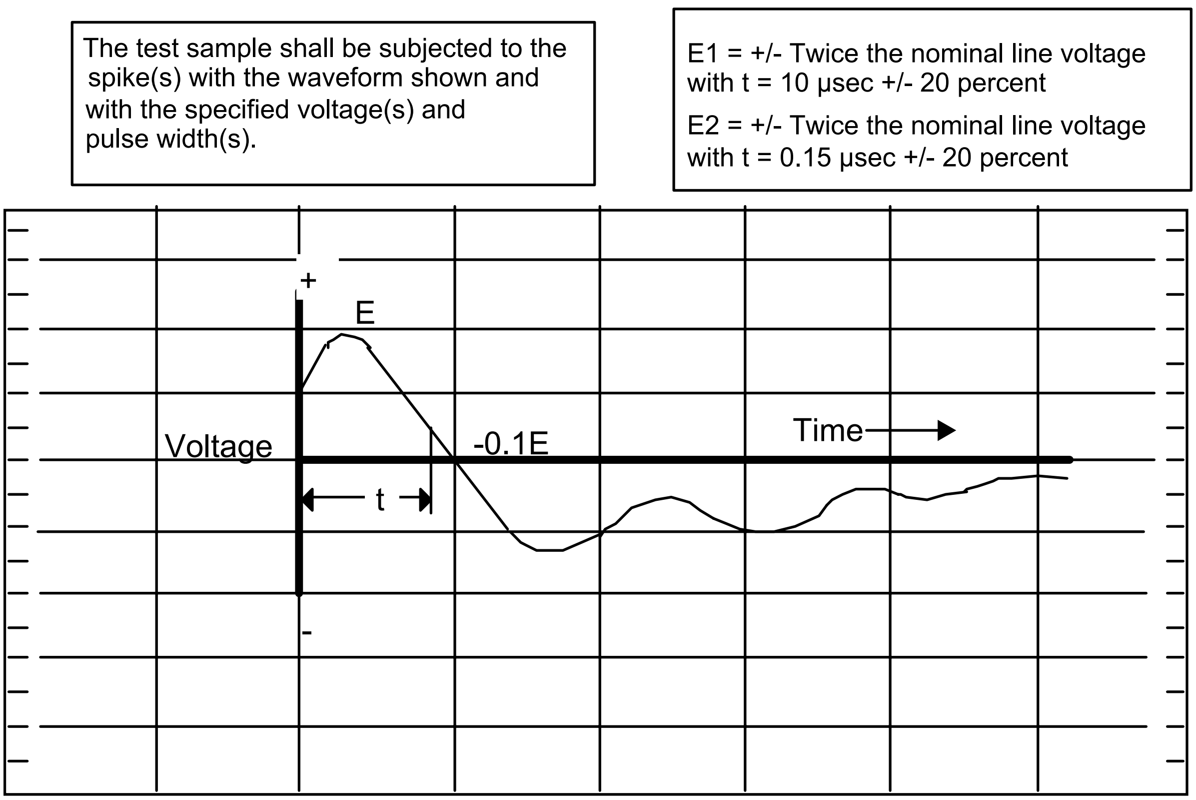


Figure 3.4.2.2.4-1 Conducted Spike Susceptibility (CS06) Limit for Equipment Providing Power to the USOS

Editorial formatting

Figure 3.4.2.2.4-2 Conducted Spike Susceptibility, (CS06) Series Injection Test Set-up for Equipment Providing Power to the USOS.

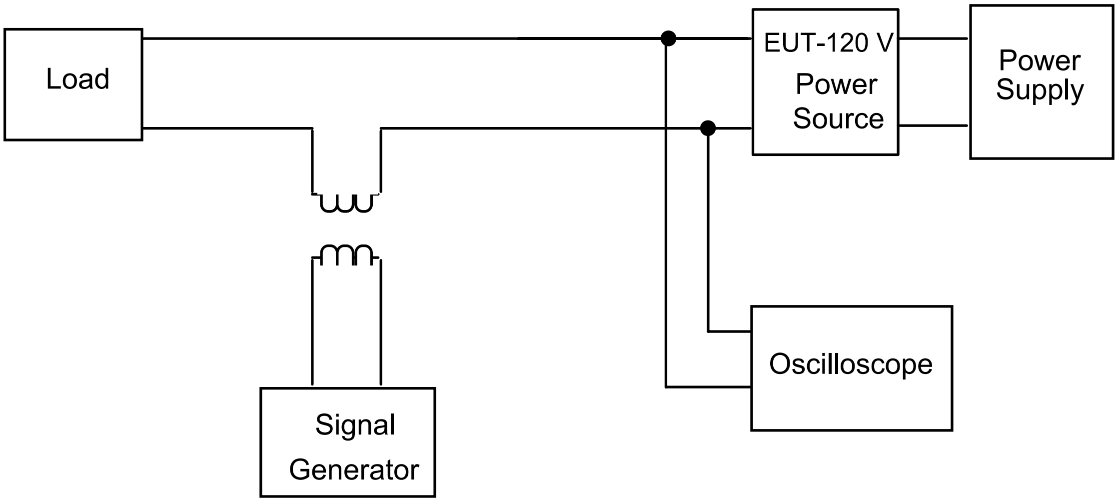


Figure 3.4.2.2.4-2 Conducted Spike Susceptibility, (CS06) Series Injection Test Set-up for Equipment Providing Power to the USOS

Editorial formatting

~~**Figure 3.4.2.2.4-3 Conducted Spike Susceptibility (CS06) Parallel Injection Test Set-Up for Equipment Providing Power to the USOS**~~

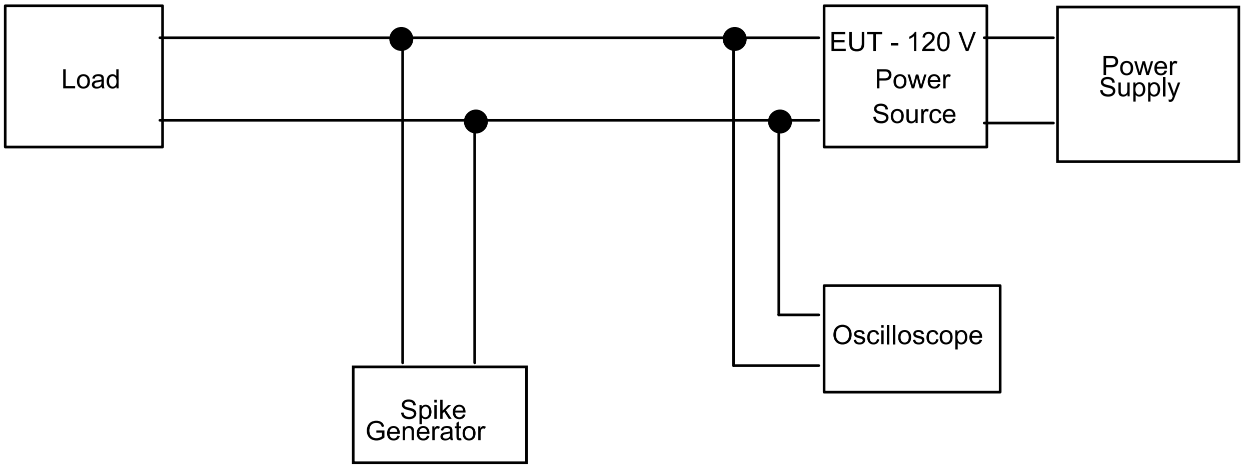


Figure 3.4.2.2.4-3 Conducted Spike Susceptibility (CS06) Parallel Injection Test Set-Up for Equipment Providing Power to the USOS

Editorial formatting

3.4.2.2.5 RADIATED RADIO FREQUENCY INTERFERENCE

Equipment shall function normally when exposed to electrical and magnetic fields outside and inside an object, as specified in items 3.4.1.2.4, 3.4.1.2.5.

3.4.3 REQUIREMENTS FOR EQUIPMENT USING U.S. ON-ORBIT SEGMENT (USOS) PRIMARY POWER

3.4.3.1 REQUIREMENTS FOR ELECTROMAGNETIC INTERFERENCE PRODUCED BY EQUIPMENT

Radio-electronic, electronic, electrical, and electromechanical equipment and electric power sources shall not produce electromagnetic interference that exceeds the requirements given in this section, with respect to the voltage of periodic interference in supply circuits, and also the intensity of the electrical field.

3.4.3.1.1 CE01/CE03 CONDUCTED EMISSIONS

The input power ports of the equipment shall not emit conducted emissions greater than the primary power system limit shown in Figure 3.4.3.1.1-1, when tested per the test set-up shown in Figure 3.4.3.1.1-2. The primary bus impedance simulator is characterized in Figure 3.4.3.1.1-3 and the equivalent network (LISN) is shown in Figure 3.4.3.1.1-4. The functionality of the equipment must be exercised during these measurements.

~~Figure 3.4.3.1.1-1 Conducted Emission Limit (CE01/CE03) for Equipment Using 160V Primary Power and for Equipment Using 120V Secondary Power~~

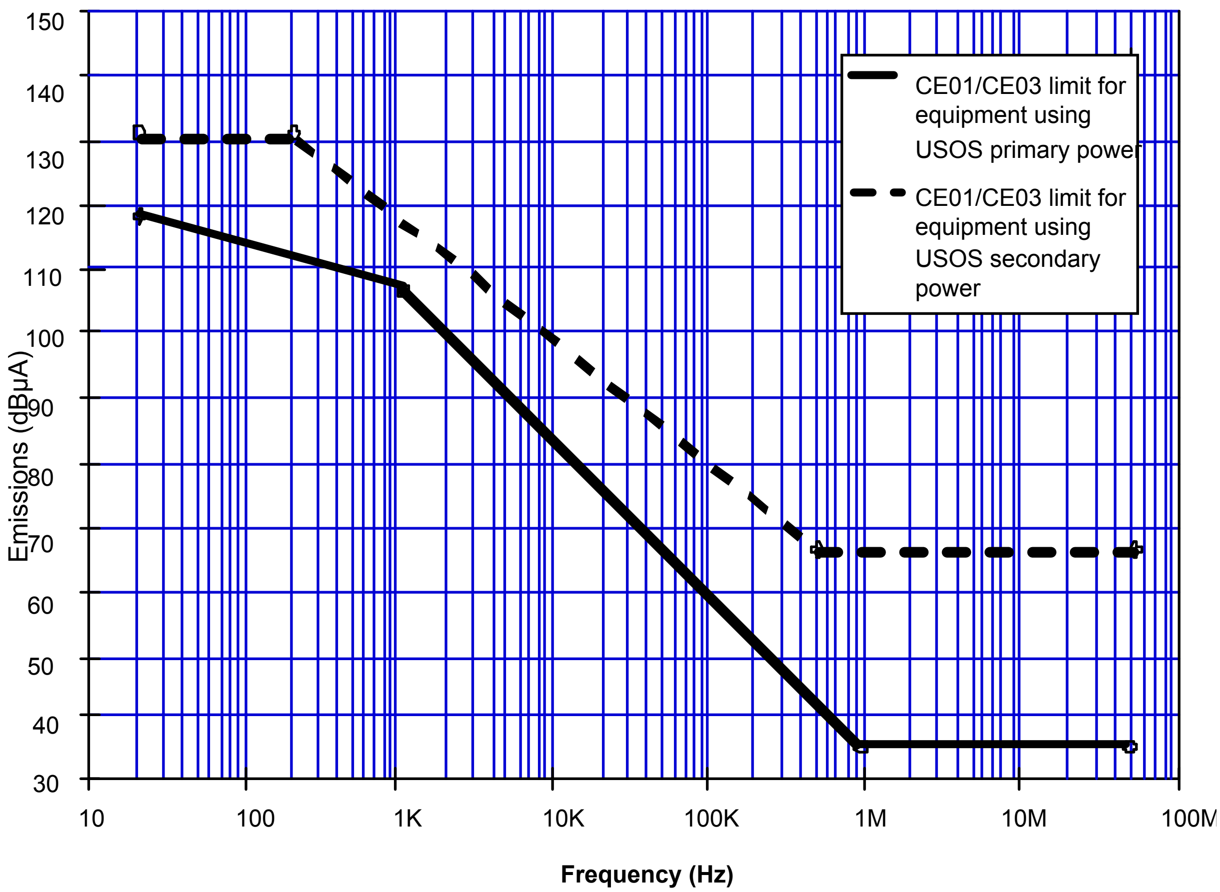
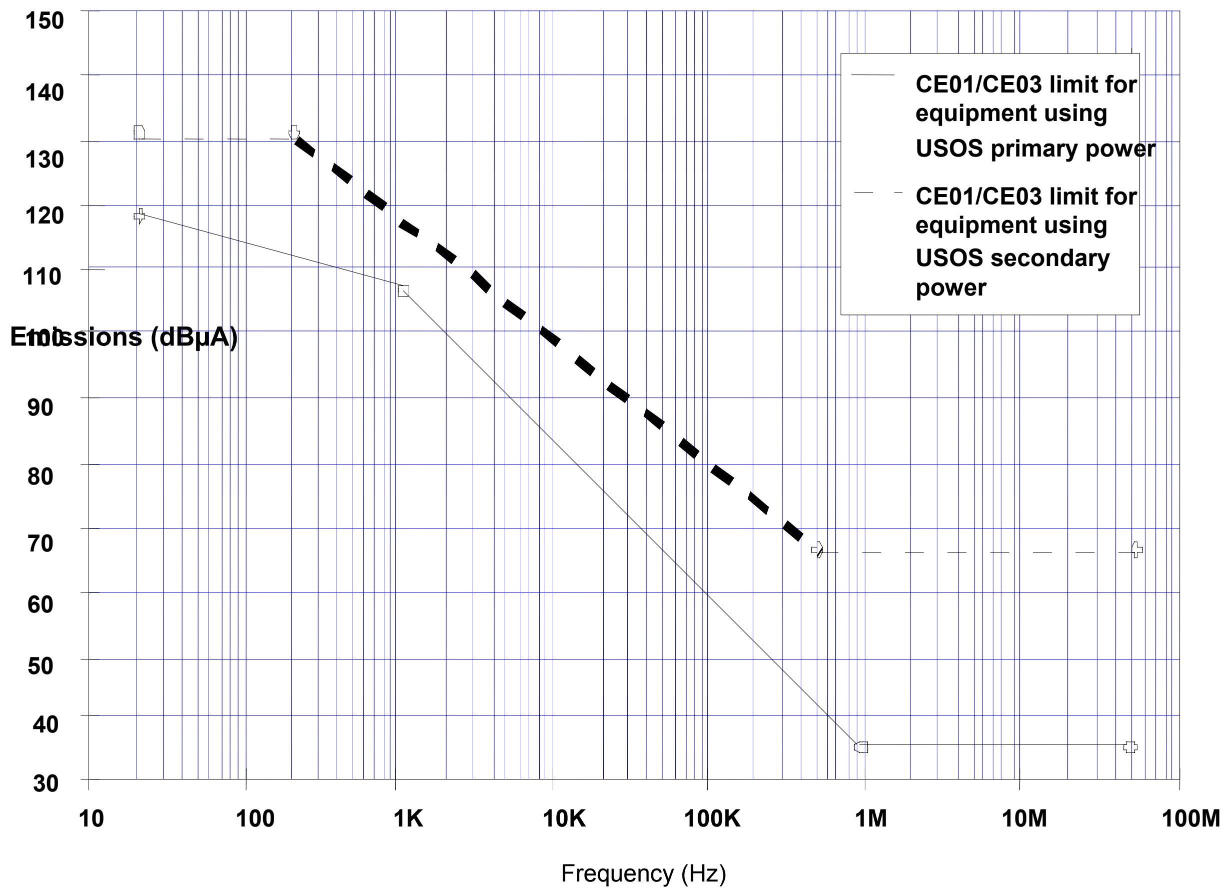


Figure 3.4.3.1.1-1 Conducted Emission Limit (CE01/CE03) for Equipment Using 160V Primary Power and for Equipment Using 120V Secondary Power

Editorial formatting


150
140
130
120
110
Emissions (dBµA)
100
90
80
70
60
50
40
30
10
100
1K
10K
100K
1M
10M
100M
Frequency (Hz)
CE01/CE03 limit for equipment using USOS primary power
CE01/CE03 limit for equipment using USOS secondary power

~~**Figure 3.4.3.1.1-2 Conducted Emissions Test Setup for USOS Primary Power Users and USOS Secondary Power Users**~~

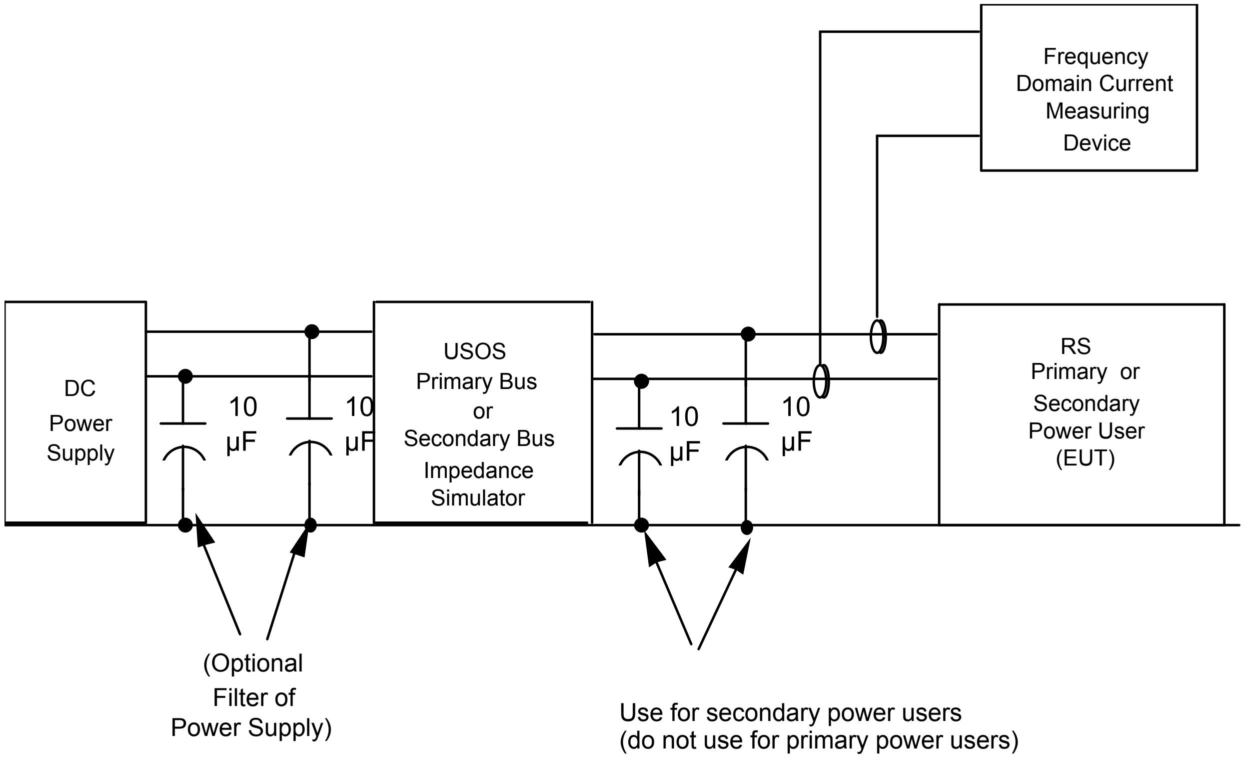


Figure 3.4.3.1.1-2 Conducted Emissions Test Setup for USOS Primary Power Users and USOS Secondary Power Users

Editorial formatting

~~**Figure 3.4.3.1.1-3 Primary Power Bus Source Impedance (Zm) and Secondary Power Bus Source Impedance (Zc)**~~

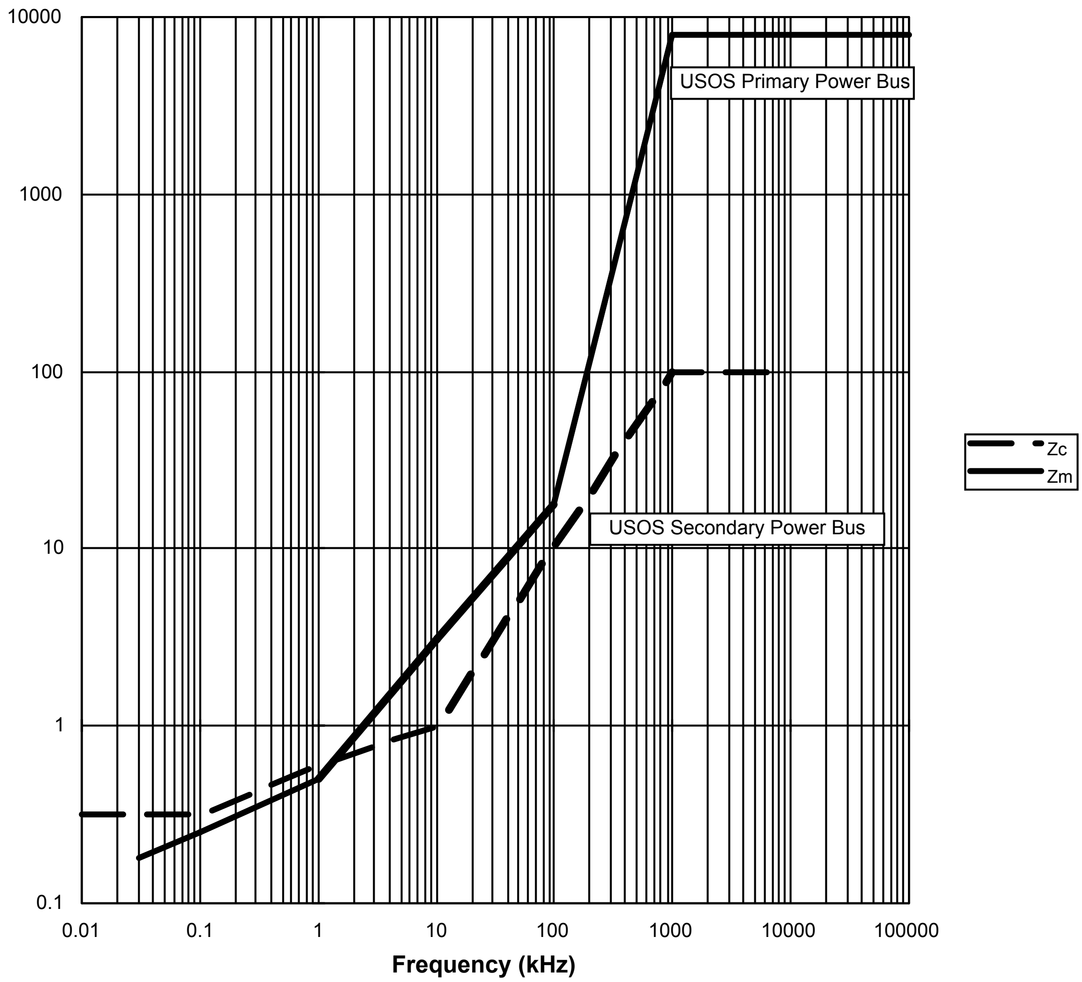


Figure 3.4.3.1.1-3 Primary Power Bus Source Impedance (Zm) and Secondary Power Bus Source Impedance (Zc)

Editorial formatting

~~Figure 3.4.3.1.1-4 USOS Primary Power Bus Impedance Equivalent Network~~

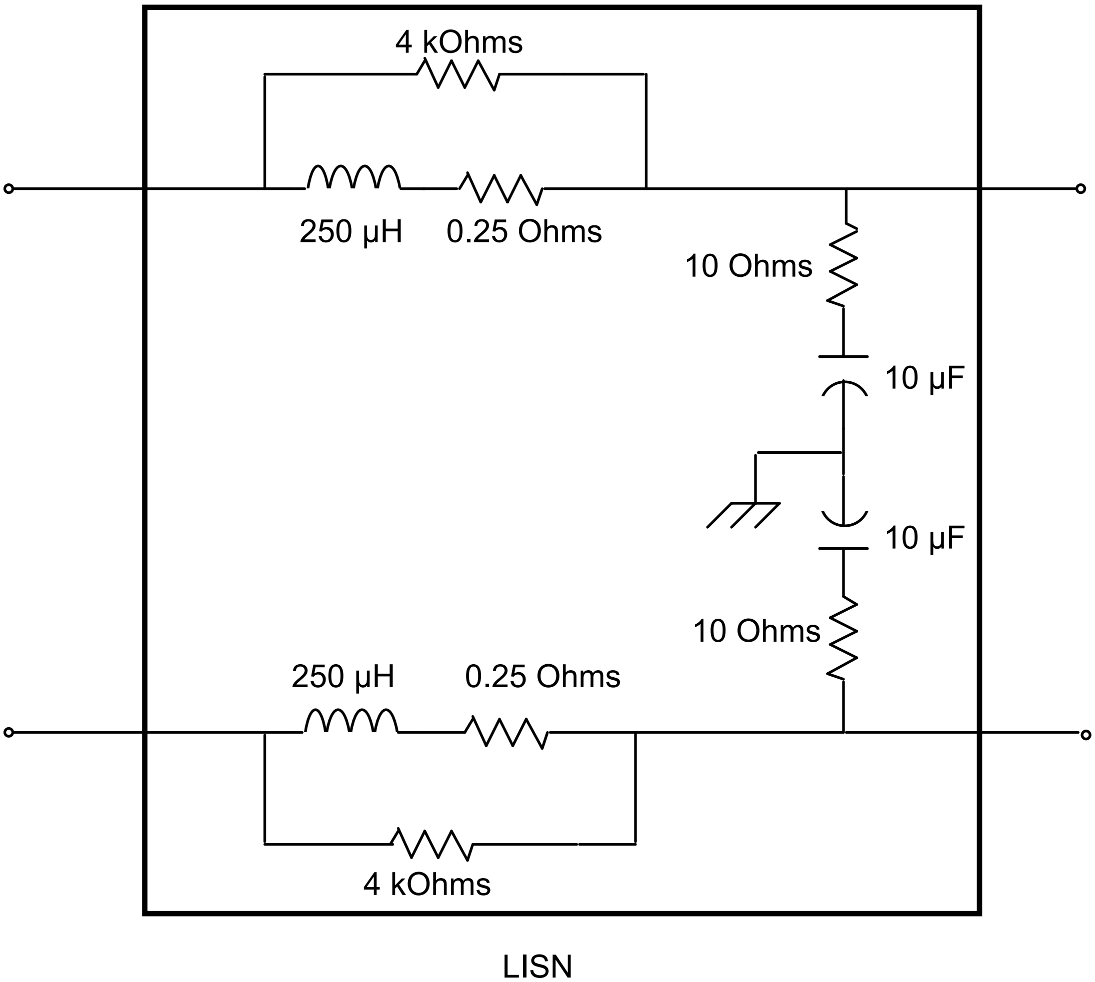


Figure 3.4.3.1.1-4 USOS Primary Power Bus Impedance Equivalent Network

Editorial formatting

~~Figure 3.4.3.1.1-5 USOS Secondary Power Bus Impedance Equivalent Network~~

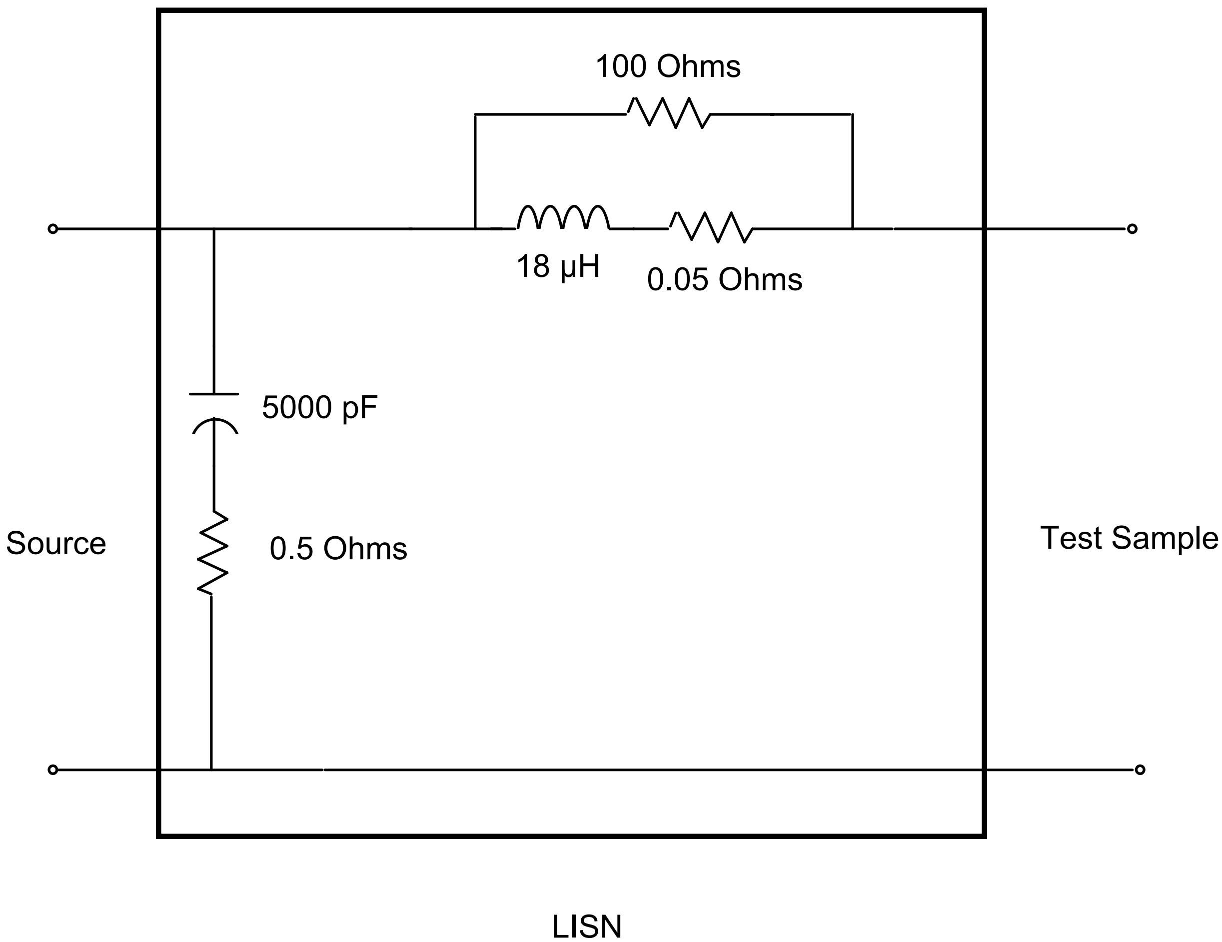


Figure 3.4.3.1.1-5 USOS Secondary Power Bus Impedance Equivalent Network

Editorial formatting

3.4.3.1.1.1 VOLTAGE RIPPLE LIMITS FOR 1.5 KW DC/DC POWER CONVERTER

The input power lines of a 1.5 kW DC/DC power converter shall not emit voltage ripple in excess of the limits shown in Figure 3.4.3.1.1.1-1 when tested as shown in Figure 3.4.3.1.1.1-2. The primary power bus impedance shown in Figure 3.4.3.1.1.1-2 is characterized in Figure 3.4.3.1.1-3 and the equivalent network (LISN) is shown in Figure 3.4.3.1.1-4.

~~**Figure 3.4.3.1.1.1-1 Voltage Ripple Limit at the input of a 1.5 kW Converter Attached to the Primary Bus at the Main Bus Switching Unit (MBSU) Measured Across a Primary Bus Impedance Simulator**~~

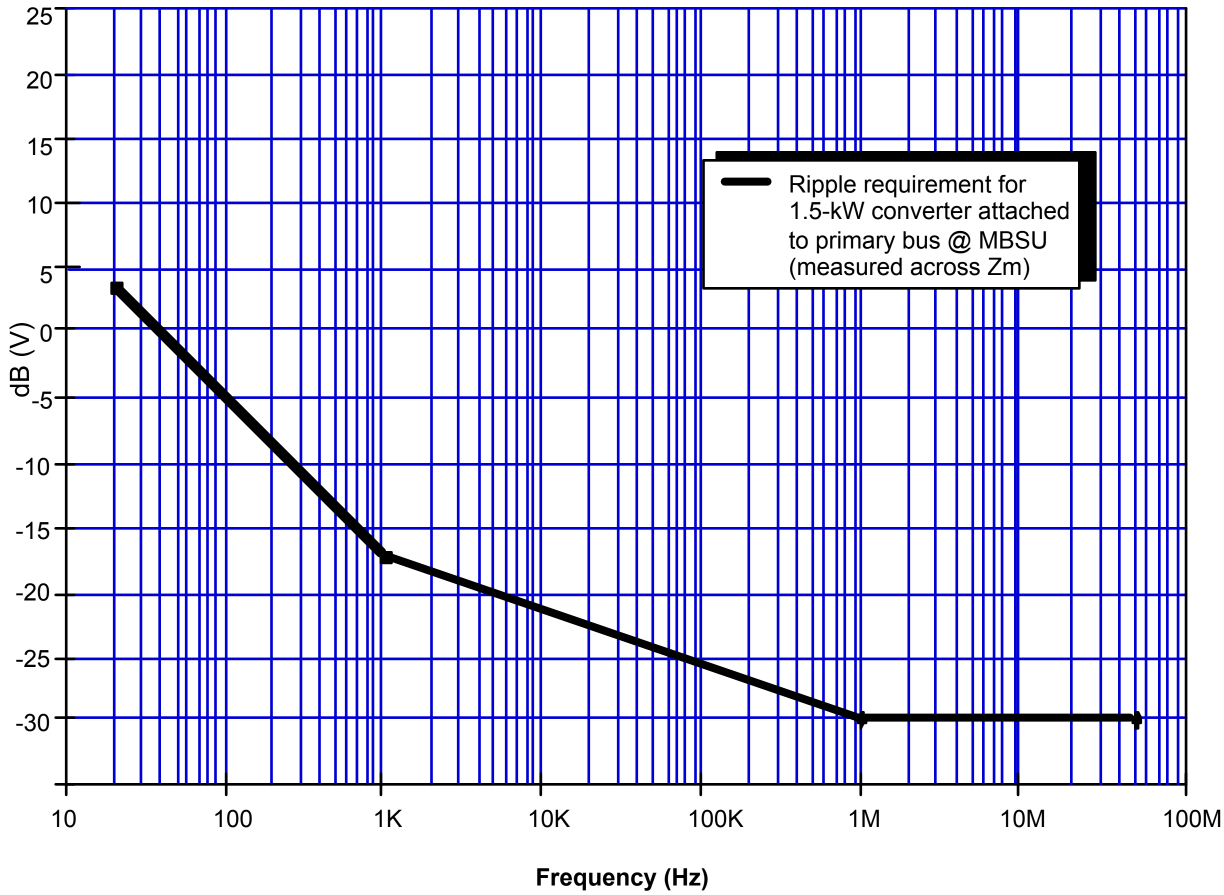


Figure 3.4.3.1.1.1-1 Voltage Ripple Limit at the input of a 1.5 kW Converter Attached to the Primary Bus at the Main Bus Switching Unit (MBSU) Measured Across a Primary Bus Impedance Simulator

Editorial formatting

~~**Figure 3.4.3.1.1.1-2 Voltage Ripple Test Set-Up for Equipment Using the USOS Primary or Secondary Power**~~

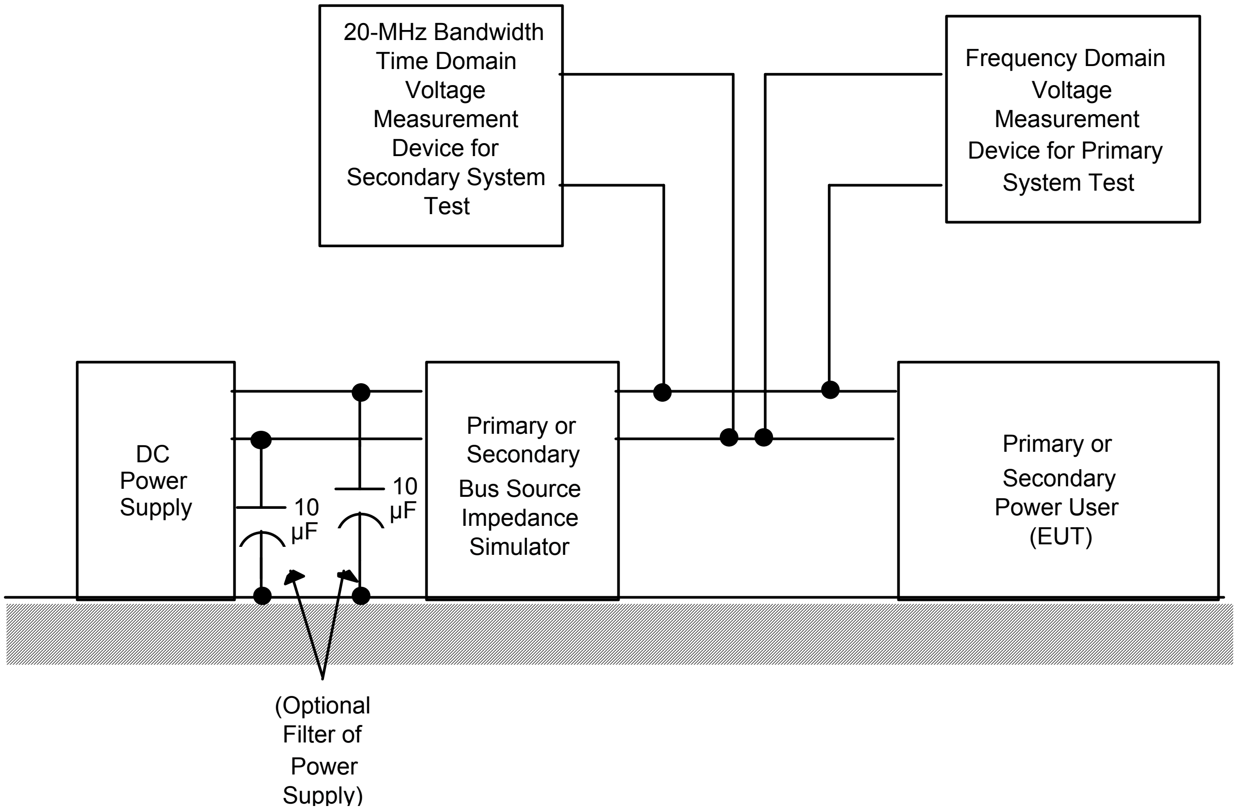


Figure 3.4.3.1.1.1-2 Voltage Ripple Test Set-Up for Equipment Using the USOS Primary or Secondary Power

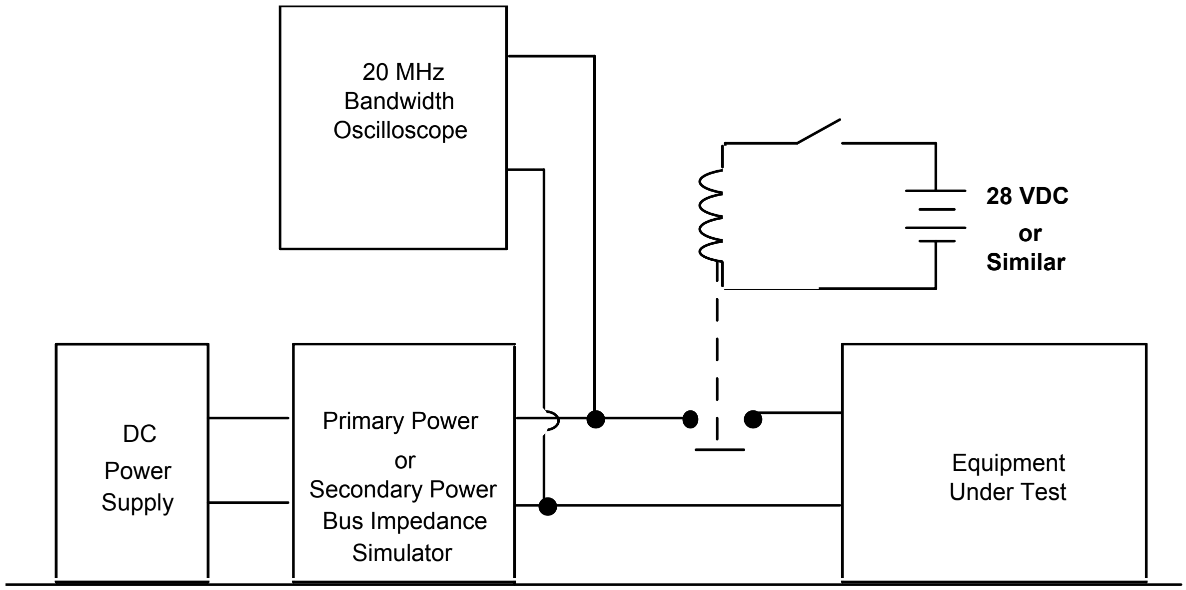
Editorial formatting

Output supply circuits of the 1.5 kW DC/DC converter shall not produce interference that exceeds the limits specified in items 3.4.1.1.1 and 3.4.1.1.2 and in Figures 3.4.1.1.1-1 and 3.4.1.1.2-1 when measurements are taken in accordance with the model shown in Figure 3.4.1.1.1-2 using the equivalent network shown in Figure 3.4.1.1.1-3.

3.4.3.1.2 CE07 CONDUCTED EMISSIONS (SPIKES)

On/off and mode switching transients measured on the input as shown in Figure 3.4.3.1.2-1 shall not exceed the limits enveloped below. Repetitive on/off and mode switching transients shall not occur more frequently than every 100 ms. The primary power bus source impedance simulator shown in Figure 3.4.3.1.2-1 is characterized in Figure 3.4.3.1.1-3 and the equivalent network is (LISN) is shown in 3.4.3.1.1-4.

~~Figure 3.4.3.1.2-1 Conducted Emissions (Spike) Test Set-Up for Equipment Using USOS Primary or Secondary Power~~



Time (microsec)	Percentage of nominal voltage in circuit
0.1-10	±50%
10-50	Falls linearly on a logarithmic scale over time from ±50% to ±20%
50-1000	Falls linearly on a logarithmic scale over time from ±20% to ±0.5% or ±0.5V, whichever is greater

Figure 3.4.3.1.2-1 Conducted Emissions (Spike) Test Set-Up for Equipment Using USOS Primary or Secondary Power

Editorial formatting

3.4.3.1.3 INTENSITY OF THE ELECTRICAL FIELD OF RADIATED RADIO FREQUENCY INTERFERENCE

Equipment installed on the ~~Russian Segment~~RS shall not produce interference that exceeds the limits given in Figure 3.4.1.1.3-1. Above 30 MHz, adherence to the limits should be ensured for both horizontally and vertically polarized waves. Measurements should be taken with the detector in quasi-peak mode (or peak). The distance between the measuring antenna and equipment must be 1m.

3.4.3.2 REQUIREMENTS FOR EQUIPMENT ELECTROMAGNETIC INTERFERENCE IMMUNITY

Radio-electronic, electronic, electrical, and electromechanical equipment and electric power sources shall function normally under the conditions of an electromagnetic environment described in this section with respect to the voltage of periodic and pulse interference in supply circuits, and also the intensity of the magnetic and electrical fields outside and inside a module.

3.4.3.2.1 CS01 CONDUCTED INTERFERENCE

Equipment shall not exhibit any malfunction, degradation in performance, or deviation from specified indications beyond the tolerances indicated in the individual equipment or subsystem specification when subjected to electromagnetic energy injected onto its input and output power leads less than or equal to the values indicated below (see the Table), as shown in Figure 3.4.3.2.1-1, when tested as shown in Figure 3.4.3.2.1-2.

~~**Figure 3.4.3.2.1-1 Limits of conducted interference susceptibility for equipment using the USOS primary power supply or 120V secondary power supply**~~

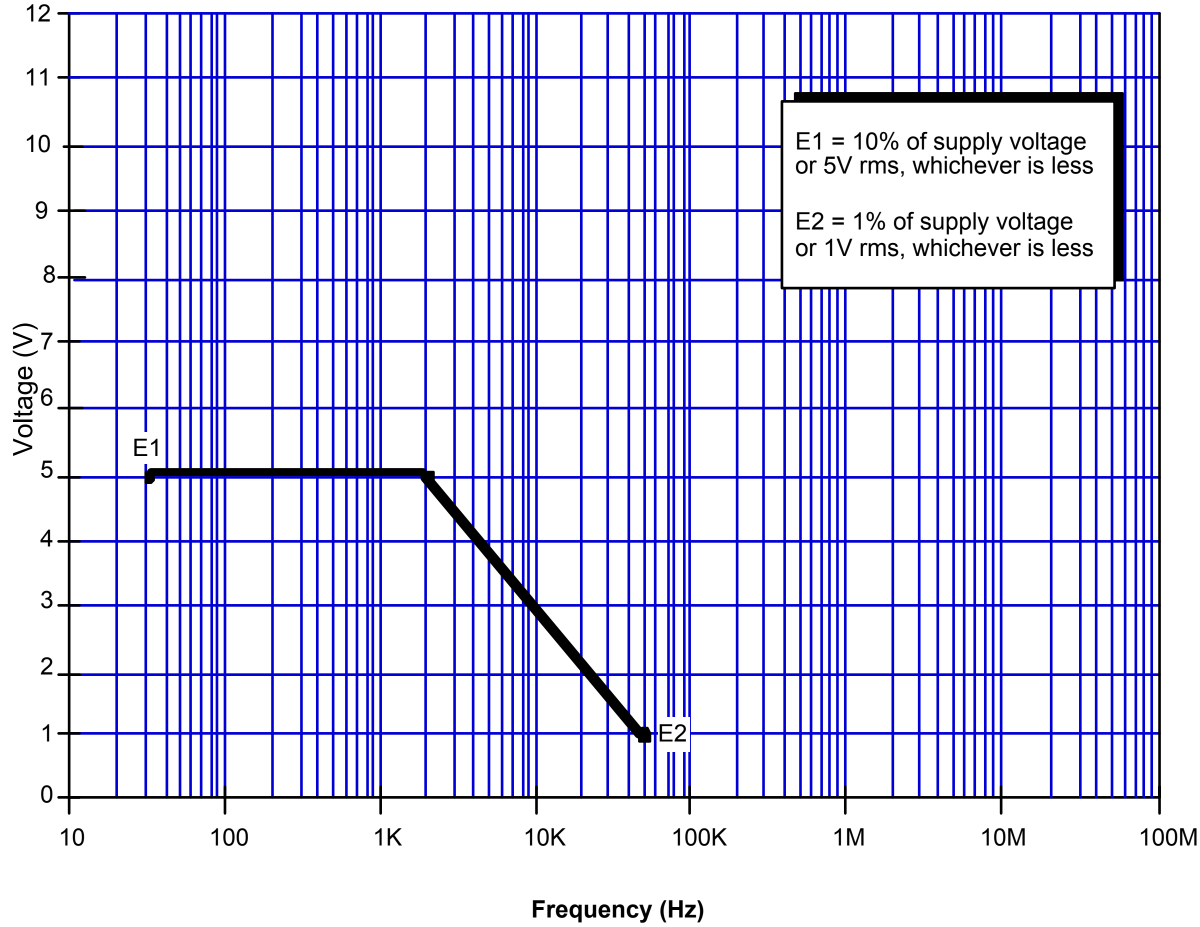
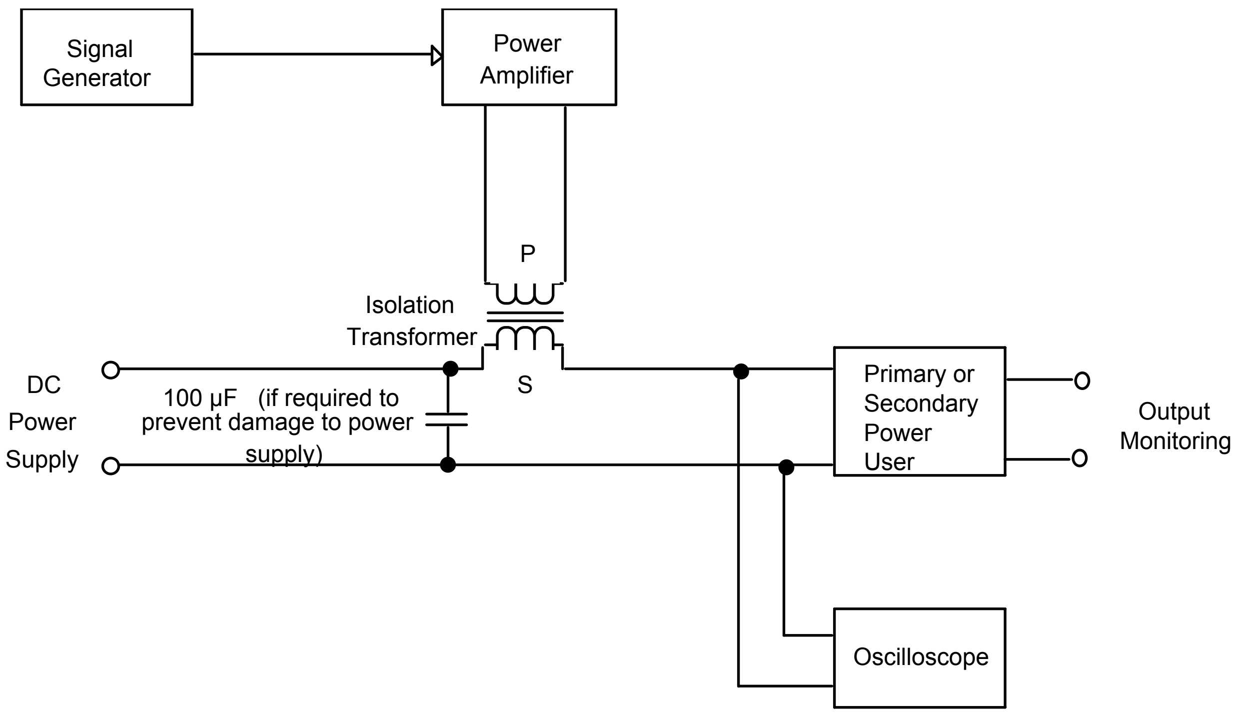


Figure 3.4.3.2.1-1 Limits of conducted interference susceptibility for equipment using the USOS primary power supply or 120V secondary power supply

Editorial formatting

Figure 3.4.3.2.1-2. Conducted Susceptibility (CS01) Test Set-Up for Equipment Using USOS Primary or Secondary Power



Frequency	Voltage
30 Hz - 2 kHz	5V rms or 10% of supply voltage, whichever is less
2 kHz - 50 kHz	Declines linearly in a logarithmic scale from 5V rms or 10% of supply voltage, whichever is less, to 1V rms or 1% of supply voltage, whichever is less

Figure 3.4.3.2.1-2 CS01 Test Set-Up for Equipment Using USOS Primary or Secondary Power

Editorial formatting

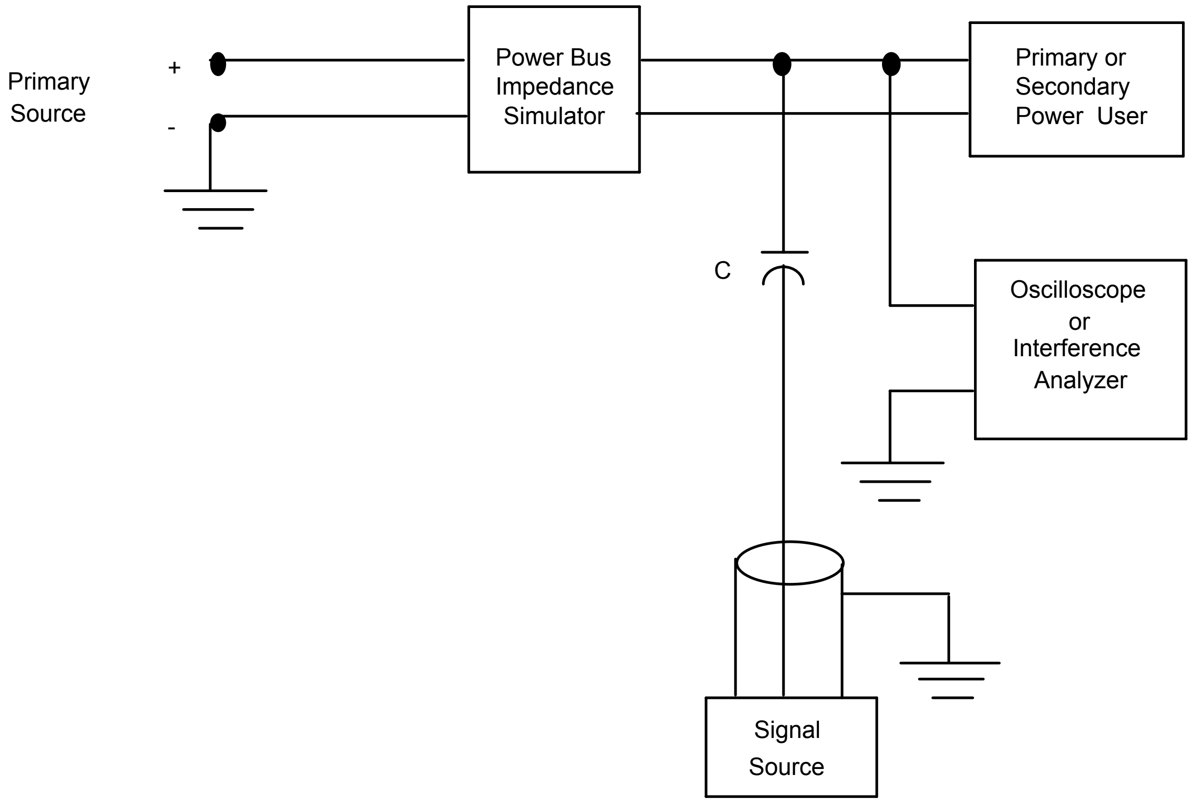
3.4.3.2.2 CS01 ALTERNATE LIMITS

The requirement is also met when the power amplifier shown in Figure 3.4.3.2.1-2 adjusted to dissipate 50 W in a load of 0.5 ohm, cannot develop the required voltage at the equipment power input terminals, and the equipment is not susceptible to the output of the signal source.

3.4.3.2.3 CS02 CONDUCTED SUSCEPTIBILITY

This requirement is applicable to DC input power leads, including power returns which are not grounded internally to the equipment. The equipment shall not exhibit any malfunction, degradation in performance, or deviation from specified indications beyond the tolerances indicated in the individual equipment or subsystem specification when subjected to 1V rms from a 50 ohm source across the frequency range of 50 kHz and 50 MHz. The test signal shall be applied to the equipment power line supply circuit near the input terminals. The requirement is also met under the following conditions: a 1 W source of 50 ohms impedance cannot develop the required voltage at the equipment power input terminals, and the equipment is not susceptible to the output of the signal source. The required CS02 test set-up is shown in Figure 3.4.3.2.3-1.

~~**Figure 3.4.3.2.3-1 Conducted Susceptibility (CS02) Test Set-Up for Equipment 160V Primary Power or 120V Secondary Power**~~



NOTES:

1. The value of C shall be chosen such that Xc <5 ohms over the test frequencies.

2. Connect the coupling capacitor and the Oscilloscope or Interference Analyzer within 5 cm of the termination to the EUT.

Figure 3.4.3.2.3-1 CS02 Test Set-Up for Equipment 160V Primary Power or 120V Secondary Power

Editorial formatting

3.4.3.2.4 POWER QUALITY

The primary power bus voltage ripple shall be controlled within the limits shown in Figure 3.4.3.2.4-1.

~~**Figure 3.4.3.2.4-1 Primary Power Bus Power Quality Voltage Ripple Limits (Guaranteed Performance)**~~

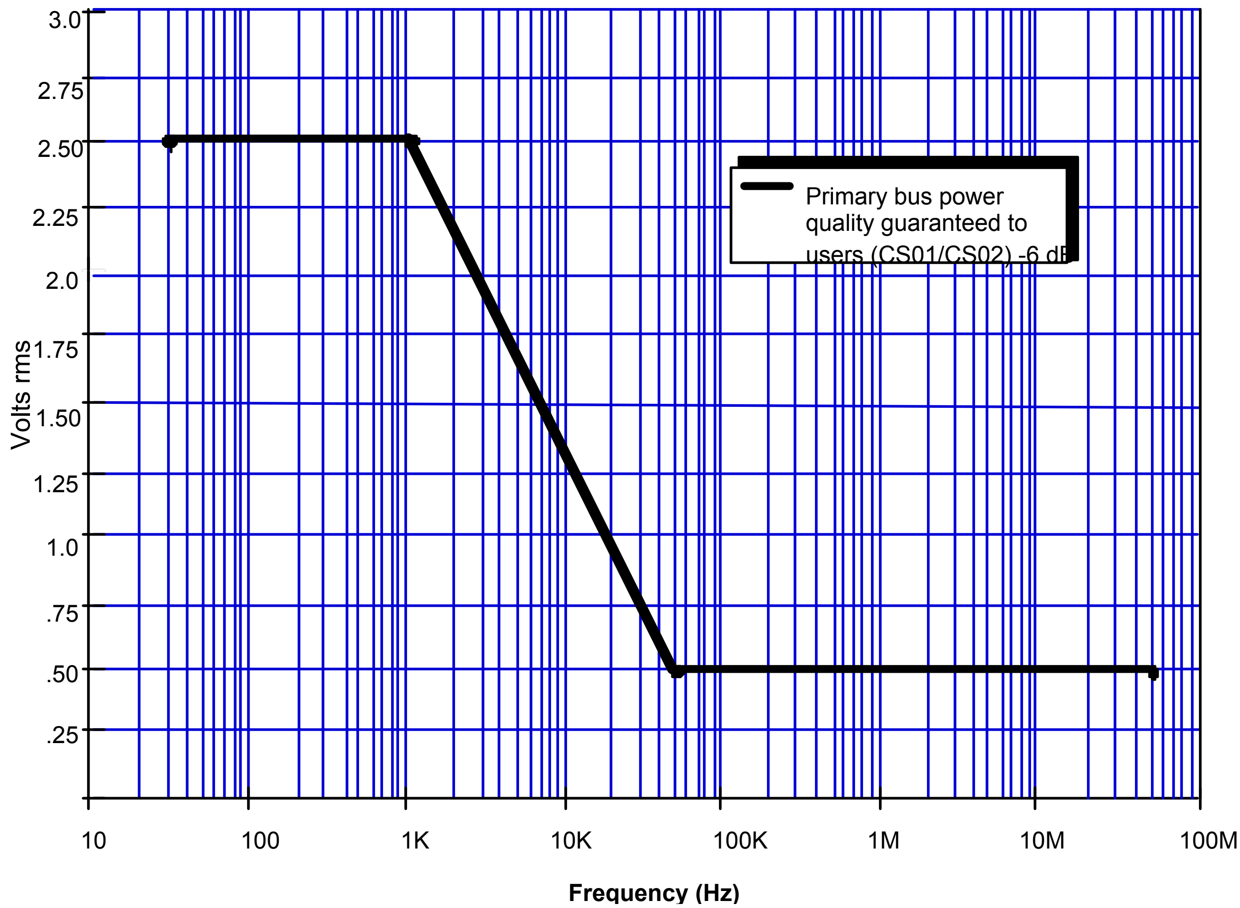


Figure 3.4.3.2.4-1 Primary Power Bus Power Quality Voltage Ripple Limits (Guaranteed Performance)

Editorial formatting

3.4.3.2.5 CS06 CONDUCTED SUSCEPTIBILITY (SPIKES)

CS06 is applicable to equipment and subsystem DC power leads, including grounds and returns which are not grounded internally to the equipment or subsystem. The equipment shall not exhibit any malfunction, degradation in performance, or deviation from specified indications beyond the tolerances indicated in the individual the equipment or subsystem specification when -test spikes, each having the waveform shown in Figure 3.4.3.2.5-1, are applied sequentially to DC power input leads. The values of E and t are given below. Each spike shall be superimposed on the power line voltage waveform.

- Spike 1 E = ± twice the nominal line voltage, with t = 10 microsec ±20%

- Spike 2 E = ± twice the nominal line voltage, with
t = 0.15 microsec ±20%.

Acceptable test block diagrams for certification of the CS06 are shown in Figures 3.4.3.2.5-2 and 3.4.3.2.5-3.

~~**Figure 3.4.3.2.5-1. Conducted Spike Susceptibility (CS06) Limit for Equipment Using the USOS Primary or Secondary Power**~~

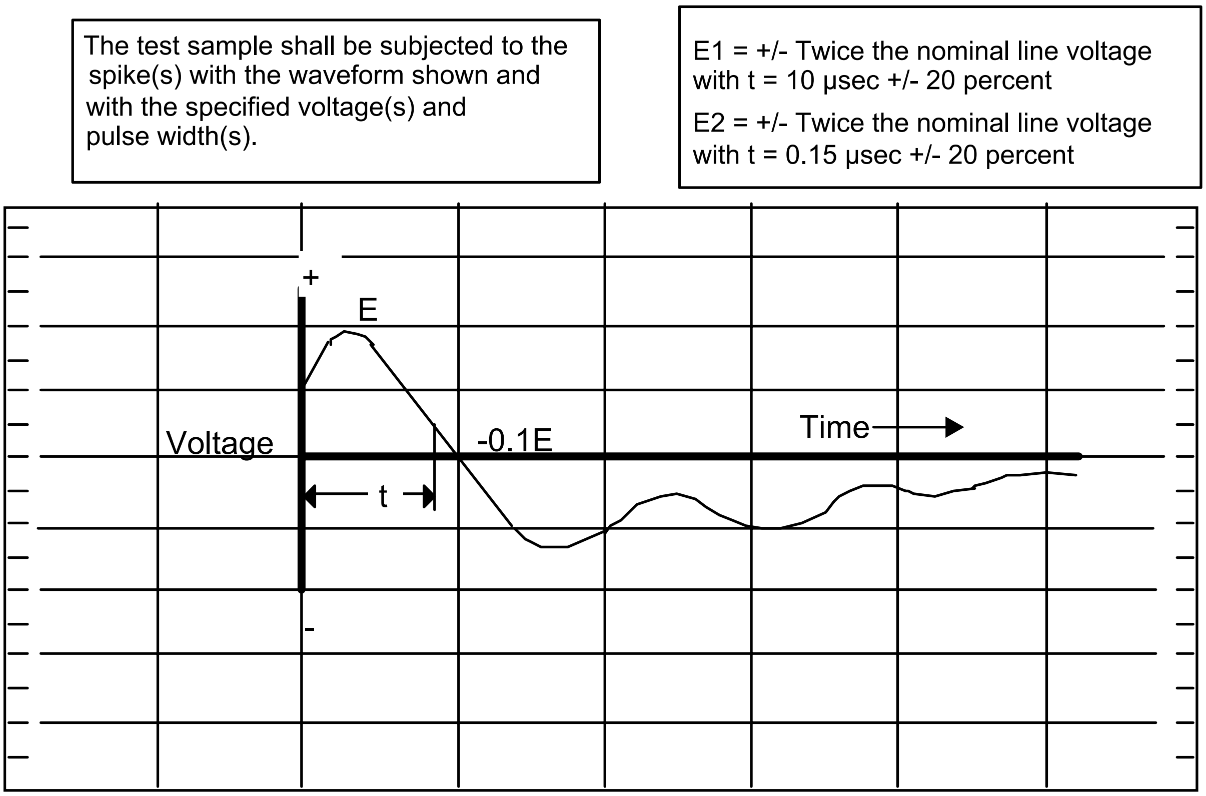
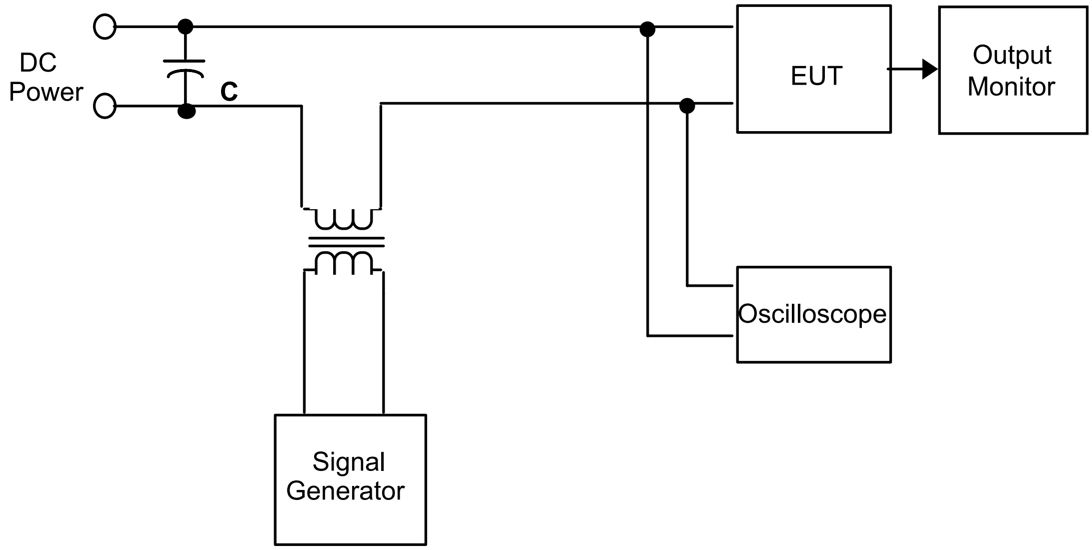


Figure 3.4.3.2.5-1 Conducted Spike Susceptibility (CS06) Limit for Equipment Using the USOS Primary or Secondary Power

Editorial formatting

~~**Figure 3.4.3.2.5-2 Conducted Spike Susceptibility (CS06) Series Injection Test Set-Up for Equipment Using the USOS Primary or Secondary Power**~~

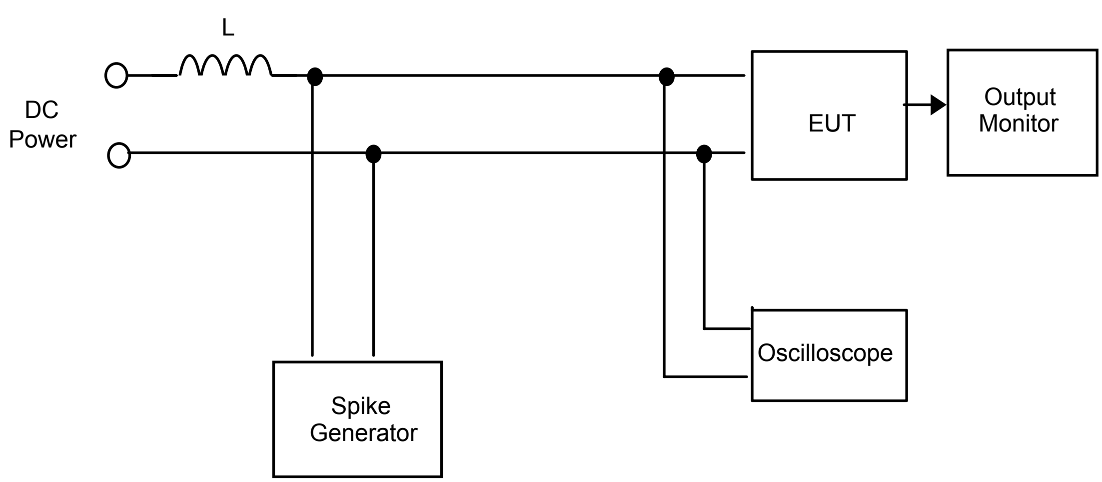


NOTE: Capacitor may be used to protect the DC power supply.

Figure 3.4.3.2.5-2 Conducted Spike Susceptibility (CS06) Series Injection Test Set-Up for Equipment Using the USOS Primary or Secondary Power

Editorial formatting

~~**Figure 3.4.3.2.5-3. Conduced Spike Susceptibility (CS06) Parallel Injection Test Set-up for Equipment Using the USOS Primary or Secondary Power**~~



NOTE: L = 20 microhenries (optional)

Figure 3.4.3.2.5-3 Conduced Spike Susceptibility (CS06) Parallel Injection Test Set-up for Equipment Using the USOS Primary or Secondary Power

Editorial formatting

3.4.3.2.6 RS03 RADIATED RADIO FREQUENCY INTERFERENCE

Equipment shall function normally when exposed to electrical and magnetic fields outside and inside a module described in items 3.4.1.2.4, 3.4.1.2.5.

3.4.4 REQUIREMENTS FOR EQUIPMENT USING ~~U.S. ON-ORBIT SEGMENT~~USOS SECONDARY POWER SUPPLY

3.4.4.1 REQUIREMENTS FOR ELECTROMAGNETIC INTERFERENCE PRODUCED BY EQUIPMENT

Radio-electronic, electronic, electrical, and electromechanical equipment and electric power sources shall not produce electromagnetic interference that exceeds the requirements given in this section, with respect to the voltage of periodic interference in supply circuits, and also the intensity of the electrical field.

3.4.4.1.1 CE01/CE03 CONDUCTED EMISSIONS

The input power ports of the equipment shall not emit conducted emissions greater than the secondary power supply system limit shown in Figure 3.4.3.1.1-1 when tested per the test set-up shown in Figure 3.4.3.1.1-2. The secondary power bus impedance simulator is characterized in Figure 3.4.3.1.1-3 and the equivalent network (LISN) is shown in Figure 3.4.3.1.1-5. The functionality of the equipment must be exercised during these measurements.

3.4.4.1.1.1 RIPPLE VOLTAGE LIMITS FOR 1.5 KW DC CONVERTER

The input power lines of the 1.5 kW DC/DC power converter shall not emit voltage ripple in excess of 0.5 volt from peak to peak when tested under as shown in Figure 3.4.3.1.1.1-2. The secondary bus impedance simulator shown in Figure 3.4.3.1.1.1-2 has the characterized in Figure 3.4.3.1.1-3 and the equivalent network (LISN) is shown in Figure 3.4.3.1.1-5.

Output power supply circuits of the 1.5 kW DC converter should not produce interference that exceeds the limits specified in item 3.4.1.1.1 and 3.4.1.1.2 and in Figures 3.4.1.1.1-1 and 3.4.1.1.2-1 when measurements are taken following the model given in Figure 3.4.1.1.1-2 using the equivalent network shown in Figure 3.4.1.1.1-3.

3.4.4.1.2 CE07 CONDUCTED EMISSIONS (SPIKES)

On/Off and mode switching transients measured on the input as shown in Figure 3.4.3.1.2-1 shall not exceed the limits enveloped below in Table 3.4.4.1.2-1. Repetitive on/off and mode switching transients shall not occur more frequently than every 100 ms. The secondary power source impedance simulator shown in Figure 3.4.3.1.2-1 is characterized in Figure 3.4.3.1.1-3 and the equivalent network (LISN) is shown in Figure 3.4.3.1.1-5.

Editorial correction

Table 3.4.4.1.2-1 Voltage Limits

Time (microsec)	Percentage of nominal voltage in circuit
0.1-10	±50%
10-50	Falls linearly on a logarithmic scale over time from ±50% to ±20%
50-1000	Falls linearly on a logarithmic scale over time from ±20% to ±0.5% or ±0.5V, whichever is greater

Editorial correction

3.4.4.1.3 INTENSITY OF THE ELECTRICAL FIELD OF RADIATED RADIO FREQUENCY INTERFERENCE

Equipment installed on the ~~Russian segment~~RS shall not produce interference that exceeds the limits given in Figure 3.4.1.1.3-1. Above 30 MHz, adherence to the limits should be ensured for both horizontally and vertically polarized waves. Measurements should be taken with the detector in a quasi-peak (or peak) mode. The distance between the measuring antenna and equipment must be 1m.

3.4.4.2 REQUIREMENTS FOR EQUIPMENT ELECTROMAGNETIC INTERFERENCE IMMUNITY

Radio-electronic, electronic, electrical, and electromechanical equipment and electric power sources shall function normally under the conditions of an electromagnetic environment described in section 3.4.3.2 (except 3.4.3.2.4) with respect to the voltage of periodic and pulse interference in supply circuits, and also the intensity of the magnetic and electrical fields outside and inside an object.

3.4.5 REQUIREMENTS FOR RADIO RECEIVERS, TRANSMITTERS, AND ANTENNA FEEDS

- Technical characteristics of receivers, transmitters, and antennas shall meet the requirements of radio communication regulations, international committee for radio frequency recommendations and regulatory documents of the country manufacturers. Particular requirements to radio electronic hardware shall be included in the Communications and Tracking ICD document and scientific hardware ICD.

- Radio receiver inputs shall withstand allowable radio interference not less than the values specified in item 3.4.1.2.5.

- Effectiveness of radio transmitter casings shielding shall not be less than calculated using the formulae below:

  $E_H \geq$ 5+2lgP/10(W)+20lgf(kHz)/0.1, at 0.02 kHz - 100 kHz,

  $E_E \geq$ 90+5lgP/10(W)-3.65lgf(kHz)/0.15, at 0.1 MHz - 300 MHz,

  $E_{EH} \geq$ 80+5lgP/10(W)-3.65lgf(kHz)/30, at 0.03 GHz - 37 GHz, where E_H, E_E, and E_{EH} -- transmitter shielding effectiveness for magnetic, electrical, or electromagnetic fields, dB;

P is the maximum value of the transmitter's output capacity, W;

and f is the radiation frequency of unintentional interference.

3.4.6 CLASSIFICATION OF WIRES AND CABLES, REQUIREMENTS FOR SEPARATION AND INSTALLATION

3.4.6.1 CLASSIFICATION

Electrical circuits are grouped as follows, depending on the circuit load, purpose, and possible interference:

- control and switching circuits with a current greater than 1A;
- power supply circuits;
- control, switching, and signal circuits with a current less than 1A;
- low-frequency circuits (signal circuits with a frequency lower than 1 MHz);
- high-frequency circuits (signal circuits with a frequency higher than 1 MHz);
- pyrotechnic circuits and firing circuits.

3.4.6.2 SEPARATION

The bundles of various onboard cable groups shall be installed 50 mm to 100 mm away from each other. Where this requirement cannot be met, an analysis shall be performed and submitted to evaluate system impacts and needed actions. If the analysis shows the interference margin is less than 6 dB, then a waiver is required. In addition to this analysis, positive results of electrical tests of every system on the integrated test stand and at the technical complex (processing complex) in the course of integrated testing may be used to support verification of the fulfillment of this requirement.

3.4.6.3 HIGH FREQUENCY CIRCUITS

Shielded coaxial or balanced double-core cables shall be used for high frequency circuits.

3.4.6.4 SHIELDING OF CABLES

High-frequency circuits shall be laid by shielded, coaxial or shielded balanced double-conductor cables.

3.4.7 REQUIREMENTS FOR CRITICAL CIRCUITS

3.4.7.1 CLASSIFICATION OF CRITICAL CIRCUITS

- Critical circuits are circuits that perform critical functions, those in which incorrect operation resulting from Electromagnetic Interference (EMI) could lead to fatal outcomes or loss of International Space Station.

- Critical circuits of the Bridge Wire Actuated Device (BWAD) type use the thermal-physical properties of a heated element in order to perform a discrete function. BWAD's can be divided into two groups: electro-explosive devices and nonexplosive devices.

3.4.7.2 INTERFERENCE IMMUNITY MARGIN FOR CRITICAL CIRCUITS

– Circuits implementing critical functions such that incorrect operation due to EMI can result in loss of life or loss of ISS shall be demonstrated to have a safety margin (6 dB by tests, or 20 dB by analysis).

– The EMI safety margins for such critical firing circuits of Electro-explosive Devices (EED) shall be demonstrated to be at least 20 dB by tests or 34 dB by analysis.

– The electro-explosive subsystem shall be designed to limit the power produced at each EED by the electromagnetic environment acting on the subsystem to a level at least 20 dB below maximum pin-to-pin ~~Direct Current (~~DC~~)~~ no-fire power of the EED.

– The electro-explosive subsystem shall be designed to limit the power produced at each device in the firing circuit that can complete any portion of the firing circuit to a level a least 6 dB below the minimum activation power for each of the safety devices.

– Permissible induced currents in pyrotechnic circuits shall not exceed 0.1 of the guaranteed no-fire current, while the induced pulse shall not exceed 0.01 of the guaranteed no-fire pulse as agreed upon under specifications for the given pyrotechnic device.

3.4.7.3 REQUIREMENTS FOR GROUNDING AND SHIELDING OF ~~ELECTROEXPLOSIVE DEVICES~~EED

– To prevent adverse electromagnetic effects, the bridge drive unit and the firing circuits, including the ignition circuits for ~~electrical explosive devices~~EED, must be isolated from other electrical circuits and from each other by a resistance of 1-Mohm. Every circuit used to initiate or ignite must be laid in the form of a shielded twisted (double-wound) pair with a multipoint ground for the shield near the source and load. Every ignition circuit must have a return path to the power source of the ignition circuit and must be isolated from "ground" with a minimum resistance of 20 Kohm. For the FGB circuits that do not pose a catastrophic hazard, the other requirements of this paragraph are imposed only if other methods of protection prove inadequate. Results of the analysis shall be reflected in FGB contract delivery SE08.

- The firing circuit including the EED shall be completely shielded, or shielded from the EED back to a point in the firing circuit at which isolators eliminate radio frequency (RF) entry into the shielded portion of the system. Isolators which provide 20 dB attenuation (regardless of source and load impedances) at all frequencies of the expected electromagnetic environment shall be considered acceptable. The adequacy of the RF protection provided by these isolators can also be demonstrated by test or analysis for each specific usage (i.e., the necessary protection is dependent on the configuration of unshielded circuits connected at this point and the expected electromagnetic environment).

- Cable shielding shall provide a minimum of 85 % of optical coverage.

- With the exception of cable shielding, there shall be no gaps or discontinuities in the shielding, including the termination at the back faces of the connectors, nor apertures in any container which houses elements of the firing circuit.

- Shields terminated at a connector shall provide 360 degrees continuous shield continuity without gaps.

- Any grounding of the firing circuits shall be done at one point only. The return path on all circuits shall be selected to minimize voltage buildup and transients on the firing circuit return with respect to the single point ground.

- Ungrounded firing output circuits shall be connected to structure by static bleed resistors.

- Structural ground shall not be used as return for ordnance circuitry.

- The source circuits shall terminate in a connector with socket contacts.

- The design shall preclude sneak circuits and unintentional electrical paths.

- Inhibits in the pyrotechnic circuits, such as relays and other switches in the general case shall not be construed as EMI protection.

- All connections to pyrotechnics will be shielded twisted pairs.

- The entire pyrotechnic electrical circuits will be enclosed in a shielded volume with all connections into that volume protected from external EMI.

- Control lines and special test lines will be configured so as not to act as antennas for EMI into the pyrotechnic circuits.

3.4.7.4 ELECTROSTATIC PROTECTION FOR ~~ELECTROEXPLOSIVE DEVICES~~EED

~~Electroexplosive devices~~EED shall be protected from electrostatic hazards by the placement of resistors from line-to-line and from line-to-ground (structure). The placement of line-to-structure static bleed resistances is not considered to violate the single-point ground requirements of this standard as long as the parallel combination of these resistors is 10 kohms or more.

For the FGB circuits that do not pose a catastrophic hazard, the other requirements of this paragraph are imposed only if other methods of protection prove inadequate. Results of the analysis shall be reflected in FGB contract delivery SE08.

3.4.7.5 TESTING OF ~~ELECTROEXPLOSIVE DEVICES~~EED FOR ELECTROMAGNETIC COMPATIBILITY

It shall be verified by analysis or testing that the ~~electroexplosive~~electro-explosive subsystem meets the requirements of paragraph 3.4.7.2. The analysis/test shall include not only the firing outputs circuits, but all the firing circuit elements, in particular the control circuits that can couple power to the ~~electroexplosive devices~~EED. The radiated and conducted electromagnetic environment will produce a peak Alternating Current (AC) power level at ~~electroexplosive devices~~EED, and this level must be compared to the maximum DC no fire power level of the ~~electroexplosive device~~EED, which is determined from the square of the DC no fire current times the nominal bridgewire resistance.

Note: The verification can be part of the normal electromagnetic compatibility conformance program, used for overall (completely assembled and powered-up) payload systems, for example, to connect the pyrotechnic device simulator or power measurement device to the firing output circuit. The monitoring device should be selected so as to minimize its effect on the entire system. This DC detector must have the capability of detecting pulses at least as short as 1 ms in duration. The pyrotechnic device simulator and measurement device should be selected with sensitivities to levels that are far less than the no fire level of the ~~electroexplosive device~~EED, so that the interference immunity margin of 20 dB can be demonstrated without irradiating the system at damaging levels.

It shall be shown by analysis or tests (see note above) that the ~~electroexplosive~~electro-explosive subsystem meets the requirements in paragraph 3.4.7.2.

3.4.8 DESIGN OF ELECTRICAL GROUNDING AND BONDING

3.4.8.1 REQUIREMENTS FOR ELECTRICAL BONDING

Basic structure shall be so designed that the conducting members provide a uniform lowest impedance path through all connections of the structure. All electrical and electronic units or components which use or produce electromagnetic energy shall be installed to provide a continuous low impedance path from the equipment enclosure to the conductive structure.

The electrical bond resistance for metal-to-metal bonds shall be in accordance with the specification for electrical bonding and grounding (33Y 0211.003).

Structure and equipment shall be bonded such that maximum electrical fault currents can be conducted without creating a thermal or electrical hazard.

Electrical connections shall be fabricated in accordance with the specification for bonding and grounding (33Y 0211. 003). Equipment shall be protected against electrostatic discharge via bonding, which ensures a reliable and stable electrical connection between parts, assembly or hardware components that might exhibit a static potential, with the objective of achieving an identical potential on all parts and hardware.

Electrical bonding of Screen-Vacuum Thermal Insulation (SVTI) shall be in accordance with the Specification for Electrical Bonding and Grounding of Screen-Vacuum Thermal Insulation (33Y.0211.005) and Vacuum-Shield Thermal Insulation of Rocket/Space Equipment, General Requirements for Protection from Static Electricity (OST 92-5168-93).

3.4.8.2 REQUIREMENTS FOR OVERALL GROUNDING

The design of the ~~Russian Segment~~RS system shall prevent electrical current from flowing in ground references. The Russian Space Station Segment, subsystems, equipment metallic components, and surfaces will be referenced to the Russian Space Station Segment conductive structure. Equipment external electrical signal and power grounds shall be DC isolated from each other. Analog and digital signal grounds external to a system, subsystem, or equipment shall be electrically isolated from each other at the equipment level. Grounding within electrical or electronic equipment is at the discretion of the designer as long as the external power and external signal return isolation requirements are met.

3.4.8.3 EQUIPMENT PROVIDING POWER TO ~~U.S. ON-ORBIT SEGMENT (~~USOS~~)~~

Equipment providing secondary power shall have its output power lines DC isolated from chassis, structure, primary power, and signal circuits by a minimum of 1 Megohm individually. The return wire of the secondary power shall be referenced to the structure via a cable.

3.4.8.4 EQUIPMENT USING USOS PRIMARY OR SECONDARY POWER

Equipment using primary (160V) or secondary (120V) power shall have its input power lines DC isolated from chassis, structure, equipment conditioned power and return, and signal circuits by a minimum of 1 Mohm individually.

3.4.8.5 ISOLATED ELECTRICAL POWER WITHIN EQUIPMENT

Within equipment, conditioned electrical power shall be DC isolated from chassis structure except at not more than one electrically conductive common point. Where termination is desired, the designer of the equipment has the option of either bringing the single point reference external to the equipment for termination- to the nearest structure ground or, of terminating the reference point to the chassis internal to the equipment. Both methods may be used simultaneously.

3.4.8.6 SIGNAL CIRCUIT RETURN GROUNDING

Signal circuit electrical power shall be DC isolated from chassis, structure and external equipment conditioned power return/reference by a minimum of 1 Mohm, individually.

Under no circumstances shall separate flight elements, assembly element, systems, subsystems, or equipment depend on other equipment for signal reference or return-wire grounding unless they are also dependent upon the other equipment for power.

3.4.8.7 ~~ALTERNATING CURRENT~~AC POWER RETURN

A neutral return wire shall accompany ~~alternating current~~AC input wires to individual loads in the distribution of power.

3.4.8.8 GROUNDING TO EQUIPMENT/VEHICLE NOT PERMANENTLY ATTACHED TO THE SPACE STATION

Temporary interface power supply shall be DC isolated from the temporarily attached equipment/vehicle. The attached equipment/vehicle shall provide ground and reference per the vehicle design. Power circuits supplied by ISS shall not be grounded in portable devices. Signal interfaces shall be referenced at one end and shall be balanced by differential transmissions or shall be isolated by a transformer, capacitor, or fiber-optic device. Signal ended signals shall be prohibited on circuits crossing an interface to non-Russian segments.

3.4.8.9 RETURNS, SIGNALS BELOW TEN ~~MEGAHERTZ (~~MHZ~~)~~

Signal circuits external to equipment with frequency content below ten megahertz shall be balanced and shall be isolated from chassis, structure, and user-conditioned power return/reference by a minimum of 6,000 ohms, individually (i.e., measured per connection, pin, wire, etc.). Otherwise external signals shall be isolated through optical isolators, transformers, etc. All references for circuits with frequencies below 10 MHz shall be referenced to structure at one point only. Shield connections shall be made to either connector shells that are grounded when mated or to connector pins.

3.4.8.10 RETURNS, SIGNALS EQUAL TO AND ABOVE TEN ~~MEGAHERTZ~~MHZ

Signal circuits with all frequency components equal to or above ten megahertz shall use controlled impedance transmission and reception media such as shielded twisted 75 ohm cable, "twin-ax" cable, "tri-ax" cable or "co-ax" cable. Circuits using "twin-ax" cable shall be balanced and shall be referenced to primary structure at one point only. "Tri-ax" cable shall use the center and inner shield conductors for unbalanced transmission and may be referenced to primary structure at no more than one point with the outer shield multipoint grounded as an "~~oversheild~~overshield." DC isolated, single-ended circuits coupled by coaxial cable with the shield terminated 360 degrees at each end and at available intermediate points, shall be permitted for signals with the lowest frequency component equal to or above 10 MHz.

3.4.8.11 SHIELD GROUNDING REQUIREMENTS

Shields shall be terminated at both ends and at intermediate break points directly to structure or chassis, through connector backshells or direct wire connection.

3.4.9 CORONA

Electrical and electronic subsystems, equipment, and systems using or providing any voltages (including input, output, and internal voltages), steady state or transients, equal to or greater than 123 Volts shall be designed to preclude damaging or destructive corona in any ISS operating environment. An analysis shall be provided to verify the corona shall not create damaging or destructive effects.

Not applicable to the FGB.

3.5 PLASMA

Space Station flight elements, systems, subsystems and equipment shall be plasma environment compatible. Plasma conditions are described by the electron density (n_e), the chemical composition of the ions (n_{O+}, n_{H+}, etc.,), and the electron and ion temperatures, T_e and T_i. There is a natural plasma component consisting of ambient ionosphere and auroral plasma, and an induced component of plasma due to the presence of the Space Station.

3.5.1 NATURAL PLASMA

3.5.1.1 IONOSPHERIC PLASMA

The properties of the ambient plasma (temperature, density, particle composition, etc.) vary in accordance with the solar cycle, altitude, sun/eclipse and the magnetic latitude. The ambient plasma properties shall be determined from International Reference Ionosphere-86 (IRI-86) model. In this mode, a factor of two shall be added to the plasma densities to overcome ionospheric environment uncertainties in calculating structure potential and current collection. The input to the model shall be determined as follows:

- Date, time -- as appropriate for the simulation
- Latitude, longitude, altitude -- as appropriate for each point on the orbit chosen for the simulation
- Solar activity -- sunspot number computed from the maximum solar flux (F10.7 curve for the "most likely" solar profiles for solar cycles 23 and 24. See Section 3.2.1.1, RSC-Energia Model of this document)

3.5.1.2 AURORAL PLASMA

Auroral plasma is primarily produced by high energy (~keV) charged particles precipitating into the atmosphere along magnetic field lines. The Space Station will occasionally pass through the auroral region which, particularly in the midnight and the solar minimum conditions, can result in significant charging on the exposed dielectric material. The auroral charging environment specified in Table 3.5.1.2-1 shall be used in predicting the charging potential on the Space Station external surface. Two sets of plasma parameters are listed. The nominal auroral environment describes auroral parameters which typically occur, and are to be used as design values. The severe auroral environment represents the extreme which may occur, and is not intended to be ~~sued~~ used as hard design numbers but instead as cautionary numbers.

Table 3.5.1.2-1 Auroral Charging Environment

Plasma Parameter	Symbol	Nominal Value	Extreme Value
Auroral electron energy (eV)	kT_e	10000	30000
Auroral electron velocity (m/sec)	v_e	5.93E + 07	1.03E + 8
Auroral electron current (A/m^2)	J_e	1.00E - 5	1.58E - 4
Auroral electron density (m^{-3})	n_e	1.00E + 6	1.00E + 7
Auroral electron flux (electrons/m^2-sec-ster)	G_e	4.97E + 12	8.44E + 12
Ramming ions energy (eV)	kT_i	5	5
Charging time (min)	t	1	5
Ionospheric plasma electron energy (eV)	E_e	0.12	0.12
Ramming ion current (A/m^2)	y_e	3.1E - 3	3.1E - 3
Ionospheric plasma electron density (m^{-3})	n_e	3.02E + 12	3.02E + 12

3.5.2 INDUCED PLASMA

The induced plasma environment is the ionized environment resulting from the ionization of molecular emissions from the whole sum of Space Station systems and payloads. plus other contributions from both man-made and natural sources, and modifications due to the movement of the Space Station through the plasma environment. The induced plasma effects such as arching and sputtering can cause rapid degradation of Space Station external materials. The induced plasma environment which shall be used for design is specified in Table 3.5.2-1

Table 3.5.2-1 _ Induced Plasma Properties

Plasma Parameter	Symbol	Ram Value	Wake Value (on the shaded side)
Induced electron density (m^{-3})	n_e	3E + 12	3E + 9
Induced electron energy (eV)	kT_e	0.12	1
Induced ion energy (eV)	kT_i	4.9	1
Induced electron current (mA/m^2)	J_e	21	<1
Induced ion current (mA/m^2)	y_e	3.1E - 3	3.1E - 3

3.6 REQUIREMENTS ON RADIATION CONDITIONS

Requirements on radiation conditions for the ISS and its modules were determined at an orbital altitude of up to 500 km and an inclination of 51.6°.

The characteristics of ionizing radiation were determined via calculation using American (NASA) models AE8MAX, AP8MAX, AP8MIN and CREME.

The characteristics of ionizing radiation that are responsible for the incremental change in material properties and instrument element base and depend on the accumulated absorbed dose were determined for the period of maximum solar activity using models AE8MAX (electrons) and AP8MAX (protons) with Epoch 1970 geometric field parameters.

The characteristics of Earth Radiation Belt (ERB) proton fluxes responsible for integral microcircuit failures are energy spectra and Linear Energy Transmission (LET) spectra determined for the period of minimum solar activity using model AP8MIN with Epoch 1964 geometric field parameters, and model CREME.

3.6.1 CHARACTERISTICS OF IONIZING RADIATION RESPONSIBLE FOR AN INCREMENTAL CHANGE IN PROPERTIES

Tables 3.6.1-1, 3.6.1-2, and 3.6.1-3 present requirements on ionizing radiation from ERB protons and electrons, which causes an incremental (over time) degradation in the characteristics of electrical radio device and materials (dose effects).

Table 3.6.1-1 presents the integral and differential energy spectra for ERB electrons and protons.

Table 3.6.1-1 Integral and differential energy spectra for radiation belt electrons and protons at maximum solar activity

ELECTRONS

Energy (MeV)	Integral Flux (elecrons/cm^2-day>E)	Differential Flux (electrons/cm^2-day-MeV)
0.01	2.0E+10	1.7E+11
0.04	1.5E+10	1.3E+11
0.07	1.2E+10	1.0E+11
0.10	9.1E+09	8.3E+10
0.20	3.5E+09	3.1E+10
0.30	1.5E+09	1.1E+10
0.50	4.4E+08	1.9E+09
0.70	2.3E+08	6.2E+08
0.90	1.5E+08	3.1E+08
1.00	1.2E+08	2.2E+08
1.10	1.1E+08	1.7E+08
1.20	9.1E+07	1.4E+08
1.30	7.8E+07	1.2E+08
1.40	6.7E+07	1.0E+08
1.50	5.7E+07	9.0E+07
1.60	4.9E+07	7.8E+07
1.70	4.1E+07	6.6E+07
1.80	3.5E+07	5.6E+07
1.90	3.0E+07	4.8E+07
2.00	2.6E+07	4.0E+07
2.50	1.2E+07	2.0E+07
2.75	7.5E+06	1.4E+07
3.00	4.8E+06	8.7E+06
3.25	3.0E+06	5.5E+06
3.50	1.9E+06	3.7E+06
4.00	6.9E+05	1.5E+06
4.50	2.2E+05	5.1E+05
5.00	6.9E+04	1.8E+05
5.40	2.2E+04	6.2E+04

PROTONS

Energy (MeV)	Integral Flux (protons/cm^2-day>E)	Differential Flux (protons/cm^2-day-MeV)
0.01	8.3E+07	5.1E+08
0.05	6.5E+07	3.7E+08
0.25	2.3E+07	9.8E+07
0.50	9.3E+06	2.3E+07
1.00	3.9E+06	4.1E+06
1.50	2.8E+06	1.4E+06
2.00	2.3E+06	6.1E+05
2.50	2.1E+06	3.3E+05

Energy (MeV)	Integral Flux (protons/cm^2-day>E)	Differential Flux (protons/cm^2-day-MeV)
3.00	2.0E+06	2.3E+05
3.75	1.8E+06	1.5E+05
4.50	1.7E+06	9.8E+04
6.00	1.6E+06	6.2E+04
10.00	1.4E+06	3.0E+04
20.00	1.2E+06	1.5E+04
30.00	1.1E+06	1.0E+04
50.00	9.5E+05	8.4E+03
80.00	7.2E+05	6.9E+03
100.00	5.9E+05	6.1E+03
150.00	3.4E+05	3.6E+03
200.00	2.1E+05	2.2E+03
250.00	1.2E+05	1.3E+03
300.00	6.9E+04	7.4E+02
350.00	4.0E+04	4.3E+02
400.00	2.4E+04	2.5E+02
450.00	1.4E+04	1.5E+02
500.00	8.2E+03	8.7E+01
550.00	4.9E+03	5.3E+01
600.00	2.7E+03	3.4E+01
650.00	1.4E+03	2.6E+01
700.00	3.7E+02	9.8E+00

The data on this table can be used to directly evaluate operational performance of materials and elements arranged outside the space vehicle, whose specifications express radiation stability parameters as spectral characteristics. On the other hand, they are more frequently used to calculate absorbed doses for materials, elements and instruments given complex shielding by space vehicle elements and materials.

Tables 3.6.1-2 and 3.6.1-3 present absorbed doses behind the shielding at the center of a solid aluminum sphere and at depths in flat semi-infinite aluminum slabs. This is the standard way of representing absorbed dose as a function of shield thickness.

Table 3.6.1-2 Absorbed doses at the center of a solid aluminum sphere (rads/year, silicon) for maximum solar activity

SHIELDING (g/cm^2)	ELECTRON (rads/year)	PROTON (rads/year)	TOTAL (rads/year)
0.00001	7.9E+05	6.1E+04	8.6E+05
0.00003	8.0E+05	6.2E+04	8.6E+05
0.00005	8.1E+05	6.3E+04	8.7E+05
0.00007	8.2E+05	6.5E+04	8.8E+05
0.0001	8.3E+05	6.5E+04	9.0E+05
0.0002	8.8E+05	8.1E+04	9.6E+05
0.0003	8.7E+05	8.5E+04	9.5E+05
0.0004	8.2E+05	7.0E+04	8.9E+05
0.0005	7.9E+05	5.9E+04	8.5E+05

0.0006	7.6E+05	4.9E+04	8.1E+05
0.0007	7.3E+05	4.0E+04	7.7E+05

Table 3.6.1-2 Absorbed doses at the center of a solid aluminum sphere (rads/year, silicon) for maximum solar activity (cont.)

0.001	6.7E+05	2.6E+04	7.0E+05
0.003	4.8E+05	5.5E+03	4.9E+05
0.005	3.9E+05	2.6E+03	3.9E+05
0.007	3.4E+05	1.6E+03	3.4E+05
0.01	2.8E+05	9.5E+02	2.8E+05
0.03	1.0E+05	3.1E+02	1.0E+05
0.05	5.0E+04	2.2E+02	5.0E+04
0.07	2.9E+04	1.8E+02	2.9E+04
0.1	1.5E+04	1.5E+02	1.5E+04
0.2	4.6E+03	1.1E+02	4.7E+03
0.3	2.4E+03	9.3E+01	2.5E+03
0.4	1.5E+03	8.4E+01	1.6E+03
0.5	1.1E+03	7.5E+01	1.2E+03
0.6	7.9E+02	7.1E+01	8.6E+02
0.7	5.9E+02	6.9E+01	6.5E+02
0.8	4.3E+02	6.4E+01	4.9E+02
0.9	3.2E+02	6.2E+01	3.8E+02
1	2.4E+02	6.2E+01	3.0E+02
2	9.0E+00	4.9E+01	5.8E+01
3	1.6E+00	4.3E+01	4.4E+01
4	1.2E+00	3.8E+01	3.9E+01
5	1.0E+00	3.4E+01	3.5E+01
6	9.2E-01	3.3E+01	3.4E+01
7	8.2E-01	2.9E+01	3.0E+01
8	7.4E-01	2.7E+01	2.8E+01
9	6.8E-01	2.5E+01	2.6E+01
10	6.2E-01	2.3E+01	2.4E+01
15	4.4E-01	1.7E+01	1.8E+01
20	3.2E-01	1.3E+01	1.3E+01
25	2.3E-01	9.5E+00	9.7E+00
30	1.6E-01	7.7E+00	7.8E+00
35	1.1E-01	6.6E+00	6.7E+00
40	7.4E-02	5.3E+00	5.3E+00
45	4.9E-02	4.3E+00	4.4E+00
50	3.3E-02	3.8E+00	3.8E+00

Table 3.6.1-3 Absorbed doses in a flat semi-infinite aluminum medium (rads/year, silicon) for maximum solar activity

SHIELDING (g/cm^2)	ELECTRON (rads/year)	PROTON (rads/year)	TOTAL (rads/year)
0.00001	4.0E+05	3.1E+04	4.3E+05
0.00002	4.0E+05	3.2E+04	4.3E+05
0.00003	4.0E+05	3.2E+04	4.4E+05
0.00004	4.1E+05	3.2E+04	4.4E+05
0.00005	4.1E+05	3.2E+04	4.4E+05
0.00006	4.1E+05	3.2E+04	4.4E+05
0.00007	4.1E+05	3.2E+04	4.4E+05
0.00008	4.1E+05	3.2E+04	4.4E+05
0.00009	4.0E+05	3.2E+04	4.4E+05
0.0001	4.0E+05	3.2E+04	4.4E+05
0.0002	3.8E+05	2.9E+04	4.1E+05
0.0003	3.5E+05	2.3E+04	3.8E+05
0.0004	3.3E+05	1.7E+04	3.5E+05
0.0005	3.1E+05	1.4E+04	3.2E+05
0.0006	2.9E+05	1.1E+04	3.1E+05
0.0007	2.8E+05	8.8E+03	2.9E+05
0.0008	2.7E+05	7.4E+03	2.8E+05
0.0009	2.6E+05	6.3E+03	2.7E+05
0.001	2.5E+05	5.5E+03	2.6E+05
0.002	1.9E+05	2.0E+03	2.0E+05
0.003	1.6E+05	1.1E+03	1.6E+05
0.004	1.4E+05	7.4E+02	1.4E+05
0.005	1.2E+05	5.5E+02	1.2E+05
0.006	1.1E+05	4.3E+02	1.1E+05
0.007	9.8E+04	3.5E+02	9.8E+04
0.008	8.8E+04	2.9E+02	8.8E+04
0.009	8.0E+04	2.6E+02	8.1E+04
0.01	7.3E+04	2.3E+02	7.4E+04
0.03	2.1E+04	9.6E+01	2.1E+04
0.05	9.3E+03	7.2E+01	9.4E+03
0.07	5.2E+03	6.1E+01	5.3E+03
0.1	2.8E+03	5.2E+01	2.8E+03
0.2	8.7E+02	3.9E+01	9.1E+02
0.3	4.5E+02	3.4E+01	4.8E+02
0.4	2.7E+02	3.1E+01	3.0E+02
0.5	1.8E+02	2.8E+01	2.0E+02
0.6	1.2E+02	2.7E+01	1.4E+02
0.7	7.8E+01	2.5E+01	1.0E+02
0.8	5.3E+01	2.4E+01	7.7E+01
0.9	3.6E+01	2.3E+01	5.9E+01
1	2.5E+01	2.2E+01	4.7E+01
2	9.6E-01	1.7E+01	1.8E+01

SHIELDING (g/cm^2)	ELECTRON (rads/year)	PROTON (rads/year)	TOTAL (rads/year)
3	4.3E-01	1.4E+01	1.4E+01
4	3.4E-01	1.2E+01	1.2E+01
5	2.9E-01	1.0E+01	1.1E+01

The data presented on Tables 3.6.1-2 and 3.6.1-3 are used to more precisely calculate local dose characteristics in equipment installation sites. They can also be used to evaluate the radiation stability of space vehicle equipment and elements at maximum, when the maximum absorbed dose is determined at a known minimal shield thickness value, and compared with the critical dose value for the examined element (instrument). If the dose is lower than the critical value (taking into account the safety factor), local radiation conditions need not be calculated more precisely, and a conclusion can be made as to whether the object (instrument, unit, element) conforms to radiation stability requirements (or can be released for radiation tests).

The data on Table 3.6.1-3 concerning the total dose from protons and electrons are used for materials of external ISS surfaces.

3.6.2 CHARACTERISTICS OF IONIZING RADIATION RESPONSIBLE FOR FAILURES DURING EXPOSURE TO HEAVY CHARGED PARTICLES

Integral and differential Heavy Charged Particle (HCP) spectra and LET spectra represent the characteristics of HCP responsible for failures in space vehicle equipment. Maximal flux density values and methodical differences in calculating the intensity of failures due to protons and heavy ions were used as the basis for specifying their LET spectra.

The LET spectra for heavy ions encompass the entire ion group, from alpha particles helium (He) nuclei to uranium (U) nuclei.

Tables 3.6.2-1 and 3.6.2-2 present averaged integral and differential ERB proton spectra behind aluminum shielding of varying thickness.

These spectra are used to calculate average daily values for the failure rate in integral microcircuits caused by ERB protons and generate the appropriate requirements on averaged ERB proton fluxes for equipment located in ~~ISSA~~ISS modules.

Table 3.6.2-1 Average daily proton integral spectra (pr/cm2/day) behind shielding of varying thickness at minimum solar activity.

ENERGY (MeV)	0.0 (g/cm^2)	0.3 (g/cm^2)	3.0 (g/cm^2)	7.0 (g/cm^2)	15.0 (g/cm^2)	30.0 (g/cm^2)	50.0 (g/cm^2)
10	3.3E+06	2.6E+06	1.7E+06	1.2E+06	7.1E+05	3.5E+05	1.8E+05
20	2.5E+06	2.2E+06	1.6E+06	1.2E+06	7.0E+05	3.5E+05	1.7E+05
30	2.1E+06	2.0E+06	1.5E+06	1.1E+06	6.7E+05	3.4E+05	1.7E+05
40	1.9E+06	1.8E+06	1.4E+06	1.0E+06	6.5E+05	3.3E+05	1.7E+05
50	1.7E+06	1.6E+06	1.3E+06	9.9E+05	6.2E+05	3.2E+05	1.6E+05
60	1.5E+06	1.5E+06	1.2E+06	9.2E+05	5.8E+05	3.1E+05	1.6E+05
70	1.4E+06	1.3E+06	1.1E+06	8.5E+05	5.5E+05	2.9E+05	1.5E+05
80	1.2E+06	1.2E+06	1.0E+06	7.8E+05	5.1E+05	2.8E+05	1.4E+05
90	1.1E+06	1.1E+06	9.0E+05	7.2E+05	4.8E+05	2.6E+05	1.4E+05
100	9.7E+05	9.6E+05	8.2E+05	6.5E+05	4.4E+05	2.5E+05	1.3E+05
120	7.7E+05	7.6E+05	6.6E+05	5.4E+05	3.7E+05	2.2E+05	1.2E+05
140	6.1E+05	6.1E+05	5.4E+05	4.5E+05	3.2E+05	1.9E+05	1.0E+05
160	4.9E+05	4.8E+05	4.4E+05	3.7E+05	2.6E+05	1.6E+05	9.2E+04
180	3.9E+05	3.9E+05	3.5E+05	3.0E+05	2.2E+05	1.4E+05	8.1E+04
200	3.1E+05	3.1E+05	2.9E+05	2.5E+05	1.9E+05	1.2E+05	7.0E+04
250	1.9E+05	1.8E+05	1.7E+05	1.5E+05	1.2E+05	7.9E+04	4.9E+04
300	1.1E+05	1.1E+05	1.0E+05	9.2E+04	7.4E+04	5.2E+04	3.3E+04
350	7.0E+04	6.9E+04	6.5E+04	5.6E+04	4.6E+04	3.3E+04	2.3E+04
400	4.3E+04	4.3E+04	4.0E+04	3.4E+04	2.8E+04	2.2E+04	1.5E+04
500	1.6E+04	1.6E+04	1.6E+04	1.2E+04	1.0E+04	8.6E+03	6.8E+03
600	5.3E+03	5.3E+03	5.0E+03	2.2E+03	2.2E+03	2.1E+03	2.1E+03

Table 3.6.2-2 Average daily proton differential spectra (pr/cm2/day/MeV) behind shielding of varying thickness at minimum solar activity.

ENERGY (MeV)	0.0 (g/cm^2)	0.3 (g/cm^2)	3.0 (g/cm^2)	7.0 (g/cm^2)	15.0 (g/cm^2)	30.0 (g/cm^2)	50.0 (g/cm^2)
10	1.3E+05	4.1E+04	5.1E+03	2.6E+03	1.2E+03	4.5E+02	1.7E+02
20	4.6E+04	2.6E+04	7.7E+03	4.2E+03	2.0E+03	7.2E+02	2.7E+02
30	2.6E+04	2.0E+04	9.3E+03	5.3E+03	2.6E+03	9.4E+02	3.6E+02
40	2.1E+04	1.9E+04	1.0E+04	6.1E+03	3.0E+03	1.1E+03	4.5E+02
50	1.8E+04	1.7E+04	1.1E+04	6.6E+03	3.3E+03	1.2E+03	5.2E+02
60	1.6E+04	1.6E+04	1.0E+04	6.8E+03	3.5E+03	1.4E+03	5.7E+02
70	1.5E+04	1.4E+04	1.0E+04	6.8E+03	3.5E+03	1.4E+03	6.1E+02
80	1.3E+04	1.3E+04	9.6E+03	6.7E+03	3.5E+03	1.5E+03	6.4E+02
90	1.2E+04	1.2E+04	9.0E+03	6.4E+03	3.5E+03	1.5E+03	6.6E+02
100	1.1E+04	1.1E+04	8.3E+03	6.0E+03	3.5E+03	1.5E+03	6.6E+02
120	8.9E+03	8.7E+03	6.9E+03	5.1E+03	3.1E+03	1.5E+03	6.4E+02
140	7.0E+03	6.9E+03	5.6E+03	4.3E+03	2.7E+03	1.3E+03	6.1E+02

ENERGY (MeV)	0.0 (g/cm^2)	0.3 (g/cm^2)	3.0 (g/cm^2)	7.0 (g/cm^2)	15.0 (g/cm^2)	30.0 (g/cm^2)	50.0 (g/cm^2)
160	5.4E+03	5.4E+03	4.6E+03	3.6E+03	2.3E+03	1.2E+03	6.0E+02
180	4.2E+03	4.2E+03	3.7E+03	3.0E+03	2.0E+03	1.1E+03	5.4E+02
200	3.3E+03	3.2E+03	2.9E+03	2.5E+03	1.6E+03	9.4E+02	5.0E+02
250	1.8E+03	1.8E+03	1.7E+03	1.5E+03	1.1E+03	6.7E+02	3.6E+02
300	1.1E+03	1.1E+03	9.9E+02	8.9E+02	6.9E+02	4.4E+02	2.5E+02
350	6.4E+02	6.4E+02	5.9E+02	5.2E+02	4.1E+02	2.8E+02	1.7E+02
400	3.9E+02	3.9E+02	3.6E+02	3.2E+02	2.5E+02	1.8E+02	1.2E+02
500	1.5E+02	1.5E+02	1.4E+02	1.3E+02	1.1E+02	8.1E+01	5.8E+01
600	6.4E+01	6.4E+01	6.1E+01	4.6E+01	4.1E+01	3.6E+01	2.9E+01

Tables 3.6.2-3 and 3.6.2-4 present peak ERB proton integral and differential spectra behind the shielding as ISS ~~Alpha~~ passes through the South Atlantic Anomaly (SAA). ERB proton flux is a maximum during passes through the SAA.

ISS will pass through the SAA on nearly 50% of its orbits, and spend 5-10 minutes of these orbits in the SAA. The charged particle fluxes in this period are almost two times higher than the average daily levels. These tables are used to calculate the maximal failure rate in integral circuits on orbit during passes of the ISS through the SAA and generate the appropriate requirements on maximum ERB proton fluxes for equipment.

Table 3.6.2-3 Peak proton integral spectra (pr/cm2/day) behind shielding of varying thickness during passes of the ISS through the SAA at minimum solar activity.

ENERGY (MeV)	0.0 (g/cm^2)	0.3 (g/cm^2)	3.0 (g/cm^2)	7.0 (g/cm^2)	15.0 (g/cm^2)	30.0 (g/cm^2)	50.0 (g/cm^2)
10	1.8E+08	1.6E+08	1.3E+08	9.5E+07	5.8E+07	2.9E+07	1.5E+07
20	1.6E+08	1.6E+08	1.2E+08	9.3E+07	5.7E+07	2.9E+07	1.5E+07
30	1.5E+08	1.5E+08	1.2E+08	8.9E+07	5.5E+07	2.8E+07	1.4E+07
40	1.4E+08	1.4E+08	1.1E+08	8.4E+07	5.3E+07	2.7E+07	1.4E+07
50	1.3E+08	1.3E+08	1.0E+08	7.9E+07	5.0E+07	2.6E+07	1.4E+07
60	1.2E+08	1.2E+08	9.6E+07	7.4E+07	4.7E+07	2.5E+07	1.3E+07
70	1.1E+08	1.1E+08	8.8E+07	6.9E+07	4.5E+07	2.4E+07	1.3E+07
80	9.7E+07	9.6E+07	8.0E+07	6.3E+07	4.2E+07	2.3E+07	1.2E+07
90	8.8E+07	8.6E+07	7.3E+07	5.8E+07	3.9E+07	2.2E+07	1.2E+07
100	7.8E+07	7.7E+07	6.6E+07	5.3E+07	3.6E+07	2.1E+07	1.1E+07
120	6.3E+07	6.2E+07	5.4E+07	4.5E+07	3.1E+07	1.8E+07	1.0E+07
140	5.0E+07	4.9E+07	4.4E+07	3.7E+07	2.6E+07	1.6E+07	8.9E+06
160	4.0E+07	4.0E+07	3.6E+07	3.1E+07	2.2E+07	1.4E+07	7.9E+06
180	3.2E+07	3.2E+07	2.9E+07	2.5E+07	1.9E+07	1.2E+07	6.9E+06
200	2.6E+07	2.6E+07	2.4E+07	2.1E+07	1.6E+07	1.0E+07	6.0E+06
250	1.6E+07	1.6E+07	1.5E+07	1.3E+07	1.0E+07	6.9E+06	4.1E+06
300	9.8E+06	9.7E+06	9.1E+06	8.0E+06	6.4E+06	4.4E+06	2.7E+06

ENERGY (MeV)	0.0 (g/cm^2)	0.3 (g/cm^2)	3.0 (g/cm^2)	7.0 (g/cm^2)	15.0 (g/cm^2)	30.0 (g/cm^2)	50.0 (g/cm^2)
350	6.0E+06	6.0E+06	5.6E+06	4.9E+06	3.9E+06	2.8E+06	1.7E+06
400	3.6E+06	3.6E+06	3.4E+06	2.9E+06	2.3E+06	1.7E+06	1.1E+06
500	1.3E+06	1.2E+06	1.2E+06	9.0E+05	7.4E+05	5.4E+05	3.5E+05
600	2.9E+05	2.9E+05	2.7E+05	9.8E+03	9.1E+03	8.0E+03	6.8E+03

Table 3.6.2-4 Peak proton differential spectra (pr/cm2/day/MeV) behind shielding of varying thickness during passes of the ISS through the SAA at minimum solar activity.

ENERGY (MeV)	0.0 (g/cm^2)	0.3 (g/cm^2)	3.0 (g/cm^2)	7.0 (g/cm^2)	15.0 (g/cm^2)	30.0 (g/cm^2)	50.0 (g/cm^2)
10	2.1E+06	8.0E+05	3.4E+05	2.1E+05	9.8E+04	3.6E+04	1.3E+04
20	1.0E+06	7.3E+05	5.2E+05	3.3E+05	1.6E+05	5.7E+04	2.2E+04
30	8.8E+05	8.2E+05	6.5E+05	4.2E+05	2.0E+05	7.5E+04	3.0E+04
40	1.0E+06	1.0E+06	7.4E+05	4.8E+05	2.4E+05	8.9E+04	3.6E+04
50	1.2E+06	1.1E+06	8.0E+05	5.1E+05	2.7E+05	9.9E+04	4.2E+04
60	1.1E+06	1.1E+06	8.2E+05	5.4E+05	2.8E+05	1.1E+05	4.7E+04
70	1.1E+06	1.1E+06	7.9E+05	5.4E+05	2.8E+05	1.1E+05	5.0E+04
80	1.0E+06	1.0E+06	7.5E+05	5.3E+05	2.8E+05	1.2E+05	5.3E+04
90	9.5E+05	9.2E+05	7.1E+05	5.1E+05	2.8E+05	1.2E+05	5.5E+04
100	8.7E+05	8.4E+05	6.6E+05	4.7E+05	2.8E+05	1.2E+05	5.5E+04
120	7.0E+05	6.9E+05	5.5E+05	4.1E+05	2.5E+05	1.2E+05	5.5E+04
140	5.6E+05	5.5E+05	4.5E+05	3.5E+05	2.2E+05	1.1E+05	5.3E+04
160	4.4E+05	4.3E+05	3.7E+05	2.9E+05	1.9E+05	9.9E+04	5.2E+04
180	3.4E+05	3.3E+05	2.9E+05	2.4E+05	1.6E+05	8.9E+04	4.7E+04
200	2.6E+05	2.6E+05	2.3E+05	2.0E+05	1.3E+05	8.0E+04	4.4E+04
250	1.5E+05	1.5E+05	1.4E+05	1.2E+05	9.0E+04	5.9E+04	3.3E+04
300	9.1E+04	9.1E+04	8.5E+04	7.7E+04	6.1E+04	3.9E+04	2.3E+04
350	5.7E+04	5.6E+04	5.2E+04	4.7E+04	3.7E+04	2.5E+04	1.5E+04
400	3.5E+04	3.5E+04	3.2E+04	2.9E+04	2.3E+04	1.6E+04	1.0E+04
500	1.3E+04	1.3E+04	1.2E+04	1.1E+04	9.0E+03	6.6E+03	4.3E+03
600	4.8E+03	4.8E+03	4.5E+03	9.6E+02	8.5E+02	6.8E+02	5.1E+02

Tables 3.6.2-5 and 3.6.2-6 present integral spectra for linear energy transmission of ERB protons and Cosmic Ray (CR) heavy ions at the center of an aluminum sphere behind shielding of varying thickness during periods where solar flares are absent. These data are used to calculate the failure rate in integral circuits caused by ERB protons and CR heavy ions on orbit and generate the appropriate requirements on HCP LET spectra for equipment during periods where solar flares are absent.

Table 3.6.2-5 CR and ERB proton integral LET spectra (pr/cm2/day) behind shielding of varying thickness given the absence of solar flares, minimum solar activity and magnetic activity index of Wi=4.

LET (MeV-cm^2/mg)	0.0 (g/cm^2)	0.3 (g/cm^2)	3.0 (g/cm^2)	7.0 (g/cm^2)	15.0 (g/cm^2)	30.0 (g/cm^2)	50.0 (g/cm^2)
0.002	4.5E+06	2.9E+06	1.7E+06	1.2E+06	7.3E+05	3.7E+05	1.9E+05
0.003	4.4E+06	2.8E+06	1.6E+06	1.1E+06	6.5E+05	3.1E+05	1.4E+05
0.004	4.2E+06	2.5E+06	1.4E+06	9.3E+05	5.2E+05	2.3E+05	1.0E+05
0.005	3.9E+06	2.2E+06	1.1E+06	7.3E+05	3.9E+05	1.6E+05	7.0E+04
0.006	3.6E+06	2.0E+06	9.1E+05	5.8E+05	3.0E+05	1.2E+05	5.0E+04
0.007	3.4E+06	1.7E+06	7.4E+05	4.5E+05	2.3E+05	8.9E+04	3.6E+04
0.008	3.2E+06	1.6E+06	6.0E+05	3.6E+05	1.8E+05	6.8E+04	2.7E+04
0.009	3.0E+06	1.4E+06	5.0E+05	2.9E+05	1.4E+05	5.4E+04	2.1E+04
0.01	2.9E+06	1.3E+06	4.2E+05	2.4E+05	1.2E+05	4.3E+04	1.7E+04
0.02	2.2E+06	6.8E+05	1.1E+05	5.8E+04	2.7E+04	1.0E+04	3.7E+03
0.03	1.6E+06	4.3E+05	4.6E+04	2.4E+04	1.1E+04	4.0E+03	1.5E+03
0.04	1.1E+06	2.8E+05	2.4E+04	1.3E+04	5.8E+03	2.1E+03	7.8E+02
0.05	8.3E+05	1.8E+05	1.5E+04	7.5E+03	3.5E+03	1.3E+03	4.7E+02
0.06	6.5E+05	1.3E+05	9.7E+03	5.0E+03	2.3E+03	8.5E+02	3.1E+02
0.07	5.3E+05	9.2E+04	6.8E+03	3.5E+03	1.6E+03	5.9E+02	2.2E+02
0.08	4.4E+05	6.9E+04	5.0E+03	2.5E+03	1.2E+03	4.3E+02	1.6E+02
0.09	3.7E+05	5.3E+04	3.8E+03	1.9E+03	9.1E+02	3.3E+02	1.2E+02
0.1	3.2E+05	4.2E+04	3.0E+03	1.5E+03	7.1E+02	2.6E+02	9.5E+01
0.2	1.0E+05	7.6E+03	5.3E+02	2.7E+02	1.3E+02	4.6E+01	1.7E+01
0.3	4.1E+04	2.4E+03	1.6E+02	8.4E+01	3.9E+01	1.4E+01	5.2E+00
0.4	1.8E+04	9.0E+02	6.1E+01	3.1E+01	1.5E+01	5.3E+00	2.0E+00
0.5	5.6E+03	2.6E+02	1.8E+01	9.2E+00	4.3E+00	1.6E+00	5.7E-01

Table 3.6.2-6 (He-U) heavy ion integral LET spectra (1/cm2/day) behind shielding of varying thickness given the absence of solar flares and a magnetic activity index of Wi=4.

LET (MeV-cm^2/mg)	0 (g/cm^2)	0.3 (g/cm^2)	3 (g/cm^2)	7 (g/cm^2)	15 (g/cm^2)	30 (g/cm^2)	50 (g/cm^2)
0.002	1.4E+04	1.4E+04	1.3E+04	1.2E+04	1.0E+04	7.1E+03	4.5E+03
0.003	1.4E+04	1.4E+04	1.3E+04	1.2E+04	1.0E+04	7.1E+03	4.5E+03
0.004	1.4E+04	1.4E+04	1.3E+04	1.2E+04	1.0E+04	7.1E+03	4.5E+03
0.005	1.4E+04	1.4E+04	1.3E+04	1.2E+04	1.0E+04	7.1E+03	4.5E+03
0.006	1.4E+04	1.4E+04	1.3E+04	1.2E+04	1.0E+04	7.1E+03	4.5E+03
0.007	9.6E+03	9.5E+03	8.9E+03	8.1E+03	6.6E+03	4.6E+03	2.8E+03
0.008	5.5E+03	5.4E+03	5.0E+03	4.5E+03	3.6E+03	2.4E+03	1.4E+03
0.009	4.5E+03	4.4E+03	4.1E+03	3.7E+03	2.9E+03	1.9E+03	1.1E+03
0.01	3.8E+03	3.8E+03	3.5E+03	3.1E+03	2.5E+03	1.6E+03	8.6E+02

LET (MeV-cm^2/mg)	0 (g/cm^2)	0.3 (g/cm^2)	3 (g/cm^2)	7 (g/cm^2)	15 (g/cm^2)	30 (g/cm^2)	50 (g/cm^2)
0.02	1.5E+03	1.5E+03	1.4E+03	1.3E+03	1.0E+03	6.3E+02	3.2E+02
0.03	1.2E+03	1.1E+03	1.0E+03	9.2E+02	7.2E+02	4.6E+02	2.3E+02
0.04	1.0E+03	1.0E+03	9.4E+02	8.3E+02	6.4E+02	4.0E+02	2.0E+02
0.05	9.4E+02	9.2E+02	8.4E+02	7.4E+02	5.7E+02	3.5E+02	1.8E+02
0.06	8.9E+02	8.7E+02	8.0E+02	7.0E+02	5.3E+02	3.2E+02	1.6E+02
0.07	6.9E+02	6.7E+02	6.2E+02	5.3E+02	4.0E+02	2.4E+02	1.2E+02
0.08	6.5E+02	6.3E+02	5.7E+02	5.0E+02	3.7E+02	2.2E+02	1.1E+02
0.09	5.8E+02	5.7E+02	5.1E+02	4.4E+02	3.3E+02	1.9E+02	9.4E+01
0.1	5.4E+02	5.3E+02	4.8E+02	4.1E+02	3.1E+02	1.8E+02	8.6E+01
0.2	2.3E+02	2.2E+02	2.0E+02	1.6E+02	1.2E+02	6.1E+01	2.7E+01
0.3	1.5E+02	1.4E+02	1.2E+02	1.0E+02	7.0E+01	3.5E+01	1.4E+01
0.4	1.0E+02	8.7E+01	7.6E+01	6.2E+01	4.1E+01	2.0E+01	7.5E+00
0.5	8.7E+01	7.1E+01	6.1E+01	5.0E+01	3.3E+01	1.5E+01	5.6E+00
0.6	7.8E+01	6.2E+01	5.3E+01	4.3E+01	2.8E+01	1.3E+01	4.6E+00
0.7	7.0E+01	5.5E+01	4.7E+01	3.8E+01	2.4E+01	1.1E+01	3.9E+00
0.8	6.5E+01	4.9E+01	4.2E+01	3.4E+01	2.2E+01	9.7E+00	3.4E+00
0.9	6.0E+01	4.4E+01	3.8E+01	3.1E+01	2.0E+01	8.7E+00	3.0E+00
1	5.5E+01	4.0E+01	3.4E+01	2.8E+01	1.8E+01	7.8E+00	2.7E+00
2	1.2E+01	2.9E+00	2.2E+00	1.8E+00	1.1E+00	4.6E-01	1.6E-01
3	6.5E+00	1.2E+00	7.8E-01	6.6E-01	4.0E-01	1.7E-01	5.6E-02
4	4.2E+00	7.4E-01	4.0E-01	3.4E-01	2.0E-01	8.4E-02	2.9E-02
5	3.1E+00	5.1E-01	2.3E-01	2.0E-01	1.2E-01	4.9E-02	1.7E-02
6	2.4E+00	3.8E-01	1.5E-01	1.3E-01	7.8E-02	3.2E-02	1.1E-02
7	1.9E+00	2.8E-01	1.1E-01	8.8E-02	5.3E-02	2.2E-02	7.1E-03
8	1.5E+00	2.2E-01	7.6E-02	6.4E-02	3.8E-02	1.5E-02	5.0E-03
9	1.3E+00	1.8E-01	5.7E-02	4.7E-02	2.8E-02	1.1E-02	3.7E-03
10	1.0E+00	1.4E-01	4.4E-02	3.6E-02	2.2E-02	8.7E-03	2.8E-03
20	1.5E-01	2.7E-02	5.9E-03	4.8E-03	2.8E-03	1.1E-03	3.4E-04
30	8.3E-07	1.7E-05	3.6E-05	3.0E-05	1.6E-05	5.9E-06	1.7E-06
40	1.9E-07	9.8E-07	1.9E-06	1.3E-06	5.7E-07	1.3E-07	2.2E-08
50	6.2E-08	4.1E-07	8.4E-07	5.5E-07	2.3E-07	4.8E-08	7.1E-09
60	2.1E-08	1.7E-07	3.6E-07	2.3E-07	9.3E-08	1.7E-08	2.2E-09
70	5.1E-09	7.5E-08	1.7E-07	1.0E-07	4.0E-08	6.8E-09	8.2E-10
80	4.9E-10	3.1E-08	7.3E-08	4.5E-08	1.7E-08	2.8E-09	3.2E-10
90	-	6.0E-09	1.4E-08	8.8E-09	3.2E-09	4.9E-10	5.5E-11

Tables 3.6.2-7 and 3.6.2-8 present peak proton integral and differential spectra behind shielding of varying thickness during the most intense solar flares. Maximum solar flare activity occurs once every 11 years, and lasts for approximately 24 hours. Peak flux values are observed every 10 minutes for 6-8 orbits on these days.

Data on the powerful solar flare on October 19, 1989 were used for these tables. The data in these tables are used to calculate the failure rate in integral circuits on orbit during a powerful solar flare, and generate requirements on Solar Cosmic Ray (SCR) proton fluxes for equipment that supports operation in the “survival” mode.

Table 3.6.2-7 _Peak proton integral spectra (pr/cm2/day) behind shielding of varying thickness for a maximum solar flare.

ENERGY (MeV)	0.0 (g/cm^2)	0.3 (g/cm^2)	3.0 (g/cm^2)	7.0 (g/cm^2)	15.0 (g/cm^2)	30.0 (g/cm^2)	50.0 (g/cm^2)
10	2.9E+10	2.0E+10	4.7E+09	2.0E+09	8.1E+08	3.0E+08	1.3E+08
20	1.8E+10	1.4E+10	4.1E+09	1.9E+09	7.8E+08	2.9E+08	1.3E+08
30	1.1E+10	9.2E+09	3.6E+09	1.7E+09	7.4E+08	2.9E+08	1.2E+08
40	7.1E+09	6.4E+09	3.0E+09	1.6E+09	7.0E+08	2.7E+08	1.2E+08
50	5.0E+09	4.6E+09	2.5E+09	1.4E+09	6.5E+08	2.6E+08	1.2E+08
60	3.7E+09	3.5E+09	2.1E+09	1.2E+09	6.0E+08	2.5E+08	1.1E+08
70	2.8E+09	2.7E+09	1.7E+09	1.1E+09	5.4E+08	2.3E+08	1.1E+08
80	2.2E+09	2.1E+09	1.4E+09	9.3E+08	4.9E+08	2.2E+08	1.0E+08
90	1.7E+09	1.7E+09	1.2E+09	8.1E+08	4.5E+08	2.1E+08	9.8E+07
100	1.4E+09	1.3E+09	9.9E+08	7.1E+08	4.0E+08	1.9E+08	9.3E+07
120	9.5E+08	9.2E+08	7.1E+08	5.4E+08	3.3E+08	1.6E+08	8.3E+07
140	6.6E+08	6.5E+08	5.2E+08	4.2E+08	2.6E+08	1.4E+08	7.3E+07
160	4.7E+08	4.6E+08	3.9E+08	3.2E+08	2.1E+08	1.2E+08	6.5E+07
180	3.5E+08	3.4E+08	2.9E+08	2.5E+08	1.7E+08	1.0E+08	5.7E+07
200	2.6E+08	2.6E+08	2.2E+08	1.9E+08	1.4E+08	8.6E+07	4.9E+07
250	1.4E+08	1.4E+08	1.2E+08	1.1E+08	8.7E+07	5.6E+07	3.4E+07
300	7.9E+07	7.8E+07	7.0E+07	6.4E+07	5.4E+07	3.7E+07	2.4E+07
350	4.7E+07	4.7E+07	4.3E+07	4.0E+07	3.4E+07	2.5E+07	1.6E+07
400	2.9E+07	2.9E+07	2.6E+07	2.5E+07	2.2E+07	1.7E+07	1.1E+07
500	1.1E+07	1.1E+07	1.0E+07	9.9E+06	8.9E+06	7.3E+06	5.2E+06
600	3.4E+06	3.4E+06	3.3E+06	3.1E+06	2.9E+06	2.5E+06	1.9E+06

Table 3.6.2-8 _ Peak proton differential spectra (pr/cm2/day/MeV) behind shielding of varying thickness for a maximum solar flare.

ENERGY (MeV)	0.0 (g/cm^2)	0.3 (g/cm^2)	3.0 (g/cm^2)	7.0 (g/cm^2)	15.0 (g/cm^2)	30.0 (g/cm^2)	50.0 (g/cm^2)
10	1.3E+09	6.7E+08	4.2E+07	9.8E+06	2.2E+06	4.9E+05	1.3E+05
20	9.1E+08	5.8E+08	5.8E+07	1.5E+07	3.5E+06	7.9E+05	2.2E+05
30	5.0E+08	3.5E+08	5.8E+07	1.7E+07	4.3E+06	1.0E+06	2.9E+05
40	2.6E+08	2.2E+08	5.5E+07	1.8E+07	4.9E+06	1.2E+06	3.6E+05
50	1.6E+08	1.4E+08	4.6E+07	1.7E+07	5.1E+06	1.3E+06	4.1E+05
60	1.1E+08	9.4E+07	3.9E+07	1.6E+07	5.2E+06	1.4E+06	4.5E+05
70	7.2E+07	6.6E+07	3.2E+07	1.4E+07	5.1E+06	1.4E+06	4.8E+05
80	5.1E+07	4.8E+07	2.5E+07	1.3E+07	4.9E+06	1.4E+06	5.0E+05
90	3.7E+07	3.5E+07	2.1E+07	1.1E+07	4.6E+06	1.4E+06	5.2E+05
100	2.8E+07	2.7E+07	1.7E+07	9.7E+06	4.2E+06	1.4E+06	5.2E+05
120	1.7E+07	1.6E+07	1.1E+07	7.2E+06	3.5E+06	1.3E+06	4.9E+05
140	1.1E+07	1.1E+07	7.7E+06	5.4E+06	2.8E+06	1.1E+06	4.5E+05
160	7.2E+06	7.0E+06	5.3E+06	4.0E+06	2.2E+06	9.6E+05	4.2E+05

ENERGY (MeV)	0.0 (g/cm^2)	0.3 (g/cm^2)	3.0 (g/cm^2)	7.0 (g/cm^2)	15.0 (g/cm^2)	30.0 (g/cm^2)	50.0 (g/cm^2)
180	5.0E+06	4.8E+06	3.8E+06	3.0E+06	1.7E+06	8.3E+05	3.9E+05
200	3.4E+06	3.3E+06	2.8E+06	2.3E+06	1.4E+06	7.2E+05	3.6E+05
250	1.5E+06	1.5E+06	1.3E+06	1.2E+06	8.2E+05	4.8E+05	2.4E+05
300	8.1E+05	8.0E+05	7.0E+05	6.2E+05	5.0E+05	2.8E+05	1.8E+05
350	4.5E+05	4.4E+05	3.9E+05	3.5E+05	2.9E+05	1.9E+05	1.2E+05
400	2.6E+05	2.6E+05	2.3E+05	2.1E+05	1.8E+05	1.3E+05	8.1E+04
500	1.0E+05	9.9E+04	9.3E+04	8.7E+04	7.7E+04	6.1E+04	4.0E+04
600	4.4E+04	4.4E+04	4.1E+04	4.0E+04	3.6E+04	3.0E+04	2.2E+04

Tables 3.6.2-9 and 3.6.2-10 present peak proton and heavy ion integral LET spectra for a maximum solar flare. The data on Table 3.6.2-9 are based on peak proton integral spectra behind shielding of varying thickness for a maximum solar flare as presented on Table 3.6.2-7.

The data on these tables are used to calculate the failure rate in integral circuits caused by protons and SCR heavy ions on orbit and generate requirements on HCP LET spectra for equipment during periods of maximum solar activity during a powerful solar flare. The failure rate is assumed to peak under these conditions.

Table 3.6.2-9 _Peak proton integral LET spectra (pr/cm2/day) for a maximum solar flare.

LET (MeV-cm^2/mg)	0 (g/cm^2)	0.3 (g/cm^2)	3 (g/cm^2)	7 (g/cm^2)	15 (g/cm^2)	30 (g/cm^2)	50 (g/cm^2)
0.002	1.7E+10	1.8E+10	4.7E+09	2.0E+09	7.8E+08	2.8E+08	1.2E+08
0.003	1.7E+10	1.8E+10	4.6E+09	1.9E+09	7.2E+08	2.4E+08	9.5E+07
0.004	1.7E+10	1.8E+10	4.4E+09	1.7E+09	6.1E+08	1.9E+08	6.7E+07
0.005	1.6E+10	1.7E+10	4.1E+09	1.5E+09	4.9E+08	1.4E+08	4.6E+07
0.006	1.6E+10	1.7E+10	3.7E+09	1.3E+09	3.9E+08	1.0E+08	3.3E+07
0.007	1.5E+10	1.6E+10	3.3E+09	1.1E+09	3.1E+08	7.7E+07	2.4E+07
0.008	1.4E+10	1.5E+10	3.0E+09	9.1E+08	2.5E+08	6.0E+07	1.8E+07
0.009	1.3E+10	1.4E+10	2.6E+09	7.7E+08	2.0E+08	4.7E+07	1.4E+07
0.01	1.2E+10	1.3E+10	2.3E+09	6.5E+08	1.6E+08	3.8E+07	1.1E+07
0.02	-	5.0E+09	7.6E+08	1.8E+08	4.0E+07	8.9E+06	2.6E+06
0.03	-	-	3.3E+08	7.4E+07	1.6E+07	3.6E+06	1.0E+06
0.04	-	-	1.8E+08	3.9E+07	8.6E+06	1.9E+06	5.4E+05
0.05	-	-	1.1E+08	2.4E+07	5.2E+06	1.1E+06	3.2E+05
0.06	-	-	7.2E+07	1.6E+07	3.4E+06	7.5E+05	2.1E+05
0.07	-	-	5.1E+07	1.1E+07	2.4E+06	5.2E+05	1.5E+05
0.08	-	-	3.7E+07	8.1E+06	1.8E+06	3.9E+05	1.1E+05
0.09	-	-	2.8E+07	6.1E+06	1.3E+06	2.9E+05	8.3E+04
0.1	-	-	2.2E+07	4.8E+06	1.0E+06	2.3E+05	6.5E+04
0.2	-	-	3.8E+06	8.3E+05	1.8E+05	3.9E+04	1.1E+04

LET (MeV-cm^2/mg)	0 (g/cm^2)	0.3 (g/cm^2)	3 (g/cm^2)	7 (g/cm^2)	15 (g/cm^2)	30 (g/cm^2)	50 (g/cm^2)
0.3	-	-	1.2E+06	2.5E+05	5.5E+04	1.2E+04	3.4E+03
0.4	-	-	4.1E+05	8.8E+04	1.9E+04	4.2E+03	1.2E+03
0.5	-	-	2.6E+04	6.5E+03	1.7E+03	4.3E+02	1.4E+02

Table 3.6.2-10 _Peak heavy ion integral LET spectra (1/cm2/day) for a maximum solar flare.

LET (MeV-cm^2/mg)	0 (g/cm^2)	0.3 (g/cm^2)	3 (g/cm^2)	7 (g/cm^2)	15 (g/cm^2)	30 (g/cm^2)	50 (g/cm^2)
0.002	5.8E+08	1.0E+08	5.2E+06	1.2E+06	2.2E+05	3.3E+04	5.9E+03
0.003	5.8E+08	1.0E+08	5.2E+06	1.2E+06	2.2E+05	3.3E+04	5.9E+03
0.004	5.8E+08	1.0E+08	5.2E+06	1.2E+06	2.2E+05	3.3E+04	5.9E+03
0.005	5.8E+08	1.0E+08	5.2E+06	1.2E+06	2.2E+05	3.3E+04	5.9E+03
0.006	5.8E+08	1.0E+08	5.2E+06	1.2E+06	2.2E+05	3.3E+04	5.9E+03
0.007	5.8E+08	1.0E+08	5.2E+06	1.2E+06	2.2E+05	3.3E+04	5.9E+03
0.008	5.8E+08	1.0E+08	5.2E+06	1.2E+06	2.2E+05	3.3E+04	5.9E+03
0.009	5.8E+08	1.0E+08	5.2E+06	1.2E+06	2.2E+05	3.3E+04	5.8E+03
0.01	5.8E+08	1.0E+08	5.2E+06	1.2E+06	2.2E+05	3.3E+04	5.7E+03
0.02	5.8E+08	1.0E+08	5.0E+06	1.0E+06	1.7E+05	2.1E+04	3.1E+03
0.03	5.8E+08	9.9E+07	4.3E+06	7.8E+05	1.1E+05	1.1E+04	1.5E+03
0.04	5.7E+08	9.6E+07	3.5E+06	5.5E+05	6.9E+04	6.8E+03	8.4E+02
0.05	5.6E+08	9.1E+07	2.7E+06	3.9E+05	4.7E+04	4.4E+03	5.3E+02
0.06	5.6E+08	8.5E+07	2.1E+06	2.9E+05	3.3E+04	3.0E+03	3.6E+02
0.07	5.4E+08	7.8E+07	1.7E+06	2.2E+05	2.4E+04	2.2E+03	2.6E+02
0.08	5.3E+08	7.1E+07	1.3E+06	1.6E+05	1.8E+04	1.6E+03	1.9E+02
0.09	5.1E+08	6.4E+07	1.1E+06	1.3E+05	1.4E+04	1.3E+03	1.5E+02
0.1	4.9E+08	5.7E+07	8.4E+05	1.0E+05	1.1E+04	9.7E+02	1.1E+02
0.2	2.4E+08	2.1E+07	2.2E+05	2.5E+04	2.5E+03	2.2E+02	2.5E+01
0.3	5.5E+07	1.0E+07	9.9E+04	1.1E+04	1.1E+03	9.0E+01	9.9E+00
0.4	5.5E+07	6.1E+06	5.8E+04	6.2E+03	5.9E+02	4.7E+01	5.2E+00
0.5	5.5E+07	4.2E+06	3.8E+04	4.0E+03	3.6E+02	2.9E+01	3.2E+00
0.6	5.5E+07	3.1E+06	2.7E+04	2.7E+03	2.4E+02	1.9E+01	2.0E+00
0.7	5.4E+07	2.4E+06	2.0E+04	1.9E+03	1.7E+02	1.3E+01	1.4E+00
0.8	5.4E+07	1.9E+06	1.5E+04	1.4E+03	1.2E+02	9.2E+00	9.8E-01
0.9	5.3E+07	1.6E+06	1.1E+04	1.1E+03	9.0E+01	6.7E+00	7.2E-01
1	5.3E+07	1.3E+06	9.0E+03	8.2E+02	6.8E+01	5.0E+00	5.3E-01
2	4.3E+07	3.6E+05	1.4E+03	9.7E+01	5.1E+00	2.0E-01	1.1E-02
3	3.2E+07	1.9E+05	6.5E+02	4.1E+01	2.1E+00	8.1E-02	4.4E-03
4	2.3E+07	1.2E+05	3.5E+02	2.1E+01	1.1E+00	4.0E-02	2.1E-03
5	1.8E+07	7.5E+04	2.0E+02	1.2E+01	5.6E-01	2.0E-02	1.0E-03
6	1.6E+07	5.1E+04	1.2E+02	7.0E+00	3.1E-01	1.1E-02	5.3E-04
7	1.4E+07	3.4E+04	7.1E+01	3.6E+00	1.5E-01	4.4E-03	1.8E-04
8	1.3E+07	2.5E+04	4.6E+01	2.2E+00	8.6E-02	2.3E-03	8.6E-05
9	1.1E+07	1.9E+04	3.3E+01	1.6E+00	5.9E-02	1.5E-03	5.7E-05
10	9.7E+06	1.5E+04	2.4E+01	1.1E+00	3.9E-02	9.4E-04	3.3E-05
20	5.9E+06	2.1E+03	2.2E+00	8.6E-02	2.2E-03	3.4E-05	6.5E-07
30	1.4E+05	1.4E+01	1.3E-02	4.4E-04	1.1E-05	1.4E-07	2.3E-09
40	6.6E+02	1.7E-01	8.3E-05	1.8E-06	2.7E-08	1.9E-10	1.7E-12

LET (MeV-cm^2/mg)	0 (g/cm^2)	0.3 (g/cm^2)	3 (g/cm^2)	7 (g/cm^2)	15 (g/cm^2)	30 (g/cm^2)	50 (g/cm^2)
50	2.7E+02	7.7E-02	2.9E-05	5.4E-07	6.3E-09	3.2E-11	2.0E-13
60	1.1E+02	3.2E-02	9.6E-06	1.5E-07	1.3E-09	5.4E-12	2.7E-14
70	4.9E+01	1.6E-02	4.1E-06	5.2E-08	3.7E-10	9.6E-13	3.0E-15
80	2.7E+01	8.3E-03	1.9E-06	2.3E-08	1.5E-10	3.4E-13	9.0E-16
90	4.8E+00	1.4E-03	2.8E-07	3.3E-09	2.0E-11	4.3E-14	1.0E-16

Tables 3.6.2-11 and 3.6.2-12 present orbit-averaged proton integral LET spectra values for a maximum solar flare. Proton fluxes are given for the duration of the whole flare.

These data are used to calculate the orbit-averaged failure rate in integral circuits caused by SCR protons and Galactic Cosmic Radiation (GCR) heavy ions, and generate requirements for the equipment.

Table 3.6.2-11 Orbit-averaged proton integral LET spectra (pr/cm2) for a maximum solar flare.

LET (MeV-cm^2/mg)	0 (g/cm^2)	0.3 (g/cm^2)	3 (g/cm^2)	7 (g/cm^2)	15 (g/cm^2)	30 (g/cm^2)	50 (g/cm^2)
0.002	7.3E+07	7.3E+07	6.1E+07	4.3E+07	2.5E+07	1.2E+07	6.5E+06
0.003	6.8E+07	6.8E+07	5.6E+07	3.9E+07	2.1E+07	9.8E+06	4.6E+06
0.004	5.9E+07	5.9E+07	4.8E+07	3.2E+07	1.7E+07	7.0E+06	3.0E+06
0.005	4.8E+07	4.8E+07	3.9E+07	2.5E+07	1.3E+07	5.0E+06	2.0E+06
0.006	3.8E+07	3.8E+07	3.2E+07	2.0E+07	9.4E+06	3.6E+06	1.4E+06
0.007	2.9E+07	3.0E+07	2.6E+07	1.6E+07	7.1E+06	2.7E+06	1.0E+06
0.008	2.1E+07	2.3E+07	2.1E+07	1.3E+07	5.6E+06	2.0E+06	7.9E+05
0.009	1.6E+07	1.7E+07	1.7E+07	1.0E+07	4.4E+06	1.6E+06	6.1E+05
0.01	1.2E+07	1.3E+07	1.4E+07	8.3E+06	3.6E+06	1.3E+06	4.9E+05
0.02	-	7.7E+05	3.1E+06	2.0E+06	8.3E+05	2.9E+05	1.1E+05
0.03	-	-	1.2E+06	8.2E+05	3.3E+05	1.2E+05	4.3E+04
0.04	-	-	6.3E+05	4.3E+05	1.8E+05	6.2E+04	2.3E+04
0.05	-	-	3.8E+05	2.6E+05	1.1E+05	3.7E+04	1.4E+04
0.06	-	-	2.5E+05	1.7E+05	6.9E+04	2.5E+04	8.9E+03
0.07	-	-	1.7E+05	1.2E+05	4.9E+04	1.7E+04	6.3E+03
0.08	-	-	1.3E+05	8.9E+04	3.6E+04	1.3E+04	4.6E+03
0.09	-	-	9.7E+04	6.7E+04	2.7E+04	9.6E+03	3.5E+03
0.1	-	-	7.5E+04	5.2E+04	2.1E+04	7.5E+03	2.7E+03
0.2	-	-	1.3E+04	9.0E+03	3.7E+03	1.3E+03	4.7E+02
0.3	-	-	4.0E+03	2.8E+03	1.1E+03	3.9E+02	1.4E+02
0.4	-	-	1.4E+03	9.6E+02	3.9E+02	1.4E+02	5.0E+01
0.5	-	-	1.6E+02	1.2E+02	5.2E+01	2.0E+01	8.3E+00

Table 3.6.2-12 Orbit-averaged heavy ion integral LET spectra (1/cm2) for a maximum solar flare.

LET (MeV-cm^2/mg)	0 (g/cm^2)	0.3 (g/cm^2)	3 (g/cm^2)	7 (g/cm^2)	15 (g/cm^2)	30 (g/cm^2)	50 (g/cm^2)
0.002	2.4E+06	1.6E+06	2.5E+05	7.5E+04	1.9E+04	3.5E+03	7.6E+02
0.003	2.4E+06	1.6E+06	2.5E+05	7.5E+04	1.9E+04	3.5E+03	7.6E+02
0.004	2.4E+06	1.6E+06	2.5E+05	7.5E+04	1.9E+04	3.5E+03	7.6E+02
0.005	2.4E+06	1.6E+06	2.5E+05	7.5E+04	1.9E+04	3.5E+03	7.6E+02
0.006	2.4E+06	1.6E+06	2.5E+05	7.5E+04	1.9E+04	3.5E+03	7.6E+02
0.007	2.4E+06	1.6E+06	2.5E+05	7.5E+04	1.9E+04	3.5E+03	7.6E+02
0.008	2.4E+06	1.6E+06	2.5E+05	7.5E+04	1.9E+04	3.5E+03	7.5E+02
0.009	2.4E+06	1.6E+06	2.5E+05	7.5E+04	1.9E+04	3.5E+03	7.4E+02
0.01	2.4E+06	1.6E+06	2.5E+05	7.5E+04	1.9E+04	3.4E+03	7.2E+02
0.02	2.4E+06	1.6E+06	2.3E+05	6.4E+04	1.4E+04	2.1E+03	3.6E+02
0.03	2.3E+06	1.5E+06	1.9E+05	4.5E+04	8.4E+03	1.1E+03	1.7E+02
0.04	2.1E+06	1.4E+06	1.4E+05	3.1E+04	5.3E+03	6.3E+02	9.5E+01
0.05	1.9E+06	1.2E+06	1.1E+05	2.2E+04	3.5E+03	4.1E+02	6.0E+01
0.06	1.7E+06	1.1E+06	8.4E+04	1.6E+04	2.4E+03	2.8E+02	4.1E+01
0.07	1.5E+06	9.2E+05	6.6E+04	1.2E+04	1.8E+03	2.0E+02	2.9E+01
0.08	1.3E+06	7.9E+05	5.2E+04	8.9E+03	1.3E+03	1.5E+02	2.2E+01
0.09	1.1E+06	6.8E+05	4.1E+04	7.0E+03	1.1E+03	1.2E+02	1.7E+01
0.1	9.2E+05	5.7E+05	3.3E+04	5.5E+03	8.3E+02	9.2E+01	1.3E+01
0.2	3.5E+05	2.0E+05	9.4E+03	1.5E+03	2.1E+02	2.2E+01	2.9E+00
0.3	3.1E+05	1.1E+05	4.8E+03	7.2E+02	9.3E+01	9.2E+00	1.2E+00
0.4	3.0E+05	8.3E+04	3.0E+03	4.2E+02	5.2E+01	4.9E+00	6.2E-01
0.5	2.9E+05	6.7E+04	2.1E+03	2.8E+02	3.3E+01	3.0E+00	3.8E-01
0.6	2.8E+05	5.7E+04	1.5E+03	2.0E+02	2.2E+01	2.0E+00	2.4E-01
0.7	2.7E+05	4.9E+04	1.2E+03	1.4E+02	1.6E+01	1.4E+00	1.7E-01
0.8	2.6E+05	4.3E+04	9.2E+02	1.1E+02	1.1E+01	9.8E-01	1.2E-01
0.9	2.5E+05	3.8E+04	7.4E+02	8.5E+01	8.6E+00	7.3E-01	8.7E-02
1	2.4E+05	3.4E+04	6.0E+02	6.8E+01	6.7E+00	5.5E-01	6.5E-02
2	1.7E+05	1.4E+04	1.5E+02	1.3E+01	8.4E-01	4.0E-02	2.6E-03
3	1.3E+05	8.4E+03	7.1E+01	5.8E+00	3.5E-01	1.6E-02	1.0E-03
4	1.1E+05	5.7E+03	4.1E+01	3.1E+00	1.8E-01	7.9E-03	5.0E-04
5	9.9E+04	4.1E+03	2.5E+01	1.8E+00	1.0E-01	4.2E-03	2.5E-04
6	8.9E+04	3.1E+03	1.6E+01	1.1E+00	5.9E-02	2.3E-03	1.4E-04
7	8.2E+04	2.3E+03	1.0E+01	6.7E-01	3.2E-02	1.1E-03	5.5E-05
8	7.7E+04	1.8E+03	7.0E+00	4.5E-01	2.0E-02	6.4E-04	2.9E-05
9	7.2E+04	1.4E+03	5.2E+00	3.3E-01	1.4E-02	4.4E-04	1.9E-05
10	6.8E+04	1.1E+03	3.9E+00	2.4E-01	1.0E-02	2.9E-04	1.2E-05
20	2.9E+04	2.0E+02	4.7E-01	2.6E-02	9.0E-04	1.7E-05	3.9E-07
30	5.8E+02	1.8E+00	3.4E-03	1.6E-04	4.9E-06	7.9E-08	1.6E-09
40	2.5E+02	1.5E-01	7.5E-05	1.7E-06	2.6E-08	1.9E-10	1.7E-12
50	1.8E+02	7.7E-02	2.9E-05	5.4E-07	6.3E-09	3.2E-11	2.0E-13
60	8.0E+01	3.2E-02	9.6E-06	1.5E-07	1.3E-09	5.4E-12	2.7E-14
70	4.2E+01	1.6E-02	4.1E-06	5.2E-08	3.7E-10	9.6E-13	3.0E-15
80	2.5E+01	8.3E-03	1.9E-06	2.3E-08	1.5E-10	3.4E-13	9.0E-16
90	4.8E+00	1.4E-03	2.8E-07	3.3E-09	2.0E-11	4.3E-14	1.0E-16

The data presented in the above tables are used to more precisely calculate local dose characteristics and spectra in equipment installation sites, and for electronic circuit and material elements. The procedure used to execute these precision calculations takes into account particle flux shielding inside the space vehicle by equipment sets and structural components from varying directions. These calculations must be performed during the design stage, and calculation results must be considered while generating design specifications for the hardware and other equipment. In addition, these data can be used directly to evaluate the radiation stability of space vehicle equipment and elements at maximum, when the maximum fluxes and absorbed dose are determined at a known minimal shield thickness value, and compared with the critical values for the examined element (instrument).

Based on orbital flight experience, equipment (instrument analogs) that operated well during the 1989 solar flares will be accepted without additional analysis to determine resistance to failures caused by HCP.

Newly developed equipment whose operation impacts station and crew safety must be checked for compliance with radiation exposure requirements via calculation or tests on simulation equipment or instrument analogs in-flight under natural conditions. Test results for one instrument can be applied to a group of instruments having identical radio-electronic components and similar circuit engineering and logic solutions.

Specification SSP 41163 was used to determine a survival mode, where specific hardware and equipment must operate if contingency or emergency situations arise on ~~ISSA~~ISS, providing crew life support and ensuring proper operation of equipment that keeps primary station functions intact. ~~ISSA~~ISS hardware and equipment that supports the survival mode (per concurred list) must remain operational when exposed to HCP fluxes during a maximum solar flare in accordance with data presented on Tables 3.6.2-7 through 3.6.2-12.

The solar arrays must have a dose safety factor equal to 1. The remaining station equipment must have a dose safety factor of at least 2.

3.7 RESERVED

3.8 METEOROIDS AND ORBITAL DEBRIS

Once in orbit, the Space Station Program Elements (SSPEs) will encounter meteoroids and orbital debris. Either type of object can pose a serious threat of damage or decompression to the SSPE upon impact. Meteoroids are natural in origin, and debris is the result of man-made material remaining in Earth orbit. General information and discussion appears in Grun et al., 1985, and Kessler et al., 1989.

For historical reasons related to measurement method, the meteoroid and debris environments are usually specified as a time-averaged flux, F_r, against a single sided, randomly tumbling surface. Flux is defined as number of intercepted objects per unit time and area. For F_r, the relevant area is the actual surface area of the satellite. One may also define a “cross sectional area flux”, F_c, for a randomly tumbling satellite, where the relevant area is the time averaged cross sectional area. A useful theorem which is obvious for a tumbling sphere, but which holds for objects of arbitrary non-self-shielding shape (no concave surfaces), is that $F_c = 4F_r$.

For spacecraft which fly with a fixed orientation, the meteoroid and orbital debris fluxes are treated as vector quantities, **F**, and the effects of directionality must be carefully evaluated. Some effects of impact will be direction dependent. To simply evaluate the expected number, N, or probability of impacts from either meteoroids or debris (or both), one may use a “k factor” method and the appropriate F_r, such that:

$$N = \int_{t}^{t+T} \sum_{i} K_i F_r A_i \, dt$$

~~(8~~(3.8.0,1)

where the summation is over the i surfaces of the spacecraft, each of area A_i, and $K_i F_r$ is the actual flux on surface A_i. The calculation of k_i is discussed in paragraph 3.8.3.

Once an N has been determined, the probability of exactly n impacts occurring in the corresponding time interval is found from Poisson statistics, thus;

$$P_n = \frac{N^n}{n!} \cdot e^{-N}$$

~~(8~~(3.8.0,2)

3.8.1 METEOROIDS

The meteoroid environment encompasses only particles of natural origin. Nearly all meteoroids originate from comets or asteroids. Meteoroids that retain the orbit of their parent body and create periods of high flux are called streams. Random fluxes with no apparent pattern are called sporadic.

The average total meteoroid environment presented here is comprised of the average sporadic meteoroids and a yearly average of the stream meteoroids. The mass density for meteoroids spans a wide range, from approximately 0.2 g/cm^3 or less for a portion of the population to values as large as 8 g/cm^3. The values for average mass density quoted in the literature vary widely, so that a value can only be estimated. Recommended mean values are 2 g/cm^3 for meteoroids smaller than 10^{-6} g; 1 g/cm^3 for meteoroids between 10^{-6} and 0.01 g; and 0.5 g/cm^3 for masses above 0.01 g. The uncertainty in density is not too serious because the model presented below was derived from crater and impact data, so it will provide a good representation of expected damage even though the absolute mass calibration could conceivably be in error by as much as a factor of ten for the smallest sizes.

Because of the precession of a satellite's orbit and the tilt of the Earth's equatorial plane with respect to the ecliptic plane, the meteoroid environment can be assumed to be omnidirectional relative to the Earth for design applications. However, it becomes directional relative to a spacecraft moving through the environment, with most meteoroids coming from the direction of motion. The directionality derives from the vector summation of the spacecraft velocity vector with the meteoroid velocity distribution. An additional directionality factor is introduced by the shielding provided by the Earth.

The normalized meteoroid velocity distribution with respect to the Earth is illustrated by Figure 3.8.1-1. It is given by the expressions (number per km/s):

$$
\begin{aligned}
n(v) &= 0.112, && 11.1 \le v < 16.3 \text{ km/s}, \\
n(v) &= 3.328 \times 10^{5}\, v^{-5.34}, && 16.3 \le v < 55 \text{ km/s}, \qquad (3.8.1,1) \\
n(v) &= 1.695 \times 10^{-4}, && 55 \le v \le 72.2 \text{ km/s}.
\end{aligned}
$$

This distribution has an average velocity of about 17 km/s; relative to an orbiting spacecraft the average velocity is about 19 km/s. To determine the velocity and direction distributions relative to any surface on an orbiting spacecraft, the vector relationship between the meteoroid velocity and the spacecraft velocity should be used as discussed in paragraph 3.8.3.

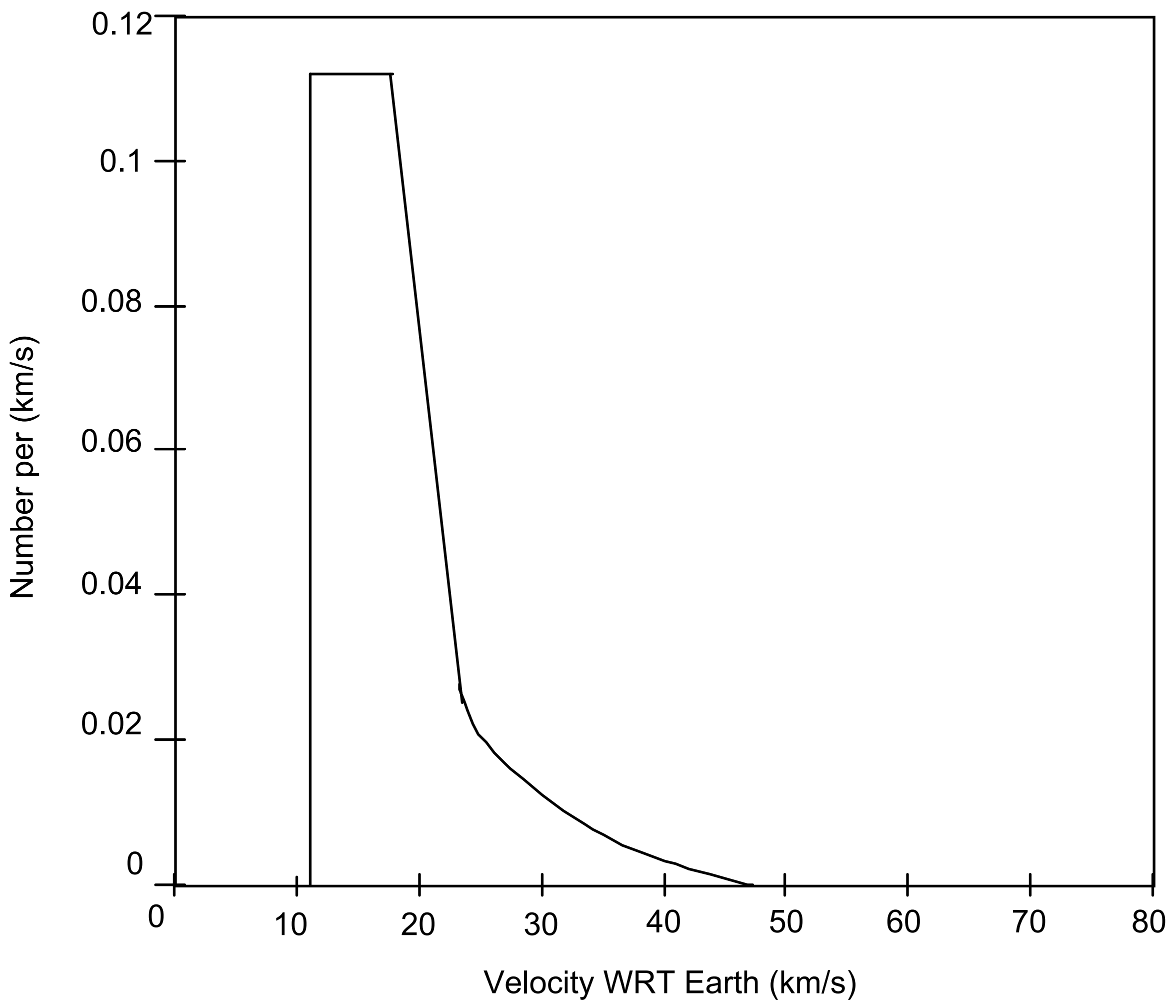


Figure 3.8.1-1 Normalized Meteoroid Velocity Distribution From Equation 3.8.1,1.

Meteoroid flux is given in terms of the integral flux F_r, the number of particles/m^2/year of mass m or greater against a randomly tumbling surface. F^{ip}_r, the interplanetary flux at 1 Astronomical Unit (A.U.) is described mathematically as follows (for $10^{-15} \leq m \leq 10$ g):

$$F^{ip}_r(m) = c_0\{(c_1 m^{0.306} + c_2)^{-4.38} + c_3(m + c_4 m^2 + c_5 m^4)^{-0.36} + c_6(m + c_7 m^2)^{-0.85}\}. \quad (8(3.8.1,2)$$

where:
$c_0 = 3.156 \times 10^7$,
$c_1 = 2.2 \times 10^3$,
$c_2 = 15$,
$c_3 = 1.3 \times 10^{-9}$,
$c_4 = 10^{11}$,
$c_5 = 10^{27}$,
$c_6 = 1.3 \times 10^{-16}$,
$c_7 = 10^6$.

To convert the meteoroid flux F^{ip}_r stated above to that in Earth orbit, F_r, both Earth shielding and focusing factors must be applied, $F_r = s_f G_E F^{ip}_r$. The formula for shielding is:

$$\text{shielding factor} = s_f = (1 + \cos h)/2, \quad (8(3.8.1,3)$$

where
$\sin h = R_E/(R_E + H)$,
R_E= Earth radius + 100 km atmosphere (6478 km),
H = height above Earth's atmosphere (Earth's atmosphere height to be taken as 100km for this purpose)

Consequently, the Earth shielding factor varies from 0.5 just above the atmosphere to 1.0 in deep space.

The factor G_E represents the focusing effect of the Earth's gravitational field which attracts the meteoroids and increases their flux. The factor ranges from a value of 2.0 just above the atmosphere to a value of 1.0 in deep space. The focusing factor is represented by the following equation:

$$\text{focusing factor} = G_E = 1 + (R_E/r) \quad (8(3.8.1,4)$$

where
R_E = Earth Radius + 100 km atmosphere (6478 km),
r = Orbit Radius.

The meteoroid environment at 500 km is illustrated in Figure 3.8.1-2.

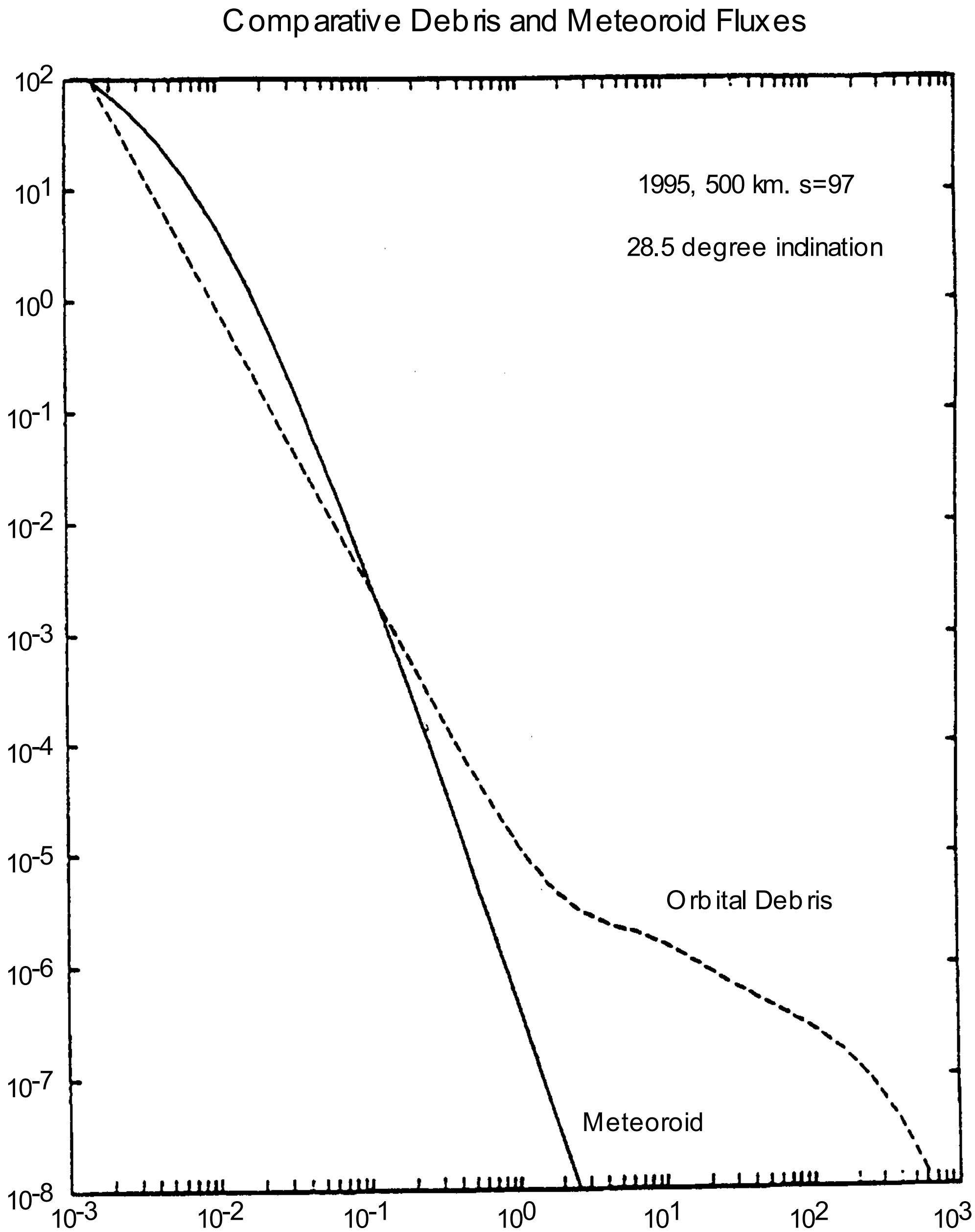


Figure 3.8.1-2 Comparison of Meteoroid and Orbital Debris Fluxes, Fr, as a Function of Size

3.8.1.1 UNCERTAINTY IN THE METEOROID ENVIRONMENT

Except for small cosmic dust grains collected directly from the stratosphere, the physical properties of meteoroids must be determined by relatively indirect means, examination of impact craters, optical scattering, etc.. Also, they are known to originate from both comets, which are apparently composed of low density "ices" and dust, and asteroids which are rock-like. Therefore, there is considerable uncertainty in their properties. In particular, the uncertainty in mass tends to dominate the uncertainties in the flux measurement. For meteoroids less than 10^{-6} grams, the mass is uncertain to within a factor from about 0.2 to 5 times the estimated value, which implies the flux is uncertain to within a factor of 0.33 to 3 at a given mass. For meteoroids above this size, the flux is well defined but the associated mass is even more uncertain. This implies an effective uncertainty in the flux (at a set mass) of a factor from 0.1 to 10 (because of the slope of the functional relationship).

3.8.2 ORBITAL DEBRIS

3.8.2.1 BACKGROUND

The natural meteoroid flux discussed above represents, at any instant, a total of about 200 kg of mass within 2000 km of the Earth's surface, most of it concentrated in the 0.1 mm meteoroids. Within this same 2000 kilometers, there is an estimated 1.5 to 3 million kilograms of man-made orbiting objects as of mid 1988. Most of these are in high inclination orbits where they sweep past each other at an average speed of 10 km/s. About 1500 spent rocket stages, inactive payloads and a few active payloads account for most of this mass. These objects are currently tracked by the U.S. Space Command, as are about 4500 others totaling 20,000 kg, mostly fragments of satellites or other orbiting hardware. Recent observations indicate a total mass of about 1000 kg for orbital debris with diameters of 1 cm or smaller and about 300 kg for orbital debris sizes smaller than 1 mm. This distribution of mass makes the orbital debris environment more hazardous than the meteoroid environment in most spacecraft applications below 2000 km altitude.

The debris model presented below represents an extension of the model presented by Kessler et. al., 1989. First, a curve fit to the "current" debris environment was developed based on the best experimental data available. This was then coupled with additional terms which represent a projection of the expected environment change into the future. 1988 was selected as the base year for the "current" environment. The applicable data sets include those referenced by Kessler et. al. in 1989, i.e., the analysis of panels returned from the Solar Max satellite, data from the Massachusetts Institute of Technology (MIT) Experimental Test Site (ETS) telescopes, and U.S. Space Command catalogued and uncatalogued data sets. In addition, updates were added from recent optical measurements made with the GEODSS telescope systems and from biphase radar measurements made with the Arecibo and Goldstone radars. Quick look data from the Long Duration Exposure Facility appears to be consistent with these data sets, but analysis was not sufficiently complete to allow incorporation of this information.

Model development, especially prediction of future trends in the debris environment, is difficult and subject to substantial uncertainty. The problems may be grouped into two categories which must be treated somewhat differently. The categories are:

(1) Uncertainties in the current environment. These uncertainties shift the flux by a factor which is independent of time (a change in intercept on a flux vs. time plot). They include uncertainties of measurement, statistical limitations of the data sets, and voids in the data sets, i.e., size and altitude ranges where no measurements have been made, limitations of debris shape and density information, etc.

(2) Uncertainties related to trend projection. These factors alter the slope of a flux vs. time plot. They derive primarily from the assumptions which must be made to predict future trends in human activities (launch rate for example, which historically has deviated significantly from the traffic model projections), and to overcome the technical uncertainties listed above. The state of the art is such that understanding is still lacking in several important areas necessary for complete engineering analysis and numerical modeling of the environment. Key examples include incomplete knowledge of satellite and rocket body fragmentation mechanics (e.g., fragment size and velocity distributions) and uncertainty in the cause and intensity of many fragmentation events. There are also important limitations in modeling capability due to the necessity of keeping computation time and model complexity within reasonable limits. These all have important influence on the final results.

Before discussing these issues in detail, we present the numerical formalism of the model in the following three sections.

Then, in section 3.8.2.5, the uncertainties and assumptions are listed in detail along with a quantitative estimate of their importance.

3.8.2.2 ORBITAL DEBRIS FLUX TO A TUMBLING SURFACE

~~A vectorial~~Vector description of the orbital debris environment is presented in section 3.8.3. However, the description is based on the flux to a randomly tumbling surface and the velocity distribution, so these concepts are presented first.

The cumulative flux of orbital debris of diameter d and larger on a randomly tumbling spacecraft orbiting at altitude h, inclination i, in the year t, when the solar activity was S one year prior to t, is given by the following equation:

$$F_r(d,h,i,t,S) = H(d)f(h,S)y(i)[F_1(d)g_1(t) + F_2(d)g_2(t)] \qquad \text{(~~8~~(3.8.2.2, 1)}$$

where

F_r = flux, impacts per square meter of surface per year,

d = orbital debris diameter in cm,
t = date (year),
h = altitude in km ($h \leq 2000$ km),
S = 13 month smoothed solar radio flux $F_{10.7}$ for t - 1 year,
expressed in 10^4 Jy,
i = inclination in degrees,

and

$$H(d) = \left[10^{\exp(-(\log_{10} d - 0.78)^2 / 0.637^2)} \right]^{1/2}$$

F(h,S) = F1(h,S)/(F1(h,S0+1),

F1(h,S) = 10(h/200-S/140-1.5),

$f(h,S) = f_1(h,S)/(f_1(h,S) + 1)$,

$f_1(h,S) = 10^{(h/200 - S/140 - 1.5)}$,

$F_1(d) = 1.22 \times 10^{-5} d^{-2.5}$,

$F_2(d) = 8.1 \times 10^{10} (d + 700)^{-6}$,

p = the assumed annual growth rate of intact objects in orbit = 0.05,
q and q' = the estimated growth rate of fragments; q = 0.02; q'q¢ = 0.04.
The q' term is only used for 2011 and later dates.

$g_1(t) = (1 + q)^{(t - 1988)}$ for t < 2011,

$g_1(t) = (1 + q)^{23} (1 + q¢)^{(t - 2011)}$ for $t \geq 2011$,

$g_2(t) = 1 + [p(t - 1988)]$.

The inclination-dependent function Ψ(i) defines the relationship between the flux on a spacecraft in an orbit of inclination i and the flux incident on a spacecraft in the current population's average inclination of about 50°. Values for Ψ(i) are as follows:

Inclination i (degrees)	Ψ(i)
28.5	0.91
30	0.92
40	0.96
50	1.02
60	1.09
70	1.26
80	1.71
90	1.37
100	1.78
120	1.18

An example orbital debris flux is compared with the meteoroid flux from equation 8.1,2 in Figure 3.8.1-2 for h = 500 km, t = 1995, i = 28.5°, and S(t-1yr) = 97.0.

Editorial per Leskin

3.8.2.3 AVERAGE SHAPE AND MASS DENSITY

The state of knowledge of debris shape and density is very scant. Actual shapes are irregular, including flat plates, rods, hollow structures, and crumpled metal. As size decreases, the objects tend to be somewhat less irregular. For the purposes of this model, the objects are assumed to be spherical, with a size dependent mass density function to approximate these irregularities and the probability that they may impact with any orientation.

The average mass density for debris 0.62 cm and larger is:

$r = 2.8d^{-0.74}$. (g/cm^3, d in cm). ~~(8~~(3.8.2.3,1)

For debris smaller than 0.62 cm,

$r = 4\ g/cm^3$, ($d < 0.62$ cm).

That is, for small objects the mean density should be assumed to be a constant, 4 g/cm^3, independent of size. Actual shape and density distributions are very broad. This issue, in particular estimated volume fraction as a function of material density, is addressed further in section 3.8.2.5.3.

3.8.2.4 VELOCITY AND DIRECTION DISTRIBUTION

Averaged over all altitudes, the non-normalized collision velocity distribution, i.e. the number of impacts with velocities between v and v + dv, relative to a spacecraft with orbital inclination i, is given by the following equations:

$$f(v) = \{2 v v_o - v^2\} \{G \exp (-((v - A v_o)/(B v_o))^2) + F \exp (-((v - D v_0)/(E v_0))^2)\} + H C (4 v v_o - v^2)$$ ~~(8~~(3.8.2.4,1)

where v is the collision velocity in km/s, A is constant, and B, C, D, E, F, G, H, and v_o are functions of the orbital inclination of the spacecraft. The values for these constants and parameters are as follows:

A =	2.5	
B=	0.5	$i<60$
	0.5-0.0.1(i-60)	$60<i<80$
	0.3	$i>80$
C=	0.0125	$i<100$
	0.0125 + 0.00125(i - 100)	$i>100$
D =	1.3 - 0.01(i - 30)	
E =	0.55 + 0.005(i - 30)	
F =	$0.3 + 0.0008\ (i-50)^2$	$i<50$
	0.3 - 0.01 (i-50)	$50<i<80$
	0.0	$i>80$
G =	18.7	$i<60$
	$18.7 + 0.0289\ (I-60)^3$	$60<i<80$

	250.0	i>80
H =	1.0 - 0.0000757(i-60)	i>60
	7.25 + 0.015(i - 30)	i<60
v_o =	7.7	i>60

When f(v) is less than zero the function is to be reset equal to zero. The user may find it convenient to numerically normalize f(v) so that;

$$f'(v) = \frac{f(v)}{\int_0^\infty f(v)\,dv} \qquad (3.8.2.4,2)$$

~~$$f'(v) = \frac{f(v)}{\int_0^\infty f(v)\,dv} \qquad (8.2.4,2)$$~~

When normalized in this manner, f'(v) over any 1 km/s velocity interval becomes the fraction of debris impacts within a 1 km/s incremental velocity band. The function is illustrated in Figure 3.8.2.4-1. Any average velocity moment may be defined as:

$$v^n = \int_0^\infty v^n f'(v)\,dv \qquad (3.8.2.4,3)$$

~~$$V^n = \int_0^\infty v^n f'(v)\,dv \qquad (8.2.4,3)$$~~

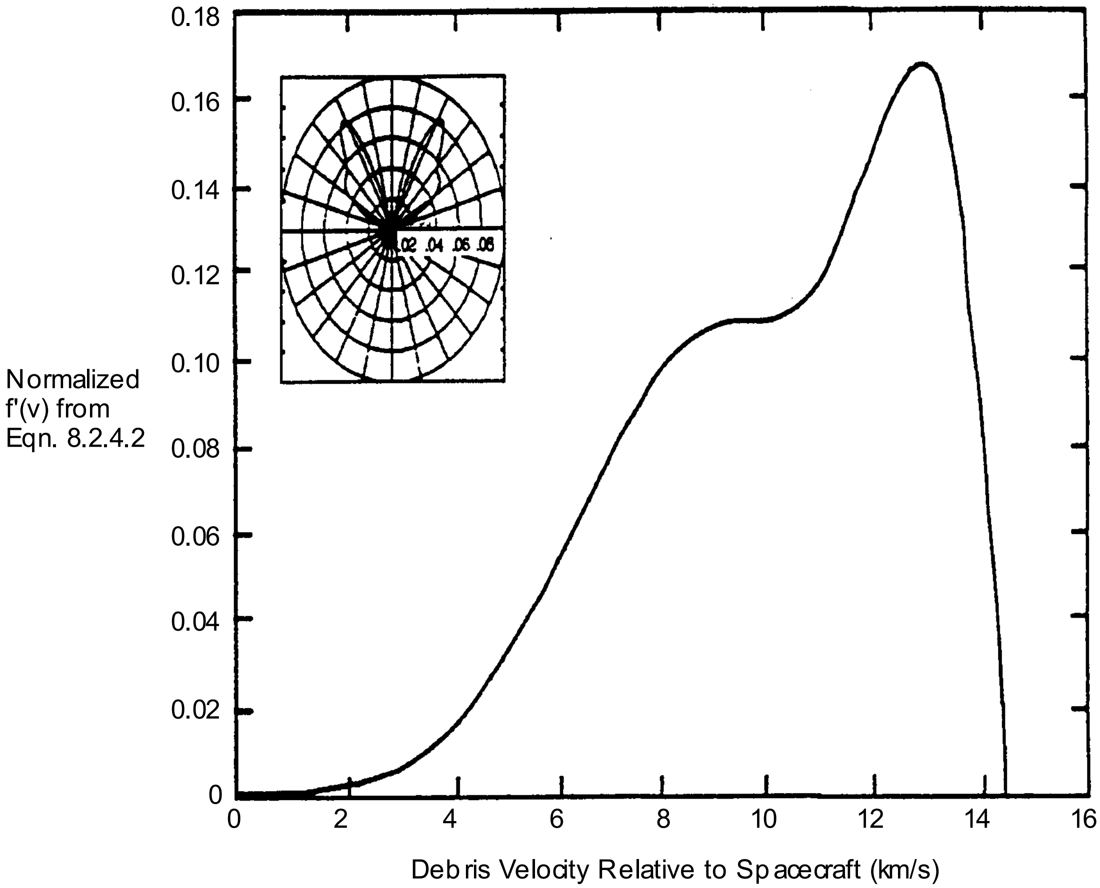


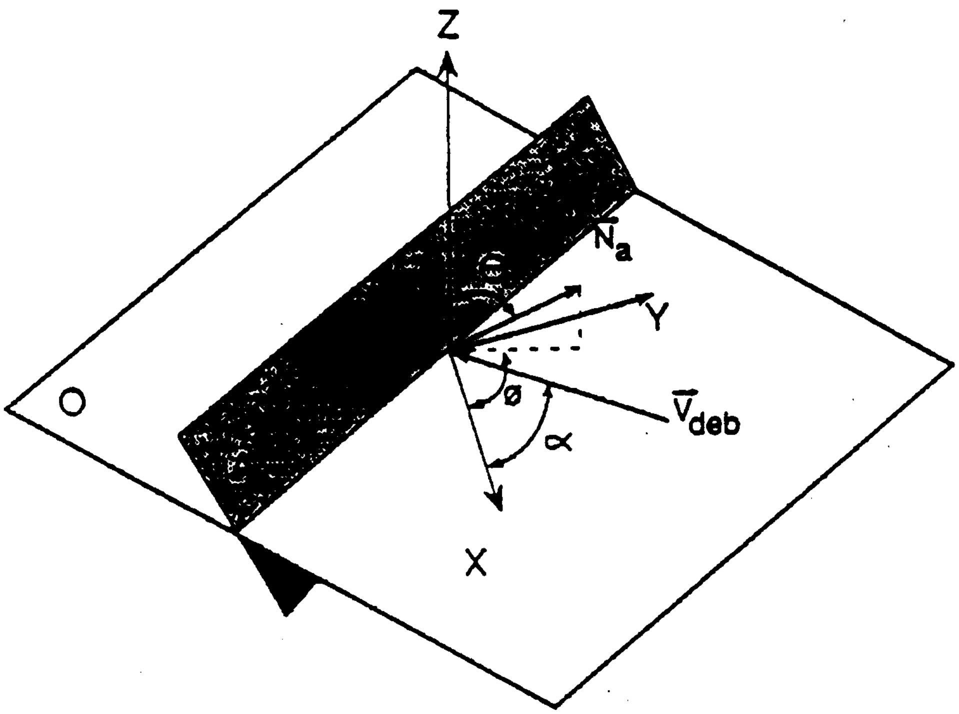
Figure 3.8.2.4-1 Normalized Collision Velocity Distribution as Function of the Debris Velocity for a Spacecraft with an Orbital Inclination of 28.5 Degrees.

The frequency of impact from a given direction can be estimated by using this velocity distribution. The direction of impact is assumed to be specified by the intersection of the spacecraft velocity vector and another circular orbit. That is, the relative velocity vectors may be obtained by vector addition in a plane tangent to the earth's surface. Since a spacecraft velocity of 7.7 km/s was used to calculate relative velocity, the direction of the relative velocity vector is given by the relationship:

$$\cos\left(\pm \alpha\right) = \frac{v}{v_{MAX}} = \frac{v}{15.4'} \qquad (3.8.2.4,4)$$

$$\cos(\pm \alpha) = \frac{V}{V_{MAX}} = \frac{V}{15.4'} \qquad (8.2.4,4)$$

where a is the angle between the impact velocity vector and the spacecraft velocity vector in a coordinate system fixed with respect to the Station, v is the impact velocity, and v_{MAX} v_{MAX} is the maximum possible velocity difference between the debris and the spacecraft. The coordinate system is illustrated in Figure 3.8.2.4-2.



DEFINITIONS
Plane A represents a surface of the spacecraft.
Na is the unit vector normal to the plane A.
x is the direction of travel of the spacecraft.
Vdeb is the debris velocity relative to the spacecraft.
O is the tangent plane (horozontal) to the spacecraft's orbit
A right-handed coordinate system (positive x, y, z, is defined in plane O as:
 x : direction of spacecraft travel
 y : 90 degrees from x and in plane O (Port direction)
 z : Earth vertical (up)

ANGLES
α is the angle between x and Vdeb
θ is the zenith of Na with respect to the Z axis in this reference frame.
F is the azimuth of Na with respect to the spacecraft direction of travel.

Figure 3.8.2.4-2 Orbital Debris Reference Frame

3.8.2.5 LIMITATIONS AND UNCERTAINTY IN THE DEBRIS FLUX MODEL

3.8.2.5.1 MEASUREMENTS OF THE CURRENT ENVIRONMENT (FACTORS WHICH ALTER THE INTERCEPT OF FLUX GROWTH CURVES)

For orbital debris sizes larger than 10 cm diameter, the environment is generally measured by ground radars. The most extensive measurements are made by the U.S. Air Force (USAF) Space Command, which also maintains a catalog of the debris population. While this data provides an adequate description of the distributions of large debris with respect to altitude and inclination, and of historical trends, analysis of GEODSS optical telescope data has shown that the radars are detecting, and the Space Command cataloging, less than half of the population in this size range. This information has been incorporated in the model presented here, so that the model represents the current environment in this size range accurately to within the range 1.5 to 0.5 times the flux, i.e., the "90 percent confidence" upper limit flux equals 1.5 times the flux from equation 8.2.2.1.1, etc.. Table 3.8.2.5.1-1 summarizes the uncertainties and accuracy limitations in the orbital debris flux model.

Table 3.8.2.5-1 Uncertainties and Accuracy Limitations

Uncertainty in Current Environment (Intercept Shift)

	Treatment	"90% Confidence"	Notes
Flux Measurements (d > 10 cm)	Best EST	1.5 to 0.5 x (1988 flux)	
Flux Measurements (0.05 cm <d<10 cm)	Best EST	3 to 0.33 x (1988 flux) in this size range	Due to statistical and Measurement limitations in portions of range. Data Missing (interpolation used) in rest of range.
Flux Measurements (d < 0.05 cm)	Best EST	2 to 0.5 x (1988 flux) in this size range	
Altitude Distribution (d < 10 cm)	Best EST	5 to 0.2 x (1988 flux) per 200 km away from 500 km	Due to difficulty in determining flux in highly elliptical orbits.
Altitude Distribution (d ≥ 10 cm)	Smoothed Best EST	2 to 0.5 x (1988 flux) see figure 3.8.2.5.2-1	Uncertainty is somewhat worse in 800 and 1000 km regions.
Debris Density (d < 1 cm)	Simplified Best EST	0.01 @ 1.8/0.5 @ 2.8 0.10 @ 4.5/0.3 @ 8.9	Estimated typical "heavy" distribution. Insufficient data to develop a true uncertainty limit estimate.

Debris Density (d > 1 cm)	Simplified Best EST	2 to 0.5 mean density	Mean values are fairly well defined but number vs. density distribution is broad.
Debris Shape	Simplified non-conserv.		Spherical shape is assumed, actual debris will be irregular.
Velocity Distribution, fraction < 5 km/s	Best EST	0.5 to 3x (slow fraction)	Distribution of orbit inclinations could be in error or change with time.
Uncertainty in trend Projection (Slope Shift)			
	Treatment	"90% Confidence"	Notes
Launch Rate	Best EST	} p=0.04 to "comp p" = 0.1 q=0 to 2p	"comp p" implies $g2 = (1 \pm p)^{(t-1988)}$. Worst case assumes combined effect of increased traffic and increased use of LEO above 400 km.
Orbit Use Profile	Best EST		
Fragmentation Rate	Best EST	} q=0 to 0.10	Assuming no changes in projected launch rate and orbit use profile.
Fragmentation Mechanics	Best EST		
Statistical Variation of Fragmentations	Best EST	0.5 to 1.5 x (current flux)	
Solar Activity	Best EST	Substitute 'Max" and "Min" s values	Model tends to overestimate variation with solar cycle, so these would be extreme limits.
"Local" Fragmentation Events	Non Conserv.	+4x (1988 flux) for 1 year	Difficulty to assess, depends strongly on type of event and proximity to station orbit. Ignored in current model.

Measurement of the debris flux at the other size extreme, sizes smaller than 0.05 cm, is made by analysis of impact craters on pieces of space hardware returned from orbit. Meteoroid impacts are distinguished from debris impacts by analysis of the chemical elements retained in the crater. For these sizes, the flux has only been measured on hardware flown at about 500 km; at this altitude the environment is known within the range 2 to 0.5 times the flux.

Until recently, the only measurements between the two debris size extremes was a limited set of optical telescope data from the MIT ETS telescopes. This provided an indication of the cumulative flux for objects believed to be 2 cm and larger. For intermediate sizes, the environment was estimated by a simple straight line interpolation on a log-log, flux versus size plot, as in Figure 3.8.1-2. This practice was retained for the current model, but in this case the interpolation is confirmed by -recent measurements by Arecibo and Goldstone radars in the important mid- range between 0.2 and 2 cm. These show a detection rate which is consistent with the current model, but both systematic and random errors in these measurements leave the environment uncertain within 3 to 0.33 times the flux for these sizes. Measurements were only made between 500 and 600 km altitude. Between 2 and 10 cm no measurements exist, but interpolation of the data from either side and modeling this region also yield an estimated uncertainty between 3 and 0.33 times the best estimate.

3.8.2.5.2 TREND PROJECTION (FACTORS WHICH ALTER THE SLOPE OF FLUX GROWTH CURVES)

As is the case with any analysis or model, the results hold only so long as the underlying assumptions remain valid. The following are the key assumptions upon which the model rests:

1) It is assumed that the rate of accumulation of objects in low Earth orbit is constant, with the annual increase equal to 5 percent of the amount accumulated by 1988. This matches the historical trend over the last few decades.

2) The relative use of different orbits is assumed to remain constant. For example, the history of launches by ~~the USS~~NASAR has been such that 80 percent of their payloads re-enter within two years of launch. These do not contribute significantly to the debris environment. If this practice changed with the increased use of higher, longer life orbits, the population of objects in orbit would grow at a proportionally increased rate.

3) It is assumed that the efforts to minimize fragmentation of satellites in orbit will continue such that fragmentation events will continue at the rate of only one per year in low Earth orbit (29 percent of past practice). In the last decade, intentional (or apparently intentional) fragmentation of satellites accounted for about 71 percent of the known fragmentation events. Apparently, recent publicity and increased awareness of the hazards associated with orbital debris has generated policy shifts among the space faring nations. No intentional fragmentation events above 300 km have been observed in the last two years and steps have been taken to lessen the likelihood of unintentional events.

4) It is assumed that the debris size distribution is independent of altitude. One would expect small debris in circular orbits to decay faster than large debris, implying an altitude dependent distribution. However, consideration of the population of small

fragments in elliptical orbits, assuming a trend similar to the one for large fragments, leads to a dependent distribution with the opposite trend. Therefore, pending further measurements and research, an intermediate assumption has been made.

5) It is assumed that future solar cycles will follow the mean of past cycles.

The uncertainties associated with these factors differ from those discussed above in that they alter the growth terms in equation 8.2.2,1, rather than entering as multipliers of the total flux. Thus the variations are expressed as variations of the p, q, and S terms.

The first two of these assumptions relate to the predicted future accumulation of objects in low Earth orbit. This is a key determinant of the expected debris growth rate - the value of p. The combination of a decreasing launch rate for the United States with an increasing rate for the rest of the world has led to the relatively constant historical trend. It is not clear, however, that this trend will continue. Expected launch rates are subject to political and economic influences which may change unpredictably, and many new countries are becoming involved in space activities. Current traffic models extended to the year 2010 predict that future growth will be at a compounded rate between 5 and 10 percent per year. The lower limit of these models corresponds to a value of p = 0.05 compounded annually. These models represent the projects that are planned, and since some projects are either canceled or postponed, the actual rate has always fallen below the traffic models. Therefore the baselined rate is a constant (not compounded) p = 0.05. A substantially lower rate would only be expected in the case of a world-wide economic depression or similar event. A higher rate is possible, especially if an increased launch rate is coupled with an increased use of higher, long life orbits. A compounded 10% per year increase, or p = 0.1, represents the “90 percent confidence level” upper limit.

The value of q, which represents the expected growth rate of small debris, primarily depends on the frequency of expected satellite breakup, assumption 3). Breakups may be intentional, or they may result from accidents and random collisions. Thus the breakup rate is partially controllable, partially not. The value selected for this model, q = 0.02, assumes no intentional breakups, and an accidental breakup rate of 1/yr. The range of possible q values is from 0.0 (random collisions are not important and improved precautions lower the accidental rate below historical values) to 0.06 (both accidental and intentional fragmentation rates match the 1980 - 87 rates). Technically, negative values of q are possible if all fragmentation events are prevented, but this is not considered a credible possibility. At the other extreme, if fragmentation rates rise above the 1/yr and the rate of accumulation of mass in orbit increases, on orbit collisions become important and q will approach 2p.

Unintentional fragmentation events can result from either explosions or collisions between objects. The first of these represents a simple linear source, the population growth is directly related to the fragmentation rate. The second is exponential in nature, since the number of fragmentation events is a function of the square of the population. Thus the coupling between p and q uncertainty limits noted above. Modeling these processes indicates that the first process will be dominant until about the year 2010. About that time, under the assumptions of the current model, the second process becomes significant and the small particle population will grow at an increasing rate. If the assumptions of the current model hold and current practices continue, q is expected to increase to 0.04 beginning about the year 2010.

Uncertainties in the mechanics of fragmentation events; i.e., fragment size, number, and velocity distribution impact the capability to model and analyze the debris environment. Fragmentation events have multiple possible causes and may vary widely in intensity. Direct data from simulations of these processes is quite limited. In the analysis supporting the current model, these limitations were overcome by tuning the fragmentation models so that the historical fragmentation record reproduced the current environment. This approach provides the “best estimate” fragmentation models for the analysis, but it is very limiting in the sense that there is no independent check of the analysis. Since there are only recent measurements of the small fragment environment, there is no second point to check the analysis against. The associated uncertainty has been included within the 2p factor described above.

Assumption 4 is necessary because there are no measurements of debris smaller than 2 cm at other than in the 500 to 600 km altitude range, and because poor knowledge of the fragment velocity distributions (and computer run-time limitations) make it impractical to model small fragments in highly elliptical orbits. Analysis of these limitations indicates that the actual flux of small material could trend either above or below the large object distribution with altitude, depending upon the assumptions used. The model presented here assumes that the distribution with altitude for the small material matches the catalog distribution. The actual amount that these fluxes differ could be as high as a factor from 5 to 0.2 for every 200 km away from the 500 km altitude. The distribution with respect to altitude is also assumed to be smooth. Actually, the U.S. Space Command data (sizes larger than 10 cm) gives fluxes at 800 km and 1000 km which approach the level predicted by the recommended flux model, as shown in Figure 3.8.2.5.2-1, not allowing for the correction factor from the GEODSS telescope study.

With respect to assumption 5, the possible variance of solar activity can be well defined based on the historical record. A high solar cycle will increase the depletion rate for debris in low altitude orbits, compared to a mean or low cycle, but prediction of the solar activity level beyond about one year is highly uncertain. Table ~~4.3-1~~3.8.2.5-1 provides profiles of maximum and minimum solar activity, and these values may be used in equation 3.8.2.2,~~.~~1 to estimate the range of variation.

An important short term factor which is not included in the model and thus contributes an additional uncertainty, is the flux arising from the intentional or inadvertent fragmentation of a satellite in an orbit at or near Space Station operating altitudes. In the region of the breakup, an enhanced flux may be apparent for a considerable period of time, depending upon the altitude of the breakup, and the size and velocity distribution of the debris. Analysis and modeling of various scenarios indicate that such an event would probably cause increases in the flux environment by factors of a few tens of percent for a year or more, although a factor of 4 may be possible as an extreme worst case.

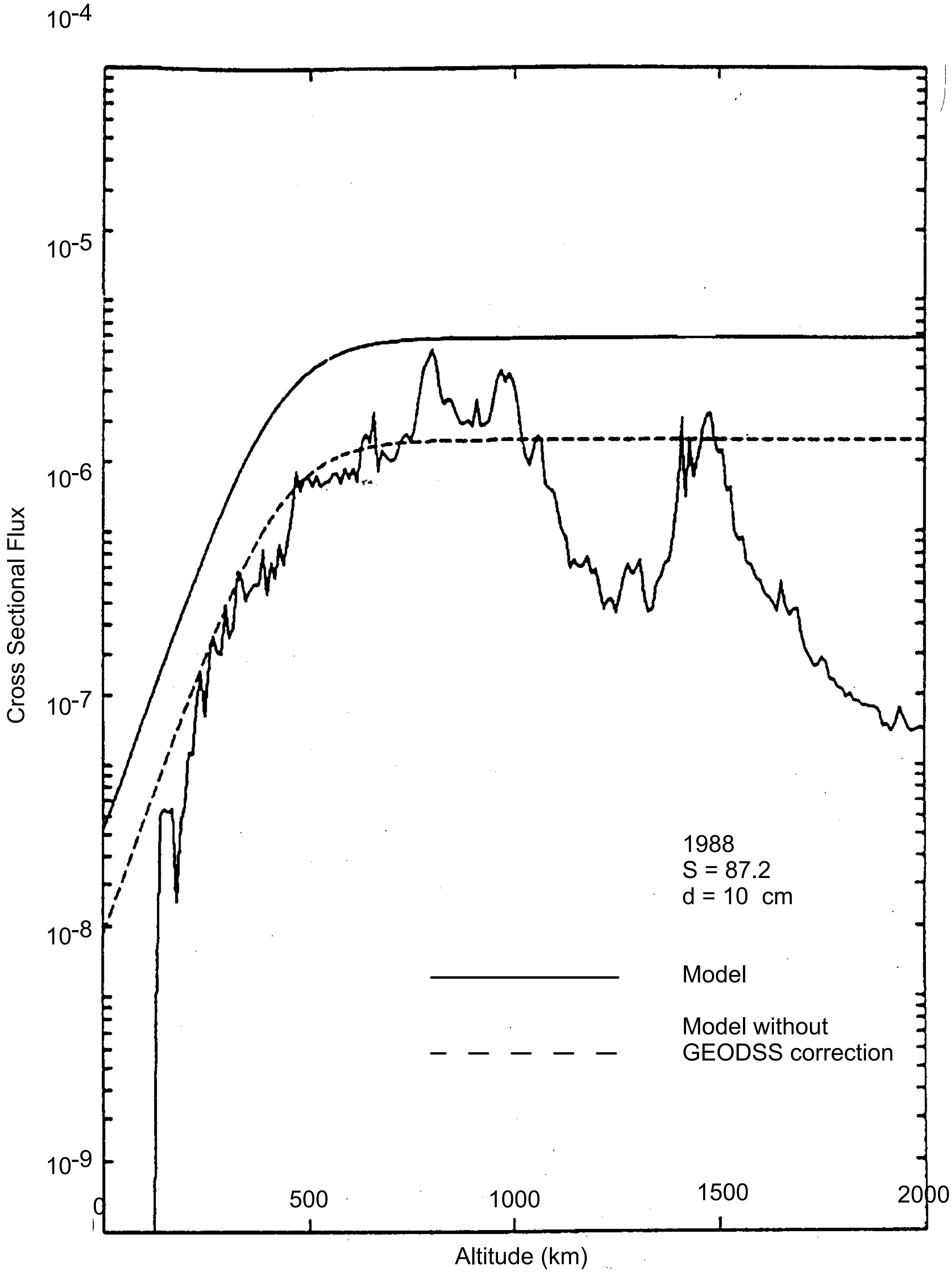


Figure 3.8.2.5.2-1 Comparison of Model Flux, Fc, with Catalog Flux Not Corrected for GEODSS Results

3.8.2.5.3 UNCERTAINTIES IN DIRECTION, VELOCITY DISTRIBUTION, AND DENSITY

The fact that orbital debris objects are not in exactly circular orbits will introduce a small error in direction. As a result of the currently small eccentricities of debris orbits, the actual directions of impacts are within 1° for most velocities derived from section 3.8.2.4. For velocities less than 2 km/s, the uncertainty is much larger with a significant fraction being more than 20° from the direction derived from section 3.8.2.4. These errors in direction can be in the local horizontal plane, or they can appear as direction errors above or below this plane.

Uncertainty in the distribution of debris orbit inclinations leads to an uncertainty in the velocity distribution which can affect penetration analysis. Since inclinations are only known for large (catalogued) debris, the small fragments may have a different distribution, or the distribution may change with time as a result of orbit selection and fragmentation events. These considerations imply that the slow fraction of the population, i.e., the fraction of debris objects with a relative speed less than 5 km/s with respect to the Station, could shift or be in error by a factor from 0.5 to 3.

The expression for debris density given in section 3.8.2.3 for objects larger than 0.5 cm has been verified by direct measurements of actual objects, studies of orbit decay, and fragmentation experiments. Thus, it is believed to be a good representation of the mean density of the debris population (within a factor of 0.5 to 2), especially for sizes above 30 cm. However, it represents the mean of a broad distribution; the density of individual objects can vary widely.

For small fragments the density issue is more difficult because information is extremely scant. To illustrate the problem, consider the following materials density profile based on a summary review of Space Shuttle materials usage (neglecting tiles):

ESTIMATED VOLUME FRACTION	SPECIFIC GRAVITY	REPRESENTATIVE MATERIALS
0.65	2.8	Aluminum, Glass
0.15	1.8	Epoxy-glass, Rubber
0.05	4.5	Titanium
0.15	7.8 to 8.9	Copper, Steel

One might expect this would be typical of many spacecraft, but it may underestimate the fraction of dense materials for several reasons. First, many objects involved in fragmentation events are believed to have had a higher fraction of dense materials used in their construction. The Delta second stages, for example, contain about 70 percent steel, 20 percent aluminum, and 10 percent titanium. Second, low density objects are more affected by drag and thus decay from orbit more rapidly. However, fragment shape is also an important determinant of effective density. The thickness of the Delta walls is between 0.2 and 0.5 cm, so fragments larger than this would be irregular in shape with an effective density less than that of steel. Since definitive studies have not been done, uncertainty bounds cannot be defined at this time. For study purposes the recommended “heavy” distribution is: 10% (by volume) at 1.8, 50% at 2.8, 10% at 4.5, 30% at 8.9 g/cm^3. This gives a mean density of 4.7 g/cm^3 for solid spheres.

3.8.3 EVALUATION OF DIRECTIONALITY EFFECTS

The parameter k which appears in equation 3.8.0,1 is defined as the ratio of the flux against an oriented surface to the flux against a randomly tumbling surface. Introduction of the k factor allows application of the flux equation 3.8.2.2,1 to evaluate the expected number and probability of impacts on surfaces flying with fixed orientation, such as Space Station. Evaluation of penetration probability should be by numerical techniques which account for the directional dependence of both the penetration equations and the meteoroid and debris fluxes, although the k factor may be useful for quick approximations.

The value of k can theoretically range from 0 to 4; a value of 4 can only be achieved when a surface normal vector is oriented in the direction of a monodirectional flux. It depends on the orientation of the surface with respect to the Earth vertical and the spacecraft velocity vector. If the surface is randomly oriented, then k = 1.

Care must be taken in evaluating k factors and other directional effects because of the complex directional nature of the meteoroid and debris fluxes. Unlike most fluxes with which the engineer and physicist deals, the meteoroid and debris fluxes do not have a unique direction associated with them at any given point in space. Meteoroids are equally likely to appear from any direction (except where the Earth provides shielding) in a reference frame fixed with respect to the Earth; they tend to appear from the ram direction on an orbiting satellite. The relative velocity with respect to a randomly tumbling spacecraft is about 19 km/s. The approach for evaluating k for meteoroids will be similar to the approach for debris which is presented below. As an illustration of the expected effect, the ram to lee ratio of the number of impacts was found to be about 7 to 1 in preliminary analysis of Long Duration Experiment Facility data for constant particle size, or about 18 to 1 for constant crater size (Zook, 1990). It is expected that meteoroids were dominant in this case.

For orbital debris the directionality in a reference frame fixed with respect to the Station is defined by combining equations 3.8.2.4,2 and 3.8.2.4,4. That is, the directionality can be written as a function of velocity alone, so differential pseudo-vector fluxes can be defined in terms of the velocity distributions such that:

$$-\,d\mathbf{F}_{+}(v) = F\,\{\,(f'(v)/2)\,d\mathbf{v}_{+}\,\} \quad \text{and} \qquad (8(3.8.3,1)$$
$$-\,d\mathbf{F}_{-}(v) = F\,\{\,(f'(v)/2)\,d\mathbf{v}_{-}\,\},$$

where f'(v) is defined by equation 3.8.2.4,2 and the + and - subscripts are associated with the +a and -a angles of equation 3.8.2.4,4, i.e., the left and right lobes of the "butterfly" shaped debris distribution (symmetric about the direction of flight). Our sign convention is such that d**F** is positive in the minus d**v** direction. (See Figure 3.8.2.4-2.) By solving the problem of the flux against a sphere it can be shown that -F = 4 F_r = F_c, where F_r is defined by equation 3.8.2.2,1

To find the expected rate of impacts on a surface, A, flying with fixed orientation one must solve the following:

$$R(A) = \iint_{v \cdot A} dF + (v) \cdot Na\, da + \iint_{v \cdot A} dF - (v) \cdot Na\, da \qquad (3.8.3,2)$$

$$R(A) = \int_{v} \int_{A} dF + (v) \cdot Na\, da + \int_{v} \int_{A} dF\, (v) \cdot Na\, da \qquad (8.3,2)$$

where $\mathbf{N_a}$ is the outward unit vector normal to the surface element da.

IMPORTANT: The limits on the surface integrals must be such that all of the surface where the dot product is positive is included, and portions where it is negative are excluded. [A negative dot product corresponds to flux leaving the surface.] The k factor for the surface A is simply:

$$k = \frac{R(A)}{A\ F_r}$$

Figures 3.8.3-1 and 3.8.3-2 illustrate k factors for a flat plate and a right circular cylinder at various orientations.

REFERENCES:

Grun, E., H. A. Zook, H. Fectig, and R. H. Giese; "Collisional Balance of the Meteoritic Complex", Icarus **62**, 244-272, 1985.

Kessler, Donald J., Robert C. Reynolds and Phillip D. Anz-Meador, "Orbital Debris Environment for Spacecraft Designed to Operate in Low Earth Orbit", NASA TM 100471, April, 1989.

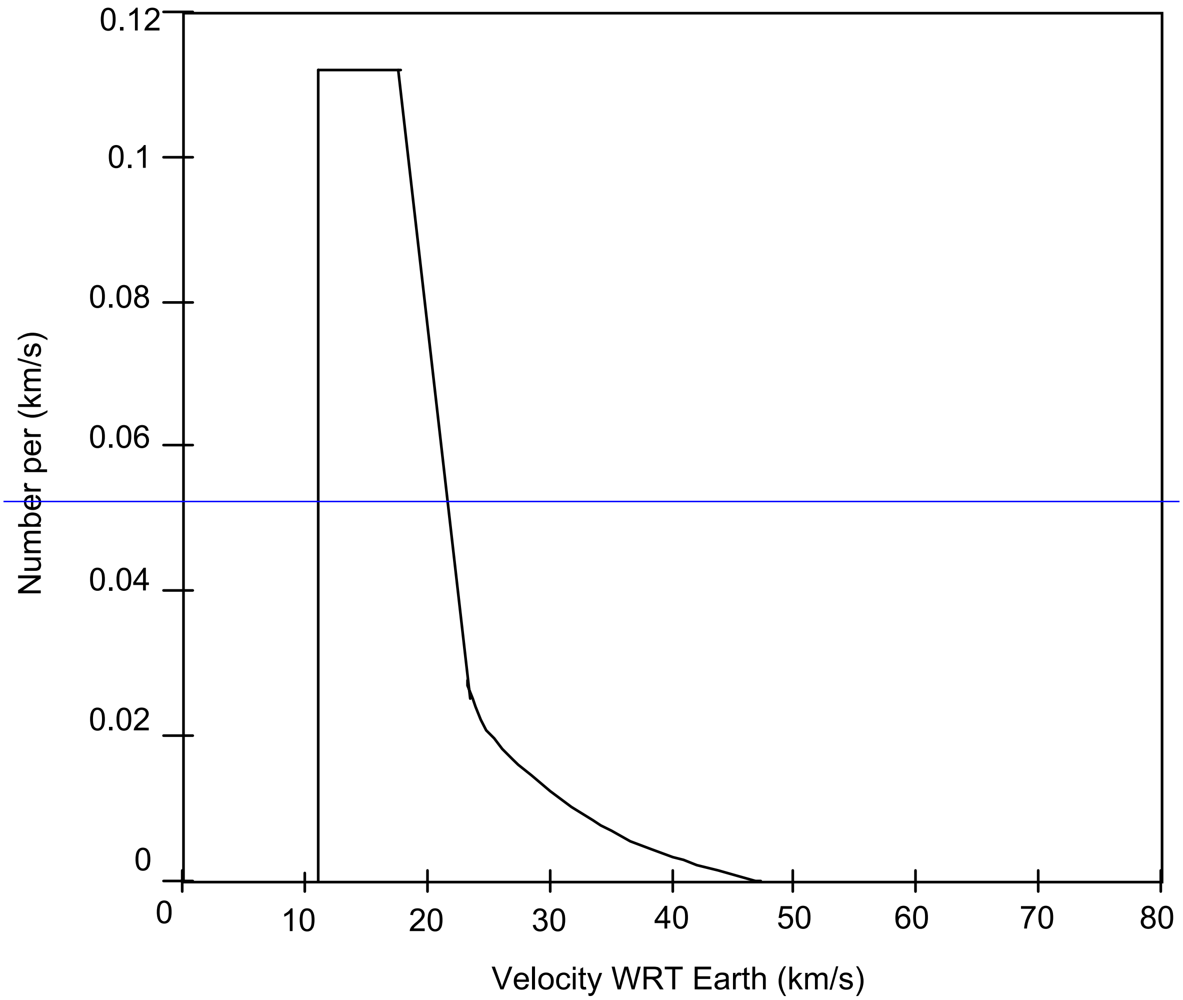
Zook, H. A., "Flux vs Direction of Impacts on LDEF by Meteoroids and Orbital Debris", Proceedings of the 21st Lunar and Planetary Science Conference, pp 1385-1386, 1990.

Zook, H. A., "The State of Meteoritic Material on the Moon", Proceedings of the 6th Lunar Science Conference, pp 1653-1672, 1975.

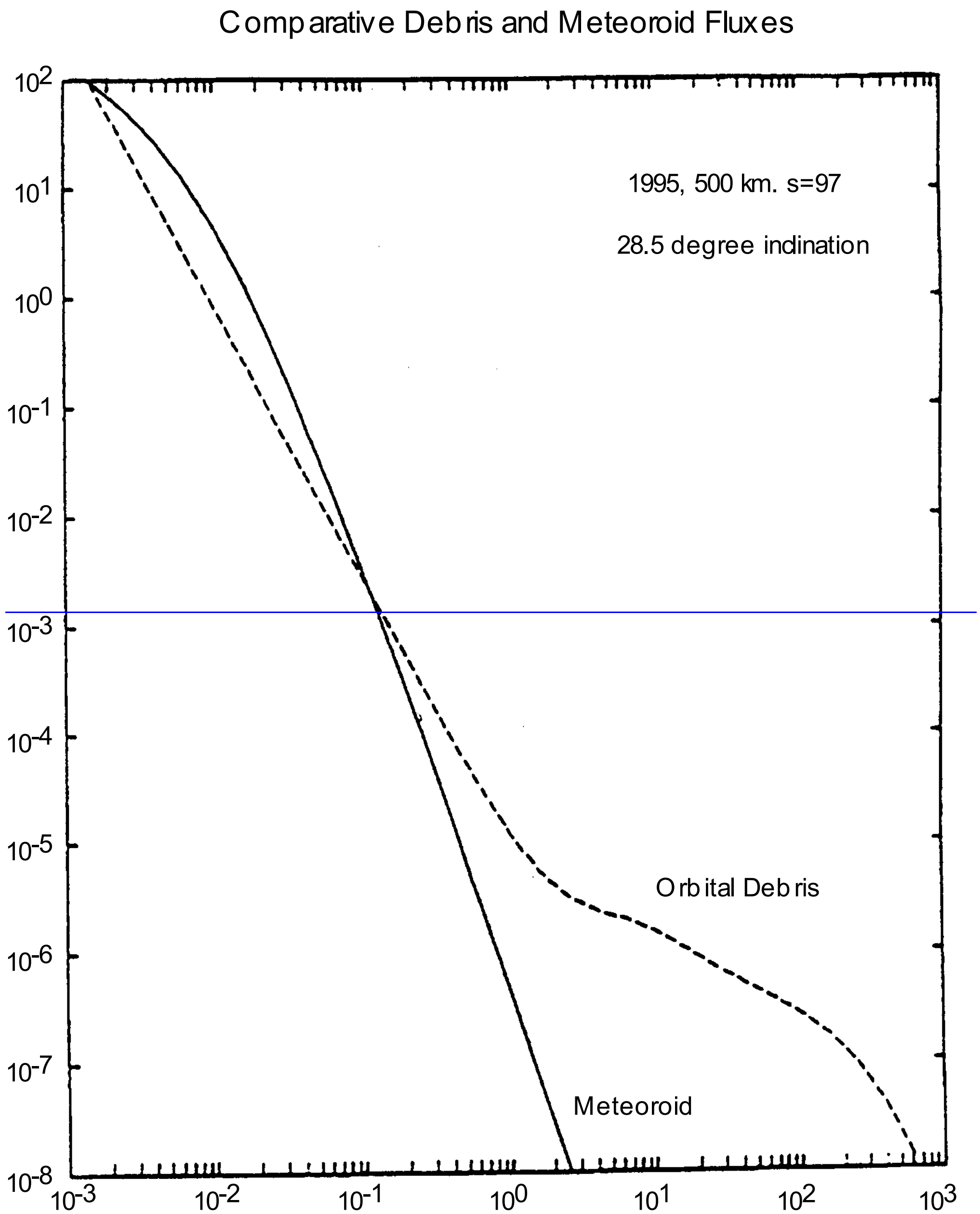
Table 3.8.2.5-1 Uncertainties and Accuracy Limitations

Uncertainty in Current Environment (Intercept Shift)

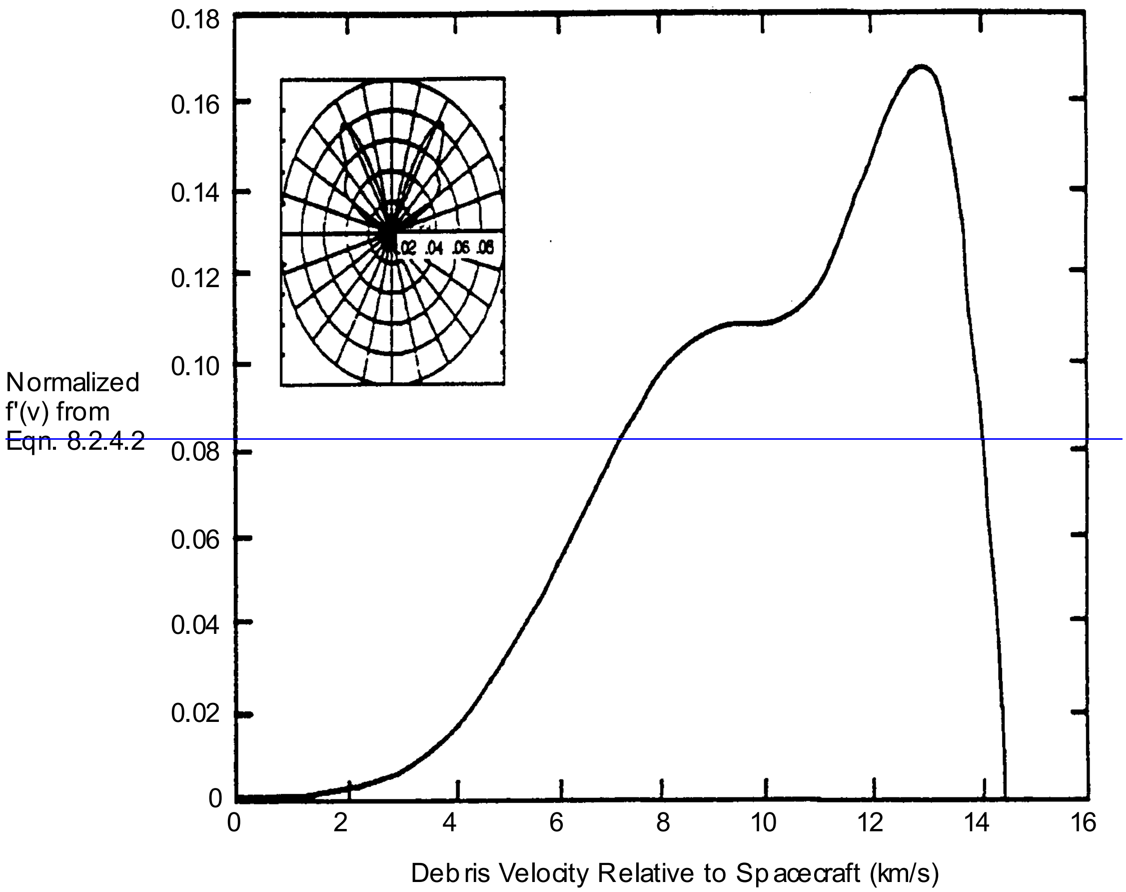
	Treatment	"90% Confidence"	Notes
Flux Measurements (d > 10 cm)	Best EST	1.5 to 0.5 x (1988 flux)	
Flux Measurements (0.05 cm <d<10 cm)	Best EST	3 to 0.33 x (1988 flux) in this size range	Due to statistical &and Measurement limitations in portions of range. Data Missing (interpolation used) in rest of range.
Flux Measurements (d < 0.05 cm)	Best EST	2 to 0.5 x (1988 flux) in this size range	
Altitude Distribution (d < 10 cm)	Best EST	5 to 0.2 x (1988 flux) per 200 km away from 500 km	Due to difficulty in determining flux in highly elliptical orbits.
Altitude Distribution (d ≥ 10 cm)	Smoothed Best EST	2 to 0.5 x (1988 flux) see figure 3.8.2.5.2-1	Uncertainty is somewhat worse in 800 and 1000 km regions.
Debris Density (d < 1 cm)	Simplified Best EST	0.01 @ 1.8/0.5 @ 2.8 0.10 @ 4.5/0.3 @ 8.9	Estimated typical "heavy" distribution. Insufficient data to develop a true uncertainty limit estimate.
Debris Density (d > 1 cm)	Simplified Best EST	2 to 0.5 mean density	Mean values are fairly well defined but number vs. density distribution is broad.
Debris Shape	Simplified non-conserv.		Spherical shape is assumed, actual debris will be irregular.
Velocity Distribution, fraction < 5 km/s	Best EST	0.5 to 3x (slow fraction)	Distribution of orbit inclinations could be in error or change with time.



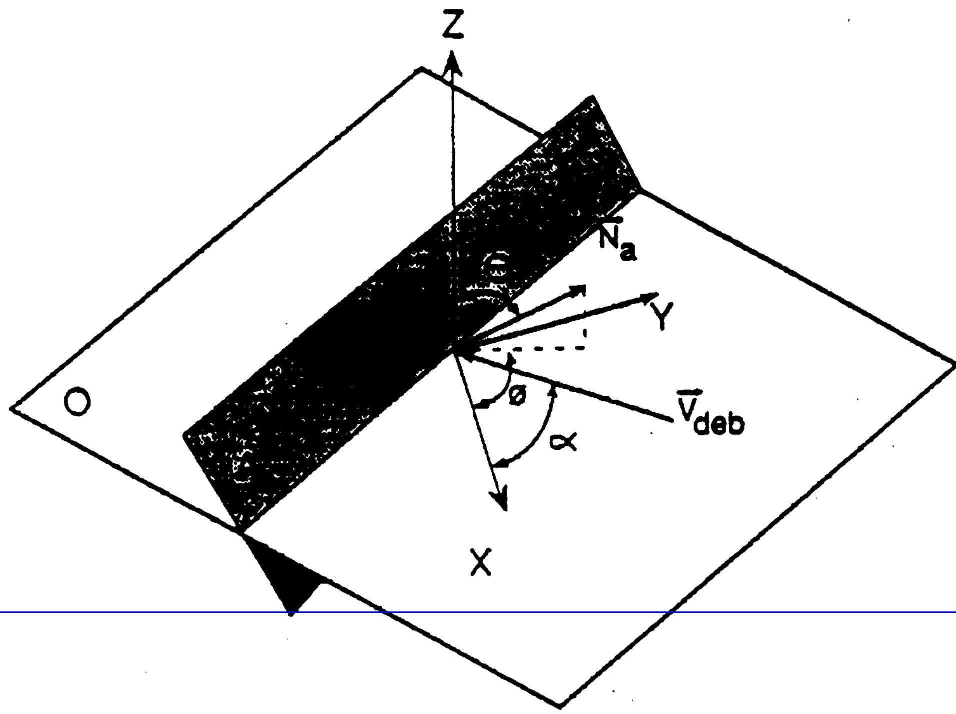
~~Figure 3.8.1-1 Normalized Meteoroid Velocity Distribution From Equation 3.8.1,1.~~



~~**Figure 3.8.1-2 Comparison of Meteoroid and Orbital Debris Fluxes, Fr, as a Function of Size**~~



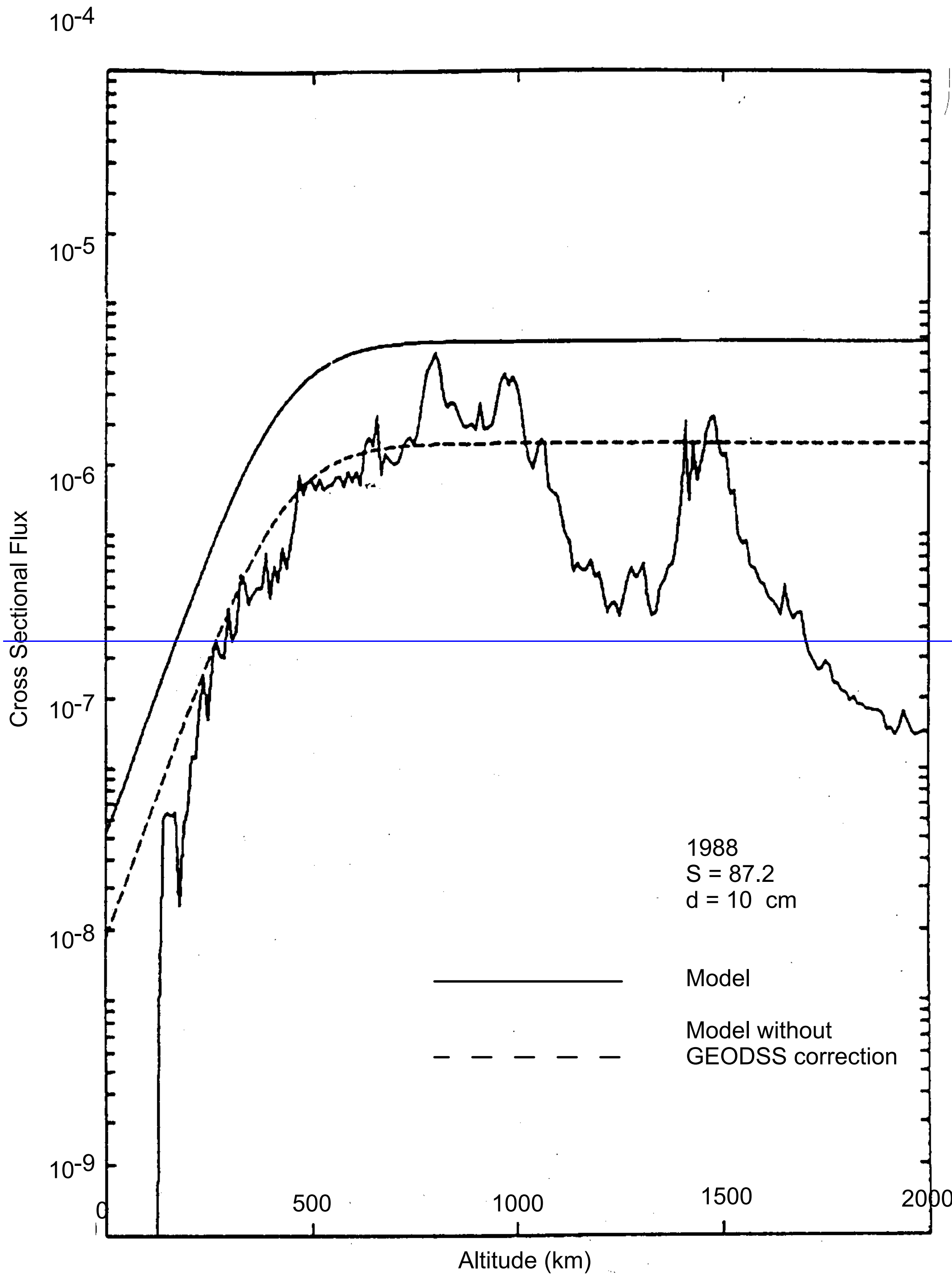
~~**Figure 3.8.2.4-1 Normalized Collision Velocity Distribution as Function of the Debris Velocity for a Spacecraft with an Orbital Inclination of 28.5 Degrees.**~~



DEFINITIONS
Plane A represents a surface of the spacecraft.
Na is the unit vector normal to the plane A.
x is the direction of travel of the spacecraft.
Vdeb is the debris velocity relative to the spacecraft.
O is the tangent plane (horozontal) to the spacecraft's orbit
A right-handed coordinate system (positive x, y, z, is defined in plane O as:
- x : direction of spacecraft travel
- y : 90 degrees from x and in plane O (Port direction)
- z : Earth vertical (up)

ANGLES
α is the angle between x and Vdeb
θ is the zenith of Na with respect to the Z axis in this reference frame.
F is the azimuth of Na with respect to the spacecraft direction of travel.

~~Figure 3.8.2.4-2 Orbital Debris Reference Frame~~



~~**Figure 3.8.2.5.2-1 Comparison of Model Flux, Fc, with Catalog Flux Not Corrected for GEODSS Results**~~

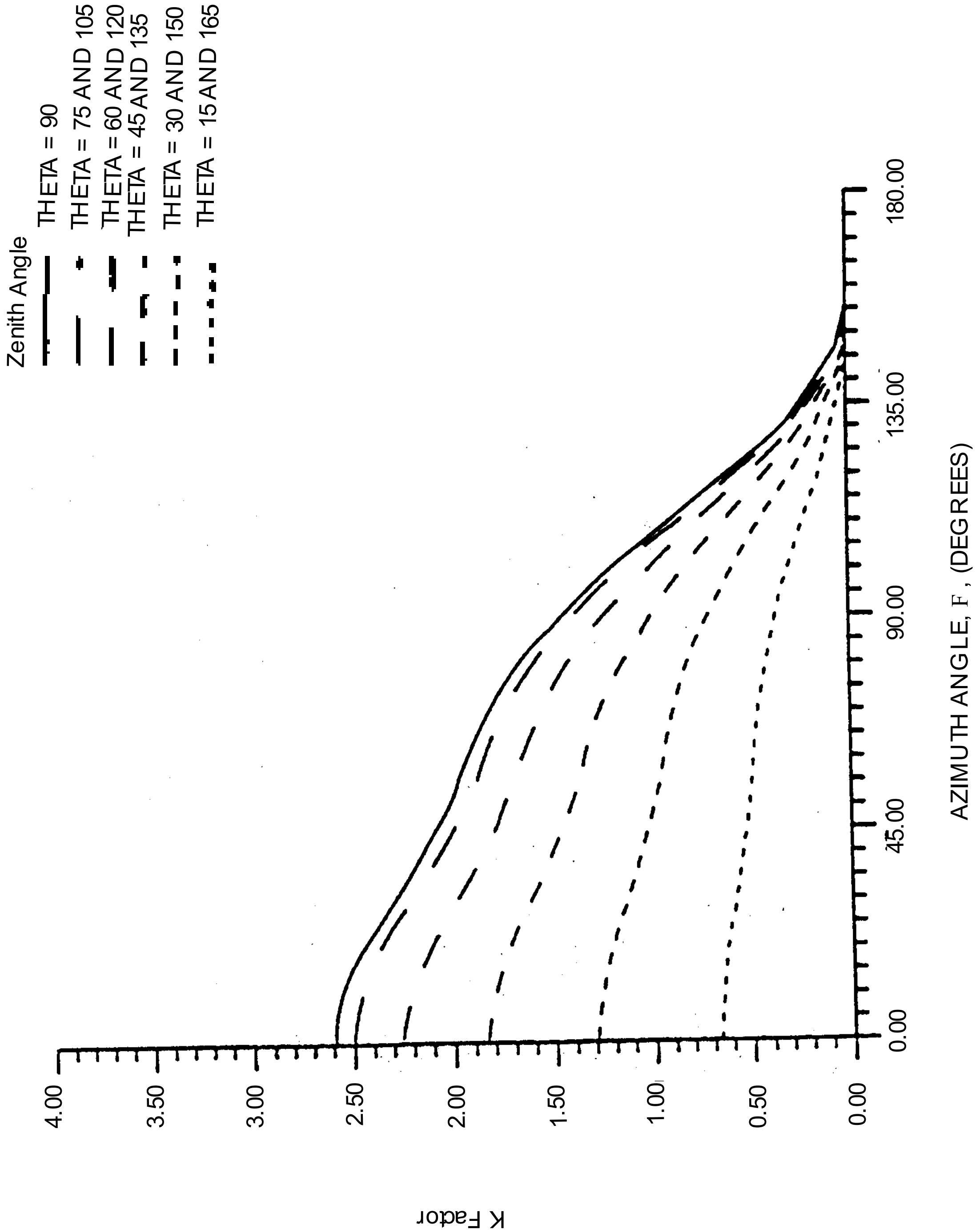


Figure 3.8.3-1_ "k" factor for Single Sided Flat Plates

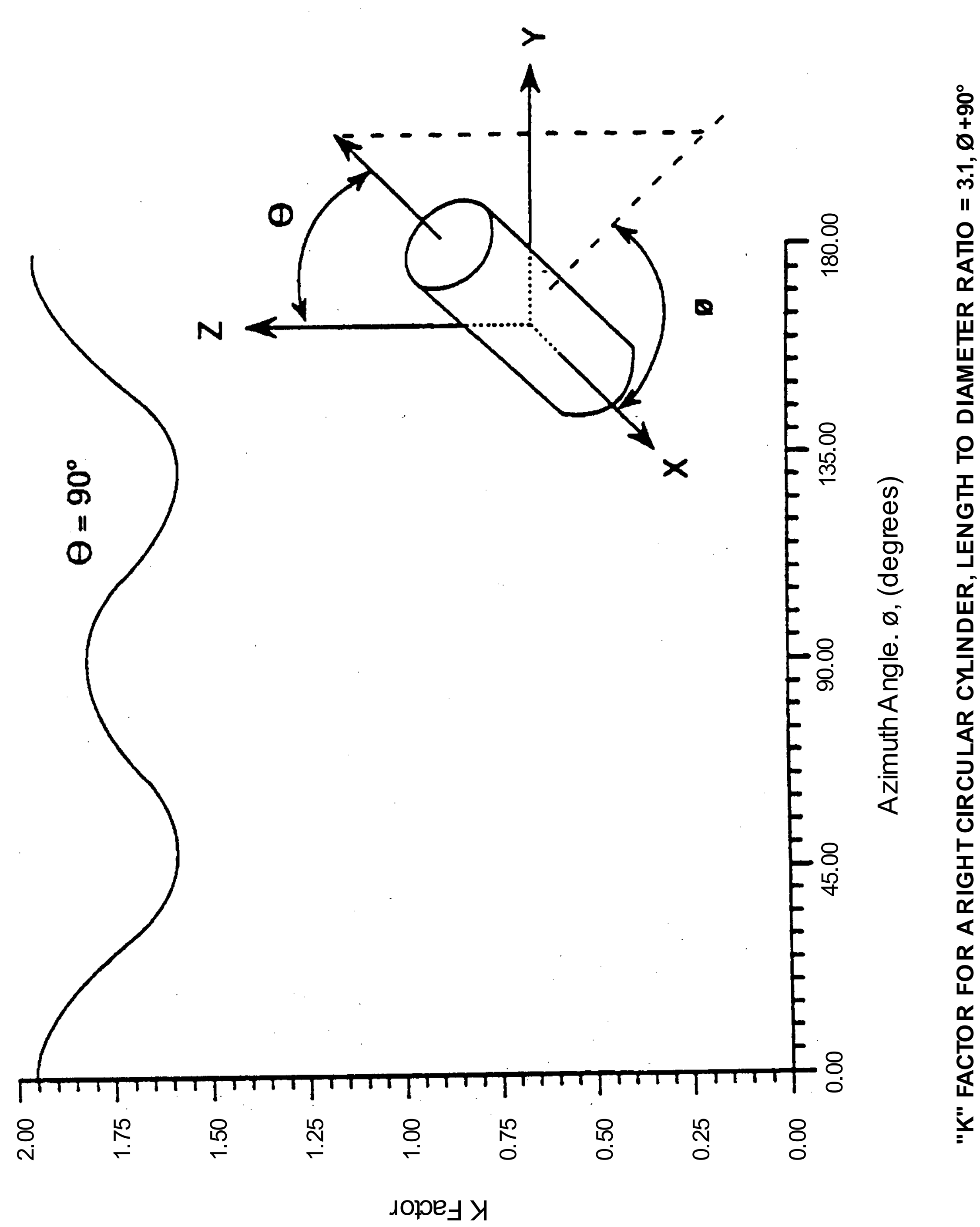


Figure 3.8.3-2 **"K" Factor for a Right Circular Cylinder, Length to Diameter Ratio =3.1, 0+90˚**

4 ELECTRICAL, ELECTRONIC AND ELECTROMECHANICAL PARTS, MATERIALS AND PROCESSES

4.1 ELECTRICAL, ELECTRONIC AND ELECTROMECHANICAL (EEE) PARTS

4.1.1 REQUIREMENTS ON ~~ELECTRICAL, ELECTRONIC AND ELECTROMECHANICAL~~ EEE PARTS FOR THE SPACE STATION

The requirements on ~~Space Station (SS)~~ISS Radio-Electronic Equipment (REE) will be governed by state standards and determined based on ~~SS~~ISS tasks.

4.1.1.1 EEE PARTS SELECTION

All EEE parts for the ISS will be selected from valid limiting lists and **~~SpS (special stability)~~special stability (SpS) index lists:**

- “List of EEE parts authorized for use in development and modernization ...” of special-purpose equipment
- SpS index hardware list
- SpSL index list of EEE components (SpS index EEE parts with low annual demand)
- List of uncased semiconductor instruments and microcircuits (N)
- Electrical hardware list (M) (SpS index for relays, switches etc.)

Priority is assigned to EEE parts with indexes SpS, SpSL, N, M

Priority documents for RSC-E equipment

- “Onboard equipment EEE components. Limiter”, STP 351-119-82.
- “Ground equipment EEE components. Limiter”, STP 351-115-82.
- “Ground equipment cable products. Limiter”, STP 351-92-80.
- “Onboard equipment cable products. Limiter”, STP 351-100-80.

Priority is assigned to SpS index EEE parts, and OVP index EEE parts can only be used in the absence of a similar SpS, SpSL, H or M index EEE part. 100% of EEE parts are subjected to incoming inspection in accordance with the valid “Incoming inspection requirements”.

4.1.1.1.1 FLIGHT HARDWARE

In selected EEE parts for flight hardware, RSA will be guided by requirements set forth in the ~~Space Station (SS)~~ISS Design Specification (DS)~~,~~ the model for External Influencing Factors (EIF) and lists specified in Paragraph 4.1.1.1.

All EEE parts will be fabricated and monitored based on General DS (GDS).~~–~~ DS, GOST’s or OST’s that define the EEE part identification, technical requirements, reliability, acceptance rules, packaging, transportation, storage, labeling, and instructions for use.

4.1.1.1.1.1 SEMICONDUCTORS

Integrated semiconductor requirements with OVP acceptance are defined in the GDS (GOST B 28146-89) and DS for the specific semiconductor. Semiconductor requirements with SpS acceptance are defined in the GDS (GOST B 28146-89), special supplement AAO.339.190 TY, and design specifications for the specific semiconductors.

4.1.1.1.1.2 INTEGRATED MICROCIRCUITS

Integrated microcircuit with OVP acceptance are defined in the GDS (OST B11 0398-87) and DS for the specific integrated microcircuit. Integrated microcircuit requirements with SpS acceptance are defined in GDS (OST B11 073.012-87) and design specifications for the specific integrated microcircuit.

4.1.1.1.2 GROUND EQUIPMENT

For ground equipment, all EEE parts must be selected in accordance with the "List of EEE parts authorized for use in development and modernization …" of special-purpose equipment and in accordance with RSC Energia documents:

- "Ground equipment EEE components. Limiter", STP 351-115-82.
- "Ground equipment cable products. Limiter", STP 351-92-80.

EEE parts with Quality Assurance (QA) acceptance or domestic (industrial) type components can only be used if they do not affect implementation of the primary objective of the space station, and do not reduce the safety and reliability of onboard equipment.

Connectors used to establish a direct link with onboard equipment must be identical in design and exhibit the same quality and reliability as onboard equipment connectors.

4.1.1.2 QUALIFICATION

Qualification acceptance for EEE parts is defined by the design specification and evaluated based on tests or analysis. Index SpS or OVP EEE parts satisfy these requirements.

4.1.1.3 EEE PARTS APPLICATIONS

To increase reliability and service life, EEE parts must be used in favorable modes and conditions in accordance with Table 4.1.1.3-1.

Table 4.1.1.3-1 Part Load Factors

Name of Component	Load Factor	Comment
Analog Microcircuits	Ki < 0.8	Ki = Current
Digital Microcircuits	Ku < 0.8	Ku = Voltage
Semiconductor Diodes	Kp < 0.6	Kp = Power
High Frequency Diodes	Ki < 0.5	
Transistors	Kp < 0.6	
Opto Electronics	Kp < 0.6	
Resistors	Kp < 0.5	
Connector	Kp < 0.5	
Radio Components (Switches, Relays, Fuses)	Kp < 0.5	
Wires	Ki < 0.8	
Wire (Bundles)	Ki < 0.4	
Capacitors	Ku = 0.2 - 0.6	

4.1.1.4 MANUFACTURER SELECTION

All EEE parts used on board the ~~Russian Segment~~RS must be delivered by manufacturers of suppliers certified for EEE parts fabrication with OVP acceptance and SpS index.

4.1.1.5 TRACEABILITY

All EEE parts used for ~~Space Station~~ISS flight hardware must be traceable to the manufacturing date and circumstances, such as numbers of parts fabricated in a particular lot, and the types of tests performed for the particular lot.

4.1.1.6 EEE PART FAILURES

EEE parts failures that occur at all stages of development, fabrication, testing, and operation of space articles must be investigated by RSC Energia and its contractors in accordance with GOST B 22027 and STP 304.408-89. If an EEE part fails, the failure will be analyzed to determine the possible causes. If the EEE part failure is determined to be random, the failed EEE part is replaced with a new one without any additional authorization. Generic (systematic) failures must be eliminated by rejecting the entire lot of obtained EEE parts and then notifying the RSA. The RSA will set up a special commission, which reviews the failure causes and takes ste~~o~~ps to eliminate them. The RSA will maintain a record about EEE part failures, and distribute the list of EEE part failures to contractors every 3 months.

4.1.1.7 IONIZING RADIATION FOR EEE PARTS

EEE parts shall be capable of operating in the equipment, in accordance with the equipment specifications, in the ionizing radiation environment as specified in paragraph 3.6.1 for total dose and paragraph 3.6.2 for single event effects.

Electronic equipment that performs critical functions that influence the safe operation of the ~~U.S. Segment~~USOS must be verified by radiation characterization testing or analysis to meet performance requirements in the radiation environment.

Electronic parts and circuits that functioned on-orbit during the October 1989 Solar Flare event are exempt from further verification.

4.2 FLUID STANDARDS AND CLEANLINESS

4.2.1 CLEANLINESS OF HABITATION MODULE SURFACES

The internal surfaces of habitation modules and external surfaces of equipment and hardware installed in the habitation module must satisfy the requirements on industrial cleanliness assurance and monitoring, and also requirements on the development of design and process documentation to ensure cleanliness in accordance with OST 92-0300-92.

4.2.2 CLEANLINESS OF SURFACES IN CONTACT WITH FLUIDS

The internal surfaces of systems, lines, valves, etc. that come into contact with fluids must satisfy the requirements on the monitoring and preservation of elevated cleanliness and degreasing of parts and device elements in accordance with 33Y.0220.006.

Before filling the systems and lines with working fluids, they must be properly packaged in accordance with 33Y.0220.006.

4.2.3 THERMAL CONTROL SYSTEM FLUID STANDARDS

External loops of the Thermal Control System (TCS) use silicone fluid PMS-1.5p TU6-02-820-79; isooctane fluid LZTK-2 TU 38.101.388-79.

Internal TCS loops use heat carrier Triol, TU0258-009-00205073-97, an aqueous glycerin solution, and carrier TU38.1011101-87, an aqueous ethylene glycol solution;

Central heat rejection system uses ammonia of extreme purity, TU301-02-185-92.

4.3 MATERIALS AND PROCESSING

Materials must be selected in accordance with the operational requirements and their design engineering properties, considering conditions which could lead to a deterioration of these properties, in accordance with OST 92-1020-89, STP 351-134-84, STP 371-77-87 and other valid documentation.

4.3.1 RESERVED

4.3.2 RESERVED

4.3.3 GENERAL REQUIREMENTS

4.3.3.1 MATERIALS AND PROCESSES, SELECTION, CONTROL, AND VERIFICATION PLAN

The Materials and Processes, Selection, Control, and Verification Program shall be in accordance with OST 92-1020-89 and OST 92-0021-87.

4.3.3.1.1 COORDINATION, APPROVAL, AND TRACKING

A method shall be established for coordinating, approving and tracking engineering documentation relating to Materials and Processes (M&P) for M&P review in accordance with OST 92-1020-89 and OST 92-0021-87.

4.3.3.1.2 APPROVAL SIGNATURE

All engineering drawings/orders shall be approved and signed by M&P.

4.3.3.1.3 MATERIALS AND PROCESS DOCUMENTATION

In accordance with OST 92-1020-89, a Materials Identification Usage List must be prepared and reviewed and must contain, for the materials used, the following information, as a minimum: material designation or specification or index/unique designation, next assembly drawing number, environment, characteristics and rationale for use. Materials used in accordance with the List must satisfy the requirements in the following documents:

- P 17375-082 for flammability, toxic offgassing and microbial resistance;
- OST 92-0919-85, OST 92-0920-85 and OST 92-1010-77 for corrosion and stress corrosion, applying the criteria in 4.3.4.1;
- 33Y.0303.001 for age life;
- GOST 12.2.052-81 for use in oxygen;
- OST 92-1020-89 and GOST 12020-72 for fluid system compatibility.

To ensure verification at all stages (traceability), reports must be maintained about the results of batch or lot testing (nonmetallic materials used in oxygen service and metals exposed to processes which produce or use hydrogen).

A procedure must be established to ensure all purchased (vendor developed) structures and equipment satisfy the requirements of this document.

Periodic review by suppliers (vendors) can be performed to ensure compliance with material and process requirements set forth in this document.

4.3.3.1.4 MATERIAL USAGE AGREEMENTS

Use of materials and processes that do not satisfy the requirements of this document will be documented with acceptance rationale in an assessment (acceptance) document (certificate). STP 351-125-82 contains requirements on flammability, allowable saturation of materials (quantity per unit volume), toxicity and microbial resistance (grade 1, 2 and 3); assessment of nonmetallic materials by hazard indications will be performed in accordance with P 11760-083; GOST R 50109-92 contains thermal vacuum stability requirements.

~~**4.3.3.1.4.1**~~**A.** Certificates (Material Usage Agreements) that could affect safety shall be approved by the procuring activity.

~~**4.3.3.1.4.2**~~**B.** Certificates (Material Usage Agreements) shall be submitted for approval with sufficient information to assess materials and processes usage.

4.3.3.2 RESERVED

4.3.3.3 MANUFACTURING PLAN

Reserved

4.3.3.4 CONTROLLING DOCUMENTS

All materials and processes must be used in strict compliance with design documentation. Any change or deviation must be documented in accordance with established procedure.

The quality of each material batch will be checked for compliance with GOST, OST or TU during the incoming inspection.

4.3.3.5 MATERIALS CERTIFICATION AND TRACEABILITY

Materials shall be certified for composition and properties and critical applications shall have traceability through processing steps to end item.

4.3.3.6 RESERVED

4.3.3.7 RESERVED

4.3.3.8 MATERIAL DESIGN ALLOWABLES

Guaranteed design mechanical properties used to assess structural integrity shall be specified by the individual specification (e.g., GOST OST or Enterprise) for those materials selected for ~~ISSA~~ISS. Verification of the design mechanical properties shall be accomplished through batch/lot testing. This approach is implemented through: OST 92-1114-80; OST 92-1311-77, Parts of Steels and Alloys, Technical Requirements and Heat Treatment; OST 92-9465-81, Parts of Titanium Alloys, Technical Requirements; OST 92-1019-81, Parts of Aluminum and Magnesium Alloys, Technical Requirements; OST 92-1020-89; OST 92-0920-85; OST 92-0919-85; and GOST 15130-86, Optical Quartz Glass, General Technical Conditions.

4.3.4 DETAILED REQUIREMENTS

4.3.4.1 METALS

Metallic materials shall be selected per OST 92-0919-85 and OST 92-0920-85, shall meet the flammability requirements of GOST 12.2.052-81 and the following criteria to control stress corrosion cracking. No materials shall be used that fail in less than 90 days due to stress corrosion cracking at stresses less than 75% of their tensile yield strength when immersed in a 3% sodium chloride (NaCl) solution.

4.3.4.1.1 ALUMINUM

Use of aluminum alloys minimizes susceptibility to general corrosion, pitting, intergranular corrosion, and stress corrosion cracking. Maximum temperatures and duration of exposure for Al-Mg system alloys containing over 3% magnesium must satisfy the requirements in OST 92-0019-78, Attachment 4. Use of alloys under temperature conditions not specified in this standard must be concurred with ~~meteorology~~ metallurgy services. Heat treatment of aluminum alloys must satisfy the requirements of OST 92-1019-81. Heat treatments not included in this standard may be used provided that test results demonstrate that they yield improved properties.

4.3.4.1.2 STEEL

Carbon ~~&~~and low alloy steels heat treated to greater than 180 ksi (1240 MPa) UTS shall not be used with the exception of spring steel usage per GOST 9389-75, GOST 3057-90, and OST 92-8847-77.

~~4.3.4.1.2.1~~A. Steels shall be heat treated per OST 92-1311-77 or test data shall be provided to demonstrate improved properties without altering susceptibility to degradation. When acid processes are used, the part shall be baked per the following: GOST 9.305-84, Metallic and Nonmetallic Inorganic Finishes, and Various Processes for Obtaining Those Finishes; OST 92-1467-90, Metallic and Nonmetallic Inorganic Finishes, Typical Processes of Their Application; OST 92-9661-89, Parts of Welded Assemblies of Corrosion Resistant Steels, General Requirements for Corrosion Resistance; and OST 92-0912-69, Parts of High Strength Carbon Steels, Alloyed and High Alloy Steels, General Requirements for Design, Manufacturing, and Corrosion Protection, to alleviate potential for hydrogen embrittlement.

~~4.3.4.1.2.2~~B. Avoid drilling of martensitic steel hardened to 180 ksi (1240 MPa) or above.

~~4.3.4.1.2.3~~C. Unstabilized, Austenitic Corrosion Resistant Steels (CRES) shall not be used above 370°C. Welded CRES assemblies shall be solution heat treated and quenched after welding, except stabilized or low carbon grades.

4.3.4.1.3 TITANIUM

Limits, including thickness and in oxygen systems per GOST 12.2.052-81. Mechanical properties, for candidate titanium alloys shall be established by OST 92-9465-81 and OST 92-0966-75, Forgings of Titanium Alloys, Technical Requirements. The surfaces of titanium parts shall be machined or chemically milled to eliminate all contamination zones formed during processing. Titanium and its alloys shall not be used.

~~4.3.4.1.3.1~~A. Titanium ~~&~~and titanium alloys shall be heat treated per OST 92-9465-81.

~~4.3.4.1.3.2~~B. Exercise care to ensure fluids and chemicals used on titanium are not detrimental to performance as controlled by GOST 9.305-84 and OST 92-1467-90.

~~4.3.4.1.3.3~~C. Structural applications of titanium and titanium alloys shall be designed to avoid fretting.

~~4.3.4.1.3.4~~D. Titanium alloys shall be welded using filler wire per GOST 27265-87, Welding Wire Made Out of Titanium and Titanium Alloys to avoid hydrogen embrittlement.

4.3.4.1.4 MAGNESIUM

Magnesium alloys shall not be used for primary structure or in areas subject to wear, abrasion, erosion, or corrosive environment, exposure.

4.3.4.1.5 BERYLLIUM

Beryllium shall not be used for primary structure.

4.3.4.1.6 CADMIUM

Cadmium shall not be used above 100°C or in vacuum without containment. Exceptions to this requirement shall be documented in paragraph 4.3.3.1.4 of this document.

4.3.4.1.7 MERCURY

Mercury shall not be used for flight or in processing.

4.3.4.1.8 REFRACTORY METALS

Refractory alloys shall be tested and characterized.

4.3.4.1.9 SUPERALLOYS (NICKEL-BASED AND COBALT-BASED)

Any foreign material which could contain sulfur shall be removed prior to high temperature exposure of high nickel content alloys to preclude embrittlement. Use of precipitation hardening superalloys (nickel-based ~~&~~and cobalt-based) in high temperature/oxidizing environment shall be avoided due to the susceptibility to alloying element depletion at the surface.

4.3.4.2 NONMETALLIC MATERIALS

4.3.4.2.1 GENERAL REQUIREMENTS ON NONMETALLIC MATERIALS

Nonmetallic materials must satisfy the flammability, odor, toxic offgassing and microbial resistance requirements of STP 351-125-82 after testing per:

- 33Y.0336.028 for flammability;
- Materials for Sanitary-Chemical and Toxicological Investigation of Nonmetallic Materials with an Evaluation of the Possibility of their Use in Hermetically Sealed Enclosures for odor (Par. 1.3) and toxic offgassing;
- GOST 9.048-89, GOST 9.049-91 and GOST 9.050-75 for microbial resistance.

Nonmetallic materials compatible with oxygen will be selected in accordance with GOST 12.2.052-81.

Compatibility of nonmetallic materials with chemically active fluids must be determined in accordance with GOST 12.020-72.

To prevent arc tracking and pyrolysis, polyimide insulation will only be used in stationary, two-wire cable networks, in which neither the positive nor negative circuits are galvanically connected with the object casing at a direct voltage not exceeding 34 V for wires having a maximal cross-section of 0.35 mm2, at a maximal current density of 5 A/mm2 for circuits having a constant current load, wherein the voltage and current are limited by a trapezoidal safety zone defined by points 0V, 70A; 34V, 45A; 34V, 0A, subject to compliance with the following conditions:

a. Cable insulated from casing at locations where attached or passing through structural components in accordance with OST 92-8730-82, Onboard cable network installation.
b. Cable bundle insulated with non-polyimide material wrapped around its entire length, including in pyro cartridge filament supply circuits.
c. Wires separated into positive and negative polarity in power supply circuits, from the power board output clamps to the users by introducing an additional fluoroplastic insulation for the positive-polarity wire group.
d. Fluoropolymer wire insulation used for positive pole in command and control circuits.

The toxic hazard must be determined according to the Materials for Sanitary-Chemical and Toxicological Investigation of Nonmetallic Materials with an Evaluation of the Possibility of their Use in Hermetically Sealed Enclosures approved by the Ministry of Health, and the Spacecraft Maximum Allowable Concentrations approved by the Institute of Biomedical Problems (IBMP). . Toxic offgassing test results will be available (accessible) to conduct an overall ISSAISS toxicity assessment.

4.3.4.2.2 ELASTOMERIC MATERIALS

Rubbers and rubber parts must have long-term resistance to aging, and exhibit the following properties depending on their purpose: resistance to aging, heat aging, low temperature, ozone, lubricants and operating media.

They must retain their properties as controlled by STP 351-134-84 and 33Y.0303.001, STP 371-77-87 and specifications on rubber parts for periods calculated starting from acceptance by the QA service of the supplier (vendor).

Rubbers vulcanized at room temperature that liberate acetic acid will not be used.

4.3.4.2.3 POLYVINYLCHLORIDE

Polyvinylchloride shall not be used above 50°C and use in vacuum shall be in accordance with 4.3.4.2.7 of this document.

4.3.4.2.4 FIBER REINFORCED PLASTICS

Manufacturing defects in fiber reinforced plastics shall be assessed through by Non-Destructive Inspection and Testing (NDI/NDT). Design allowable mechanical properties for fiber reinforced plastics shall be obtained on samples using M&P representative of flight hardware.

4.3.4.2.5 LUBRICANTS

Lubricants shall be selected considering long life performance and using OST 92-5051-88, Lubricant Grades Allowed for Use in the Field of Aerospace and OST 92-4556-85, Solid Lubricant Coatings, Technical Requirements. Lubricants containing chloro-fluoro components shall not be used under high shear stresses in contact with aluminum or magnesium.

4.3.4.2.6 LIMITED-LIFE ITEMS

Materials shall be selected to ensure maximum life and minimum maintenance. Static age life requirements are contained in 33Y.0303.001 and OST 92-1010-77. Materials which are not expected to meet design life requirements but must be used for functional reasons shall be identified as limited-life items requiring periodic replacement.

4.3.4.2.7 VACUUM OUTGASSING

Nonmetallic materials exposed to space vacuum shall meet GOST R 50109-92 and shall have a Total Mass Loss (TML) less than 1% and Collected Volatile Condensable Materials (CVCM) less than 0.1%. Materials not meeting these requirements shall be in conformance with paragraph 6.4 of GOST R 50109-92 and shall be documented in accordance with paragraph 4.3.3.1.4 of this document.

4.3.4.2.8 LOW EARTH ORBIT ENVIRONMENT SURVIVABILITY

Materials shall be selected to perform for their intended life cycle exposure in low earth orbit environments of atomic oxygen, solar ultraviolet radiation, ionizing radiation~~-~~, plasma, vacuum, thermal cycling, contamination, meteoroids and~~&~~ debris according to OST 92-1020-89.

4.3.4.2.9 RESERVED

4.3.4.2.10 MOISTURE AND FUNGUS RESISTANCE

Materials that are moisture resistant and non-nutrient to fungi as defined by GOST 9.048-89, GOST 9.049-91, and GOST 9.050-75 shall be used.

4.3.4.2.11 RESERVED

4.3.4.3 TECHNOLOGICAL PROCESS

4.3.4.3.1 FORGINGS

Forging techniques shall produce an internal grain flow pattern with a direction essentially parallel to principal stresses (configuration of the part), and shall be free of re-entrant and sharply folded flow lines per OST 92-1025-82, paragraph 3.1.7, OST 92-0966-75, paragraph 1.16, OST1 90073-85, paragraph 3.11. First production forging, or after any change in forging techniques, shall be sectioned to show grain-flow patterns and~~&~~ mechanical properties at control areas; in critical applications, trim ring or protrusion specimens from each forging shall be tested for required minimum mechanical properties as required by OST 92-1025-82, Steel and Heat Resistant Alloy Forgings and Stampings, Technical Requirements, OST 92-0966-75, Titanium Alloys, Stampings and Forgings, Technical Requirements, and OST1 90073-85, Aluminum Alloy, Stampings and Forgings, Technical Requirements.

4.3.4.3.2 CASTINGS

Castings shall meet OST1 90060-92, Titanium Alloy Castings, Technical Requirements, OST 92-1166-86, Castings Made from Wax Models, Technical Requirements, GOST 977-88, Steel Castings, General Specifications, OST 92-1165-75, Castings of Aluminum Alloys Technical Requirements, and OST1 90248-77, Castings of Magnesium, Technical Requirements.

4.3.4.3.3 ADHESIVE BONDING

Structural adhesive bonding shall meet the requirements of OST 92-0949-74, Glues, Typical Materials Adhesive Bonding Process. Adhesive materials shall be selected from OST 92-0948-74, Glues, Selection and Applications, Technical Requirements.

4.3.4.3.4 WELDING

Welding procedures shall provide required weld quality, minimum energy input, and protection of heated metal from contamination per OST 92-1114-80, and OST 92-1186-81, Arc Welding from Metals and Alloys in Shielded Environments of Inert Gasses. Suitability of welding equipment, processes, supplies, and supplementary treatments shall be demonstrated by qualification testing of specimens representative of production parts as required by OST 92-1114-80, Welded Assemblies, General Technical Requirements and OST 92-1126-76, Welding Production. General Technical Requirements. Weld operators shall be qualified by OST 92-1107-79, Rules for Welders Certification, and along with the applicable welding equipment, shall be certified by training and qualification for the specific welding tasks.

~~4.3.4.3.4.1~~A. Weld repair limited to fusion repair of weld defects as revealed by inspection shall be fully documented, and quality of repair confirmed by 100% inspection of surface and subsurface using visual, dimensional and NDI techniques per OST 92-1114-80. Repair of welds in high performance or critical parts must be approved by materials review committee which includes the customer as required by OST 92-1114-80, chapter 6. Weld repair processes and inspection plans shall be qualified to same level of assurance as primary process specification as required by OST 92-1114-80, paragraph 6.1.4. Rework (additional mechanical treatment) of welds, which is limited to mechanical processes, may be made at the manufacturing engineer's discretion. Rework of welds shall be limited to mechanical processes, for example, grinding of the root, crown face reinforcement, straightening, etc. per OST 92-1114-80.

~~4.3.4.3.4.2~~B. Weld filler metal shall be controlled per the appendix of OST 92-1186-81.

~~4.3.4.3.4.3~~C. Welding of aluminum alloys shall meet OST 92-1114-80 and OST 92-1186-81 or alternate as approved by customer.

~~4.3.4.3.4.4~~D. Welding of steel alloys shall meet OST 92-1114-80 and OST 92-1186-81 or alternate, as approved by customer.

~~4.3.4.3.4.5~~E. Low stress weldments meeting specified criteria are suitable for reduced qualification and inspection in accordance with OST 92-1126-76, paragraph 3.4.

4.3.4.3.5 BRAZING

Brazing shall meet OST 92-1190-88, Metallic and Ceramic Braze Joints, Typical Technological Process of Brazing and OST 92-1152-75, Welding and Brazing, Preparation of the Surface for Welding and Brazing, Treatment of Assembling Units after Brazing and Welding. Subsequent high temperature operations in the vicinity of brazed joints shall not degrade the braze joint design requirements. Brazed joints shall be designed for shear loading and shall not be relied on for strength in tension for structural parts.

4.3.4.3.6 STRUCTURAL SOLDERING

Soldering shall not be used for structural applications.

4.3.4.3.7 ELECTRICAL DISCHARGE MACHINING

The Electrical Discharge Machining (EDM) process developed in accordance with OST 92-0021-87, Industrial System Technological Preparation of Production Procedure for the Development and Usage of Process Documentation, shall minimize the severity of the recast layer and heat effected zone. The EDM process shall be controlled by OST 92-1347-83, Electrical Discharge Machining, Process Recommendations for EDM.

4.3.4.4 MATERIAL NONDESTRUCTIVE INSPECTION

4.3.4.4.1 NDE PLAN

Nondestructive Evaluation (NDE) activities shall meet the requirements of the following documents: GOST 18353-79, Nondestructive Control - Methods Classification; GOST 7512-82, Nondestructive Control of Welded Joints - Radiographic Method; GOST 21105-87, Nondestructive Testing, Method of Magnetic Particle Testing; GOST 20415-82, Nondestructive Control - Acoustic methods, General Statement; OST 92-1173-87, Ultrasonic Inspection; OST 92-1611-74, Control by Exposure to Rays of Welded and Brazed Joints, Methods of Control; OST 92-4272-86, Nondestructive Dye Penetrant Control - Methods of Control; M117-472-89, Methods of Control of Semi-finished Parts and Assemblies and Eddy Current Portable Detectors. An NDE plan which identifies the type of NDE control to be implemented and organizations responsible for implementation, is STP 351-54-86, Organization and Implementation of Nondestructive Control at the Enterprise.

4.3.4.4.2 ETCHING BEFORE NON-DESTRUCTIVE VERIFICATION USING THE CAPILLARY METHOD

If defect cavities become smeared during machining, including while removing defects via surface conditioning, the items will be cleaned prior to inspection in chemical or electrochemical methods. The senior expert (chief technologist, chief metallurgist) will decide whether chemical or electrochemical operations are necessary to clean the item in accordance with OST 92-4272-86.

4.3.4.5 SPECIAL MATERIALS REQUIREMENTS

4.3.4.5.1 RESIDUAL STRESSES

Residual tensile stresses shall be controlled by special treatments such as annealing and stress relieving.

4.3.4.5.2 SANDWICH ASSEMBLIES

Sandwich assemblies shall be designed to prevent the entrance ~~&~~and entrapment of water vapor or other contaminants into the core structure. Honeycomb sandwich assemblies subjected to heating shall use metallic or glass reinforced core. Sandwich assemblies shall meet requirements and test methods for sandwich constructions and core materials in accordance with the following: GOST 25.602-80, Method of Mechanical Testing of Composite Materials with Polymer Matrix, Compression Testing at Normal, Elevated, and Low Temperature; OST1 90122-74, Plastics, Testing for Shear Strength of the Honeycomb Core Material; OST1 90147-74, Plastics the Testing for Modulus of Elasticity at the Shear of the Honeycomb Core; OST1 90150-74, Plastics Strength Testing at the Tension of the Honeycomb Core. Design properties shall be verified on witness samples.

4.3.4.5.3 RESERVED

4.3.4.5.4 CORROSION PREVENTION AND CONTROL

All parts shall be finished to provide protection from corrosion and corrosion control of galvanic couples in accordance with the following: GOST 9.303-84, Unified System for Corrosion and Aging Protection, Metallic and Nonmetallic Inorganic Coatings, General Requirements for Selection; OST 92-1443-87, Finishes, Metallic and Nonmetallic Inorganic, Requirements for Structural Materials; OST 92-9501-81, Metallic and Nonmetallic Inorganic Finishes for Manufacturing of Instruments, Requirements for Selection; OST 92-1481-79, Lacquer and Paint Finishes for Metallic Surfaces, Typical Processes; and GOST 9.005-72, Permissible and Nonpermissible Contacts of Metals, General Requirements. Corrosion evaluations shall assess the possible effects of fluid release from failure or permeation of barriers.

Steels exposed to corrosive environments, including low alloy, high strength fasteners, shall be protected. Plating on high strength steels shall be applied by a nonembrittling processes compatible with space environment in accordance with OST 92-0912-69.

Faying surfaces of mechanical joints and seams in corrosive environments shall be sealed, with removable panels and access doors sealed by mechanical seals or separable faying-surface sealing.

4.3.4.5.5 FASTENERS

Self locking fasteners shall not be reused except when the running torque prior to clamp up remains between the maximum self locking torque and minimum breakaway torque (ref. STP 33-32-75, Fasteners for Main Production Restriction List). Fasteners shall be wet installed with sealant in condensing or corrosive environments. Titanium alloy threaded fasteners applications shall use locking features to maintain locking torque. Reuse cycles shall be limited to 5 times.

4.3.4.6 ELECTRICAL MATERIAL AND PROCESSES

4.3.4.6.1 FABRICATION REQUIREMENTS FOR PRINTED WIRING BOARDS

This paragraph is applicable to rigid single-sided, double-sided, and multilayer printed wiring boards for the ~~Russian Segment~~RS flight electronic components for ~~International Space Station Alpha~~ISS.

~~4.3.4.6.1.1~~A. Rigid/Flex and flexible circuits will not be used.

~~4.3.4.6.1.2~~B. Printed wiring boards shall be fabricated in accordance with GOST 23752-79 using the highest level of control, and RSC-E factory standard 33Y.0247.010.

~~4.3.4.6.1.3~~C. Manufacturing and inspection personnel shall be trained in fabrication, inspection, and procedures pertinent to their area of responsibility.

~~4.3.4.6.1.4~~D. Equipment and tools shall be checked and calibrated at regular intervals to assure their proper function.

~~4.3.4.6.1.5~~E. All foil and laminate materials shall meet the requirements of GOST 10316-78, shall have a certificate of compliance from the supplier, and shall receive incoming inspection.

~~4.3.4.6.1.6~~F. All boards shall be tin-lead plated and hot fused.

~~4.3.4.6.1.7~~G. The copper plating thickness in the hole shall be 0.020 mm minimum.

~~4.3.4.6.1.8~~H. There shall be a polished section of each multilayer board or lot of multilayer boards that shall be used for plated through hole inspection as part of the board acceptance.

4.3.4.6.1.9I. There shall be no delamination of individual layers of the board.

4.3.4.6.1.10J. After cleaning, the printed wiring board shall be free of ionic and other contaminants such as dirt, oil, corrosion, corrosive products, salts, grease, and fingerprints.

4.3.4.6.1.11K. The minimum annular ring on a non-plated hole shall be 0.35 mm.

4.3.4.6.1.12L. The minimum annular ring on a plated through hole shall be 0.085 mm.

4.3.4.6.1.13M. Multilayer boards shall have a minimum dielectric layer thickness of 0.09 mm. There shall be not less than 2 sheets of prepreg used between each pair of adjacent conductor layers.

4.3.4.6.2 REQUIREMENTS FOR SOLDERED ELECTRICAL CONNECTIONS

This paragraph is applicable to soldered electrical connections for the Russian SegmentRS flight electronic components for International Space Station AlphaISS.

4.3.4.6.2.1A. All soldered electrical connections are to be hand soldered.

4.3.4.6.2.2B. Solder joints are to be made in accordance with OST 92-1042-82.

4.3.4.6.2.3C. Internal connections of piece parts are not subject to these requirements.

4.3.4.6.2.4D. All operators and inspectors shall be trained and certified as being currently qualified to fulfill all requirements pertaining to the types of connections involved in their assigned work. Demonstration of proficiency shall be a prerequisite for such certification.

4.3.4.6.2.5E. There shall be procedures and maintenance schedules for tools and equipment requiring calibration or set-up.

4.3.4.6.2.6F. Insulation strippers and bending tools shall periodically be verified for proper operation.

4.3.4.6.2.7G. Solders and fluxes shall be in accordance with OST 4G0.033.200 1986.

4.3.4.6.2.8H. When activated fluxes are used, special cleaning procedures shall be specified to assure their complete removal.

4.3.4.6.2.9I. Solvent control and composition shall be in accordance with OST 92-0286-80.

~~4.3.4.6.2.10~~J. The portion of stranded or solid wires that will eventually become a part of the finished solder connection shall be tinned with hot tin-lead solder and cleaned prior to attachment.

~~4.3.4.6.2.11~~K. Terminals and solder cups shall be examined and cleaned prior to attachment of conductors. Terminals and solder cups shall not be modified to accommodate improper wire sizes.

~~4.3.4.6.2.12~~L. Part leads shall be formed in accordance with OST 93-9388-80.

~~4.3.4.6.2.13~~M. Parts shall be mounted in accordance with OST 92-9389-80.

~~4.3.4.6.2.14~~N. Broken or damaged wires, part leads, or printed wiring conductors shall not be spliced.

~~4.3.4.6.2.15~~O. There shall be no relative motion between conductors, part leads, terminals, and printed wiring board termination areas during solder application and solidification. The method used to immobilize the elements shall not result in the holding of part leads against normal springback forces.

~~4.3.4.6.2.16~~P. All lapped round and ribbon leaded parts with solder termination~~'~~s on the part side of the board shall have a full heel fillet.

4~~.3.4.6.2.17~~Q. After the solder has solidified and cooled, flux and residue shall be carefully removed from each joint using an approved solvent.

~~4.3.4.6.2.18~~R. Acceptance and rejection criteria shall be in accordance with OST 92 1042-82.

4.3.4.6.3 CABLE AND HARNESS FABRICATION

Cable and harness fabrication shall be in accordance with RSC-E factory standard 33Y.0242.010, OST 92-8584-74 through OST 92-8593-74 and OST 92-0320-68.

4.3.4.6.4 CRIMPING AND WIRE WRAP

Crimping shall be in accordance with RSC-E factory standard 33Y.0242.010 and OST 92-8584-74 through OST 92-8593-74.

Wire wrap will not be used.

4.3.4.6.5 FIBER OPTICS

Fiber optics will not be used in the ~~Russian Segment~~RS flight electrical equipment for ~~International Space Station Alpha~~ISS.

4.3.4.6.6 DESIGN REQUIREMENTS FOR PRINTED WIRING BOARDS AND ASSEMBLIES

This is applicable to the design of rigid single sided, two sided, and multilayer printed wiring boards and assemblies.

Printed wiring boards shall be designed in accordance with GOST 23751-86.

Board materials shall be specified in accordance with GOST 10316-78.

Parts mounting shall be specified in accordance with OST 92-9389-80.

4.3.4.6.7 CONFORMAL COATING AND STAKING

Conformal coating shall be in accordance with OST 92-1468-90.

Staking shall be in accordance with OST 92-9389-80 and RSC-E document 33Y.0342.026.

5 BATTERIES

These requirements shall provide for adequate controls within the battery or power system designs to preclude the occurrence of hazardous events.

5.1 NICKEL-CADMIUM BATTERY SYSTEMS

All nickel-cadmium battery systems supplied as part of the ~~Russian Segment~~RS for ~~ISSA~~ISS will adhere to the following requirements.

5.1.1 CELL DESIGN REQUIREMENTS

~~5.1.1.1~~A. All cells shall be of a sealed construction.

~~5.1.1.2~~B, All cells shall be activated with an appropriate amount of electrolyte to eliminate the presence of excess free electrolyte within the cell case during operation.

~~5.1.1.3~~C. Each cell shall be equipped with a mechanical pressure sensor set to provide a discrete output at 1.5 atm. This output shall be telemetered to ground personnel as well as incorporated in the automatic charge control methodology to terminate charge.

~~5.1.1.4~~D. At least one temperature sensor shall be installed on each battery case. The temperature reading shall be telemetered to ground personnel.

5.1.2 BATTERY DESIGN REQUIREMENTS

~~5.1.2.1~~A. A physical separation shall be maintained between the positive and negative power leads and between both power leads and the battery case.

~~5.1.2.2~~B. A physical separation shall be maintained between cell cases and between cell cases and battery case.

~~5.1.2.3~~C. Positive and negative connectors shall be sufficiently different in design to preclude accidental cross-connecting.

~~5.1.2.4~~D. A fine metal mesh shall be installed over battery case vents to preclude the introduction into the battery case of metal particles greater than approximately 4 mm in diameter.

~~5.1.2.5~~E. The battery case and cell configuration within the case shall be designed to facilitate thermal control via the forced-air ventilation system.

~~5.1.2.6~~F. The installation orientation of each battery shall facilitate the unrestricted passage of air through the battery case vents.

5.1.3 SYSTEM DESIGN REQUIREMENTS

~~5.1.3.1~~A. A floating two-wire system design shall be implemented.

~~5.1.3.2~~B. Circuit breakers are to be installed for protection from the main bus to the loads.

~~5.1.3.3~~C. A regulator shall be installed in each battery circuit that will provide a 50 A discharge and 35 A charge current limitation as well as prevent circulating currents. Each regulator shall be comprised of multiple modules which are individually fused.

~~5.1.3.4~~D. The power leads between the battery and the regulator shall be a minimal length to reduce the potential for shorting paths to develop.

~~5.1.3.5~~E. For each battery an Ampere-hour (Ah) integrator shall be used to monitor the state of charge of the battery. The value calculated by the Ah integrator shall be telemetered to ground personnel as well as incorporated in the automatic charge control methodology to preclude overcharge. During normal cycling, the Ah integrator shall provide for charge termination if its value reaches 48 Ah.

5.1.4 TEST REQUIREMENTS

~~5.1.4.1~~A. All batteries shall be subjected to appropriate environmental testing for qualification and acceptance.

~~5.1.4.2~~B. Samples of cell cases shall be subjected to a burst pressure test.

~~5.1.4.3~~C. All cells shall be subjected to a phenolphthalein electrolyte leak test.

~~5.1.4.4~~D. Both positive and negative power connector pins shall be checked for electrical isolation from the battery case after activation.

5.1.5 OPERATIONAL REQUIREMENTS

~~5.1.5.1~~A. During normal cycling, battery charge voltage shall be limited during the high-rate (<= 35 A) portion of the charge process to no more than 32.5 volts (V). During the two lower-rate (<=25 A and <=10 A) portions of the charge process, battery charge voltage shall be limited to 34.0 V.

~~5.1.5.2~~B. During the full charge/discharge cycling, ideally performed every 2 weeks, battery charge voltage shall not exceed 34.0 V.

~~5.1.5.3~~C. During discharge, battery voltage shall be no less than 24.0 V and a single cell voltage shall be no less than 0.8 V. If either of these limits ~~are~~ is reached, discharge for that battery shall be terminated.

5.2 SILVER-ZINC BATTERY SYSTEM

All silver-zinc battery systems supplied as part of the ~~Russian Segment~~RS for ~~ISSA~~ISS will adhere to the following requirements.

5.2.1 CELL DESIGN REQUIREMENTS

~~5.2.1.1~~A. All cells shall be equipped with a pressure relief valve protruding into the cell such that, if inverted in a gravity environment, the electrolyte level collecting on the inside of the cell cover cannot rise above the valve opening.

~~5.2.1.2~~B. The cell pressure relief valve shall be set to open between 0.8 and 1.2 atm to preclude aspiration of electrolyte during venting and to preclude deformation or cracking of cell case.

5.2.2 BATTERY DESIGN REQUIREMENTS

~~5.2.2.1~~A. A physical separation shall be maintained between the positive and negative power leads and between both power leads and the battery case.

~~5.2.2.2~~B. An insulating barrier shall be placed between the cell terminals and the battery cover to preclude physical contact.

~~5.2.2.3~~C. A paint coating shall be applied to the inside surface of the metallic battery case.

~~5.2.2.4~~D. Positive and negative connectors shall be sufficiently different in design to preclude accidental cross-connecting.

5.2.3 SYSTEM DESIGN REQUIREMENTS

~~5.2.3.1~~A. A floating two-wire system design shall be implemented.

~~5.2.3.2~~B. The power leads between the battery and the regulator shall be a minimal length to reduce the potential for shorting paths to develop.

5.2.4 TEST REQUIREMENTS

~~5.2.4.1~~A. All batteries shall be subjected to appropriate environmental testing for qualification and acceptance.

~~5.2.4.2~~B. Both positive and negative power connector pins shall be checked for electrical isolation from the battery case after activation.

5.2.5 OPERATIONAL REQUIREMENTS

There are no operational requirements that apply to silver-zinc batteries flown on the ~~Russian Segment~~RS for ~~ISSA~~ISS.

5.3 SOYUZ BUFFER/BACKUP BATTERY UNIQUE REQUIREMENTS

5.3.1 CELL DESIGN REQUIREMENTS

There are no cell design requirements that apply uniquely to the Buffer/Backup battery.

5.3.2 BATTERY DESIGN REQUIREMENTS

~~5.3.2.1~~A. Sufficient capacity shall be available to complete the mission should either the buffer or backup battery need to be disconnected.

~~5.3.2.2~~B. At least one temperature sensor shall be installed on each battery case. The temperature reading shall be telemetered to ground personnel.

~~5.3.2.3~~C. The battery case shall be equipped with a pressure relief valve set to open at 0.25 atm thus minimizing the absolute pressure of potentially explosive gases and precluding deformation or cracking of cell or battery cases.

~~5.3.2.4~~D. Battery internal void volume shall be minimized by the inclusion of a porous non-conductive material thus reducing the volume of potentially explosive gases.

5.3.3 SYSTEM DESIGN REQUIREMENTS

~~5.3.3.1~~A. Circuit breakers are to be installed for protection from the main bus to the loads.

~~5.3.3.2~~B. A thermal insulating material shall be placed over the battery case.

5.3.4 TEST REQUIREMENTS

~~5.3.4.1~~A. Proof pressure tests shall be performed on all battery cases.

~~5.3.4.2~~B. Nitrogen purge shall be performed just prior to installation.

5.3.5 OPERATIONAL REQUIREMENTS

~~5.3.5.1~~A. Battery voltage shall not exceed 34.0 V during charge.

~~5.3.5.2~~B. Battery voltage shall not fall below 24.0 V during discharge.

5.4 SOYUZ DESCENT MODULE BATTERY UNIQUE REQUIREMENTS

5.4.1 CELL DESIGN REQUIREMENTS

There are no cell design requirements that apply uniquely to the Descent Module battery.

5.4.2 BATTERY DESIGN REQUIREMENTS

~~5.4.2.1~~A. The battery case shall be equipped with a pressure relief valve set to open at 0.25 atm thus minimizing the absolute pressure of potentially explosive gases and precluding deformation or cracking of cell or battery cases.

~~5.4.2.2~~B. Battery internal void volume shall be minimized by the inclusion of a porous non-conductive material thus reducing the volume of potentially explosive gases.

~~5.4.2.3~~C. Battery shall be cooled by spacecraft ventilation to minimize its temperature (and thus minimize hydrogen generation) during mission open circuit storage.

5.4.3 SYSTEM DESIGN REQUIREMENTS

~~5.4.3.1~~A. Circuit breakers are to be installed for protection from the main bus to the loads.

5.4.4 TEST REQUIREMENTS

~~5.4.4.1~~A. Proof pressure tests shall be performed on all battery cases.

~~5.4.4.2~~B. Nitrogen purge shall be performed just prior to installation.

5.4.5 OPERATIONAL REQUIREMENTS

~~5.4.5.1~~A. Operational time shall be short enough such that the effects of circulating currents would be minimized.

5.5 SOYUZ PYROTECHNIC BATTERY UNIQUE REQUIREMENTS.

5.5.1 CELL DESIGN REQUIREMENTS

There are no cell design requirements that apply uniquely to the Pyrotechnic battery.

5.5.2 BATTERY DESIGN REQUIREMENTS

~~5.5.2.1~~A. Battery shall be cooled by spacecraft ventilation to minimize its temperature (and thus minimize hydrogen generation) during mission open circuit storage.

~~5.5.2.2~~B. Battery case shall not be designed as a sealed container.

5.5.3 SYSTEM DESIGN REQUIREMENTS

5.5.3.1A. – Batteries shall not be connected in parallel so as to preclude the occurrence of circulating currents.

5.5.4 TEST REQUIREMENTS

There are no test requirements that apply uniquely to the Pyrotechnic battery.

5.5.5 OPERATIONAL REQUIREMENTS

There are no operational requirements that apply uniquely to the Pyrotechnic battery.

5.6 OTHER BATTERY SYSTEMS

Smaller battery systems used in tools, cameras, flashlights, etc., on the Russian SegmentRS for the ISSAISS will adhere to the following requirements.

5.6.1A. Small batteries/cells using potassium hydroxide electrolyte will have an overwrap of absorbent material to preclude the dispersion of electrolyte in the event of a leak.

5.6.2B. Batteries using potassium hydroxide electrolyte shall not be contained in a gas-tight battery enclosure.

5.6.3C. Batteries capable of generating temperatures in excess of 113 degrees F on short circuit (e.g., 9V alkaline-manganese batteries) shall have a fuse in the negative leg of the battery circuit.

5.6.4D. Primary (non-rechargeable) batteries that are connected in parallel with a higher voltage source to provide a back-up function shall be protected from charging by the use of a diode. In the case of lithium anode batteries, two diodes in series or a diode and a current limiting resistor will be used.

5.6.5E. Lithium-thionyl chloride batteries will be of a non-venting construction.

5.6.6F. Secondary (rechargeable) batteries shall use charging procedures that are designed for the specific battery type, with special attention paid to the method of charge cut-off and float or trickle charge.

6 ANTHROPOMETRY AND BIOMECHANICS

6.1 ANTHROPOMETRY AND BIOMECHANICS

6.1.1 INTRODUCTION

6.1.1.1 ANTHROPOMETRY

Anthropometry is a scientific discipline that examines the dimensions of the human body. Anthropometric data are divided into two categories:

A. Static anthropometry, which involves the geometric dimensions of a stationary individual; e.g., weight, height, lengths, widths, depths, girths, volumes, masses, surface areas, centers of mass, and moments of inertia of the human.

B. Dynamic anthropometry, which involves the dimensions of a body in motion, e.g., linear and angular movements of various joints.

6.1.1.2 BIOMECHANICS

Biomechanics is a scientific discipline that examines the mass and inertial characteristics of the human body. Its application in ergonomics deals with the mechanisms, ranges and accuracy of human movement, and also with the force and velocity characteristics of the human body.

6.1.2 GENERAL ANTHROPOMETRIC AND BIOMECHANICAL DESIGN PRINCIPLE

The anthropocentric approach should constitute the main design principles for the structural components, habitation module components, workstations, equipment, work aids, instruments, etc. (anything affecting the anthropometry or biomechanics of the crew.)

6.1.3 ANTHROPOMETRIC AND BIOMECHANICAL DESIGN DATA

6.1.3.1 BODY DIMENSIONS

This section provides specific body distances, dimensions, contours, and other data useful in developing design requirements. There is no attempt to include all potentially useful anthropometric data in this section because much of this data is already available in other conveniently published forms. Rather, one description set of both Russian and American size ranges for projected crewmember populations is presented.

6.1.3.1.1 DESIGN PRINCIPLES BASED ON BODY DIMENSIONS

Anthropometric and biomechanical data must be taken into account while designing all components of the space station where human activity occurs. A ~~manditory~~mandatory check of anthropometric and biomechanical data must occur during the design/development/verification of the following parameters:

A. Minimal dimensions of large volumes (modules, zones, passages, workstations, etc.).

B. Accessibility of work areas and of devices used for high-precision work; placement of restraints.

C. Hole diameters and gap widths commensurate with the diameters of hands, arms, legs, heads, ~~trunks~~and trunks (including space suit).

D. Maximum level of effort and work required to perform operations.

E. Sizing of structural components, equipment, instruments, etc., with which the crew interfaces.

6.1.3.1.2 DESIGN REQUIREMENTS BASED ON BODY DIMENSION DATA

The anthropometric data for men and women presented in figures 6.1.3.1.2-1 to 6.1.3.1.2-14 must be used during the development of all interfaces necessary for crew activity inside the vehicle. These data do not reflect actual postures. They are intended for use in further calculating accessibility zones and performing a rough ergonomic assessment of the geometric characteristics of structural components, configurations, equipment, clothes, tools, etc.

The body surface area data for men presented in figure 6.1.3.4.1.-1, the body volume data for men presented in figures 6.1.3.5.1.-1 and 6.1.3.5.2.-1, the body mass data for men in figures 6.1.3.6.1.1.-1 and 6.1.3.6.1.2.-1, the center-of-mass data for men in figures 6.1.3.6.2.1.-1 to 6.1.3.6.2.2.-2, and the moment of inertia data for men in figures 6.1.3.6.3.1.-1 to 6.1.3.6.3.2.-6 must all be used in the structural development of each interface for the crew of the space station.

6.1.3.2 JOINT MOVEMENT

This section provides information for developing design requirements related to biomechanics, particularly skeletal joint angular motion capabilities and limitations. Joint motion data can be used to determine possible positions for various parts of the body.

6.1.3.2.1 DESIGN REQUIREMENTS BASED ON JOINT MOVEMENT DATA

The data presented in this section concerning the range of motion for individual joints in men and women must be used in the development of all interfaces necessary for crew activity inside the vehicle.

6.1.3.2.1.1 DESIGN REQUIREMENTS BASED ON SINGLE JOINT MOVEMENT DATA

~~6.1.3.2.1.1~~
~~DATA~~

Figures 6.1.3.2.1-1 to 6.1.3.2.1-3 show the range of motion for an individual joint in men and women.

6.1.3.2.1.2 DESIGN REQUIREMENTS BASED ON TWO-JOINT MOVEMENT DATA

The data presented in figure 6.1.3.2.1-4 show the range of motion for two joints in men and women.

6.1.3.3 ACCESSIBILITY ZONES

This section discusses human body reach limits in terms of functional reach in several different postures. Reach-accessibility figures 6.1.3.3.1-1 to 6.1.3.3.1-21 are taken from American statistical data calculated in order to define reach area for seated figures performing grasping tasks. Reach-accessibility figures 6.1.3.3.1-22 to 6.1.3.3.1-51 are taken from a Russian computer model which accounts for the following postures: seated, standing, and floating in micro-gravity while restrained.

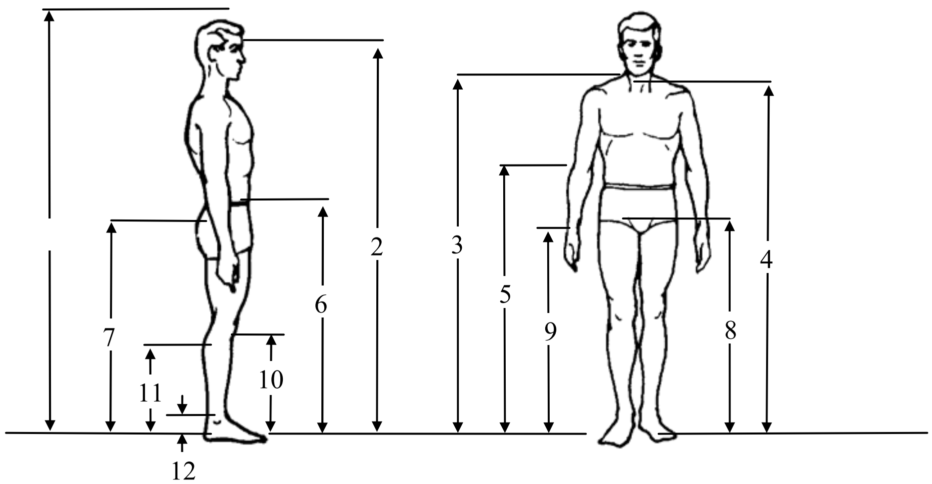
6.1.3.3.1 DESIGN REQUIREMENTS BASED ON FUNCTIONAL ACCESSIBILITY ZONES

The data presented in figures 6.1.3.3.1-1 to 6.1.3.3.1-51 must be used in the development of crew interfaces in the space station. Equipment and control devices necessary for executing specific tasks must be located within the working range of the crew member executing the task. Data concerning the functional accessibility limits are presented for an individual in clothes that do not restrict movement.

A. Body movement limits. Figures 6.1.3.3.1-1 to 6.1.3.3.1-19 present functional working range limits for women and men seated on a chair with a straight back. These functional limits are applied in cases where the thumb and index fingers must perform a grasping action. Figure 6.1.3.3.1-20 illustrates the adjustment necessary to perform other grasping actions.

B. Waist movement restrictions. The data presented in figures 6.1.3.3.1-1 to 6.1.3.3.1-19 for movements at the waist must be corrected for various angles of inclination of the spine. Figure 6.1.3.3.3.1-21 presents data on how best to implement this correction. These data are suitable only for 1-g accelerations and must be revised taking into account the elongation of the spinal column under micro-gravity conditions.

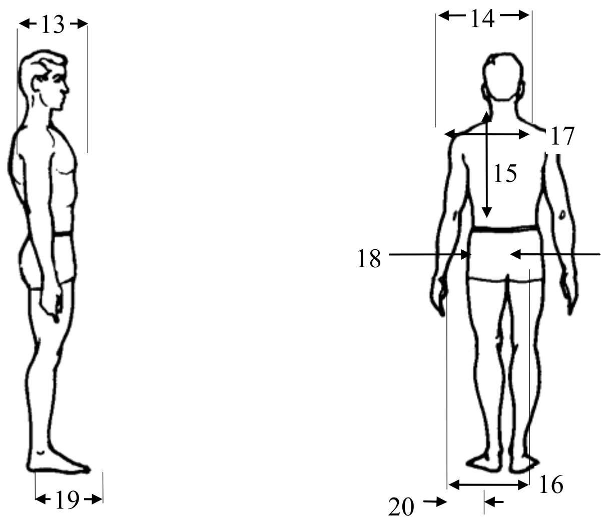
C. Seating and standing poses. The data presented in figures 6.1.3.3.1-22 to 6.1.3.3.1-51 illustrate accessibility zones for the Russian male population represented in the data.



No.	Code	Dimension	5th percentile	50th percentile	95th percentile	b*
1 (*,**)	805 h1	Stature (USA) (Russia)	169.7	179.9 170.4	190.1	55
2 (*)	h2	Eye height (Russia)	---	--- 158.7	---	53
3 (*)	h3	Cervical height (USA) (Russia)	---	--- 146.6	---	53
4 (*)	23 h4	Shoulder height (USA) (joint) (Russia)	138.0	147.6 139.3	157.3	52
5 (*)	309 h5	Elbow height (USA) (joint) (Russia)	---	--- 106.8	---	41
6	949	Height to waist (USA) (Russia)	100.4	106.3 ---	116.2	---
7	894 h6	Trochanteric Height (USA) Height to thigh bone (Russia)	88.3	95.8 91.5	102.9	40
8	249 I19	Crotch Height (USA) Height to groin (Russia)	79.4	86.4 81.9	93.3	39
9 (*)	973 h7	Wrist height (USA) (digit point) (Russia)	---	--- 63.7	---	32
10	873 h8	Tibiale Height (USA) Height to shin bone (Russia)	---	--- 46.2	---	23
11	215	Calf Height (USA) Height to back of shin (Russia)	32.5	36.2 ---	40.0	---
12	64 h9	Ankle bone height (USA) Lower shin point height (Russia) (talocrural joint)	12.0	13.9 7.6	15.8	6

Figure 6.1.3.1.2.-1 Anthropometric data. Men. Longitudinal dimensions standing.

Reference: Man-Systems Integration Standards: NASA STD 3000; Volume 1, Revision B
*b is +/- one standard deviation from the Russian 50th percentile data point

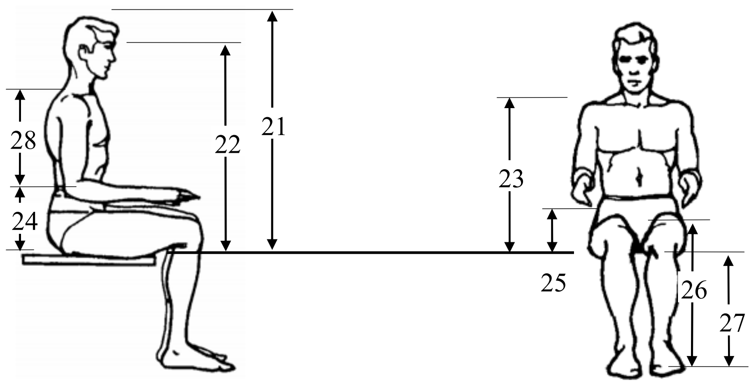


No.	Code	Dimensions	5th percentile	50th percentile	95th percentile	b*
13	169 d1	Bust depth (USA) Front-to-back chest diameter (Russia)	21.8	25.0 24.8	28.2	18
14	122 d4	Shoulder breadth (USA) Bideltoid diameter (Russia)	44.6	48.9 47.2	53.2	21
15	921 d5	Waist back (USA) Transverse diameter of waist (Russia)	43.7	47.6 47.2	51.6	24
16	457 d6	Hip breadth (USA) (Russia)	32.7	35.8 33.9	39.0	16
17	506	Interscye (USA) Acromial diameter (Russia)	32.9	39.2 40.7	45.4	28
18	d8	Distance between centers of hip joints (USA) (Russia)	---	--- 20.4	---	14
19	362 l1	Foot length (USA) (Russia)	25.4	27.3 26.5	29.3	11
20	356 d9	Foot breadth (USA) (Russia)	9.0	9.9 10.0	10.7	5

Figure 6.1.3.1.2.-2 Anthropometric data. Men. (Continued). Front-to-back and transverse dimensions standing ~~Front-to-back and transverse dimensions standing~~.

Reference: Man-Systems Integration Standards: NASA STD 3000; Volume 1, Revision B

*b is +/- one standard deviation from the Russian 50th percentile data point

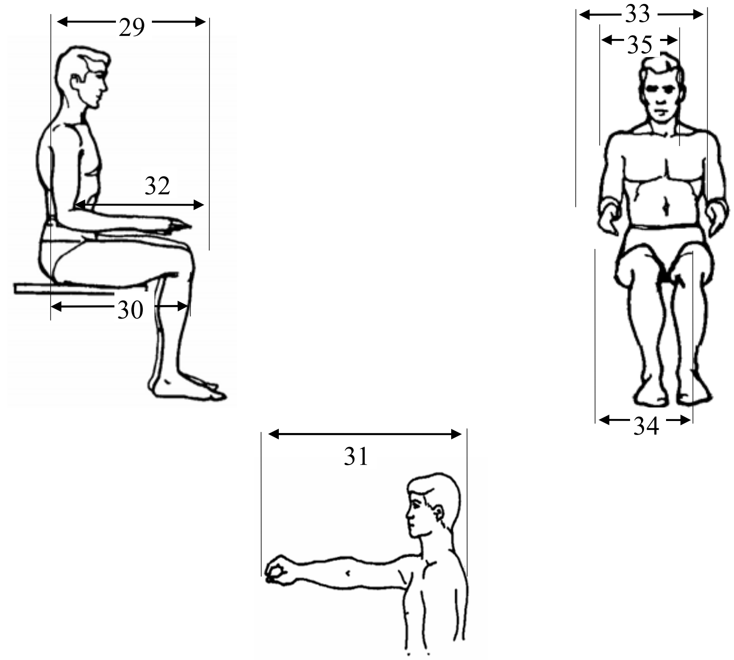


No.	Code	Dimension	5th percentile	50th percentile	95th percentile	b*
21 (*,**)	758 h21	Sitting height (USA) Height over seat (Russia)	88.9	94.2 90.1	99.5	 38
22 (*)	330 h23	Eye height sitting (USA) Height of eyes (Russia)	76.8	81.9 78.4	86.9	 26
23 (*)	612 h26	Mid-shoulder height (USA) Height to middle of shoulders (Russia)	60.8	65.4 59.0	70.0	 24
24 (*)	312 h28	Elbow rest height (USA) Height of elbow over seat (Russia)	21.3	25.4 24.4	29.7	 22
25	856	Thigh clearance (USA) (Russia)	14.5	18.8 ---	19.1	 ---
26	529 h30	Knee height (USA) Height of knee over floor (Russia)	52.6	58.7 53.4	60.9	 22
27	678 h31	Popliteal height (USA) Height of popliteal ligament (Russia)	40.6	44.4 40.7	48.1	 17
28	751	Shoulder-to-elbow (USA) length (Russia)	33.7	36.6 ---	39.4	 ---

Figure 6.1.3.1.2.-3 Anthropometric data. Men. (Continued) Longitudinal dimensions seated.

~~.~~
~~**Longitudinal dimensions seated.**~~

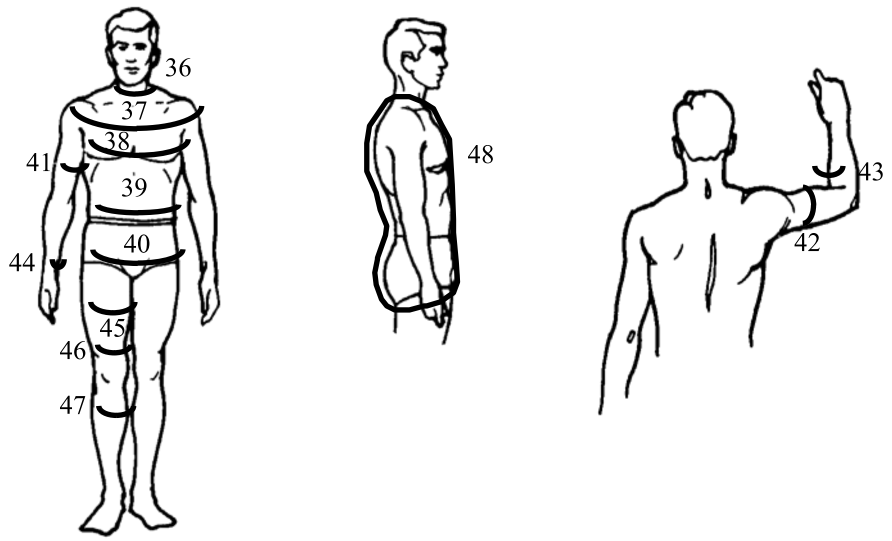
Reference: Man-Systems Integration Standards: NASA STD 3000; Volume 1, Revision B
*b is +/- one standard deviation from the Russian 50th percentile data point



No.	Code	Dimensions	5th percentile	50th percentile	95th percentile	b*
29	194 l11	Buttock-knee length (USA) Seat back to knee (Russia)	58.8	61.3 58.4	65.8	24
30	200 l12	Buttock-popliteal length (USA) Seat back to shin (Russia)	46.9	51.2 48.0	56.5	22
31	67 l4	Thumb-tip reach (USA) Horizontal range of arms from seat back to 3rd digit point (Russia)	74.9	81.6 85.3	88.2	36
32	381 l5	Forearm-hand length (USA) Distance from elbow (Russia) to palm	----	--- 46.5	---	19
33	378 d12	Distance between (USA) forearms (Russia)	48.8	56.1 52.1	61.5	30
34	459 d14	Hip breadth-sitting (USA) Transverse dimension of thigh (Russia)	34.8	38.4 35.7	42.3	19
35	103 d7	Biacromial breadth (USA) Spine width (Russia)	37.9	41.1 39.1	44.3	17

Figure 6.1.3.1.2.-4 Anthropometric data. Men. (Continued) ~~.~~ Front-to-back and transverse dimensions seated.
~~**Front-to-back and transverse dimensions seated.**~~

Reference: Man-Systems Integration Standards: NASA STD 3000; Volume 1, Revision B
*b is +/- one standard deviation from the Russian 50th percentile data point

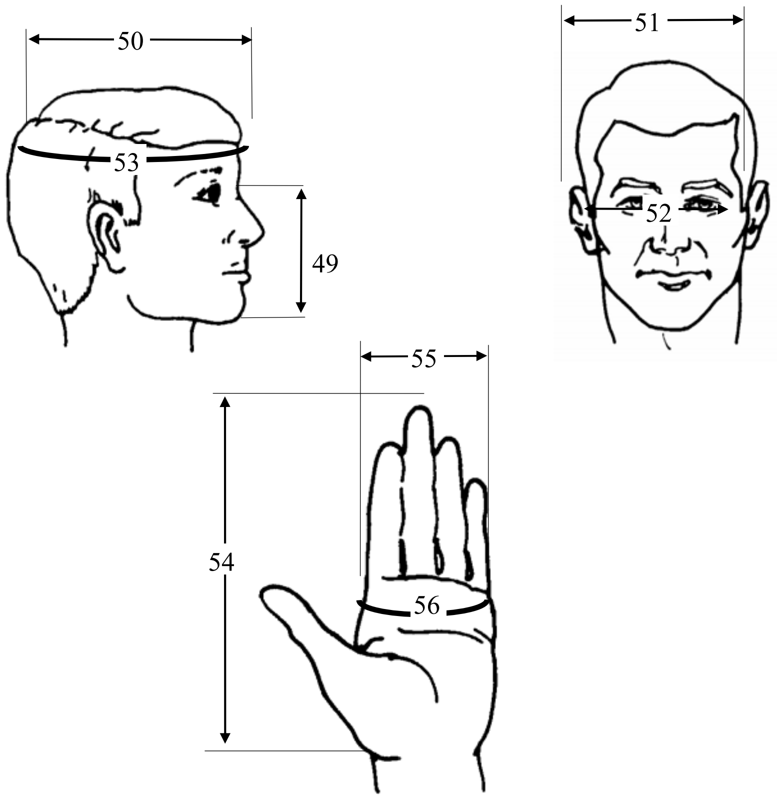


No.	Code	Dimensions		5th percentile	50th percentile	95th percentile	b*
36	639 i1	Neck Circumference	(USA) (Russia)	35.5	38.7 38.1	41.9	17
37	747	Shoulder Circumference	(USA) (Russia)	109.5	119.2 ---	128.8	---
38 (**)	230 i3	Chest Circumference	(USA) (Russia)	89.4	100.0 102.3	110.6	54
39 (*)	931 i5	Waist Circumference	(USA) (Russia)	77.1	89.5 85.3	101.9	76
40 (*)	178 i7	Buttocks Circumference	(USA) (Russia)	91.0	100.2 97.6	109.4	47
41	113 i8	Biceps Circumference, relaxed	(USA) (Russia)	27.3	31.2 32.2	35.1	22
42	111	Biceps Circumference, flexed	(USA) (Russia)	29.4	33.2 ---	36.9	---
43	369 i9	Arm Circumference, relaxed	(USA) (Russia)	27.4	30.1 28.3	32.7	14
44	967 i10	Wrist Circumference	(USA) (Russia)	16.2	17.7 18.0	19.3	8
45 (*)	852 i11	Thigh Circumference	(USA) (Russia)	52.5	60.0 55.3	67.4	---
46	515 i12	Knee Circumference	(USA) (Russia)	35.9	38.4 40.4	42.9	---
47 (*)	207 i13	Calf Circumference	(USA) (Russia)	33.9	37.6 37.3	41.4	21
48	916 i15	Circumference of trunk along vertical	(USA) (Russia)	158.7	170.7 165.2	182.6	68

Figure 6.1.3.1.2.-5 Anthropometric data. Men. (Continued). Circumferential dimensions of the human body.

~~Circumferential dimensions of the human body.~~

Reference: Man-Systems Integration Standards: NASA STD 3000; Volume 1, Revision B
*b is +/- one standard deviation from the Russian 50th percentile data point



No.	Code	Dimensions		5th percentile	50th percentile	95th percentile	b*
49	586 y21	Menton-sellion length (face)	(USA) (Russia)	11.1	12.1 11.8	13.1	6.1
50	441 õ3	Head length Distance from glabella to occipital point	(USA) (Russia)	18.8	20.0 19.3	21.1	6.1
51	427 z2	Head breadth	(USA) (Russia)	14.8	15.7 16.0	16.5	6.8
52	165 z9	Bizygomatic breadth (USA) (face)	(Russia)	13.4	14.3 13.0	15.1	6.9
53	430 o1	Head circumference	(USA) (Russia)	55.5	57.8 57.3	60.2	13.7
54	420 l1	Hand length	(USA) (Russia)	17.9	19.3 19.5	20.6	10.2
55	411 d8	Hand breadth	(USA) (Russia)	8.2	8.9 8.5	9.6	4.4
56	416 i4	Hand circumference	(USA) (Russia)	20.3	21.8 21.5	23.4	10.2

Figure 6.1.3.1.2.-6 Anthropometric data. Men. (Continued). Head and arm dimensions.

~~**Head and arm dimensions.**~~

Reference: Man-Systems Integration Standards: NASA STD 3000; Volume 1, Revision B
*b is +/- one standard deviation from the Russian 50th percentile data point

Comments:

A) Dimensional data:

1. The numbers accompanying each dimension are footnote codes.

2. Anthropometric data presented for 1 g.

3. Limits on anthropometric data (**):

   a) The height of crew members (Figure 6.1.3.1.2.-1, No. 1, code 805, h1) to be launched in the "Sokol-KB" space suit on the Soyuz-T rescue vehicle is confined to 164-182 cm.
   b) The height seated (Figure 6.1.3.1.2.-3, No. 21, code 758, h21), but measured lying down, of crew members to be launched in the "Kazbek-U" seat on the Soyuz-T rescue vehicle may not exceed 94 cm.
   c) The chest circumference (Figure 6.1.3.1.2.-5, No. 38, code 230, i3) is confined to 96-112 cm for crew members to be launched in the "Sokol-KB" space suit on the Soyuz-T rescue vehicle, and 96-108 cm for crew members to perform EVAs in the Orlan-D space suit.

B) Use of (*) dimensions under microgravity conditions:

1. The height increases by roughly 3% in the first 3-4 days of zero gravity (see ill. 3.2.3.1-2). Nearly all of this change takes place in the spinal column, which affects other associated dimensions (e.g., height seated (from buttocks to crown), height of shoulders seated, height of eyes seated, and all dimensions associated with the spinal column).

2. A more accurate gauge of sitting height under microgravity conditions is the height from the buttocks to the crown, provided no pressure is exerted on the shoulders of the crew member during the measurement which would press him against the immobile, flat supporting surface of the seat. All dimensions seated (height to crown, eyes, shoulders and elbows) in zero gravity increase for two reasons:

   a) No pressure exerted on surface of buttocks (calculated increase in height 1.3-2.0 cm (from 0.5 to 0.8 inches~~);~~) ;
   b) As explained in comment 1 above, the spinal column elongates by 3% relative to the height of the individual on earth.

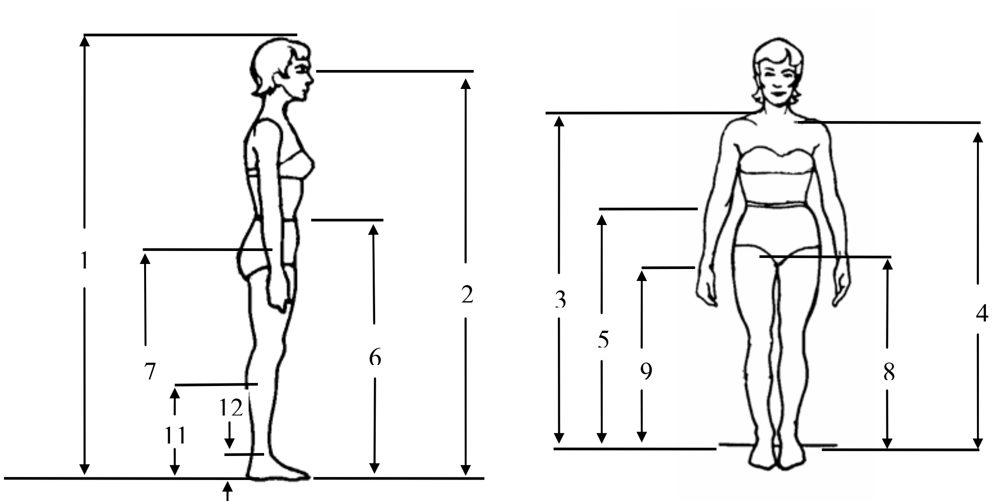
3. The period of adaptation to zero gravity in the first day of flight is accompanied by a significant reduction in leg circumference and diameter.

4. The reduction in waist circumference in microgravity conditions can be explained by a shift of fluids to the upper torso.

C) Anthropometric data are presented for a 40-year old American man, 40-year old Japanese woman for the year 2000, and for a 28-year old Russian male for 1990.

Reference: Man-Systems Integration Standards: NASA STD 3000; Volume 1, Revision B.

Figure 6.1.3.1.2.-7 Anthropometric data - Men. (Continued). Notes for Figures 6.1.3.1.2.-1 through 6.1.3.1.2.-6

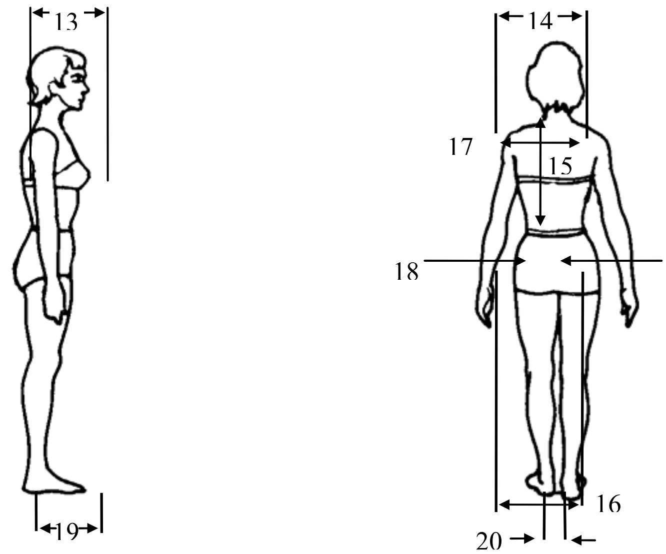


No.	Code	Dimension	5th percentile	50th percentile	95th percentile	b*
1 (*,**)	805 h1	Stature (USA) (Russia)	148.9 150.84	157.0 159.52	165.1 173.13	---
2 (*)	h2	Eye height (USA) (Russia)	--- 139.39	--- 147.81	--- 161.50	---
3 (*)	h3	Cervical height (USA) (Russia)	--- ---	--- ---	--- ---	---
4 (*)	23 h4	Shoulder height (joint) (USA) (Russia)	119.6 123.66	127.1 131.76	134.5 143.91	---
5 (*)	309 h5	Elbow height (joint) (USA) (Russia)	92.8 94.11	98.4 100.17	104.1 106.22	---
6	949	Height to waist (USA) (Russia)	90.1 ---	96.7 ---	103.4 ---	---
7	894 h6	Trochanteric Height (USA) Height to thigh bone (Russia)	71.0 ---	76.7 ---	82.4 ---	---
8	249 h19	Crotch Height (USA) Height to groin (Russia)	65.2 ---	70.6 ---	76.1 ---	---
9 (*)	973 h7	Wrist height (digit point) (USA) (Russia)	70.8 ---	76.6 ---	82.4 ---	---
10	873 h8	Tibiale Height (USA) Height to shin bone (Russia)	35.9 ---	39.3 ---	42.7 ---	---
11	215	Calf Height (USA) Height to back of shin (Russia)	25.5 ---	28.9 ---	32.3 ---	---
12	64 h9	Ankle bone height (USA) Lower shin point height (talocrural joint) (Russia)	5.2 ---	6.1 ---	7.0 ---	---

Figure 6.1.3.1.2.-8 Anthropometric data. Women. Longitudinal dimensions standing.

Reference: Man-Systems Integration Standards: NASA STD 3000; Volume 1, Revision B`

*b is +/- one standard deviation from the Russian 50th percentile data point



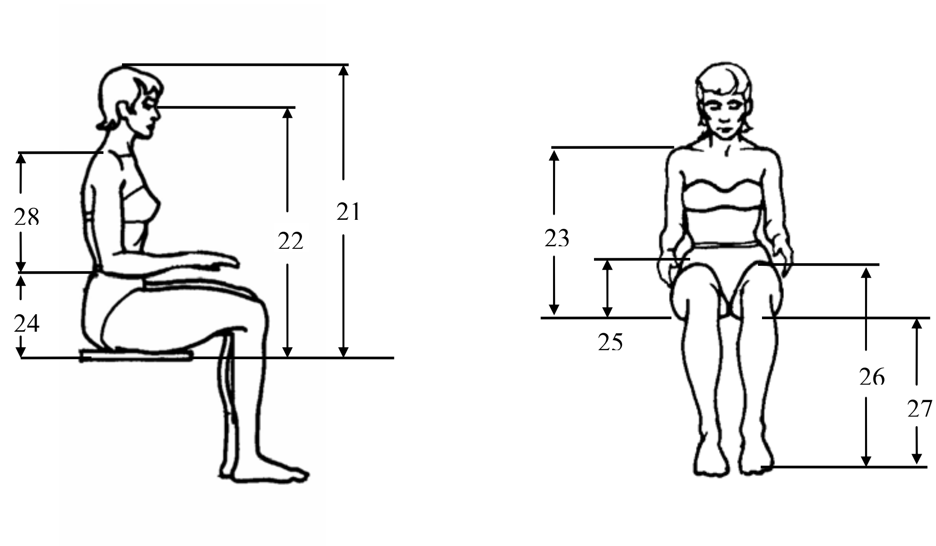
No.	Code	Dimension	5th percentile	50th percentile	95th percentile	b*
13	169 d1	Bust depth (USA) Front-to-back chest diameter (Russia)	17.4 21.86	20.5 25.97	23.6 26.23	---
14	122 d4	Shoulder breadth (USA) Bideltoid diameter (Russia)	35.6 40.75	38.9 46.65	42.1 50.15	---
15	921 d5	Waist back (USA) Transverse diameter of waist (Russia)	35.2 ---	38.1 ---	41.0 ---	---
16	457 d6	Thigh width (USA) (Russia)	30.5 ---	32.9 ---	35.3 ---	---
17	506 d7	Interscye (USA) Spine width (Russia)	32.4 ---	35.7 ---	39.0 ---	---
18	 d8	Distance between centers of hip joints (USA) (Russia)	--- ---	--- ---	--- ---	---
19	362 l1	Foot length (USA) (Russia)	21.3 ---	22.9 ---	24.4 ---	---
20	356 d9	Foot breadth (USA) (Russia)	8.8 ---	9.3 ---	10.0 ---	---

Figure 6.1.3.1.2.-9 Anthropometric data. Women. (Continued). Front-to-back and transverse dimensions standing.

~~Front-to-back and transverse dimensions standing.~~

Reference: Man-Systems Integration Standards: NASA STD 3000; Volume 1, Revision B

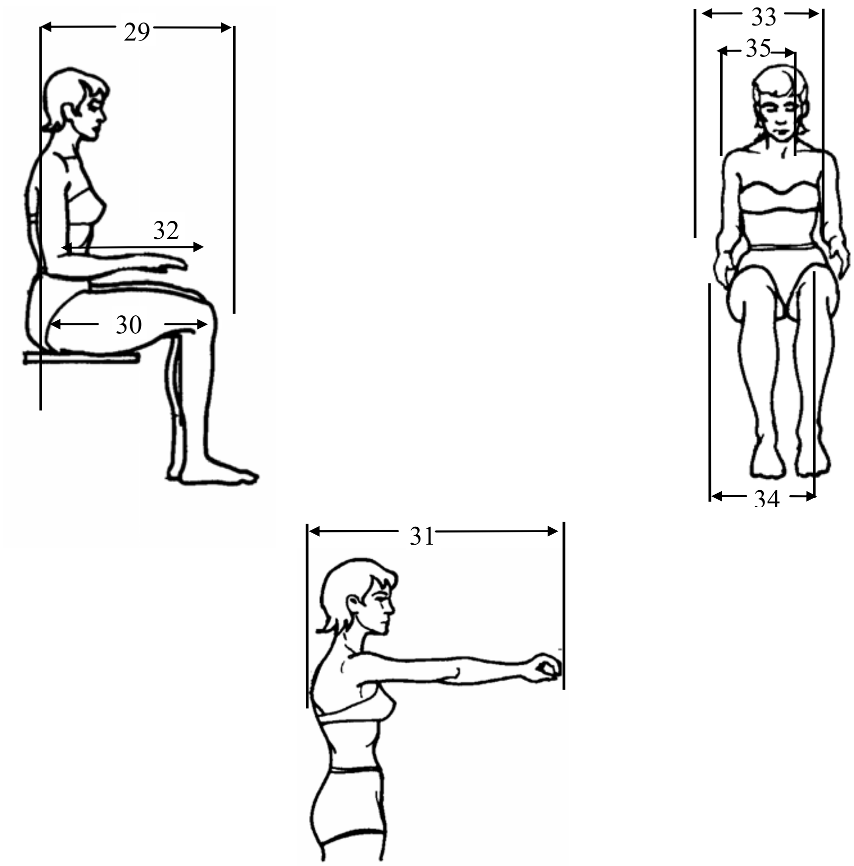
*b is +/- one standard deviation from the Russian 50th percentile data point



No.	Code	Dimension	5th percentile	50th percentile	95th percentile	b*
21 (*,**)	758 h21	Sitting Height (USA) Height over seat (Russia)	78.3 ---	84.8 ---	91.2 ---	---
22 (*)	330 h23	Eye Height sitting (USA) Height of eyes (Russia)	68.1 ---	73.8 ---	79.8 ---	---
23 (*)	612 h26	Mid-Shoulder Height (USA) Height to middle of shoulders (Russia)	119.6 ---	127.1 ---	134.5 ---	---
24 (*)	312 h28	Elbow Rest Height (USA) Height of elbow over seat (Russia)	21.3 ---	25.4 ---	29.7 ---	---
25	856	Thigh clearance (USA) (Russia)	11.2 ---	12.9 ---	14.5 ---	---
26	529 h30	Knee Height Height of knee over floor (Russia)	41.8 ---	45.6 ---	49.5 ---	---
27	678 h31	Popliteal Height (USA) Height of popliteal ligament (Russia)	34.7 ---	38.3 ---	41.9 ---	---
28	751	Shoulder-to-elbow (USA) length (Russia)	27.2 ---	29.8 ---	32.4 ---	---

Figure 6.1.3.1.2.-10Anthropometric data. Women. (Continued). Longitudinal dimensions seated.
~~Longitudinal dimensions seated.~~

Reference: Man-Systems Integration Standards: NASA STD 3000; Volume 1, Revision B
*b is +/- one standard deviation from the Russian 50th percentile data point

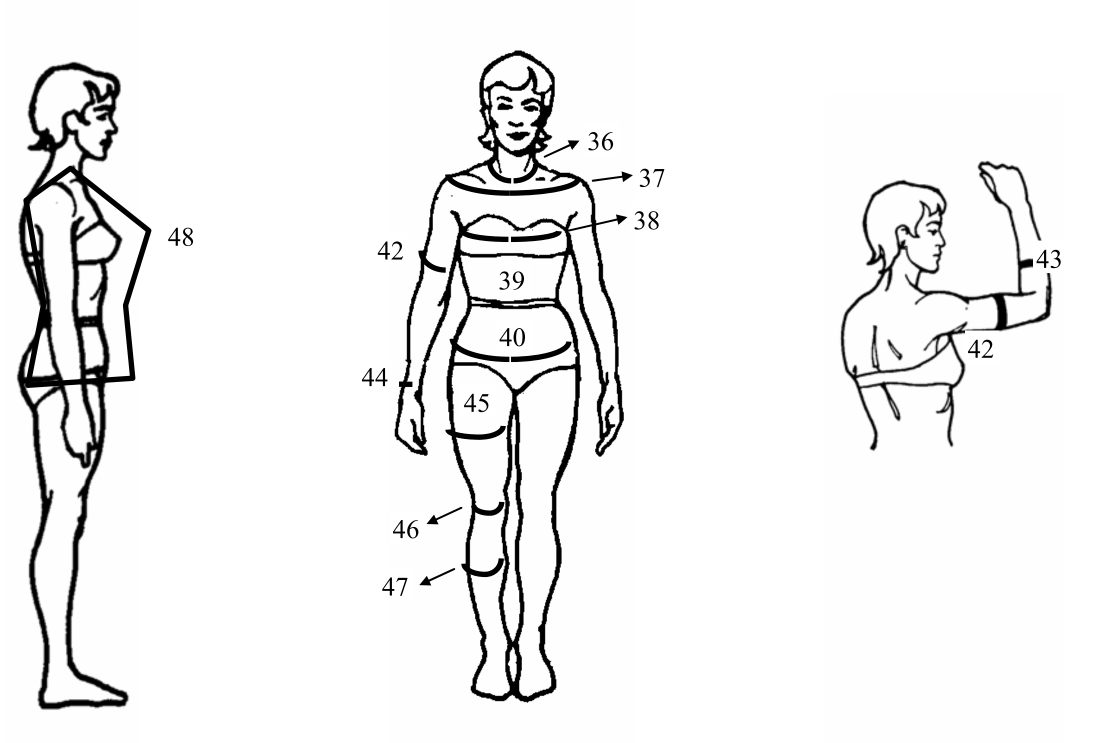


No.	Code	Dimension	5th percentile	50th percentile	95th percentile	b*
29	194 i11	Buttock-knee length (USA) Distance from buttocks to knee (Russia)	48.9 ---	53.3 ---	57.8 ---	---
30	200 i12	Buttock-popliteal length (USA) Distance from buttocks to popliteal ligament (Russia)	37.9 ---	41.7 ---	45.5 ---	---
31	67 i4	Thumb-tip reach (USA) Distance to tip of thumb (Russia)	65.2 ---	71.6 ---	78.0 ---	---
32	381 i5	Forearm-hand length (USA) Distance from elbow to palm (Russia)	37.3 ---	41.7 ---	44.6 ---	---
33	378 d12	Distance between forearms (USA) (Russia)	--- ---	--- ---	--- ---	---
34	459 d14	Hip Breadth-sitting (USA) Transverse dimension of thigh (Russia)	30.4 ---	33.7 ---	37.0 ---	---
35	103	Biacromial breadth (USA) Acromial diameter (Russia)	32.4 ---	35.7 ---	39.0 ---	---

Figure 6.1.3.1.2.-11 Anthropometric data. Women. (Continued). Front-to-back and transverse dimensions seated.

~~**Front-to-back and transverse dimensions seated.**~~

Reference: Man-Systems Integration Standards: NASA STD 3000; Volume 1, Revision B
*b is +/- one standard deviation from the Russian 50th percentile data point

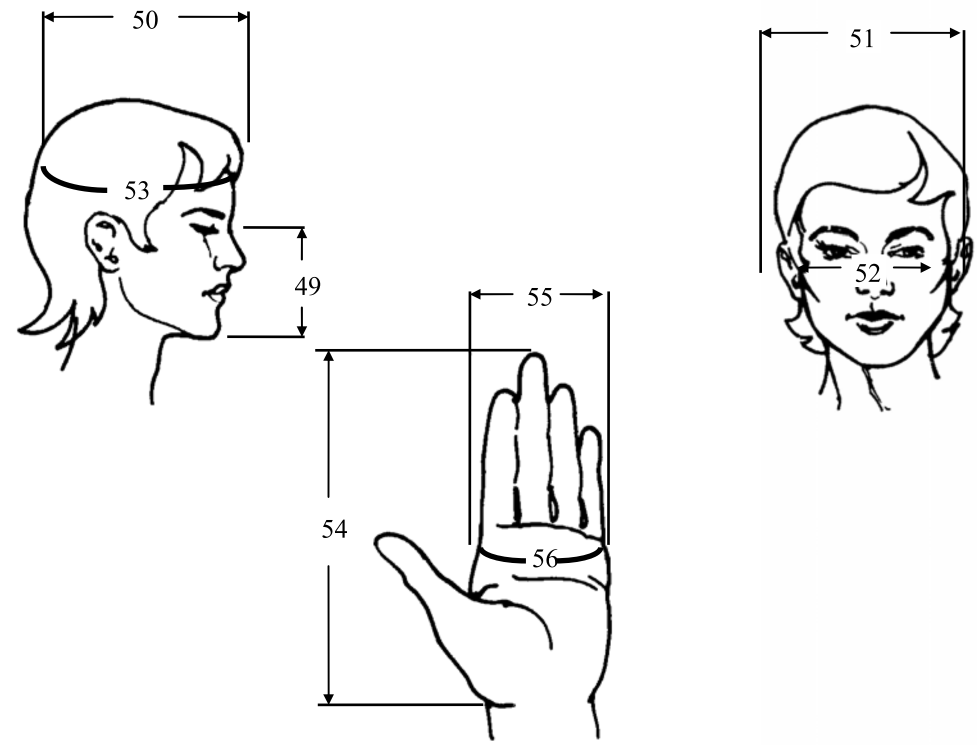


No.	Code	Dimension		5th percentile	50th percentile	95th percentile	b*
36	639 i1	Neck Circumference	(USA) (Russia)	34.5 29.91	37.1 31.13	39.7 34.77	---
37	747	Shoulder Circumference	(USA) (Russia)	--- ---	--- ---	--- ---	---
38 (**)	230 i3	Chest Circumference	(USA) (Russia)	73.2 ---	82.1 ---	90.9 ---	---
39 (*)	931 i5	Waist Circumference	(USA) (Russia)	55.3 ---	63.2 ---	71.2 ---	---
40 (*)	178 i7	Buttocks Circumference	(USA) (Russia)	79.9 ---	87.1 ---	94.3 ---	---
41	113 i8	Biceps Circumference, relaxed	(USA) (Russia)	21.8 ---	25.5 ---	29.3 ---	---
42	111	Biceps Circumference, flexed	(USA) (Russia)	--- ---	--- ---	--- ---	---
43	369 i9	Arm Circumference, relaxed	(USA) (Russia)	19.9 ---	22.0 ---	24.1 ---	---
44	967 i10	Wrist Circumference	(USA) (Russia)	13.7 ---	15.0 ---	16.2 ---	---
45 (*)	852 i11	Thigh Circumference	(USA) (Russia)	45.6 ---	51.6 ---	57.7 ---	---
46	515 i12	Knee Circumference	(USA) (Russia)	31.0 ---	34.6 ---	38.2 ---	---
47 (*)	207 i13	Calf Circumference	(USA) (Russia)	30.3 ---	34.1 ---	37.8 ---	---
48	916 i15	Circumference of trunk along vertical		136.9 ---	146.0 ---	155.2 ---	---

Figure 6.1.3.1.2.-12 Anthropometric data. Women. (Continued). Circumferential dimensions of the human body.

Reference: Man-Systems Integration Standards: NASA STD 3000; Volume 1, Revision B

*b is +/- one standard deviation from the Russian 50th percentile data point



No.	Code	Dimension	5th percentile	50th percentile	95th percentile	b*
49	586 y21	Menton-sellion (USA) length (face) (Russia)	9.0 ---	10.8 ---	12.6 ---	---
50	441 o3	Head Length (USA) Distance from glabella to occipital point (Russia)	16.7 ---	18.2 ---	19.6 ---	---
51	427 z2	Head breadth (USA) (Russia)	14.4 ---	15.6 ---	16.8 ---	---
52	165 z9	Bizygomatic breadth (USA) (face) (Russia)	13.3 ---	14.5 ---	15.7 ---	---
53	430 o1	Head circumference (USA) (Russia)	53.2 ---	55.2 ---	57.2 ---	---
54	420 l1	Hand length (USA) (Russia)	15.8 15.41	17.2 16.99	18.7 18.53	---
55	411 d8	Hand breadth (USA) (Russia)	6.9 8.24	7.8 9.14	8.6 10.50	---
56	416 i4	Hand circumference (USA) (Russia)	16.5 ---	17.9 ---	19.3 ---	---

Figure 6.1.3.1.2.-13Anthropometric data. Women. (Continued). Head and arm dimensions.
~~**Head and arm dimensions.**~~

Reference: Man-Systems Integration Standards: NASA STD 3000; Volume 1, Revision B
*b is +/- one standard deviation from the Russian 50th percentile data point

Comments:

A) Dimensional data:

1. The numbers accompanying each dimension are footnote codes.

2. Anthropometric data presented for 1 g.

3. Limits on anthropometric data (**):

   a) The height of crew members (Figure 6.1.3.1.2.-8, No. 1, code 805, h1) to be launched in the "Sokol-KB" space suit on the Soyuz-T rescue vehicle is confined to 164-182 cm.
   b) The height seated (Figure 6.1.3.1.2.-10, No. 21, code 758, h21), but measured lying down, of crew members to be launched in the "Kazbek-U" seat on the Soyuz-T rescue vehicle may not exceed a 94 cm.
   c) The chest circumference (Figure 6.1.3.1.2.-12, No. 38, code 230,i3) is confined to 96-112 cm for crew members to be launched in the "Sokol-KB" space suit on the Soyuz-T rescue vehicle, and 96-108 cm for crew members to perform EVAs in the Orlan-D space suit.

B) Use of (*) dimensions under microgravity conditions:

1. The height increases by roughly 3% in the first 3-4 days of zero gravity (see ill. 3.2.3.1-2). Nearly all of this change takes place in the spinal column, which affects other associated dimensions (e.g., height seated (from buttocks to crown), height of shoulders seated, height of eyes seated, and all dimensions associated with the spinal column.

2. A more accurate gauge of sitting height under microgravity conditions is the height from the buttocks to the crown, provided no pressure is exerted on the shoulders of the crew member during the measurement which would press him against the immobile, flat supporting surface of the seat. All dimensions seated (height to crown, eyes, shoulders and elbows) in zero gravity increase for two reasons:

   a) No pressure exerted on surface of buttocks (calculated increase in height 1.3-2.0 cm (from 0.5 to 0.8 inches);
   b) As explained in comment 1 above, the spinal column elongates by 3% relative to the height of the individual on earth.

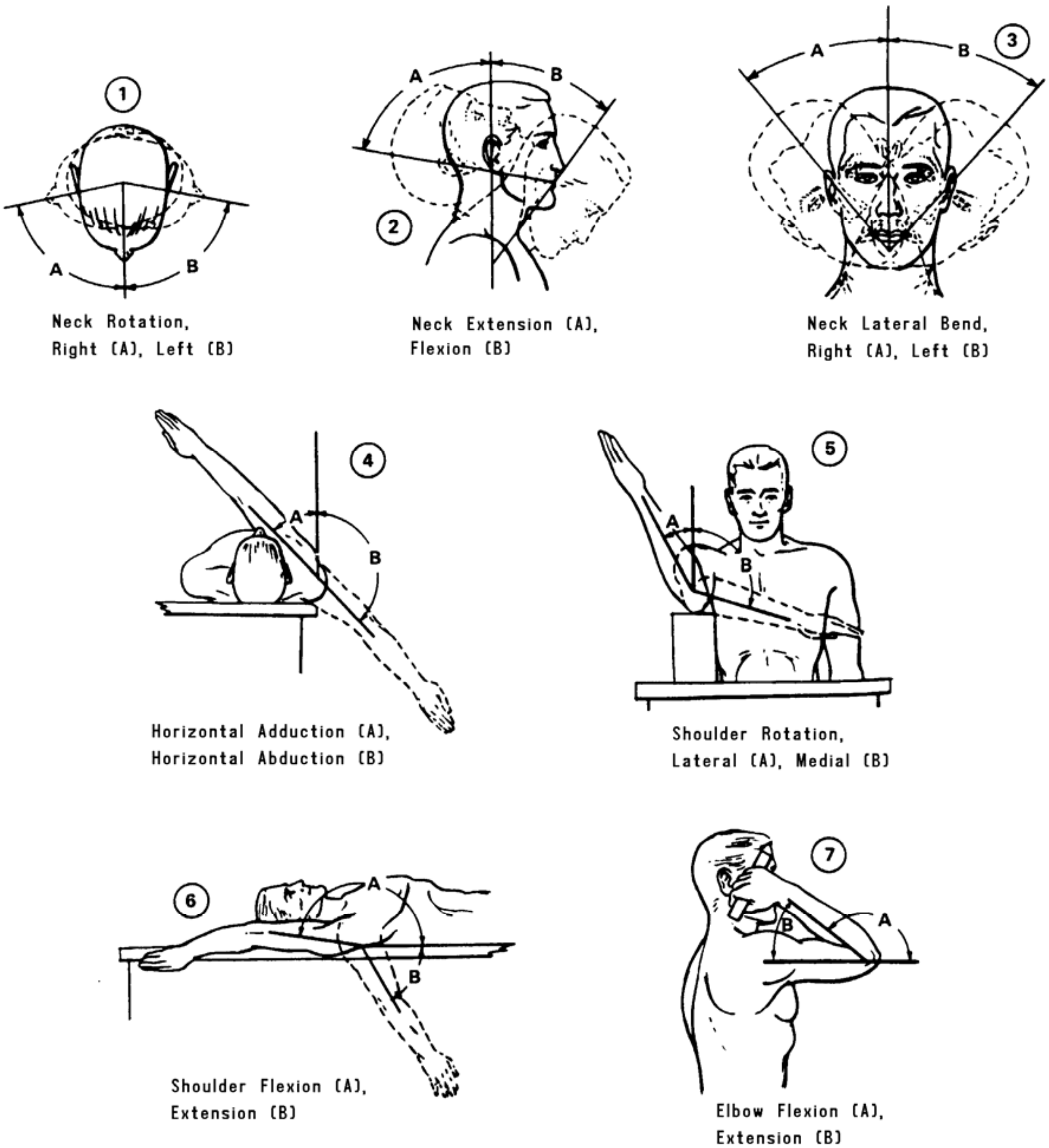
3. The period of adaptation to zero gravity in the first day of flight is accompanied by a significant reduction in leg circumference and diameter.

4. The reduction in waist circumference in microgravity conditions can be explained by a shift of fluids to the upper torso.

C) Anthropometric data are presented for a 40-year old American man, 40-year old Japanese woman for the year 2000, and for a 28-year old Russian male for 1990.

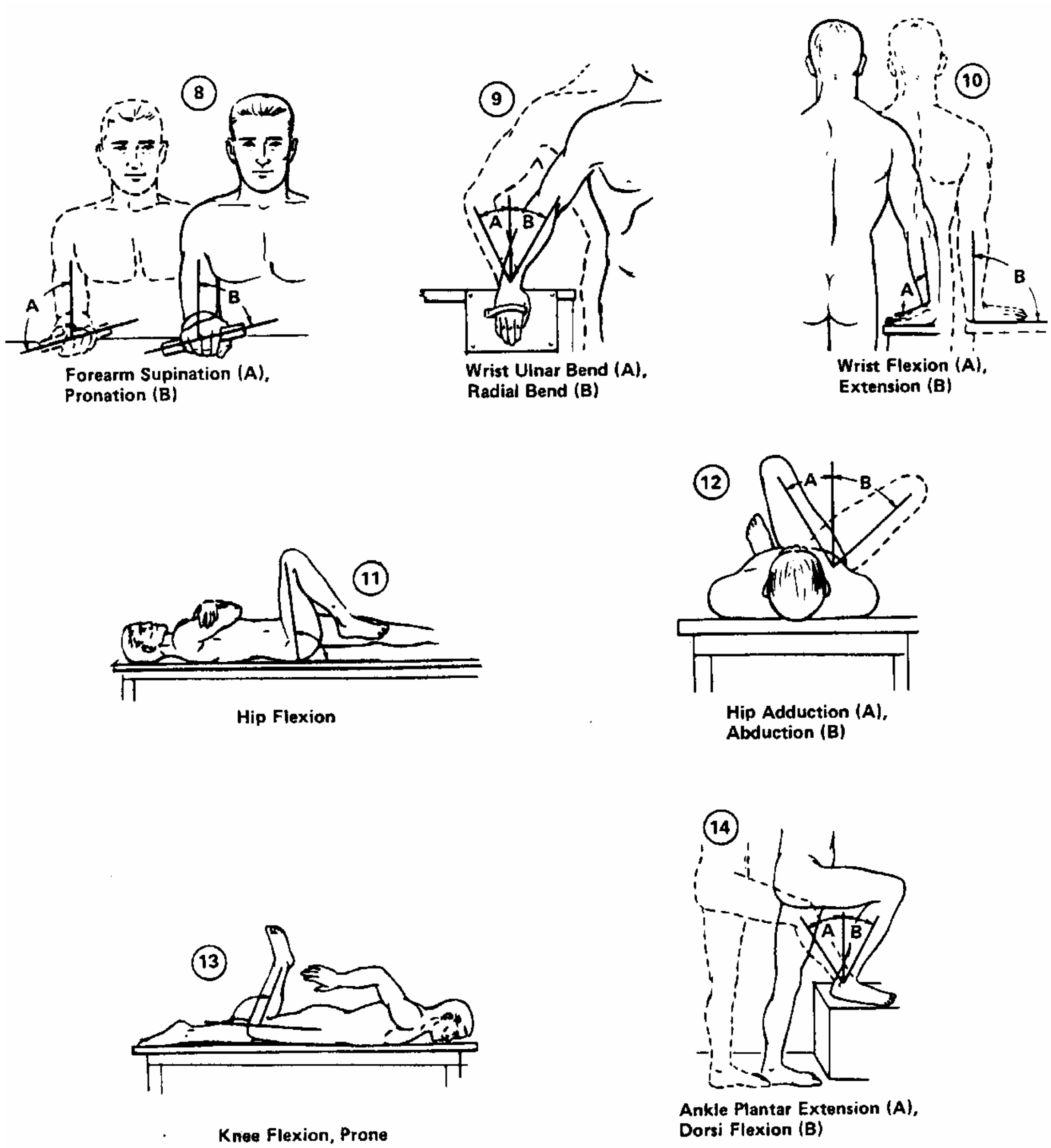
Reference: Man-Systems Integration Standards: NASA STD 3000; Volume 1, Revision B.

Figure 6.1.3.1.2.-14 —Anthropometric data - Women. (Continued). Notes for Figures 6.1.3.1.2.-8 through 6.1.3.1.2.-13.



Reference: Man-Systems Integration Standards: NASA STD 3000; Volume 1, Revision B.

Figure 6.1.3.2.1-1 Range of motion for single joints in men and women.



Reference: Man-Systems Integration Standards: NASA STD 3000; Volume 1, Revision B.

Figure 6.1.3.2.1-2 Range of motion for single joints in men and women. (Continued).

Figure	Joint movement (note b)	Range of motion (degrees)			
		Males (note a)		Females (note a)	
		5th percentile	95th percentile	5th percentile	95th percentile
1	Neck, rotation right	73.3	99.6	74.9	108.8
	Neck, rotation left	74.3	99.1	72.2	109.0
2	Neck, flexion	34.5	71.0	46.0	84.4
	Neck, extension	65.4	103.0	64.9	103.0
3	Neck, lateral right	34.9	63.5	37.0	63.2
	Neck, lateral left	35.5	63.5	29.1	77.2
4	Shoulder, abduction	173.2	188.7	172.6	192.9
5	Shoulder, rotation lat	46.3	96.7	53.8	85.8
	Shoulder, rotation med	90.5	126.6	95.8	130.9
6	Shoulder, flexion	164.4	210.9	152.0	217.0
	Shoulder, extension	39.6	83.3	33.7	87.9
7	Elbow, flexion	140.5	159.0	144.9	165.9
8	Forearm, pronation	78.2	116.1	82.3	118.9
	Forearm, supination	83.4	125.8	90.4	139.5
9	Wrist, radial	16.9	36.7	16.1	36.1
	Wrist, ulnar	18.6	47.9	21.5	43.0
10	Wrist, flexion	61.5	94.8	68.3	98.1
	Wrist, extension	40.1	78.0	42.3	74.7
11	Hip, flexion	116.5	148.0	118.5	145.0
12	Hip, abduction	26.8	53.5	27.2	55.9
13	Knee, flexion	118.4	145.6	125.2	145.2
14	Ankle, plantar	36.1	79.6	44.2	91.1
	Ankle, dorsi	8.1	19.9	6.9	17.4

Reference: Man-Systems Integration Standards: NASA STD 3000; Volume 1, Revision B.

Figure 6.1.3.2.1-3 Range of motion for single joints in men and women. (Continued).

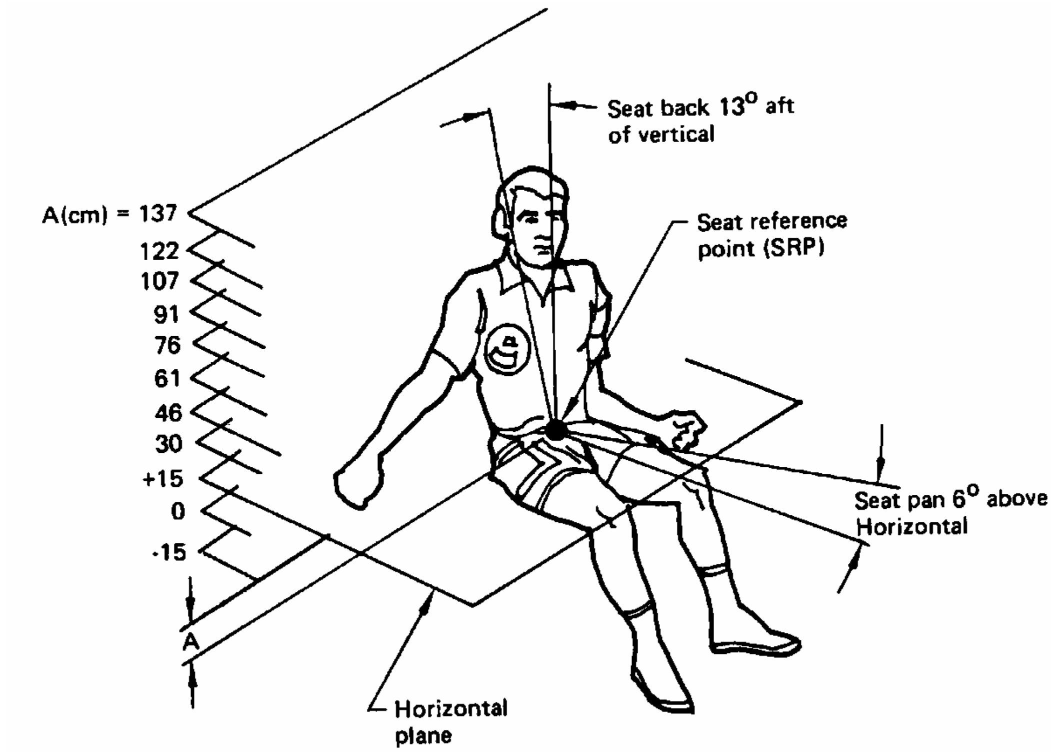
Two-joint movement	Full range of (A) (degrees)	Change in range of movement of (A) (degrees)				
		Movement of B (fraction of full range):				
		Zero	1/3	1/2	2/3	Full
Shoulder extension (A) with elbow flextion (B)	59.3 deg		+1.6 deg (102.7%)		+0.9 deg (101.5%)	+5.3 deg (108.9%)
Shoulder flexion (A) with elbow flexion (B)	190.7 deg		-24.9 deg (86.9%)		-36.1 deg (81.0%)	-47.4 deg (75.0%)
Elbow flexion (A) with shoulder extension (B)	152.2 deg			-3.78 deg (97.5%)		-1.22 deg (99.2%)
Elbow flexion (A) with shoulder flexion (B)	152.2 deg		-0.6 deg (99.6%)		-0.8 deg (99.5%)	-69.0 deg (54.7%)
Hip flexion (A) with shoulder flexion (B)	53.3 deg	-35.6 deg (33.2%) *	-24.0 deg (55.0%)		-6.2 deg (88.4%)	-12.3 deg (54.7%)
Ankle plantar flexion (A) with knee flexion (B)	48.0 deg		-3.4 deg (92.9%)		+0.2 deg (100.4%)	+1.6 deg (103.3%)
Ankle dorsiflexion (A) with knee flexion(B)	26.1 deg		-7.3 deg (72.0%)		-2.7 deg (89.7%)	-3.2 deg (87.7%)
Knee flexion (A) with ankle plantar flexion (B)	127.0 deg			-9.9 deg (92.2%)		-4.7 deg (96.3%)
Knee flexion(A) with ankle dorsiflexion (B)	127.0 deg					-8.7 deg (93.0%)
Knee flexion (A) with hip flexion (B)	127.0 deg			-19.6 deg (84.6%)		-33.6 deg (73.5%)

* The knee joint is locked and the unsupported leg extends out in front of the subject.

Reference: Man-Systems Integration Standards: NASA STD 3000; Volume 1, Revision B.

Figure 6.1.3.2.1-4 Change in range of motion during the movement of adjacent joints.

XY Plane



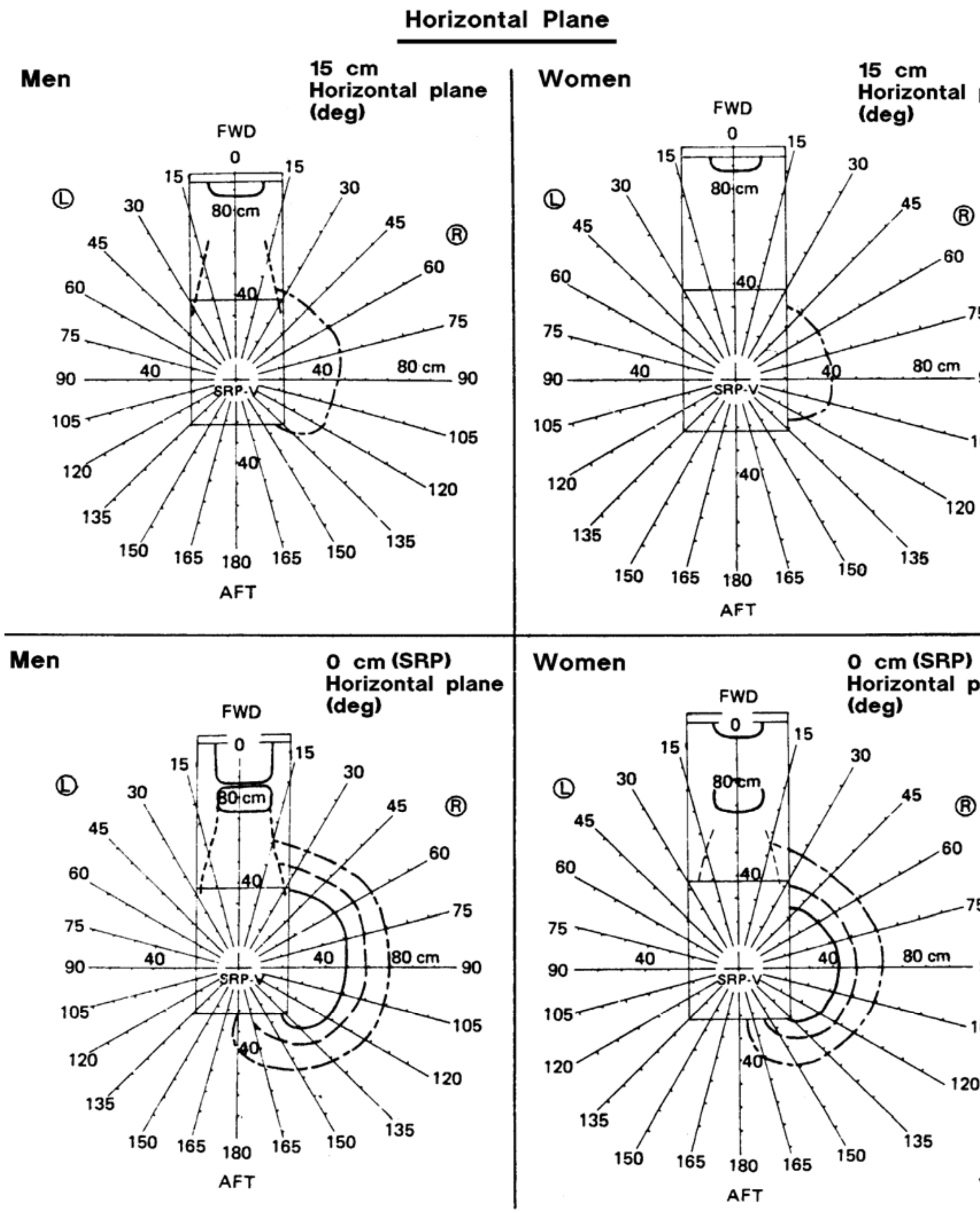
Comments:

__________ 5th percentile outer boundary and inner boundary (inner curve);
_ _ _ _ _ _ _ _ 50th percentile outer boundary;
__ _ __ _ __ 95th percentile outer boundary;

The boundaries apply to 1-G conditions only. Microgravity will cause the spine to lengthen, and adjustments should be made based on a new shoulder pivot location.

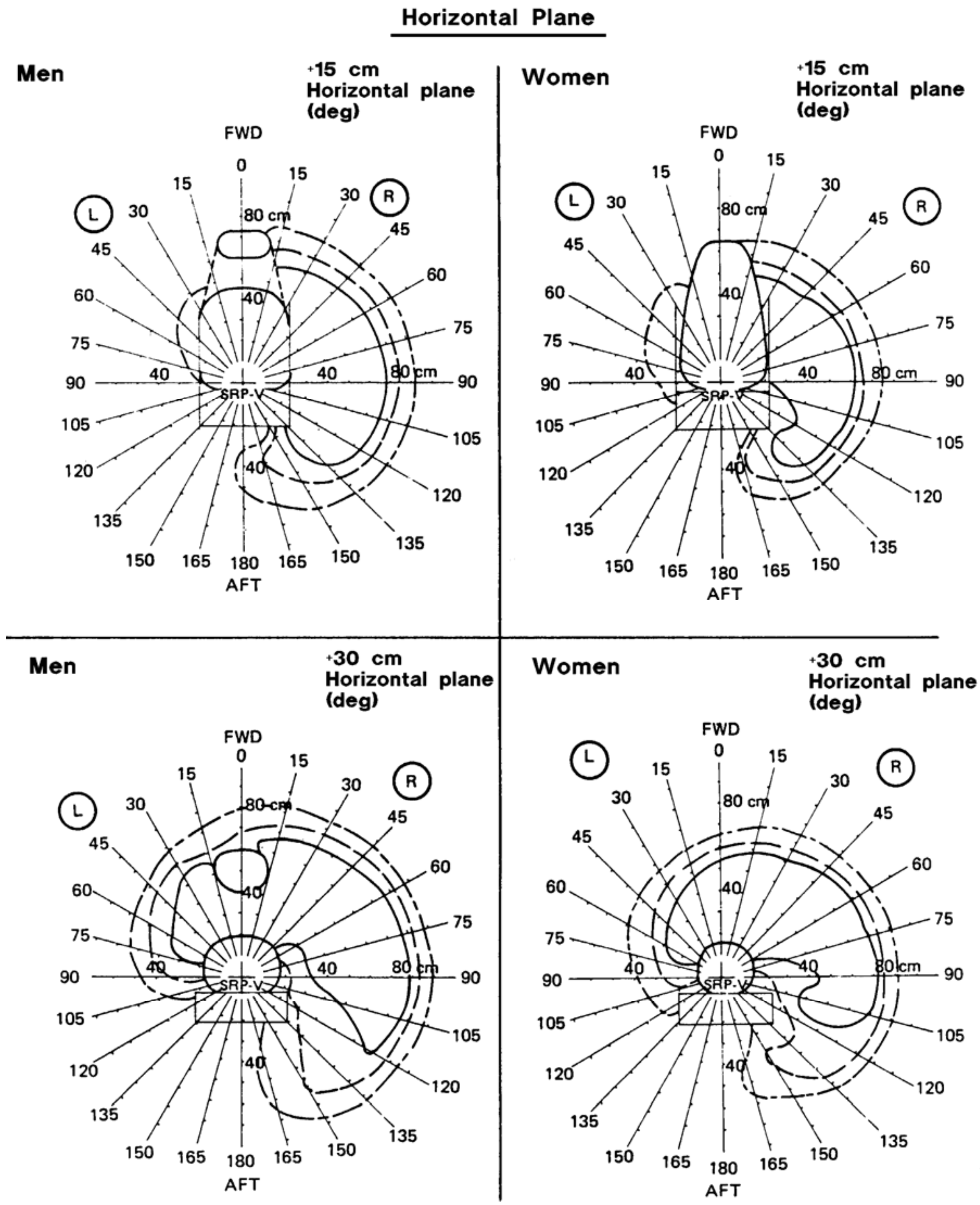
Reference: Man-Systems Integration Standards: NASA STD 3000; Volume 1, Revision B.

Figure 6.1.3.3.1-1 Accessibility zones with right hand, horizontal plane.



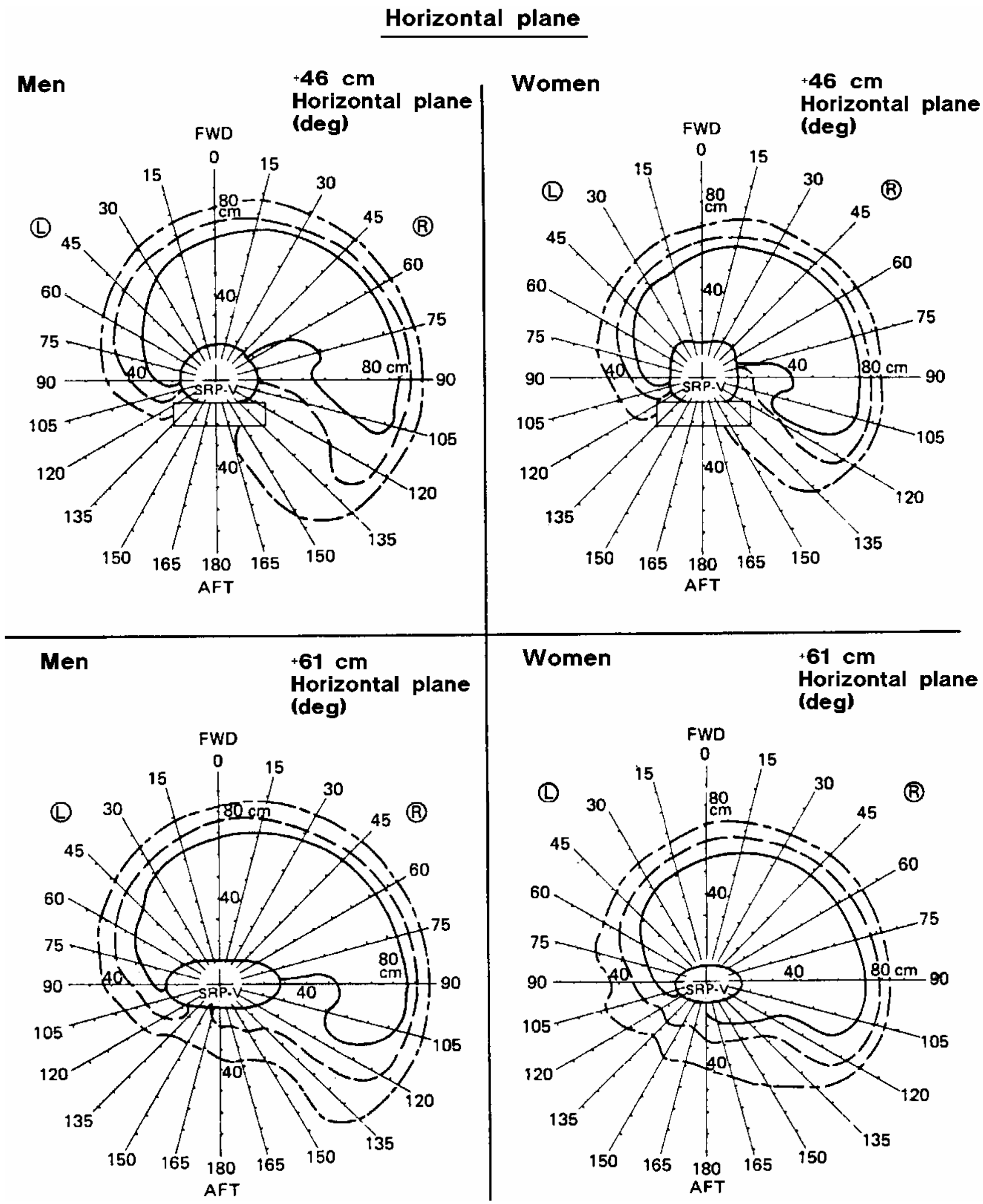
Reference: Man-Systems Integration Standards: NASA STD 3000; Volume 1, Revision B.

Figure 6.1.3.3.1-2 Accessibility zones with right hand, horizontal plane. (Continued).



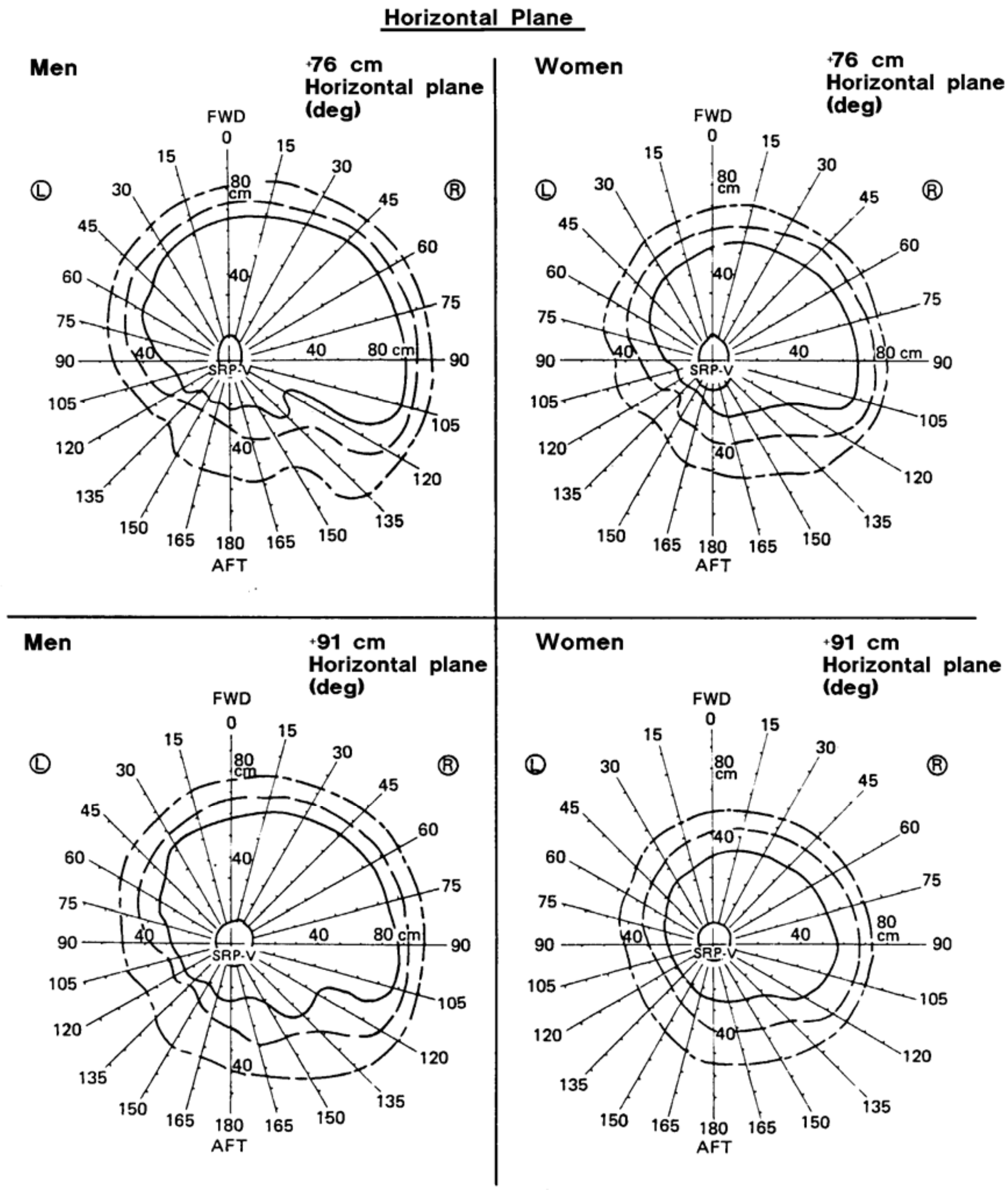
Reference: Man-Systems Integration Standards: NASA STD 3000; Volume 1, Revision B.

Figure 6.1.3.3.1-3 Accessibility zones with right hand, horizontal plane. (Continued).



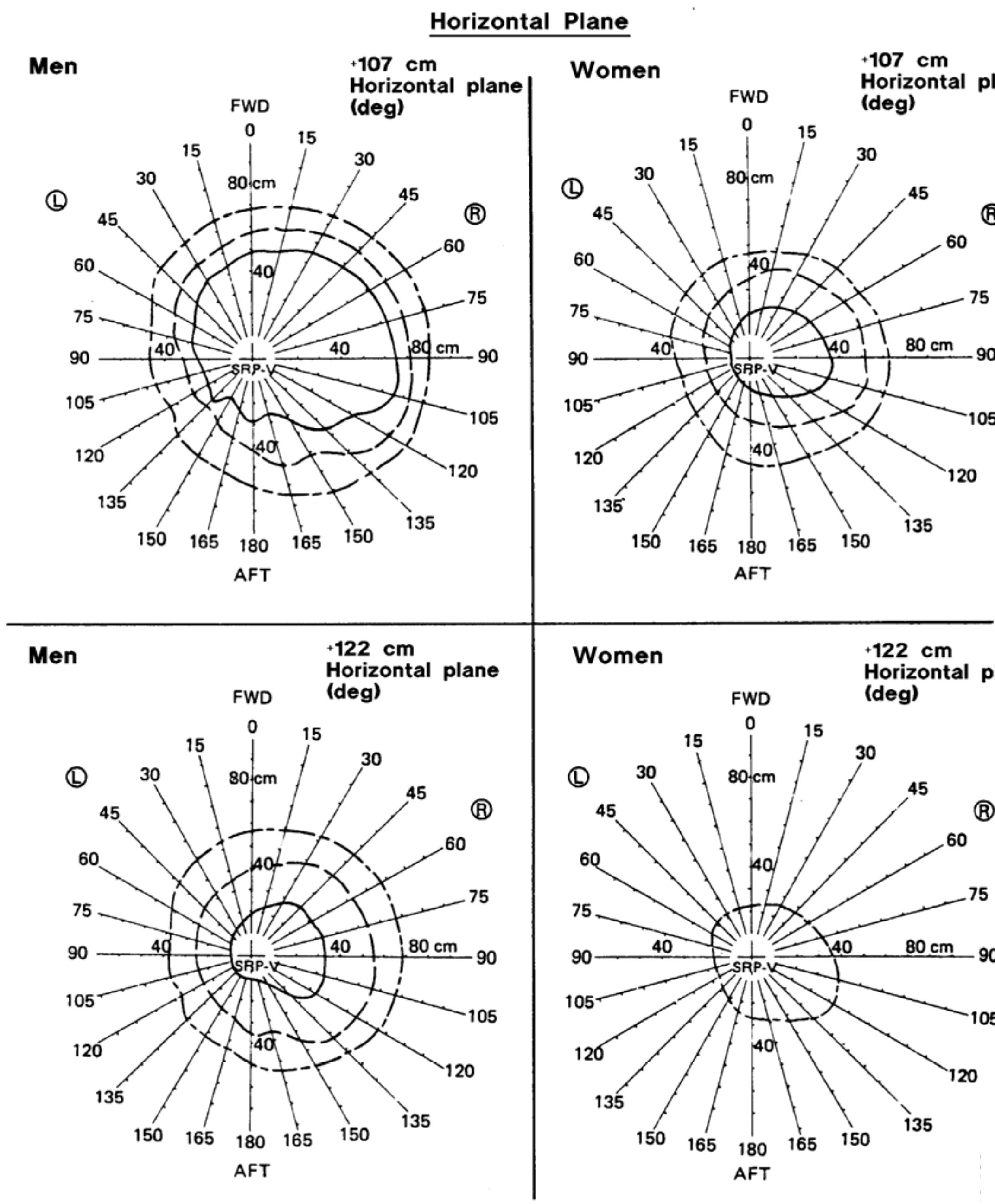
Reference: Man-Systems Integration Standards: NASA STD 3000; Volume 1, Revision B.

Figure 6.1.3.3.1-4 Accessibility zones with right hand, horizontal plane. (Continued).



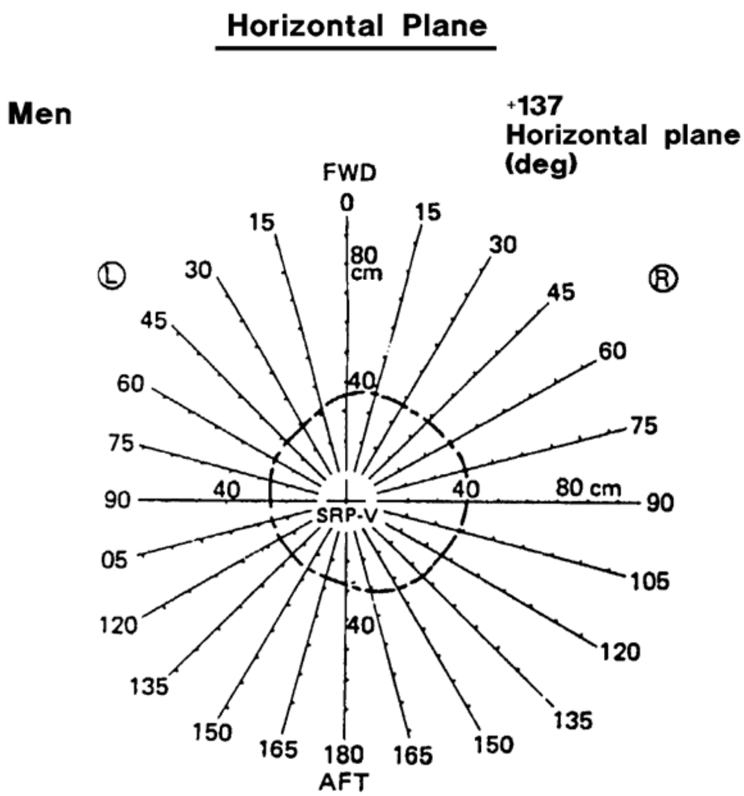
Reference: Man-Systems Integration Standards: NASA STD 3000; Volume 1, Revision B.

Figure 6.1.3.3.1-5   Accessibility zones with right hand, horizontal plane. (Continued).



Reference: Man-Systems Integration Standards: NASA STD 3000; Volume 1, Revision B.

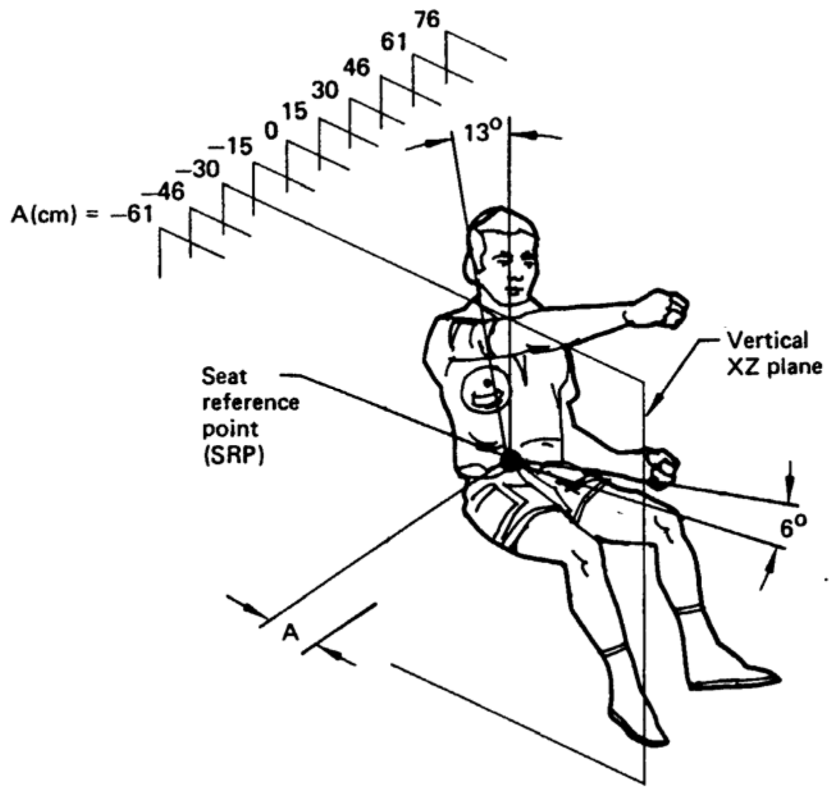
Figure 6.1.3.3.1-6 Accessibility zones with right hand, horizontal plane. (Continued).



Reference: Man-Systems Integration Standards: NASA STD 3000; Volume 1, Revision B.

Figure 6.1.3.3.1-7 Accessibility zones with right hand, horizontal plane. (Continued).

XZ Plane



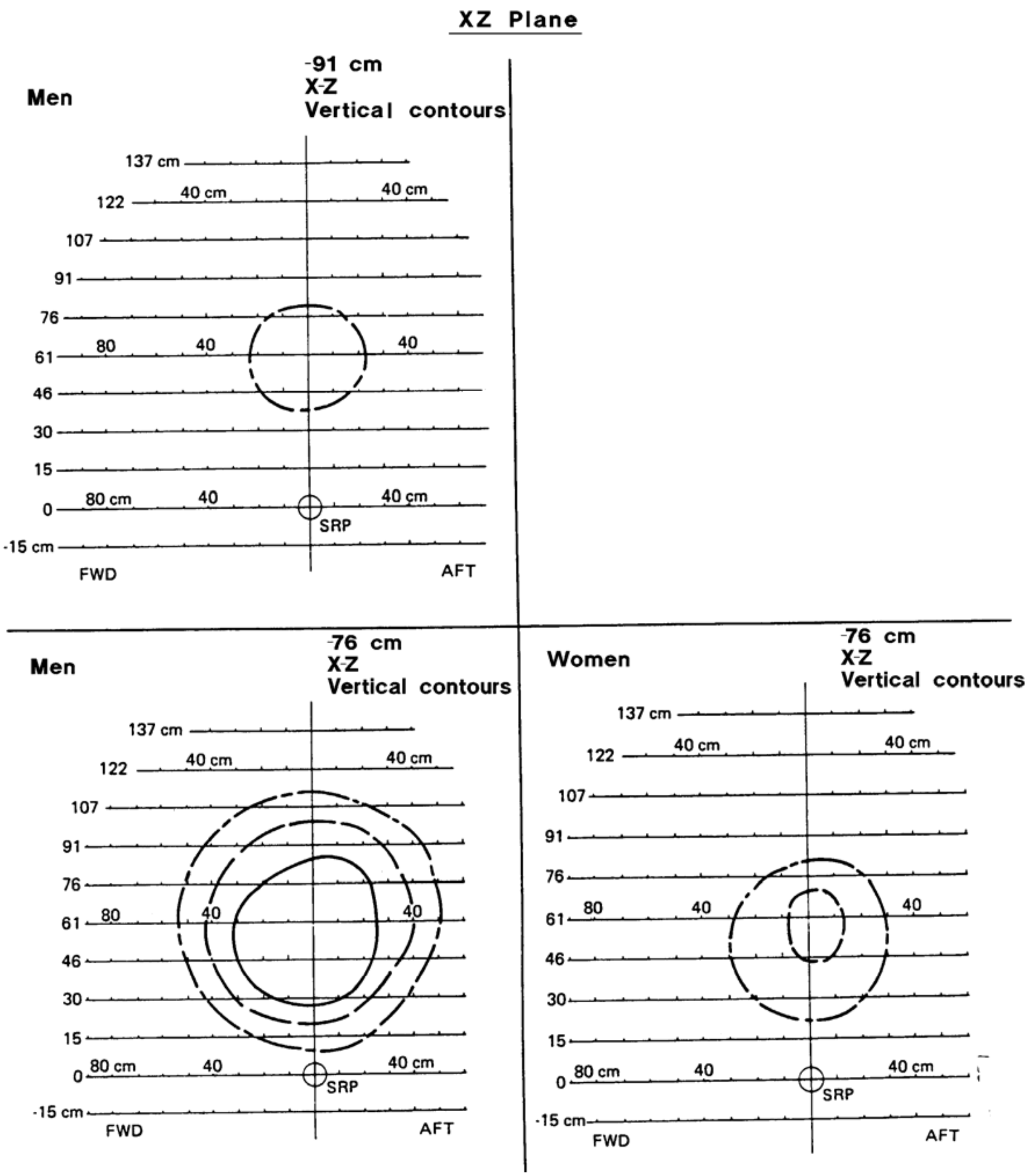
Comments:

___________ 5th percentile outer boundary and inner boundary (inner curve);
_ _ _ _ _ _ _ _ 50th percentile outer boundary;
__ _ __ _ __ 95th percentile outer boundary;

The boundaries apply to 1-G conditions only. Microgravity will cause the spine to lengthen, and adjustments should be made based on a new shoulder pivot location.

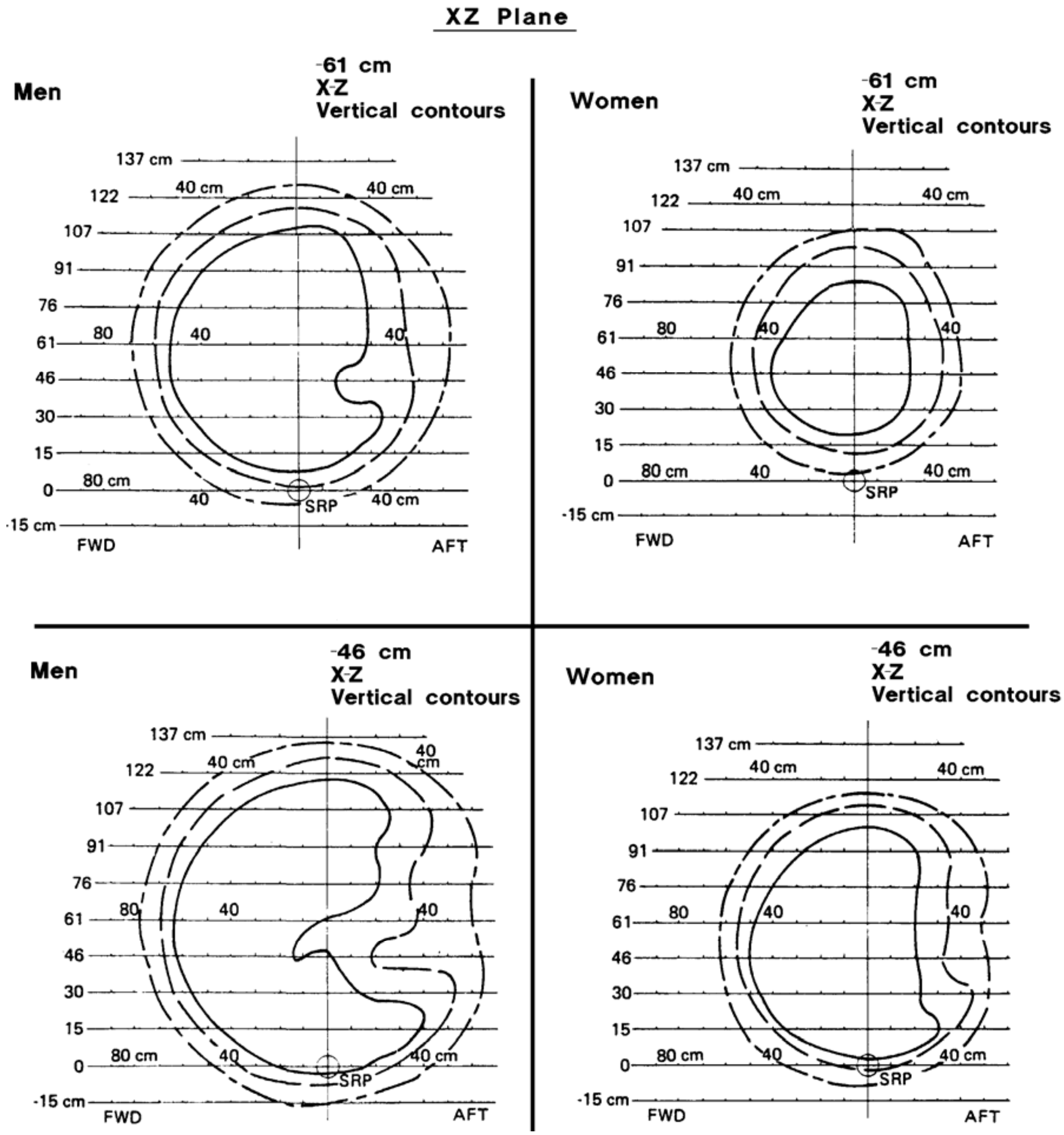
Reference: Man-Systems Integration Standards: NASA STD 3000; Volume 1, Revision B.

Figure 6.1.3.3.1-8 Accessibility zones with right hand, XZ plane.



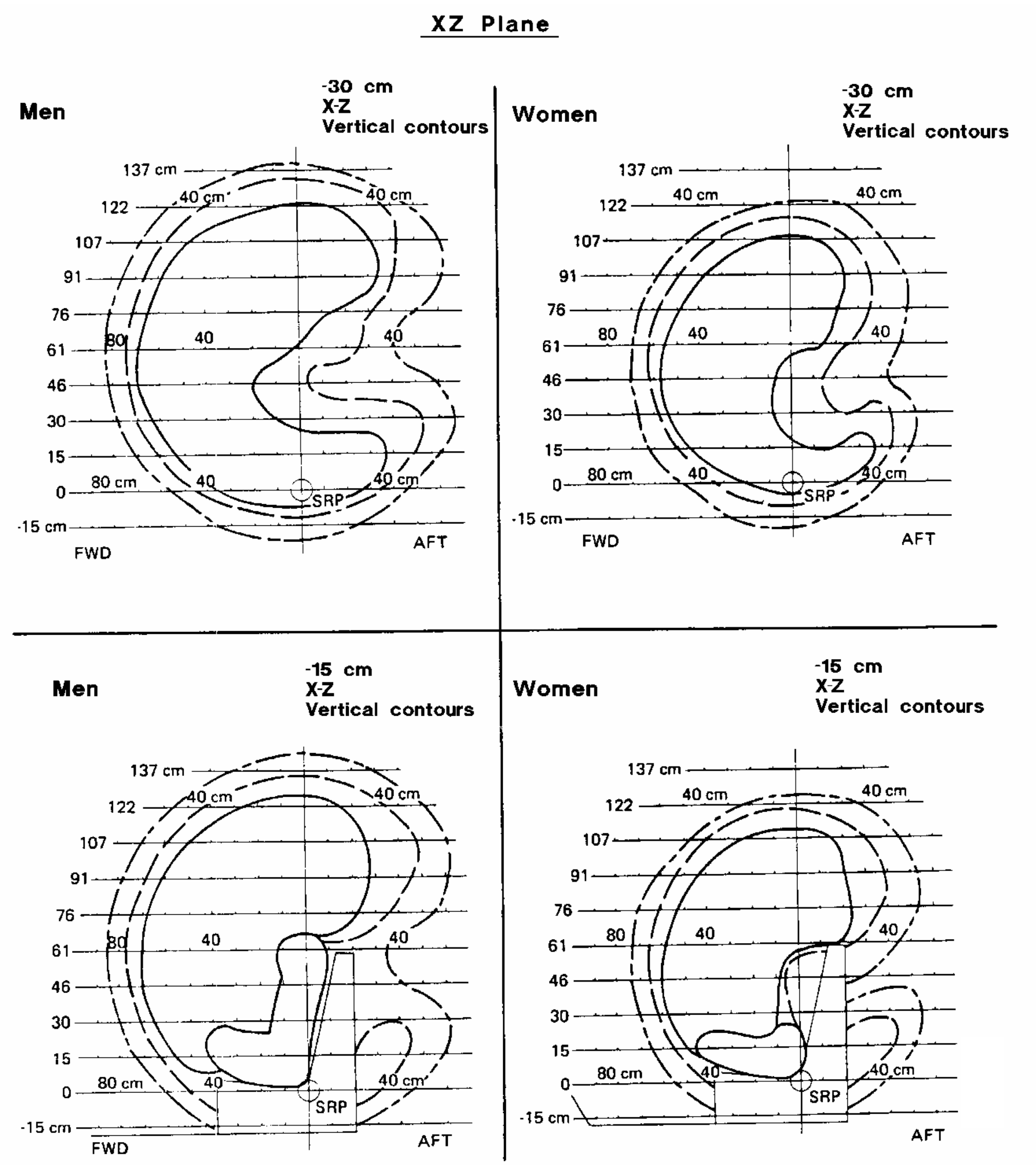
Reference: Man-Systems Integration Standards: NASA STD 3000; Volume 1, Revision B.

Figure 6.1.3.3.1-9 Accessibility zones with right hand, XZ plane. (Continued).



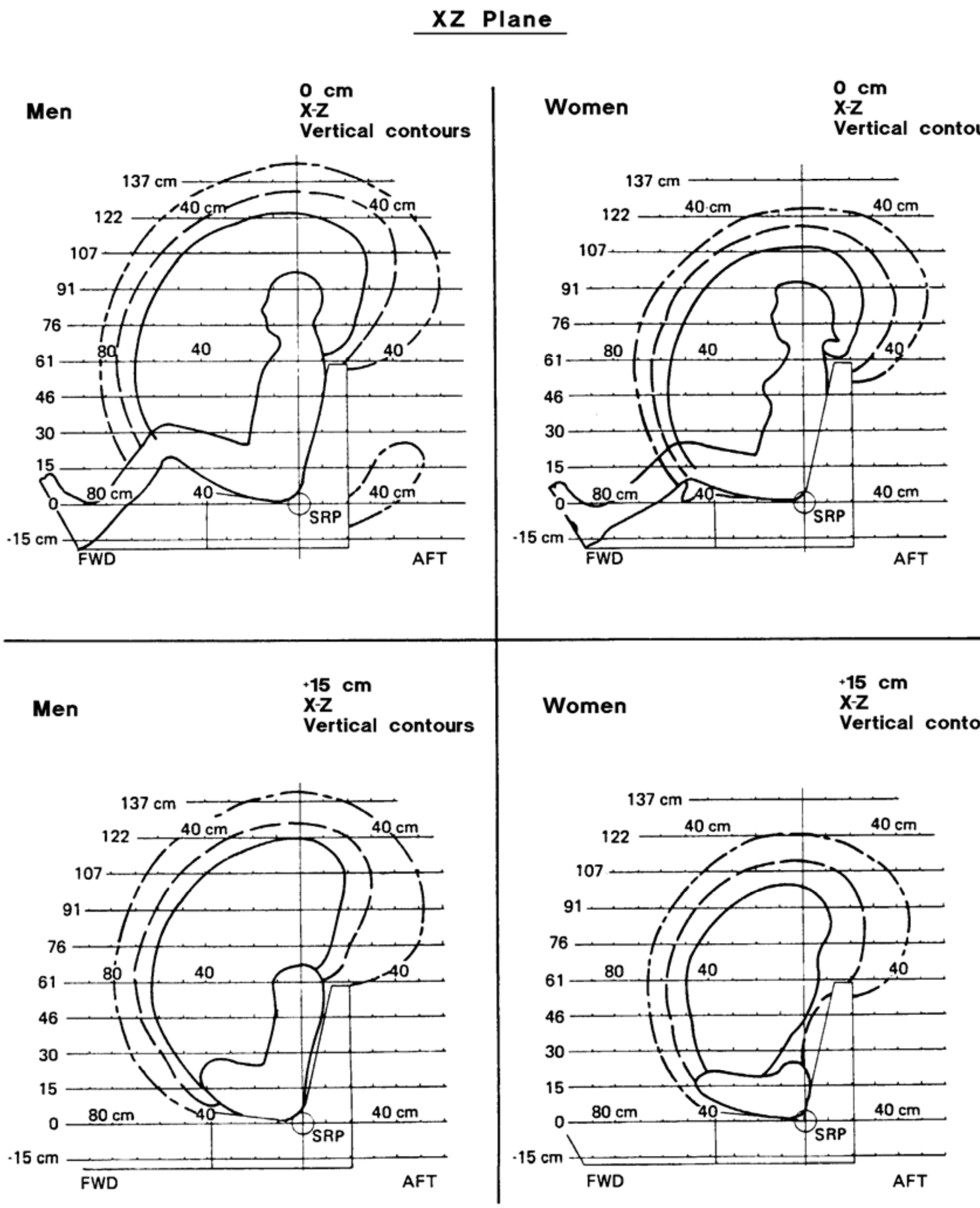
Reference: Man-Systems Integration Standards: NASA STD 3000; Volume 1, Revision B.

Figure 6.1.3.3.1-10 Accessibility zones with right hand, XZ plane. (Continued).



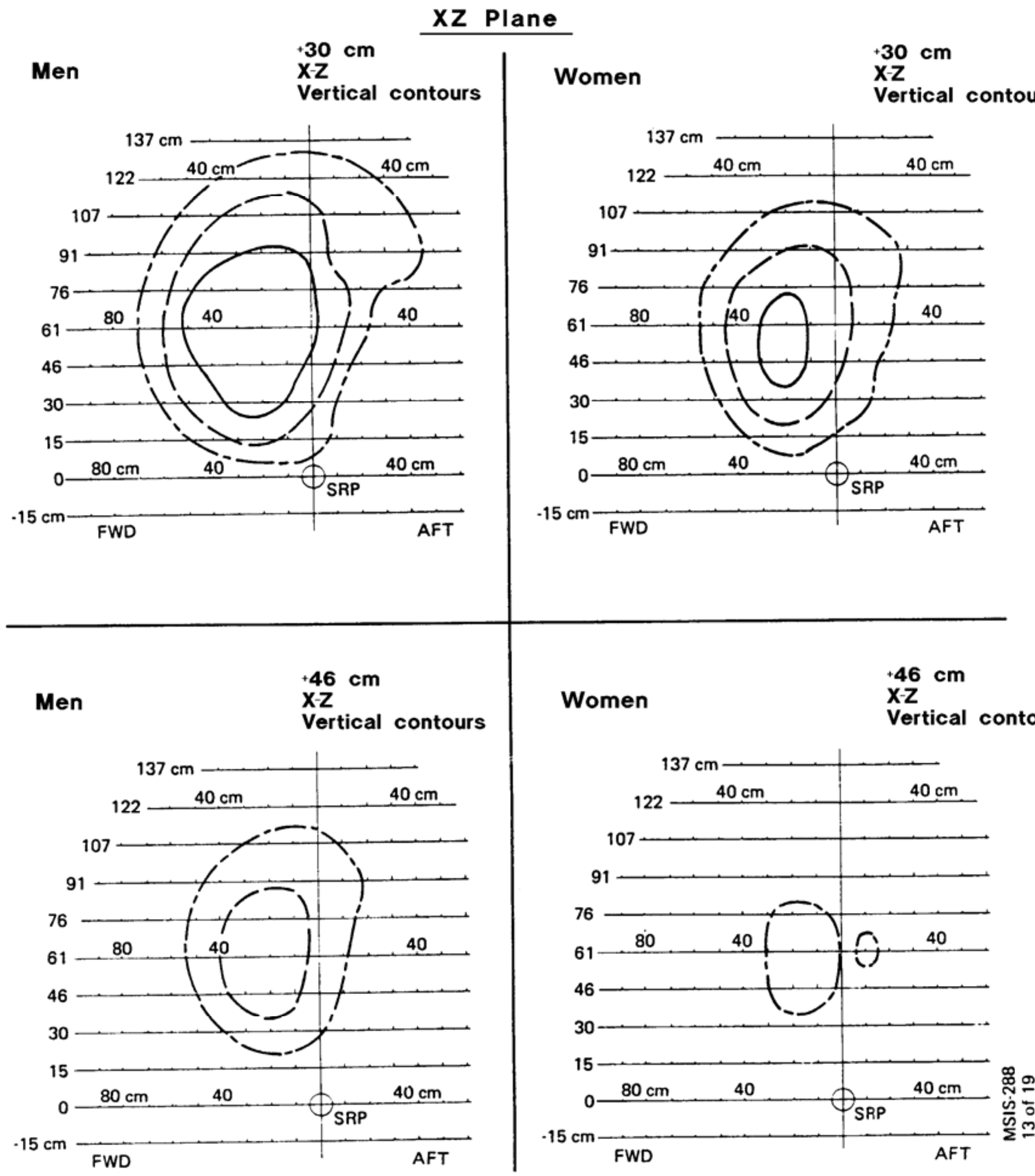
Reference: Man-Systems Integration Standards: NASA STD 3000; Volume 1, Revision B.

Figure 6.1.3.3.1-11 Accessibility zones with right hand, XZ plane. (Continued).



Reference: Man-Systems Integration Standards: NASA STD 3000; Volume 1, Revision B.

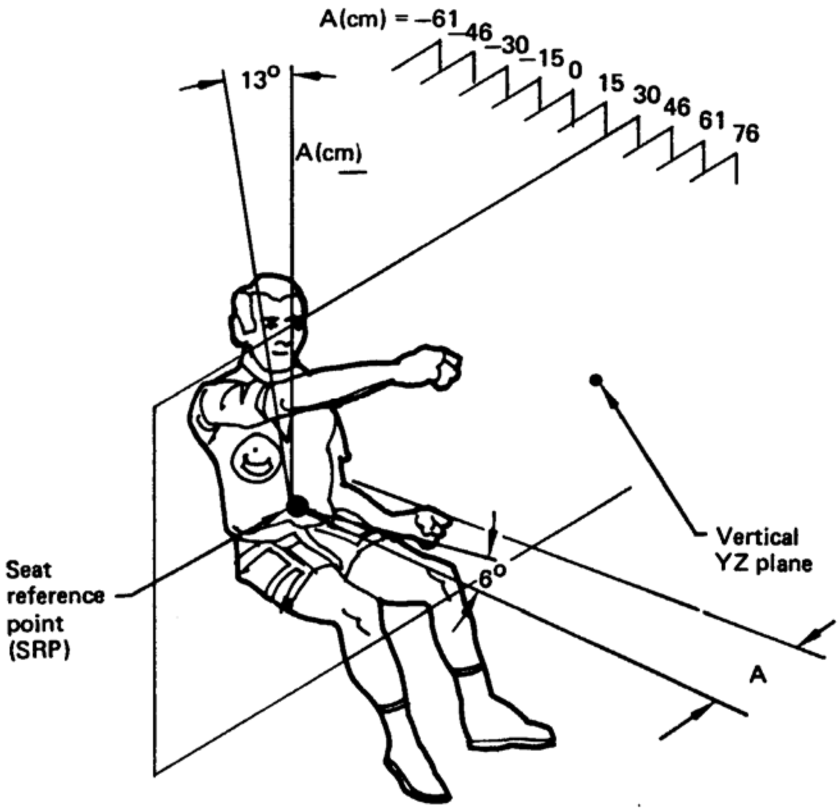
Figure 6.1.3.3.1-12 Accessibility zones with right hand, XZ plane. (Continued).



Reference: Man-Systems Integration Standards: NASA STD 3000; Volume 1, Revision B.

Figure 6.1.3.3.1-13 Accessibility zones with right hand, XZ plane. (Continued).

YZ Plane



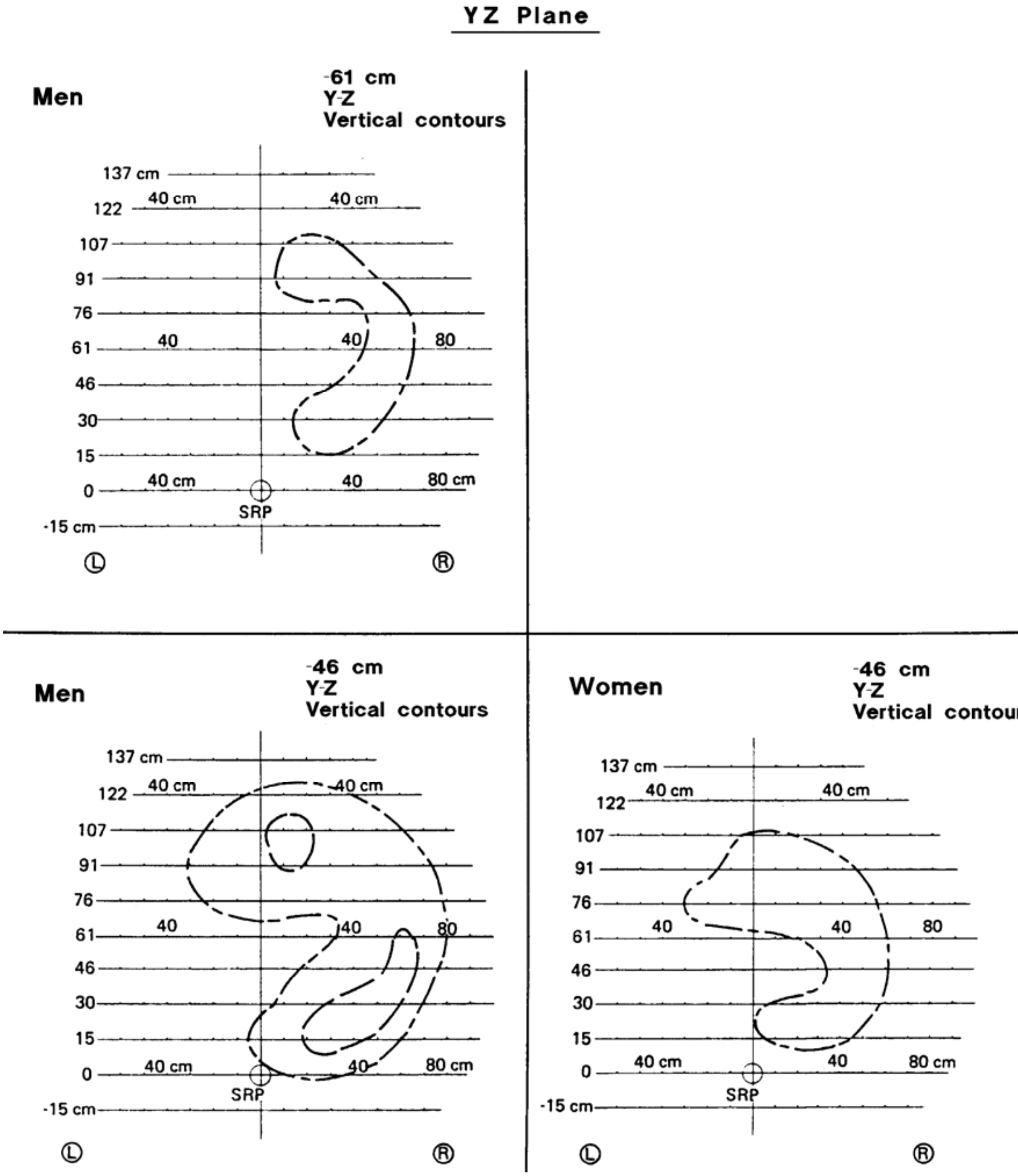
Comments:

___________ 5th percentile outer boundary and inner boundary (inner curve);
_ _ _ _ _ _ _ _ 50th percentile outer boundary;
__ _ __ _ __ 95th percentile outer boundary;

The boundaries apply to 1-G conditions only. Microgravity will cause the spine to lengthen, and adjustments should be made based on a new shoulder pivot location.

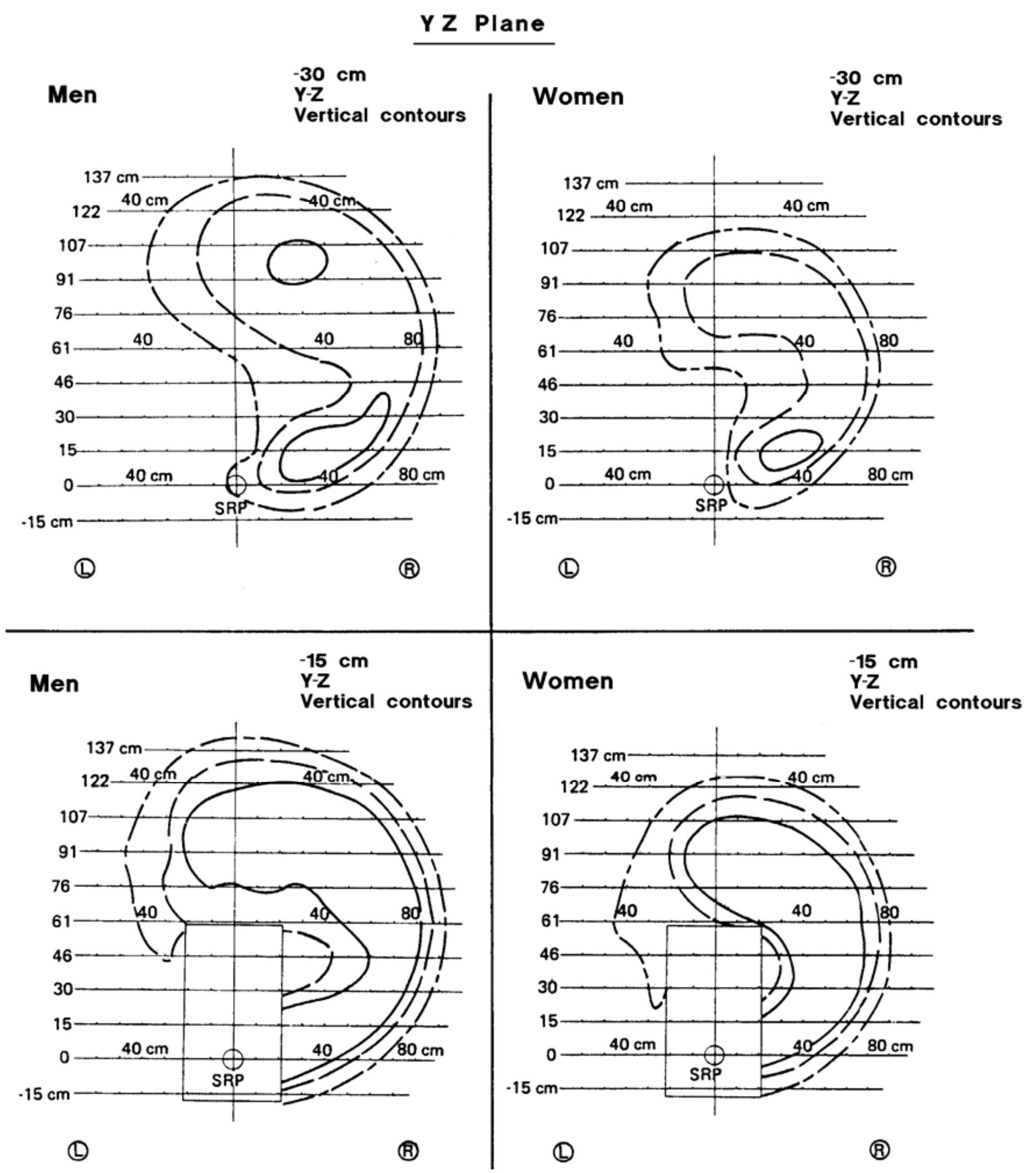
Reference: Man-Systems Integration Standards: NASA STD 3000; Volume 1, Revision B.

Figure 6.1.3.3.1-14 Accessibility zones with right hand, YZ plane. (Continued).



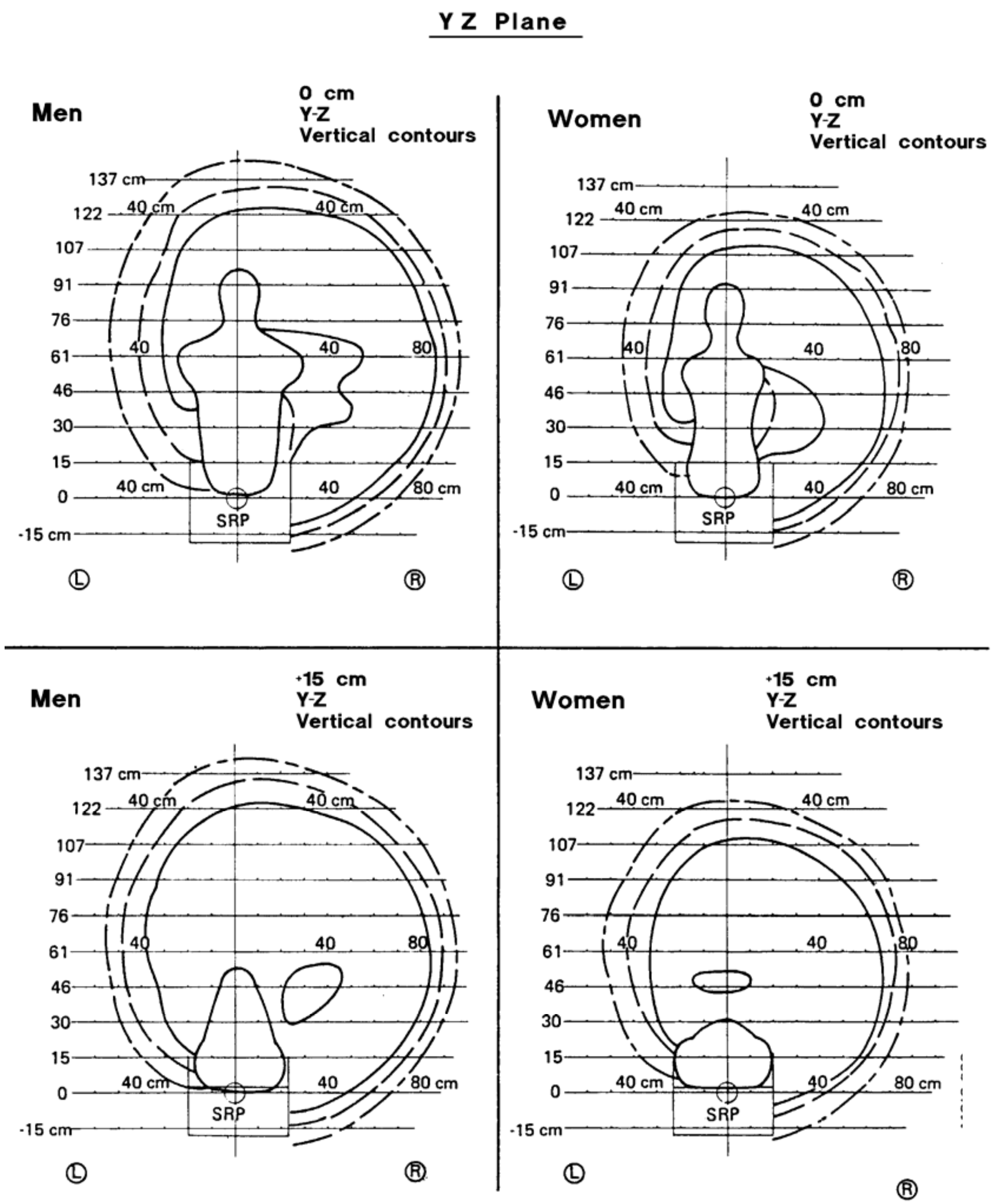
Reference: Man-Systems Integration Standards: NASA STD 3000; Volume 1, Revision B.

Figure 6.1.3.3.1-15 Accessibility zones with right hand, YZ plane. (Continued).



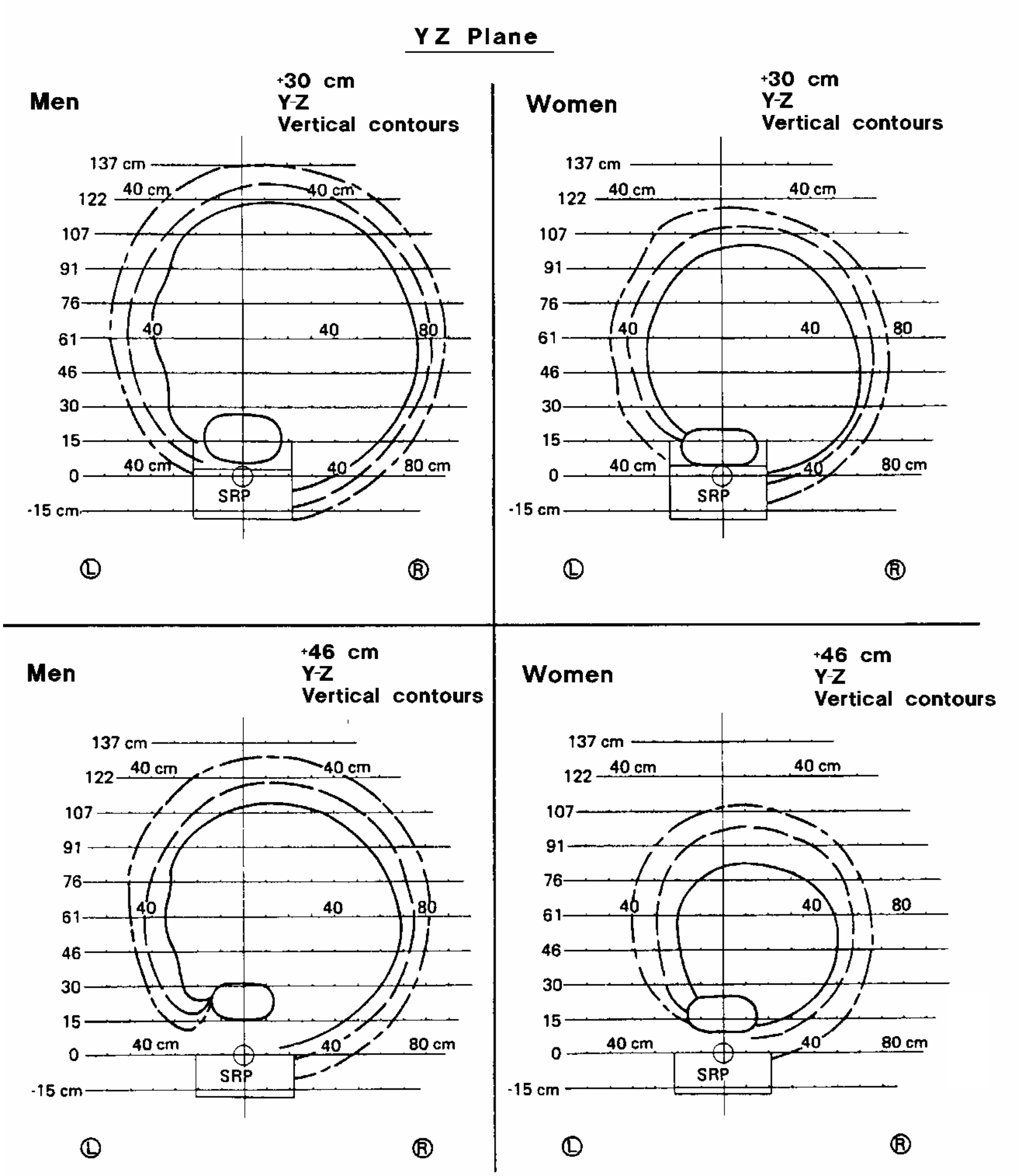
Reference: Man-Systems Integration Standards: NASA STD 3000; Volume 1, Revision B.

Figure 6.1.3.3.1-16 Accessibility zones with right hand, YZ plane. (Continued).



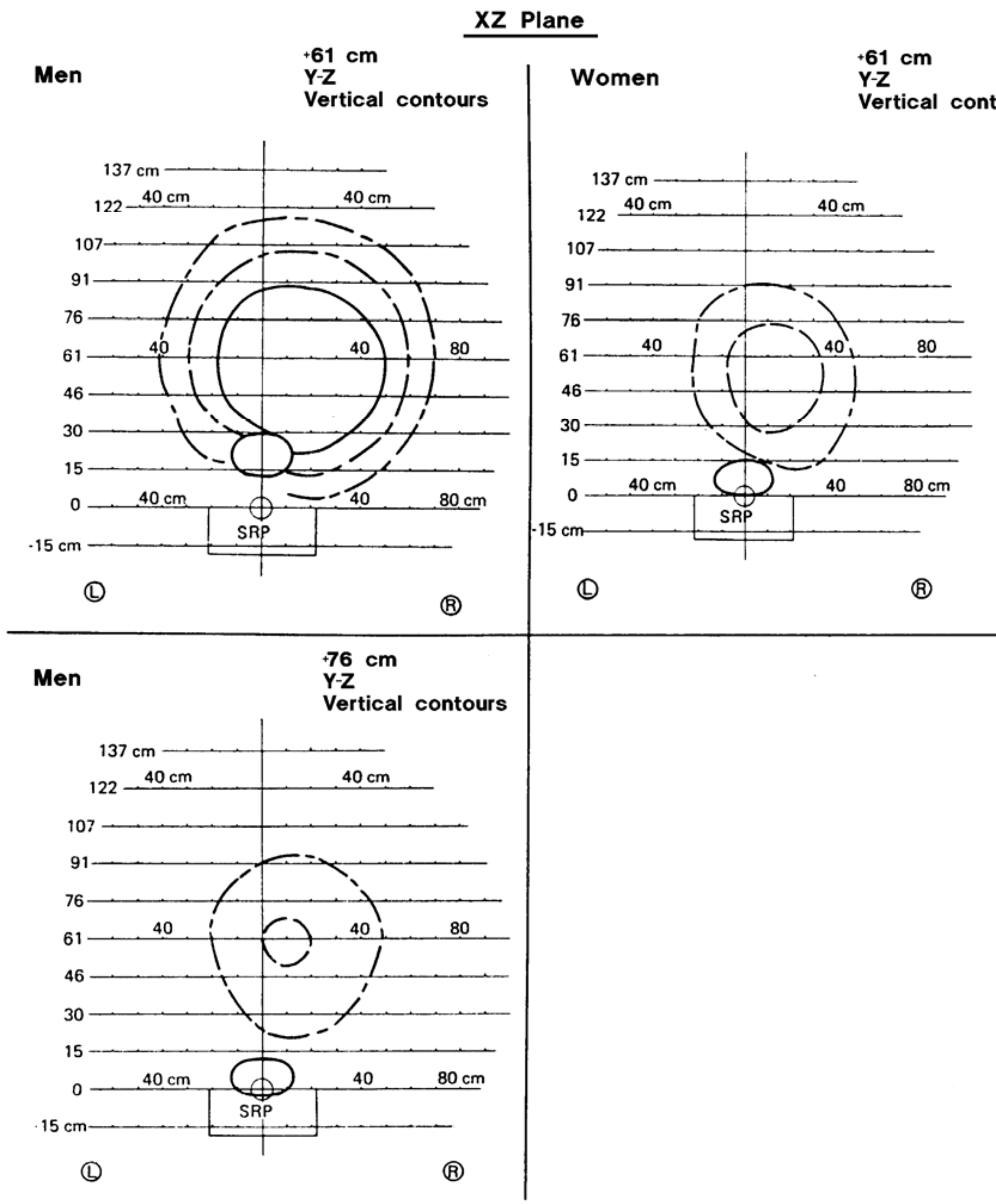
Reference: Man-Systems Integration Standards: NASA STD 3000; Volume 1, Revision B.

Figure 6.1.3.3.1-17 Accessibility zones with right hand, YZ plane. (Continued).



Reference: Man-Systems Integration Standards: NASA STD 3000; Volume 1, Revision B.

Figure 6.1.3.3.1-18 Accessibility zones with right hand, YZ plane. (Continued).



Reference: Man-Systems Integration Standards: NASA STD 3000; Volume 1, Revision B.

Figure 6.1.3.3.1-19 Accessibility zones with right hand, YZ plane. (Continued).

Type of work	Correction
Finger tip activity	+7.0 cm (2.8 inches)
Grip of entire hand	-5.5 cm (2.2 inches)

Reference: Man-Systems Integration Standards: NASA STD 3000; Volume 1, Revision B.

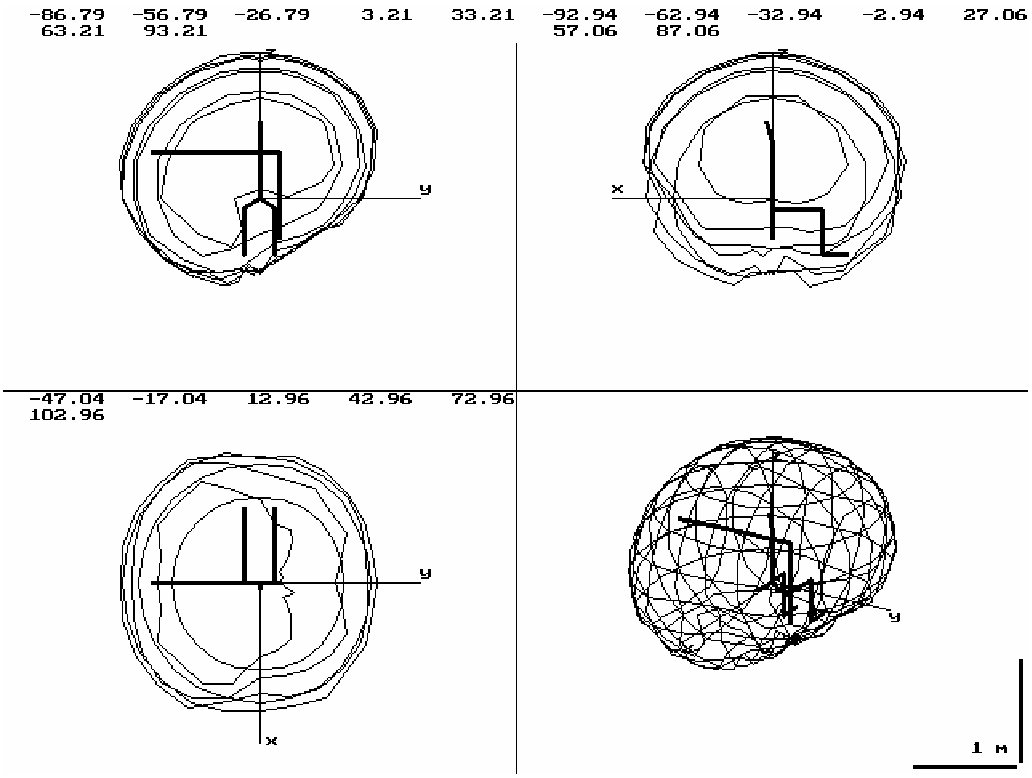
Figure 6.1.3.3.1-20 Adjustment to thumb and forefinger grasp reach boundaries for other types of grasping tasks.

Direction of arm reach (from 0 deg or "straight ahead," to 90 deg to the right) (deg)	Approximate changes in reach for each single degree of change in backrest angle (reach increases as backrest angle moves to vertical, and vice versa)
0	±1.02 cm (±0.40 in)
15	±1.27 cm (±0.50 in)
30	±1.14 cm (±0.45 in)
45	±0.94 cm (±0.37 in)
60	±0.66 cm (±0.26 in)
75	±0.36 cm (±0.14 in)
90	±0.25 cm (±0.10 in)

Reference: Man-Systems Integration Standards: NASA STD 3000; Volume 1, Revision B.

Figure 6.1.3.3.1-21 Changes in arm reach boundaries as a function of variation in backrest angle of 13 degrees from vertical.

Seated pose, taking into account the flexibility of the spine



Comments:

Accessibility zones with right hand, seated pose, horizontal plane (XY), for men and women :

---------------	5th percentile outer boundary and inner boundary (inner curve);
- - - - - - - -	50th percentile outer boundary;
_._._._._.	95th percentile outer boundary.

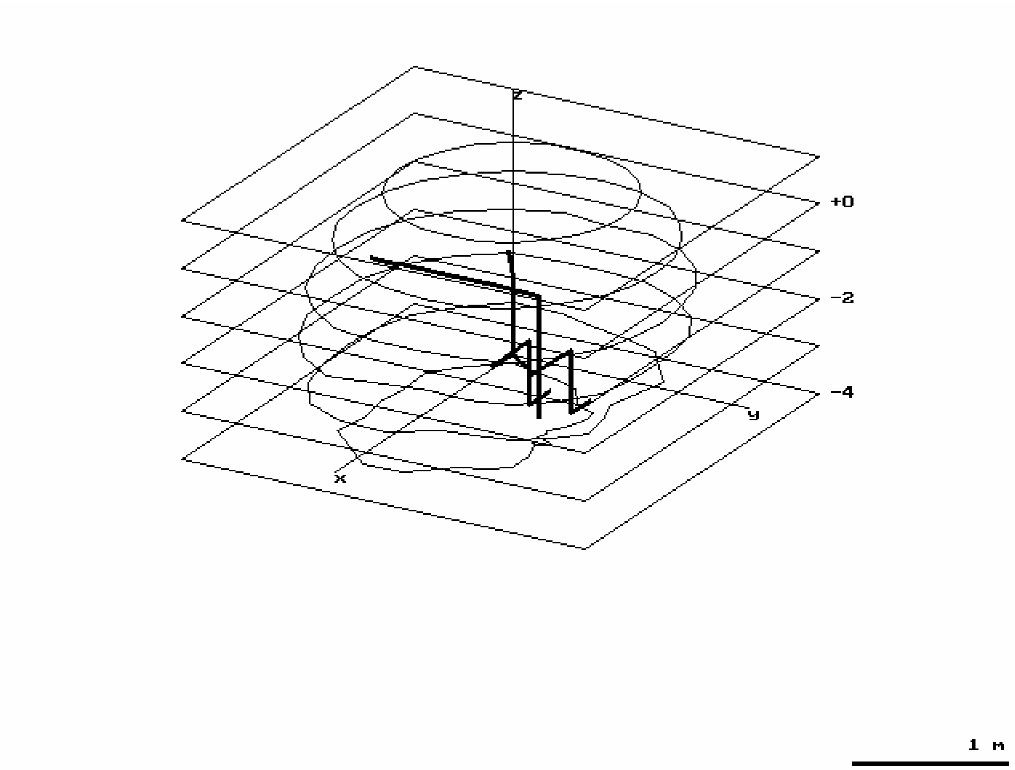
The boundaries apply to 1-g conditions only. Microgravity will cause the spine to lengthen, and adjustments should be made based on a new shoulder pivot location.

The data presented in Figures 6.1.3.3.1-22 to 6.1.3.3.1-31 illustrate the results obtained from calculating accessibility zones using a computer model based on the initial data contained in this document for Russian men and women. The computer model looks at seated, standing, and floating-while-restrained postures. This model also makes it possible to obtain three-dimensional accessibility zones and any cross sections thereof in the polar or Cartesian coordinate systems for groups or separate operators, various gravitational conditions, and postures involving different restraint modes and limitations on joint motion (e.g., due to movement conditions, restraint devices, space suit, etc.).

Reference: RSC Energia documents

Figure 6.1.3.3.1-22 Accessibility zones with right hand, seated pose, taking into account the flexibility of the spine.

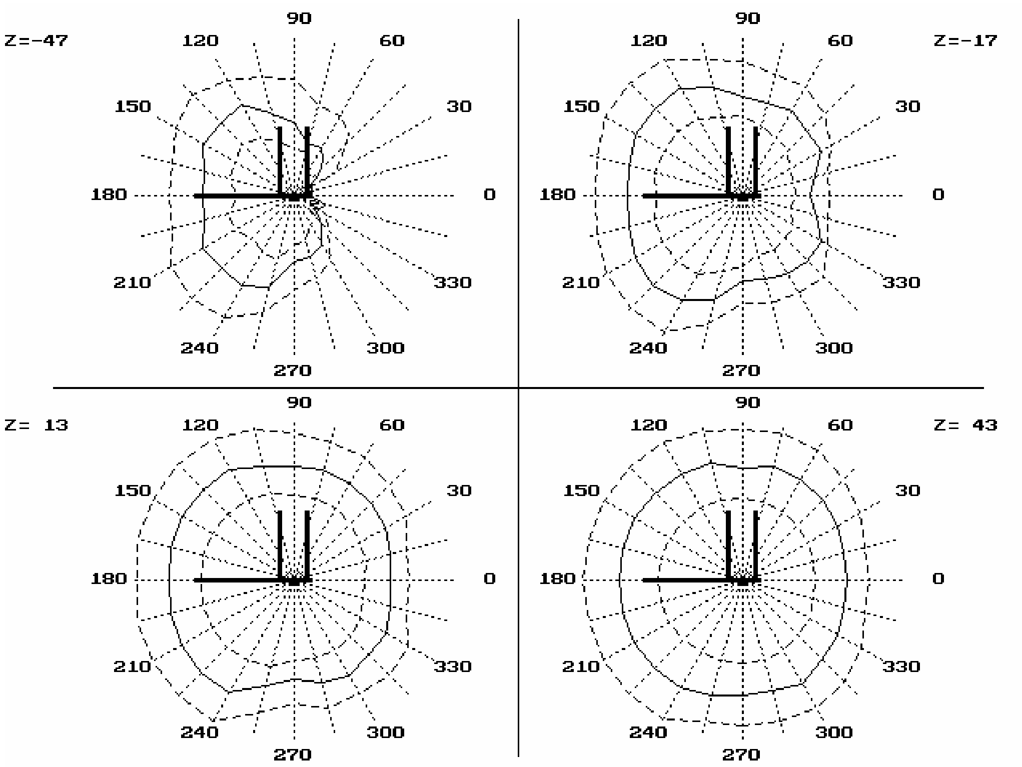
Horizontal Plane (XY)



Reference: RSC Energia Documents

Figure 6.1.3.3.1-23 Accessibility zones with right hand, seated pose, horizontal plane (XY), taking into account the flexibility of the spine.

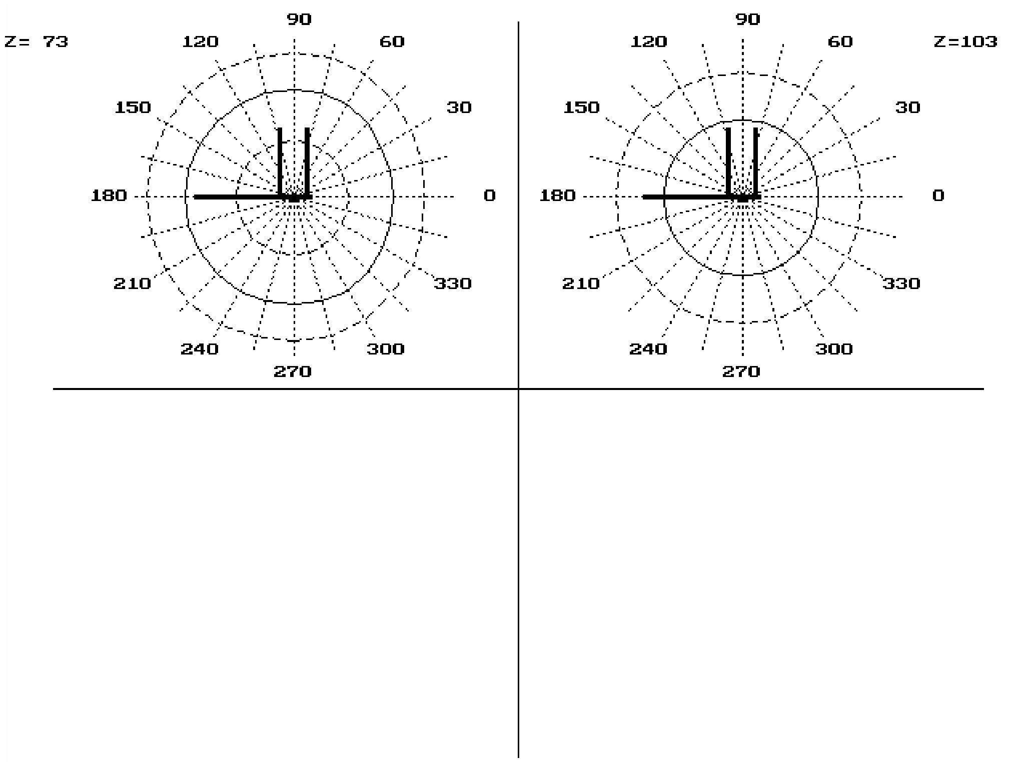
Horizontal Plane (XY)



Reference: RSC Energia Documents

Figure 6.1.3.3.1-24 Accessibility zones with right hand, seated pose, horizontal plane (XY), taking into account the flexibility of the spine.

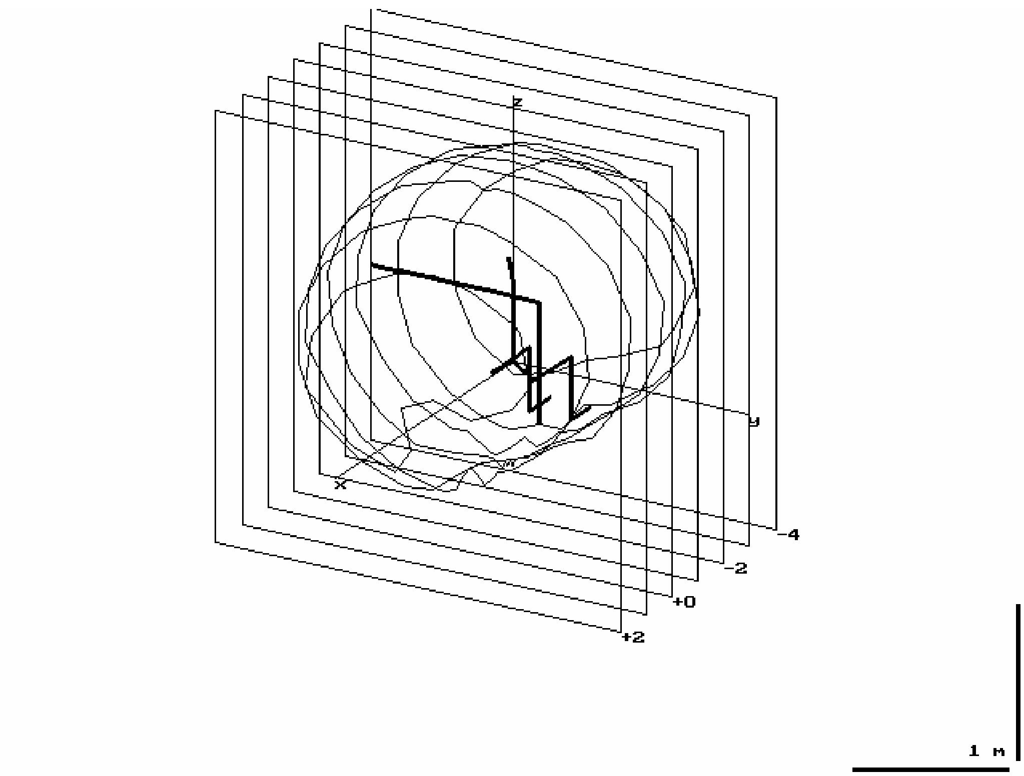
Horizontal Plane (XY)



Reference: RSC Energia Documents

Figure 6.1.3.3.1-25 Accessibility zones with right hand, seated pose, horizontal plane (XY), taking into account the flexibility of the spine.

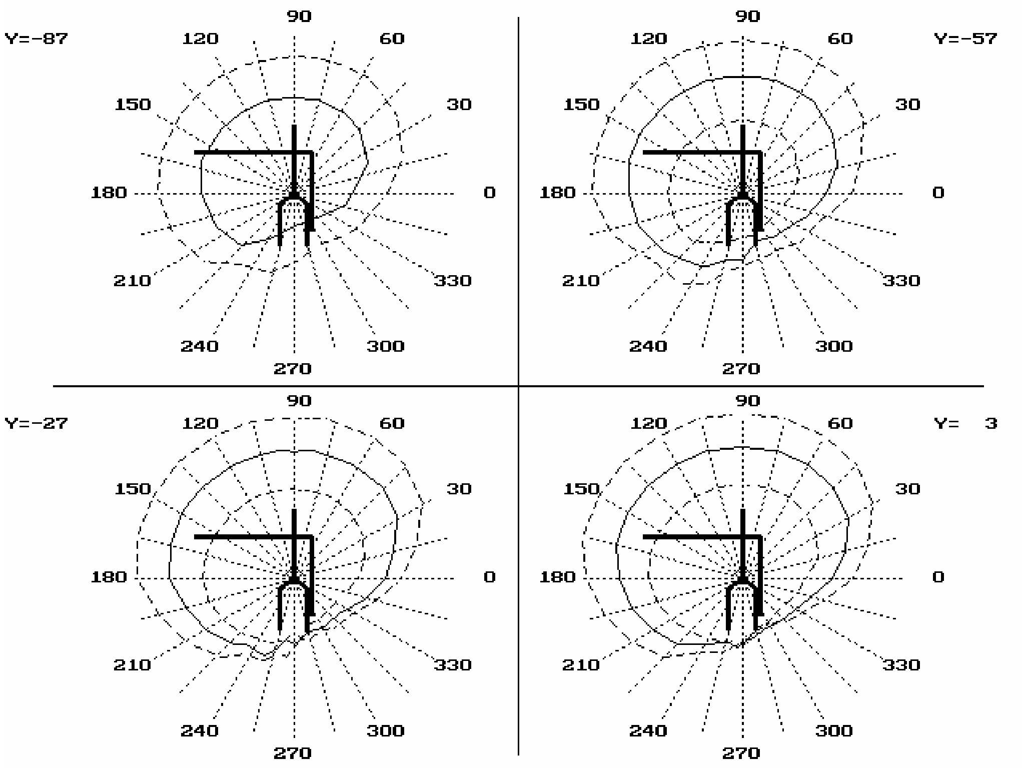
Frontal Plane (YZ)



Reference: RSC Energia Documents

Figure 6.1.3.3.1-26 Accessibility zones with right hand, seated pose, frontal plane (YZ), taking into account the flexibility of the spine.

Frontal Plane (YZ)



Reference: RSC Energia Documents

Figure 6.1.3.3.1-27 Accessibility zones with right hand, seated pose, frontal plane (YZ), taking into account the flexibility of the spine.

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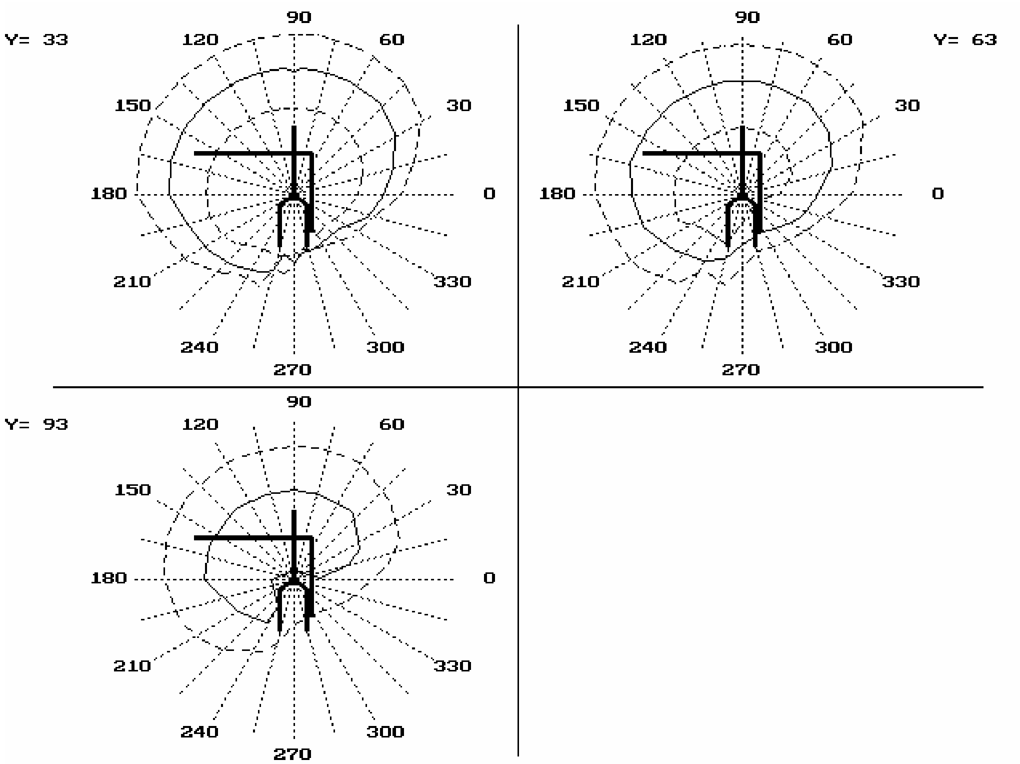
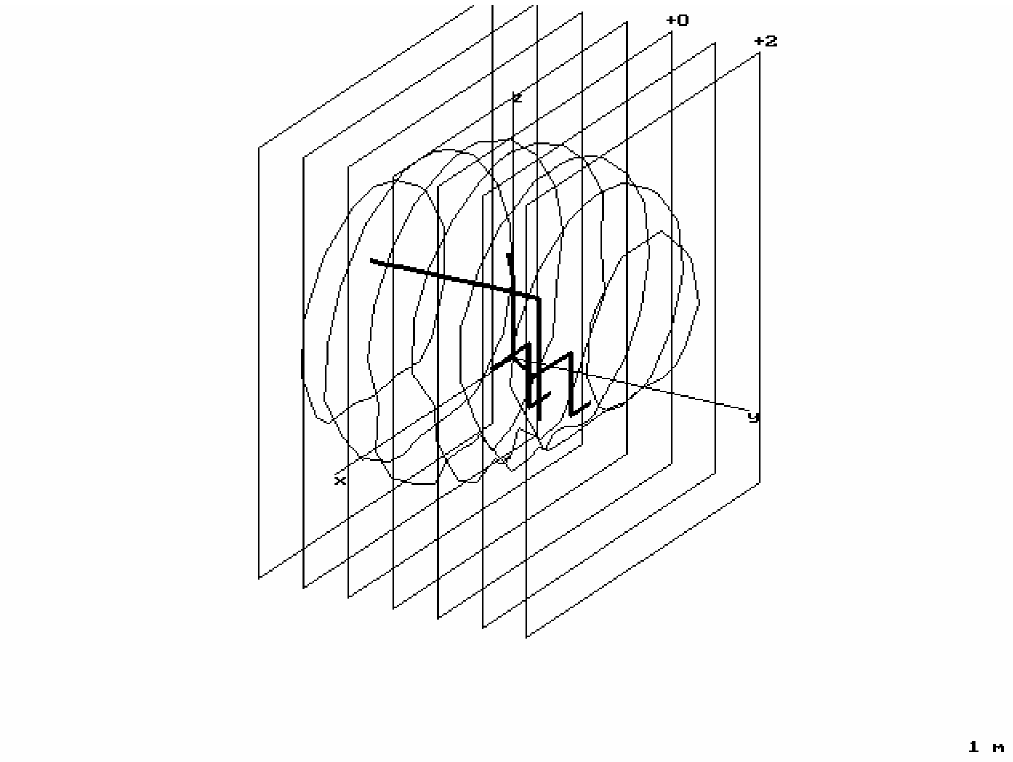
Frontal Plane (YZ)



Reference: RSC Energia Documents

Figure 6.1.3.3.1-28 Accessibility zones with right hand, seated pose, frontal plane (YZ), taking into account the flexibility of the spine.

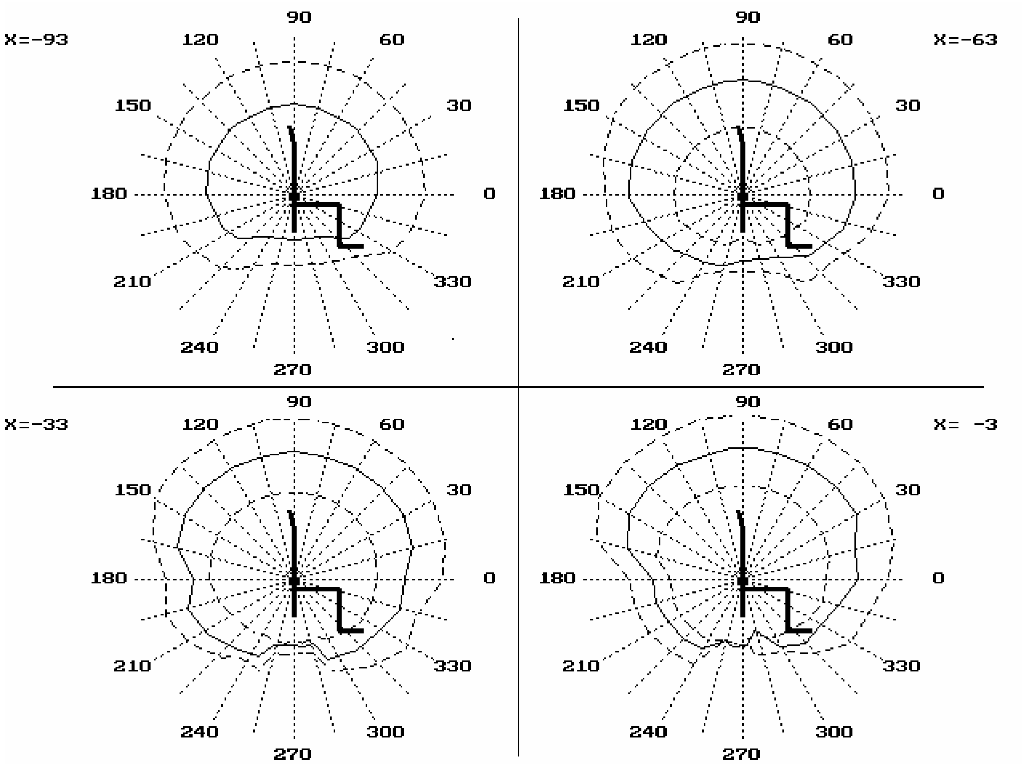
Profile Plane (XZ)



Reference: RSC Energia Documents

Figure 6.1.3.3.1-29 Accessibility zones with right hand, seated pose, profile plane (YZ), taking into account the flexibility of the spine.

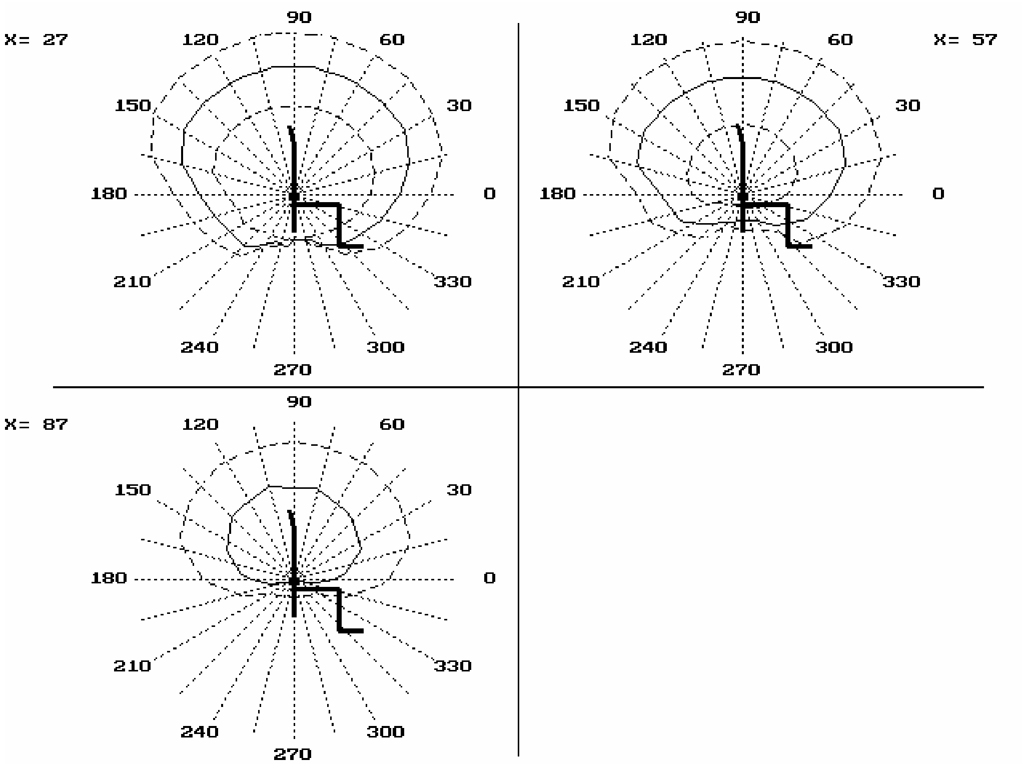
Profile Plane (XZ)



Reference: RSC Energia Documents

Figure 6.1.3.3.1-30 Accessibility zones with right hand, seated pose, profile plane (YZ), taking into account the flexibility of the spine.

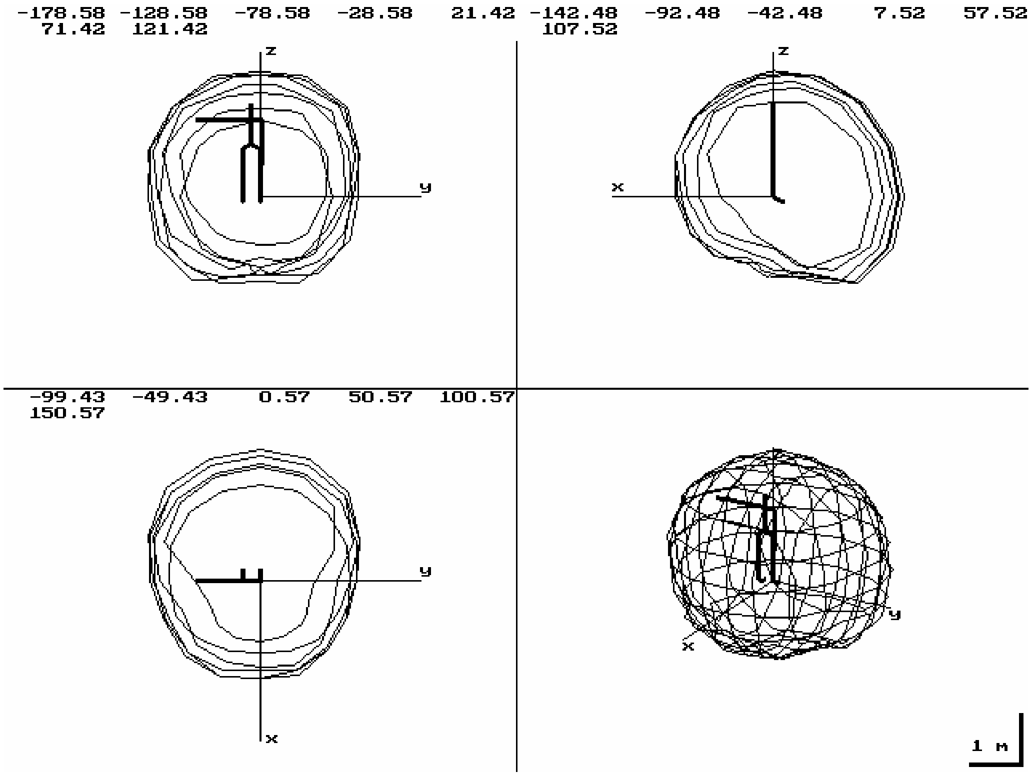
Profile Plane (XZ)



Reference: RSC Energia Documents

Figure 6.1.3.3.1-31 Accessibility zones with right hand, seated pose, profile plane (YZ), taking into account the flexibility of the spine.

Standing pose, taking into account the flexibility of the spine



Comments:

Accessibility zones with right hand, seated pose, horizontal plane (XY), for men and women :

---------------	5th percentile outer boundary and inner boundary (inner curve);
- - - - - - - -	50th percentile outer boundary;
_._._._._.	95th percentile outer boundary.

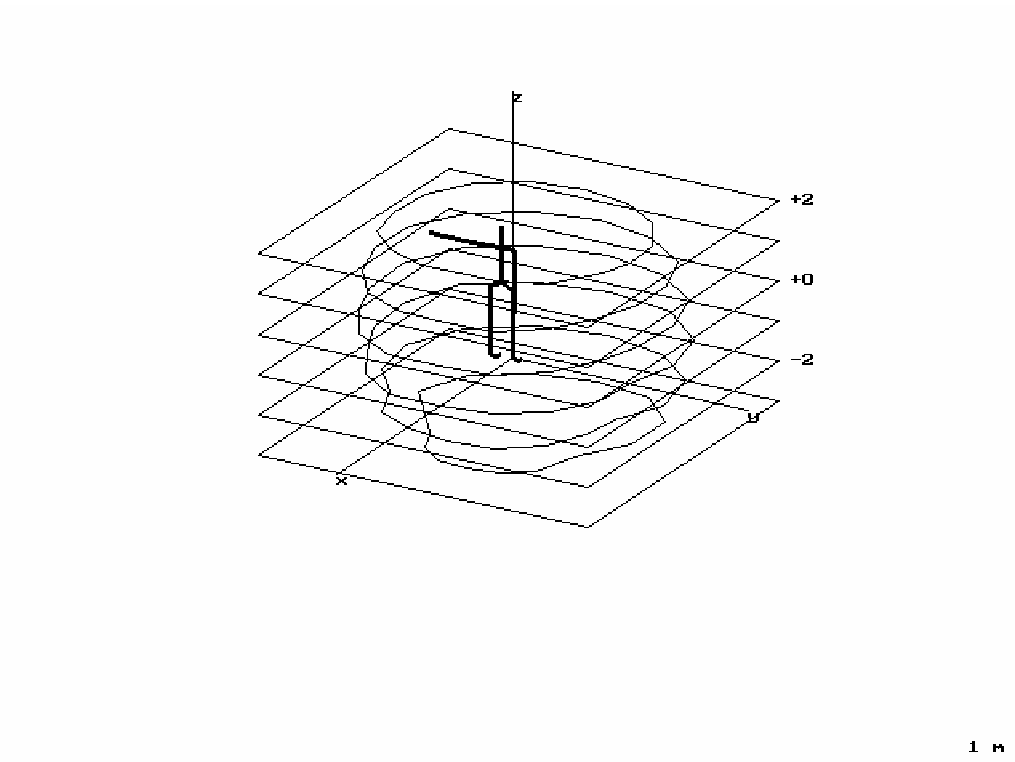
The boundaries apply to 1-g conditions only. Microgravity will cause the spine to lengthen, and adjustments should be made based on a new shoulder pivot location.

The data presented in Figures 6.1.3.3.1-32 to 6.1.3.3.1-41 illustrate the results obtained from calculating accessibility zones using a computer model based on the initial data contained in this document for Russian men and women. The computer model looks at seated, standing, and floating-while-restrained postures. This model also makes it possible to obtain three-dimensional accessibility zones and any cross sections thereof in the polar or Cartesian coordinate systems for groups or separate operators, various gravitational conditions, and postures involving different restraint modes and limitations on joint motion (e.g., due to movement conditions, restraint devices, space suit, etc.).

Reference: RSC Energia documents

Figure 6.1.3.3.1-32 Accessibility zones with right hand, standing pose, taking into account the flexibility of the spine.

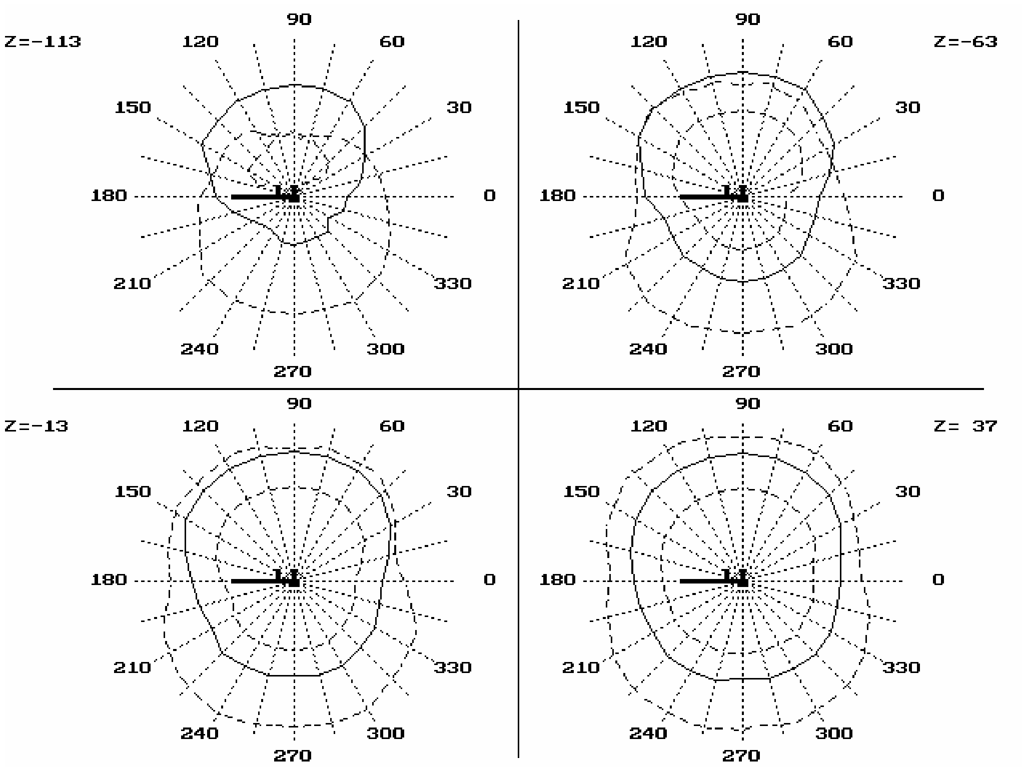
Horizontal Plane (XY)



Reference: RSC Energia documents

Figure 6.1.3.3.1-33 Accessibility zones with right hand, standing pose, horizontal plane (XY), taking into account the flexibility of the spine.

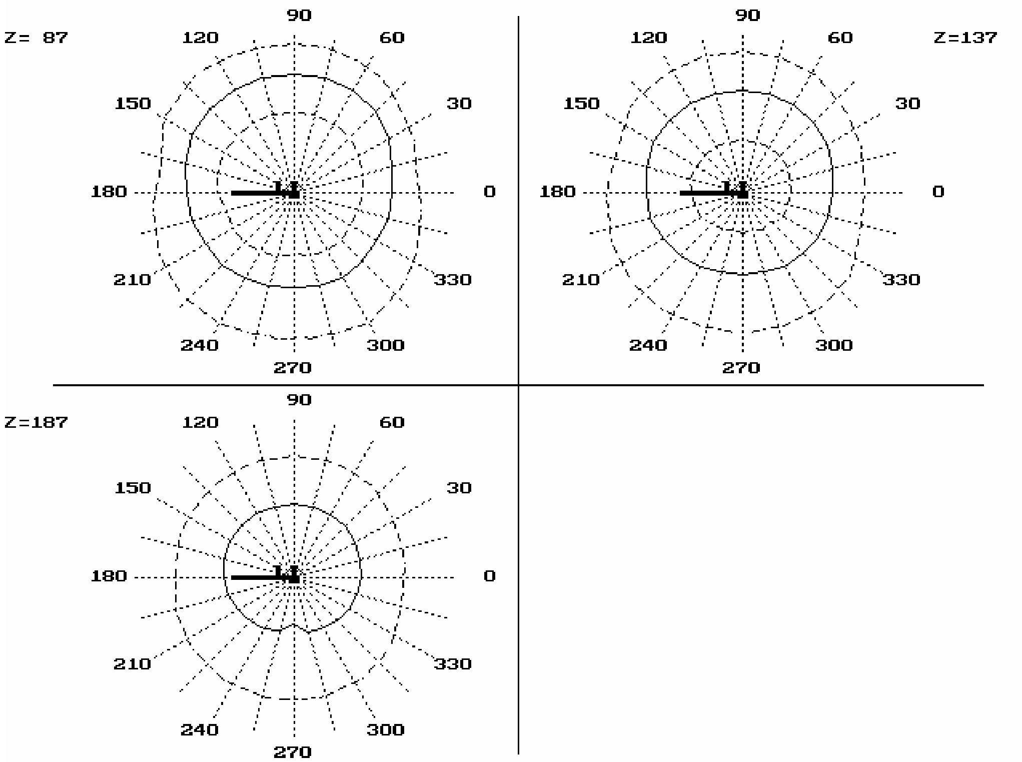
Horizontal Plane (XY)



Reference: RSC Energia documents

Figure 6.1.3.3.1-34 Accessibility zones with right hand, standing pose, horizontal plane (XY), taking into account the flexibility of the spine.

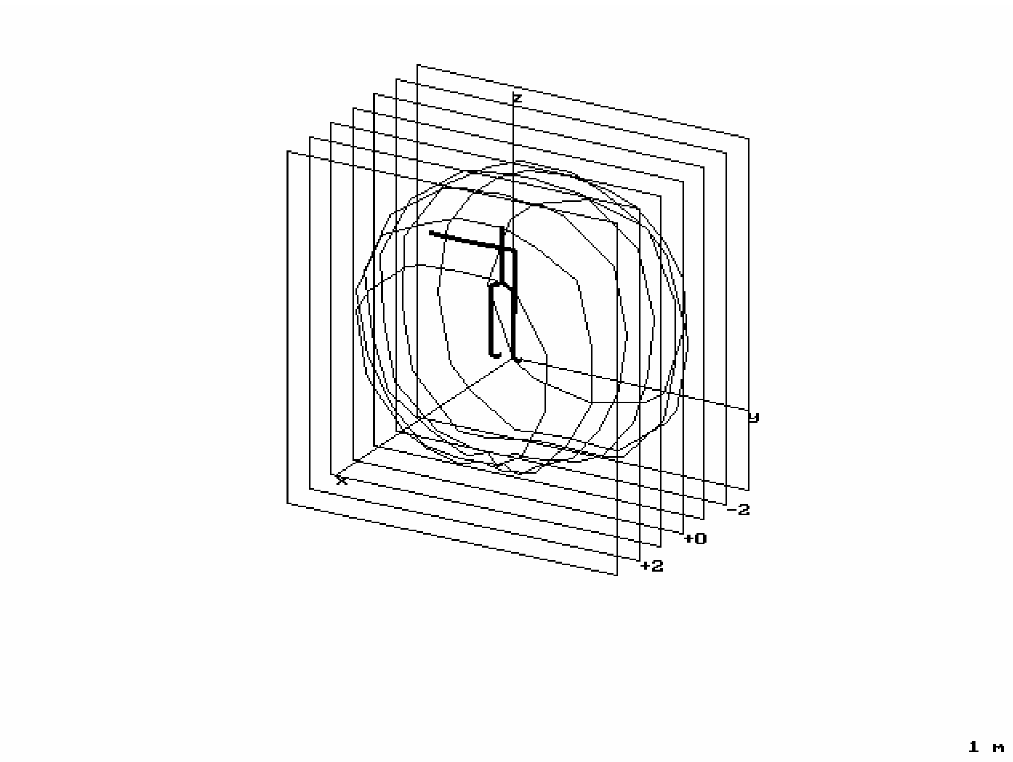
Horizontal Plane (XY)



Reference: RSC Energia documents

Figure 6.1.3.3.1-35 Accessibility zones with right hand, standing pose, horizontal plane (XY), taking into account the flexibility of the spine.

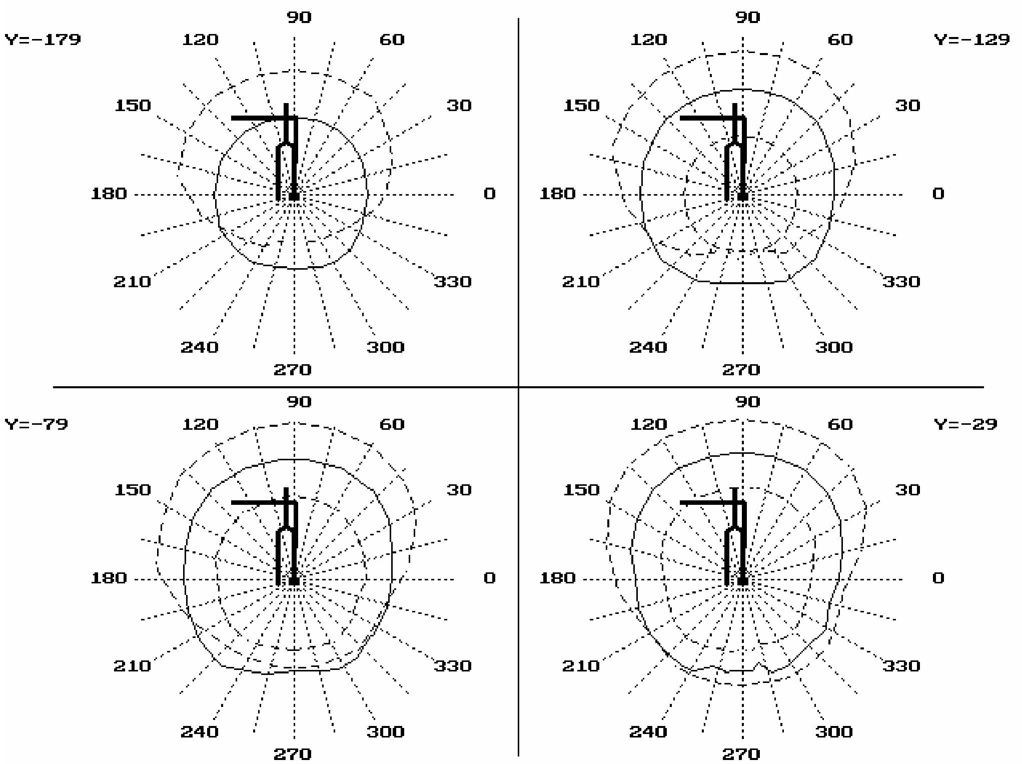
Frontal Plane (YZ)



Reference: RSC Energia documents

Figure 6.1.3.3.1-36 Accessibility zones with right hand, standing pose, frontal plane (YZ), taking into account the flexibility of the spine.

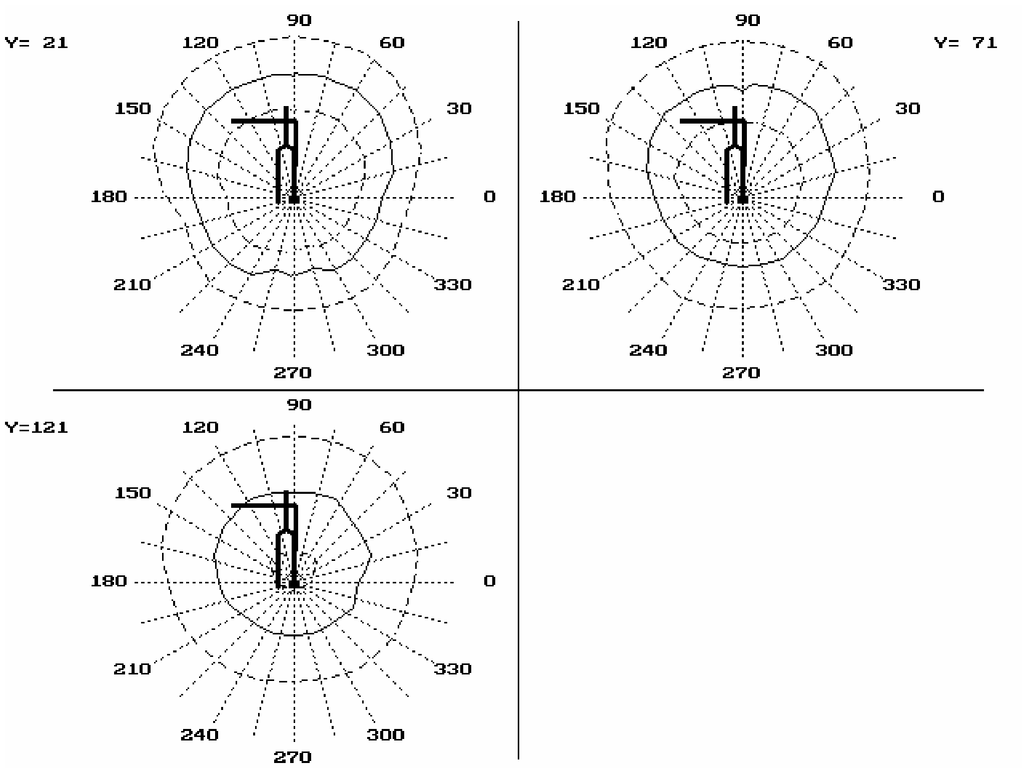
Frontal Plane (YZ)



Reference: RSC Energia documents

Figure 6.1.3.3.1-37 Accessibility zones with right hand, standing pose, frontal plane (YZ), taking into account the flexibility of the spine.

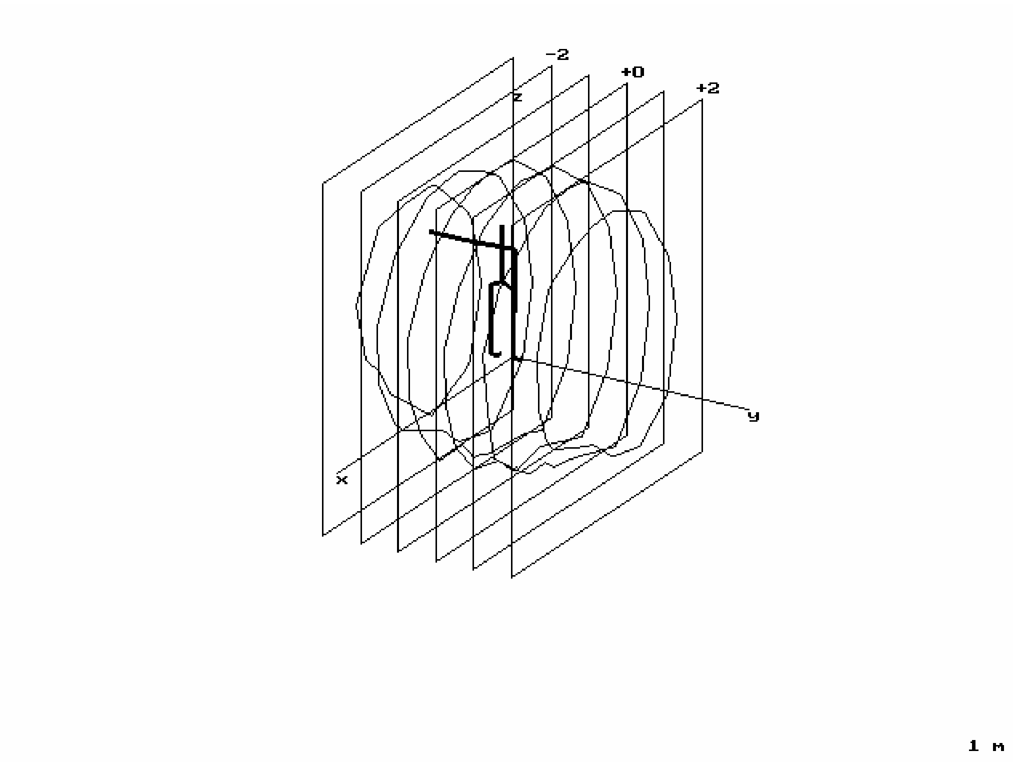
Frontal Plane (YZ)



Reference: RSC Energia documents

Figure 6.1.3.3.1-38 Accessibility zones with right hand, standing pose, frontal plane (YZ), taking into account the flexibility of the spine.

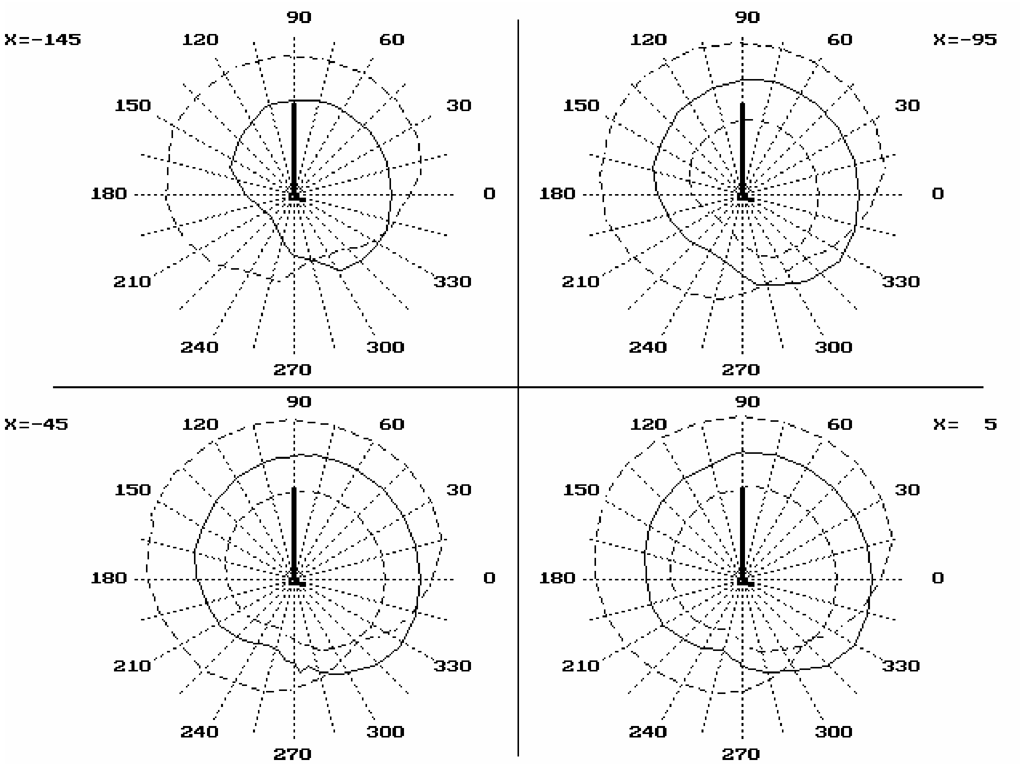
Profile Plane (XZ)



Reference: RSC Energia documents

Figure 6.1.3.3.1-39 Accessibility zones with right hand, standing pose, profile plane (XZ), taking into account the flexibility of the spine.

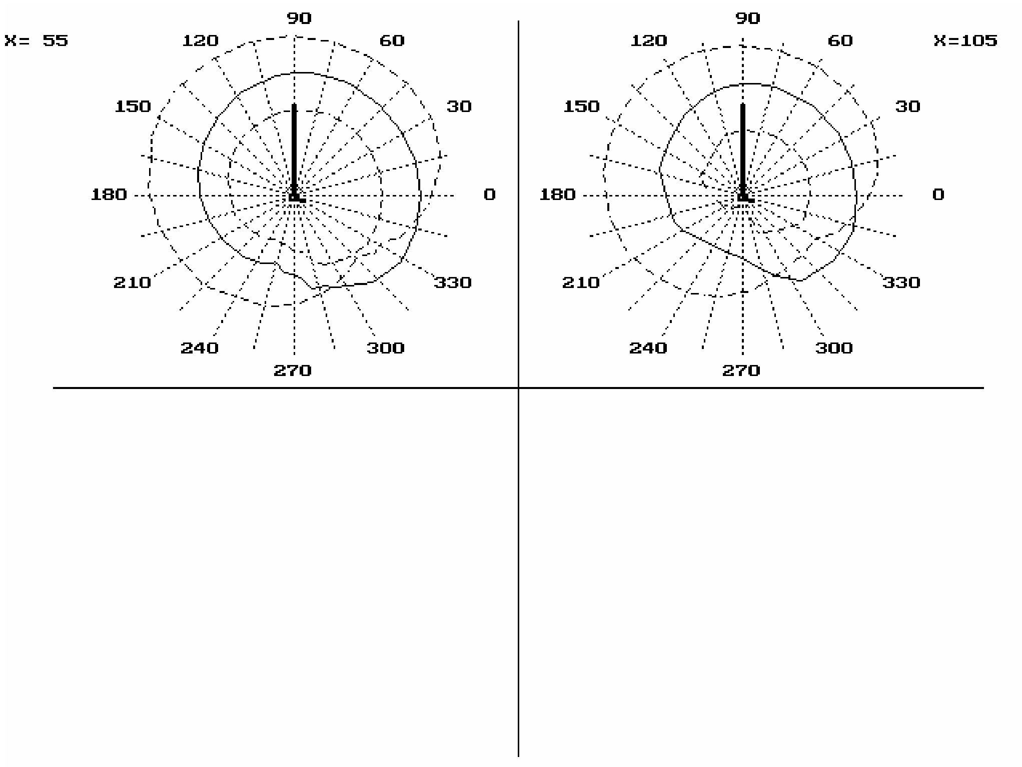
Profile Plane (XZ)



Reference: RSC Energia documents

Figure 6.1.3.3.1-40 Accessibility zones with right hand, standing pose, profile plane (XZ), taking into account the flexibility of the spine.

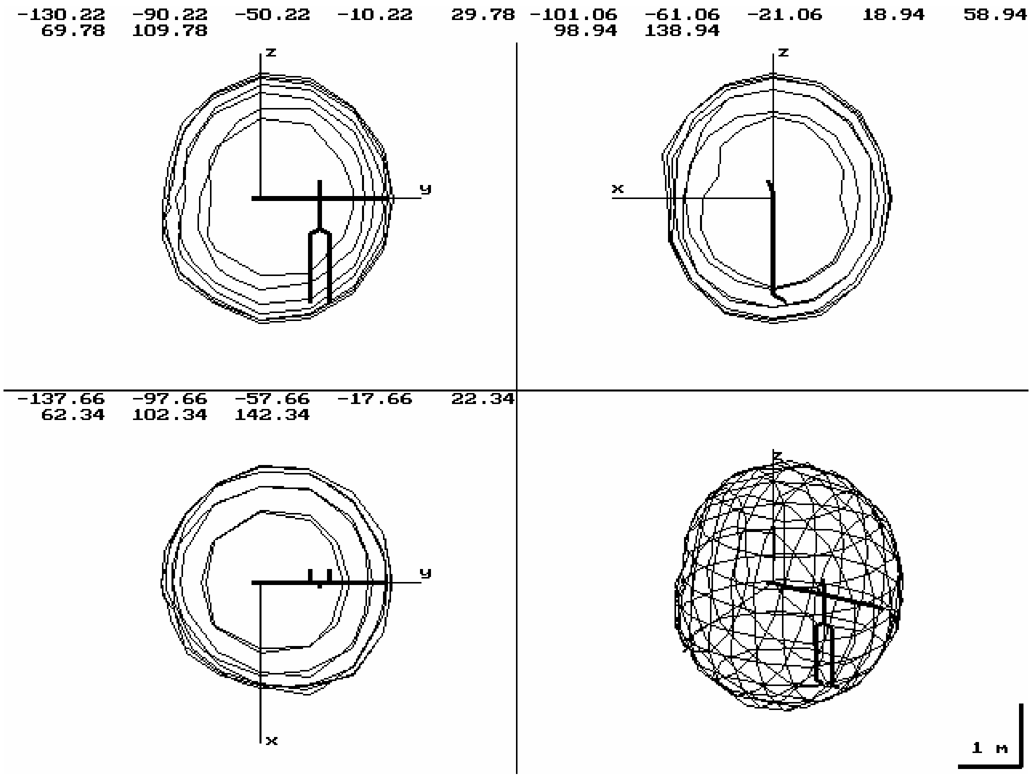
Profile Plane (XZ)



Reference: RSC Energia documents

Figure 6.1.3.3.1-41 Accessibility zones with right hand, standing pose, profile plane (XZ), taking into account the flexibility of the spine.

Free-floating pose with one hand restrained



Comments:

Accessibility zones with right hand, seated pose, horizontal plane (XY), for men and women :

---------------	5th percentile outer boundary and inner boundary (inner curve);
- - - - - - - -	50th percentile outer boundary;
_._._._._.	95th percentile outer boundary.

The boundaries apply to 1-g conditions only. Microgravity will cause the spine to lengthen, and adjustments should be made based on a new shoulder pivot location.

The data presented in Figures 6.1.3.3.1-42 to 6.1.3.3.1-51 illustrate the results obtained from calculating accessibility zones using a computer model based on the initial data contained in this document for Russian men and women. The computer model looks at seated, standing, and floating-while-restrained postures. This model also makes it possible to obtain three-dimensional accessibility zones and any cross sections thereof in the polar or Cartesian coordinate systems for groups or separate operators, various gravitational conditions, and postures involving different restraint modes and limitations on joint motion (e.g., due to movement conditions, restraint devices, space suit, etc.).

Reference: RSC Energia documents

Figure 6.1.3.3.1-42 Accessibility zones, free-floating with one hand restrained.

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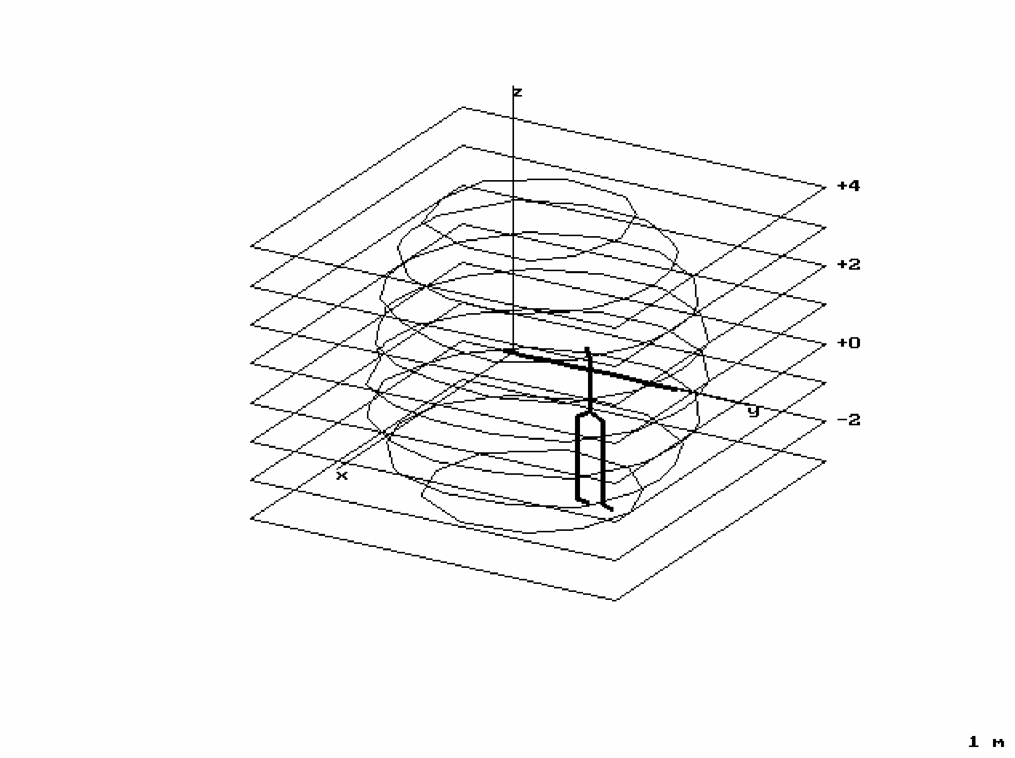
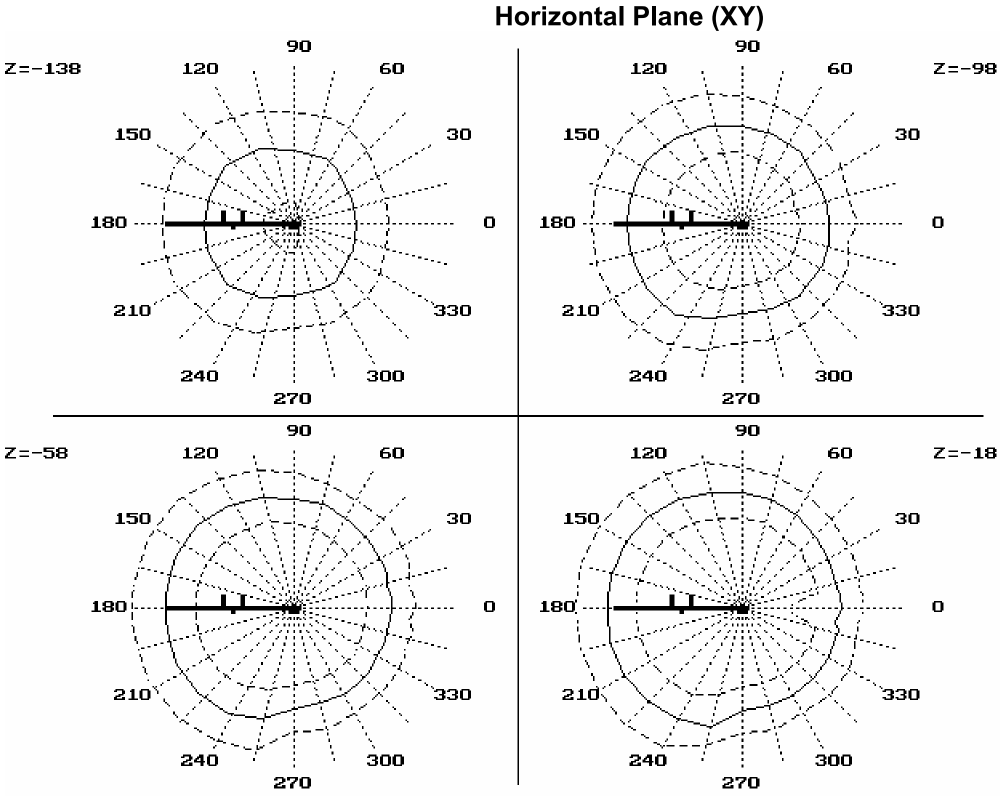
Horizontal Plane (XY)



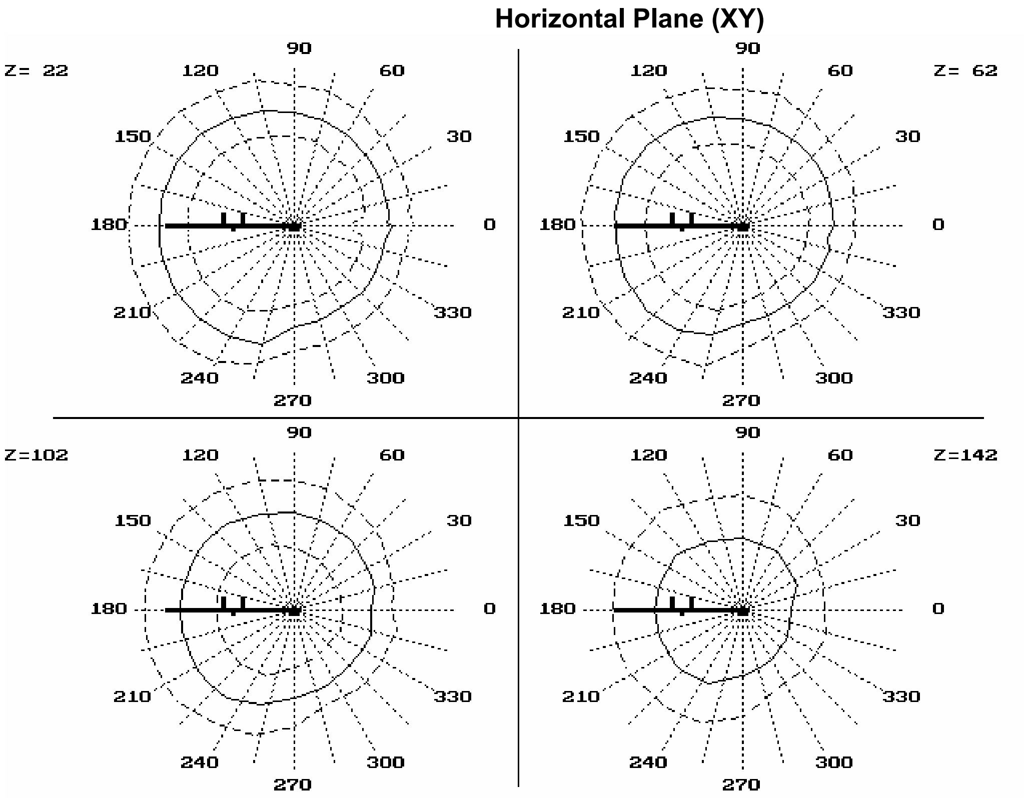
Reference: RSC Energia documents

Figure 6.1.3.3.1-43 Accessibility zones, free-floating with one hand restrained, horizontal plane (XY).



Reference: RSC Energia documents

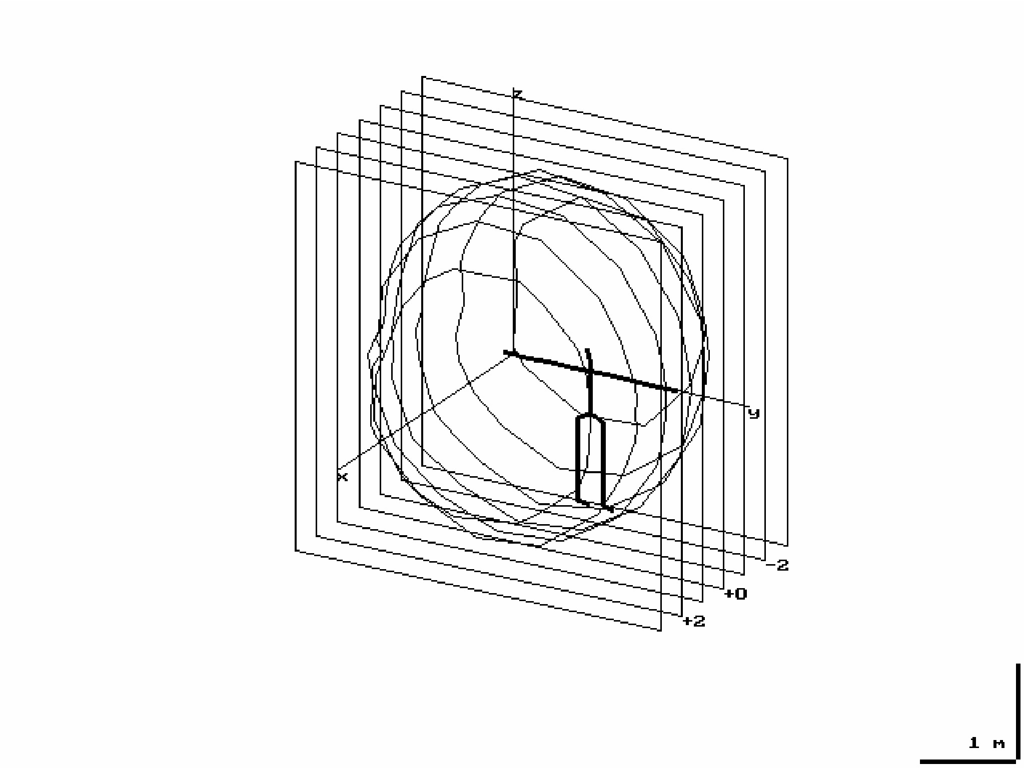
Figure 6.1.3.3.1-44 Accessibility zones, free-floating with one hand restrained, horizontal plane (XY).



Reference: RSC Energia documents

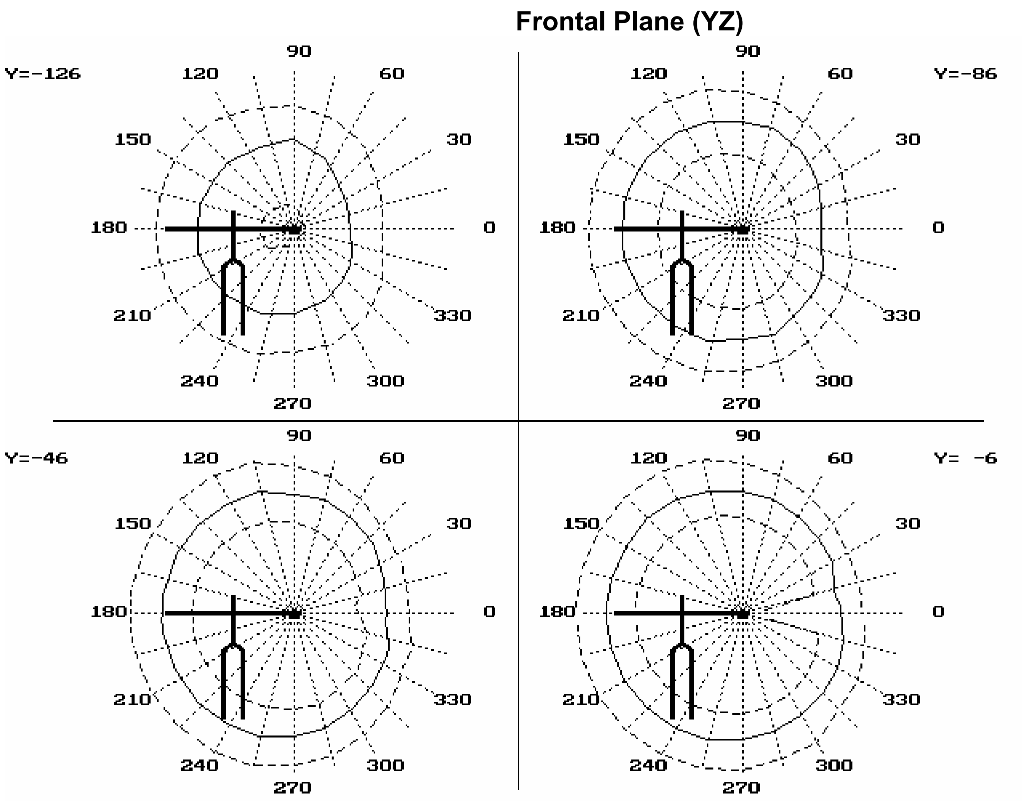
Figure 6.1.3.3.1-45 Accessibility zones, free-floating with one hand restrained, horizontal plane (XY).

Frontal Plane (XZ)



Reference: RSC Energia documents

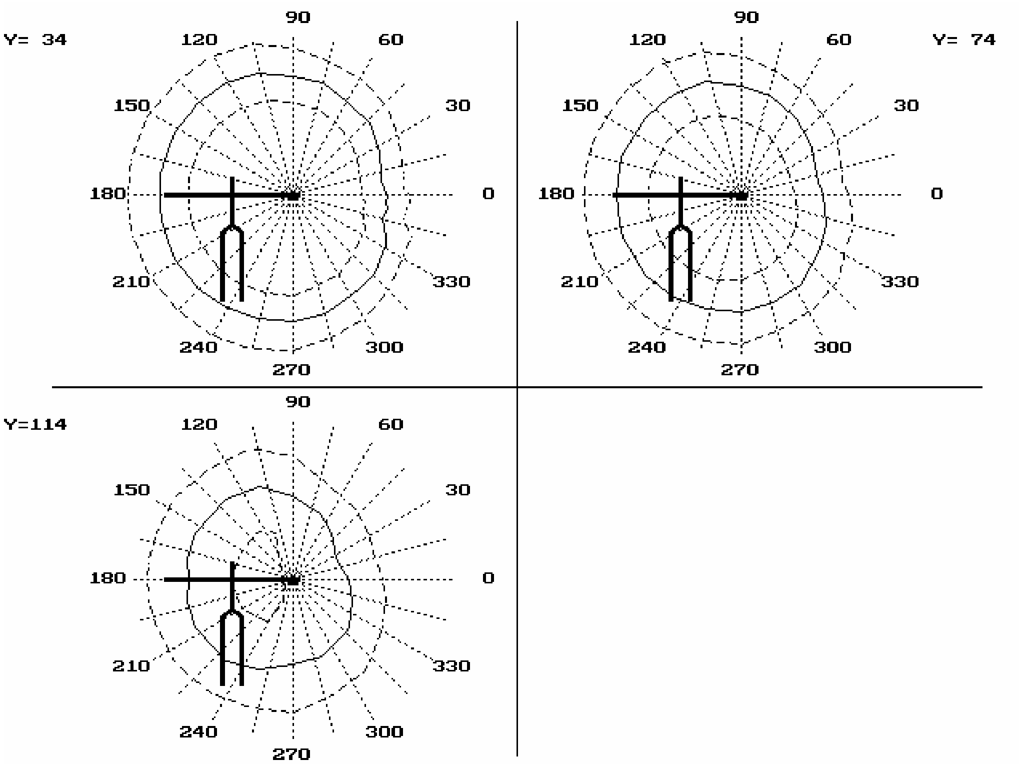
Figure 6.1.3.3.1-46 Accessibility zones, free-floating with one hand restrained, frontal plane (YZ).



Reference: RSC Energia documents

Figure 6.1.3.3.1-47 Accessibility zones, free-floating with one hand restrained, frontal plane (YZ).

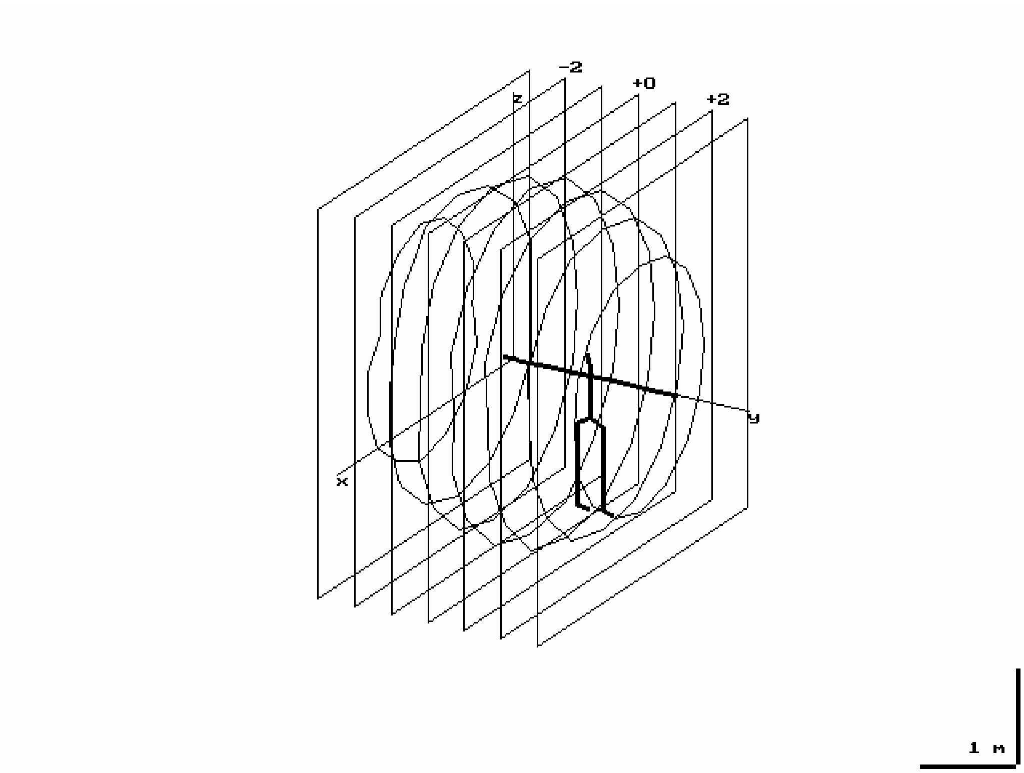
Frontal Plane (YZ)



Reference: RSC Energia documents

Figure 6.1.3.3.1-48 Accessibility zones, free-floating with one hand restrained, frontal plane (YZ).

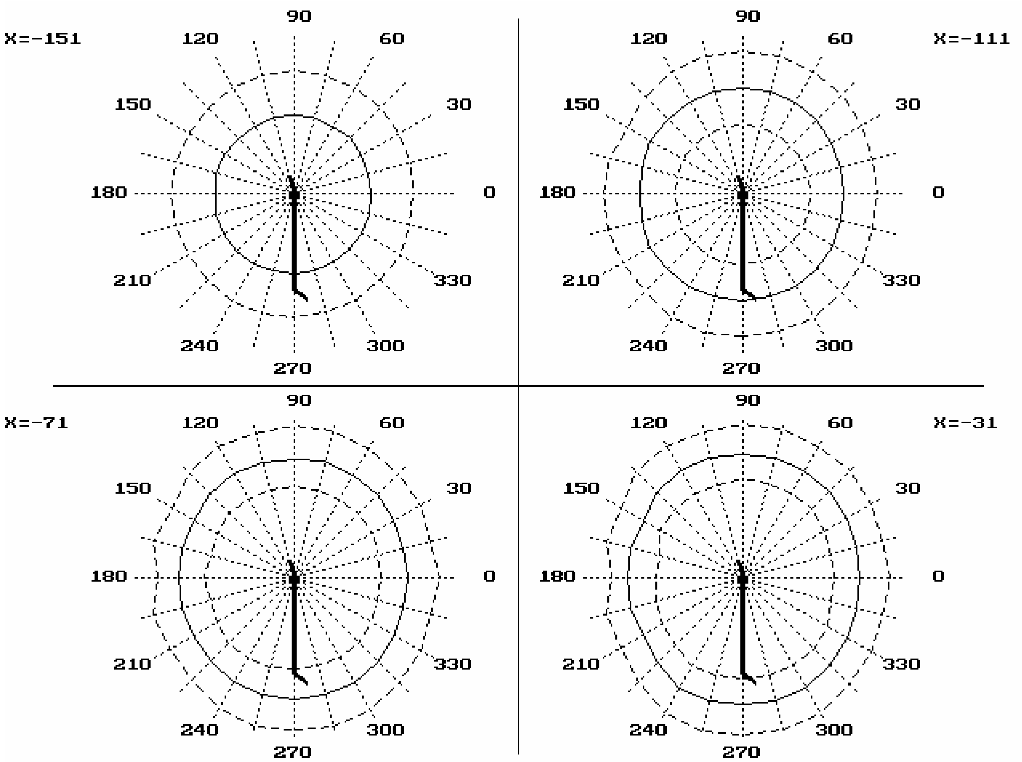
Profile Plane (XZ)



Reference: RSC Energia documents

Figure 6.1.3.3.1-49 Accessibility zones, free-floating with one hand restrained, profile plane (XZ).

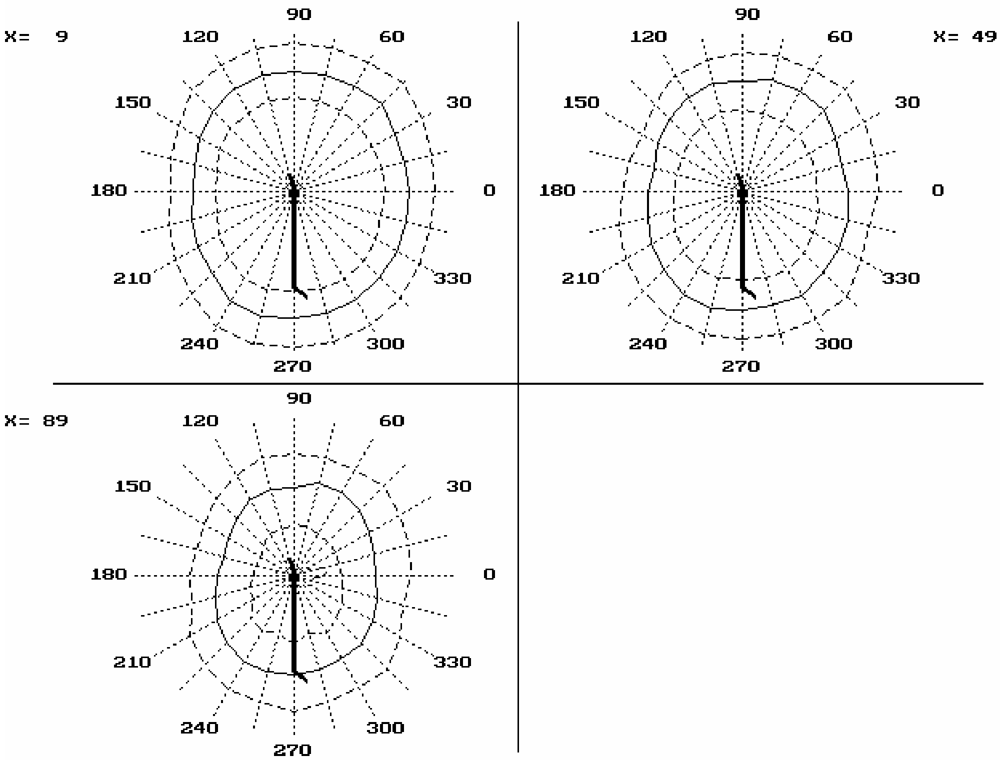
Profile Plane (XZ)



Reference: RSC Energia documents

Figure 6.1.3.3.1-50 Accessibility zones, free-floating with one hand restrained, profile plane (XZ).

Profile Plane (XZ)



Reference: RSC Energia documents

Figure 6.1.3.3.1-51 Accessibility zones, free-floating with one hand restrained, profile plane (XZ).

6.1.3.4 BODY SURFACE AREA

6.1.3.4.1 DESIGN REQUIREMENTS BASED ON BODY SURFACE AREA DATA

	Body surface area cm^2 ($inches^2$)
5th percentile	17, 600 (2730)
50th percentile	20, 190 (3130)
95th percentile	22, 690 (3520)

Comments:

(a) The body surface area was determined for the selection presented in 6.1.3.2.1 of this document.

(b) Body surface areas are valid for 1 g.

Reference: Man-Systems Integration Standards: NASA STD 3000; Volume 1, Revision B

Figure 6.1.3.4.1.-1 Body surface area of crew members (men).

6.1.3.5 BODY VOLUME

6.1.3.5.1 DESIGN REQUIREMENTS BASED ON WHOLE BODY VOLUME DATA

	Body volume cm^3 ($inches^3$)
5th percentile	68, 640 (4190)
50th percentile	85, 310 (4210)
95th percentile	101, 840 (6210)

Comments:

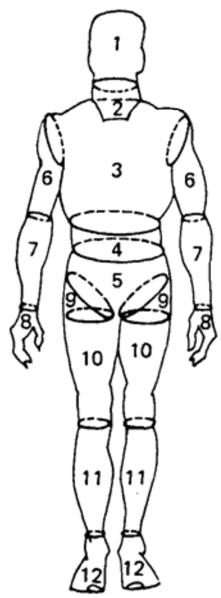
(à) The body volume was determined for the selection presented in 6.1.3.2.1 of this document.

(b) Body volumes are valid for 1 g.

Reference: Man-Systems Integration Standards: NASA STD 3000; Volume 1, Revision B

Figure 6.1.3.5.1-1 Body volume of crew members (men).

6.1.3.5.2 . DESIGN REQUIREMENTS BASED ON BODY SEGMENT VOLUME DATA



Segment		Volume, cm^3 (in^3) 5th percentile	50th percentile	95th percentile
1	Head	4260 (260)	4400 (270)	4550 (280)
2	Neck	930 (60)	1100 (70)	1270 (80)
3	Thorax	20420 (1250)	26110 (1590)	31760 (1940)
4	Abdomen	2030 (120)	2500 (150)	2960 (180)
5	Pelvis	9420 (570)	12300 (750)	15150 (920)
6	Upper arm *	1600 (100)	2050 (130)	2500 (150)
7	Forearm *	1180 (70)	1450 (90)	1720 (100)
8	Hand	460 (30)	530 (30)	610 (40)
9	Hip flap *	2890 (180)	3640 (220)	4380 (270)
10	Thigh minus flap *	5480 (330)	6700 (410)	7920 (480)
11	Calf *	3320 (200)	4040 (250)	4760 (290)
12	Foot *	840 (50)	1010 (60)	1180 (70)
5 + 4 + 3	Torso	31870 (1940)	40910 (2450)	49870 (3040)
9 + 10	Thigh *	8360 (510)	10340 (630)	12300 (750)
7 + 8	Forearm plus hand *	1640 (100)	1980 (120)	2320 (140)

Notes:
* Average of right and left sides

Comments:

a) The body volume was determined for the selection presented in 6.1.3.2.1 of this document.

b) Body volumes are valid for 1 g.

Reference: Man-Systems Integration Standards: NASA STD 3000; Volume 1, Revision B

Figure 6.1.3.5.2.-1 Body segment volume of crew members (men).

6.1.3.6 BODY MASS CHARACTERISTICS

6.1.3.6.1 BODY MASS

6.1.3.6.1.1 DESIGN REQUIREMENTS BASED ON WHOLE BODY MASS DATA

	Total body mass, kg		
	5th percentile	50th percentile	95th percentile
Men	65.8	82.2	98.5
Women	41.0	51.5	61.7

Comments:

(a) The body mass was determined for the selection presented in 6.1.3.2.1 of this document.

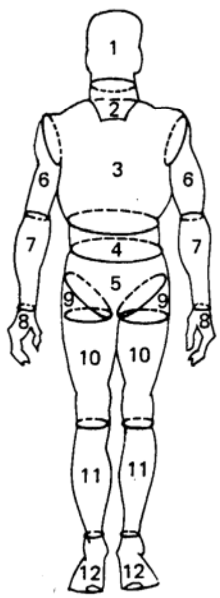
(b) Body masses are valid for 1 g.

(c) The mass of crew members to be launched in the Kazbek-U chair on the Soyuz-T rescue vehicle may not exceed 85 kg.

Reference: Man-Systems Integration Standards: NASA STD 3000; Volume 1, Revision B

Figure 6.1.3.6.1.1-1Whole body mass for crew members

6.1.3.6.1.2 DESIGN REQUIREMENTS BASED ON BODY PART MASS DATA



Segment		Mass, gm (oz, weight) 5th percentile	50th percentile	95th percentile
1	Head	4260 (150)	4400 (160)	4550 (160)
2	Neck	930 (30)	1100 (40)	1270 (40)
3	Thorax	20420 (720)	26110 (920)	31760 (1120)
4	Abdomen	2030 (70)	2500 (90)	2960 (100)
5	Pelvis	9420 (330)	12300 (430)	15150 (530)
6	Upper arm *	1600 (60)	2050 (70)	2500 (90)
7	Forearm *	1180 (40)	1450 (50)	1720 (60)
8	Hand	460 (20)	530 (20)	610 (20)
9	Hip flap *	2890 (100)	3640 (130)	4380 (150)
10	Thigh minus flap *	5480 (190)	6700 (240)	7920 (280)
11	Calf *	3320 (120)	4040 (140)	4760 (170)
12	Foot *	840 (30)	1010 (40)	1180 (40)
5 + 4 + 3	Torso	31870 (1120)	40910 (1440)	49870 (1760)
9 + 10	Thigh *	8360 (290)	10340 (360)	12300 (430)
7 + 8	Forearm plus hand *	1640 (60)	1980 (70)	2320 (80)

* Average of right and left sides

Comments:

(a) The body part mass was determined for the selection presented in 6.1.3.2.1 of this document.

(b) Body part masses are valid for 1 g.

Reference: Man-Systems Integration Standards: NASA STD 3000; Volume 1, Revision B

Figure 6.1.3.6.1.2-1——Mass of body parts for U.S. male crew members

6.1.3.6.2 CENTER OF MASS

6.1.3.6.2.1 DESIGN REQUIREMENTS BASED ON WHOLE BODY CENTER OF MASS DATA

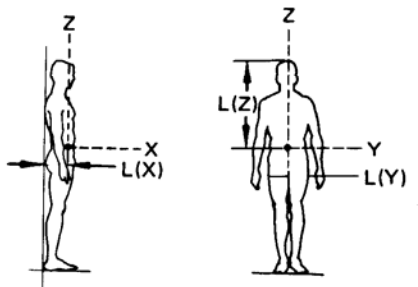
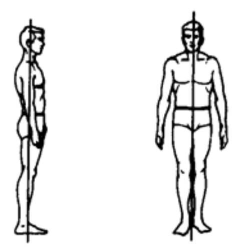
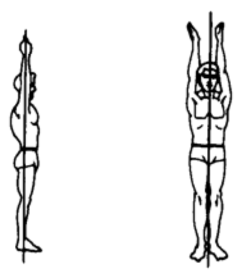
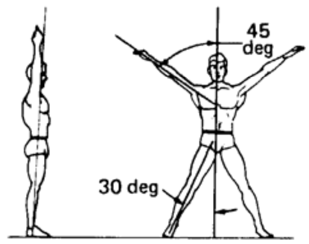
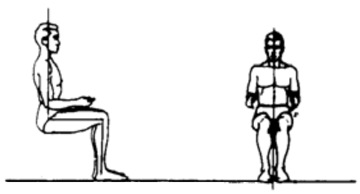
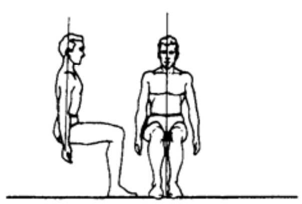
Whole body center of mass for the American male crewmember (1 gravity only) cm (in)				
	Dimension	5th percentile	50th percentile	95th percentile
 L(Y) = 1/2 distance between anterior superior iliac spine landmarks (1/2 bispinous breadth)				
	L(X)	8.6 (3.4)	9.1 (3.6)	9.6 (3.8)
	L(Y)	11.7 (4.6)	12.5 (4.9)	13.3 (5.2)
1. Standing	L(Z)	75.7 (29.8)	80.2 (31.6)	84.7 (33.3)
	L(X)	8.7 (3.4)	9.0 (3.6)	9.4 (3.7)
	L(Y)	11.7 (4.6)	12.5 (4.9)	13.3 (5.2)
2. Standing, Arms Over Head	L(Z)	69.9 (27.5)	73.9 (29.1)	77.9 (30.7)

Figure 6.1.3.6.2.1-1 Center of mass location for whole body (men).

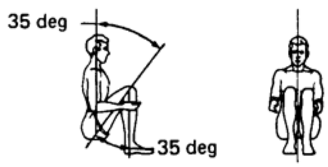
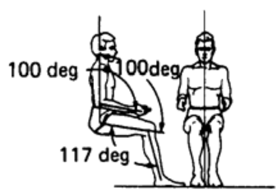
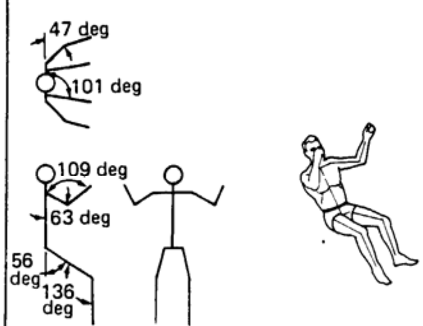
Comments: (a) The centers of mass were determined for the selection presented in 6.1.3.2.1 of this document. (b) Whole body centers of mass are valid for 1 g. L(Z) must be multiplied by 0.9 to evaluate the location of the center of mass under microgravity conditions. Reference: Man-Systems Integration Standards: NASA STD 3000; Volume 1, Revision B

Whole body center of mass for the American male crewmember (1 gravity only) cm (in)				
	Dimension	5th percentile	50th percentile	95th percentile
 3. Spread Eagle	L(X)	8.2 (3.2)	8.6 (3.4)	9.0 (3.6)
	L(Y)	11.7 (4.6)	12.5 (4.9)	13.3 (5.2)
	L(Z)	69.4 (27.3)	73.5 (28.9)	77.5 (30.5)
 4. Sitting	L(X)	19.4 (7.7)	20.6 (8.1)	21.8 (8.6)
	L(Y)	11.7 (4.6)	12.5 (4.9)	13.3 (5.2)
	L(Z)	65.2 (25.7)	68.6 (27.0)	71.9 (28.3)
 5. Sitting, Forearms Down	L(X)	18.9 (7.4)	20.0 (7.9)	21.1 (8.3)
	L(Y)	11.7 (4.6)	12.5 (4.9)	13.3 (5.2)
	L(Z)	66.0 (26.0)	69.3 (27.3)	72.5 (28.6)

Comments:
(a) Centers of mass were determined for the selection presented in 6.1.3.2.1 of this document.
(b) Centers of mass are valid for 1 g. L(Z) must be multiplied by 0.9 to evaluate the location of the center of mass under microgravity conditions.

Reference: Man-Systems Integration Standards: NASA STD 3000; Volume 1, Revision B

Figure 6.1.3.6.2.1-2Center of mass location for whole body (men). (Continued).

Whole body center of mass for the American male crewmember (1 gravity only) cm (in)				
	Dimension	5th percentile	50th percentile	95th percentile
 6. Sitting, Thighs Elevated	L(X)	17.6 (6.9)	18.8 (7.4)	20.1 (7.9)
	L(Y)	11.7 (4.6)	12.5 (4.9)	13.3 (5.2)
	L(Z)	57.3 (22.5)	59.4 (23.4)	61.5 (24.2)
 7. Mercury Configuration	L(X)	19.4 (7.6)	20.5 (8.1)	21.5 (8.5)
	L(Y)	11.7 (4.6)	12.5 (4.9)	13.3 (5.2)
	L(Z)	66.8 (26.3)	69.9 (27.5)	73.0 (28.7)
 8. Relaxed (weightless)	L(X)	18.0 (7.1)	18.8 (7.4)	19.6 (7.7)
	L(Y)	11.7 (4.6)	12.5 (4.9)	13.3 (5.2)
	L(Z)	68.0 (26.8)	70.9 (27.9)	73.7 (29.0)

Comments:

(a) Centers of mass were determined for the selection presented in 6.1.3.2.1 of this document.

(b) Centers of mass are valid for 1 g. L(Z) must be multiplied by 0.9 to evaluate the location of the center of mass under microgravity conditions.

Reference: Man-Systems Integration Standards: NASA STD 3000; Volume 1, Revision B

Figure 6.1.3.6.2.1-3Center of mass location for whole body (men). (Continued).

Location of center of mass, cm = [A x (stature, cm)] + [B x (weight, lbs)] + [C]

Posture	Dimension	A	B	C	SE* (cm)	R**
1. Standing	L (X)	−0.035	0.024	11.008	0.33	0.7636
	L (Y)	0	0.021	8.609	0.89	0.4310
	L (Z)	0.486	−0.014	−4.775	1.33	0.9329
2. Standing (arms over head)	L (X)	−0.040	0.020	12.632	0.45	0.5823
	L (Y)	0	0.021	8.609	0.89	0.4310
	L (Z)	0.416	−0.007	0.305	1.52	0.8927
3. Spread eagle	L (X)	−0.031	0.020	10.443	0.36	0.6706
	L (Y)	0	0.021	8.609	0.89	0.4310
	L (Z)	0.392	0.002	2.547	1.48	0.8921
4. Sitting	L (X)	0.080	0.010	4.450	0.56	0.7900
	L (Y)	0	0.021	8.609	0.89	0.4310
	L (Z)	0.344	−0.004	7.327	1.46	0.8632
5. Sitting (thighs elevated)	L (X)	0.041	0.022	7.405	0.66	0.7104
	L (Y)	0	0.021	8.610	0.89	0.4310
	L (Z)	0.212	−0.002	21.582	1.24	0.7801
6. Sitting (with arms down)	L (X)	0.075	0.010	4.628	0.51	0.8030
	L (Y)	0	0.021	8.609	0.89	0.4310
	L (Z)	0.355	−0.010	7.389	1.56	0.8489
7. Mercury configuration	L (X)	0.076	0.008	5.253	0.54	0.7828
	L (Y)	0	0.021	8.609	0.89	0.4310
	L (Z)	0.311	−0.002	14.425	1.80	0.7841
8. Weightless	L (X)	0.077	0.001	4.692	0.60	0.6973
	L (Y)	0	0.021	8.609	0.89	0.4310
	L (Z)	0.218	0.017	28.552	3.16	0.5015

Reference: 250

Notes:
– Refer to Figure 3.3.7.3.2.1-1 for measurement landmarks
*SE = Standard error of the estimate
**R = Multiple correlation coefficient

Figure 6.1.3.6.2.1-4Center of mass location for whole body (men). (Continued).

Comments: - The measuring points are shown on Attachment 6.1.3.7.2.1-1.

- These data are used only for 1 g accelerations. L(Z) must be multiplied by 0.9 to evaluate the location of the center of mass under microgravity conditions.

- The body mass was determined for the selection presented in 6.1.3.2.1 of this document.

- A: dimensionless constant for a specific posture that describes the correlation between center of mass position and height.

- B: constant for a specific posture that describes the correlation between center of mass and weight, measured in cm/lb.

- C: constant measured in cm for a specific posture that is used to determine the center of mass position.

Reference: Man-Systems Integration Standards: NASA STD 3000; Volume 1, Revision B.

6.1.3.6.2.2 DESIGN REQUIREMENTS BASED ON BODY PART CENTER OF MASS DATA

		Center of mass position, cm								
		5th percentile			50th percentile			95th percentile		
		X	Y	Z	X	Y	Z	X	Y	Z
Head										
- Back of neck	X									
- Kozelkov point	Y or Z	9.4	6.8	2.1	10.4	7.2	2.3	11.5	7.7	2.5
- Eye (or ear)	Y or Z									
Torso										
- Wall plane	X									
- Sternum	Z	8.4	13.8	21.0	10.0	15.8	21.8	11.6	17.8	22.6
- Upper anterior iliac bone	Y									
Shoulder		*	*	14.1	*	*	14.0	*	*	15.7
- Shoulder joint	Z									

Comments:

(a) These data are used only for 1 g accelerations. L(Z) must be multiplied by 0.9 to evaluate the location of the center of mass under microgravity conditions.

(b) Body segment centers of mass were determined for the selection presented in 6.1.3.2.1 of this document.

* - assuming symmetry

Reference: Man-Systems Integration Standards: NASA STD 3000; Volume 1, Revision B

Figure 6.1.3.6.2.2-1 Center of mass location for body segments (men).

		Center of mass position, cm								
		5th percentile			50th percentile			95th percentile		
		X	Y	Z	X	Y	Z	X	Y	Z
Forearm - elbow	Z	*	*	10.9	*	*	11.9	*	*	12.1
Hand - wrist	Z	*	*	5.1	*	*	5.6	*	*	6.0
Thigh - coxofemoral joint	Z	*	*	17.0	*	*	18.0	*	*	19.1

Comments:

(a) These data are used only for 1 g accelerations. L(Z) must be multiplied by 0.9 to evaluate the location of the center of mass under microgravity conditions.

(b) Body segment centers of mass were determined for the selection presented in 6.1.3.2.1 of this document.

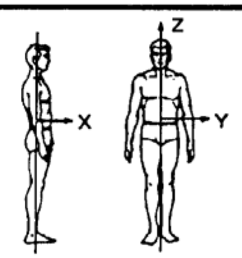
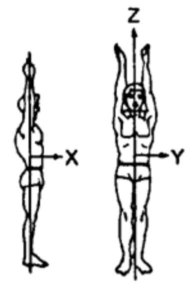
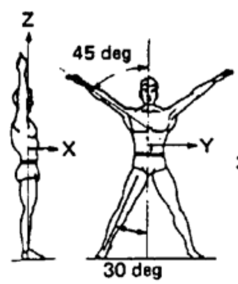
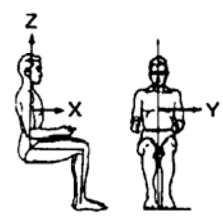
* - assuming symmetry

Reference: Man-Systems Integration Standards: NASA STD 3000; Volume 1, Revision B

Figure 6.1.3.6.2.2-2Center of mass location for body segments (men). (Continued)

6.1.3.6.3 MOMENT OF INERTIA

6.1.3.6.3.1 DESIGN REQUIREMENTS BASED ON WHOLE BODY MOMENT OF INERTIA DATA

Moment of inertia, g-cm^2 x 10^6 (lb-in-sec^2)				
Posture	Axis	5th percentile	50th percentile	95 percentile
 1. Standing	X	106.5 (94.2)	144.5 (101.3)	182.3 (161.2)
	Y	94.9 (83.9)	129.2 (114.3)	163.4 (144.5)
	Z	10.3 (9.1)	14.4 (12.7)	18.5 (16.4)
2. Standing, Arms Over Head 	X	141.0 (124.7)	191.9 (169.7)	242.6 (214.6)
	Y	124.6 (110.2)	172.9 (152.9)	221.0 (195.5)
	Z	10.6 (9.4)	14.1 (12.5)	17.5 (15.5)
 3. Spread Eagle	X	137.2 (121.3).	190.4 (168.4)	243.4 (215.3)
	Y	104.2 (92.2)	144.8 (128.1)	185.2 (163.8)
	Z	32.0 (28.3)	46.6 (41.2)	61.3 (54.2)
4. Sitting 	X	57.3 (50.7)	76.9 (68.0)	96.5 (85.3)
	Y	62.0 (54.8)	83.2 (73.6)	104.3 (92.2)
	Z	30.7 (27.2)	42.4 (37.3)	54.0 (47.8)

›nly.

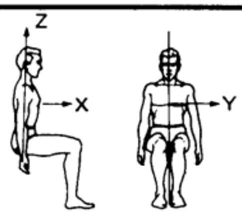
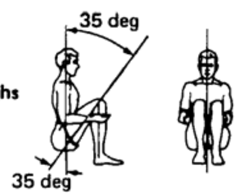
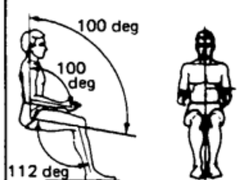
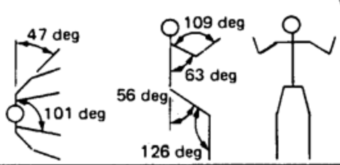
Figure 6.1.3.6.3.1-1Whole body moment of inertia (men).

Comments:

(a) These data apply to 1 g conditions only.

(b) The population is as defined in 6.1.3.2.1 of this document.

Reference: Man-Systems Integration Standards: NASA STD 3000; Volume 1, Revision B

Moment of inertia, g-cm^2 x 10^6, (lb-in-sec^2)				
Posture	Axis	5th percentile	50th percentile	95 percentile
 5. Sitting, Forearms Down	X	59.2 (52.4)	77.6 (68.6)	96.0 (84.9)
	Y	63.9 (56.5)	86.3 (76.3)	108.6 (96.0)
	Z	30.9 (27.3)	42.8 (37.9)	54.6 (48.3)
6. Sitting, Thighs Elevated 	X	37.6 (33.3)	48.7 (43.1)	59.8 (52.9)
	Y	37.2 (32.9)	46.6 (41.2)	55.8 (49.3)
	Z	23.9 (21.1)	33.7 (29.8)	43.5 (38.5)
 7. Mercury Configuration	X	62.5 (55.3)	82.2 (72.7)	101.8 (90.0)
	Y	69.6 (61.6)	95.5 (84.5)	121.3 (107.3)
	Z	31.9 (28.2)	43.0 (38.0)	54.0 (47.8)
8. Relaxed (Weightless) (Does not account for spinal lengthening)  	X	88.0 (77.8)	114.5 (101.3)	140.9 (124.6)
	Y	84.1 (74.4)	109.6 (96.9)	134.8 (119.2)
	Z	39.8 (35.2)	50.5 (44.7)	61.2 (54.1)

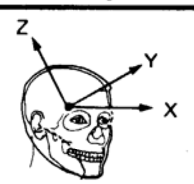
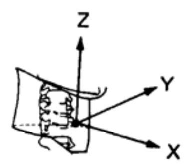
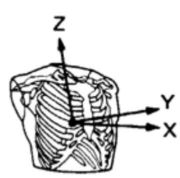
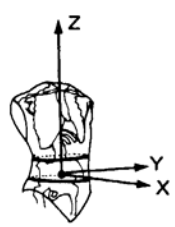
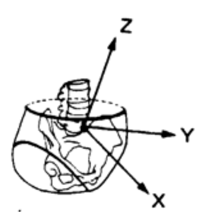
nly.

Comments.
(a) These data apply to 1 g conditions only.
(b) The population is as defined in 6.1.3.2.1 of this document.

Reference: Man-Systems Integration Standards: NASA STD 3000; Volume 1, Revision B

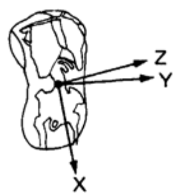
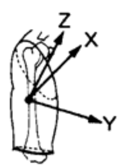
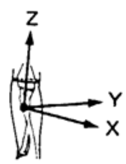
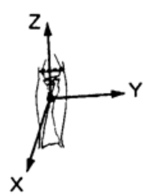
Figure 6.1.3.6.3.1-2Whole body moment of inertia (men). (Continued).

6.1.3.6.3.2 DESIGN REQUIREMENTS BASED ON BODY SEGMENT MOMENT OF INERTIA DATA

Moment of inertia, g-cm^2 x 10^3, (lb-in-sec^2 x 10^3)				
Segment	**Axis**	**5th percentile**	**50th percentile**	**95th percentile**
Head 	X	195.2 (172.7)	207.1 (183.2)	218.9 (193.6)
	Y	221.8 (196.2)	236.8 (209.4)	251.6 (222.6)
	Z	144.9 (128.1)	153.2 (135.5)	161.4 (142.7)
Neck 	X	13.4 (11.9)	18.2 (16.1)	23.0 (20.3)
	Y	16.6 (14.7)	22.0 (19.5)	27.4 (24.2)
	Z	20.3 (17.9)	27.5 (24.3)	34.6 (30.6)
Thorax 	X	3509.6 (3103.9)	5312.0 (4697.9)	7100.2 (6279.4)
	Y	2556.3 (2260.8)	3920.6 (3467.4)	5274.0 (4664.3)
	Z	2153.8 (1904.8)	3320.1 (2936.3)	4475.5 (3958.1)
Abdomen 	X	116.6 (103.1)	175.2 (155.0)	233.2 (206.2)
	Y	63.3 (56.0)	98.2 (86.8)	132.6 (117.3)
	Z	173.6 (153.5)	265.4 (234.7)	356.1 (315.0)
Pelvis 	X	713.7 (631.2)	1123.4 (993.6)	1528.9 (1352.1)
	Y	646.4 (571.7)	1033.5 (914.0)	1416.4 (1252.7)
	Z	820.0 (752.2)	1303.6 (1152.9)	1782.0 (1576.0)

Comments:
(a) These data apply to 1 g conditions only.
(b) The population is as defined in 6.1.3.2.1 of this document.
Reference: Man-Systems Integration Standards: NASA STD 3000; Volume 1, Revision B

Figure 6.1.3.6.3.2-1_Body segment moment of inertia (men).

Moment of inertia, g-cm^2 x 10^3, (lb-in-sec^2 x 10^3)				
Segment	Axis	5th percentile	50th percentile	95th percentile
Torso 	X	10731.4 (9490.9)	15957.8 (14113.0)	21141.0 (18697.1)
	Y	2556.3 (2260.8)	3920.6 (3467.4)	5274.0 (4664.3)
	Z	2153.8 (19004.8)	3320.1 (2936.3)	5274.0 (4664.3)
Right upper arm 	X	92.6 (81.9)	141.7 (125.4)	190.5 (168.6)
	Y	97.6 (86.3)	151.2 (133.7)	204.4 (180.8)
	Z	18.5 (16.3)	29.2 (25.8)	39.8 (35.2)
Left upper arm 	X	89.1 (78.8)	137.2 (121.43)	185.0 (163.6)
	Y	93.3 (82.5)	145.7 (128.9)	197.8 (174.9)
	Z	17.8 (15.8)	28.2 (24.9)	38.4 (34.0)
Right forearm 	X	65.3 (57.7)	93.9 (83.1)	122.4 (108.3)
	Y	66.3 (58.6)	95.6 (84.6)	124.8 (110.4)
	Z	9.6 (8.5)	14.2 (12.6)	18.8 (16.6)
Left forearm 	X	63.7 (56.3)	88.9 (78.6)	113.9 (100.7)
	Y	65.4 (57.8)	91.5 (80.9)	117.4 (103.9)
	Z	8.9 (7.9)	12.9 (11.4)	16.9 (14.9)

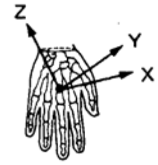
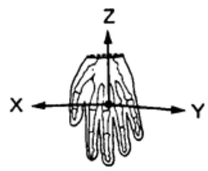
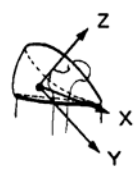
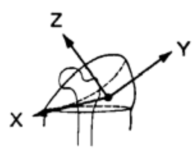
Comments:

(a) The population is as defined in 6.1.3.2.1 of this document.

(b) These data apply to 1-G conditions only.

Reference: Man-Systems Integration Standards: NASA STD 3000; Volume 1, Revision B

Figure 6.1.3.6.3.2-2_Body segment moment of inertia (men). (Continued).

Moment of inertia, g-cm^2 x 10^3, (lb-in-sec^2 x 10^3)				
Segment	Axis	5th percentile	50th percentile	95th percentile
Right hand 	X	10.7 (9.4)	13.8 (12.2)	16.8 (14.9)
	Y	8.7 (7.7)	11.2 (9.9)	13.7 (12.1)
	Z	3.4 (3.0)	4.5 (4.0)	5.5 (4.9)
Left hand 	X	10.8 (9.5)	13.6 (12.0)	16.4 (14.5)
	Y	9.0 (7.9)	11.3 (10.0)	13.6 (12.0)
	Z	3.5 (3.1)	4.4 (3.9)	5.3 (4.7)
Right hip flap 	X	88.8 (78.5)	134.1 (118.6)	178.9 (158.2)
	Y	116.3 (102.8)	173.1 (153.1)	229.4 (202.9)
	Z	150.4 (133.1)	226.5 (200.3)	301.7 (266.9)
Left hip flap 	X	85.0 (75.1)	128.8 (133.9)	172.2 (152.3)
	Y	113.4 (100.3)	169.2 (149.7)	224.5 (198.5)
	Z	146.7 (129.8)	219.2 (193.8)	290.8 (257.2)

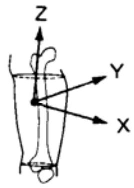
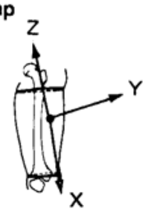
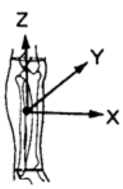
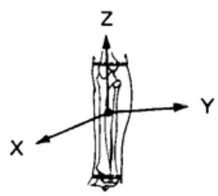
Comments:

(a) The population is as defined in 6.1.3.2.1 of this document.

(b) These data apply to 1-G conditions only.

Reference: Man-Systems Integration Standards: NASA STD 3000; Volume 1, Revision B

Figure 6.1.3.6.3.2-3 Body segment moment of inertia (men). (Continued).

Moment of inertia, g-cm^2 x 10^3, (lb-in-sec^2 x 10^3)				
Segment	Axis	5th percentile	50th percentile	95th percentile
Right thigh minus flap 	X	453.6 (401.2)	653.1 (577.6)	852.3 (753.8)
	Y	469.2 (415.0)	673.4 (595.6)	877.3 (775.9)
	Z	178.4 (157.8)	255.2 (225.7)	331.3 (293.0)
Left thigh minus flap 	X	437.3 (386.8)	620.9 (549.1)	804.0 (711.1)
	Y	460.7 (407.5)	653.4 (577.9)	845.7 (747.9)
	Z	172.3 (152.4)	246.9 (218.3)	321.0 (283.8)
Right calf 	X	430.7 (381.0)	618.1 (546.6)	804.8 (711.8)
	Y	437.7 (387.1)	627.1 (554.6)	816.0 (721.7)
	Z	51.8 (45.8)	72.0 (63.7)	92.1 (81.5)
Left calf 	X	434.1 (383.9)	629.6 (556.8)	824.7 (729.4)
	Y	441.4 (390.3)	639.7 (565.8)	837.7 (740.9)
	Z	50.7 (44.9)	72.8 (64.4)	94.7 (83.7)

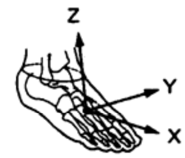
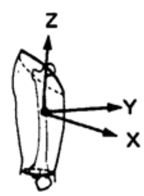
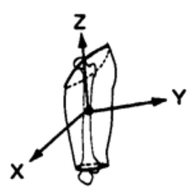
Comments:

(a) The population is as defined in 6.1.3.2.1 of this document.

(b) These data apply to 1-G conditions only.

Reference: Man-Systems Integration Standards: NASA STD 3000; Volume 1, Revision B

Figure 6.1.3.6.3.2-4_Body segment moment of inertia (men). (Continued).

Moment of inertia, g-cm² x 10³, (lb-in-sec² x 10³)							
Segment	Axis	5th percentile		50th percentile		95th percentile	
Right foot 	X	6.5	(5.7)	8.7	(7.7)	10.9	(9.6)
	Y	33.8	(29.9)	46.1	(40.7)	58.3	(51.5)
	Z	36.0	(31.8)	48.8	(43.2)	61.7	(54.5)
Left foot 	X	6.1	(5.4)	8.3	(7.4)	10.6	(9.3)
	Y	32.4	(28.6)	44.7	(39.5)	57.0	(50.4)
	Z	34.2	(30.2)	47.0	(41.6)	59.8	(52.9)
Right thigh 	X	1163.7	(1029.2)	1689.8	(1494.4)	2213.9	(1958.0)
	Y	1225.4	(1083.8)	1780.9	(1575.0)	2334.2	(2064.4)
	Z	316.5	(279.9)	464.6	(410.9)	611.3	(540.6)
Left thigh 	X	1122.6	(992.6)	1623.0	(1435.4)	2121.1	(1875.9)
	Y	1186.3	(1049.2)	1713.2	(1515.1)	2237.5	(1978.8)
	Z	306.2	(270.8)	448.5	(396.6)	589.5	(521.3)

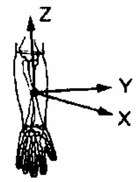
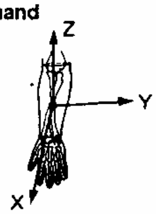
Comments:

(a) The population is as defined in 6.1.3.2.1 of this document.

(b) These data apply to 1-G conditions only.

Reference: Man-Systems Integration Standards: NASA STD 3000; Volume 1, Revision B

Figure 6.1.3.6.3.2-5_Body segment moment of inertia (men). (Continued).

Moment of inertia, $g\text{-}cm^2 \times 10^3$, ($lb\text{-}in\text{-}sec^2 \times 10^3$)				
Segment	Axis	5th percentile	50th percentile	95th percentile
Right forearm plus hand 	X	238.5 (210.9)	327.8 (289.9)	416.7 (368.5)
	Y	237.5 (210.0)	326.5 (288.8)	415.1 (367.2)
	Z	13.4 (11.9)	19.2 (17.0)	25.0 (22.1)
Left forearm plus hand 	X	234.1 (207.0)	314.1 (277.8)	293.8 (348.3)
	Y	232.8 (205.9)	312.2 (276.1)	391.2 (346.0)
	Z	12.8 (11.4)	17.9 (15.9)	23.0 (20.3)

Comments:

(a) The population is as defined in 6.1.3.2.1 of this document.

(b) These data apply to 1-G conditions only.

Reference: Man-Systems Integration Standards: NASA STD 3000; Volume 1, Revision B

Figure 6.1.3.6.3.2-6 Body segment moment of inertia (men). (Continued)

6.2 STRENGTH DESIGN REQUIREMENTS

6.2.1 ZERO-G DESIGN FORCES

6.2.1.1 SEATED POSTURE

6.2.1.1.1 HORIZONTAL FORCES

Force developed by an operator:

- by one hand;
- at the chest level;
- waist restrained;
- direction: backward, forward, and rotations.

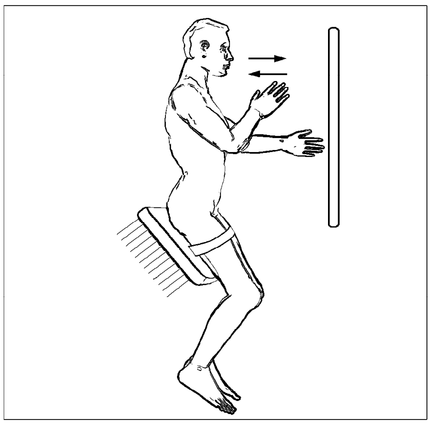


Figure 6.2.1.1.1-1 Seated posture with waist restrained, force directed forward and backward in the horizontal plane.

Duration, second	Direction		Rotation of flywheel, 60 mm in -diameter, kg-m
	backward, kg	forward, kg	
0.5	20	18	0.6
5.0	10	8	0.3

Notes:

1. When holding handgrip with both hands, increase force by 20 - -30%.
2. Forces may vary ±10 - 15% among individuals.

6.2.1.1.2 VERTICAL FORCES

Force developed by an operator:

- by one hand;
- at the chest level;
- waist restrained;
- direction: upward, downward, and rotations.

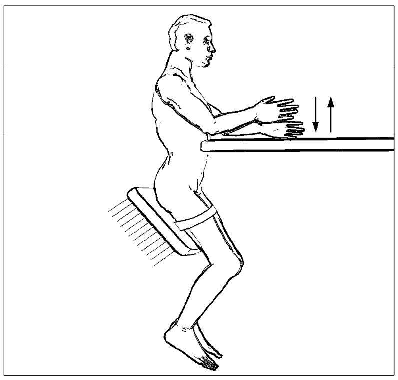


Figure 6.2.1.1.2-1 Seated posture with waist restrained, force directed upward and downward in the vertical plane.

Duration, second	Direction		Rotation of flywheel, 60 mm in diameter, kg-m
	upward, kg	downward, kg	
0.5	20	16	0.6
5.0	10	8	0.3

Notes:

1. When holding handgrip with both hands, increase force by 15 - 25%.
2. Forces may vary ±10 - 15% among individuals.

6.2.1.2 STANDING POSTURE

6.2.1.2.1 HORIZONTAL FORCES

Force developed by an operator:

- by one hand;
- at the chest level;
- feet restrained;
- direction: backward, forward, and rotations.

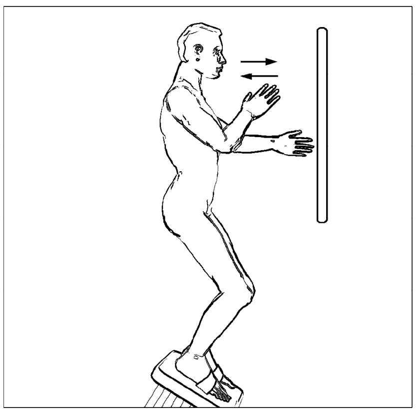


Figure 6.2.1.2.1-1 Standing posture with semi-rigid foot restraints, force directed forward and backward in the horizontal plane.

Duration, second	Direction		Rotation of flywheel, 60 mm in diameter, kg-m
	backward, kg	forward, kg	
0.5	15	12	0.6
5.0	8	6	0.3

Notes:

1. When holding handgrip with both hands, increase force by 40 - -50%.
2. Forces may vary ±10 - 15% among individuals.

6.2.1.2.2 VERTICAL FORCES

Force developed by an operator:

- by one hand;
- at the chest level;
- feet restrained;
- direction: upward, downward, and rotations.

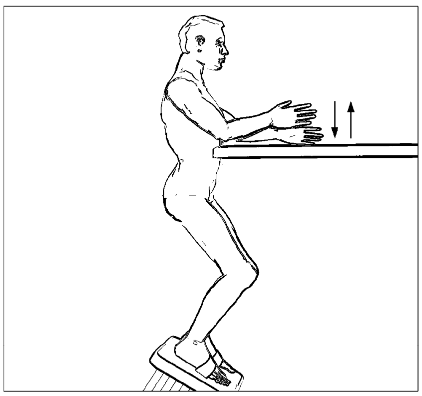


Figure 6.2.1.2.2-1 Standing posture with semi-rigid foot restraints, force directed upward and downward in the vertical plane.

Duration, second	Direction		Rotation of flywheel, 60 mm in diameter, kg-m
	upward, kg	downward, kg	
0.5	16	12	0.6
5.0	10	7	0.3

Notes:

1. When holding handgrip with both hands, increase force by 30 - 40%.
2. Forces may vary ±10 - 15% among individuals.

6.2.1.3 NEUTRAL POSTURE

6.2.1.3.1 HORIZONTAL

Force developed by an operator:

- by one hand;
- at the chest level;
- body unrestrained, holding handgrip with one hand;
- direction: backward, forward, and rotations.

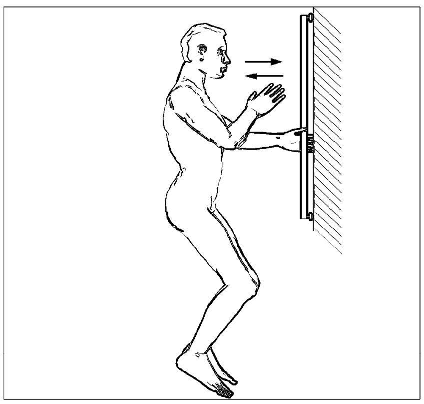


Figure 6.2.1.3.1-1 Equilibrium posture, holding rigid handgrip with one hand, force directed forward and backward in the horizontal plane.

Duration, second	Direction		Rotation of flywheel, 60 mm in diameter, kg-m
	backward, kg	forward, kg	
0.5	12	8	0.4
5.0	6	5	0.15

Notes:

1. Variations in neutral body posture may result in force variations of ±15 - 25%.
2. Forces may vary ±10 - 15% among individuals.

6.2.1.3.2 VERTICAL FORCE

Force developed by an operator:

- by one hand;
- at the chest level;
- body unrestrained, holding handgrip with one hand;
- direction: upward, downward, and rotations.

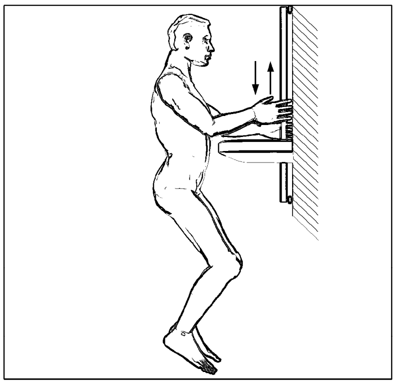


Figure 6.2.1.3.2-1 Equilibrium posture, holding rigid handgrip with one hand, force directed upward and downward in the vertical plane.

Duration, second	Direction		Rotation of flywheel, 60 mm in diameter, kg-m
	upward, kg	downward, kg	
0.5	8	8	0.4
5.0	6	5	0.15

Notes:

1. Variations in neutral body posture may result in force variations of ±15 - 25%.
2. Forces may vary ±10 - 15% among individuals.

6.3 ARCHITECTURE

6.3.1 TRANSLATION PATHS

6.3.1.1 MINIMUM TRANSLATION PATH DIMENSIONS DESIGN REQUIREMENTS

Minimum cross sectional dimensions of microgravity translation paths for one crewmember in light clothing shall be 65 cm

6.3.1.2 CLEARANCES DESIGN REQUIREMENTS

Minimum interior cross section dimensions of 80 cm shall be maintained to support equipment translation.

6.3.1.3 TRANSLATION PATH OBSTRUCTIONS AND HAZARDS DESIGN REQUIREMENTS

The following translation path obstructions and hazards requirements will apply:

A. Damage to Nearby Equipment - Equipment exposed to the translation path shall be designed to withstand a design load of 556 N (125 lbf) and a minimum ultimate load of 778 N (175 lbf).
B. Obstructions and Entanglements - The crew shall be provided clear and safe translation paths.

6.3.1.4 MARKING OF TRANSLATION PATHS DESIGN REQUIREMENTS

Emergency translation paths shall be marked.

6.3.2 MOBILITY AIDS AND& RESTRAINTS ARCHITECTURAL INTEGRATION

6.3.2.1 INTERNAL MOBILITY AID LOCATIONS DESIGN REQUIREMENTS

Fixed or portable internal mobility aids shall be provided at the following locations:

A. Crew stations - Mobility aids shall be placed around workstations, access hatches, doors, windows, and pressure hatches.
B. Terminal and Direction Change Points - Mobility aids shall be located at designated terminal points and direction change points on established crew translation paths.
C. Contingency internal Operations by EVA- suited crewmember - Crew mobility aid provisions shall be made for contingency EVA-suited operations.
D. Orientation - The orientation and locations of translation and mobility handholds shall be consistent with the crew tasks they are supporting.

6.3.2.2 INTERNAL RESTRAINT LOCATIONS DESIGN REQUIREMENTS

Areas Requiring High Force Application - Restraints shall be provided at identified locations where crewmembers are expected to exert forces which cause the body to move in reaction.

6.3.3 FOOD PREPARATION AND CONSUMPTION AREA

6.3.3.1 DESIGN REQUIREMENTS

6.3.3.1.1 OVERALL LAYOUT DESIGN REQUIREMENTS

The following requirements apply to the overall layout of the Space Station food preparation and consumption area.

A. Traffic Flow - The food preparation and consumption area shall be configured to provide clear traffic paths for the crew to perform the following tasks:
   (1) Food Selection and Inventory Control
   (2) Food Retrieval from Storage
   (3) Food Preparation
   (4) Food Consumption
   (5) Cleanup
B. Size of Crewmembers - Food preparation and consumption area hardware shall accommodate the full size range of crewmembers as specified in Section 6.1.
C. Restraints - Restraints shall be provided for crewmembers, food, utensils, cooking equipment, and other loose items at food preparation and consumption area locations.

6.3.3.1.2 FOOD SELECTION, PREPARATION, AND CONSUMPTION DESIGN REQUIREMENTS

The Space Station food preparation and consumption area will provide the following facilities for food selection, preparation, and consumption:

A. Inventory Update and Review - Food packages will provide labels for inventory.
B. Identification - All food items shall be identifiable in terms of food name and method of preparation.
C. Heating - A means shall be provided in the food preparation area for heating food and liquids to at least 58°C (136.4°F) in less than 30 minutes and maintaining that temperature.
D. Chilling - A means shall be provided in the food preparation area for cooling 30 liters (1 cu. ft.) of food to:
   1. -3°C, +/- 2°C (27°F +/- 3°F)
   2. +3°C to +8°C, +/- 2°C (37°F to 46°F, +/-3°F)
E. Rehydration - A means shall be provided in the food preparation area for injecting necessary potable water for rehydration of food.
F. Serving and Preparation Utensils-Area shall be provided in the food preparation area for stowage of the following serving and preparation items:

(1) Eating utensils.
(3) Preparation tools and containers.

G. Table - A table shall be provided for eating.

6.3.3.1.3 FOOD PACKAGING AND STORAGE DESIGN REQUIREMENTS

In addition to the general packaging design requirements given in Paragraph 6.3.3.1.5, all food packaging will be designed to meet the following requirements:

Rehydration Provisions - For foods that require water for reconstitution, provisions shall be made for the package to accept water directly from a probe without contaminating the probe and to hold the water and contents without spillage after removal of the probe.

6.3.3.1.4 FOOD PREPARATION AND CONSUMPTION AREA CLEANING DESIGN REQUIREMENTS

The following facilities shall be provided for food preparation and consumption area cleaning and sanitation:

A. Design for Cleaning - The surfaces in the food preparation and consumption area shall be accessible for cleaning and sanitation. The surface texture shall be capable of being wiped clean. Closeouts shall be provided to preclude contamination in areas that are inaccessible.
B. Cleaning Supplies and Equipment - Cleaning supplies and equipment shall be available to the food preparation and consumption area-. The equipment and supplies shall be capable of the following:
   (1) Sanitizing the food preparation and consumption area.
   (2) Collection, containment, and isolation of debris.
   (3) Sanitizing of reusable utensils, serving equipment, and preparation equipment.
C. Trash Collection - A trash collection point shall be provided in the food preparation and consumption area for left over food and trash. Trash shall be kept out of sight.

6.3.3.1.5 PACKAGING DESIGN REQUIREMENTS

A. All non-reusable packaging shall be compatible with the trash collection and disposal system.
B. Hazards
   (1) Packaging features shall be designed to preclude injury to the crew member.
   (2) Packaging materials shall not introduce contaminants into the atmosphere.

6.3.3.1.6 CREW NUTRITIONAL REQUIREMENTS

Crew nutritional requirements have been designed to provide optimal crew performance during extended-duration (120-360d) ~~International Space Station~~ISS missions. The requirements listed in this report are divided into two main categories: (1) specific nutrients required (on a per-day basis), and (2) the requirement to monitor nutrient intake.

6.3.3.1.6.1 NUTRIENT REQUIREMENTS

The daily diet will supply the basic nutritional requirements as specified below. Mass size should be taken into account in individual calculations, since the following requirements are designed for a 70 kg person.

a. Energy Intake

Intake of energy shall be sufficient to maintain body weight, body composition, and the level of activity required for the extensive activities planned for International Space Station crewmembers. Energy requirements will be defined on an individual basis as calculated using the following equations:

men:	(18-30 yrs):	1.7 (15.3W+679) = kcal/day required
	(30-60 yrs):	1.7 (11.6W+879) = kcal/day required
women:	(18-30 yrs):	1.6 (14.7W+496) = kcal/day required
	(30-60 yrs):	1.6 (8.7W+829) = kcal/day required

Where W = weight in kg

Note that these equations account for moderate levels of activity. An additional 500 kcal/d will be supplied to the diet during the period where end of mission countermeasures are being conducted.

Based on previous space missions, it is recommended that an additional 500 kcal/d be supplied to crewmembers on days of extravehicular activity (EVA) the extra energy should be of similar nutrient composition as the rest of the diet.

b. Protein

Intake of protein shall provide 12-15 percent of total calories consumed. This should be provided from both animal and plant sources, in a 60:40 ratio. This ratio will facilitate meeting other nutrient requirements while ensuring an adequate intake of all essential amnio acids. It is important to provide protein in the amounts specified, as higher or lower intakes may exacerbate space-induced musculoskeletal changes.

c. Carbohydrate
Carbohydrates shall provide 50 to 55 percent of daily caloric intake. This should be provided primarily in the form of complex carbohydrates (i.e., starches) such as cereal products - flour, bread, rice, and corn. Less than 10 percent of total carbohydrate intake should be provided as simple sugars (e. g., sucrose and other sweeteners).

Ten to twenty-five grams per day of total dietary fiber should be provided, in both soluble and insoluble forms. This will help maintain gastrointestinal function and decrease the incidence of constipation.

d. Fat
Thirty to thirty-five percent of dietary calories shall be provided as fat, with a distribution among polyunsaturated:monounsaturated:saturated of 1:1.5-2:1. This is designed to increase the palatability and calorie density of the diet while simultaneously reducing the health risks associated with a high-fat intake.

e. Fluid
Intake of fluid shall be sufficient to reduce the incidence of kidney stones and prevent dehydration. The daily fluid requirement is estimated to be 1.0-1.5 ml per kcal consumed (at least 2000 ml per day). It is imperative for the health of the crew that fluid intake be maintained. This will be facilitated through provision of a fully hydrated diet.

f. Fat-Soluble Vitamins
Vitamin A
Intake of Vitamin A shall be 1000 µg RE/d for men and women. (RE = retinol equivalents; 1 RE = 1 µg retinol or 6 µg ß-carotene).

Vitamin D
Intake of Vitamin D shall be 10 µg/d for men and women. This is designed to augment calcium and bone retention in light decreased exposure to ultraviolet light (and thus, decreased endogenous production).

Vitamin E
Intake of Vitamin E shall be 20 mg TE/d for men and women. (TE = α-tocopherol equivalents; 1 TE = 1 mg d-α-tocopherol).

Vitamin K
Intake of Vitamin K shall be 80 µg/d for men and women. Meeting this requirement is important because of the role of Vitamin K in calcium and bone metabolism. Owing to the uncertainty of production of Vitamin K in the gastrointestinal tract in humans exposed to microgravity, the Vitamin K requirement shall be provided as Vitamin K-1 (phylloquinone), which is obtained primarily in plant sources.

g. Water-Soluble Vitamins

Vitamin C
Because of the increased level of stress predicted for orbiting crews, the Vitamin C requirement is 100 mg/d.

Vitamin B_{12}
Intake of vitamin B_{12} shall be 2.0 μg/d for men and women.

Vitamin B_6
Intake of vitamin B_6 shall be 2.0 mg/d for men and women.

Thiamin
Because of the high level of activity expected during these missions, the daily thiamin intake shall be 1.5 mg/d for men and women.

Riboflavin
Intake of riboflavin shall be 2.0 mg/d for men and women.

Folate
Intake of Folate shall be 400 μg/d for men and women.

Niacin
Intake of niacin shall be 20 mg NE/d for men and women. (NE = niacin equivalents; 1 NE = 1 mg niacin or 60 mg dietary tryptophan).

Biotin
Intake of biotin shall be 100 μg/d.

Pantothenic Acid
Intake of Pantothenic acid shall be 5 mg/d.

h. Minerals

Calcium and Phosphorus
Calcium intake shall be 1000-1200 mg/d to minimize bone and calcium imbalance during the mission. The phosphorus intake shall not exceed 1.5 times the calcium intake.

Magnesium
Intake of magnesium shall be 350 mg/d for men and women.

Sodium
Intake of sodium shall be 1500-3500 mg/d.

Potassium
Intake of potassium shall be approximately 3500 mg/d.

i. Trace Elements

Iron
Iron intake shall not exceed 10 mg/day for men and women. This is based on space-induced changes in iron storage, and is designed to prevent iron overload, a situation that may lead to oxidative tissue damage.

Copper
Intake of copper shall be 1.5-3.0 mg/day for men and women.

Manganese
Intake of manganese shall be 2-5 mg/day for men and women.

Fluoride
Fluoride shall be provided in the diet in amounts of 4.0 mg/d for men and women.

Zinc
Intake f zinc shall be 15 mg/day for men and women

Selenium
Intake of selenium shall be 70 μg/d for men and women.

Iodine
Intake of iodine shall be 150 μg/d for men and women.

Chromium
Chromium shall be provided in the diet in amounts of 100-200 μg/d.

6.3.3.1.6.2 OVERVIEW

The above listed nutrients shall be provided in standard foods. This is critical, as these foods provide other non-nutrient substances such as fiber and carotenoids as well as a sense of palatability and psychological well being that will be critical during long missions. Standard foods, which provide many vitamins and minerals, will counter some of the physiological changes associated with space flight.

Many nutrients when provided as supplements/pills are not metabolized by the body as when in foods, and thus can increase the risk of diseases. Vitamin or mineral supplements shall be used as a countermeasure only when the nutrient content of standard foods do not meet the requirements.

6.3.3.1.6.3 MONITORING NUTRIENT INTAKE DURING FLIGHT

Adequate monitoring of food consumption by crewmembers is important from several perspectives. Among these are the implications of nutrient intake as a counter-measure for microgravity-induced changes in physiological function. As such, nutrient intake data are required as part of biomedical monitoring.

The means of monitoring food inventory and nutrient intake may be two individual systems. This will allow the nutrient intake system to provide a more accurate estimate of food intake by individuals during periods when this is required (e. g., specific experiments, periods of illness). Accurate nutrient-intake data has been obtained using a bar-code reader system to document type and amount of foods eaten after each meal.

Table 6.3.3.1.6.3-1 Food Microbiological Limits

Area/Item	Microorganism Tolerances	
Food Production & packaging Area	**Samples Collected**	**Limits (CFU)**
Surfaces	3 surfaces sampled per day	≤ 3/cm^2
Packaging Film	Before use	≤ 3/cm^2
Food Processing Equipment	2 pieces sampled per day	≤ 3/cm^2
Air	1 sample per 320 liters	<113/320 liters

Food Product	Factor	Limits
Non-thermostabilized	Total aerobic count Coliform Coagulase positive Staphylococci Salmonella Yeasts and Molds Escherichia coli Bacillus cereus	<20.000/g <10/g 0/g 0/25g <50/g 0/10g <10/g
Commercial sterile products (hermostabilized and irradiated)	 Sporogenic mesophilic bacilli Mesophilic anaerobes Yeasts, fungi (in items with pH<4.2)	100% inspection for package integrity <10/g 0/5g 0/2g

6.4 HARDWARE AND EQUIPMENT

6.4.1 CLOSURES AND COVERS DESIGN REQUIREMENTS

Equipment housings (e.g., electrical bays, cabinets, lockers, and consoles) shall be designed to provide closures and covers for inaccessible areas. The following requirements will apply:

A. Sealing - The inaccessible areas shall be sealed to prevent any loose item from drifting into them.
B. Removal - Closures shall be removable to allow maintenance of equipment.
C. Securing - Closures shall have a positive means of indicating that it is locked.
D. Loads - Non-structural closures shall be capable of sustaining a crew-imposed minimum design load of 556 N (125 lbf) and a minimum ultimate load of 778 N (175 lbf).
E. Clearance - Bulkheads, brackets, and other units shall not interfere with removal or opening of covers.
F. Application - An access cover shall be provided whenever routine maintenance operations would otherwise require removing the entire case or cover, or dismantling an item of equipment.
G. Self-Supporting Covers - All access covers that are not completely removable shall be self-supporting in the open position.
H. Ventilation Screen Access - Where ventilation screens, -holes, or grids are used, the ventilation surface shall be accessible for vacuuming in its installed position

6.4.2 HANDLES ~~&~~AND GRASP AREAS (FOR PORTABLE ITEMS)

6.4.2.1 GENERAL HANDLE AND GRASP AREA DESIGN REQUIREMENTS

The following general requirements will be observed:

Provide Handles - All removable or portable units shall be provided with handles or other suitable means for grasping, tethering, handling, and carrying.

6.4.2.2 HANDLE AND GRASP AREA LOCATION DESIGN REQUIREMENTS

The following general location requirements of handles or grasp areas shall apply:

A. Interference - Handles and grasp areas shall be located so that they do not interfere with equipment location or maintenance.
B. Clearance - internal clearances shall be provided between handles and obstructions consistent with anthropometric dimensions given in paragraph 6.1.3.1.2.
C. Tether Attachments - Handles and grasp areas shall be suitable as tether or bracket attachment positions.
D. Location - Handles and grasp areas relocated in passageways shall be recessed or shall be designed so they do not pose a personnel safety hazard.
E. Location/Front Access - Handles and grasp areas shall be placed on the accessible surface of an item consistent with the removal direction.

6.4.2.3 NON-FIXED HANDLES DESIGN REQUIREMENTS

Hinged, foldout, or attachable (i.e., non-fixed) handles will comply with the following:

A. Locked or Use Position - Non fixed handles shall have a stop open position.
B. One Handed Operation - Non fixed handles shall primarily be capable of being placed in the use position by one hand and shall be capable of being removed or stowed with one hand.
C. Tactile or Visual Indicators - Attachable/removable handles shall incorporate tactile and/or visual indication of locked/unlocked status.

6.4.2.4 HANDLE DIMENSIONS DESIGN REQUIREMENTS

Internal handles for movable or portable units shall be designed to be compatible with the anthropometric range identified in Section 6.1.

6.4.3 RESTRAINTS

6.4.3.1 GENERAL PERSONNEL RESTRAINTS DESIGN REQUIREMENTS

All internal personnel restraints (i.e., seat belts, shoulder harnesses, body restraints, foot restraints, and sleep restraints) shall comply with the following requirements:

A. Muscular Tension - Restraint design shall eliminate muscular tension.
B. Anthropometric Range - All personnel restraints shall accommodate the full range of anthropometric requirements per Section 3.
C. Cleaning -The personnel restraint system shall be capable of on-orbit cleaning and repair.

6.4.3.2 FOOT RESTRAINT DESIGN REQUIREMENTS

6.4.3.2.1 GENERAL FOOT RESTRAINT DESIGN REQUIREMENTS

The following general requirements apply to all internal fixed and portable foot restraints:

A. Range of Motion - All foot restraints shall maintain foot position to allow the crewmember a complete range of motion (roll and pitch).
B. Foot Restraints - The foot restraint shall be capable of being removed for replacement/repair.

6.4.3.2.2 FOOT RESTRAINT DONNING/DOFFING DESIGN REQUIREMENTS

Foot restraints will comply with the following donning and doffing requirements:

A. No-Hand Operation - The use of hands for placing/removing the foot shall not be required for foot restraint ingress/egress.
B. Handholds - Handholds or structure shall be available at all positions to aid foot restraint ingress and egress.

6.4.3.2.3 FOOT RESTRAINT LOADS DESIGN REQUIREMENTS

Internal restraints must meet the following load requirements:

A. Tension Loads - Foot restraints shall be designed to withstand a tension load of 445 N (100 lbf) as a minimum (see Figure 6.4.3.2.3-1).
B. Torsion Loads - The restraints shall withstand a torsion load of 100 Nm (75 ft-lb) as a minimum with the torsion vector parallel.

6.4.3.3 BODY RESTRAINT DESIGN REQUIREMENTS

6.4.3.3.1 BODY RESTRAINT DONNING/DOFFING DESIGN REQUIREMENTS

The following personal body restraint donning and doffing requirements will apply to all tether attachments, seat belts, and shoulder harnesses:

A. Latching Mechanisms - The latching mechanism attachment shall require a positive action by the crewmember to both latch and unlatch the mechanism.
B. One-Handed Operation - The latching mechanism shall have the capability of being latched and unlatched with one hand.

6.4.3.3.2 BODY RESTRAINT LOADS DESIGN REQUIREMENTS

The following load requirements shall apply to seat belts, shoulder harnesses, and internal tethers:

A. Seat Belts and Shoulder Harnesses- N/A.
B. Tether Attachments - internal tether attachments shall be capable of sustaining a load of 756 N (170 lbf) along the longitudinal axis. They shall be designed to prevent any side loading.
C. Attach Points for Tether Attachment - internal translation and mobility handhold tether attachment attach points shall be designed to a minimum ultimate load of 902 N (250 lb) in any direction.

6.4.3.4 EQUIPMENT RESTRAINT DESIGN REQUIREMENTS

All internal equipment restraints will be designed to the following requirements:

A. Cause No Damage - The equipment restraint shall be designed such that it cannot damage the item to be restrained or the spacecraft interfacing surfaces and adjacent hardware.
B. Tether attachment points - All equipment items which will require tethering shall provide a standardized tether hook receptacle which is an integral part of the item. This standardized receptacle shall also be provided on the interfacing surface to which the item is to be secured.
C. Group Restraints - Group restraints shall provide a system which allows the removal of one item at a time.
D. Hook and Loop - When hook and loop fasteners are used as a restraint, the item to be restrained (i.e., the free item) shall be equipped with hook type fastener and the restraining surface shall be equipped with pile type fastener.

6.4.4 MOBILITY AIDS

6.4.4.1 HANDHOLD AND HANDRAIL DESIGN REQUIREMENTS

This section provides the design requirements for internal handholds and handrails.

6.4.4.2 HANDHOLD AND HANDRAIL DESIGN LOADS DESIGN REQUIREMENTS

All fixed and portable internal handholds and handrails shall be designed to an ultimate load of 445 N (100 lbs.) applied in any direction without failure or damage.

6.4.4.3 HANDHOLD AND HANDRAIL MOUNTING DESIGN REQUIREMENTS

The following requirements will apply to all handhold and handrail mounting:

A. Portable Handhold and Handrail Lock Status Indication - Portable handholds and handrails shall provide a positive indication of when they are in the locked position.
B. Visibility and Accessibility - Handholds and handrails shall be mounted so that they are visible and accessible.
C. Handhold Removal - Fixed handholds shall be removable with common tools.

6.4.5 CONNECTORS

6.4.5.1 CONNECTOR DESIGN REQUIREMENTS

All types of internal connectors shall meet the following general requirements:

One-Handed Operation - All connectors shall be designed so they can be mated/demated using one hand.

Two-Handed Operation is allowed provided that one of the mating parts is hard-mounted to the structure (panel) of the FGB and is appropriate to be used as a hand-hold.

6.4.5.1.1 FLUID CONNECTORS DESIGN REQUIREMENTS

All internal liquid and gas connectors identified as repairable on-orbit shall be designed to permit on-orbit replacement.

A. Brazed or Welded Fluid Lines - All brazed or welded gas and liquid lines shall be provided with permanently installed connectors that permit on-orbit maintenance.
B. Indication of Pressure Flow - All non-brazed or non-welded gas and liquid lines shall be provided with a positive indication of the gas pressure/fluid flow to verify that the line is passive before disconnection of connectors. Any liquid or gas lines equipped with quick disconnect connectors which are designed to be operated under pressure shall not be required to be fitted with pressure/flow indicators.

6.4.5.1.2 ELECTRICAL CONNECTORS DESIGN REQUIREMENTS

All internal electrical connectors shall comply with the following general requirements in addition to the requirements in 6.5.1.5, Plugs and Receptacles.

A. Locking - Electrical connector plugs shall provide a locking safety catch.
B. Access - Electrical connectors and cable installations shall permit disconnection and reconnection without damage to wiring or connectors.
C. Arc Containment - Electrical connector plugs shall be unpowered during mate/demate.
D. Contact Protection - All demated connectors shall be protected against physical damage and contamination.

6.4.5.1.3 STRUCTURAL CONNECTORS DESIGN REQUIREMENTS

All internal structural connectors shall meet the following requirements:

A. Alignment Provisions - All structural connectors shall incorporate alignment features.
B. Soft Latching - All structural connectors shall provide the capability to "soft latch" prior to full firm connection or full release.
C. Locking - All structural connectors shall have a means to ensure locking.

6.4.5.2 CONNECTOR IDENTIFICATION/ALIGNMENT DESIGN REQUIREMENTS

As much as possible, connectors shall be selected, designed, and installed so they cannot be mismated or cross-connected. Where applicable, the following requirements are to ensure that connectors are properly mated and can be verified by visual inspection:

A. Connector Shape - Connectors which are of different shapes and physically incompatible shall be used when lines differ in content (i.e., different voltages, liquids, gases, etc.).
B. Alignment Provisions
   (1) Mating connectors shall be provided with aligning pins or equivalent devices to aid in alignment and to preclude inserting in other than the desired orientation.
   (2) If aligning pins are used on electrical connectors, they shall extend beyond the plug's electrical pins to ensure that alignment is obtained before the electrical pins engage.
C. Alignment Marks
   (1) Alignment marks shall be applied to mating parts.
   (2) Alignment marks shall consist of a straight or curved line of a width and length sufficient to allow accurate alignment
   (Not applicable to the FGB.)
D. Coding

(1) Both halves of mating connectors shall display a code or identifier which is unique to that connection.
(2) The labels or codes on connectors shall be located so they are visible when connected or disconnected.

E. Pin Identification - A method shall be provided so that the crew can identify the pin in each electrical plug and receptacle.
F. Orientation - Grouped plugs and receptacles shall be oriented so that the aligning pins or equivalent devices are in the same relative position.
G. Loose Hoses or Cables
   (1) If the connectors on the ends of a loose electrical cable or fluid hose are not identical, each end shall be identified.
   (2) The loose ends of hoses and cables shall be restrained.

6.4.5.3 INTERNAL CONNECTOR ARRANGEMENT DESIGN REQUIREMENTS

A. Connectors and Adjacent Obstructions - Space between connectors and adjacent obstructions shall be a minimum of 25 mm (1 in). (Not applicable to the FGB.)
B. Single Rows - Connectors in a single row which require removal and replacement by the crew shall be a minimum of 25 mm (1 in.) apart (edge-to-edge) for hand access during alignment and insertion. (Not applicable to the FGB.)
C. Staggered Rows - Staggered rows of connectors shall be a minimum of 40.4 mm (1.6 in.) apart from any other connector. (Not applicable to the FGB.)
D. Connectors which do not meet the requirements of a, b, or c above, shall be capable of being mated/demated by hand (as specified by the anthropometric limits of Section 6.1) or by on-orbit tools provided by the RS. Mating/demating of connectors shall not require removal of adjacent connectors for the sole purpose of gaining access.

6.4.6 AIR FILTER DESIGN REQUIREMENTS

Equipment filters will be designed to provide the following housekeeping features:

A. Access - Air filters shall be accessible for cleaning and replacement.
B. Configuration - Non-disposable air filters shall be configured to allow them to be cleaned by a vacuum cleaner attachment.
C. Replacement of filter shall comply with its service life.

6.4.7 CODING AND LABELING

The coding and labeling system is intended to simplify the crew's work in flight.

Sections of standard 6.4.7.1, 6.4.7.2, 6.4.7.3 apply to the crew activities inside the vehicle.

Due to the unique conditions of the environment and the limitations associated with performing EVA, the requirements for coding, labeling and inventory are in a separate section, 6.4.7.4.

Considering that the use of this section of the joint standard will lead to considerable modifications of the transport vehicles, its application to the Progress-M vehicle is limited to the interior of the cargo compartment and the cargo delivered.

For the Soyuz TM, it is possible to use individual sections of this standard by special agreement after the decision has been made concerning the use of the Soyuz TM ~~fot~~ for the international crew or as assured crew return vehicle.

6.4.7.1 INTRAVEHICULAR ACTIVITY (IVA) CODING

6.4.7.1.1 PURPOSE OF CODING

This section of the standard pertains to the signs that are on onboard equipment linked to the crew interface and that hereinafter shall be called the Onboard Information Labels, or OILs.

The coding system must ensure the following:

1. Unambiguity of code of all labeled components.

2. Uniform principles of coding under circumstances in which there are numerous manufacturers suppliers of the various equipment components participating in the international project.

3. The coding system must be simple, logical, and clear.

The software must provide functional support of the coding principles and logic that are developed, guaranteeing the unambiguity of each code assigned, and it must enable control of the equipment for manufacturing labels with bar codes. OILs with bar codes must be as lightweight as possible and small and must be able to be affixed to virtually any console, instrument, cable, or pipe.

4. Engineering Units. Numerical values must be displayed and controlled in metric units.

6.4.7.1.2 TYPES OF CODING

6.4.7.1.2.1- LOCATION CODING

For purposes of location coding, all interior panels must have OIL-placards that bear the following information (Figure 6.4.7.1.2.1-1):

(1) Name of the module.

(2) Identification number of the panel, the first digit of which indicating the side (wall, ceiling, or floor).

(3) Letter designation: deck (D) or overhead (O) or starboard (S) or port (P), which are based on the module's coordinate system.

(4) Bar code on a separate line.

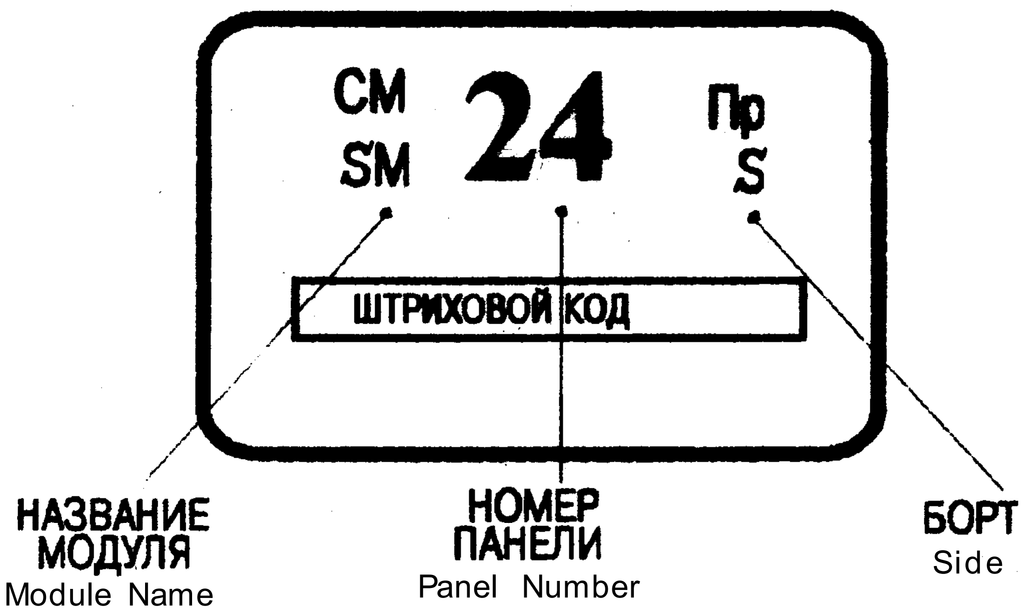


Figure 6.4.7.1.2.1-1 Location Coding

These graphic layouts of labels do not apply to the FGB

6.4.7.1.2.2- ORIENTATION CODING

For purposes of orientation coding, all entrances, exits, passages, etc., must have OILs that bear the following information (Figure 6.4.7.1.2.2-1):

(1) Numeric designation of the numbers of all four sides, are based on the module's coordinate system; the required side must be distinguishable by its larger, boldface type.

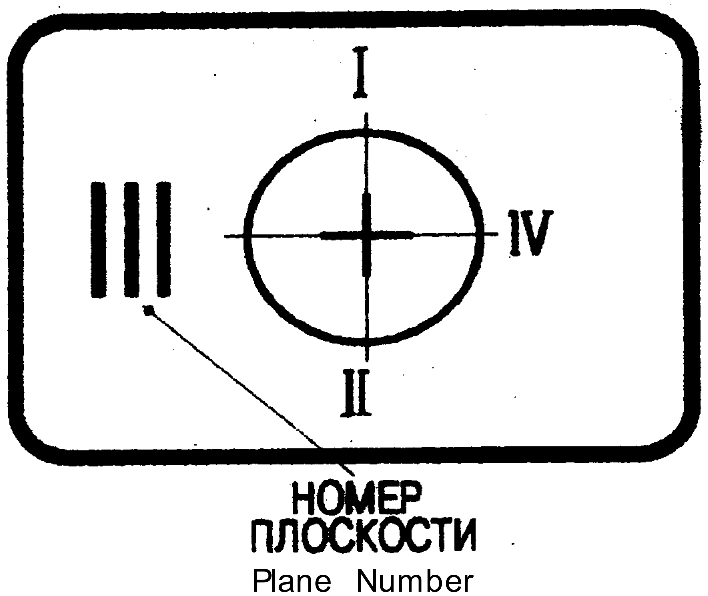


Figure 6.4.7.1.2.2-1 Attitude Code

These graphic layouts of labels do not apply to the FGB.

6.4.7.1.2.3 EQUIPMENT CODING

(1) Stationary equipment (Figure 6.4.7.1.2.3-1)

OILs bearing the following information must be installed on stationary onboard equipment in places that can be easily seen by the crew:

- abbreviated name of the system.
- name of the equipment.
- the equipment's designation on the block diagram.
- bar code on a separate line (as necessary).

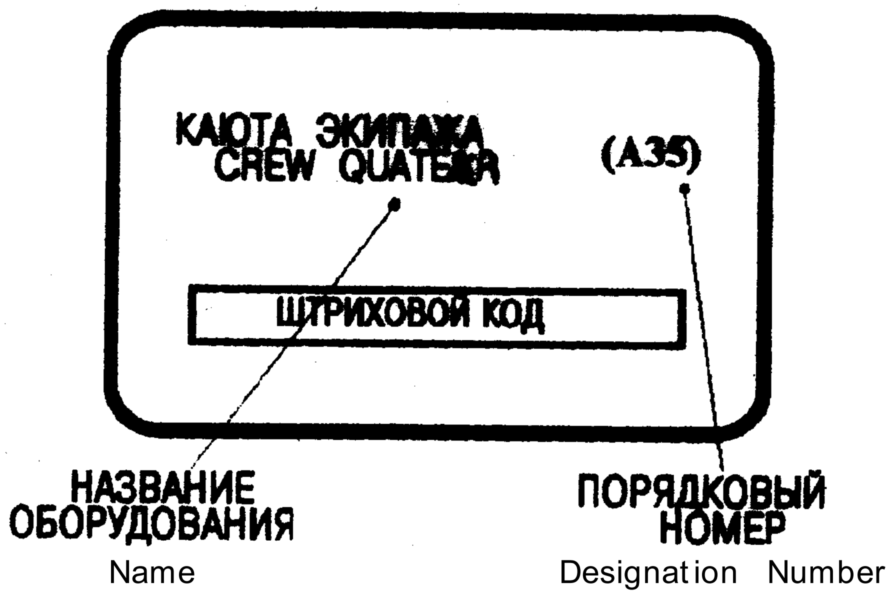


Figure 6.4.7.1.2.3-1_Stationary Equipment

These graphic layouts of labels do not apply to the FGB.

(2) Portable equipment (Figure 6.4.7.1.2.3-2)

OILs bearing the following information must be installed on portable onboard equipment in places that can be easily seen by the crew:

- abbreviated name of the system
- name of the equipment.
- the equipment's designation on the block diagram.
- Removable bar code on a separate line.

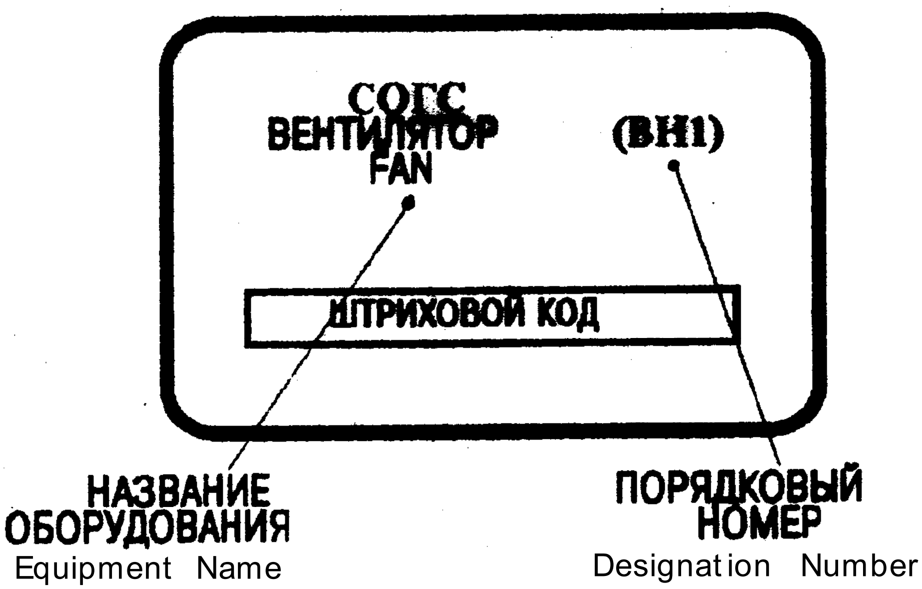


Figure 6.4.7.1.2.3-2_Portable Equipment

These graphic layouts of labels do not apply to the FGB.

(3) Cables, pipes (Figure 6.4.7.1.2.3-3)

Each cable or pipe with which the crew works must have an OIL bearing the following information:

- specific cable to which the connectors belong (acronym of system, or index on the electrical diagram).
- system to which the cable belongs.
- bar code on a separate line as necessary (upon an appropriate decision made by a joint NASA/RSA Energia team).

In addition, the cables and pipes must be color coded, which enables the crew to quickly determine the cable (or wire) needed, the degree of hazard, pressure, or direction of flow in electrical systems or hydraulic or gas lines.

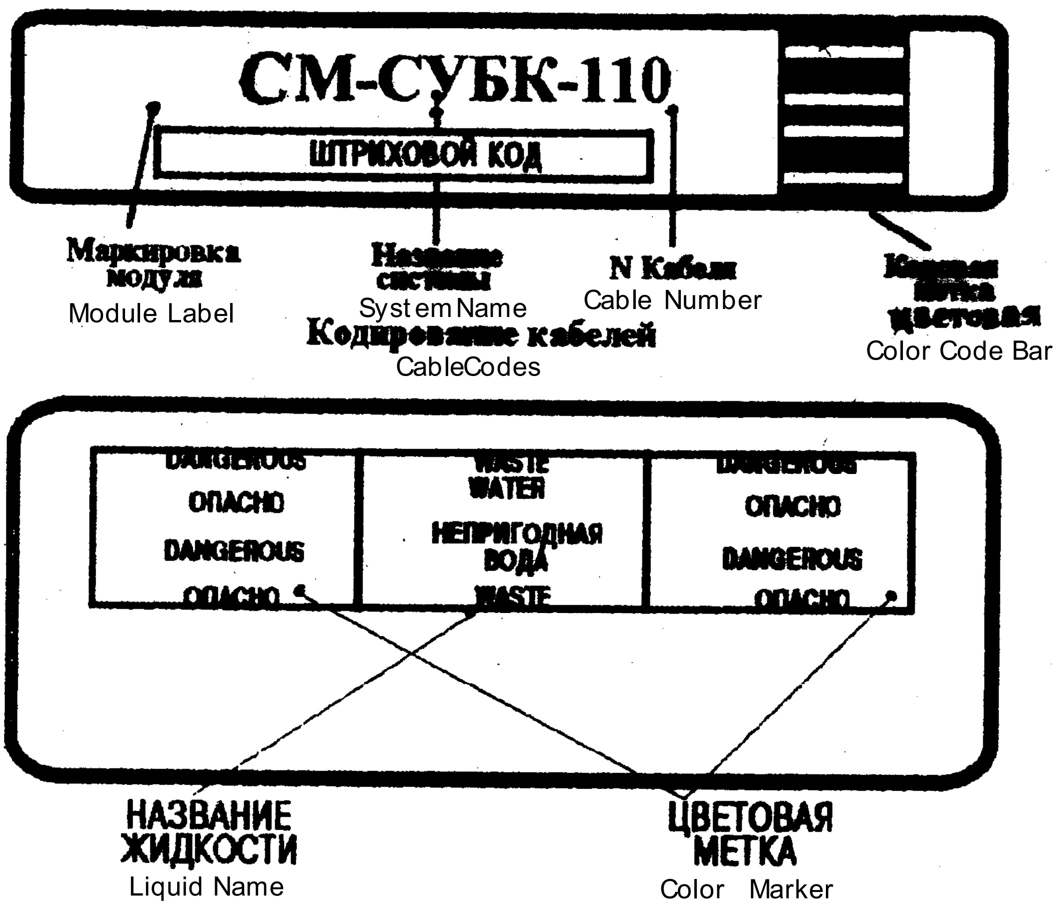


Figure 6.4.7.1.2.3-3 Piping Code

These graphic layouts of labels do not apply to the FGB.

(4) Front panels of instruments

OILs bearing the following information must be installed on or near the front panels of consoles or controls (Figure 6.4.7.1.2.3-4):

name of the console or control.

bar code on a separate line as necessary.

Figure 6.4.7.1.2.3-4 Panels and Controls Code

These graphic layouts of labels do not apply to the FGB.

6.4.7.1.2.4 EMERGENCY WARNING CODING

OILs bearing the following information must be used for emergency-and-warning coding (Figure 6.4.7.1.2.4-1):

- name of warning
- color designation of hazard characteristics
- Bar-code on a separate line as necessary

Figure 6.4.7.1.2.4-1 Caution and Warning Code

These graphic layouts of labels do not apply to the FGB.

6.4.7.1.2.5 MANUFACTURING PLANT CODING

Manufacturing-plant coding on instruments, assemblies, and any other onboard equipment must not interfere with the placement of OILs.

6.4.7.1.3 SYSTEMS OF CODING

6.4.7.1.3.1 ALPHANUMERIC CODING

Alphanumeric coding is designed for the following:

(1) Quick determination by the crew of their location and orientation inside and outside the station.

(2) Location of required equipment, instrumentation, and cables.

(3) Ability to use required fonts and abbreviations.

6.4.7.1.3.2 COLOR CODING

Color coding is designed for the following:

(1) Warning of different types of hazards.

(2) Identifying chemical and other compositions of working medium.

(3) Making determinations of orientation and location by the crew easier.

6.4.7.1.3.3 AURAL CODING

Aural coding is designed for making various types of commands heard.

(1) There must not be more than 5-7 types of aural coding.

(2) Aural signals must be easily distinguishable from one another in terms of both amplitude and frequency.

6.4.7.1.3.4 VOICE CODING

(1) Standardization of words and expressions.

(2) Unambiguity of interpretation.

6.4.7.1.3.5 BAR CODING

Bar coding is designed for the following:

(1) Ensuring that each unit of onboard equipment is matched with its proper site of installation.

(2) Tracking the movement of any detachable or delivered equipment or materials that pass through the station during the station's operation.

6.4.7.1.3.6 PICTOGRAM CODING

Pictogram coding is designed for the following:

(1) The most frequently encountered types of coding.

(2) Making the work of the international crew easier (language barrier).

6.4.7.1.4 REQUIREMENTS FOR THE USE OF LANGUAGES

6.4.7.1.4.1 PRINCIPLES OF USE

Equipment labels (IVA and EVA) in the RS must be written in two languages: Russian and English. To the extent specified in section 6.4.7.1.4.3, English Language text shall be provided in the RS on equipment OILs, faces of control panels, controls, etc. Requirements for equipment brought into the RS temporarily are dispositioned in section 6.4.7.1.4.7.

Specific implementation of English Language terminology on equipment and control panels in the FGB is contained in Section 6.4.7.1.4.8.

6.4.7.1.4.2 READABILITY REQUIREMENTS

The size of the letters must be the same in both languages.

6.4.7.1.4.3 REQUIREMENTS FOR USE OF ENGLISH

English must be used on the RS in the following areas:

(1) Emergency systems

English Language inscriptions shall be provided on critical equipment, controls, control panels, etc., which provides for crew safety to provide direction/instructions to the crew to indicate the source of a dangerous condition, or the method of recovery or escape.

(2) Equipment used by non-Russian crew members

Equipment (hardware, controls, and control panels) in the RS which will be operated by non-Russian crewmembers during the course of normal station activities, including maintenance, or in any critical or emergency situation, will provide for English markings, labels, inscriptions, etc.

(3) Orientation and Location coding

English Language inscriptions shall be provided on all entrances, exits, passages, etc., for the purposes of orientation coding in accordance with section 6.4.7.1.2.1 of this document.

English Language inscriptions shall be provided on all interior panels showing that panel's location.

6.4.7.1.4.4 ACRONYMS (OR ABRIDGEMENTS) AND ABBREVIATIONS

Russian acronyms associated with the equipment described above in Point 6.4.7.1.4.3, point 2 shall be either directly translated into existing NASA corresponding English acronyms or the English terminology that best describes the Russian acronym's meaning wil be established. Wording which is installed on the above mentioned equipment shall be included in the established joint terminology contained in the ISS Lexicon.

6.4.7.1.4.5 RESERVED

6.4.7.1.4.6 ON-BOARD COMPUTER DISPLAYS

RS displays shall provide the crew with the option to view all text in either English of Russian for use on RS computers. The English and Russian displays shall utilize identical format, present identical information to the crew, and allow commands to be executed form either the English or Russian text.

6.4.7.1.4.7 REQUIREMENTS FOR TEMPORARY SUPPLIED EQUIPMENT

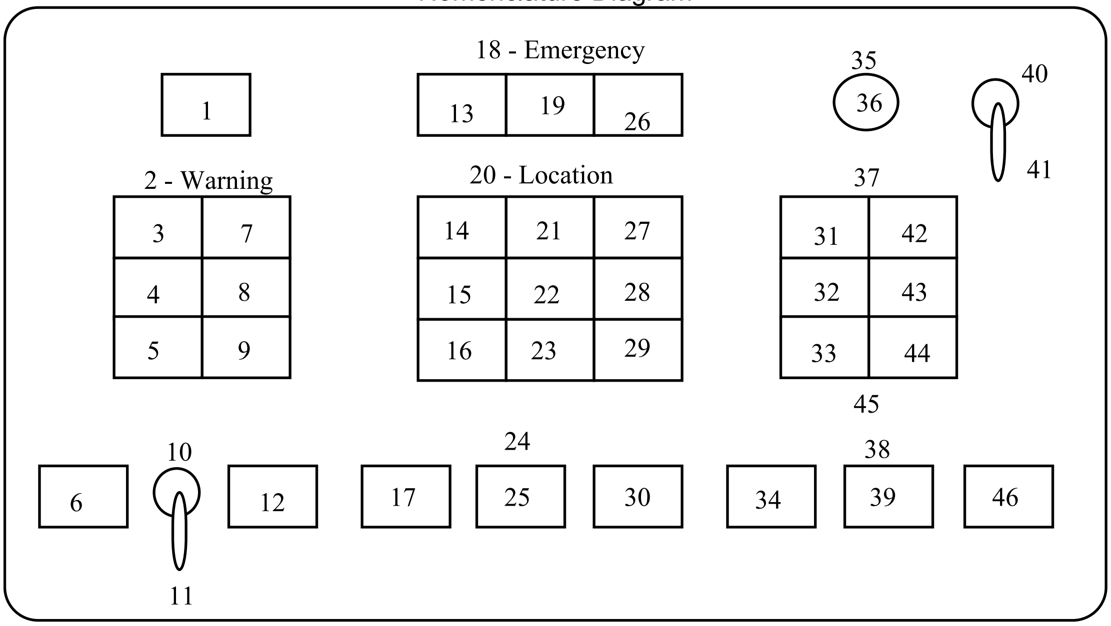
OILs for equipment temporarily supplied to the RS are not regulated by this standard, but are determined by separate decisions.

6.4.7.1.4.8 SPECIFIC IMPLEMENTATION OF ENGLISH IN THE FGB

1. FGB Control Panels

~~**Figure 6.4.7.1.3-1 Caution/Warning Panel**~~

Nomenclature Diagram



Caution/Warning Panel Nomenclature

No.	Nomenclature	Description of Function
1.	None	Pictogram on light which indicates a caution/warning event
2.	WARNING	General heading over block of warning lights
3.	OTHER	Warning light for other warnings than the specifically called out warnings in this block
4.	POWER SYSTEM	Warning light associated with the power system. Examples include low voltage, etc.
5.	ATM COND	Warning light associated with traces of toxins in the atmosphere. More sensitive than class 1 tox. May indicate time to change filter, etc.
6.	ACK	Button to acknowledge tones and switch them off
7.	TRANS VEHICLE	Warning light associated with transportation vehicles docked with the station. Ex is depress of equipment compartment.
8.	SMOKE	Warning light that smoke has been detected by smoke sensor
9.	ATM PRESS	Warning light to indicate a slow leak of atmosphere has hit low press threshold.
10.	TTS	Switch for SM to select TTS to broadcast C/W tones
11.	LOCAL	Other modules than SM must use C/W speaker to broadcast tones
12.	TEST	Button to test all lights in the panel
13.	FIRE	Lamp emergency associated with the fire sensor
14.	SM	Location light showing that the C/W event is in the SM
15.	DC	Location light showing that the C/W event is in the DC
16.	LSM	Location light showing that the C/W event is in the LSM
17.	FIRE	Button to identify location of fire in case of multiple events
18.	EMERGENCY (1 word)	General heading over block of emergency lights
19.	$\Delta P/\Delta t$	Emergency light associated with rate depress events
20.	LOCATION	General heading over block of lights showing event locations in modules
21.	FGB	Location light showing that the C/W event is in the FGB
22.	UDM	Location light showing that the C/W event is in the UDM

No.	Nomenclature	Description of Function
23.	RMI	Location light showing that the C/W event is in the RMI
24.	MODULE IDENTIFY (one line)	General heading over three buttons to identify event locations by module in the case of multiple alarms
25.	ΔP/Δt	Button to identify location of depress in case of multiple events
26.	ATM	Emergency light associated with toxic atmosphere events (gross)
27.	USOS	Location light showing that the C/W event is in the USOS
28.	SPP	Location light showing that the C/W event is in the SPP
29.	RM2	Location light showing that the C/W event is in the RM2
30.	ATM	Button to identify location of class 1 toxic even in case of multiple events
31.	OTHER	Caution light for other caution events than the specifically called out caution events in this block
32	CMPTR	Caution light associated with computer system failures
33.	MANUAL	Advisory light signifying a manual activation of class 1 tones
34.	FIRE	Button to manually activate the Class 1 fire alarm
35.	POWER	General heading over panel power controls
36.	FUSE	Label on fuse
37.	CAUTION	General heading over block of lights associated with Caution events
38.	MANUAL ALARM	General heading over three buttons to activate class 1 alarms-fire, depress, and toxic atm
39.	ΔP/Δt	Button to manually activate the Class 2 depress alarm
40.	ON	Showing position of switch to turn panel power on
41.	OFF	Showing position of switch to turn panel power off
42.	TIMER	Caution light playing class 3 tones to act as alarm clock, and timer
43.	COMM	Caution light signifying a crew call to the communications system
44.	MESSAGE	General advisory light for all class 4 events (no tones)
45.	ADVISORY	General heading showing that "MANUAL" and "GENERAL" are advisory signals, and not Caution events
46.	ATM	Button to manually activate the Class 1 toxic atmosphere alarm

Figure 6.4.7.1.3-1 Caution/Warning Panel

~~Figure 6.4.7.1.3-2 On Board Recepticle RBS - 10/3~~

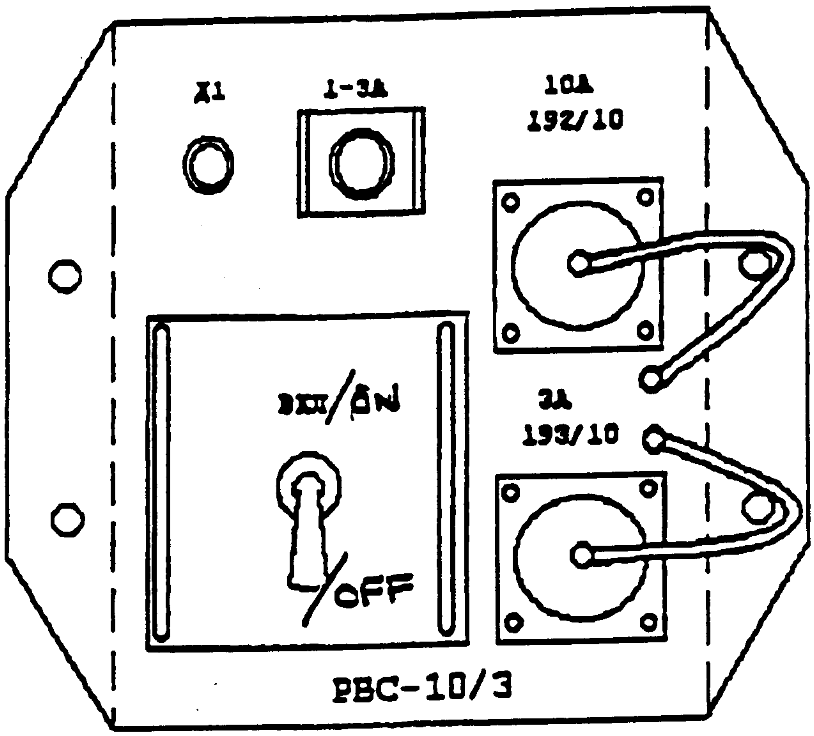


Figure 6.4.7.1.3-2 On Board Receptacle RBS - 10/3

~~Figure 6.4.7.1.3-3 Communication Panel~~

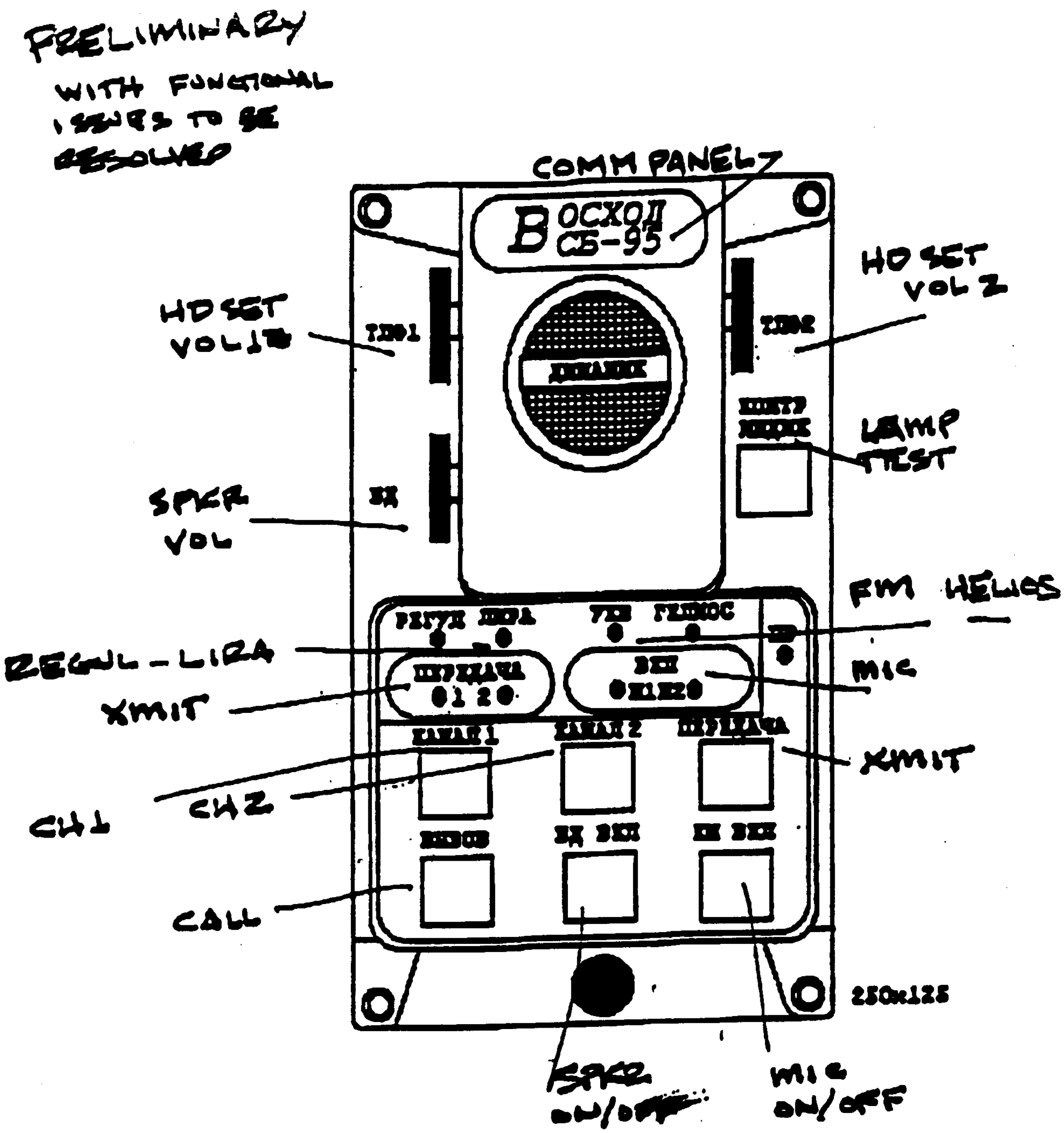


Figure 6.4.7.1.3-3 Communication Panel

~~**Figure 6.4.7.1.3-4 Light Panel**~~

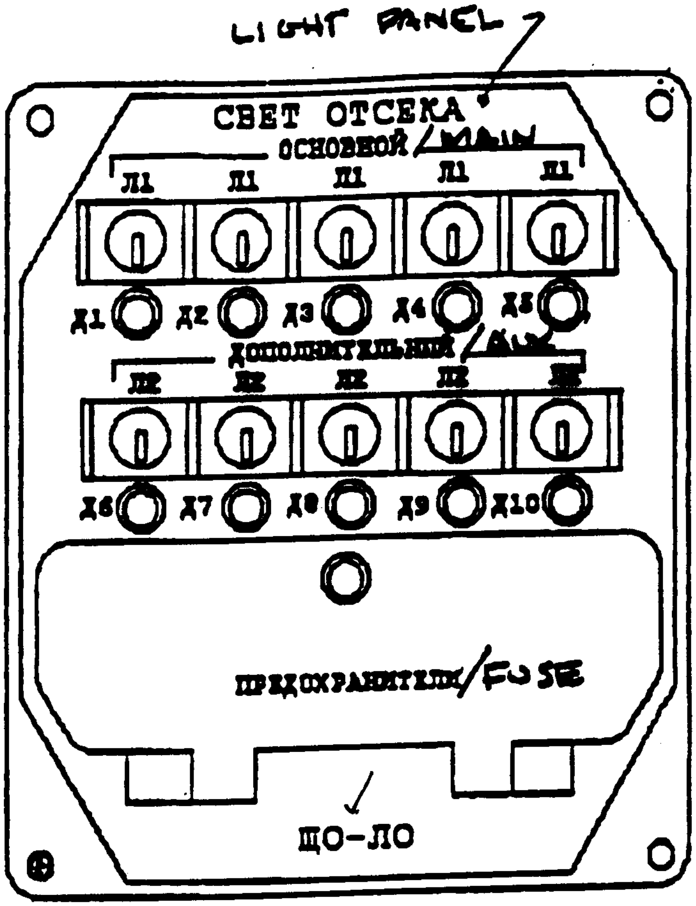


Figure 6.4.7.1.3-4 Light Panel

2. FGB Labels

Label	Label text
FGB 001	FGB 001 CNC UFHYBNEHF (F8) HEADSET
FGB 002	FGB 002 CNC UFHYBNEHF (F9) HEADSET
FGB 003	FGB 003 CNC NFYUTYNF (F4) PUSH TO TALK
FGB 004	FGB 004 CNC NFYUTYNF (F5) PUSH TO TALK
FGB 005	FGB 005 CNC NFYUTYNF (F6) PUSH TO TALK
FGB 006	FGB 006 CNC NFYUTYNF (F7) PUSH TO TALK
FGB 007	FGB 007 CE<R <K GHTL (F20) FUSE BOX
FGB 008	FGB 008 CE<R <K GHTL (F21) FUSE BOX
FGB 009	FGB 009 CE<R <K GHTL (F22) FUSE BOX

NOTES:

1. Labels are 20mm wide by 60 mm high.
2. Corners are radiused to 5mm.
3. Text is centered on label.
4. English text font is Ariel 11 point
5. Russian text font is Ariel equivilen 11 point.
6. Label number (top right hand corner) is 6 point font.
7. Five (5) copies are required for each label.

FGB LABELS-GENERAL H/W

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Label	Label number	Label text
FGB 010	FGB010	CE<R <K GHTL (F23) FUSE BOX
FGB 011	FGB 011	CE<R <K GHTL (F29) FUSE BOX
FGB 012	FGB 012	CE<R <K GHTL (F11) FUSE BOX
FGB 013	FGB 013	C” C FRR <FN (F71) BATTERY
FGB 014	FGB 014	C” C FRR <FN (F72) BATTERY
FGB 015	FGB 015	C” C FRR <FN (F73) BATTERY
FGB 016	FGB 016	C” C FRR <FN (F74) BATTERY
FGB 017	FGB 017	C” C FRR <FN (F75) BATTERY
FGB 018	FGB 018	C” C FRR <FN (F76) BATTERY

NOTES:

1. Labels are 20mm wide by 60 mm high.
2. Corners are radiused to 5mm.
3. Text is centered on label.
4. English text font is Ariel 11 point
5. Russian text font is Ariel equivilen 11 point.
6. Label number (top right hand corner) is 6 point font.
7. Five (5) copies are required for each label.

FGB LABELS-GENERAL H/W		
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Label	Label text
FGB 019	FGB019 CJNH CGY DUR1 (1) INTERNAL PUMP ASSEMBLY
FGB 020	FGB 020 CJNH CGY DUR1 (2) INTERNAL PUMP ASSEMBLY
FGB 021	FGB 021 CJNH CGY DUR2 (1) INTERNAL PUMP ASSEMBLY
FGB 022	FGB 022 CJNH CGY DUR2 (2) INTERNAL PUMP ASSEMBLY
FGB 023	FGB 023 CJNH DTYNBKZNJH RJVAJHNYSQ (E14) PERSONAL FAN
FGB 024	FGB 024 CJNH DTYNBKZNJH RJVAJHNYSQ (E15) PERSONAL FAN
FGB 025	FGB 025 CJNH DTYNBKZNJH RJVAJHNYSQ (E16) PERSONAL FAN
FGB 026	FGB 026 CJ: GSKTC<JHYBR (GC1) CABIN AIR CLEANER
FGB 027	FGB 027 CJ: GSKTC<JHYBR (GC2) CABIN AIR CLEANER

NOTES:

1. Labels are 20mm wide by 60 mm high.
2. Corners are radiused to 5mm.
3. Text is centered on label.
4. English text font is Ariel 11 point
5. Russian text font is Ariel equivilen 11 point.
6. Label number (top right hand corner) is 6 point font.
7. Five (5) copies are required for each label.

FGB LABELS-GENERAL H/W

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Label	Label text
FGB 028	FGB028 CJ: CFKATNRB (C1) CLEANING WIPES
FGB 029	FGB 029 CJ: CFKATNRB (C2) CLEANING WIPES
FGB 030	FGB 030 CJ: CFKATNRB (C3) CLEANING WIPES
FGB 031	FGB 031 CJ: CFKATNRB (C4) CLEANING WIPES
FGB 032	FGB 032 CJ: CFKATNRB (C5) CLEANING WIPES
FGB 033	FGB 033 CJ: GSKTABKMNH (GA1) AIR FILTER
FGB 034	FGB 034 CJ: GSKTABKMNH (GA2) AIR FILTER
FGB 035	FGB 035 CJ: GSKTABKMNH (GA3) AIR FILTER
FGB 036	FGB 036 CJ: GSKTABKMNH (GA4) AIR FILTER

NOTES:

1. Labels are 20mm wide by 60 mm high.
2. Corners are radiused to 5mm.
3. Text is centered on label.
4. English text font is Ariel 11 point
5. Russian text font is Ariel equivilen 11 point.
6. Label number (top right hand corner) is 6 point font.
7. Five (5) copies are required for each label.

FGB LABELS-GENERAL H/W

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Label	Label text
FGB 037	FGB037 CJ: GSKTABKMNH (GA5) AIR FILTER
FGB 038	FGB 038 CJ: GSKTABKMNH (GA6) AIR FILTER
FGB 039	FGB 039 CJ: GSKTABKMNH (GA7) AIR FILTER
FGB 040	FGB 040 CJ: GSKTABKMNH (GA8) AIR FILTER
FGB 041	FGB 041 PRESSURE EQUALIZATION VALVE
FGB 045	FGB 045 PRESSURE MONITORING VALVE

NOTES:

1. Labels are 20mm wide by 60 mm high.
2. Corners are radiused to 5mm.
3. Text is centered on label.
4. English text font is Ariel 11 point
5. Russian text font is Ariel equivilen 11 point.
6. Label number (top right hand corner) is 6 point font.
7. Five (5) copies are required for each label.

Twenty (20) copies are required for FGB 041, and FGB 045.

FGB LABELS-GENERAL H/W		
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Label	FGB number	Text
FGB 102	FGB 102	CJ: /CJUC ABKNMH LKZ UFPJFYFKBPFNJH GAS ANALYZER SPARE FILTER
FGB 048	FGB 048	CJ: /CJUC GFYTKM "GR PRESSURE CHECK VALVE ASSEMBLY
FGB 049	FGB 049	CJ: /CJUC DTYNBKZNJH (D1) TRACE CONTAMINANT FAN
FGB 050	FGB 050	CJ: /CJUC UFPJFYFKBPFNJH (UF1) GAS ANALYZER
FGB 051	FGB 051	CJ: /CJUC VFYJVTNH VFL (VY1) MANOMETER
FGB 052	FGB 052	CGJGN LFNXBR LSVF (F1) SMOKE DETECTOR
FGB 053	FGB 053	CGJGN LFNXBR LSVF (F2) SMOKE DETECTOR
FGB 054	FGB 054	CGJGN LFNXBR LSVF (F3) SMOKE DETECTOR

NOTES:

1. Labels are 20mm wide by 60 mm high.
2. Corners are radiused to 5mm.
3. Text is centered on label.
4. English text font is Ariel 11 point
5. Russian text font is Ariel equivilen 11 point.
6. Label number (top right hand corner) is 6 point font.
7. Five (5) copies are required for each label.

Note: If Ariel 11 point will not fit (as in these drawings), then use Ariel Narrow.

FGB LABELS-GENERAL H/W

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Label No.	Label
FGB 055	FGB 055 CGJGN LFNXBR LSVF (F4) SMOKE DETECTOR
FGB 056	FGB 056 CGJGN LFNXBR LSVF (F5) SMOKE DETECTOR
FGB 057	FGB 057 CGJGN LFNXBR LSVF (F6) SMOKE DETECTOR
FGB 058	FGB 058 CGJGN LFNXBR LSVF (F7) SMOKE DETECTOR
FGB 059	FGB 059 CGJGN LFNXBR LSVF (F8) SMOKE DETECTOR
FGB 060	FGB 060 CGJGN LFNXBR LSVF (F9) SMOKE DETECTOR
FGB 061	FGB 061 CGJGN LFNXBR LSVF (F10) SMOKE DETECTOR
FGB 062	FGB 062 CGJGN JUYTNEIBNTKM (F1) FIRE EXTINGUISHER
FGB 063	FGB 063 CGJGN JUYTNEIBNTKM (F2) FIRE EXTINGUISHER

NOTES:

1. Labels are 20mm wide by 60 mm high.
2. Corners are radiused to 5mm.
3. Text is centered on label.
4. English text font is Ariel 11 point
5. Russian text font is Ariel equivilen 11 point.
6. Label number (top right hand corner) is 6 point font.
7. Five (5) copies are required for each label.

FGB LABELS-GENERAL H/W

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Label	Label text
FGB 064	FGB 064 CGJGN JUYTNEIBNTKM (F3) FIRE EXTINGUISHER
FGB 065	FGB 065 CGJGN CBP JH LS{ (F1) GAS MASK
FGB 066	FGB 066 CGJGN CBP JH LS{ (F2) GAS MASK
FGB 067	FGB 067 CGJGN CBP JH LS{ (F3) GAS MASK
FGB 068	FGB 068 CJ CDTNBKMYBR GTHTYJCYSQ PORTABLE LIGHT
FGB 069	FGB 069 CJ CDTNBKMYBR GTHTYJCYSQ PORTABLE LIGHT
FGB 070	FGB 070 CJ CDTNBKMYBR GTHTYJCYSQ PORTABLE LIGHT
FGB 071	FGB 071 CJ CDTNBKMYBR GTHTYJCYSQ PORTABLE LIGHT
FGB 072	FGB 072 RF<TKB NTKTRFVTHS TV CAMERA CABLES

NOTES:

1. Labels are 20mm wide by 60 mm high.
2. Corners are radiused to 5mm.
3. Text is centered on label.
4. English text font is Ariel 11 point
5. Russian text font is Ariel equivilen 11 point.
6. Label number (top right hand corner) is 6 point font.
7. Five (5) copies are required for each label.

FGB LABELS-GENERAL H/W

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FGB 073

FGB 073
RF<TKB VJYBNJHF
TV MONITOR CABLES

FGB 074

FGB 074
HJPTNRF KFGNJGF
LAPTOP DATA

FGB 075

FGB 075
BYCNHEVTYNS LKZ CnF
HATCH AND DOCKING TOOLS

NOTES:

1. Labels are 20mm wide by 60 mm high.
2. Corners are radiused to 5mm.
3. Text is centered on label.
4. English text font is Ariel 11 point
5. Russian text font is Ariel equivilen 11 point.
6. Label number (top right hand corner) is 6 point font.
7. Five (5) copies are required for each label.

FGB LABELS-GENERAL H/W		
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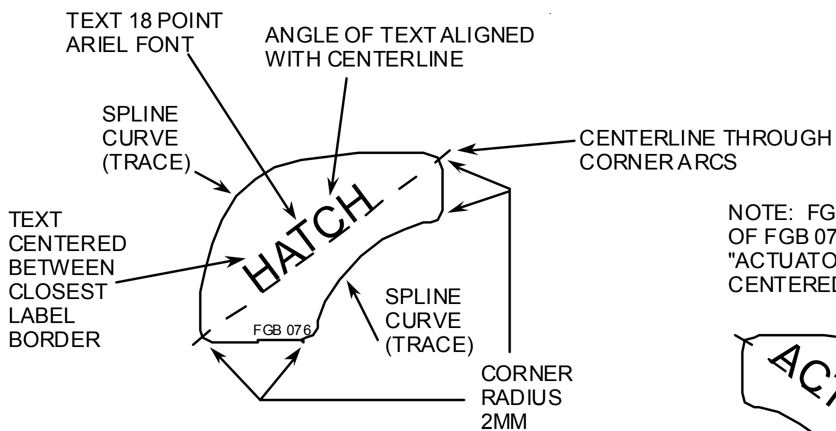
LABEL INSTALLATION

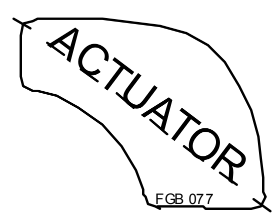
GENERAL NOTES FOR FGB 076, 077, 078, 079:

1. THESE LABELS ARE FOR IVA USE.
2. FIVE (5) COPIES ARE REQUIRED OF EACH LABEL.
3. SMALL FGB NUMBER IS 6 POINT ARIEL FONT.
4. COMPLEX CURVE ON FGB 076, 077 MUST BE TRACED.

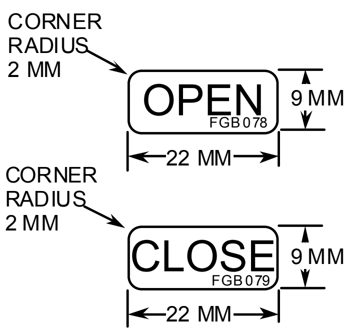
FGB 076, 077 DETAILS:



NOTE: FGB 077 MIRROR IMAGE OF FGB 076. WORDING "ACTUATOR" ALIGNED AND CENTERED AS IN FGB 076.



FGB 078, 079 DETAILS:



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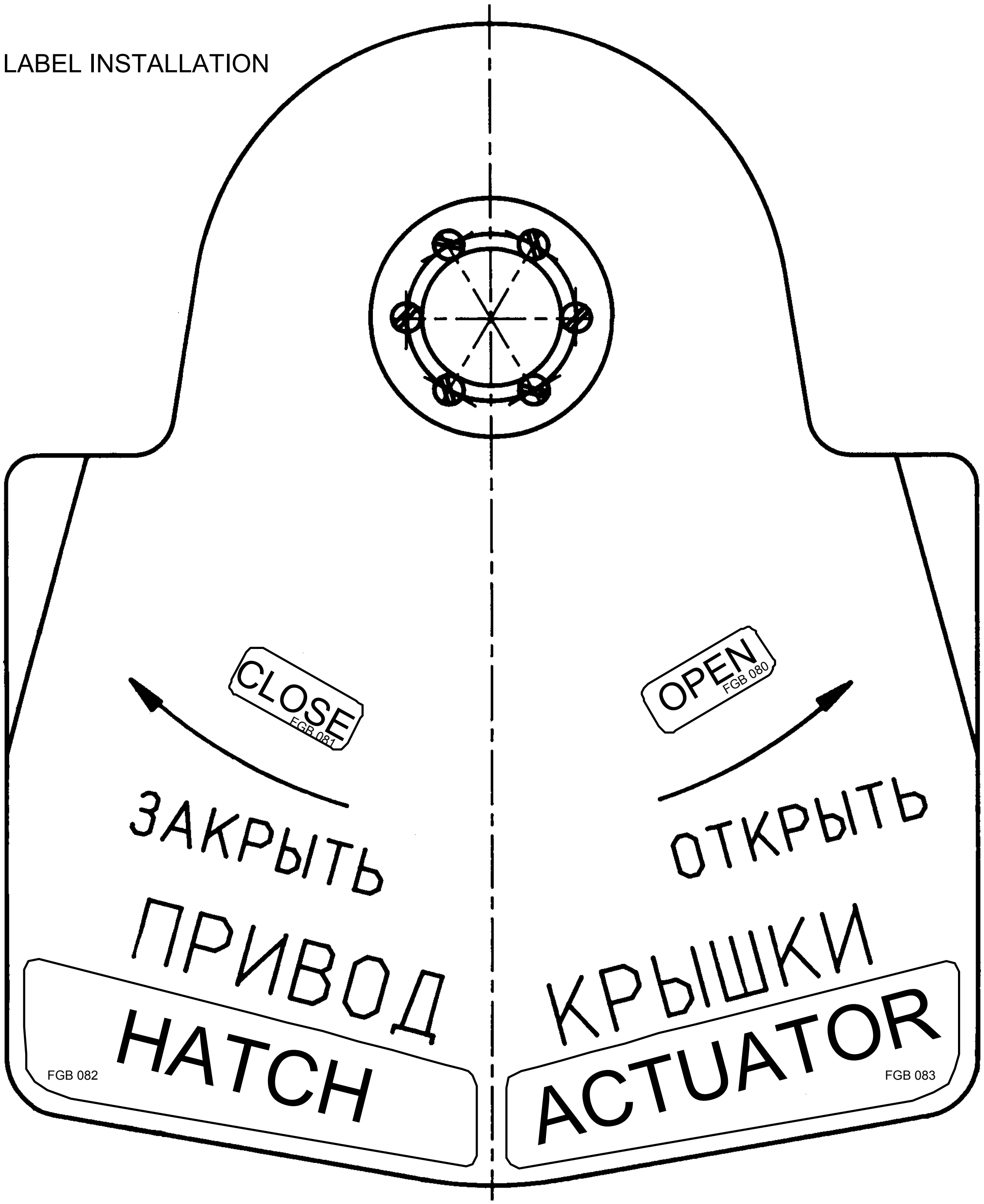
LABEL INSTALLATION



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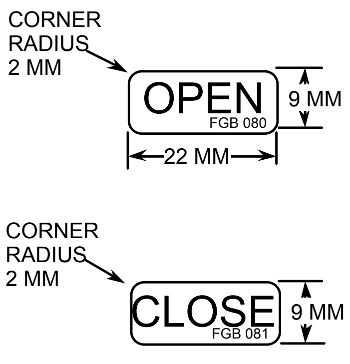
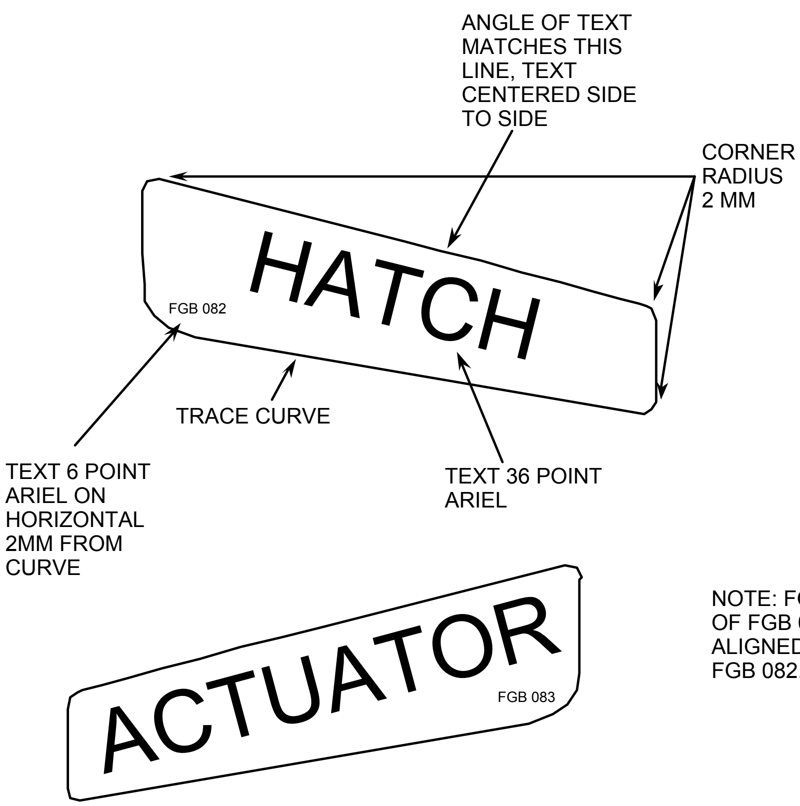
FGB 080, 081 DETAILS:



GENERAL NOTES FOR FGB 080, 081, 082, 083:

1. THESE LABELS ARE FOR IVA USE.
2. FIVE (5) COPIES ARE REQUIRED OF EACH LABEL.
3. SMALL FGB NUMBER IS 6 POINT ARIEL FONT.
4. COMPLEX CURVE ON FGB 082, 083 MUST BE TRACED.

FGB 082, 083 DETAILS:



NOTE: FGB 083 MIRROR IMAGE OF FGB 082. TEXT "ACTUATOR" ALIGNED AND CENTERED AS IN FGB 082.

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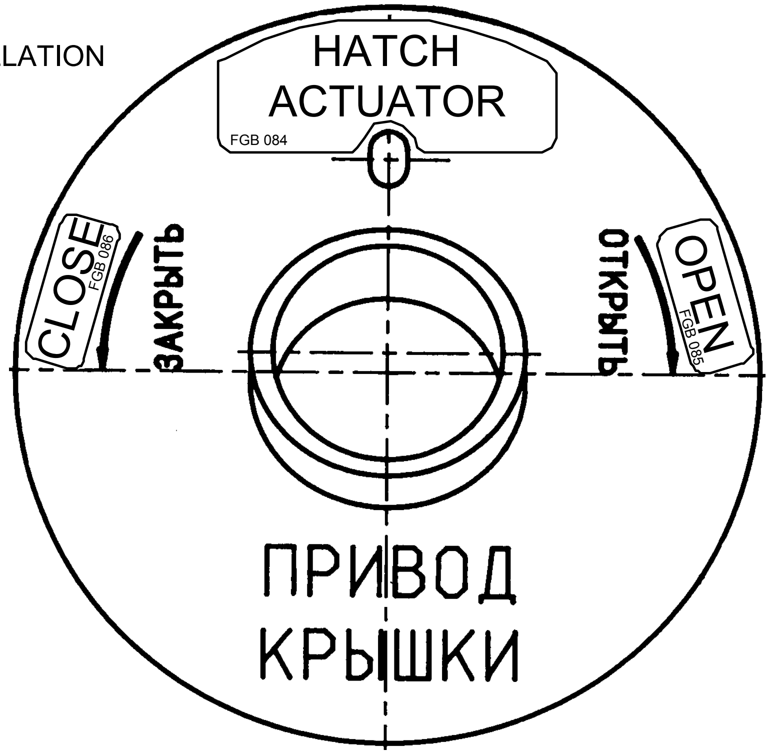
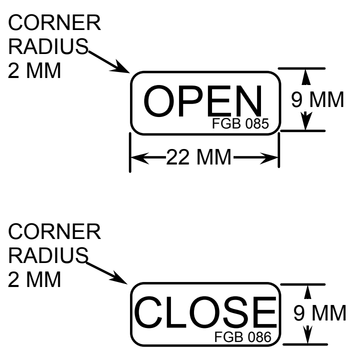
LABEL INSTALLATION



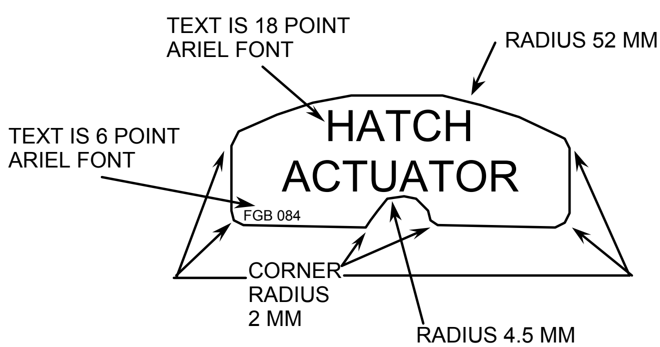
GENERAL NOTES FOR FGB 084, 085, 086:

1. THESE LABELS ARE FOR EVA USE (VACUUM).
2. FIVE (5) COPIES ARE REQUIRED OF EACH LABEL.
3. SMALL FGB NUMBER IS 6 POINT ARIEL FONT.
4. COMPLEX CURVE ON FGB 084 MUST BE TRACED.

FGB 085, 086 DETAILS:



FGB 084 DETAILS:



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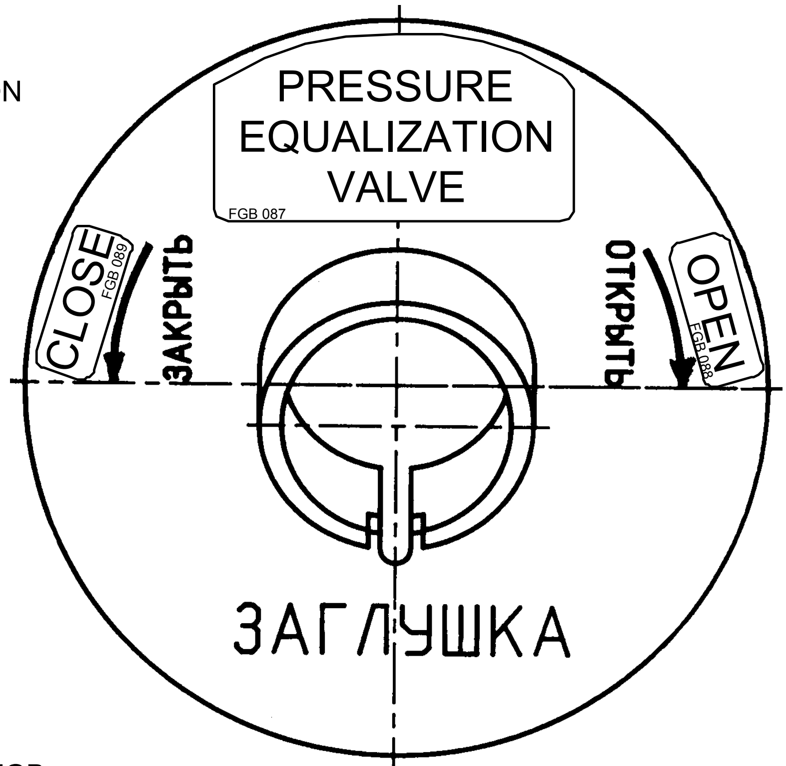
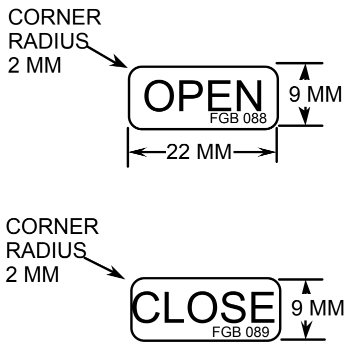
LABEL INSTALLATION



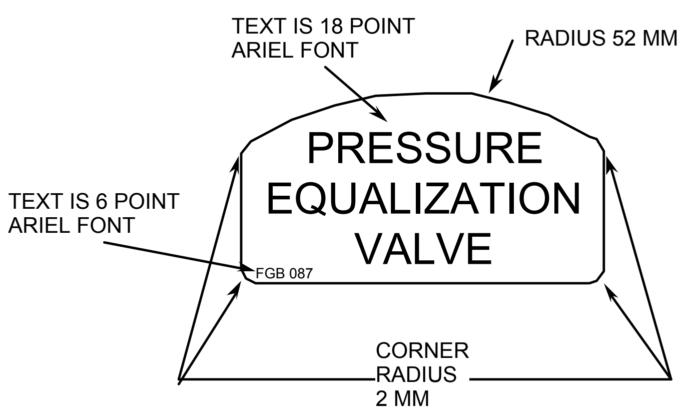
FGB 088, 089 DETAILS:



GENERAL NOTES FOR FGB 087, 088, 089:

1. THESE LABELS ARE FOR EVA USE (VACUUM).
2. FIVE (5) COPIES ARE REQUIRED OF EACH LABEL.
3. SMALL FGB NUMBER IS 6 POINT ARIEL FONT.

FGB 087 DETAILS:



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FGB 092 

FGB 093 

FGB 094 

FGB 095 

NOTES FOR FGB 092, 093, 094, 095:

1. Sizes of labels are: 5mm x 15mm
2. Corners are radiused to 2mm.
3. Large text in 12 point Ariel font (except for FGB 095, which is in 12 point Ariel Narrow).
4. Small FGB number in upper right corner is in 4 point Ariel font.
5. The following quantities are required:

   FGB 092: 80 pieces
   FGB 093: 80 pieces
   FGB 094: 40 pieces
   FGB 095: 40 Pieces

FGB 096 

FGB 097 

NOTES FOR FGB 096, 097

1. Sizes of labels are: 8mm x 25mm
2. Corners are radiused to 2mm.
3. Large text in 20 point Ariel font
4. Small FGB number in upper right corner is in 6 point Ariel font.
5. The following quantities are required:

   FGB 096: 34 pieces
   FGB 097: 34 pieces

FGB 098 

NOTES FOR FGB 098:

1. Dimensions of label: outer radius 8.5mm, inner radius 4mm
2. Text in 8 point Ariel font.

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6.4.7.1.5 RUSSIAN PROPER NAMES

1. Russian Proper names (Priroda, Rodnik, Elektron, etc.) will be used in a transliterated form (verses translated form), when their use would best portray the identity of an object or system. Examples: “Priroda” would be written “Priroda” verses “Nature”, or “Simvol” would be “Symvol”, not “Symbol”. Some adjustments may be necessary to enhance readability. Example: “Centr” would be written “Center” verses “Tsentr”. In order to identify these as proper names, pointed brackets (<>) will be used around the transliterated word. Example: <Symvol>.

2. Some Cyrillic letters (such as those used to designate channels, circuits, etc.) will stay as Cyrillic letters when associated with English text. For example, “Kanaly A, B, V” would NOT become “Channels A, B, C” or “Channels A, B, V”; rather would be written , “Channels [A], [B], [V]”. Note that square brackets are be used around the letters when associated with English text.

6.4.7.2 IVA LABELING

The technology for manufacturing OILs and for fastening them on instruments, assemblies, cables, pipes, and other inventory must ensure their resistance to damage by impact and the reliability of bar-code reading over the span of the entire period of operation.

~~The technology for manufacturing БИЛs and for fastening them on instruments, assemblies, cables, pipes, and other inventory must ensure their resistance to damage by impact and the reliability of bar-code reading over the span of the entire period of operation.~~

6.4.7.2.1 DESIGN REQUIREMENTS

6.4.7.2.1.1 ~~REQUIREMENTS FOR STANDARDIZATION OF SIGNS~~COMPONENTS OF LABELING

~~1. Standardization~~

~~Signs must be standardized both within each system and between systems.~~

~~2. Categories~~

~~The various categories of signs must be distinguishable from one another.~~

1. In order for on-board equipment to be labeled, it should have a pre-defined area (60x40mm) for the following labeling items:
   Two independent types of labels should be placed in the labeling frame (see Figure 6.4.7.2.1.1-1 and 6.4.7.2.1.1-2.

-On-Board Information Patch label for the crew (OILs ~~БИЛ~~)
***-Bar code** label for the inventory system*

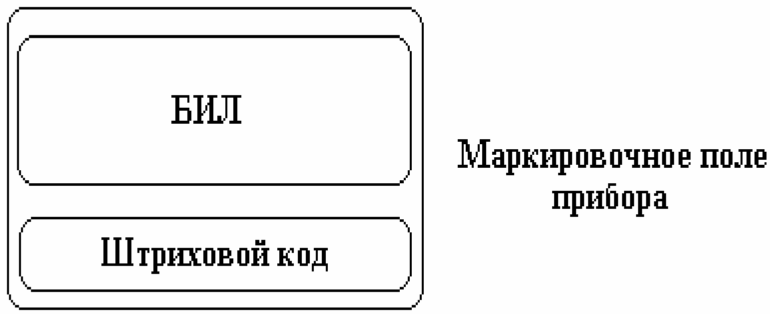


Figure 6.4.7.2.1.1-1 Device Labeling Area

2. Labeling in the form of a OILs ~~БИЛ~~, engraving on the equipment itself, or other forms of marking (such as adhesive labels) which are the responsibility of the Hardware Provider. The OILs~~БИЛ~~ should be placed on the side of the unit that is easy for the crew to see (in case it is impossible to determine which side is the best, the label should be placed on two or three sides of the unit).

3. Typical dimensions of OILs ~~БИЛ's~~ are 60x20mm (min.) but up to 60x35mm.

4. Information which should be contained on a OIL ~~БИЛ~~ consists of these 4 lines:

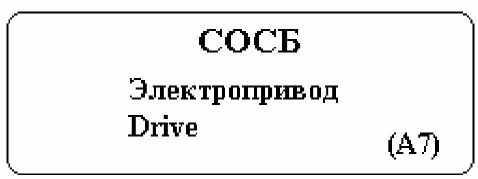


Figure 6.4.7.2.1.1-2 Label Format

- System Name Abbreviation (typically Russian Acronym such as СУБК). Height of the Font from 2.5- 5mm.
- Name of the equipment in Russian (either in full, or abbreviated if necessary) consisting of up to 35 letters including any spaces. Height of font is 2.5-4mm.
- Name of the equipment in English (either full, or abbreviated if necessary) consisting of up to 35 letters including any spaces. Height of font is 2.5-4mm.
- The schematic number of the equipment. The number should be shown in parenthesis and after the letter A , W, Г, C (A125)

  If the unit has electrical or pneumatic connectors, it's number should consist of the following elements: letter "A" and a numeric code corresponding to the electrical or pneumatic scheme. For example: (A125) or (BH 125).

  - For antennas, letter "W" may be used instead of letter "A"

- For the [ССВП] hardware, letter “Г” may be used.
- For video and audio cassettes, letter “С” may be used.

In the case of equipment that does not have an association with either electrical or pneumatic schematics (i.e. bags or kits), its number should correspond to the serial number determined by the designer with the preceding letter “A”, (for example (A11).

On the labeling area of the equipment, a label with a bar code should be attached on top of the OIL~~БИЛ~~ or next to it.

5. For equipment in the category of “on-orbit installed equipment” to the fore-mentioned information contained on the OIL should be added in the top left corner the name of the module (for example SM). Font should be italic 2.5-5mm.

Figure 6.4.7.2.1.1-3 Labeling On-orbit Installed Equipment

6. For equipment spares, in addition to the fore-mentioned information contained on the OIL~~БИЛ~~ should be added in the top left corner the module name and after the word “OIL~~ЗИП~~” which means “Spare”. The font should be italic 2.5-5mm. For this, an area should be left in the bottom right corner for it’s schematic number to be added by the crew per direction from the ground (A8).

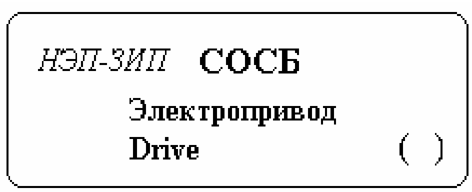


Figure 6.4.7.2.1.1-4 Labeling Equipment Spares

7. For hardware which is to be used by two or more systems:
   -The names of the systems should be listed separated by a slash (example СОСБ/СОРЦТ) Height of font: 2.5-5mm.
   -An area should be left open for two schematic numbers. If both are not known, then the area for the second can be made available by empty parenthesis (A7) ( ). The second number can be marked by the crew per direction from the ground.

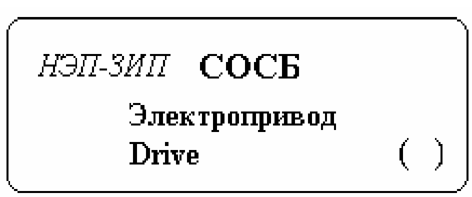


Figure 6.4.7.2.1.1-5 Hardware for Several Systems

8. For hardware falling into the category of "on-orbit installed" or "spares", the name of the module, and the schematic number should be installed on the OIL~~БИЛ~~ in the form of another separate label that can be installed on top of the OIL~~БИЛ~~ and easily changed.

НЭП	НЭП-ЗИП	(А7)

Figure 6.4.7.2.1.1-6 Separate Labels Utilization

9. For Hardware classified as "Scientific" or "Payload", on the first line of the OIL~~БИЛ~~ should be the name of the experiment. All other information should be in accord with points 3-8.

NDC 026

6.4.7.2.1.2 SIGN READABILITY REQUIREMENTS

Signs and conventional symbols must be as large as possible. They must meet the following requirements:

1. Size

The size of a warning sign must be appropriate to the distance at which it must be read (6.4.7.2.1.3 - 6.4.7.2.1.11).

2. Lighting

Warning signs must be easy to read under all the lighting conditions and with all the light-source spectral characteristics indicated in Table 6.4.7.2.1.2-1

3. Reflectability

The surface of signs must have a matte or nonluster finish.

4. Sharpness, contrast, durability

The technology for the manufacture of OILs must ensure the normal functioning and replacement of the signs over the span of 15 years of service.

Table 6.4.7.2.1.2-1 Space Vehicle Luminosity Levels

Area or function	Luminosity (lx)	Luminosity (ft. candal)
COMMON USE, SLEEP AREA	20-30	2-3
Corridors	30	3
Dark Color Panels (negative)	30	3
Emergency Light System	30	3
Night Lights	20	2
Sleep Zone	30	3
COMMON USE, WORKING AREA	300	30
Cabins	108	10
Personal Hygiene Locations	108	10
Waste Treatment	164	14
Controls Area	215	20
Light Color Panels (positive)	215	20
Maintenance Area	269	25
Galley Area	269	25
First Medical Aid	269	25
Restrooms	269	25
Bathrooms	269	25
Recreational Area	323	30
WORKING AREA	300-450	30-45
Assembly Area	323	30
Repair Area	323	30
Data Processing Area	450	45

Reading Area	450	45
Gymnasium	450	45
FILMING/PICTURE SHOOTING	800-850	80-85

NOTE: Luminosity levels shall be measured at the worksites or 760 mm (30”) from floor level. All luminosity values are minimal. To create comfortable luminosity conditions, crew members shall use individual lamps.

6.4.7.2.1.3 TYPEFACE REQUIREMENTS

Typefaces should be selected on the basis of the following requirements:

(1) Dark letters

For dark opaque letters and symbols against a light opaque or transparent background and for signs on equipment placards, the following widely used typefaces should be used (in order of preference):

Faces for engraved letters:
- a. Futuris Extra Demibold CTT
- b. Arial Sur TsTT
- c. Times New Roman Cyr CTT

Faces for engraved numbers:
- a. Futuris Extra Demibold CTT
- b. Arial Sur TsTT
- c. Times New Roman Cyr CTT

Faces for typeset letters and numbers:
- a. Futuris Extra Demibold CTT
- b. Arial Sur TsTT
- c. Times New Roman Cyr CTT

(2) Light letters

For light transparent or opaque signs against a dark, opaque background, Futuris Extra Demibold TsTT must be used.

(3) Accommodating lines that do not fit

A narrow typeface or abbreviations should be used for fitting lengthy texts.

(4)_Stenciled letters

Stenciled letters must not be used on control or test panels.

6.4.7.2.1.4 PUNCTUATION REQUIREMENTS FOR SIGNS

1. Periods

Periods (.) must not be used in equipment signs.

2. Hyphens

Hyphens (-) must not be used in equipment signs.

3. Brackets and symbols “,” (&)

Brackets and symbols “,” (&) must not be used in signs on control or test panels.

4. Slashes (/) may be used in signs in place of the words “and” “or” if they do not affect the meaning of the sign.

6.4.7.2.1.5 REQUIREMENTS FOR THE USE OF LOWERCASE AND CAPITAL

Lowercase letters must be used in abbreviations and symbols as per specifications in the Design Document for each module.

6.4.7.2.1.6 REQUIREMENTS FOR SPECIAL SYMBOLS AND LETTERS

1. Size of subscripts and superscripts

The height of letters in subscripts and superscripts must be 0.6- to 0.7-fold the height of the standard letters in a line.

2. Subscripts

Numerals and capital letters in subscripts must be centered on the baseline of the type in the line.

3. Lowercase letters in subscripts

The baseline of lowercase letters and letter ovals such as —, y, □□ (g, p, q) in subscripts must be on the same baseline as that of capital letters in subscripts.

4. Degrees symbol

The degrees symbol (°) must be centered on an imaginary line passing through the top of the symbols M and ¬, (F and C).

5. Symbol for “number” N (#)

The symbol for “number” is N. In English, the symbol for “number” is #. The symbol must be centered on an imaginary line passing through the top of the numeral and must be separated from the numeral by two numeral-line widths.

6.4.7.2.1.7 REQUIREMENTS FOR LETTER HEIGHTS

1. Letter height

Letter height depends on distance and lighting level. At a reading distance of 710 mm (28 inches), the height of letters and numerals must correspond to the range of values indicated on Table 6.4.7.2.1.7-1.

2. Letter height as a function of reading distance.

For distances D other than 710 mm (28 inches), to obtain letter height, multiply the value from Table 6.4.7.2.1.7-1 and by the ratio D/710 (D/28).

Table 6.4.7.2.1.7-1 Height of Symbols At Distance of 710mm (28”)

Type of Label or Inscription	Height of Symbols at Luminosity	
	35 lux (ft.lumen) and less	>35 lux (1ft/lumen)
Labels of critical importance or inscriptions with variable symbol positions (such as digital values on reading devices and adjustable or moving scales)	5-8 mm (0.20 - 0.31”)	3-5 mm (0.12 - 0.20”)
Labels or inscriptions of critical importance with fixed symbol positions (such as digital values on fixed scales, labels for controls and switches or emergency instructions)	4-8 mm (0.16 - 0.31”)	2.5-5 mm (0.10-0.20”)
Labels that are not of critical importance (such as identification tables, general instructions or inscriptions for familiarization purposes)	1.3-5 mm (0.05-0.20”)	1.3-5 mm (0.50-0.20”)

3. Letter height as a function of text category

Letters in signs must be separated into categories based on size. For determining letter height, all designation in signs fall into three categories: headings, subheadings, and text. The design-basis height for a reading distance of 710 mm (28 inches) must be as follows:

(1) headings — 5 mm (0.19 inch)

(2) subheadings — 4 mm (0.16 inch)

(3) text — 3 mm (0.12 inch)

If several type sizes are used in a sign, the height of the letter in the different types must differ by at least 25%.

4. Limited space in notes

If space is limited in a sign, letters or numerals of the same size may be used for all the categories. Adequate clarity of text must be ensured. The height of the letters and numerals must be at least 3 mm (0.12 inch).

6.4.7.2.1.8 REQUIREMENTS FOR SYMBOL WIDTH

1. Width of letters

The width of a letter must be 0.6 of its height.

Exceptions are the letter “I”, whose width must be equal to the width of the letter’s line; the letters “y” (J) and “M” (L), whose width must be 0.5 of the height; the letter “M”, whose width must be 0.7 of its height; and the letter “*“ (W), whose width MUST be 0.8 of its height.

2. Numerals

The width of numerals must be 0.6 of their height, with the exception of the numeral 4, which must be wider by one linewidth, and the numeral 1, which must be narrower by one letter-line width.

3. Wide characters

When wider characters are used on curved surfaces, the basic ratio of width to height must be increased 1:1.

6.4.7.2.1.9 REQUIREMENTS FOR LETTER-LINE WIDTH

1. Ratio of letter height to line width

The ratio of height to line width in letters and numerals must be in the range of 5:1 to 8:1.

2. Transparent background

With opaque symbols against a transparent background, the ratio of height to line width in letters and numerals is from 5:1 to 6:1.

3. Transparent signs

In transparent signs against an opaque background, the ratio of height to line width in letters and numerals must be in the range of 7:1 to 8:1.

4. Signs to be read under general lighting

In test-panel and equipment signs that must be read under general, unfocused lighting, the ratio of height to width in letters and numerals must be in the range of 6:1 to 7:1.

6.4.7.2.1.10 REQUIREMENTS FOR THE MEASUREMENT OF SYMBOL DIMENSIONS

1. Measurement of symbol dimensions

The dimensions of letters and numerals must be measured between the outer edges of the lines that make up the symbols, with the exception of letters and numerals that are mechanically engraved on opaque surfaces.

2. Engraved symbols

The dimensions of all symbols mechanically engraved on opaque surfaces must be measured between the axes of the lines that make up the symbols.

6.4.7.2.1.11 REQUIREMENTS FOR DISTANCES BETWEEN LETTERS AND NUMERALS IN TEXT

1. Letter spacing

The spacing between the letters in a word and between the numerals in numbers must be equivalent to the width of the lines in the letters for symbols with straight lines, such as H and I (this requirement is based on standard typographical practice for achieving unbroken text with good visibility; the requirement allows the kerning of open letters such as C and T, so as to avoid seeming breaks within words.

2. Word spacing

The distance between words must be equivalent to the width of the letter “*“ (W) for symbols with straight lateral lines, such as “H” (N) and “E” (F).

3. Line spacing

The distance between lines in solid text must be 0.5 of the height of capital letters.

The distance from heading to text must be 0.6 - 1.0 of the height of capital letters.

6.4.7.2.2 REQUIREMENTS FOR CONVENTIONAL SYMBOLS

6.4.7.2.2.1 GENERAL REQUIREMENTS FOR CODING

The methods for using conventional symbols must be standardized both within a system and between systems.

6.4.7.2.2.2 CONVENTIONAL SYMBOL BRIGHTNESS

No more than three levels of brightness must be used in conventional symbols. Each level of brightness must differ from those near it by at least a factor of 2.

6.4.7.2.2.3 SIZE OF CONVENTIONAL SYMBOLS

(1) Symbols

No more than three symbol sizes may be used; the primary spacing in larger symbols must be at least 1.5-fold greater than the primary spacing of symbols of the next smaller size.

6.4.7.2.2.4 BLINKING CONVENTIONAL SYMBOLS (NOT ON VIDEO TERMINALS)

(1) Blink rate:

- no more than two blink rates may be used
- if one blink rate is used, it must be in the range of 3 - 5 blinks per second
- if two rates are used, the second rate must be less than 2 blinks per second

(2) Blink cycles:

The length of the ON and OFF intervals must be the same

(3) Simultaneously functioning signals:

Blinking lights that must function simultaneously must be synchronized with each other.

(4) Designation of indicator failure:

If an indicator is switched on, but the blinking device has failed, the indicator must light up continuously.

6.4.7.2.2.5 COLOR CONVENTIONAL SYMBOLS

The numerical designations of colors used below conform to the FED-STD-595a standard.

(1) Difference in color designations:

A color must have only one meaning.

(2) Number of colors:

No more than 9 colors, including white and black, may be used in the system of conventional symbols.

(3) Ambient lighting

- Colored conventional symbols must be compatible with the expected ambient lighting over the span of the entire flight.

- Colored conventional symbols on equipment placards must be used solely in areas in which ambient light is white (i.e., the color temperature, measured with an illumination of 4-2000 foot-candles, must be no less than 2750 K).

(4) Adopted color values:

Enumerated below are conventional symbols that are matched with their customary use and conform to existing standards. All the color coordinates for transparent objects that light up are given in conformance with the color coordinate designation diagram of the 1976 International Commission on Illumination.

- Red No. 21105. Emergency, warning, and main alarm indicator lights; emergency controls; critical controls requiring rapid identification; emergency switch-on; control panel frame around section that is functionally critical in emergency situation. Transparent objects that light up must have color coordinates u' = 0.410 (N 0.03), v' = 0.520 (N 0.03).

- Yellow No. 33538. Warning; emergency exits; emergency controls associated with less hazardous situations.

- Yellow No. 33538 with black No. 47038 stripes. Fast access areas; emergency exits.

- Orange No. 32246. Hazardous moving parts; machinery; start switches etc.

- Green No. 14187. Important, frequently used controls that are not associated with urgent or emergency actions. Transparent objects that light up MUST have color coordinates u' = 0.155 (N 0.05), v' = 0.750 (N 0.05).

- Green (grayish green) No. 14260. First aid and emergency life-support.

- Blue No. 25102. Advisory communications (not recommended for general use). Transparent objects that light up MUST have color coordinates u' = 0.150 (N 0.03).

- Light violet (magenta) No. 37142. Radiation hazard.

- White. Advisory communications (only for signs that light up). Transparent objects that light up must have color coordinates u’ = 0.200 (N 0.03), v’ = 0.475 (N 0.03).

(5) Limited color perception (daltonism):

To avoid incorrect perception of colors by observers suffering from daltonism, do not use green in color systems with more than six colors.

If six or fewer colors are used, including green No. 14260 and yellow, then yellow No. 23655 must be replaced by yellow No. 33538. Red No. 11302 and blue No. 15177 can also be used; however, do not use red and green in the same bank.

(6) Placards

Placards are larger signs that contain more information than conventional signs and labels.

Enumerated below are the colors preferred for signs and for background for placards:

Sign	Background
White	Black
Black	Yellow
Black	White
Yellow	Blue
White	Red
Blue	Yellow

(7) Area designation

The following requirements must be met for conventional symbols used for indicating areas with varying working conditions:

- The basic colors must be limited to red, yellow, orange, and green, in conformance with the color selection criterion given above.

- Conventional symbols for areas must be applied and located such that they can be easily removed.

- Conventional symbols for areas must not hinder the reading of numerical information.

- Colors used for designating areas with identical working conditions must be identical in all instances of use.

(8) Color contrast

For colors to be easily perceived, the contrast between colors should be taken into account when the colors are chosen. However, in addition to the recommended color combinations, the standardized purpose of each color should be taken into account.

The color list below, borrowed from ~~form~~ the FED-STD-595 B standard, must be used for selecting a color that contrasts as much as possible with the color that precedes it and satisfactorily combines with all the colors after it on the list.

Colors 1 through 9 provide satisfactory contrast both for people with normal vision and for people with inadequate perception of the differences between red and green (individuals with daltonism).

The other 13 colors can be used only by people with normal color vision.

1 - White No. 19875, 2 - Black No. 17038, 3 - Yellow No. 13655
4 - Light violet (purple) No. 17142
5 - Orange No. 12246, 6 - Light blue (blue) No. 15102
7 - Red No. 11105, 8 - Yellowish-brown No. 33494
9 - Gray No. 32651, 10 - Green No. 34138
11 - Pinkish-violet No. 31538, 12 - Blue No. 35180
13 - Yellowish-pink No. 33613, 14 - Lilac (violet) No. 37142, 15 - Orange-yellow No. 33538
16 - Violet-red No. 31135, 17 - Greenish-yellow No. 33814
18 - Reddish-brown No. 30160, 19 - Yellowish-green No. 34666
20 - Yellowish-brown 30260, 21 - Reddish-orange No. 32246, 22 - Olive-green No. 34108

6.4.7.2.3 REQUIREMENTS FOR ONBOARD DOCUMENTATION

Onboard documentation requirements are contained in ISS Multi-lateral -Document SSP 50253, Operations Data File Standards.

6.4.7.2.4 METHODS OF APPLICATION

6.4.7.2.4.1 INSIDE THE RS

For operations inside the RS, one of the following methods must be used for applying OILs:

(1) Onto paper, film, metal, plastic, and fabric—with self-adhesive substrates

(2) Offset printing

(3) Engraving

(4) Tags

(5) Painted signs

6.4.7.2.5 LABELING SUPPORT

6.4.7.2.5.1 RUSSIAN LABELING STANDARDS

The following needs to be used in the development of labeling instructions:

(1) International standard ISO 3864: 1984 "Colorcoding and safety signs."

(2) GOST 12.4.026-76 "System of Labor Safety Standards (SLSS). Warning colors and safety signs."

(3) GOST 2930-62 "Typefaces and signs."

(4) GOST 26.008-85 "Typefaces for engraved signs."

(5) OST 92-8768-76 "Piping and containers. Color-coded identification labeling."

6.4.7.2.5.2 REQUIREMENTS FOR EQUIPMENT IDENTIFICAITON DESIGNATIONS

(1) Each individual element of equipment must be labeled with conventional symbols describing its purpose and its interfaces with other equipment. This does not apply to equipment whose purpose is obvious to the crew (such as a dining table or a viewing port).

The labeling of equipment that is delivered needs to include information regarding the specific mission the equipment belongs to (such as ME-1, ME-2, or ME-21).

(2) Individual numbers

A number of objects that are of the same type and have individualized purposes, but are not standardized (except for their names), must have individual numbers.

(3) Serial numbers

The labeling of all standardized objects that are of the same type must indicate the serial number.

(4) Identification placards

The identification placard for any piece of onboard equipment—with the name of the manufacturer, the factory number, etc.—must not interfere with the placement of the OIL.

6.4.7.2.5.3 DESCRIPTION OF LOCATION OILS:

1) Overhead Panels

- On overhead panels, designations and signs must be oriented such that they can be read from left to right at the working angle of vision, i.e., the signs must have an orientation that can be read by a cosmonaut facing along the +X axis, in a vertical position in relation to the coordinate system of the module (feet in the direction of the DECK, -Y; head in the direction of the OVERHEAD , +Y; right hand to STARBOARD, +Z; left hand to PORT, -Z). Such a position for the cosmonaut is taken to be the BASE position.

- For modules that have cosmonaut work stations, the base position is determined by the cosmonaut's physical orientation at that work station.

- Mistakes involving the combining of signs: Designations on panels must be positioned such that there can be no mistake resulting ~~form~~ from the combining of one or more signs with nearby signs.

2) Registration marks and interface designations:

- Orientation designations

  If an element of a piece of equipment must be oriented in a specific manner and that orientation cannot be assigned with registration marks, arrows or signs must be used to indicate the proper orientation.

- Color

  Registration marks must be nonluster white on dark structural elements and nonluster black on light-colored equipment elements (if color coding is not used).

3) Placement and orientation designations:

- Placement and orientation designations must conform to the requirements of section 6.4.7.3.

- In addition to identification labeling, all delivered equipment must have location OILs.

  Pallets with cases or equipment that is in any sort of packaging must have location OILs on the adjacent immobile surface.

6.4.7.2.5.4 DESCRIPTION OF OILS FOR EQUIPMENT

(1) Stationary equipment, and

(2) Portable equipment

- Group identification

  Functional groups of controls must be distinguished (by a given color with a frame, for example).

- Signs for functional groups

  Signs must be located above the group to which they apply.

- Frame lines

  If the boundaries of a group are delineated with a line, then the sign for that group must be in a break in the line over the group and must be centered within the line. The width of the frame must be no greater than the letter-line width.

- Interrelated controls

  If, during operation, instrument displays (indicators) and controls must be used together, then clearly visible signs or labels must indicate their functional interrelationship.

(3) Equipment of the cable system and piping:

- Connecting cables must be labeled with conventional symbols or text that describes the interfaces for the cable ends and system affiliation.

- In addition, cables and pipes must have color-coded marks as required so that they can be rapidly identified.

(4) Front panels of instruments

- All designations and signs must be oriented horizontally, i.e., parallel to the plane of the deck such that they can be read from left to right. A vertical orientation is allowed only when the size of a designation or sign does not allow it to be placed in the required place.

- Signs indicating the purpose of a display (or instrument) must be located on the panel over the display (or instrument). Such signs can be put in other places only when the size of the designations or sign does not allow it to be placed in the required place.

- Designation must be oriented at an angle of 90 [text illegible] 5 to the line of sight of the operator.

(5) Instrument -scale markings

- Divisibility of markings

  The values corresponding to the points of the scale must have as many or fewer significant numbers as the input signal has.

  As a rule, scales on which the measured values are read from the nearest point on the scale must be designed such that no interpolation between points is needed. Interpolation must be limited to half the distance between the finest scale points.

- Intervals between scale points.

  Points must be marked (in order of [reference) every 1, 5, or 2 units, in tens, in hundreds, etc.

  The number of scale intervals between numbered points may not exceed 10.

- Scale markings with high level of illumination, greater than 35 lux:

  The minimum width of large, medium (intermediate), and small graduation lines must be 0.32 mm (0.0125 inch).

  The length of large, medium, and small graduation lines must be at least 5.6 mm, 4.1 mm, and 2.5 mm (0.22, 0.16, 0.09 inch), respectively.

  The smallest distance between large graduation lines must be 13 mm (0.5 inch).

  Small graduation lines may be located every 0.89 mm (0.035 inch); that distance, however, must be at least twice the width of a line for white lines against a black background and at least the same width of a line for black lines against a white background.

- Scale markings with low level of illumination, below 35 lux:

Large graduation lines must have a minimum width of 0.89 mm (0.035 inch); medium lines, 0.76 mm (0.030 inch); small lines, 0.64 mm (0.025 inch).

Large, medium, and small graduation lines must have lengths of at least 5.6 mm, 4.1 mm, and 2.5 mm (0.22, 0.16, 0.10 inch), respectively.

The minimum distance between large graduation lines must be 16.5 mm (0.65 inch).

Graduation lines must be separated by intervals a minimum of 1.5 mm (0.06 inch) between the center lines of the graduation lines.

(6) Interface designations

Individual equipment elements joined to other equipment elements must have interface designation marks on the connecting parts, except in cases in which the positioning of the elements is obvious.

(7) Connected elements

There need not be any interface designations on detachable elements connected to equipment (such as on attached covers for connecting assemblies or on hinged lids of containers with stowage).

(8) Labeling of containers with cases:

- Packing list

  On the facing surface, visible to the crewmembers, on each container with cases, there must be a packing list. The items I the list must be enumerated with one name per line; the number of items under a given name must be indicated if there is more than one.

  On-orbit insertion of corrections in the packing list on each container with cases must be possible.

- Individual items of crewmembers

  Items intended for individual crewmembers must be marked in the packing lists with the title or name of the user or with other designations.

- Containers with dividers

  If a container with cases is separated inside into several compartments, each compartment must have a list of contents.

If there is no room in the compartments for a complete list of contents, the list must be placed in another place in the container, with a clear indication of the compartment to which it belongs.

The specific contents of each container compartment and its code must be enumerated on the front surface of the container (or lid) or near it.

- Labeling of similar element

  Containers with spaces for the placement of a number of similar elements (such as end wrenches and wrenches for electrical connector assemblies in tool sets) must have indications of the spaces for the elements, along with the names of the elements.

(9) Designations of items that are inoperative or expended and disposable items:

- Inoperative or expended items must be designated with arbitrary color marks that make it possible to visually ascertain that they are not serviceable.

- Disposable items must have a mark indicating the need to dispose of them and the manner in which they are to be destroyed.

6.4.7.2.5.5 DESCRIPTION OF EMERGENCY-WARNING OILS

(1) Caution and warning signs must specify the type of hazard and must indicate the action that will avert the hazard, and (if required) must indicate the method of recovery or escape.

(2) All controls, buttons, and small knobs or levers to which rapid access may be required must be marked with a color at the base on the panel, as indicated in the appropriate part of 6.4.7.2.2; large knobs and levers must be striped.

(3) Instruments and equipment meant for use in emergencies (such as emergency lamps, fire extinguishers, repair equipment) must bear the sign “EMERGENCY USE” and red or diagonal red-and-white striping (see “Painted warning stripes” below) on the items themselves or right next to them.

If such items are kept in a container, the diagonal stripes must be applied to the outer surface (or cover) of the container; the names of the emergency items must be on the container placard, in place of the words “EMERGENCY USE”.

(4) Painted warning stripes shall be applied in alternating stripes of yellow No. 33538 and black No. 47038, in conformance with the FED-STD-595a standard. The black stripes must be at least 1.6 mm (0.63 inch) wide, and the yellow stripes must be at least twice as wide as the black stripes.

- The stripes must be applied at a 45° angle relative to the vertical.
- The striping must begin and end with a yellow stripe.
- The striping around a switch or button must be no wider than 25 mm (1 inch) and no narrower than 3 mm (0.125 inch).
- If the space on one side of the button or switch is less than 3 mm (0.125 inch), the stripe is not applied on that side.

(5) The size of the letters on caution and warning signs must be as indicated in Figure. 10, Appendix 4.

~~**Figure 6.4.7.2.5.5-1 Symbol Dimensions and Distance Between Lines on Warning Labels**~~

A - Height of Main Text Symbols	= A
B - Height of Title Symbols	= 1.25 - 2 A
B - Distance between Title and Text Symbols	= 0.65 - 1 A
G - Distance between Lines	= min. 0.5 A
D - Box Width	= 0.6 A
E - Distance between Box Edges and Text Field	

Figure 6.4.7.2.5.5-1 Symbol Dimensions and Distance Between Lines on Warning Labels

6.4.7.3 IVA INVENTORY SYSTEM

6.4.7.3.1 OBJECTIVES

The purpose of the system must be to record and track the movements of all inventory (any ~~removeable~~removable equipment, materials, or items that can be moved, replaced, ~~delvered~~delivered to the station, or removed from the station) that passes through the space station during the station's operation.

6.4.7.3.2 REQUIREMENTS FOR IDENTIFICATION AND LABELING

The inventory management system must match each unit of inventory with its place of deployment and must maintain that matchup in a manner that reflects the current arrangement of the inventory aboard the space station.

The coding must support labeling both for each unit of inventory or cargo and for each possible place of deployment.

The movement of inventory aboard the space station must be monitored during all periods of ~~acitve~~active operation of the crew aboard the space station.

OILs with bar codes must have their own drawing (inventory) number and name.

The bar coding system Code 39 must be used for inventory management.

6.4.7.3.3 REQUIREMENTS FOR SPARE TAGS AND MARKING DEVICES

(1) Blank spare tags must be on hand.

(2) Marking devices for labeling blank spare tags and for altering information regarding quantities on packing lists must be on hand.

6.4.7.3.4 REQUIREMENTS FOR COMPOSITION OF INFORMATION RETAINED

Retained information must be divided into two main groups:

(1) information on each inventory element.

(2) information on each storage (or deployment) location.

A. Requirements for information on inventory element.

Inventory element information must contain data that makes it possible to clearly identify the element from among the multitude of elements stored. In connection with that, when the information on each inventory element is being entered, a special, unique inventory element identifier must be formulated that must also be used when the bar code is being formulated. The unique identifier must be formulated both manually and automatically, and the algorithm for that must preclude duplication.

The structure of the unique identifier must include both group characteristics (indication of affiliation with a given system or subsystem) and individual drawing-decimal-number-type characteristics.

In addition to that, the following data must be contained for each inventory element:

- full and abbreviated name of element
- serial (factory) number and date of manufacture
- warranty periods for the element both when in storage and when in use
- data on the design-basis and actual values for the center-of-mass characteristics
- information on the number of elements in a package/unit (including when delivery is in packages) both in a design-basis package (at the time of supply) and in an actual package at every moment in time
- information on the removal of the element form storage, with indication of reason (put into use, removed from station upon expiration of warranty, etc.)
- information on the availability/absence of operating instructions (including data on the presence of electronic documentation and references to it)

B. Requirements for information on storage location

This block of information is intended for formulating and storing data on all the storage locations aboard the orbital station, with allowance made for the possibilities of the docking of new modules and the undocking of spent modules.

The system must contain the following basic information for each storage location:

- unique storage location identifier that is also used in formulating the bar code
- brief description of storage location, which includes mandatory information regarding which module the storage location belongs to
- data with dimensional (volumetric) and center-of-mass constraints on the deployment of inventory elements for each storage location (if such constraints exist)

- coordinate characteristics of the storage location as they relate to the engineering system of coordinates for the module or for the overall coordinate system of the station.
- information on the presence or absence of constraints on the composition of the inventory elements stored in that location and on the nature of the constraints
- reference information on the presence of any special constraints on the use of the storage location

6.4.7.4 EVA CODING, LABELING, AND INVENTORY MANAGEMENT SYSTEM

6.4.7.4.1 APPLICABILITY

The coding and label requirements are only applicable to hardware and designs newly created for ISS. Existing EVA equipment and designs are not required to be modified, but may be altered if desired. New EVA equipment that must conform to these requirements includes airlocks, suits, tools, vehicle worksites/mechanisms, translation paths, Orbital Replacement Units (ORU)'s and safety equipment.

6.4.7.4.2 SAFETY HAZARDS AND AIRLOCK LABELS

External OIL's related to safety hazards and airlock return paths shall be written in both English and Russian languages with equal letter sizes. Other OIL's on suits, tools, ORU's or worksite mechanisms may be written in both languages if surface area is adequate for the proper size text and spacing. These items will be agreed to on an individual basis.

6.4.7.4.3 METHODS OF APPLICATION FOR EXTERNAL OILS'S

1. Labels on metal
2. Offset printing
3. Engraving
4. Tags (detachable labels)
5. Paint inscriptions

6.4.7.4.4 DESCRIPTION OF EVA OIL'S

EVA OIL's shall be compatible with the requirement from the point of view of visual inspection and optical characteristics of suit helmets used during EVA both by the US and Russian sides.

6.4.7.4.5 INSTALLATION CONSIDERATIONS FOR EXTERNAL LABELS

1 Anodized metal labels attached with adhesive are only permitted on flat surfaces. Bonded labels are not permitted on concave or convex surfaces to assure proper initial and long term adhesion, thereby preventing subsequent separation and exposure of hazardous sharp edges.

2 Engraved and paint filled labels are preferred if the material life is adequate for the external environment.

3 Labels may be applied with approved permanent ink on metallic of non-metallic surfaces

4 Sewn-on Fabric labels for Multilayer Insulation (MLI) blanket.

5 Other application technologies are acceptable if jointly approved.

6.4.7.4.6 External Equipment OILs

No inventory system will be operated by the on-orbit EVA crew. Any bar codes placed on external equipment are intended for ground processing use or for IVA use if the equipment is transferred to the pressurized cabin. Bar code labels on external equipment must not interfere with the hardware design, function or safety. No removable bar codes are permitted on external equipment.

6.4.7.4.7 Labels

Portable and detachable external equipment which are not uniquely and easily identifiable shall be marked with the name of the equipment and a unique tracking number (design drawing number and serial number if multiple copies exist). This information will be visible in both stowed and installed positions.

6.4.7.4.8 Exterior Location Coding

Exterior location coding shall be standardized and consistent between modules and shall indicate the quadrants of the Russian vehicle coordinate system. (I, II, III, IV)

6.4.7.4.9 EVA HANDRAIL NUMBERING

Handrails will be labeled with a unique number if needed for special purposes (for example, science equipment) or with black diagonal stripes if not load rated for crew safety. If the continuation of handrail translation paths turn corners or are visually obstructed by structures, an arrow will be placed at the end of the last handrail to indicate the direction of the next handrail. Handrail paths leading to a dead end away from the main route will be marked with a “T”.

Handrail segments shall be numbered.

6.4.7.4.10 EXTERNAL PIPES, CABLES, AND WIRES HANDLED BY EVA CREWS

External pipes, cables, and wires that must be handled by the EVA crew for assembly or maintenance shall be uniquely identifiable by location, size, connector keying and connector identification labels. Each half of each connector will be labeled with matching numbers. Additional identification to specify individual wire functions or piping fluid type, pressure and flow direction is beneficial, but not mandatory.

6.4.7.4.11 BOLT LABELS

When appropriate and jointly approved, bolts will be labeled with the loosen/tighten directions, number of turns, and torque. When more than one bolt must be operated for a specific mechanism, each bolt will be labeled with a unique number (~~preferrable~~preferable numbered in the order of nominal operation). In general, this information is contained in the on-board documentation.

6.4.7.4.12 PICTOGRAMS

Pictograms on external hazard labels shall be reinforced with text since not all pictograms are universally acknowledged.

6.4.7.4.13 EXTERNAL HAZARD AND TRANSLATION PATH LABELS

External hazard and translation path labels shall be sized to be read by a suited crewmember from a distance by using a minimum text height of 10mm with 20mm preferred.

6.4.7.4.14 EXTERNAL CREW DISPLAYS AND CONTROLS

External crew displays and controls shall be sized to be read by a suited crewmember in close proximity by using a minimum text height of 5mm with 10mm preferred.

6.4.7.4.15 TEXT AND BACKGROUND COLORS

External labels shall use high contrast non-reflective colors for text/graphics and the background surface (for example, black text on white/grey surface). Hazards for external labels shall be highlighted by a black and yellow striped border (equal width stripes angled at 45 degrees). Yellow will be similar to FED-STD-595B 17038 or International Lighting Commission 37036. Black will be FED-STD-595B 15655 or International Lighting Commission 33538. If jointly approved, other colors are acceptable on a case by case basis for specific applications.

6.4.7.4.16 READABILITY AND HELMET AND AMBIENT LIGHT

External labels shall be readable using standard space suit helmet lights and any other available ambient light from the sun and earth albedo.

6.4.7.4.17 FONTS AND LETTERING

External labels shall use simple bold faced fonts as the standard lettering type (e.g. Ariel).

6.4.7.4.18 LABELS FOR STOWED EQUIPMENT

Equipment or tools stowed in a rigid or soft container shall have labels on the interior and exterior of the container to indicate the container content.

6.4.7.4.19 SAFETY HAZARDS LABELS CONSISTENCY

The size and format of external labels that indicate safety hazards and airlock return translation paths shall be consistent. Safety hazard labels shall be located within 2 meters of the hazard along nearby handrail translation paths. Airlock return labels will be located within sight of each other.

6.4.7.4.20 SERVICE LIFE

All external labels must survive and be readable for 15 years without replacement.

6.4.7.4.21 LABEL UNITS

Numerical values must use metric units.

6.4.7.4.22 SPECIFIC IVA REQUIREMENTS

Specific IVA requirements also applicable to EVA:

1. Punctuation
2. Abbreviations
3. Specific symbols
4. Ratio of letter/symbol width and height
5. Scale marking

6.5 SAFETY

6.5.1 ELECTRICAL HAZARDS DESIGN REQUIREMENTS

Equipment design shall protect the crewmembers from electrical hazards.

In designing to minimize electrical shock hazards, controls shall be incorporated such that if the worst case credible failure can result in a crewmember exposure that:

a. is below the threshold for shock (i.e., below maximum leakage current and voltage requirements as defined within Section 6.5.1.15, Leakage Current Design Requirements), no controls shall -be required;
b. exceeds the threshold for shock and is below the threshold of let-go (critical hazard) as defined in Figure 6.5.1-1, two independent controls (e.g., a safety (green) wire, bonding, insulation, leakage current levels below maximum requirements) shall be required such that no single failure, event, or environment can eliminate more than one control; or,
c. exceeds the threshold of let-go (catastrophic hazardous event), three independent controls shall -be required.

If two independent controls are provided, the physiological effect of the combination of the highest internal voltage applied to or generated within the equipment and the frequency and wave form associated with a worst case credible failure that can be applied to the crewmember shall be below the threshold of let-go.

Non-patient equipment with internal voltages not exceeding 30 volts rms ~~(root-mean-squared)~~ shall be considered as containing potentials below the threshold for electrical shock.

If the classification of the hazard is marginal or unclear, three independent hazard controls shall -be required.

~~**Figure 6.5.1-1**~~

~~**LET-GO CURRENT PROFILE, THRESHOLD VERSUS FREQUENCY**~~

(Based on 99.5 Percentile Rank of Adults)

Frequency (Hertz)	Max Total Peak Current (ac + dc components combined) milliamperes
DC	40.0
15	8.5
2000	8.5
3000	13.5
4000	15.0
5000	16.5
6000	17.9
7000	19.4
8000	20.9
9000	22.5
>10000	24.3

Figure 6.5.1-1 LET-GO CURRENT PROFILE, THRESHOLD VERSUS FREQUENCY

6.5.1.1 GROUNDING

All electrical powered equipment external, non-isolated metal parts subject to user contact shall be at ground potential. All electrical powered equipment external, non-isolated metal parts subject to user contact shall be bonded to ground prior to the connection of any electrical signals or power. The removal of all electrical signals and power shall be accomplished prior to the removal of any bonded metal parts from ground.

Grounding conductors internal to an ORU shall be secured internally to the ORU's metal enclosure by means of a fastening technique unlikely to be removed during any servicing operation. Soldered grounding conductors used as an electrical shock hazard control shall not rely on solder alone for securing the grounding conductor.

Each grounding or bonding means used as an electrical shock hazard control shall be capable of conducting the maximum ground fault current amplitude and duration which might occur as the result of discharges (static, plasma, etc.), induced RF voltages, internal power-faulted equipment, and accidental short circuits.

All grounding shall conform to the NASA/RSA Joint Specification/Standards Document for the ~~ISSA~~ISS ~~Russian Segment~~RS, paragraph 3.4.8.2.

6.5.1.1.1 HINGED OR SLIDE MOUNTED PANELS AND DOORS GROUNDING

Hinges or slides shall not be used for grounding paths. A ground shall be considered satisfactory if the electrical connection between the conductive door or panel, in both the open and closed position, and the equipment tie point exhibits a resistance of less than 0.1 ohms and has sufficient ca~~am~~pacity to insure the reliable and immediate tripping of associated equipment over-current protection devices.

6.5.1.2 ELECTRICAL BONDING

On-orbit electrical bonding shall meet the requirements of the NASA/RSA Joint Specification/Standards Document for the ~~ISSA~~ISS ~~Russian Segment~~RS, paragraph 3.4.8.1, to prevent damage to the vehicle or injury to crewmembers due to discharges (static, plasma, etc.), induced RF voltages, internal power-faulted equipment, and accidental short circuits. Each independent bonding path is considered a hazard control for electrical shock.

6.5.1.3 PROTECTIVE COVERS

Equipment shall provide grounded or non-conductive protective covering for all electrical hardware.

Electrical termination points shall be protected from inadvertent contact by crewmembers, inadvertent contact from foreign objects entering electrical junctions, and moisture accumulation.

6.5.1.4 WARNING LABELS

Warning labels shall be provided where inadvertent contact with electrical potentials are hazardous to crewmembers. Warning labels shall comply with the requirements in Section 6.4.7 Labeling and Coding.

6.5.1.5 PLUGS AND RECEPTACLES

Plugs and receptacles shall -meet the requirements of Section 6.4.5 Connectors. In addition:

A. Plugs and receptacles (connectors) used by the crew on-orbit shall -be selected and applied such that -they cannot be mismated or cross-connected in the intended system as well as adjacent systems. Although required, the use of identification alone is not sufficient.
B. Connectors shall -be selected and applied such that they have sufficient mechanical protection to mitigate inadvertent crewmember contact with exposed electrical contacts.
C. Connectors shall -be specifically designed and approved for mating and demating in the existing environment under the loads being carried, or connectors shall -not be mated or demated until voltages have been removed (dead-faced) from the powered side(s) of the connectors.

6.5.1.6 INSULATION

All materials shall -meet the requirements of the NASA/RSA Joint Specification/Standards Document for the ~~ISSA~~ISS ~~Russian Segment~~RS.

In addition:

A. All exposed electrical conductors and terminations shall be insulated.
B. The crew shall be protected from electrical hazards when it is necessary to use tools within 24 inches of exposed electrical potentials.

6.5.1.7 PORTABLE EQUIPMENT/POWER CORDS

A Ground Fault Circuit Interrupter (GFCI) used in conjunction with a portable equipment is considered as one hazard control. Non-battery powered portable equipment shall incorporate a three-wire power cord with one wire at ground potential. A system of double insulation or its equivalent, when approved by the procuring agency, may be used without a ground wire.

6.5.1.8 MOISTURE PROTECTION

Equipment shall- be designed so that moisture collection will not present a safety hazard to the crew.

6.5.1.9 STATIC DISCHARGE PROTECTION

Equipment shall -be designed so that the crewmembers are protected from static charge buildup.

6.5.1.10 OVERLOAD PROTECTION

A. The functioning of an overload protective device shall -not result in a fire, electric shock, or crewmember injury.
B. An overload protective device shall -not be accessible without opening a door or cover, except that the operating handle or operating button of a circuit breaker, the cap of an extractor-type fuseholder, and similar parts may project outside the enclosure.
C. The arrangement of extractor-type fuseholders shall be such that the fuse and the fuseholder have no electrically energized parts exposed to the crew at any time during fuse replacement.
D. Overload protection (fuses and circuit breakers) intended to be manually replaced or physically reset on-orbit shall -be located where they can be seen and replaced or reset without removing other components.
E. Each overload protector (fuses and circuit breakers) intended to be manually replaced or physically reset on-orbit shall -be readily identified or keyed for its proper value.
F. Overload protection shall -be designed and rated for on-orbit use including the maximum environmental range expected as the result of contingencies.

6.5.1.11 BATTERIES

Unless intentionally designed for the purpose, batteries shall not be connected to or disconnected from a current drawing load.

Batteries/battery packs with potentials above 30 volts dc shall provide hazard controls as specified in Section 6.5.1.

6.5.1.11.1 NON-ORU BATTERIES

Batteries intended to be replaced shall be located so that they can be easily disconnected and removed without special equipment. Mounting provisions shall ensure retention for all service conditions. Polarity of the battery terminals shall be prominently marked or battery terminal connections shall be polarized to mitigate erroneous installation.

6.5.1.12 MECHANICAL ASSEMBLY

A switch, fuseholder, lampholder, attachment plug receptacle, or other energized component that is handled by a crewmember shall not rely on friction alone to prevent turning in its mounting panel.

The mounting of components to a printed wiring board and the mounting of the printed wiring board itself shall -be such that any forces that might be exerted on the components or board will not displace the components or deflect the board so as to produce an electric shock or fire.

6.5.1.13 SWITCHES/CONTROLS

Switches/controls shall -be designed such as to prevent hazardous unexpected manual or automatic operation. Switches/controls which provide automatic starting after an overload initiated shutdown shall not be employed.

6.5.1.13.1 POWER SWITCHES/CONTROLS

Switches/controls performing on/off power functions shall -open or dead-face all supply circuit conductors except the power return and the equipment grounding conductor while in the power OFF position.

Power OFF markings and/or indications shall -only be used if all parts, with the exception of overcurrent devices and associated EMI filters, are disconnected from the supply circuit. STANDBY, CHARGING, or other appropriate nomenclature shall -be used to indicate that the supply circuit is not completely disconnected for this power condition.

6.5.1.14 GROUND FAULT CIRCUIT INTERRUPTERS (GFCI)

A non-portable utility outlet intended to supply power to portable equipment shall include a GFCI, as an electrical hazard control, in the power path to the portable equipment. GFCI trip current detection shall -be independent of the portable equipment's safety (green) wire.

GFCI will be designed to trip below the threshold of let-go based upon the 99.5 percentile rank of adults. Non-portable utility outlets supplying power to portable equipment shall include a GFCI with trip point characteristics such that tripping will not exceed the currents specified in the profile shown in Figure 6.5.1-1.

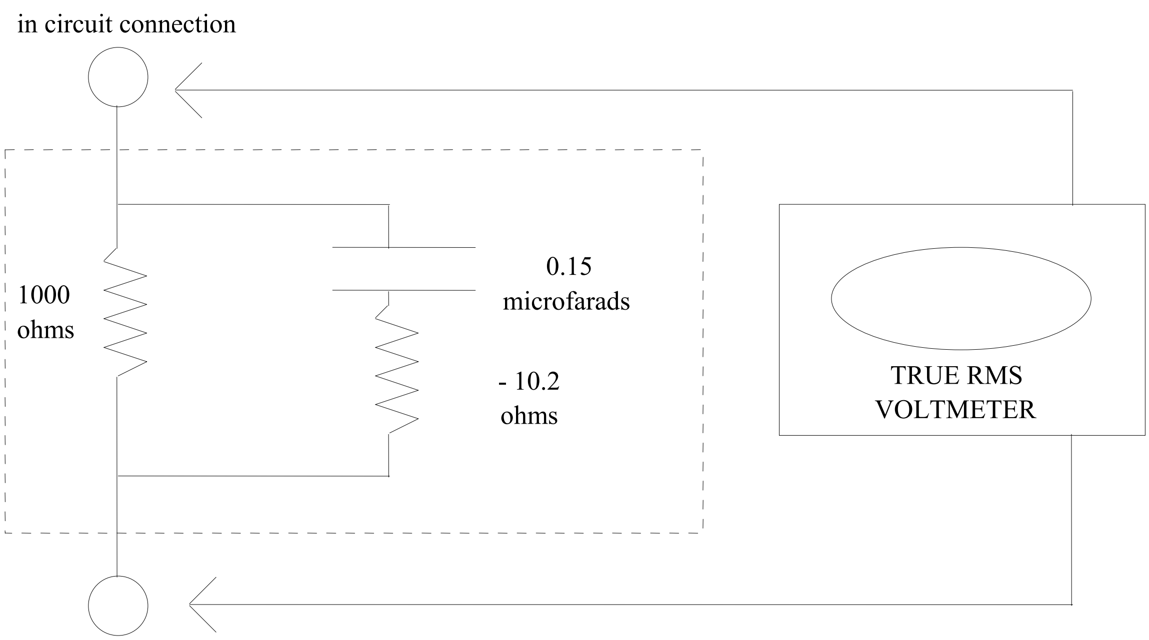
~~Ground fault circuit interrupters~~GFCIs that depend upon the analysis of current shall remove power within 25 milliseconds upon encountering the fault current.

GFCI shall provide an on-orbit method for testing trip current detection threshold at a frequency within the maximum human sensitivity range of 15 to 70 Hertz.

6.5.1.15 LEAKAGE CURRENT DESIGN REQUIREMENTS

Non-patient equipment with internal voltages not exceeding 30 volts rms ~~(root-mean-squared)~~ and non-patient equipment incorporating three independent hazard controls (excluding non-patient equipment incorporating leakage current as a control) shall not be required to verify leakage current design requirements.

For designs using leakage current as a control, verification of leakage current design requirements shall be accomplished using the network shown in Figure 6.5.1.15-1. The leakage current (milliamperes) shall -be computed as the voltage (volts) measured across the network in series with the grounding conductor (for chassis leakage current), or in series with the crewmember connection lead (for ordinary patient connection leakage current), divided by 1000. For isolated patient connection lead leakage current, a non-inductive, 1000 ohm resistor shall replace the network shown in Figure 6.5.1.15-1 for this measurement.



Notes:

1. Resistors are non-inductive.
2. Voltmeter is a true RMS (root-mean-squared) type with frequency bandwidth appropriate for the frequencies of the voltages being measured. Voltmeter frequency bandwidth may be limited to 20 ~~megaHertz (~~MHz~~)~~ for equipment-under-test frequencies above 20 MHz.

Figure 6.5.1.15-1 Leakage Current Verification Network

6.5.1.15.1 CHASSIS LEAKAGE CURRENT

Crewmembers shall not be exposed to excessive levels of leakage current from direct or indirect contact with electrically powered equipment. Equipment qualification shall include verification of acceptable chassis leakage currents as defined within Section 6.5.1.15. Leakage current test procedures for DC powered equipment shall not include reversed polarity input power tests.

6.5.1.15.1.1 CHASSIS LEAKAGE CURRENT--NONPATIENT EQUIPMENT

The chassis leakage currents for nonpatient equipment shall not exceed the values shown in Figure 6.5.1.15.1.1-1. Leakage current shall not exceed 0.700 milliamperes (ma) DC for grounded non-patient equipment, and leakage current shall not exceed 0.350 ma DC for double-insulated non-patient equipment.

~~Figure 6.5.1.15.1.1-1~~

~~NON-PATIENT EQUIPMENT MAXIMUM CHASSIS LEAKAGE CURRENT~~

ENCLOSURE OR CHASSIS			
GROUNDED		DOUBLE INSULATED	
DC ma	AC ma RMS	DC ma	AC ma RMS
0.700	0.500	0.350	0.250

Figure 6.5.1.15.1.1-1 Non-patient Equipment Maximum Chassis Leakage Current

6.5.1.15.1.2 CHASSIS LEAKAGE CURRENT--PATIENT CARE EQUIPMENT

The chassis leakage currents for patient care equipment shall not exceed the values shown in figure 6.5.1.15.1.2-1. Leakage current shall not exceed 0.140 ma DC for grounded patient care equipment, and leakage current shall not exceed 0.070 ma DC for double-insulated patient care equipment.

~~Figure 6.5.1.15.1.2-1~~

~~PATIENT CARE EQUIPMENT MAXIMUM LEAKAGE CURRENT~~

Patient Interface	PATIENT CONNECTION ISOLATED (1)		ORDINARY	
	DC ma	AC ma RMS	DC ma	AC ma RMS
Invasive	0.014	0.010	Not Permitted	
Non-Invasive	0.070 (1)	0.050 (1)	0.070	0.050

Patient Interface	ENCLOSURE OR CHASSIS GROUNDED		DOUBLE INSULATED	
	DC ma	AC ma RMS	DC ma	AC ma RMS
Invasive	0.140	0.100	0.070	0.050
Non-Invasive	0.140	0.100	0.070	0.050

Notes: 1. If equipment labeling indicates "isolated," the maximum current is 0.014 ma DC/0.010 ma AC RMS.

Figure 6.5.1.15.1.2-1 PATIENT CARE EQUIPMENT MAXIMUM LEAKAGE CURRENT

6.5.1.15.2 CREWMEMBER APPLIED CURRENT

Crewmembers shall not be exposed to excessive levels of leakage current from direct or indirect contact with electrically powered equipment. Equipment qualification shall include verification of acceptable patient connection leakage currents as defined within Section 6.5.1.15. Leakage current test procedures for DC powered equipment shall not include reversed polarity input power tests.

The leakage currents for patient care equipment as seen from the patient end of cables or terminals shall not exceed the values shown in figure 6.5.1.15.2.-1.
Leakage currents shall be tested:

A. Lead to ground
   1. Between each patient lead and ground, and
   2. Between combined patient leads and ground; and,

B. Between leads
   1. Between any pair of patient leads, and
   2. Between any single patient lead and all other patient leads.

6.5.1.15.2.1 LEAKAGE CURRENT--PATIENT CARE EQUIPMENT--PATIENT CONNECTION--ISOLATED

Isolated, patient connected, patient care equipment leakage current shall not exceed 0.014 ma DC for isolated, patient connected, patient care equipment, such as intro-aortic pressure monitors (i. e., invasive interface).

Isolated, patient connected, patient care equipment leakage current shall not exceed 0.070 ma DC for isolated, patient connected, patient care, equipment such as muscle stimulators utilizing attached body surface electrodes (i.e., non-invasive interface) provided that equipment labeling does not indicate the equipment is isolated.

6.5.1.15.2.2 LEAKAGE CURRENT--PATIENT CARE EQUIPMENT--PATIENT CONNECTION--ORDINARY

Ordinary, patient connected, patient care equipment leakage current shall not exceed 0.070 ma DC for ordinary, patient connected, patient care, equipment such as blood pressure cuffs, thermometers, and limb muscle stimulators.

6.5.1.15.2.3 HEALTH MAINTENANCE SYSTEM INSTRUMENTATION GROUNDING

Any two exposed conductive surfaces in the instrumented crewmember's vicinity shall not exceed a 40.0 millivolt potential difference at frequencies up to 1000 Hertz or less measured across a 1000 ohm resistor. Conductive surfaces which can be contacted by an attending crewmember while the attending crewmember is in contact with the instrumented crewmember shall -be considered as within the crewmember's vicinity.

6.5.1.15.2.4 COUNTERMEASURE SYSTEM

Any two exposed conductive surfaces in the instrumented crewmember's vicinity shall not exceed a 40.0 millivolt potential difference at frequencies up to 1000 Hertz or less measured across a 1000 ohm resistor. Conductive surfaces which can be contacted by an attending crewmember while the attending crewmember is in contact with the instrumented crewmember shall be considered as within the crewmember's vicinity.

6.5.1.15.2.5 AMBULATORY CREWMEMBER INSTRUMENTATION

While attached to an ambulatory crewmember, electrically powered medical instrumentation shall- be:

A. Battery powered,
B. Double insulated,
C. Electrically isolated from ground, and
D. Not connected to vehicle power (e.g., charging).

6.5.1.16 BIOINSTRUMENTATION SYSTEM MICROSHOCK PROTECTION

All bioinstrumentation systems shall be designed with sufficient series resistance/isolation to limit to safe levels electrical shock currents that could flow through an instrumented crewmember including as the result of:

A. Contact with available electric sources, including those sources applied by an attending crewmember's simultaneous contact with the instrumented crewmember and other equipment or ground, and
B. Transients that may occur when the bioinstrumentation is either energized (turned ON) or deenergized (turned OFF).

Bioinstrumentation shall be designed with fault tolerant protection to prevent exceeding the current limit requirements defined within figure 6.5.1.16-1.

~~**Figure 6.5.1.16-1**~~

~~**MAXIMUM PERMISSABLE BIOINSTRUMENTATION FAULT CURRENT**~~

CLASSIFICATION	NUMBER OF FAULTS	MAXIMUM CURRENT (milliamperes DC/RMS)
INVASIVE	0	0.014/0.010
(ref para. 6.5.1.15.2.1)	1	0.014/0.010
	2	0.020/0.020
NON-INVASIVE	0	0.070/0.050
(ref para. 6.5.1.15.2.2)	1	0.140/0.100
	2	0.500/0.500

Figure 6.5.1.16-1 MAXIMUM PERMISSABLE BIOINSTRUMENTATION FAULT CURRENT

6.5.1.17 DEFINITIONS

DEAD-FACED - An electrically conductive surface incapable of supplying sufficient energy under normal conditions to present a hazard (e.g., the output of a solid-state switch when in the "STANDBY" state).

DIRECT CONTACT - The personal contact of a crewmember to electrically powered surfaces.

DOUBLE INSULATED ENCLOSURE/CHASSIS - An enclosure/chassis which incorporates an insulation system comprised of basic insulation and supplementary insulation with the two insulations physically separated and so arranged that they are not subject to the same deteriorating influences (e.g., temperature, contaminants, and the like) to the same degree.

ENCLOSURE/CHASSIS - The outer casing of an electrical/electronic device such as an ~~orbital replacement unit (~~ORU~~)~~.

GROUNDED ENCLOSURE/CHASSIS - An enclosure/chassis electrically connected to the ground return.

GROUND FAULT CIRCUIT INTERRUPTER ~~(GFCI)~~ - A device intended to interrupt the source current flow to an electrical load upon encountering a predefined difference current between the source current flow to the load and the returned current from the load to the source. A worst case assumption is made that all of the difference current is being applied to a human and, as such, the predefined difference current is selected to be below the threshold of a human's ability to let go of the electrically conductive surface. The GFCI includes a manual test capability which synthesizes the predefined difference current to cause the GFCI to interrupt the circuit. The GFCI also includes a manual reset capability to reestablish the electrical connection from the source to the load.

IN-LINE CIRCUIT LEAKAGE CURRENTS - Unintentional currents which can flow in a conductor. These currents may result from the inability of solid-state electronics to reach an "infinite" impedance "OFF" state, as is the ability of a mechanical switch. The solid-state electronic device has a finite impedance which undesirably completes the input/output circuit thus providing a means for current to flow. Connections to in-line circuits are normally isolated from crewmember inadvertent contact by barriers and may be considered a hazard if accessible to inadvertent crewmember contact. In-line circuits with leakage currents are referred to as in "STANDBY" when placed in the high impedance state since a complete disconnect is not possible and the circuit output is still energized.

INDIRECT CONTACT - The contact of a crewmember to electrically powered surfaces through an electrically conducting medium (e.g., probe, rod).

ISOLATED PATIENT CONNECTION - A direct or indirect patient contact that is deliberately separated from the supply circuit and ground by virtue of ~~spacings~~spacing, insulation, protective impedance, or a combination thereof (e.g., intra-aortic pressure monitor)

LEAKAGE CURRENTS - Unintentional currents which can be applied to a crewmember.

MEAN PERCEPTION - A mild shock perceived by 50% of the population.

NO SENSATION - The level of perception only perceived by a fractional percentage of the population.

ORDINARY PATIENT CONNECTION - A direct patient contact that does not have the spacing, insulation, or protective impedance associated with an isolated patient connection (e.g., blood pressure cuff).

ORU CHASSIS LEAKAGE CURRENTS - Currents generated by such internal sources as filter capacitors terminated to accessible parts or ground, and capacitive and inductive coupling to accessible parts or ground. These currents can be conveyed from accessible parts to ground or to other accessible parts and subsequently applied to a crewmember.

PATIENT - A crewmember instrumented with electrical/electronic equipment.

PATIENT CONNECTION LEAKAGE CURRENT - Leakage currents measured between patient leads at the patient interface, or between patient leads at the patient interface and ground.

PERCEPTION - A mild shock.

STANDBY - A high impedance state of an electronic device, usually to minimize the amount of energy consumed or supplied (e.g., the off state of an electronic switch).

6.5.2 DESIGN REQUIREMENTS ON ACOUSTIC CONDITIONS

The acoustic environment in manned space vehicles is controlled during phases as follows:

- During fabrication: certified acoustic materials and the acoustic parameters of equipment and hardware;
- During operation and ground testing: periodically measuring the acoustical living environments to determine the acoustic load on the crew.

6.5.2.1 ACOUSTIC NOISE DEFINITIONS

Noise is any unwanted or unpleasant sound or combination of sounds that impedes identification of useful signals, disturbs a quiet environment (25 dBA), has a detrimental or irritating effect on the human body, or interferes with the ability to perform work.

~~A~~ This standard establishes noise classification, characteristics, and permissible noise levels in habitable volumes.

In terms of its nature, noise is divided into two categories:

- ~~Continuous w~~Wide-band noise is noise of more than one octave width where the spectral shape varies smoothly as a function of frequency (varies from one band to the other by less than 10 dB).~~;~~
- Narrow band noise, encompassing audible discrete tones of a single frequency. Narrow-band noise is measured or characterized in 1/3 octave bands if the level in one band has exceeded either contiguous one by at least 10 dB.

In terms of Sound Pressure Level (SPL) and temporal characteristics, noises are divided into:

- Stationary noise, whose sound level over 24-hours (16-hour work period and 8-hour sleep period) changes over time by less than 5 dBA using the “slow” Sound Level Meter (SLM) averaging time;
- Non-stationary noise, whose SPL changes over 24 hours (16-hour work period and 8-hour sleep period) in time by more than 5 dBA using the “slow” SLM averaging time.

Non-stationary noise~~s are~~ is subdivided into:

- Noise~~s~~ that fluctuates gradually over long periods of time;
- Intermittent noise~~s~~, whose SPL increases abruptly when the source comes on and remains fairly constant while it is on, and drops to the background level when it turns off. It lasts for more than one second when it is on;
- Impuls~~iv~~e noise~~s, whose SPL lasts less than 1 second. The SPL (dBA) is measured using the SLM impulse response.~~. is a change in sound pressure level of more than 10 dB for one second or less.

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Continuous audible noise is characterized by octave-band SPLs at the following (geometric mean) frequencies: 63; 125; 250; 500; 1000; 2000; 4000; 8000 Hz. The acoustic frequency range can be expanded when performing special investigations.

Non-stationary noises are characterized or evaluated by a long duration average to determine an equivalent sound level.

The equivalent sound level of non-stationary noise ($L(A)_{eq}$) is an equivalent A-weighted continuous SPL that has the same energy content as a steady noise of the same level over the same period of time.

6.5.2.2 BIO-ACOUSTICMEDICAL EVALUATION OF NOISE LEVEL IN HABITABLE VOLUMES OF MANNED SPACE VEHICLES

A bio-acoustic (or medical) evaluation is performed on the acoustic environment in habitable volumes of manned space vehicles:

- At cosmonaut work and rest stations;
- To assess the level of noise coming from individual sources (life support systems, equipment);
- To assess how sound is distributed along the vehicle axis.

A bio-acoustic evaluation of noise includes:

1. A tentative assessment of acoustic conditions under which it is possible to use a single-valued characteristic (the weighted SPL in dBA using the “slow” SLM response).
2. An evaluation of stationary noise by measuring the spectrum in octave frequency bands.
3. An evaluation of non-stationary noise usingof equivalent sound levels.
4. An evaluation of impulse noise using the impulse response with peak sound pressure level.

In addition, maximal A-weighted SPLs measured using the “slow” time response are limiting factors for chronologically fluctuating and intermittent noise while the maximal level (in dBA) measured using the “pulse” time response apply to pulsed noise.

6.5.2.3 NOISE SOURCES

A. Basic sources of continuous stationary noise that operate for a cumulative total of 8 hours or more on any 24 hour period are regarded as continuous noise sources.

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B. Additional sources of noise that operate for a cumulative total of less than 8 hours on any 24 hour period are regarded as additional (intermittent) noise sources.

C. The SPL in octave frequency bands from all simultaneously operating equipment must not exceed the levels indicated in Table 6.5.2.4.1-1. In order to fulfill this requirement, sound pressure levels in octave frequency bands during the operation of individual assemblies, instruments, and acoustic noise sources must be at least 7 dB lower than sound pressure levels specified in Table 6.5.2.4.1-1.Meeting the noise level requirements in Table 6.5.2.4.1-1 will be ensured by implementing sound level reduction measures at all stages of design and verification of the manned spacecraft project.~~Sound pressure levels in octave frequency bands during the operation of individual assemblies, instruments and acoustic noise sources must be 5 dB or lower than sound pressure levels specified in Table 6.5.4.1-1; the levels of sound coming from all simultaneously operating equipment must not exceed the levels specified on the same table.~~

6.5.2.4 NOISE STANDARDS

6.5.2.4.1 ~~Table 6.5.2.4.1-1 presents T~~the permissible sound pressure levels in octave frequency bands ~~and A-weighted~~, sound levels and equivalent ~~overall~~ sound ~~pressure~~ levels at work ~~and rest~~ stations in habitable volumes of the ~~ISS~~ integrated ~~Russian segment~~RS during exposure to basic sources of continuous sound ~~shall be according to Table 6.5.2.4.1-1~~.

Table 6.5.2.4.1-1 –Allowable Octave Band and A-weighted Equivalent Overall ~~Sound and~~ Sound Pressure Levels for Continuous Noise in Habitable Volumes of Manned Space Vehicles

Flight duration over 30 days	Octave-band Sound Pressure Levels (~~SPLs~~dB)								A-weighted Equivalent Overall SPL~~,~~ (dBA)
Geometric. Mean Frequencies, Hz	63	125	250	500	1000	2000	4000	8000	
WORK (16 Hours)	79	70	63	58	55	52	50	49	60
REST (8 Hours)	71	61	54	49	45	42	40	38	50
*Note: These noise levels are rounded values of the summation of octave bands.									

6.5.2.4.2 During the simultaneous operation of basic (continuous) and additional (intermittent) sources of noise, a goal should be set such that the equivalent sound level for crew work times (16 hours), not exceed 60 dBA. However for all instances where the equivalent sound level exceeds 60 dBA because of additional intermittent noise sources, the noise produced by the intermittent sources shall be limited by the equipment operation/crew exposure times according to Table 6.5.2.4.2-1.~~When intermittent noise sources are present, the total daily cumulative A-weighted noise level in habitable volumes (including areas of limited crew stay time) cannot exceed the levels specified in Table 6.5.2.4.2-1. This equivalent level for crew activity shall not exceed 60 dBA. Permissible level increases in the table do not include voice-to-voice communication.~~

Table 6.5.2.4.2-1 Maximum ~~Daily~~ Allowable Sound Levels of Additional Noise Sources in Habitable Volumes and Crew Short term Stay Areas ~~During the~~

~~Operation of Additional Noise Sources~~ as a Function of Crew Exposure Time During a 16-hour Work Period

Maximal exposure time (hours) during any one 16-hour work period	~~Permissible increase in exposure levels~~ A-weighted Overall SPL (dBA)
4	~~+5~~63
2	~~+10~~66
1	~~+15~~69
0.5	~~+20~~72

Allowable levels for tonal ~~and pulsed~~ noise ~~are assumed to~~ shall be 5 dB lower than values specified on Table 6.5.2.4.1-1.

6.5.2.4.3 Sound pressure levels in octave bands from additional equipment (not covered by the above requirements in Tables 6.5.2.4.1-1 and 6.5.2.4.2-1, but including payloads/experiments) delivered to the manned space vehicle must be lower than those indicated in Tables 6.5.2.4.1-1 and 6.5.2.4.2-1, depending on the operational duration. In order to assess the impact of the additional equipment, an acoustic Stage Analysis including this source and all other significant noise sources in the module will be performed on a case-by-case basis.

6.5.2.4.4 Taking into consideration all noise sources on the ~~Russian Segment~~RS, the impulse noise measured in main areas where a crewmember (head) is located shall not exceed a peak overall SPL of 125 dB during all mission stages. The limit peak overall SPL value of 125 dB for impulse noise will prevent auditory injury and reduce startle effects.

6.5.2.4.5 To ensure speech intelligibility, the reverberation time in manned space vehicle compartments where workstations are located shall be 0.6 seconds or less in the 1000 Hz octave frequency band.

6.5.2.5 WORKSTATION NOISE MEASUREMENT PROCEDURES

6.5.2.5.1 Noise is measured according to the ground methodology and on-board crew-procedures.~~procedures contained in flight data files.~~

6.5.2.5.2 Measurement sites shall be determined by the configuration of basic and additional noise sources and main areas where crew members work and rest ~~stay~~.

6.5.2.5.3 During the measurements, the microphone shall be positioned:

- at a height of 1.5 m;
- at a distance of 0.6 m from the source;
- at a distance of at least 0.5 m from the operator conducting the measurement

6.5.2.6 RESULT PROCESSING

6.5.2.6.1 The noise level measurement results ~~are~~ shall be compiled into a report and dispositioned~~or findings~~.

6.5.2.6.2 When processing the results of noise level measurements obtained using a measuring system other than a handheld SLM and/or dosimeter, result processing sequences shall comply with the "slow" SLM responses in accordance with Appendix D. Impulse noise should be measured using the peak response and "impulse" mode on the handheld SLM.~~Results of the measurements are to be exchanged as agreed by parties.~~

[redacted]

6.5.2.7 These requirements cover all of the manned space vehicles in the ISS ~~Russian Segment~~RS~~Russian habitable modules~~. Should measured noise levels of individual assemblies and systems exceed the required levels, specific decisions shall be made based upon review of the acoustic data and the operational situation ~~the scheduled crew activities~~.

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6.5.3 CREW RADIATION SAFETY

6.5.3.1 IONIZING RADIATION

6.5.3.1.1 IONIZING RADIATION PROTECTION DESIGN REQUIREMENTS

If radioisotopes and/or equipment generating ionizing radiation onboard the space station are used, a safety analysis and analysis of radiation source usage shall be conducted, with mandatory NASA/RSA Safety Review Panel review and approval.

6.5.3.2 NON-IONIZING RADIATION

6.5.3.2.1 NON-IONIZING RADIATION PROTECTION DESIGN REQUIREMENTS

6.5.3.2.1.1 RADIO-FREQUENCY AND OPTICAL RADIATION MONITORING

When radio-frequency or optical radiation devices are used onboard the station, monitoring shall be performed and annunciation made in the event of a hazard resulting from each source exceeding allowable levels.

6.5.3.2.1.2 PROCEDURES FOR OPERATION OF RF AND OPTICAL SOURCES

The radio-frequency and optical radiation devices that impact crew safety shall have the capability of powering off when required.

6.5.3.2.1.3 PROTECTIVE MEASURES

Procedures and equipment shall be provided to enable positive protective measures to be taken to prevent accidental exposures from RF and optical radiation.

6.5.3.2.1.4 PERSONNEL PROTECTION DEVICES

Based on the safety requirements and the results of the electromagnetic hazards analysis, personal protective device requirements (eyewear, clothing) shall be established and the requisite personnel equipment shall be provided.

6.5.3.2.2 NON-IONIZING RADIATION EMISSION REQUIREMENTS

6.5.3.2.2.1 RADIO-FREQUENCY ELECTROMAGNETIC FIELDS

Radio Frequency electromagnetic field emissions shall comply with the limits specified in Figure 6.5.3.2-1. Additional information regarding Russian crew exposure standards for radio-frequency radiation can be found in Appendix C.

6.5.3.2.2.2 LASER LIGHT

6.5.3.2.2.2.1 DETERMINATION OF SOURCE CRITERIA APPLICABILITY

Determination of “point source” or “extended source” laser eye exposure criteria applicability shall be accomplished based on the minimum angular subtense (alpha-minimum) values given in Figure 6.5.3.2-2. “Point Source” values shall apply to sources that subtend a visual angle measured at the eye which is less than the alpha-minimums given in Figure 6.5.3.2-2. “Extended Source” values shall apply to sources that subtend a visual angle measured at the eye which is greater than the alpha-minimums given in Figure 6.5.3.2-2.

6.5.3.2.2.2.2 POINT SOURCE LASER EYE EXPOSURE LIMITS

The Maximum Permissible Eye Exposures to Point Source Lasers given in Figure 6.5.3.2-3 shall apply to all point source lasers.

6.5.3.2.2.2.3 EXTENDED SOURCE LASER EYE EXPOSURE LIMITS

The Maximum Permissible Eye Exposures to Extended Source Lasers given in Figure 6.5.3.2-4 shall apply to all extended source lasers.

6.5.3.2.2.2.4 LASER SKIN EXPOSURE LIMITS

The Maximum Permissible Skin Exposures to Lasers given in Figure 6.5.3.2-5 shall apply.

6.5.3.2.2.2.5 EXPOSURE LIMITS FOR COMMONLY AVAILABLE TYPES OF LASERS

The intrabeam ~~MPEs~~ Maximum Permissible Exposure for the Eye and Skin for Selected CW Lasers given in Figure 6.5.3.2-6 shall apply.

6.5.3.2.2.3 ULTRAVIOLET (UV) RADIATION

6.5.3.2.2.3.1 NEAR ULTRAVIOLET EXPOSURE

For the near UV spectral region (320 to 400 nm), total irradiance incident upon the unprotected eye should not exceed 1.0 mW/cm^2 for periods greater than 10^3 seconds (16.67 minutes) and for exposure times less than 10^3 seconds should not exceed 1.0 J/cm^2.

6.5.3.2.2.3.2 EFFECTIVE IRRADIANCE AND UV EXPOSURE CALCULATIONS

The UV effective Irradiance $E_{eff.}$ shall not exceed 3000 μJ/cm^2 within an eight-hour period. $E_{eff.}$ is calculated according to the following:

$$E_{eff} = \sum E_{\lambda} \cdot S_{\lambda} \cdot \Delta\lambda$$ where:

$E_{eff.}$ is the effective irradiance of the source relative to a –monochromatic source at 270 nm, given in W/cm^2.
E_{λ} is the spectral irradiance of the source at wavelength λ in W/cm^2/nm.
S_{λ} is the relative spectral effectiveness (~~unitless~~non-dimensional)
Δλ is the bandwidth in nm.

Figure 6.5.3.2-7 gives a table of monochromatic Threshold Limit Values (TLV~~s~~) along with the spectral effectiveness at each wavelength These values represent the irradiances at each listed wavelength equal to the 8-hour limit for Effective Irradiance.

6.5.3.2.2.3.3 PERMISSIBLE EXPOSURE TIME

Permissible exposure time (exposure time necessary to reach 8-hour limit) in seconds for exposure to actinic (180 to 315 nm) UV radiation incident upon the unprotected skin or eye may be computed ~~by the following~~as follows:

.003 (J/cm^2) / $E_{eff.}$ (W/cm^2).

Figure 6.5.3.2-8 gives a table of permissible exposure times corresponding to effective irradiances given in μW/cm^2.

6.5.3.2.2.4 BROAD-BAND OPTICAL EXPOSURE

Protection from broad-band optical sources requires knowledge of the spectral radiation distribution L_{λ} W/(cm^2·sr) (Watts per square centimeter-steradian), of the source measured at the position of the eye of the crewmember. Such detailed spectral data of white light sources are generally required only if the luminance of the source exceeds 1 cd/cm^2 (candela per square centimeter). At luminescence~~s~~ less than this value, the exposure limits would not be exceeded. Optical lasers should be evaluated with using laser exposure guidelines.

6.5.3.2.2.4.1 RETINAL THERMAL INJURY FROM VISIBLE LIGHT

To protect against retinal thermal injury from a visible light source, the spectral irradiance of the source should not exceed the following:

$$\sum_{\lambda=400}^{1400} L_\lambda \cdot R_\lambda \cdot \Delta_\lambda < \frac{5}{\alpha \cdot t^{\frac{1}{4}}}$$ where:

L_λ is the spectral radiance in $\frac{W}{cm^2 \cdot Sr \cdot nm}$

R_λ is the Retinal Thermal (Burn) Hazard Function from Figure 6.5.3.2-9.

Δ_λ is the bandwidth used in the analysis (Figure 6.5.3.2-9 uses 5 nm).

t is the viewing time in seconds (this relationship is valid for $10^{-6} \le t \le 10$ s)

α is the angle subtended by the source at the point of exposure given in radians.

6.5.3.2.2.4.2 RETINAL PHOTOCHEMICAL INJURY FROM BLUE LIGHT

To protect against retinal photochemical damage from chronic blue light (400-700 nm) exposure, the integrated spectral radiance of a light source weighted against the blue light hazard function B_λ (Figure 6.5.3.2-9) should not exceed:

$$\sum_{\lambda=400}^{700} L_\gamma \cdot B_\lambda \cdot t \cdot \Delta_\lambda \le 100 \text{ J/(cm}^2\text{·Sr)}$$ for t ≤ 10,000 s

$$\sum_{\lambda=400}^{700} L_\gamma \cdot B_\lambda \cdot \Delta_\lambda \le .01 \text{ W/(cm}^2\text{·Sr)}$$ for t > 10,000 s

For sources which will exceed .01 W/(cm^2·Sr), in the blue spectral region, the following relationship, the permissible exposure duration, t_{max} is given by:

$$t_{max} \le (100 \text{ J/cm}^2)/ \left(\sum_{\lambda=400}^{700} L_\lambda \cdot B_\lambda \cdot \Delta_\lambda \right)$$

For sources that subtend an angle less than .011 radians, the above limits may be relaxed such that:

$$\sum_{\lambda=400}^{700} E_\lambda \cdot B_\lambda \cdot t \cdot \Delta_\lambda \le .01 \text{ J/(cm}^2\text{·Sr)}$$ for t ≤ 10,000 s

$$\sum_{\lambda=400}^{700} E_\lambda \cdot B_\lambda \cdot \Delta_\lambda \le 1E(-6) \text{ W/(cm}^2\text{·Sr)}$$ for t > 10,000 s

where E_λ is the total spectral irradiance W/(cm^2·nm)

For sources which will exceed 1 microwatt/cm^2 in the blue light region, the following relationship for maximum permissible viewing time shall be used:

$t_{max} \leq \dfrac{.01 J / cm^2}{\sum_{\lambda=400}^{700} E_\lambda \cdot B_\lambda \cdot \Delta_\lambda}$ for $t \leq 10{,}000$ s

6.5.3.2.2.4.3 PROTECTION FROM INFRA-RED RADIATION

Protection for the Cornea and Lens: To avoid thermal injury of the cornea and possible delayed effects upon the lens of the eye, the infra-red radiation (770-3000 nm) exposure should be limited to:

$\sum_{\lambda=770}^{3000} E_\lambda \cdot \Delta_\lambda \leq .01 \text{ W/cm}^2$ for $t \geq 1000$ s

$\sum_{\lambda=770}^{3000} E_\lambda \cdot \Delta_\lambda \leq 1.8 \cdot t^{(-.75)} \text{ W/cm}^2$ for $t < 1000$ s

Protection for the retina: For an infra-red heat lamp, or any near infra-red source where a strong visual stimulus is absent (luminescence of less than .01 candela/m^2) the near infra-red (770-1400 nm) radiance as viewed by the eye should be limited to:

$\sum_{\lambda=770}^{1440} L_\lambda \cdot \Delta_\lambda \leq .6/\alpha$ for $t > 10$ s

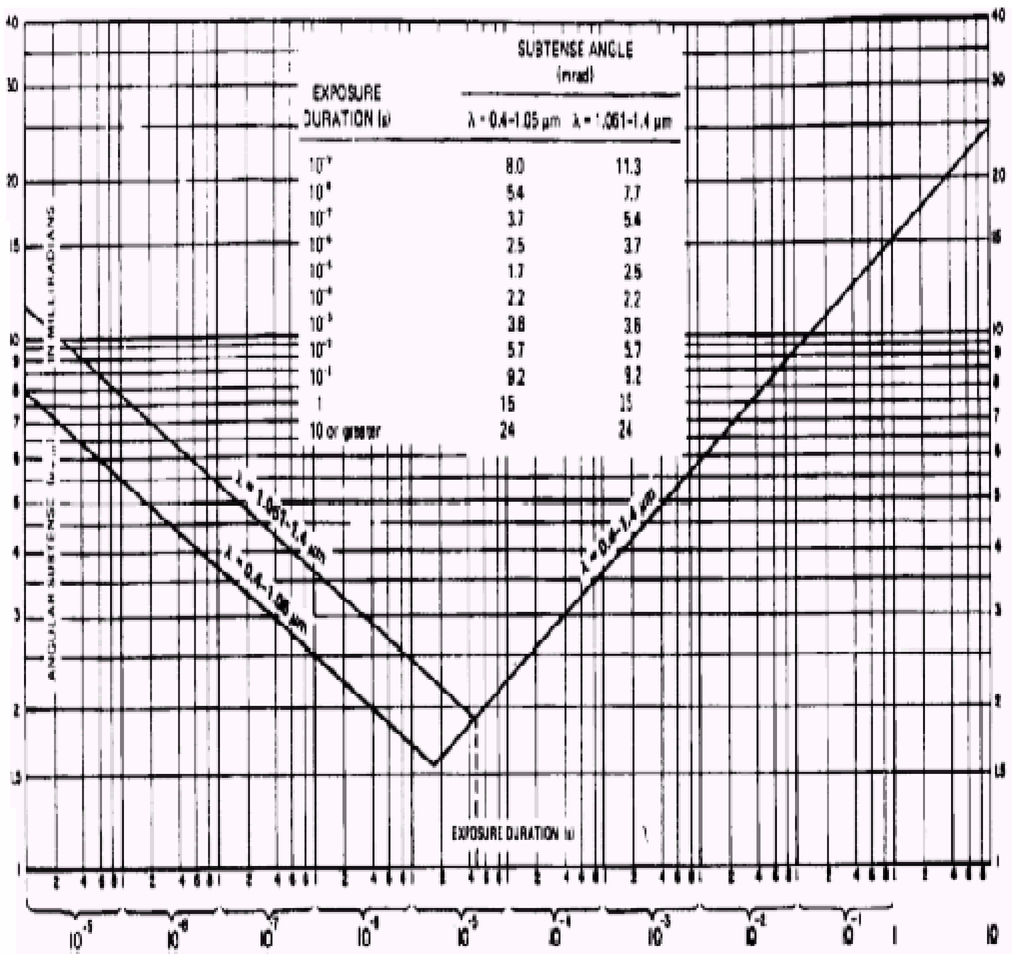
Note: This limit is based on a 7 mm pupil diameter, since aversion response may not exist due to an absence of light, and a detector field of view of 11 mrad.

Maximum Permissible Exposures to Radio-Frequency Electromagnetic Radiation

	Frequency Range MHz	Maximum Permissible Exposure (MPE)	Maximum Time at MPE Level (hrs.)
Electric Field Intensity, **E**, V/m	.01-.03	500	8
	.01-.03	1000	2
	.03-.06	$\sqrt{\frac{20,000}{T}}$	T
	.06-.3	50	8
	.3-3	50	8
	3-30	25	8
	30-50	10	8
	50-300	5	8
Magnetic Field Intensity, **H**, A/m	.01-.03	50	8
	.01-.03	100	2
	.03-.06	$\sqrt{\frac{200}{T}}$	T
	.06-1.5	5	8
	1.5-50	.3	-
	50-300	.1	8
	300-300,000	$\leq$.1	8
		.1-1.0	2
		1.0-10	.33

Figure 6.5.3.2-1 - Maximum Permissible Exposure Levels for Radio-Frequency Radiation

Angular Subtenses Used to Determine "Point Source" or "Extended Source" Exposure Limit Applicability



Alpha-Minimum Used to Determine
"Point Source" or "Extended Source"
Laser Exposures

Figure 6.5.3.2-2. Minimum Angular Subtenses to Determine Source Criteria Applicability

Maximum Permissible Exposures to the Unprotected Eye for Point Source Lasers

Wavelength, nm	Exposure Duration, s	Maximum Permissible Exposure, (MPE)
Ultraviolet		
200-302	10^{-9} to $3*10^{4}$	$3*10^{-3}$ J/cm^2
303	10^{-9} to $3*10^{4}$	$4*10^{-3}$ J/cm^2
304	10^{-9} to $3*10^{4}$	$6*10^{-3}$ J/cm^2
305	10^{-9} to $3*10^{4}$	10^{-2} J/cm^2
306	10^{-9} to $3*10^{4}$	$1.6*10^{-2}$ J/cm^2
307	10^{-9} to $3*10^{4}$	$2.5*10^{-2}$ J/cm^2
308	10^{-9} to $3*10^{4}$	$4*10^{-2}$ J/cm^2
309	10^{-9} to $3*10^{4}$	$6.3*10^{-2}$ J/cm^2
310	10^{-9} to $3*10^{4}$	0.1 J/cm^2
311	10^{-9} to $3*10^{4}$	0.16 J/cm^2
312	10^{-9} to $3*10^{4}$	0.25 J/cm^2
313	10^{-9} to $3*10^{4}$	0.4 J/cm^2
314	10^{-9} to $3*10^{4}$	0.63 J/cm^2
315 to 400	10^{-9} to 10	$0.56\ t^{1/4}$ J/cm^2
315 to 400	10 to $3*10^{4}$	1.0 J/cm^2
Visible and Near Infrared		
400 to 700	10^{-9} to $1.8*10^{-5}$	$5*10^{-7}$ J/cm^2
400 to 700	$1.8*10^{-5}$ to 10	$(1.8\ t^{3/4})*10^{-3}$ J/cm^2
400 to 550	10 to 10000	10^{-2} J/cm^2
550 to 700	10 to T_1	$(1.8\ t^{3/4})*10^{-3}$ J/cm^2
550 to 700	T_1 to 10000	$(10\ C_B)*10^{-3}$ J/cm^2
400 to 700	10000 to 30000	C_B*10^{-6} W/cm^2
700 to 1050	10^{-9} to $1.8*10^{-5}$	$(5\ C_A)*10^{-7}$ J/cm^2
700 to 1050	$1.8*10^{-5}$ to 1000	$(1.8\ C_A\ t^{3/4})*10^{-3}$ J/cm^2
1051 to 1400	10^{-9} to $5*10^{-5}$	$5*10^{-6}$ J/cm^2
1051 to 1400	$5*10^{-5}$ to 1000	$(9\ t^{3/4})*10^{-3}$ J/cm^2
700 to 1400	1000 to 30000	$(320\ C_A)*10^{-6}$ W/cm^2
Far Infrared		
1400 to 10^{6}	10^{-9} to 10^{-7}	10^{-2} J/cm^2
	10^{-7} to 10	$0.56\ t^{1/4}$ J/cm^2
	>10	0.1 W/cm^2
1540 only	10^{-9} to 10^{-6}	1.0 J/cm^2

Notes:

$C_A = 1$	for λ = 400 to 700 nm
C_A = 10^(2*(λ -700)/1000)	for λ = 700 to 1050 nm
$C_A = 5$	for λ = 1050 to 1400 nm
$C_B = 1$	for λ = 400 to 550 nm
C_B = 10^(15(λ-550)/1000)	for λ = 550 to 700 nm
T_1 = 10 * 10^(20(λ-550)/1000)	for λ = 550 to 700 nm

Figure 6.5.3.2-3 . “Point Source” Eye MPE’s

Maximum Permissible Exposures to the Unprotected Eye for Laser Light from an Extended Source

Wavelength, nm	Exposure Duration, s	Maximum Permissible Exposure, (MPE)
Ultraviolet		
200-302	10^{-9} to $3*10^{4}$	$3*10^{-3}$ J/cm^2
303	10^{-9} to $3*10^{4}$	$4*10^{-3}$ J/cm^2
304	10^{-9} to $3*10^{4}$	$6*10^{-3}$ J/cm^2
305	10^{-9} to $3*10^{4}$	10^{-2} J/cm^2
306	10^{-9} to $3*10^{4}$	$1.6*10^{-2}$ J/cm^2
307	10^{-9} to $3*10^{4}$	$2.5*10^{-2}$ J/cm^2
308	10^{-9} to $3*10^{4}$	$4*10^{-2}$ J/cm^2
309	10^{-9} to $3*10^{4}$	$6.3*10^{-2}$ J/cm^2
310	10^{-9} to $3*10^{4}$	0.1 J/cm^2
311	10^{-9} to $3*10^{4}$	0.16 J/cm^2
312	10^{-9} to $3*10^{4}$	0.25 J/cm^2
313	10^{-9} to $3*10^{4}$	0.4 J/cm^2
314	10^{-9} to $3*10^{4}$	0.63 J/cm^2
315 to 400	10^{-9} to 10	$0.56\ t^{1/4}$ J/cm^2
315 to 400	10 to $3*10^{4}$	1.0 J/cm^2
Visible		
400 to 700`	10^{-9} to 10	$10\ t^{1/3}$ J/(cm^2·sr)
400 to 550	10 to 10^{4}	21 J/(cm^2·sr)
550 to 700	10 to T_1	$3.83\ t^{3/4}$ J/(cm^2·sr)
550 to 700	T_1 to 10^{4}	21 C_B J/(cm^2·sr)
400 to 700	10^{3} to $3*10^{4}$	$2.1\ C_B*10^{-3}$ W/(cm^2·sr)
Near Infrared		
700 to 1400	10^{-9} to 10	$10\ t^{1/3}$ J/(cm^2·sr)
700 to 1400	10 to 10^{3}	$3.83\ C_A\ t^{3/4}$ J/(cm^2·sr)
700 to 1400	10^{3} to $3*10^{4}$	0.64 C_A W/(cm^2·sr)
Far Infrared		
1400 to 10^{6}	10^{-9} to 10^{-7}	10^{-2} J/cm^2
	10^{-7} to 10	$0.56\ t^{1/4}$ J/cm^2
	>10	0.1 W/cm^2
1540 only	10^{-9} to 10^{-6}	1.0 J/cm^2

Notes:

$C_A = 1$	for λ = 400 to 700 nm
$C_A = 10$^(2*(λ -700)/1000)	for λ = 700 to 1050 nm
$C_A = 5$	for λ = 1050 to 1400 nm
$C_B = 1$	for λ = 400 to 550 nm
$C_B = 10$^(15(λ-550)/1000)	for λ = 550 to 700 nm
$T_1 = 10$ * 10^(20(λ-550)/1000)	for λ = 550 to 700 nm

Figure 6.5.3.2-4 “Extended Source” Eye MPE’s

Maximum Permissible Exposures to the Unprotected Skin for Laser Light

Wavelength, nm	Exposure Duration, s	Maximum Permissible Exposure, (MPE)
Ultraviolet		
200-302	10^{-9} to $3*10^4$	$3*10^{-3}$ J/cm^2
303	10^{-9} to $3*10^4$	$4*10^{-3}$ J/cm^2
304	10^{-9} to $3*10^4$	$6*10^{-3}$ J/cm^2
305	10^{-9} to $3*10^4$	10^{-2} J/cm^2
306	10^{-9} to $3*10^4$	$1.6*10^{-2}$ J/cm^2
307	10^{-9} to $3*10^4$	$2.5*10^{-2}$ J/cm^2
308	10^{-9} to $3*10^4$	$4*10^{-2}$ J/cm^2
309	10^{-9} to $3*10^4$	$6.3*10^{-2}$ J/cm^2
310	10^{-9} to $3*10^4$	0.1 J/cm^2
311	10^{-9} to $3*10^4$	0.16 J/cm^2
312	10^{-9} to $3*10^4$	0.25 J/cm^2
313	10^{-9} to $3*10^4$	0.4 J/cm^2
314	10^{-9} to $3*10^4$	0.63 J/cm^2
315 to 400	10^{-9} to 10	0.56 $t^{1/4}$ J/cm^2
315 to 400	10 to 10^3	1.0 J/cm^2
315 to 400	10^3 to $3*10^4$	$1.0*10^{-3}$ wcm^2
Visible and Near Infrared		
400 to 1400	10^{-9} to 10^{-7}	2 C_A*10^{-2} J/cm^2
	10^{-7} to 10	1.1 C_A $t^{1/4}$ J/cm^2
	10 to $3*10^4$	.2 C_A W/cm^2
Far Infrared		
1400 to 10^6	10^{-9} to 10^{-7}	10^{-2} J/cm^2
	10^{-7} to 10	0.56 $t^{1/4}$ J/cm^2
	>10	0.1 W/cm^2
1540 only	10^{-9} to 10^{-6}	1.0 J/cm^2

Notes:

$C_A = 1$	for λ = 400 to 700 nm
$C_A = 10\text{^}(2*(\lambda -700)/1000)$	for λ = 700 to 1050 nm
$C_A = 5$	for λ = 1050 to 1400 nm
$C_B = 1$	for λ = 400 to 550 nm
$C_B = 10\text{^}(15(\lambda-550)/1000)$	for λ = 550 to 700 nm
$T_1 = 10 * 10\text{^}(20(\lambda-550)/1000)$	for λ = 550 to 700 nm

Figure 6.5.3.2-5. Maximum Permissible Exposure for Laser on Unprotected Skin

Intrabeam MPE for the Eye and Skin for Selected CW Lasers

Laser Type	Primary Wavelength(s), nm	Exposure Limit Eye	Exposure Limit Skin
Helium-Cadmium Argon	441.6 488/514.5	a) 2.5 mW/cm^2 for .25 s b) 10 mJ/cm^2 for 10 to 10^4 s c) 1.0 μW/cm^2 for t > 10^4 s	0.2 W/cm^2 for t > 10 s
Helium-Neon	632.8	a) 2.5 mW/cm^2 for .25 s b) 10 mJ/cm^2 for 10 s c) 170 mJ/cm^2 for t > 453 s d) 17 μW/ cm^2 for t > 10^4 s	0.2 W/cm^2 for t > 10 s
Krypton	647	a) 2.5 mW/cm^2 for .25 s b) 10 mJ/cm^2 for 10 s c) 280 mJ/cm^2 for t > 871 s d) 28 μW/cm^2 for t > 10^4 s	0.2 W/cm^2 for t > 10 s
Neodymium: YAG Gallium-Arsenide at Room Temperature	1,064 905	1.6 mW/cm^2 for t > 1000 s 0.8 mW/cm^2 for t > 1000 s	1.0 W/cm^2 0.5 W/cm^2 for t > 10 s
Helium-Cadmium Nitrogen	325 337.1	1.0 J/cm^2 for 10 to 3*10^4 s	a) 1.0 J/cm^2 for 10 to 1000 s b) 1.0 mW/cm^2 for t > 1000 s
Carbon-Dioxide and other lasers 1.4 μm to 1 mm	10,600	0.1 W/cm^2 for t > 10 s	0.1 W/cm^2 for t > 10 s

Figure 6.5.3.2-6 Intrabeam MPE for the Eye and Skin for Selected CW Lasers

Ultraviolet Radiation Exposure TLV and Spectral Weighting Function

Wavelength	TLV (J/m^2)	TLV (mJ/cm^2)	Relative Spectral Effectiveness, S_λ
180	2500	250	.012
190	1600	160	.019
200	1000	100	.030
205	590	59	.051
210	400	40	.075
215	320	32	.095
220	250	25	.120
225	200	20	.150
230	160	16	.190
235	130	13	.240
240	100	10	.300
245	83	8.3	.360
250	70	7.0	.430
255	58	5.8	.520
260	46	4.6	.650
265	37	3.7	.810
270	30	3.0	1.000
275	31	3.1	.960
280	34	3.4	.880
285	39	3.9	.770
290	47	4.7	.640
295	56	5.6	.540
300	100	10	.300
305	500	50	.06
310	2000	200	. 015
315	$1.0*10^4$	1000	. 003
320	$2.9*10^4$	2900	.0024
325	$6.0*10^4$	6000	.00050
330	$7.3*10^4$	7300	.00041
335	$8.8*10^4$	8800	.00034
340	$1.1*10^5$	$1.1*10^4$	.00028
345	$1.3*10^5$	$1.3*10^4$	.00024
350	$1.5*10^5$	$1.5*10^4$	.00020
355	$1.9*10^5$	$1.9*10^4$	.00016
360	$2.3*10^5$	$2.3*10^4$	.00013
365	$2.7*10^5$	$2.7*10^4$	.00011
370	$3.2*10^5$	$3.2*10^4$	.000093
375	$3.9*10^5$	$3.9*10^4$	.000077
380	$4.7*10^5$	$4.7*10^4$	.000064
385	$5.7*10^5$	$5.7*10^4$	.000053
390	$6.8*10^5$	$6.8*10^4$	.000044
395	$8.3*10^5$	$8.3*10^4$	.000036
400	$1.0*10^6$	$1.0*10^5$	.000030

Figure 6.5.3.2-7 . Ultraviolet Radiation Exposure TLV and Spectral Weighting Function

Permissible Ultraviolet Exposures

Duration of Exposure Per Day	Effective Irradiance, μW/cm^2
8 hrs.	0.1
4 hrs.	0.2
2 hrs.	0.4
1 hr.	0.8
30 min.	1.7
15 min.	3.3
10 min.	5
5 min.	10
1 min.	50
30 sec.	100
10 sec.	300
1 sec.	3000
0.5 sec.	6000
0.1 sec.	30000

Figure 6.5.3.2-8. Permissible Ultraviolet Exposures

Retinal and UVR Hazard Spectral Weighting Functions

Wavelength, (nm)	Blue-Light Hazard Function, B_λ	Retinal Thermal Hazard Function, R_λ
400	0.10	1.0
405	0.20	2.0
410	0.40	4.0
415	0.80	8.0
420	0.90	9.0
425	0.95	9.5
430	0.98	9.8
435	1.0	10.0
440	1.0	10.0
445	0.97	9.7
450	0.94	9.4
455	0.90	9.0
460	0.80	8.0
465	0.70	7.0
470	0.62	6.2
475	0.55	5.5
480	0.45	4.5
485	0.40	4.0
490	0.22	2.2
495	0.16	1.6
500 to 600	$10^{-\frac{(450-\lambda)}{50}}$	1.0
600 to 700	0.001	1.0
700 to 1050	--	$10^{\frac{(1700-\lambda)}{500}}$
1050 to 1400	--	0.2

Figure 6.5.3.2-9. Blue-Light and UV Retinal Thermal Hazard Functions for Assessing MPEs for Broad-Band Optical Sources

6.6 WORKSTATIONS

6.6.1 CAUTION AND WARNING

6.6.1.1 ALARM CLASSIFICATION, ANNUNCIATION, AND IMPLEMENTATION REQUIREMENTS

The three classes that shall be used in ISS are:

A. Emergency (class 1 alarm)

B. Warning (class 2 alarm)

C. Caution (class 3 alarm)

6.6.1.1.1 REQUIREMENTS FOR THE DESIGN OF EMERGENCY (CLASS 1) CAUTION/WARNING ALARMS

A. Definition of Class 1 alarm - A life threatening condition requiring immediate attention. Predefined crew responses may be required prior to taking corrective action. Safe haven concept activation may be necessary. Included are the presence of fire and smoke, the presence of toxicity in the atmosphere, the rapid loss of atmospheric pressure, and others.

B. Annunciation Requirements

(1) Each condition shall trigger a unique visual signal and an emergency tone which cannot be confused with a class 2 or class 3 tone. The emergency tones for all ISS are as follows:

> A square wave at 2000 H~~h~~z plus or minus 10% with an on/off cycle of 2.5 H~~h~~z (or 400 milliseconds) plus or minus 10% on, and 2.5 H~~h~~z (or 400 milliseconds) plus or minus 10% off.

(2) In designated pressurized elements, illuminated visual annunciation shall be present to indicate presence of specific emergency condition.

(3) Tones and visual annunciation shall be resettable at all major control consoles/areas.

(4) Corrective action information shall be available.

(5) Alarms shall have the ability to be manually activated.

(6) For an emergency condition, a visual display of condition location shall be provided at all integrated workstations.

(7) Methods shall be provided to indicate when conditions return within limits.

6.6.1.1.2 REQUIREMENTS FOR THE DESIGN OF WARNING (CLASS 2) CAUTION/WARNING ALARMS

A. Definition of Class 2 Alarm - Conditions that require immediate correction to avoid loss or major impact to mission or potential loss of crew. Included are faults, failures, and out of tolerance conditions for functions critical to station survival and crew survival.

B. Annunciation Requirements

(1) A warning condition shall trigger a visual signal and an emergency tone which cannot be confused with a class 1 or class 3 tone. The emergency tones for all ISS are as follows:

> A square wave which alternates between 500 ~~hz~~Hz plus or minus 10% and 2000 ~~hz~~Hz plus or minus 10% for equal durations at 2.5 ~~hz~~Hz plus or minus 10%.

(2) Tone and light shall be reset only by crew action.

(3) Message or light shall be provided to specify condition.

(4) Method shall be provided to indicate when condition returns within limits.

(5) Corrective action information shall be available upon crew request.

(6) For each Caution and Warning condition, visual display shall be provided. If a Caution or Warning condition is detectable at the rack or functional unit level, indication of that specific location shall be provided.

6.6.1.1.3 REQUIREMENTS FOR THE DESIGN OF CAUTION (CLASS 3) CAUTION/WARNING ALARMS

A. Definition of Class 3 Alarm - Conditions of a less time critical nature, but with the potential for further degradation if crew attention is not given. Included are faults, failures, and out of tolerance conditions for functions critical to mission success.

B. Annunciation Requirements:

(1) A Caution condition shall trigger a visual signal and an emergency tone which cannot be confused with a class 1 or class 2 tone. The emergency tones for all ISS are as follows:

A square wave at 500 hzHz plus of or minus 10%.

(2) Data system message shall specify condition and corrective action at the discretion of the crew.

(3) A method shall be provided to determine if condition returns within limits.

(4) A method shall be provided to identify momentary out of limits condition.

6.6.1.2 GENERAL ANALOGUE CAUTION AND WARNING SYSTEM DESIGN REQUIREMENTS

General requirements for analogue caution and warning systems (CWS's) are provided below.

A. CWS Recovery - Any CWS that is software dependent SHALL be recoverable from a software system crash.

B. CWS Test Limits - Permanent limit or test conditions SHALL be stored redundantly in such a way that they are protected from system crashes and single operator errors involved with temporary limit changes.

C. System Failure - The CWS SHALL fall into the category of most important systems in the RS, and shall remain operable during system failures until the point in which it's supplied utilities (power, data, etc.) fail during a contingency.

D. Life-Support - Life support and rescue systems status SHALL be provided to crewmembers at all times.

E. Sensor Changeout - Critical CWS sensors SHALL be accessible for changeout.

F. System Status During Alarm - After an alarm is triggered, indication SHALL be provided if the out-of-limit condition still exists and/or if a new out-of-limit condition occurs.

G. CWS Suppression - The CWS SHALL allow alarms to be suppressed.

H. Alarm Source - The source of an alarm condition SHALL be displayed.

I. Time History - The history of all alarms SHALL be maintained and SHALL be retrievable, with the time of occurrence noted.

J. Alarm Classification - The level of classification of an alarm SHALL be displayed.

K. CWS Status - After real-time modifications are made to CWS software, the status SHALL be displayed.

L. CWS Baseline Limits - After a modification or system failure, the CWS SHALL return to the baseline (default) configuration.

M. Multiple Alarms:

(1) Information about all out-of-limit conditions for each event SHALL be presented to the crew.

(2) Multiple caution and warning tones SHALL be annunciated simultaneously for multiple simultaneous related caution and warning events.

(3) Multiple alarms of the same class SHALL be displayed in FIFO (first in - first out) order by default.

(4) ~~(4)~~ During multiple alarms, the CWS shall annunciate the signal of the highest priority.

N. Flexibility - The CWS design shall provide for anticipated expansion or reconfiguration of the space station or the addition of new modules, payloads, or experiments.

These requirements are applicable to FGB after SM docking only.

6.6.1.3 VISUAL CAUTION AND WARNING SYSTEM DESIGN REQUIREMENTS

Requirements for the design of visual analogue caution and warning systems are presented below.

A. Master Alarm Light

(1) Illumination of the master alarm light SHALL indicate that at least one or more caution, warning, or emergency lights have been energized.

(2) The capability SHALL be provided for master alarm lights to be energized simultaneously. (as in different modules of the RS)

(3) Master alarm status lights SHALL be visible from most locations in the open volume of a module.

B. Extinguishing Signal Lights - Signal lights SHALL be extinguished by one or more of the following methods:

(1) Restoration of a within tolerance condition without remedial action or as a result of automatic switch-over.

(2) Correction of the situation as a result of remedial action by the crew. (note, in the RS, there is no manual shut-off of CWS lights by the crew).

C. Color - The color of CWS indicator lights SHALL use the following as indications:

Red - Emergency, or warning.

Yellow - Caution

Green - Important or frequently accessed lights having no urgent or emergency implications.

D. –Flashing lights - When used, the flash rate SHALL be within 3 to 5 flashes per sec ?? with approximately equal duration on and off time. The light SHALL illuminate and burn steadily if the indicator is energized and the flasher device fails.

These requirements are applicable to FGB after SM docking only.

6.6.1.4 AUDIO CAUTION AND WARNING SYSTEM DISPLAY DESIGN REQUIREMENTS

A. Audibility - A signal-to-noise ration of at least 20dB SHALL be provided in at least one octave band between 200 and 5,000 Hz at the operating position of the intended receiver.

B. Headset - When the operator is wearing earphones covering both ears during normal equipment operation, the audio alarm signal SHALL be directed to the operator's headset as well as to the work area.

C. Action Segment - The identifying or action segment of an audio emergency signal SHALL specify the precise class of emergency or condition requiring action.

D. Critical Signals - The first 0.5 seconds of an audio signal SHALL be discriminable from the first 0.5 seconds of any other signal which may occur.

E. Differentiation From Routine Signals - Audio alarms intended to bring the operator's attention to a malfunction or failure SHALL be differentiated from the routine signals, such as normal operation noises.

These requirements are applicable to FGB after SM docking only.

6.6.2 COMPUTER DISPLAYS

Computer displays in support of ISS operations shall be in accordance with SSP 50005~~TBD~~.

7 STRUCTURES

7.1 STRUCTURES AND MECHANISMS

7.1.1 GENERAL STRUCTURAL DESIGN REQUIREMENTS

7.1.1.1 STRENGTH AND STIFFNESS

~~Space Station~~ISS structures shall have adequate strength and stiffness in all necessary configurations and stages, to support ultimate load without failure. Detrimental (dangerous) deformation shall not occur at limit loads imposed during transfer of the payload to orbit, or during on-orbit operations, or during proof or acceptance testing.

7.1.1.2 CYCLIC LOADS

~~Space Station~~ISS structure shall be designed to preclude failure resulting from cumulative damage due to cyclic and sustained loads during the design service life. Structural life shall be demonstrated by analysis and/or test based on a derived load spectrum that includes all appropriate loads that occur prior to launch, during transport to and from orbit, and on-orbit. It shall be demonstrated that the fatigue life is at least four (4.0) times the required service life.

7.1.1.3 FACTORS OF SAFETY

Strength calculations shall be performed for design (ultimate) loads by multiplying maximum operating (limit) loads by safety factors meant for different design cases, structural elements, and materials. The values of safety factors used in Russian hardware design are given in Table 7.1.1.3-1.

Table 7.1.1.3-1 —Russian Minimum Factors of Safety for Metallic and Composite Space Station Structure

External(Mechanical) Loads	
Load Event	Ultimate Factor of Safety
A. Ground Operation	1.5-2.0
B. Pre-launch Preparation	1.5
C. Launch	1.3-1.5
D. Injection to Orbit	1.3-1.5
E. Landing	1.0*-1.5(* emergency landing)
F. Orbital Flight(excluding docking)	1.5
G. Docking on Orbit	2.0
For Docking Mechanisms	1.5 (Yield factor of safety)
	Interior Delta Pressure
A. Habitation Modules and Hatches	2.0
B. Windows(full pressure)	2.5
C. Pipelines	2.25
D. Pressure Vessels	2.0
E. Valves, Hydrodrives, Filters, etc.	2.25
F. Fuel Tanks and Instrument Modules	1.5
Interior Pressure Combined with External Loads	1.5**

** For all of the design cases and all of the structural components, the interior pressure safety factor is 1.5 if it gives additional load to the structure and is equal to 1.0 if it reduces the load.

7.1.1.4 THERMAL STRESS

Thermal stresses/loads shall be combined with mechanical and pressure stresses/loads when they are additive but shall not be taken into account when they are relieving.

7.1.1.5 BUCKLING

General instability due to buckling is considered an ultimate failure. All structural components that are subject to compressive stresses shall be evaluated for buckling failure modes. When calculating the ultimate load, any load component that tends to alleviate buckling shall not be increased by the ultimate safety factor. Example: For a pressurized cylinder, the external load is multiplied by the appropriate safety factor but the interior pressure is considered without the safety factor taken into account.

7.1.1.6 MATERIAL PROPERTIES

Structural material allowables shall be derived according to the procedures delineated in the material properties section (Section 4.3)

7.1.1.7 DESIGN LOADS

~~Space Station~~ISS structure shall meet its performance requirements when exposed to all appropriate static, transient, and random loads, pressure, thermal effects, and EVA and IVA crew induced loading for all phases of hardware service life. Loads shall be generated for all significant forcing functions and appropriate combinations of forcing functions. Loads shall be calculated using mutually coordinated dynamic math models of components of the ~~ISSA~~ISS. The parameters of the math models shall be verified experimentally.

Structural math models of on-orbit element flight hardware consistent with each phase of the Program shall be forwarded to the NASA Space Station Program Office. The responsible NASA loads authority will utilize the models for the calculation of on-orbit loads. The detailed data transfer requirements will be determined jointly by NASA and ~~RSA~~Roscosmos.

7.1.1.7.1 ON-ORBIT INTEGRATED STRUCTURAL DESIGN LIMIT LOADS

On-orbit load environments including structural design limit loads and load cycle spectra for transient dynamic loads, thermally induced loads and pressure induced loads shall be developed jointly by the Russian Side (Roscosmos~~RS~~) and the U. S. Side (~~USS~~NASA). In general, loading events caused by operations of Roscosmos~~the RS~~ shall be analyzed by Roscosmos~~the RS~~ and Roscosmos~~the RS~~ shall specify resulting design limit loads and loads spectra at the USOS/Russian Segment (R~~O~~S) interface and shall provide to ~~the USS~~NASA, load indicators for such events at agreed to structural locations within ~~the USS~~NASA. Similarly, loading events caused by operations of ~~the USS~~NASA shall be analyzed by ~~the USS~~NASA and ~~the USS~~NASA shall specify resulting design limit loads and loads spectra at the USOS/R~~O~~S interface and shall provide to Roscosmos~~the RS~~, load indicators for such events at agreed to structural locations within the R~~O~~S. Roscosmos E~~The RS~~ shall be responsible for defining structural design limit loads and loads spectra for all Roscosmos~~RS~~ structures. ~~The USS~~NASA shall be responsible for defining structural design limit loads and loads spectra for all USOS structures in accordance with the Space Station Structural Loads Control Plan, D684-10019-01.

Design limit loads for each type of load shall be defined to be a value which conservatively envelopes all such loads which have probability of occurrence greater than 0.0013.

7.1.1.7.1.1 TRANSIENT DYNAMIC LOADS

7.1.1.7.1.1.1 TRANSIENT DESIGN LIMIT LOADS

7.1.1.7.1.1.1.1 STRUCTURAL DYNAMIC MATH MODELS

To accomplish responsibilities for defining transient design limit loads, ~~the USS~~NASA shall supply structural dynamic models of USOS structures to Roscosmos ~~the RS~~ in formats specified by Roscosmos~~the RS~~ and Roscosmos ~~the RS~~ shall supply structural dynamic models of R~~O~~S structures to ~~the USS~~NASA in formats specified by ~~the USS~~NASA. Structural mode damping ratios of 0.01 shall be assumed for all structural dynamic models for computing transient dynamic loads unless larger damping ratios can be justified by on-orbit measurements of structural damping.

7.1.1.7.1.1.1.2 TRANSIENT DYNAMIC FORCING FUNCTIONS

Transient disturbance forcing functions developed by each segment which maximize transient loads at the USOS/R~~O~~S interface and selected agreed to load indicator locations within each segment shall be supplied by the one segment to the other for purposes of developing design limit loads on structures internal to each segment for such transient disturbances caused by the other segment. Major transient events, including but not limited to, docking, berthing, thruster plume impingement, attitude control, reboost, crew member ~~Extra-Vehicular Activity (~~EVA~~)~~ and ~~Inter-Vehicular Activity (~~IVA~~)~~, propulsive venting of fluids, and robotic equipment operations occurring due to operations of either segment shall be analyzed by the responsible segment. In lieu of providing the transient forcing functions which maximize load indicators in the other segment, models which can be used to develop and screen the forcing functions for maximum design loads may be provided as negotiated by each segment.

7.1.1.7.1.1.1.3 TRANSIENT LOAD UNCERTAINTY FACTORS

Uncertainty factors shall be applied to calculations of transient dynamic loads appropriate to the maturity and verification level of structural models and forcing functions used to calculate the transient loads. The appropriate uncertainty factor for each type of transient loading event shall be negotiated and specified by joint RoscosmosRS/USS NASA protocols of agreement for each load cycle.

7.1.1.7.1.1.1.4 ON-ORBIT TRANSIENT LOAD SPECTRA

RoscosmosThe RS and USS NASA shall jointly develop and agree on an operational model of various types of events and number of occurrences of such events for purposes of developing transient loads spectra for the required 15-year service life. Structural mode damping ratios of 0.01 shall be assumed for computing transient decay of structural responses to transient loading events unless larger damping ratios can be justified by on-orbit measurements of structural damping. Statistical distributions of peak loads and transient load decay cycles resulting from events such as docking may be utilized where sufficient statistical representation of such events is available rather than assuming each occurrence of an event produces the associated design limit load.

7.1.1.7.1.2 THERMALLY INDUCED LOADS

Thermally induced loads at the USOS/ROS interface shall be calculated by the USSNASA and shall be jointly reviewed and specified by the USS NASA and RoscosmosRS. Thermally induced loads for structures within each segment shall be specified by the segment responsible for providing the structure for ISSAISS. Thermal models required to calculate temperature distributions and structural models required to calculate loads for specification of thermally induced loads shall be specified and requested by the segment responsible for calculating the thermally induced loads. Thermally induced loads calculations shall consider extreme temperature due to spacecraft attitudes, seasonal variations in solar beta incident angle, variations in positions around each orbit, hot and cold environments due to variations in radiation exchange between the ISSAISS and the earth, and ISSAISS configuration changes due to assembly build-up or operational configuration changes such as solar array and radiator orientations.

7.1.1.7.1.2.1 THERMALLY INDUCED LOAD SPECTRA

Thermal load cycle spectra based on maximum and minimum temperature variations over the period of each orbit and seasonal variations with solar beta angles shall be computed and specified for each structural component for which structural life must be demonstrated. RoscosmosThe RS shall specify thermal load spectra for all ROS structures and the USSNASA shall specify thermal load spectra for all USOS structures. The USSNASA shall calculate thermal load spectra for the USOS/ROS interface and Roscosmosthe RS shall review and jointly specify with the USSNASA the thermal load spectra for the USOS/ROS interface.

7.1.1.7.1.3 PRESSURE INDUCED LOADS

Pressure induced loads at the USOS/ROS interface caused by pressurization, depressurization and pressure fluctuations of pressurized modules in the USOS shall be defined by the USSNASA. Similarly, pressure induced loads at the USOS/ROS interface caused by pressurization, depressurization or pressure fluctuations of pressurized modules within the ROS shall be specified by Roscosmosthe ROS. Structural models required from one segment by the other to perform the required calculations shall be requested by the segment responsible for the analysis. RoscosmosThe RS shall be responsible for defining structural design limit pressure loads and loads spectra for all RS pressurized structures. The USSNASA shall be responsible for defining structural design limit pressure loads and loads spectra for USOS pressurized structures.

7.1.1.7.1.3.1 PRESSURE INDUCED LOADS SPECTRA

For purposes of calculating pressure load cycles on USOS structures, the USSNASA shall assume 10 complete on-orbit pressurization/depressurization cycles for each pressurized module during the required 15 year service life in addition to small amplitude pressure cycles due to normal pressure regulation and control. RoscosmosThe RS shall use an appropriate similar conservative assumption regarding pressure cycles of RoscosmosRS pressurized modules based on planned and unplanned contingency operations within the RS.

7.1.1.7.1.4 LOADS COMBINATIONS

7.1.1.7.1.4.1 TRANSIENT LOAD COMBINATIONS

Transient loads from independent disturbance sources which occur during the same time period shall be combined in a time consistent or event consistent manner. When precise time sequencing of independent disturbances is unknown, an even consistent combination which conservatively envelopes combined load values which have a probability of occurrence greater than 0.0013 shall be used to define the combined transient limit load. Monte Carlo methods may be used to combine transient loads when appropriate statistical distributions of loads are available, or root-sum-square (RSS) combinations may be used when this method provides a conservative estimate of the required transient structural design limit load.

7.1.1.7.1.4.2 TRANSIENT, THERMAL, AND PRESSURE LOAD COMBINATIONS

Combined transient, thermally induced, and pressure induced design limit load conditions shall conservatively envelope all such loads combinations which have a probability of occurrence greater than 0.0013. Monte Carlo methods may be used to combine loads when appropriate statistical distributions of loads are available, or root-sum-square (RSS) combinations may be used when this method provides a conservative estimate of the required structural design limit load.

7.1.1.7.1.5 COMBINATION OF TRANSIENT, PRESSURE, AND THERMAL LOAD SPECTRA

Transient loading events occur over very short time intervals compared to cycle times of pressure and thermally induced loads. Therefore, the pressure loads shall be assumed to be at the normal operating mean pressure load at the time of the specific transient or thermal load cycle events. Thermally induced loads shall be assumed to be at the mean of their cyclic load values at the time of occurrence of on-orbit transient or pressure cycle loading events. The individual transient, pressure and thermal load spectra specified for structural interfaces and components shall be combined as independent load cycle events. In cases where an assumed sequence of loading events affects safe life analyses, transient load cycles and thermal load cycles may be assumed to be proportionately distributed over each year of service life. Major on-orbit pressure load cycles which are unplanned and result from assumptions of contingency scenarios, may be assumed to occur at evenly spaced intervals over the lifetime of the structural component.

7.1.1.8 PRESSURE VESSELS ~~&~~AND PRESSURIZED COMPARTMENTS

7.1.1.8.1 HIGH PRESSURE VESSELS

Storage containers which are classified as pressure vessels shall be designed and fabricated utilizing safe pressure vessel operation requirements in accordance with Technical Specification 33Y.0221.003.

7.1.1.8.2 OVERPRESSURE

The maximum expected operating pressure is defined as the nominal operating pressure of the system plus any pressure transients, instrumentation measurement tolerances and thermal effects.

7.1.1.8.3 DESIGN FACTORS

Pressure vessels shall be designed and proof tested to the -pressure defined in paragraph 7.1.1.9.2 multiplied by the appropriate factors listed in Table 7.1.1.3-1. The proof test factors for are given in table 7.1.3.3.1-1.

7.1.1.8.4 SAFE LIFE/LEAK BEFORE BURST (LBB)

All pressure vessels whose failure would release a hazardous fluid or be potentially catastrophic shall be shown to have safe life. Pressure vessels whose failure would not be catastrophic shall be either safe life or leak before burst. Safe life will be demonstrated per the requirements of 7.1.3.

7.1.1.8.5 COMPOSITE PRESSURE VESSELS

Composite pressure vessels shall be shown to have adequate stress rupture life.

7.1.1.8.6 NONDESTRUCTIVE EVALUATION ~~(NDE)~~

NDE of pressure vessels shall include inspection of welds before and after proof testing.

7.1.1.8.7 LINES AND FITTINGS

In addition to proof testing of individual parts per Table 7.1.1.4-1, the complete pressure system shall also be tested to the maximum expected operating pressure and leak checked to demonstrate system integrity. Pressurized lines and fittings shall be considered fracture critical if they contain a hazardous fluid or if loss of pressurization would result in a catastrophic hazard. All welded joints on fracture critical components shall be inspected using a qualified NDE method.

7.1.1.9 STRUCTURAL DEGRADATION FROM MATERIAL EROSION

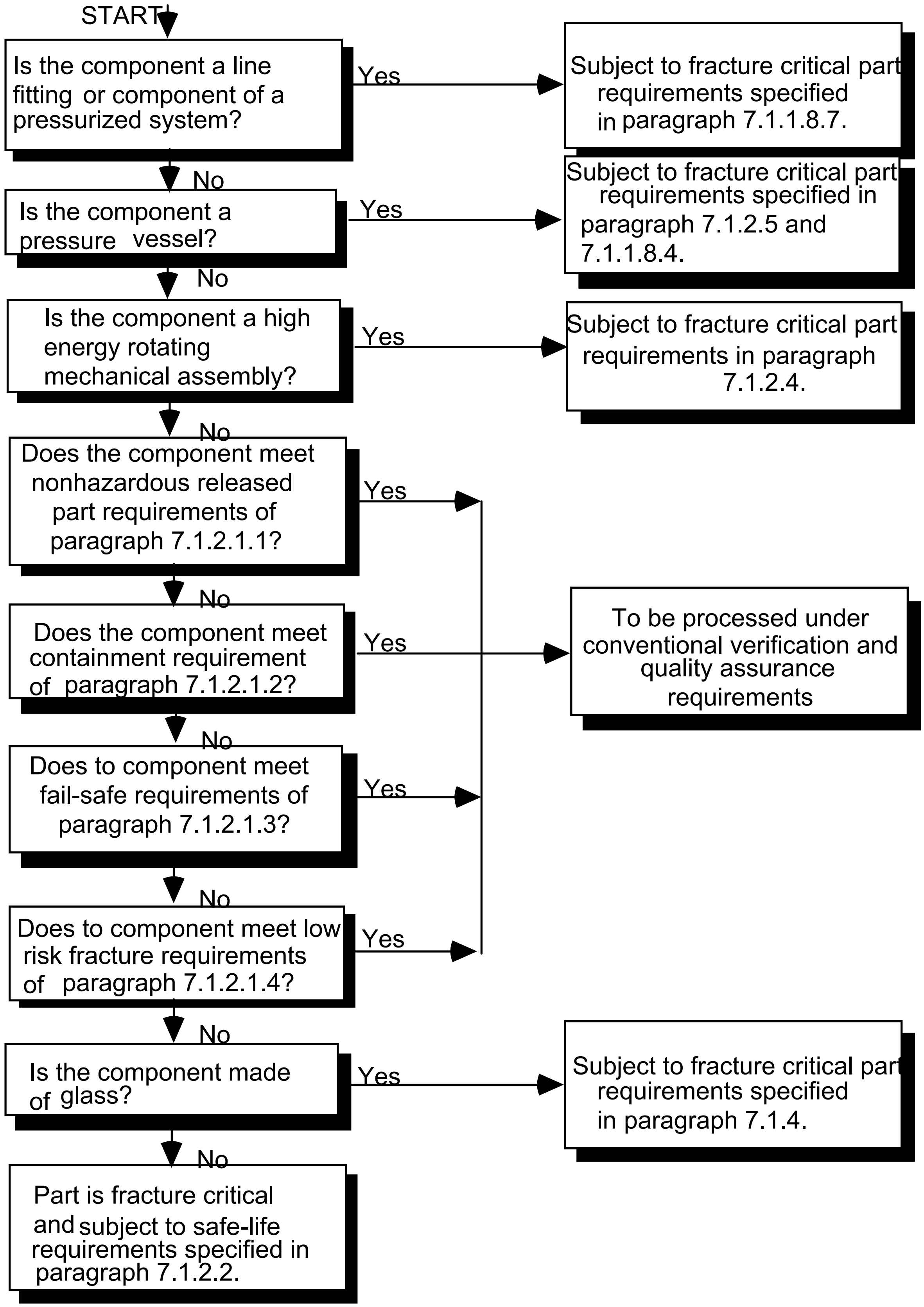
Potential structural erosion during the design life, e.g., from atomic oxygen, shall be included in the design and analysis of the structure.

7.1.2 FRACTURE CONTROL

Fracture control for each element of the ~~Russian on-orbit segment~~RS and all Russian provided hardware launched on the Space Shuttle shall be in accordance with the joint fracture control plan as given in Appendix B.
The joint fracture control plan requires the following:

a. Fracture Control classification of components
b. Analysis and/or testing to determine the acceptability of hardware
c. Control of materials, manufacturing processes, nondestructive evaluation inspections, and testing
d. Overall review and assessment of fracture control activities and results.

Figure 7.1.2-1 Fracture Control Classification of Space Station Components



7.1.2.1 CLASSIFICATION OF COMPONENTS

Fracture control classification for ~~Space Station~~ISS components shall be determined as shown in Figure 7.1.2.1-1. Parts which are classified as nonhazardous released, contained, fail-safe, or low risk are not fracture critical, and are therefore not subject to further fracture control. A description of these non-fracture critical categories follows.

7.1.2.1.1 NONHAZARDOUS RELEASED PART

For a component to be classified as a nonhazardous released part, it shall be shown by analysis, test, or engineering rationale that release of the part due to fracture will not create a catastrophic hazard.

7.1.2.1.2 CONTAINED PART

For a component to be classified as contained, it shall be shown by analysis, test, or engineering rationale that if the part fails, all fragments of the part will be contained and will not create a catastrophic hazard.

7.1.2.1.3 FAIL-SAFE PART

To be classified as a fail-safe part, it shall be shown by analysis, test, or engineering rationale that due to structural redundancy, the structure remaining after any single failure can withstand the resulting redistributed loads with a minimum ultimate factor of safety of 1.0. Changes in the dynamic characteristics of the structure due to the failure shall be considered when assessing redundancy.

7.1.2.1.4 LOW RISK PART

To be classified as low risk, a part must meet the following criteria:

a. The part must be fabricated from a well characterized metal which is not sensitive to stress corrosion cracking.
b. The part must not be fabricated using a process that has a recognized risk of causing crack-like defects, such as welding.
c. The part must receive at least a visual inspection.
d. The maximum far field tensile stress in the part at limit load is less than 30% of the ultimate strength.
e. Pressure vessels and high energy rotating machinery (>19,307 joules) are excluded.

7.1.2.2 SAFE LIFE ANALYSIS CRITERIA

A fracture critical component shall be acceptable if it can be shown by analysis or test that the largest undetected flaw that could exist in the component will not grow to failure when subjected to the cyclic and sustained loads encountered in not less than four service lifetimes.

When crack growth analysis is used to demonstrate safe-life, an undetected flaw shall be assumed to be in the most critical area and orientation for the part. The size of the assumed initial flaw shall be based on the appropriate NDE technique used for the part.

Either of two analysis approaches may be utilized to show that an NDE inspected part meets safe-life requirements. The first is to assume an initial flaw equal to the minimum flaw size that the NDE technique can detect, and show that the flaw will not grow to critical size in not less than four lifetimes. The second approach is to calculate the critical initial flaw size for which the part can survive the required lifetimes, and to verify by inspection that there are no cracks greater than or equal to this size.

The Fatigue Crack Growth Computer Program "NASA/FLAGRO, JSC-22267" is an approved computer code for crack growth analysis of ~~Space Station~~ISS components. Other programs or analysis methods are acceptable if they are shown to give comparable results.

7.1.2.2.1 SAFE LIFE TESTING CRITERIA

Testing to predict life is an acceptable alternative to safe life analysis. Safe life testing shall be performed on precracked specimens representative of the structural design of the part and shall demonstrate not less than four lifetimes. Worst case dimensions, tolerances, material properties, and environmental conditions shall be simulated in the tests.

7.1.2.3 FRACTURE MECHANICS MATERIAL PROPERTIES

Material properties for fracture mechanics analysis shall be determined in accordance with the joint fracture control plan and added to section 4.0 of SSP 50094.

7.1.2.4 ROTATING MACHINERY

A rotating mechanical assembly that has a kinetic energy of 19,307 joules or greater shall be considered by definition, fracture critical.
Rotating machinery shall be spin tested to design revolutions per minute (RPM) and shall be subjected to NDE before and after testing.

7.1.2.5 PRESSURE VESSELS

Pressure vessels shall be considered fracture critical. A pressure vessel is defined as a pressurized storage container which contains stored energy of 19,307 joules or greater; or contains a gas or liquid in excess of 103.4 kPa which will create a hazard if released.

7.1.2.6 BRITTLE FRACTURE CONTROL

A detailed description of the Russian approach to fracture control is given in Appendix B. Below is a summary of the Russian approach.

A series of measures that guarantee that flaws of unacceptable size are not present in structure of the ~~ISSA~~ISS ~~Russian segment~~RS are undertaken. These measures guarantee that the initial flaw will not grow to its critical size during service. These measures are:

1. Materials of high elasticity and ductility are chosen.
2. Material control is employed to detect unacceptable flaws.
3. Weld control is employed to detect unacceptable flaws.
4. Acceptance tests of the structure per section 7.1.3.3 are performed.
5. Structural life tests per section 7.1.3.5 are performed.

7.1.3 STRUCTURAL STRENGTH VERIFICATION

7.1.3.1 STATIC TESTS

Structural strength is experimentally verified by peak static load tests. A test article that completely simulates the load bearing structure of a flight article undergoes the static tests. The test article is manufactured to the same specifications and at the same production site as that of the flight article. Standard boundary conditions are simulated during the tests, ie. the attachment or loading is performed via fittings that simulate the adjacent flight structure. The test loading sequentially demonstrates the major design cases. Each design case has external loads up to the following values.

P test = K test x P oper.
P test = test load value
P oper = operating (limit) loads
K test = test load coefficient, K test > 0.8 x f
f = safety factor for a corresponding design case (ref. Table 7.1.1.4-1)

The maximum operating pressure will be superposed during the static test if the pressure adds load to the structure. The minimum operating pressure will be superposed if pressure stabilizes the structure.

During the static tests, a measurement of displacements, deformations, and stresses in the structure will be performed. These measurements aid in predicting the safety margin for ultimate loads for a certain design case.

Residual (plastic) strain that causes a degradation of structural serviceability, is not acceptable at operational (limit) loads.

From all of the design cases, the most dangerous (critical) one is chosen for an ultimate load test. The structure is loaded up to 100% of the design (ultimate) load (K test = f), or is taken to failure. In the case of a pressure vessel, a dedicated test vessel is tested to design (ultimate) pressure.

7.1.3.2 DYNAMIC MODAL TESTS

Modal tests are required for verification of a design dynamic math model of the structure. These tests include frequency and stiffness tests of particular structural elements. The scope of these tests shall be sufficient for verification of modal model parameters.

7.1.3.3 ACCEPTANCE TESTS OF FLIGHT STRUCTURE

7.1.3.3.1 PRESSURIZED STRUCTURE

Pressurized structure undergoes tests at the plant/manufacturer. The objective of these tests is to verify production technology, reliability, stability, quality, and consistency of adequate welds. The following components will be pressure tested.

(a) Habitation Module
(b) Pressurized instrumentation container-type modules
(c) Propellant tanks and other liquid vessels
(d) High pressure vessels and reservoirs
(e) Pipelines
(f) Flexible lines and installed bellows
(g) Valves and fittings

Leakage and proof tests will be performed. Leakage tests are conducted at the operating pressure, and shall be performed after proof tests. Proof tests will be performed according to the following formula.

$P_{appl.} = K_{pr} \times P_{oper}$

where,

$P_{appl.}$ = applied pressure
K_{pr} = proof test coefficient (the values of which are given in Table 7.1.3.3.1-1)
$P_{oper.}$ = operating (limit) pressure

7.1.3.3.2 UNPRESSURIZED STRUCTURE

Load bearing rod structures of truss and frame type are subjected to proof tests by the application of external loads. A test load is determined by the following formula.

$P_{appl.} = K_{pr} \times P_{oper.}$

where, $P_{appl.}$ = applied load
K_{pr} = proof test coefficient
$P_{oper.}$ = operating (limit) load

The proof test coefficient value depends on the structural type, material composition, and operating conditions, and varies from 1.0 to 1.3.

Table 7.1.3.3.1-1 –Acceptance Test Factors (Pressurized Structure)

Structure Type	NPOE K pr
Habitation Modules	1.3
Pressurized Modules	1.3
Propellant Tanks	1.05 - 1.2
High Pressure Vessels	1.5
Pipelines	1.5
Bellows	1.05 - 1.2
Valve bodies	-1.5
Composite structures	-1.0 -1.3

7.1.3.4 VIBRATION AND ACOUSTIC TESTS

Vibration or acoustic testing as applicable, shall be performed on structural elements in order to ensure the strength of attached systems during exposure to the launch vehicle environment. Vibration levels used to size component attachments can be verified using this method.

7.1.3.5 LIFE TESTS

Life tests are conducted to experimentally verify structural life. These tests are applied to the structural components affected by high level repeated loads during their operation. Examples of these components are docking units, areas of the modules located close to the docking units, solar panels, antenna attachments, component attachments, etc. These tests are conducted at the operating loads (safety factor = 1). Under these tests, the life factor is not less than four times the required operational life.

A spectrum of loads that acts upon the structure is reduced to an equivalent test spectrum. For purposes of decreasing the test time period, it is possible to increase loads with a corresponding reduction of a number of cycles. Depending on the structural features and the loading, the tests are conducted with full size prototype or with subscale parts.

7.1.3.6 TEST REPORTS

Structural qualification tests shall be documented. The documentation shall include a summary of the objectives of the test, a description of the test article configuration including locations of instrumentation, a description of the test boundary conditions, a summary of the applied loads and their method of application, and a summary of the test data which is applicable to strength verification.

7.1.4 GLASS WINDOWPANE DESIGN REQUIREMENTS

This section specifies the minimum structural design requirements for the design and verification of flight windows, and glass structure.

7.1.4.1 INTRODUCTION

Glass is a brittle material which obeys Hooke's law until failure. Glass failures result from tensile stresses and usually originate from a pre-existing flaw in or near the surface. Manufacturing flaws in glass cannot be determined by inspection because the visible portion of the flaw is removed in the finishing process. Flaws in glass grow as a function of stress, flaw size, environment, and time; this phenomenon is called static fatigue. Extreme care must be exercised in the design and the handling of glass due to its brittle nature.

7.1.4.2 REDUNDANCY

All ~~Space Station~~ISS windows which are a part of the crew-inhabiting pressure shell shall have redundant pressure panes. The redundant pane shall be capable of maintaining the internal pressure in the event of failure of the primary pane.

7.1.4.3 FACTORS OF SAFETY

Windows shall be designed to the factors of safety based on ultimate strength. Windows shall be designed to an initial factor of safety of 3.0 and shall be designed to an end of life factor of safety of 1.4 based on a 15 year life requirement.

7.1.4.4 DESIGN LIFE FACTOR

~~Space Station~~ISS windows shall be designed to sustain all loads without failure for not less than four times the design life.

7.1.4.5 STRUCTURAL LIFE ASSESSMENT OF WINDOWS

Structural life assessment of windows shall take into account the following factors: static fatigue and the linear summation of accumulated damages.

7.1.4.5.1 ANALYSIS TECHNIQUES

Analysis techniques for windows shall use the method of linear summation of accumulated damages resulting from variation in the applied stress (Bailey's principle).

7.1.4.5.2 DETERMINATION OF PROOF TEST CONDITIONS

For proof testing, ground handling loads applied to the window as a separate component as well as the loads induced on the window as part of the module and loads applied during its entire service life shall be considered as well as the requirements of 7.1.4.3 and 7.1.4.4.

7.1.4.5.3 GLASS TESTING ENVIRONMENT

To assess the windows service life, a static fatigue curve for the window material shall be required. This curve shall be determined on the basis of glass sample testing results. Three point bending tests and central symmetrical bending tests shall be performed in a 60% +/- 10% humidity environment.

7.1.4.5.4 INITIAL DESIGN SURFACE DEFECT

The initial design flaw depth that is assumed to exist for design purposes shall be greater than 0.046 mm. This is to provide a reasonable damage tolerance since windowpanes typically receive damage during handling and use. A manufacturing grinding schedule shall be developed to limit the maximum initial flaw depth to less than or equal to the initial design flaw depth.

7.1.4.5.5 ERROR FACTOR TO BE USED IN STRESS ANALYSIS

A factor of 1.1 shall be applied to the maximum windowpane design stress to account for tolerances and inaccuracies in analysis and measurement. This factor shall not be applied to circular windows or to windows that have shapes for which there is a precise analytical solution.

7.1.4.6 INSPECTION/CONTROL

The depth and location of any visible flaws shall be recorded on a map for each windowpane surface. The maps shall be maintained and updated to support future evaluations of the windowpanes after their manufacture. The maps shall be maintained and updated until the time of launch. In assessment of detected flaws, the total flaw depth shall be assumed to be three times the measured flaw depth. Empirical data has shown that an invisible crack tail extends past the visible flaw and this factor is to account for the tail. This activity shall be performed by the window manufacturer.

7.1.4.7 MATERIAL PROPERTIES

Material properties for flaw growth and fracture toughness shall be defined according to the methods delineated in the material properties section (Section 4.3).

7.1.4.8 GLASS STRUCTURAL VERIFICATION

7.1.4.8.1 PROOF TEST

A proof test shall be performed on all flight windowpanes. The purpose of the proof test shall be to screen all flaws that are larger than the initial design flaw. Both sides of each flight pane shall be tested. The requirements for this test shall be determined in accordance with 7.1.4.5.2.

7.1.4.8.1.1 PROOF TEST ENVIRONMENT

The environment for the proof test shall be selected and controlled to eliminate flaw growth during the proof test. Care shall be exercised to remove humidity and encapsulated water from the surface of the glass. The time to apply, hold, and drop the proof test pressure shall be limited to as short a time as is practical to accomplish the test.

7.1.4.8.1.2 PROOF TEST FIXTURE VERIFICATION

The stress distribution in the windowpane during the proof test shall be verified to equal or exceed the stress in the windowpane when in the specific flight configuration at the same pressure.

7.1.4.8.2 INSPECTION PRIOR TO FINAL ASSEMBLY

Prior to final assembly in flight configuration, a detailed visual inspection shall be performed to detect any surface flaws which may have occurred subsequent to the proof test. This inspection shall be performed by the window manufacturer

7.1.4.8.3 WINDOWPANE STRESS DISTRIBUTION

The applied stress distribution in the windowpane shall be verified by a test which includes the actual boundary conditions of the pressurized module and shall locate the point of maximum stress on the surface of the pane.

7.1.4.8.4 TRANSMISSIBILITY REQUIREMENTS FOR IR ~~&~~AND UV~~-~~ (TBR)

~~(An ocular hazard analysis of RS windows needs to be completed by NASA before differences in the IR and UV transmissibility requirements between Russian and U.S. windows can be resolved.)~~

~~The current characteristics of SM windows with special optical coatings are as follows:~~

- ~~transmittance in the UV range (up to 330 NM) is less than 0.01%~~
- ~~transmittance in visible spectrum (400 - 800 NM) - no lower 80%~~
- ~~transmittance in the infrared wave spectrum area (850 - 1000 NM) - from 60 - 40%.~~

A. Crew Safety Considerations:

For the purposes of ensuring crew safety, the IR and UV transmittance of the window assembly shall be evaluated according to the limits specified in 6.5.3.2.2.3 and 6.5.3.2.2.4.3. This evaluation shall be carried out assuming that the solar spectrum is modeled by that given in Figure 7.1.4.8.4-1, and further that the Sun subtends an angle of 9.3E-03 radians (perihelion value) and a solid angle of 6.8E-05 steradians at the eye of the observer in Low Earth Orbit (LEO).

NDC 020

Figure 7.1.4.8.4-1: Solar Spectrum

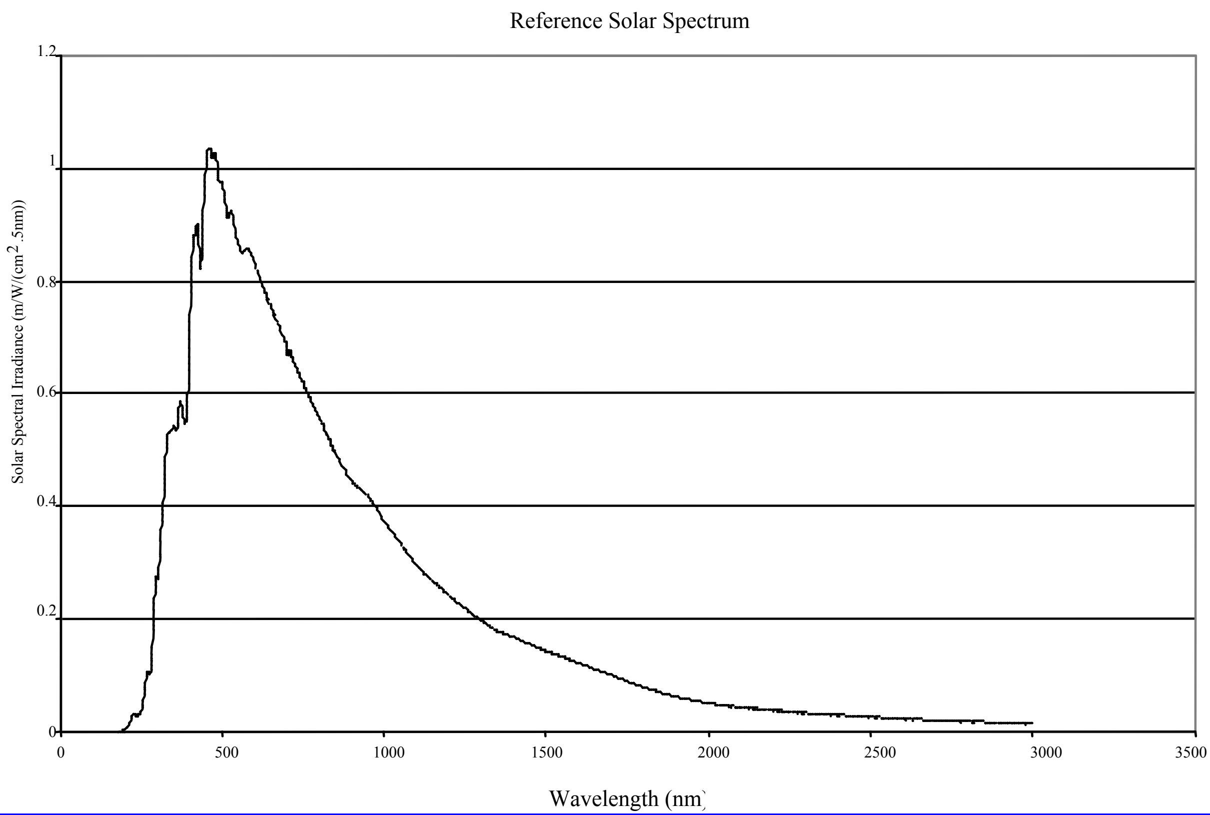


Figure 7.1.4.8.4-1 Solar Spectrum

B. Damage Mechanism Exposure Limits:

The requirements of Sections 6.5.3.2.2.3 and 6.5.3.2.2.4.3 are considered to have been met if the window port being considered has transmittance values which yield acceptable viewing times that are less than or equal to those specified in Table 7.1.4.8.4-1 when using the source terms discussed in 7.1.4.8.4 part A. The infrared requirement is applicable to cases where a strong visual stimulus is present. If the window port does not meet the values defined in Table 7.1.4.8.4-1, additional means (sunglasses, additional films, etc.) can be used to meet the required attenuation. To utilize alternate means, the NASA Radiation Health Officer shall concur.

NDC 020

Table 7.1.4.8.4-1: Exposure Limits for Different Damage Mechanisms

	SOLAR IRRADIANCE
Mechanism	Exposure Time Limits
Infrared Exposure	10 minutes
Ultraviolet Exposure	8 hours

NDC 020

7.1.5 FASTENERS AND PRELOADED JOINTS

7.1.5.1 ANALYSIS OF PRELOADED JOINTS

A preloaded joint is a joint in which the preload is necessary to preserve linear structural behavior and to have adequate life due to cyclic loads or to assure that no joint separation and resulting stiffness change occurs up to limit load or to assure that no joint separation occurs at limit load which would affect pressure seals. RS preloaded joints shall be analyzed using methodologies which are equivalent to those in NSTS 08307 “Criteria for Preloaded Bolts”.

7.1.5.2 FRACTURE CRITICAL FASTENERS

Fasteners and shear pins shall be classified as fracture critical parts when their fracture results in a single point direct catastrophic failure (of the entire bolted assembly).

Fracture critical tension fasteners shall have the required safe-life demonstrated by analysis or test. Fracture critical fasteners with any detected crack-like flaws shall be rejected. Fracture critical shear bolts and shear pins shall be inspected in the shank area. All fracture critical fasteners shall be marked and stored separately following NDE or proof testing. Installation of fracture critical fasteners shall employ appropriate methods to accurately apply required preloads.

7.1.5.2.1 LOW-RISK FASTENERS

Fasteners and shear pins may be classified as low risk when their fracture does not result in a single point catastrophic failure. Low-risk fasteners and shear pins shall be fabricated and inspected in accordance with aerospace type specifications from well-characterized materials which are not sensitive to stress corrosion cracking and which meet all appropriate structural, fatigue and torque/preload requirements.

8 QUALIFICATION AND ACCEPTANCE TESTING

8.1 REQUIREMENT FOR TEST

The requirements contained in this section are produced as the minimum necessary for planning and conducting Qualification Tests (QT) and Acceptance Tests (AT) to prove the readiness of the on-board components, structures, and flight elements (also referred to as "hardware" in this text) developed by the Russian side for ~~ISSA~~ISS.

The flight element is understood to be a whole assembly (vehicle, module, high level assembly) put into orbit as a separate assembly.

While working on the contract, the full scope of tests and types of tests are determined by this very contract or by a corresponding agreed document. ~~Qualification tests~~QTs are performed on samples (qualification samples) not used for flight:

- Onboard components (for classification see table 8.3.2-1)
- Structural elements and full module structures will be referred to as “structures”.
- Flight equivalent units (mockups, stands, structures, experimental installations for complex testing of the systems with different functional meaning).

Acceptance tests are performed on every manufactured sample that is meant for actual flight operation as well as conduction qualification tests. For FGB the scope of acceptance tests can include the following types of tests:

- individual component test
- selection test

Accepted terminology in Russian standards that are considered a common analog to "qualification testing" (QT) is either the terminology "Design Developmental Test" (DDT) or “Developmental Preliminary and Acceptance Test” (DPAT) or “complex ground test” of stand structures. Because of that in the Standard-Technical Documentation (STD) and Design Documentation (~~STD and~~ DD) it is allowed to use both of these terms (in the "parallel transcription" "QT-DDT" or "QT(DDT)") or only one of the terms.

Testing of on-board electronics and electromechanical equipment, antennas and antenna-feeder units, electromechanical and electrohydraulic drives and devices (including docking components and thermal control equipment) can be performed as indicated by the appropriate technical requirements (PS) and Program Procedures (PP) in accordance with OST 92-5100-89, Industry Standard, Ground and On-board Equipment, General Technical requirements for, provided the requirements of SSP 50094, Section 8 are met as a minimum. In the event of a conflict, this document shall take precedence.

8.2 TEST CONDITION TOLERANCES

In this section are shown allowed tolerances of the control parameters that shall be maintained during testing, if different values are not shown specifically.

Temperature	-200°C to -85°C	±5°C
	-85°C to +100°C	±2°C *
	+100°C to +200°C	±5°C
	Over +200°C	±10°C
Relative Humidity		±3% **
Low Pressure		
	Above 1.3 x 10^2Pa (1 Torr)	±5 % or 1.33x10^2 Pa (±1Torr), whichever is larger
	1.33 to 1.33 x 10^2Pa (10^{-2} Torr to 1 Torr)	±60 %
	Less that 1.3 Pa (10^{-2} Torr)	±30 %
High Pressure		±20 %
Vibration Frequency		
	25 Hz and above	±2 %
	Below 25 Hz	±0.5 Hz
Sinusoidal Vibration Acceleration Amplitude		±20 %
Random Vibration Acceleration Spectral Density Level		±2 dB
Acoustic Noise, Level of Sound Pressure		±5 dB
Shock Response Spectrum Peak Shock Acceleration Amplitude		±20 %
Linear Acceleration		±10 %
Static Load		±5 %
Duration of Exposure		±10 %
Number of Cycles, Pulses, Actions, etc.		±5 %

* ±5°C is allowed, because of the capabilities of the test equipment

** ±5% is allowed, because of the capabilities of the test equipment.

8.3 QUALIFICATION TESTING (QT)

The minimal requirements for QT are contained in the following items and subitems of this subsection.

The main purpose of the QT is to check, using a qualifying sample, the correspondence of the flight article to the requirements of the Technical Specifications (TS) under the conditions that approximate to the utmost operation conditions and with the use of the ultimate test conditions. The volume and the test procedures of QT are defined by the programs and procedures (PP) in accordance with the specification requirements and taking into account the requirements/standards of this subsection.

While drawing up PP, the following is taken into account: type, operation conditions, and preliminary work out of a qualifying sample or its design analog, if one exists.

8.3.1 ACCEPTANCE AND QUALIFICATION TESTS RELATIONSHIP

For hardware samples that passed the AT and are to be installed on the flight article, it shall be mandatory to have the confirmation by the positive results of the QT that correspond to the flight service conditions for the article of this type.

8.3.2 COMPONENT QUALIFICATION TESTS

The minimum value (requirements) for the component QT is shown in Table 8.3.2-1 according to the test types and the classification of component by group. If a component belongs to different groups, it is necessary to perform a test on each of these groups.

Components that undergo different levels of influencing factors (depending upon the location on the article) are subjected to the toughest requirements.

TABLE 8.3.2-1 COMPONENT QUALIFICATION TEST

Test	CLASSIFICATION OF COMPONENT BY GROUP										
	Elec. or Elec. Equip.	Anten-na Feeder Units	Drives & other mech. units	Solar Panel	Stor-age Batts.	Fluid & Fuel Sys. Acces-sories	High - Press. Vessels & Fuel Tanks	Therm. Cont. Equip.	Optical Equip.	Ext. TV Came-ra	Cables
Functional (1)	R	R	R	R	R	R		R	R	R	R
Vacuum (2)	R	R	R	R (3)					R	R	R
Thermal Cycling		R		R(3)		R(4)					
Thermal (5)	R	R	R	R	R	R		R	R	R	R
Sinusoidal (6) Vibration	R	R	R	R	R	R		R	R	R	R
Random (7) Vibration	R	R	R	R	R	R		R	R	R	R
Acoustic Vibration				R(3)							
Shock Impulsive Loading	R	R	R	R	R	R		R	R	R	R
Linear Acceleration (8)	R	R	R			R					R
Elevated (High) Humidity (9)	R	R	R						R	R	R
Pressure (10)			R		R	R	R	R			
Leakproofness (10)	R		R		R	R	R	R	R	R	
Acoustic noise measurement (13)			R					R			
EMI/EMC (11)	R									R	
Life (12)	R		R			R	R		R	R	

LEGEND: R=Required - The ~~International Space Station Alpha~~ISS Program requires, the performance of the appropriate test as a minimum in the QT list.

Notes:
1. The primary functional checks indicated, as well as the checks after the individual types of tests, shall be performed under normal climatic conditions
2. Tests are conducted only for the components that work under vacuum conditions. In a vacuum, the tests can be performed while exposed to extreme temperatures
3. Tests are conducted only on the separate assembly parts of the solar arrays critical to influencing

factors
4. Tests are conducted only on the valves and regulators
5. The tests are not conducted if during vacuum test the extreme temperature were simulated or if the thermostability with the cycling temperature change was tested
6. Sinusoidal vibration mode is used that is equivalent to the random vibration
7. Tests are conducted for the newly designed components instead of sinusoidal vibration with 20 Hz
8. Strength tests are conducted only where linear acceleration is above 10g or above the level of the vibration effect, vibration exposure, and for resistance -- only if its is required that the component be functional during exposure to linear acceleration.
9. It is allowed not to conduct tests of large-sized components if tests of their elements were conducted
10. Tests are conducted for hermetically sealed components
11. Tests are conducted, as a rule, at the article complex stand testing stage or at the stage of the first flight article
12. The tests are conducted only in case of absence of the guarantees in the TS to provide the design life requirements. It is allowed to take into account the results of life tests in the higher level components
13. Measurements are performed for newly developed components that have obviously noisy elements and will be installed in habitation modules.

8.3.2.1 FUNCTIONAL CHECKS, COMPONENT QUALIFICATION TESTS

8.3.2.1.1 PURPOSE

Functional testing verifies electrical and mechanical performance meets the requirements of the component TS.

8.3.2.1.2 TEST DESCRIPTION

a. Electrical tests can include:
   1. Initial state checks
   2. Circuit diagram, electrical circuit stability and integrity checks
   3. Circuit disconnect check
   4. Electrical stability and insulation strength checks
   5. Function and output parameter check (with verification of frequencies and signal shape, if necessary) under a minimal and/or maximal supply voltage
   6. Circuit stability and response time check
   7. Current consumption measurement

b. Mechanical tests can include:
   1. Dynamic function checks (with and/or without load application)
   2. Output parameter and characteristics check: generated forces, torques, response angles, displacements, pressures, etc.)

c. Checks must be performed with special checkout equipment (GSE). The engineering specification or PPs must contain a list of checkout equipment and related connection diagrams.

8.3.2.1.3 SUPPLEMENTARY REQUIREMENTS

All functional checks must be performed in correspondence with TS or PP before and after each test under normal climate conditions. This will ensure compliance of operating parameters with outlined in specific component specifications. The scope of checks during and after each separate test may be incomplete, and defined by the TS or PP for the component. For example, when testing antenna feeder devices, a check of High-Frequency (HF) parameters for sending and receiving radio signals may be performed only during the first and after the last tests for exposure to external conditions.

8.3.2.2 VACUUM TEST, COMPONENT QUALIFICATION

Vacuum tests are performed on components that operate in unpressurized bays or on the external surface of the vehicle (including while climbing in the ascent phase), and also during emergency depressurization of a pressurized bays. Vacuum tests that take into account the temperature criticality of a component can be performed during exposure to extreme operating temperatures. In this case, separate thermal tests (see 8.3.2.3) for stability during exposure to extreme operating temperatures are not conducted.

8.3.2.2.1 PURPOSE

The tests are conducted to check the ability of a component to perform under a vacuum (vacuum stability).

8.3.2.2.2 TEST DESCRIPTION

The component is placed in a vacuum (or thermal vacuum) chamber, and hooked up to the GSE via feedthrough connectors. The connection diagram must be contained in the TS and PP, and also permit the execution of specific functional checks, including a sparking and corona discharge check during an ascent or emergency depressurization of a bay (especially for components operating at radio frequencies), if necessary. The pressure in the vacuum chamber must be reduced from normal levels to 20 Pa (0.15 Torr) at a slow enough rate, at least over a period of 10 minutes.

If the component has to be checked for sparking or corona discharge, it must be switched on during the pressure reduction process inside the chamber. After the test pressure (vacuum) has been reached, the necessary functional checks will be performed.

If the vacuum tests involve exposure to extreme operating temperatures, the temperature in the chamber is first reduced (via temperature controllers) to the set lower value and thermal stability of the component is maintained. This must be followed by mandatory functional checks.

The temperature inside the chamber is then increased (via temperature controllers) to the set upper limit. After the temperature of the component has stabilized, mandatory functional checks are performed.

The temperature inside the chamber is then decreased, while the pressure is increased to a level reflecting normal climatic conditions.

8.3.2.2.3 TEST LEVELS AND DURATION

a. Pressure. The pressure inside the vacuum chamber must be reduced from atmospheric to $1 \cdot 10^{-4}$ - $1 \cdot 10^{-5}$ Torr, unless otherwise specified in the PP, and kept within this range until all tests are complete.

b. Temperature. During vacuum tests involving exposure to temperature, the lower and upper temperature values are set 3-5°C lower or higher than the extreme operating range values outlined in the engineering specification for the component.

c. Test duration. The component must be exposed to extreme temperatures (if subjected to vacuum tests involving extreme temperature values) until its temperature has stabilized after activation, but for at least 1 hour. In the course of the test, temperature should not exceed the extablished tolerance.

8.3.2.2.4 SUPPLEMENTARY REQUIREMENTS

The functional checks on components under a continuous vacuum described in the PP must be conducted at both the low and high ends of the temperature and supply voltage range, respectively.

The need for and instances of switching the component on (off) are a function of its schematic and structural features and operating conditions, as specified in PP.

The checks must also be conducted after completion of the tests at normal pressure and temperature values.

8.3.2.3 THERMAL CYCLING/THERMAL TEST, COMPONENT QUALIFICATION

a. Thermal cycling tests are performed on components that operate in unpressurized bays or on the external surface of the vehicle during which it is allowed to disregard the effect of the vacuum, if the tested component has no vacuum critical mechanical subassemblies, gas-yielding materials, radio frequencies, etc.

b. Thermal tests are performed on components that operate in pressurized bays; specifically, components exposed to a slowly changing temperature undergo cold and heat stability tests.

c. Thermal tests of those components irregardless of the installation place, specifically components exposed to limiting temperature values beyond the working range (after subjected to temperatures during transportation, storage) undergo cold and heat resistance tests.

d. Thermal stability tests are not planned if vacuum tests involve exposure to elevated and reduced temperature, or an independent test for stability during thermal cycling.

8.3.2.3.1 PURPOSE

The tests are conducted to verify the functional capability (stability) of components during or remain serviceable (stable) after exposure to extreme operating or, correspondingly, limiting temperature values.

In technically substantiated cases, components can be tested for heat stability given a significant deterioration in convective heat exchange during zero gravity.

8.3.2.3.2 TEST DESCRIPTION

Stability or resistance tests are conducted at an ambient (normal) pressure and extreme operating (with margin) and limiting temperature values. It is allowed to perform functional tests under normal temperature, under condition of keeping operational temperature of structure elements in the given range within the minimum possible functional test time.

During the stability tests, the components must be hooked up to the GSE to perform functional checks. The TS or PP must contain a connection diagram.

a. During thermal cycling tests, a supply voltage is fed to the component, and the necessary functional checks are performed as the temperature decreases in the chamber. The temperature in the chamber decreases to the set lower value at a rate of at least 0.5°C/min and thermally stabilizes. This is followed by the necessary functional checks.

   The temperature inside the chamber is then increased at a rate of at least 0.5°C/min to the set upper value. After the temperature of the component has stabilized, mandatory functional checks are performed.

   The temperature is then again decreased to the set lower value. The first test cycle is complete after reaching the normal temperature value.

   The set number of cycles is repeated.

   Thermal cycling tests for solar arrays are performed on separate components of solar arrays that are sensitive to other influences

b. The procedures of the appropriate half-cycle described in a. are completely repeated in thermal tests for cold or heat stability during exposure to extreme operating temperatures.

c. Thermal tests for cold or heat resistance are performed without activating or checking the component at extreme limiting temperatures, and the transition to these temperature modes is made according to the procedures described in the appropriate half-cycle in a.

8.3.2.3.3 TEST LEVELS AND DURATION

a. Temperature values during stability tests are set for a 3-5°C margin relative to the extreme operating temperature range values based on the TS requirements for the component.

b. According to requirements contained in standards, limiting temperatures usually are -60°C to 60°C. Therefore, the temperature values during tests for resistance as specified in TS or PP and with a tolerance of 5°C should measure -60-5°C to 60+5°C.

c. The tests are conducted under a normal atmospheric pressure. This excludes tests for thermal stability under conditions of deteriorating convective heat transfer, where the pressure inside the chamber must measure $1.33 \cdot 10^3$ - $4.00 \cdot 10^3$ Pa (10-30 Torr).

d. During thermal stability tests, the time for which the component must stay in the chamber to ensure its complete thermal stabilization is specified in the TS or PP as a function of structural characteristics (mass, structural materials, component sets, volumetric density), but has to be at least 1 hour. It is not allowed for the temperature to go beyond the set tolerances.

e. During thermal tests for resistance, the time for which the component must stay in the chamber is specified in the TS or PP, and measures: 24 hours during cold resistance tests; -as specified in d., but at least 6 hours, during heat resistance tests.

f. During thermal cycling tests, the components are subjected to at least three cycles.

g. As a rule, limiting values during QT must exceed the limiting values during AT.

8.3.2.3.4 SUPPLEMENTARY REQUIREMENTS

The functional checks specified in the TS or PP must be performed as a minimum at extreme values for temperature operational range, and also after the test at a normal temperature. The checks can be taken into account before conducting the next type of test.

The necessity and time of switching on (off) the component is determined by its schematic structural features and operational conditions which are indicated in PP.

8.3.2.4 SINUSOIDAL VIBRATION TEST, COMPONENT QUALIFICATION

Sinusoidal vibration tests in a frequency range of 20-2000 Hz will be conducted in order to determine the amplitude-frequency characteristics, as well as, in place of random vibration tests, in accordance with section 8.3.2.5, when random vibration tests are not possible.

8.3.2.4.1 PURPOSE

Sinusoidal vibration testing is performed:

1. To check the vibrational strength or stability of a component during exposure to a stationary (frequency range up to 2000 Hz) and nonstationary (up to 30 Hz) short-term damping low-frequency vibration.

2. To determine the Amplitude Frequency Characteristics (AFC) of the component structure in the entire operating frequency range and, as a separate task, in order to determine the structural components resonances.

8.3.2.4.2 TEST DESCRIPTION

a. Standard attachment elements are used to rigidly secure the component to the test fixture, and the test fixture to the test bench.

b. Measuring transducers (sensors) are installed on the component at the control point(s) specified in the TS or PP, which must be in close proximity to component attachment elements on the standard fixture.

c. The component must be tested along three (or two for structurally symmetrical components) mutually perpendicular axes.

d. During stability tests, the component must be hooked up to the GSE to support the functional checks specified in the TS or PP.

e. The pressure inside the test valves must be brought to operating levels to check the drop in pressure inside the valves.

8.3.2.4.3 TEST LEVELS AND DURATION

a. The test can be conducted using one of the following methods:

1. Octave method: Change in frequency within the confines of each octave sub-range with a preset frequency change rate. The amplitude of vibrational acceleration (g) and the length of the test is specified in the TS or PP.
2. Resonance frequency method: The test is performed only at specific resonance frequencies with amplitudes of vibration~~al~~ acceleration that satisfy the requirements for the frequency in question.

b. The test must be long enough to ensure reliable component diagnosis, both in terms of structural strength and, if necessary, operational stability during vibration.

The test duration for each octave when using the resonance frequency method for stationary vibration and while determining structural resonances must be not less than 40% from the vibration time given in TS. The speed of frequency charge must not be more than 1 octave per minute.

The test duration when using the octave method for nonstationary short-term damping low-frequency vibration is determined by the frequency change rate of 10 octaves per minute, and the number of exposures indicated in the TS requirements for the component.
The vibration exposure time during tests for resonance frequencies at each frequency must be at least 4% of the total vibration time set in the component TS requirements but not less than 10 seconds.

c. The sinusoidal vibration level (amplitude of vibration~~al~~ acceleration, g) must correspond to the maximum (peak) values. If the component TS outlines requirements in terms of random vibration, the level of sinusoidal vibration (n) equivalent to random vibration will be calculated according to the formula below, unless otherwise indicated in the standard-technical documentation:

n = 1.5 Square root of (S · f)

where S = spectral density of vibration~~al~~ acceleration specified in the component TS requirements, which corresponds to frequency f (g2/Hz);
f = frequency (Hz)

8.3.2.4.4 SUPPLEMENTARY REQUIREMENTS

a. Strength tests must be followed by the TS ~~&~~and PP range of functional checks.

b. During stability tests, the component must be checked for breaks and short circuits, or for function within a defined scope. After the stability tests, the component must be subjected to the TS ~~&~~and PP range of checks.

c. If the component is secured to dampers that comprise part of the component according to the DD while operating on the vehicle, it must be installed on the same dampers during the QT; the exposure level is set using transducers installed before the dampers on the standard fixture, and checked after the dampers on the casing of the component itself.

8.3.2.5 RANDOM VIBRATION TEST, COMPONENT QUALIFICATION

Some of the previously designed and currently used components for ~~ISSA~~ISS are subjected to sinusoidal (equivalent to random) vibration in accordance with section 8.3.2.4.

8.3.2.5.1 PURPOSE

The test is performed to check vibrational strength or stability during exposure to stationary vibration in a frequency range of 20-2000 Hz.

8.3.2.5.2 TEST DESCRIPTION

a. Standard attachment elements are used to rigidly secure the component to the test fixture, and the test fixture to the test bench.

b. Measuring transducers (sensors) are installed on the component at the control point(s) specified in the TS or PP, which must be in close proximity to component attachment elements on the standard fixture.

c. The component must be tested along three (or two for structurally symmetrical components) mutually perpendicular axes.

d. During stability tests, the component must be hooked up to the GSE to support the functional checks specified in the TS or PP.

e. The pressure inside the test valves must be brought to operating levels to check the drop in pressure inside the valves.

8.3.2.5.3 TEST LEVELS AND DURATION

a. The random vibration level is set by the maximum values for the spectral density of vibrational acceleration (g2/Hz) for a frequency range of 20-2000 Hz, which reflects the different phases of vehicle flight. It is more preferable to conduct the tests under the “harshest” conditions, specifically during the active phase of launch vehicle ascent into orbit.

b. Components developed by Russia to be launched on the Shuttle must be tested under the following conditions, unless otherwise specified in the TS and PP for the component:

Frequency	Spectral density of vibrational acceleration

20 - 80 Hz	Increases by 3 dB/octave from 0.017 g^2/Hz (at 20 Hz) to 0.067 g^2/Hz (at 80 Hz);
80 - 500 Hz	Constant 0.067 g^2/Hz;
500 - 2000 Hz	Decreases by 3 dB/octave from 0.067 g^2/Hz (at 500 Hz) to 0.017 g^2/Hz (at 2000 Hz)

c. The test duration for each of the three (two) mutually perpendicular axes must correspond, as a minimum, to the duration of vibration exposure indicated in the TS requirements for the component, and must be long enough to ensure reliable component diagnosis, both in terms of structural strength and, if necessary, operational stability during vibration.

8.3.2.5.4 SUPPLEMENTARY REQUIREMENTS

a. Strength tests must be followed by the TS ~~&~~and PP range of functional checks.

b. During stability tests, the component must be hooked up to the GSE and checked for breaks and short circuits, or for function within a defined scope. After the stability tests, the component must be subjected to theTS ~~&~~and PP range of checks.

c. If the component is secured to dampers that comprise part of the component according to the DD while operating on the vehicle, it must be installed on the same dampers during the QT; the exposure level is set using transducers installed before the dampers on the standard fixture, and checked after the dampers on the casing of the component itself.

8.3.2.6 ACOUSTIC VIBRATION TEST, COMPONENT QUALIFICATION

Tests for exposure to acoustic vibration are performed for components having thin-walled casings, panels, plates and other spatial structural components, subject to the condition that the root-mean-square value for sound pressure in component installation locations in the article exceed 130 dB.

Tests for solar arrays are performed on separate components of solar arrays that are sensitive to acoustic influences.

Positive results from acoustic vibration exposure tests performed on previously tested components with similar design solutions (tested components) can be taken into account.

8.3.2.6.1 PURPOSE

The test is performed to check the strength or stability of a component in cases where this type of exposure can pose more danger to the component than vibrational exposure (not excluding vibration tests from the scope of QT's).

8.3.2.6.2 TEST DESCRIPTION

a. The component must be placed in an acoustic (reverberation) chamber as configured for transport during the phase of launch vehicle ascent into orbit. It is recommended that simulation of standard support structure elements be used for attachment.

b. During the stability tests, the component must be hooked up to the GSE to support the functional checks specified in the component TS or PP.

8.3.2.6.3 TEST LEVELS AND DURATIONS

a. The acoustic vibration level corresponding to the ascent of the launch vehicle into orbit is established by the distribution of sound pressure spectral density (dB/Hz) and the total root-mean-square level (dB) for the sound frequency range, usually 20-4000 Hz. It is allowed to take into account spectral density of sound pressure in the frequency range 0-50 Hz to allow for the capability of the test equipment.

b. Components designed by Russia for launch on the Shuttle must be tested as a minimum at a total root-mean-square level of 141 dB unless otherwise indicated in the TS or PP.

c. The test must be at least as long as the duration of exposure to acoustic vibration as specified in the TS requirements for the component, and must be long enough to ensure reliable component diagnosis, both in terms of structural strength and, if necessary, operational stability during noise exposure.

8.3.2.6.4 SUPPLEMENTARY REQUIREMENTS

a. Strength tests must be followed by a range of functional checks defined in TS or PP.

b. During stability tests, the component must be hooked up to the GSE and checked for breaks and short circuits, or for function within a defined scope. After the stability tests, the component must be subjected to the full range of checks.

c. If the component is secured to dampers that comprise part of the component according to the DD while operating on the vehicle, it must be installed on the same dampers during the QT; the exposure level is set using transducers installed before the dampers on the standard fixture, and checked after the dampers on the casing of the component itself.

8.3.2.7 SHOCK IMPULSIVE LOADING TEST, COMPONENT QUALIFICATION

Depending on available technical capabilities, impact-impulse tests are performed by simulating exposure to equivalent levels of mechanical impacts, or by using standard sources for these impacts.

8.3.2.7.1 PURPOSE

This test is performed to check the component strength or stability during exposure to possible effects stemming from:

1. pyrotechnic devices;
2. operation of rocket engines - equivalent to vibrational fluctuations;
3. impacts during the process of docking and undocking (separating) space vehicles and their separate modules.
4. impacts experienced during the landing of the space vehicle on earth.

8.3.2.7.2 TEST DESCRIPTION

a. Standard attachment elements are used to rigidly secure the component to the test fixture, and the test fixture to the test bench.

b. Measuring transducers (sensors) are installed on the component at the control point(s) specified in the TS or PP, which must be in close proximity to component attachment elements on the standard fixture.

c. During the stability tests, the component must be hooked up to the GSE to support the functional checks specified in the component TS or PP.

d. Components for which there are no reliable figures for structural strength equivalence in both opposite directions all axes are tested along all of these directions.

8.3.2.7.3 TEST LEVELS AND NUMBER OF EXPOSURES

a. The impact-impulse exposure level (peak impact acceleration, g) and duration of exposure to impact acceleration (ms) must be identical or equivalent to the mechanical impact values specified in the TS requirements for the component or, correspondingly, to the impact range values.

b. The number of exposures (impacts) along each direction must be equal to at least the number specified in the TS requirements for the component.

8.3.2.7.4 SUPPLEMENTARY REQUIREMENTS

a. Strength tests must be followed by a complete range of functional checks.

b. During stability tests, the component must checked for breaks and short circuits, or for function within a defined scope. After the stability tests, the component must be subjected to the full range of checks.

c. If the component is secured to dampers that comprise part of the component according to the DD while operating on the vehicle, it must be installed on the same dampers during the QT; the exposure level is set using transducers installed before the dampers on the standard fixture, and checked after the dampers on the casing of the component itself.

8.3.2.8 LINEAR ACCELERATION TEST, COMPONENT QUALIFICATION

Mechanical strength tests are performed on components during exposure to linear acceleration only where linear acceleration exceeds 10 g or the level of vibration effect, while stability tests are conducted only when requirements state that components must be serviceable when exposed to acceleration.

8.3.2.8.1 PURPOSE

The acceleration test demonstrates the capability of the component to withstand or operate, if appropriate, in the design-level acceleration environment.

8.3.2.8.2 TEST DESCRIPTION

a. Standard attachment elements are used to rigidly secure the component to the test fixture, and the test fixture to the test bench.

b. Measuring transducers (sensors) are installed on the component at the control point(s) specified in the TS or PP, which must be in close proximity to component attachment elements on the standard fixture.

c. During the stability tests, the component must be hooked up to the GSE to support the functional checks specified in the component TS or PP.

d. Components for which there are no reliable figures for structural strength equivalence in both opposite directions along all axes are tested along all of these directions.

8.3.2.8.3 TEST LEVELS AND DURATIONS

a. The value for linear acceleration during the test must be equal at least to that specified in the TS requirements for the component.

b. Duration of the test is to be not less than 5 minutes for each axis (not including acceleration and deceleration times).

8.3.2.8.4 SUPPLEMENTARY REQUIREMENTS

a. Strength tests must be followed by a complete range of functional checks.

b. During stability tests, the component must be checked for breaks and short circuits, or for function within a defined scope. After the stability tests, the component must be subjected to the full range of checks.

c. If the component is secured to dampers that comprise part of the component according to the DD while operating on the vehicle, it must be installed on the same dampers during the QT.

8.3.2.9 ELEVATED (HIGH) HUMIDITY TEST, COMPONENT QUALIFICATION

Tests for exposure to elevated humidity need not be performed for large components, provided these tests are conducted on the constituent parts of this component.

8.3.2.9.1 PURPOSE

The test is performed to check the stability or resistance of the component during exposure to elevated humidity during ground transport, storage, test execution, launch preparations, launch and on-orbit operations. Stability or resistance requirements will be indicated in the TS or PP for the component, depending on the installation site on the vehicle.

8.3.2.9.2 TEST DESCRIPTION

The component is placed in a humidity chamber, hooked up to GSE using service cables with air-tight connectors based on the layout diagram contained in the TS or PP for the component. Unused connectors are secured with temporary covers. The humidity chamber is pressurized, and the set relative humidity and temperature conditions are brought about.

The component is subjected to checks after the holding time has expired without any violation of test conditions:

- electrical insulation stability for humidity resistance;
- electrical insulation stability, function and output parameters for humidity stability (scope of checks specified in TS or PP for component).

It is allowed to conduct these tests during minimum possible time after the removal of the component from the chamber.

Upon completion of the checks and removal from the chamber, the component is dried, and the following factors are verified under normal climatic conditions:

- electrical insulation stability for humidity resistance;

- electrical insulation stability, function and output parameters for humidity stability (scope of checks specified in TS or PP for component).

This is also accompanied by a careful technical inspection (for non-tight components with removal of the casings that are opened) to reveal possible corrosion or damage to the anti-corrosive coating of the component.

8.3.2.9.3 CONDITIONS AND DURATION

a. The relative humidity is kept at a level of 95±3% during the entire holding time for the component.

b. The temperature of the medium inside the chamber during the test measures 20^{+5}°C.

c. The temperature must be 40^{+5}°C for components that operate after the descent vehicle has landed.

d. The holding time for the component in the humidity chamber must be at least 96 hours.

8.3.2.9.4 SUPPLEMENTARY REQUIREMENTS

Sealed components that operate on vehicles under conditions of elevated humidity can be tested only for humidity resistance (i.e., without function checks and output parameters).

8.3.2.10 PRESSURE TEST, COMPONENT QUALIFICATION

The tests are performed for components or their separate sealed parts that operate under an internal excess pressure: actuators, high-pressure tanks, pipes, valves, governors, etc.

8.3.2.10.1 PURPOSE

The pressure test demonstrates that the design and fabrication of items such as pressure vessels, pressure lines, fittings, valves, and sealed battery boxes provide an adequate margin against structural failure or excessive deformation at maximum expected operating pressure.

8.3.2.10.2 TEST DESCRIPTION

a. Test pressure. Hardware items like high-pressure tanks, pressure lines and fittings must be subjected to a test pressure and critical temperature for at least

one complete cycle. The test pressure exposure cycle consists of the following stages:
Increase internal pressure (hydrostatically or pneumatically) to the test pressure (exceeds nominal operating value by a factor of 1.5 for high-pressure tanks), maintain this pressure for 5 minutes and decrease the pressure to normal ambient pressure. Any residual deformation or damage is interpreted as a negative test result.

b. Pressure tests for valves must be performed under normal ambient temperatures; the valves must be open or closed. Exposure to test pressure takes place for one complete five-minute cycle at the inlet. After 5 minutes, the inlet pressure must be reduced to normal ambient levels. Any visible deformation is interpreted as a negative test result.
c. Tests at a design pressure for high-pressure tanks, pressure lines and fittings must be performed with the component at a critical temperature.
The component is subjected to the calculated limiting or a higher pressure for a period of at least 10 minutes. The internal pressure must be applied uniformly to prevent impact loads from coming about.
d. Pressure tests for valves must be performed at a design (limiting) pressure and under normal ambient temperatures; the valves must be open or closed. The inlet is subjected to the calculated limiting pressure for 10 minutes. After that, the inlet pressure must be reduced to normal ambient levels.

8.3.2.10.3 TEST LEVELS

a. The tests are performed at a normal ambient temperature, assuming a test pressure calculated taking into account the effect of temperature on the strength and toughness of structural materials.
b. Table 7.1.3.3.1-1 presents the test pressure value.
c. Table 7.1.1.3-1 presents the limiting pressure value.

8.3.2.11 LEAKAGE TEST, COMPONENT QUALIFICATION

8.3.2.11.1 PURPOSE

These tests are intended to confirm the proper choice of the structural and engineering designs by means of assessing the state of the leaktightness of the component structure sealed loop during manufacture and experimental development in order to ensure the operational safety of the spacecraft components.

8.3.2.11.2 TEST DESCRIPTION

To ensure safety, proof tests (pressure tests) shall be conducted just before the leak tests after any assembly that involves soldering or welding or after the cycle of leading associated with experimental development. The testing shall meet existing safety regulation requirements.

The leak tests shall be used, basically as a tool of evaluating the impacts produced on the component sealed loop by such operational conditions as the various types of vibrodynamic and thermal loads.

The scope and sequence of the leak tests under various loads shall be based on the objectives of the qualification tests, with allowances made for the data of the experimental development of the component structure analogs.

The leak tests shall be performed prior to loading and also after specific loading/all types of loading completion.

For qualification leak tests, mainly, gas-based leak testing methods are used exposing the component structure to the maximum flight operational pressure of the proper direction.

8.3.2.11.3 TEST SCOPE AND METHODS

The specific scope of tests and leak test methods are selected from the list of methods shown on Table 8.3.2.11.3-1 in a view of technical characteristics and requirements to the test object.

Table 8.3.2.11.3-1 Test Methods

	Stages of testing	Test Object	Leak testing method	Brief description of test method	
1	2	3	4	5	6
1	Before and after loading stages	Pressurized shell of pressurized compartment and sealed loops of units and fluid systems	Vacuum chamber method	The essence of the vacuum chambers method is as follows: the test object is placed in a vacuum chamber that is connected to a recording instrument (a leak detector), the chamber is evacuated to a residual pressure of $1 \cdot 10^{-3}$-$1 \cdot 10^{-4}$, and the test object is filled with the test gas. The value of the leakage rate is determined from the change in the concentration of the tracer gas inside the vacuum chamber. The sensitivity of the method is $1 \cdot 10^{-3}$. l˙Torr/s (l m Torr = 10^{-3} Torr).	
			Leak-in method	The essence of the leak in method is as follows: the internal cavity of the test object is evacuated, and the leakage rate is determined from the rate of pressure rise or value of steady pressure in the test object. The method has a sensitivity of l˙-10^{-2} l˙m Torr/s	
			Sniffer Method	The essence of the “sniffer” method is	

	Stages of testing	Test Object	Leak testing method	Brief description of test method	
1	2	3	4	5	6
				as follows: the test object is filled with the test gas, and the candidate locations of the leaks on the structural element being tested are examined with a sniffer that is connected to a recording instrument (leak detector). The method has a sensitivity of at least 5˙10^{-4} l˙m Torr/s	
2	During loading	Sealed loops units assemblies and fluid systems	Compensation-differential method	The essence of the compensation differential method is as follows: the test object and a reference vessel connected to it via a pressure difference sensor are filled with the test gas. The value of the leakage rate of the test object is determined by the measurement of the pressure micro differential at the sensor over a specified period of time. The method has a sensitivity of up to l˙10^{-2} l˙m Torr/s for the empty test object having internal volume no more than 2m^3.	
			Vacuum chambers method	See prior description	
			Pressure decay method	The essence of the method is as follows: the test object is filled with the test gas to the working pressure, and the value of the leakage rate of the test object is determined from the prssure and temperature change over a specified period of time.	

8.3.2.11.4 ADDITIONAL REQUIREMENTS

The use of leak tests to assess whether the leakage rate of the component sealed loop meets ~~sspecified~~ specified requirements after simulation of the effects of operational conditions on the structure during qualification testing requires the use of the identical methods (or, at least, methods with identical sensitivity) before and after the exposure to the conditions so that one can, with sufficient confidence, both identify any defects in the structure of the sealed loop and assess the dynamics of the propagation of those defects. To ensure the reliability and objectivity of the assessment, the methods enable one to evaluate the total (i. e., overall) leakage rate of the sealed loop shall be used.

8.3.2.12 ACCOUSTIC NOISE LEVEL GENERATION MEASUREMENT, COMPONENT QUALIFICATION

8.3.2.12.1 PURPOSE

Measurements are performed to determine the structural compliance of the component with requirements outlining permissible acoustic noise levels generated during component operation.

8.3.2.12.2 TEST DESCRIPTION

a. Measurements are performed in a reverberation chamber. The volume of sound from the source is measured in accordance with GOCT 12.1.027-80 (corresponds to international standard ISO-3743) entitled "Noise -Determination of Noise Characteristics for Source of Noise in a Reverberation Room: Technical Method."
b. The component is installed with the surface of the standard fastener on the table (support) covered with a flexible material.
   The component must take up no more than 1% of the chamber, and the distance from the component to the chamber surfaces must be at least 1.5 m.

8.3.2.12.3 TEST LEVELS AND DURATION

a. The component is incorporated and employed in the operating mode that produces maximal levels of acoustic noise.
b. The volume of the noise source is measured in 1/3 octave frequency bands from 100 Hz to 10000 Hz while passing the measuring microphone around a circumference having a radius of at least 1m. The distance from the measuring microphone to the reverberation chamber surfaces must also be at least 1 m.
c. The total (integral) value for noise source volume is used to compute the component sound level at a distance of 1 m from its surface.
d. None of the calculated noise levels can exceed values indicated in the specifications or program and procedure for the component. As a rule, this value measure 65 dB for components that operate for prolonged periods of time, and cannot exceed 70dB for components that operate continuously for 5 minutes or less.

8.3.2.12.4 SUPPLEMENTARY REQUIREMENTS

The acoustic noise of components can be measured not just in independent tests, but as part of checks performed in other tests in accordance with Table 8.3.2-1 (e. g., check after mechanical impact tests, periodic checks while accumulating running time during margin tests, etc.)."

8.3.2.13 ELECTROMAGNETIC INTERFERENCE AND ELECTROMAGNETIC COMPATIBILITY TESTS, COMPONENT QUALIFICATION

Tests are performed as a rule, as part of complex electric stand item (complex stand) or the first flight item.

8.3.2.13.1 PURPOSE

The electromagnetic compatibility test verifies that the electromagnetic interference characteristics (emission and susceptibility) of the component under normal operating conditions does not result in malfunction of the component and that that the component does not emit, radiate, or conduct interference which results in malfunction of other system components.

8.3.2.13.2 TEST DESCRIPTION

Test shall be conducted in accordance with this document (Section 3.4).

8.3.2.14 LIFE TEST, COMPONENT QUALIFICATION TEST

Life tests (designated service life tests, designated service life margin confirmation tests, technical service life tests) are only performed if the TS for the component do not guarantee compliance with the designed service life requirements.

Life expectancy tests can be performed when items are used as components for higher level assemblies.

8.3.2.14.1 PURPOSE

a. Designated service life tests are performed to check the capability of a component exposed to mechanical or physical wear during its operation to perform without failure for the designated (set) period without functional parameters and characteristics falling outside TS requirements for the component.
b. Designated service life margin confirmation tests are performed as an additional test to verify compliance with failure-free performance over the service life stipulated in the standards.
c. Technical service life tests are also performed as an additional test to assess the actual (technical) service life of the component before reaching the limiting condition, i. e., before a failure occurs that results in complete loss of function. The TS or PP

for the component specify the limiting condition criteria or operating life restriction expressed as a multiple of the designated service life.

8.3.2.14.2 DESCRIPTION

a. Ensures component operation for the entire period specified in the TS or PP (in hours, cycles, responses, switchings, etc.).
b. For continuous or periodic checks during the tests, the component is hooked up to the GSE according to the diagram shown in the TS or PP.
c. In light of the purpose and structural features of the component, we recommend performing the tests:
   1. at various power supply voltages (e. g., 25% of test duration at maximum, 50% at nominal and 25% at minimal);
   2. under loads and with timelines that simulate reality as closely as possible;
   3. during exposure to external factors (temperature, vacuum, gaseous medium, etc.)

8.3.2.14.3 TEST LEVELS AND DURATIONS

a. The tests are performed under nominal climatic conditions and/or under the worse environmental conditions (see 8.3.2.14.2. c-3)
b. The duration of the designated service life test is as specified in the TS requirements for the component. Depending on the period of active existence for the hardware item and maximum possible operation life under ground conditions, the designated service life can measure (1.05-2.00) times the predicted component operating life in flight.
c. The duration of additional tests to confirm the designated service life margin is specified in the TS or PP for the component. The percentage of additional tests relative to the designated service life (in hours, cycles, responses, switchings, etc.) must measure:
   100% at a designated service life not to exceed 500;
   50% at a designated service life of 500 to 1000;
   20% at a designated service life of 1000 to 10000;
   10% at a designated service life in excess of 10000.
d. The scope and frequency of component checks during the testing process is specified in the TS or PP for the component. A complete range of functional checks must be performed before and after the tests.

8.3.2.14.4 ADDITIONAL REQUIREMENTS

a. The operating life of the component can be taken into account in service life test examinations during the process of other tests.
b. Accelerated test procedures can be used for components subject to extended service life requirements.

8.3.3 STRUCTURAL QUALIFICATION TESTS

8.3.3.1 STATIC STRUCTURAL LOAD TEST

8.3.3.1.1 PURPOSE

The Static Structural Load Test demonstrates the adequacy of the structure to meet requirements of strength or stiffness, or both, with the desired margin when subjected to simulated critical environments predicted to occur during its service life.

8.3.3.1.2 TEST DESCRIPTION

a. Structural configuration, materials, and manufacturing processes employed in the qualification test article shall be identical to those of flight articles.
b. Modifications to structural items shall be structurally identical to changes incorporated in flight articles.
c. The support and load application fixture shall provide boundary conditions which simulate adjacent structural sections existing in the flight article.
d. Strain and deformation shall be measured and recorded with operational-limit load and at intermediate levels up to limit/ultimate load.
e. Test conditions shall take into account the combined effects of acceleration, pressure, loads, and temperature. Simulations of these effects shall envelope failure situations.
f. The final test may be taken to failure to substantiate the capability to accommodate load distribution.
g. Failures at limit load shall include material yielding or deflection which degrade mission performance and at ultimate load shall include rupture or collapse.

8.3.3.1.3 TEST LEVELS AND DURATIONS

a. Loads, other than internal pressure in pressure vessels, shall be increased until test loads are reached.
b. Critical flight temperature-load combinations shall be used to determine the expected worst-case stress anticipated in flight.
c. Loads shall be applied as closely as possible to actual flight loading times with a minimum dwell time sufficient to record data.

8.3.3.1.4 SUPPLEMENTARY REQUIREMENTS

a. Locations of minimum design margins and associated failure modes shall be identified.
b. Internal loads resulting from the limit-test conditions shall envelope all critical internal loads expected in flight.

8.3.3.2 MODAL SURVEY

A modal survey shall be conducted to define or verify an analytically derived dynamic model for use in flight loading event simulations and for use in examinations of postboost configuration elastic effects upon control precision and stability. This test is conducted on a flight-quality structural subsystem as augmented by mass-simulated components. The data obtained shall be adequate to define orthogonal mode shapes, mode frequencies, and mode damping ratios of all modes which occur within the frequency range of interest.

For analogous structures, use can be made of results obtained from modal tests performed on the qualification sample of the element analog.

In certain cases, the flight element can be certified by the beginning of its flight tests without executing modal tests on the qualification sample of the element or its analog. These certification methods are based on results obtained from analyzing the design dynamic model, taking into account the findings of static tests (for determining stiffness) on the qualification sample of the flight element. In this instance, the dynamic characteristics of the flight element are experimentally confirmed based on results of dynamic on-orbit flight tests of the flight element or its analog as part of the orbital station under a special program.

8.3.4 FLIGHT ELEMENT QUALIFICATION TEST

QTs of flight elements are performed on qualification samples of the flight elements. The required tests for the qualification test item are (1) Functional Test, (2) Electromagnetic Compatibility (EMC) Test, (3) Pressure/Leak Test. The following apply to the flight element qualification tests:

a.- Electrical and mechanical functional tests shall be conducted prior to and following each environmental test as specified in Pps of TSs.

b.- Functional Test and EMC Test do not apply to structures.

Where it is impractical to test flight elements as a single entity, testing of major assemblies that constitute the flight element may be utilized with the appropriate analyses, simulations, and/or simulators to satisfy this requirement.

If the flight element is controlled by on-board data processing, the flight software shall be resident in the on-board computer for these tests. The verification of the operational requirements shall be demonstrated.

Mockups of flight element system fidelity can be used for flight element qualification testing.

8.3.4.1 FUNCTIONAL TEST, FLIGHT ELEMENT QUALIFICATION

8.3.4.1.1 PURPOSE

The functional test for flight element qualification verifies that mechanical and electrical performance of the flight element (1) meets the specification requirements, (2) verifies compatibility with ground support equipment, (3) validates all test techniques, and (4) validates software algorithms used in computer-assisted commanding and data processing.

8.3.4.1.2 MECHANICAL FUNCTIONAL TEST

Mechanical functional testing (as stated in TS) shall be performed on mechanical devices, valves, deployables and separate entities with the flight element in the ascent, orbital, or recovery configuration appropriate to the function. Alignment checks shall be made where appropriate.

Maximum and minimum limits of acceptable performance shall be determined with respect to mechanics, time, and other applicable requirements in accordance with TS.

Where operation in a 1-G environment cannot be performed, a suitable ground-test fixture may be utilized to permit operation and evaluation of the devices.

Fit checks shall be made of the flight element physical interfaces with other flight elements and the launch vehicle by means of master gauges or interface assemblies.

8.3.4.1.3 ELECTRICAL FUNCTIONAL TEST

Electrical functional testing shall be performed with all components and subsystems connected (as in flight ~~congfiguration~~configuration) except pyrotechnic devices. The test shall verify the integrity of all electrical circuits, including redundant paths, by application of an initiating stimulus and the confirmation of the successful completion of the event.

The test shall be designed to operate all components, primary and redundant. All commands shall be exercised. Operation of all thermal control components, such as heaters and thermostats, shall be verified by tests.

The test shall demonstrate that all commands having preconditioning requirements (such as enable, disable, specific equipment configuration, specific command sequence, etc.) cannot be executed unless the preconditions are satisfied. Autonomous functions shall be verified to occur when the conditions exist for which they are designed.

Equipment performance parameters (such as power, voltage, gain, frequency, command, and data rates) shall be varied over specification ranges to demonstrate the performance margins. The flight element main bus shall be continuously monitored by a power transient monitor system. All telemetry monitors shall be verified, and pyrotechnic circuits shall be energized and monitored.

A segment of the electrical functional test shall operate the flight element through an ascent and mission profile with all events occurring in actual flight sequence.

8.3.4.1.4 SUPPLEMENTARY REQUIREMENTS

Mechanical and electrical functional tests shall be conducted prior to and after each of the flight element environmental tests, if they are required by PP ~~&~~and ST for the given qualification sample. These tests do not require the mission profile sequence.

Data analysis to verify the adequacy of testing and the validity of the data shall be completed before disconnection from a particular environmental test configuration so that any required retesting can be accomplished.

8.3.4.2 ELECTROMAGNETIC COMPATIBILITY TEST, FLIGHT ELEMENT QUALIFICATION

8.3.4.2.1 PURPOSE

This test demonstrates the Electromagnetic Compatibility (EMC) of the element and ensures the element has adequate margins.

8.3.4.2.2 TEST DESCRIPTION

This test shall be defined and conducted in accordance with this document (Section 3.4).

8.3.4.3 RESERVED

8.3.4.4 LEAK TESTS, FLIGHT ELEMENT QUALIFICATION

8.3.4.4.1 PURPOSE

The tests are intended to confirm the proper choice of the structural and engineering designs by means of assessing the state of the leaktightness of the flight unit structure sealed loop during manufacture and experimental development in order to ensure the operational safety of the Space Vehicles (SV).

The leak tests shall be used, basically, as a tool of evaluating the impacts produced on the flight unit sealed loop by such operational conditions as the various types of vibrodynamic and thermal loads.

8.3.4.4.2 TEST DESCRIPTION

The scope and sequence of the leak tests under various loads shall be based on the objectives of the qualification tests, with allowances made for the data of the experimental development of the structural analogs.

To ensure safety, proof tests (pressure tests) shall be conducted just before the leak tests after any assembly that involves soldering or welding or after the cycle of loading associated with experimental development. The testing shall meet existing safety regulation requirements.

If necessary, assessments of how various types of operating loads impact the structure of sealed loops in modules and Fluid Systems (FS) will be accompanied by the development of methods and equipment to verify the pressure integrity of sealed loops with respect to conditions for preparing ~~nomnal~~ nominal flight unit structures, with the objective of revealing structural defects (leaks) at an earlier stage of fabrication and preparation for flight.

For qualification leak tests, mainly, gas-based leak testing methods are used exposing the component structure to the maximum flight operational pressure of the proper direction.

8.3.4.4.3 TEST LEVELS AND METHODS

The specific scope of tests and leak test methods are selected from the list of methods shown on Table 8.3.4.4.3-1 in a view of technical characteristics and requirements to the test object.

Table 8.3.4.4.3-1 –Flight Element Leak Tests

No.	Stages of Testing	Test Object	Leak Testing Method	Method sensitivity
1	Before and after load application stage	Pressurized shell of pressurized compartment, sealed loops of FS elements / assemblies	Vacuum chambers method	$1\cdot10^{-3}$ l·mTorr/s
			Leak-in method	$1\cdot10^{-2}$ l·mTorr/s
			"Sniffer" method	$5\cdot10^{-4}$ l·mTorr/s
2.	During loading	Sealed loops of FS elements / assemblies	Compensation differential method	$1\cdot10^{-2}$ l·mTorr/s
			Vacuum chambers method	$1\cdot10^{-3}$ l·mTorr/s
			Pressure decay drop method	

Note: Brief descriptions of the leak test methods specified on this table are contained in the Table 8.3.2.11.3-1.

8.3.4.4.4 ADDITIONAL REQUIREMENTS

The use of leak test to assess whether the leakage rate of the component sealed loop meets specified requirements after simulation of the effects of operational conditions on the structure during qualification testing requires the use of the identical methods (or, at least, methods with identical sensitivity) before and after the exposure to the conditions so that one can, with sufficient confidence, both identify any sealed loop structure defects and assess the dynamics of the propagation of those defects. To ensure the reliability and objectivity of the assessment, the methods enable to evaluate the total (I. e. overall) leakage rate of the sealed loop shall be used.

The allowable localized leak rate shall not exceed $1 \cdot 10^{-3}$ l·mTorr/s

The allowable total leak rate range is $1 \cdot 10^{-1}$ - 15 l·mTorr/s (for different sealed loops).

8.4 ACCEPTANCE TESTS ~~(AT)~~

Minimum requirements for AT are included in the following items and subitems of this subsection.

The main purpose of the AT is the effective detection of the manufacturing defects with the use of non-destructive methods of testing for each produced flight item of hardware.

The volume and methods of hardware AT conducting are determined in the specifications or the Technical Requirements of Drawings (TRD) and standards with consideration of these subsection requirements.

8.4.1 ACCEPTANCE TESTS OF COMPONENTS

The minimal volume of acceptance testing is shown in Table 8.4.1-1 according to the test types and classification of components by group. Where components fall into more than one category, the required tests for each category shall be applied with regard to the toughest requirement for each influencing factor for these categories.

TABLE 8.4.1-1 — COMPONENT ACCEPTANCE TESTS

Test	CLASSIFICATION OF COMPONENTS BY GROUP										
	Elec. or Elecl. Equip.	Antenna Fender Units	Drives & other Mech. Units	Solar Panel	Storage Batts.	Fluid & Fuel Sys. Acces.	High Pres. Vessels and Fuel Tanks	Therm. Cont. Sys. Equip.	Optical Equip.	Ext. TV Camera	Cables
Functional (1)	R	R	R	R	R	R		R	R	R	R
Vacuum (2)				R(9)							
Thermal	R		R		R(3)	R(4)		R(4)	R	R	

Test	CLASSIFICATION OF COMPONENTS BY GROUP										
	Elec. or Elecl. Equip.	Anten-na Fender Units	Drives & other Mech. Units	Solar Panel	Stor-age Batts.	Fluid & Fuel Sys. Acces.	High Pres. Vess-els and Fuel Tanks	Therm. Cont. Sys. Equip.	Optical Equip.	Ext. TV Came-ra	Cables
Sinusodial (5,6) Vibration	R	R	R	R		R(4)		R(4)	R		
Random (5) Vibration	R	R	R	R		R(4)		R(4)	R		
Humidity (7)	R	R									
Pressure (8)			R		R	R	R	R			
Leakage (8)	R		R		R	R	R	R			
Mass Check	R	R	R	R	R	R	R	R	R	R	R

LEGEND: R=Required - Requires - The ~~International Space Station Alpha~~ISS Program requires, the performance of the appropriate test as a minimum in the acceptance test list.

Notes:
1. The primary functional checks indicated, as well as the checks after the individual types of tests, shall be performed under normal climatic conditions
2. The test can be performed during exposure to extreme temperatures
3. Tests are conducted Ni-Cd batteries only
4. For structurally simple components, the testing shall be performed, as a rule, during random check tests on batches of components
5. Based on the technical capability of component manufacturing one can be allowed to conduct either random vibration or equivalent sinusoidal vibration testing
6. Sinusoidal vibration mode is used that is equivalent to the random vibration
7. It is allowed not to test large-sized components if tests of their parts were tested
8. Tests are conducted for hermetically sealed components
9. This test is not required for FGB solar panels

8.4.1.1 FUNCTIONAL TEST, COMPONENT ACCEPTANCE

8.4.1.1.1 PURPOSE

The Functional Test verifies that the electrical and/or mechanical performance of the component meets the specified operational requirements of the component.

8.4.1.1.2 ELECTRICAL AND MECHANICAL TESTS

a. Electrical tests can include:
   1. Initial state checks
   2. Circuit diagram, electrical resistance and integrity checks
   3. Circuit disconnect check
   4. Electrical stability and insulation strength

5. Function and initial parameter check (with verification of frequencies and signal shape, if necessary) under a minimal and/or maximal supply voltage
6. Circuit stability and response time check
7. Current consumption measurement

b. Mechanical tests can include:

1. Dynamic function checks (with and/or without load application)
2. Initial parameter and characteristics check: generated forces, torques, response angles, displacements, pressures, etc.)

c. Checks must be performed with special Ground Support Equipment (GSE). The TS or special PP for autonomous component must contain a list of GSE and related connection diagrams.

8.4.1.1.3 SUPPLEMENTARY REQUIREMENTS

All functional checks must be performed before and after each test under normal climate conditions as specified in appropriate PP or TS. This will ensure compliance of operating parameters with outlined in specific component specifications. The scope of checks during and after each separate test may be incomplete, and defined by the TS or PP for the component.

8.4.1.2 VACUUM TEST, COMPONENT ACCEPTANCE

8.4.1.2.1 PURPOSE

The tests are performed to detect defects in material and element sets, and also to detect manufacturing defects in each fabricated component sample, by conducting stability tests under a vacuum, as a rule during exposure to elevated and reduced temperature. In this case, additional thermal testing specified in 8.4.1.3 is not required.

8.4.1.2.2 TEST DESCRIPTION

The component is placed in a vacuum (or thermal vacuum) chamber, and hooked up to the GSE via pressurized connectors. The connection diagram must be contained in the TS and PP, and also permit the execution of specific functional checks, including a sparking and corona discharge check during an ascent or emergency depressurization of a bay (especially for components operating at radio frequencies), if necessary. The pressure in the vacuum chamber must be reduced from normal levels to

$2 \cdot 10$ Pa (0.15 Torr) at a slow enough rate, at least over a period of 10 minutes.

If the component has to be checked for sparking or corona discharge, it must be included in the pressure reduction process inside the chamber. After the test pressure (vacuum) has been reached, the necessary functional checks will be performed.

If the tests involve exposure to extreme operating temperatures, the temperature in the chamber is first reduced (via temperature controllers) to the set lower value after reaching the test pressure (vacuum). Components that operate on-orbit must be activated after a stable temperature has been established in the chamber, and kept there until the entire component volume has achieved temperature stability. This must be followed by mandatory functional checks.

The temperature inside the chamber is then increased (via temperature controllers) to the set upper limit. After the temperature of the component has stabilized, mandatory functional checks are performed.

The temperature inside the chamber is then decreased, while the pressure is increased to a level reflecting normal climatic conditions.

8.4.1.2.3 TEST LEVELS AND DURATION

a. Pressure. The pressure inside the vacuum chamber must be reduced from atmospheric to
$1 \cdot 10^{-4}$ - $1 \cdot 10^{-5}$ Torr, unless otherwise specified in the PP, and kept within this range until all tests are complete.

b. Temperature. During vacuum tests involving exposure to temperature, the lower and upper temperature values are made equal to the extreme operating range values outlined in the engineering specification for the component.

c. Test duration. The component must be exposed to extreme temperatures (if subjected to vacuum tests involving extreme temperature values) after it has reached its set value for at least 1 hour. Temperature shall remain within appropriate tolerances during this time per paragraph 8.2.

8.4.1.2.4 SUPPLEMENTARY REQUIREMENTS

The functional checks on components under a continuous vacuum described in the TS or PP must be conducted at both the low and high ends of the temperature and supply voltage range, respectively.

The necessity for and time of activation and deactivation of components shall be determined by their appropriate design specifications and the operational conditions specific in the appropriate TS. The checks must also be conducted after completion of the tests at normal pressure and temperature values.

8.4.1.3 THERMAL TEST, COMPONENT ACCEPTANCE

Thermal tests are performed on components that operate in pressurized bays, i.e., are exposed to a slowly changing temperature.

8.4.1.3.1 PURPOSE

The tests are performed to detect defects in material and element sets (especially with respect to the quality of electrical adjustments and thermal stability of output parameters), and also to detect manufacturing defects in each fabricated component sample, by conducting thermal stability tests during exposure to extreme operating temperatures.

8.4.1.3.2 TEST DESCRIPTION

Thermal stability tests are conducted at an ambient (normal) pressure and extreme operating temperature values-.

Functional external tests may be performed after thermal vacuum tests at extreme temperatures provided the tests are performed immediately after removing the article from the vacuum chamber and within the minimum possible functional test time.

The components must be hooked up to the GSE to perform functional checks. The TS or PP must contain a connection diagram.

Semicycle procedures are then performed in their entirety as described in 8.3.2.3.2 paragraph a.

8.4.1.3.3 TEST LEVELS AND DURATION

a. Temperature: The test temperature should be equal the extreme values of the functional range as specified in the appropriate TS for the component.
b. Pressure: Tests are conducted at normal atmospheric pressure.
c. Exposure time: During thermal tests of stability the exposure time for the component in the chamber to ensure thermal stabilization throughout the volume of the component is specified in TS or PP depending on design parameters (mass, construction materials, elements of assembly, volume density) but not less than 1 hour. During this time the temperatures shall remain within tolerances as specified in paragraph 8.2.

8.4.1.3.4 SUPPLEMENTARY REQUIREMENTS

The functional checks specified in the TS or PP must be performed as a minimum at extreme values for temperature operational range, and also after the test at a normal temperature. The checks can be taken into account before conducting the next type of test.

The necessity and time of switching on (off) the component is determined by its schematic structural features and operational conditions which are indicated in PP.

8.4.1.4 SINUSOIDAL VIBRATION TEST - COMPONENT ACCEPTANCE TESTS

Test for sinusodial vibration may be substituted for random vibration test as specified by 8.4.1.5. This substitution may occur if random vibration facilities are not available.

8.4.1.4.1 PURPOSE

The tests are performed to detect defects in material and element sets, and also to detect manufacturing defects (especially with respect to the quality of mechanical and electrical assembly), by conducting vibration strength tests.

8.4.1.4.2 DESCRIPTION

a. Standard attachment elements are used to rigidly secure the component to the test fixture, and the test fixture to the test bench.

b. Measuring transducers (sensors) are installed on the component at the control point(s) specified in the TS or PP, which must be in close proximity to component attachment elements on the test fixture.

8.4.1.4.3 CONDITIONS AND DURATION

a. The test can be conducted using one of the following methods:
   1. Octave method: In the frequency of 20-2000 Hz change (oscillation) in frequency within the confines of each octave sub-range with a preset frequency change rate. The amplitude of vibrational acceleration and duration (g) is specified in the TS or PP.
   2. At a single fixed frequency of 20^{+5} Hz with a vibration acceleration amplitude of 2±0.4 g (for structurally simple components).

b. The test duration when using the octave method must measure twice as low as the test duration for QT's. Frequency change rate not exceeding 1 octave per minute.

c. The test duration for a single fixed frequency measures 30 minutes.

d. The sinusoidal vibration level (amplitude of vibrational acceleration, g) for the octave method must (a) be 1.5 times lower than maximum (peak) values, unless otherwise indicated in the standard technical documentation. In this case, the level of sinusoidal vibration (n) equivalent to random vibration will be calculated according to the formula below:

n = Square root of (S · f)

where S - spectral density of vibrational acceleration specified in the component TS requirements, which corresponds to frequency f (g2/Hz);
f - frequency (Hz)

e. The vibrational acceleration amplitude during tests at a single fixed frequency of 20^{+5} Hz equals 2±0.4 g.

8.4.1.4.4 SUPPLEMENTARY REQUIREMENTS

a. Strength tests must be followed by a complete range of functional checks.

b. If the component is secured to dampers that comprise part of the component according to the DD while operating on the vehicle, the dampers must be deactivated (interlocked) during the AT's.

8.4.1.5 RANDOM VIBRATION TEST, COMPONENT ACCEPTANCE

Random vibration tests have priority over sinusodial vibration tests. Equivalent sinusodial vibration tests may be carried out only if production facilities do not have test equipment for random vibration tests.

8.4.1.5.1 PURPOSE

The tests are performed to detect defects in material and element sets, and also to detect manufacturing defects in each fabricated component sample (especially with respect to the quality of mechanical and electrical assembly), by conducting vibration strength tests.

8.4.1.5.2 TEST DESCRIPTION

a. Standard attachment elements are used to rigidly secure the component to the test fixture, and the test fixture to the test bench.

b. Measuring transducers (sensors) are installed on the component at the control point(s) specified in the TS or PP, which must be in close proximity to component attachment elements on the test fixture.

8.4.1.5.3 TEST LEVELS AND DURATION

a. The random vibration level set by the distribution of peak values for the spectral density of vibrational acceleration (g2/Hz) for a frequency range of 20-2000 Hz, must (a) be 2 times lower than maximum (peak) values, unless otherwise indicated in the standard technical documentation, during QT's involving the active phase of vehicle ascent into orbit.

b. Components developed by Russia to be launched on the Shuttle must be tested under the following conditions, unless otherwise specified in the TS and PP for the component:

Frequency	Spectral density of vibrational acceleration
20 - 80 Hz	Increases by 3 dB/octave from 0.01 g^2/Hz (at 20 Hz) to 0.04 g^2/Hz (at 80 Hz);
80 - 500 Hz	Constant 0.04 g^2/Hz;
500 - 2000 Hz	Decreases by 3 dB/octave from 0.04 g^2/Hz (at 500 Hz) to 0.01 g^2/Hz (at 2000 Hz)

c. The test duration for each of the three (two) mutually perpendicular axes is twice as low than the duration for QT's.

8.4.1.5.4 SUPPLEMENTARY REQUIREMENTS

a. Strength tests must be followed by the TS ~~&~~and PP range of functional checks.

b. If the component is secured to dampers that comprise part of the component according to the DD while operating on the vehicle, the dampers must be deactivated (interlocked) during the AT's.

8.4.1.6 ELEVATED (HIGH) HUMIDITY TEST, COMPONENT ACCEPTANCE

Tests for exposure to elevated humidity need not be performed for large components, provided these tests are conducted on the constituent parts of this component.

8.4.1.6.1 PURPOSE

The test is performed to detect defects in material and element sets, and also to detect manufacturing defects (especially with respect to the quality of electrical assembly and compliance with standards concerning insulation stability) by conducting humidity resistance tests.

8.4.1.6.2 TEST DESCRIPTION

The component is placed in a humidity chamber, hooked up to GSE using service cables with air-tight connectors based on the layout diagram contained in the TS or PP for the component. Unused connectors are secured with temporary covers. The humidity chamber is pressurized, and the set relative humidity and temperature conditions are brought about.

The component is subjected to checks after the holding time has expired without any violation of test conditions:

electrical insulation stability for humidity resistance;

Upon completion of the checks and removal from the chamber, the component is dried, and the following factors are verified under normal climatic conditions:

electrical insulation stability, function and output parameters as specified in the appropriate PP or TS.

This is also accompanied by a careful technical inspection (for non-tight components that are opened) to reveal possible corrosion or damage to the anti-corrosive coating of the component.

8.4.1.6.3 CONDITIONS AND DURATION

a. The relative humidity is kept at a level of 95±3% during the entire holding time for the component.
b. The temperature of the medium inside the chamber during the test measures 20^{+5}°C.
c. The holding time for the component in the humidity chamber must be at least 48 hours.

8.4.1.7 PRESSURE TEST, COMPONENT ACCEPTANCE TEST

The tests are performed for components or their separate sealed parts that operate under an internal excess pressure: actuators, high-pressure tanks, pipes, valves, governors, etc.

8.4.1.7.1 PURPOSE

The test is performed to detect defects in material and element sets, and also to detect manufacturing defects (especially with respect to the quality of mechanical assembly and compliance with standards concerning leakage) by conducting tests during exposure to elevated excess pressure.

8.4.1.7.2 DESCRIPTION

a. Test pressure. Hardware items like high-pressure tanks, pressure lines and fittings must be subjected to a test pressure and critical temperature for at least one complete cycle. The test pressure exposure cycle consists of the following stages:
Increase internal pressure (hydrostatically or pneumatically) to the test pressure (exceeds nominal operating value by a factor of 1.5 for high-pressure tanks),

maintain this pressure for 5 minutes and decrease the pressure to normal ambient pressure. Any residual deformation or damage is interpreted as a negative test result.

b. Pressure tests for valves must be performed under normal ambient temperatures; the valves must be open or closed. Exposure to test pressure takes place for one complete five-minute cycle at the inlet. After 5 minutes, the inlet pressure must be reduced to normal ambient levels. Any visible deformation is interpreted as a negative test result.

8.4.1.7.3 CONDITIONS

a. The tests are performed at a normal ambient temperature, assuming a test pressure calculated taking into account the effect of temperature on the strength and toughness of structural materials.
b. Table 7.1.3.3.1-1 presents the test pressure value.

8.4.1.7.4 SUPPLEMENTARY REQUIREMENTS

No supplementary requirements

8.4.1.8 LEAK TEST, COMPONENT ACCEPTANCE TEST

8.4.1.8.1 PURPOSE

Leak tests under component acceptance tests shall be performed in order to assess the quality of manufacturing and assembly of real structure of the component sealed loops for the purpose of providing the capability to store working gases or liquids within specified limits required for normal operation. Leak tests are intended, as well, for the purpose of detecting the possible propagation of the structure through microdefects to ensure spacecraft ground and flight operational safety.

8.4.1.8.2 TEST DESCRIPTION

Depending on the objectives of the acceptance tests, the leak tests of the sealed loops shall be used at the component manufacturing and assembly stages.

Test methods for either local or total (overall) leakage may be used depending on the stage of manufacture or assembly of the component structure. Testing for local leaks shall screen specific areas of the surface of the sealed loop structure (e. g., welds, sealed joints of fluids manifolds and compartments), and there is the possibility of defects being missed (due to a lack of access to the search area or low qualification of operator). These tests are, as a rule, a component of the preliminary inspection that is performed just before the assessment of total leakage rate for the sealed loop structure. Testing for total leakage is the most objective tool of screening for products that are not suitable for use and makes it possible to evaluate the changes of the sealed loop's leakage rates beginning with manufacture and ending with the final stages of ground processing.

The sensitivity of the methods used for the leak tests shall be chosen in such a manner that it ensures certain detection of leakage rate that is less than or equal to the half that allowed for the sealed loop structure of the component being tested.

For leak tests of component structure sealed loop, as a rule, gas-based leak testing methods are used exposing the structure to the maximum flight operational pressure of the proper direction. The use of methods that employ fluids or special detecting coatings as the test medium is limited to the preliminary stages of leak testing, because of low sensitivity and the possibility of the test medium to close the structure through microdefects (due to capillary action).

8.4.1.8.3 SCOPE AND METHODS

All leaktight components shall undergo leak tests at the sequential stages of manufacture, assembly and processing of the spacecraft at the factory.

The specific scope to tests and leak test methods are selected from the list of methods shown on Table 8.4.1.8.3-1 in a view of technical characteristics and requirements to the test object.

Table 8.4.1.8.3-1 Component Acceptance Leak Tests

	Stages of Testing	Test Object	Leak Testing Method		Brief Description of Test Method
			Local	Total	
1	Constituent parts (assembled units) at stage of incoming (or outgoing) inspection at manufacturing factory	Sealed loop of assembled unit	Bubble test		The essence of the bubble test method is as follows: the internal cavity of the sealed loop is filled with test gas, whereas outside, at the candidate locations of the leaks on the structural element being tested. A layer of a soapy (or other bubble-forming) solution is applied. The location of the actual leakage is determined from the formation of the bubbles. The method has a sensitivity of at least 5˚10^{-2} l˚m Torr/s
			"Sniffer" method		The essence of the "sniffer" method is as follows: the test object is filled with the test gas, and the candidate locations of the leaks on the structural element being tested are examined with a sniffer that is connected to a recording instrument (leak detector). The method hs a sensitivity of at least 5˚10^{-4} l˚m Torr/s.
			Evacuation with external blasting with test gas		The essence of the method of evacuation with external blasing with the test gas is as follows: the internal cavity of the sealed loop is

	Stages of Testing	Test Object	Leak Testing Method		Brief Description of Test Method
					evacuated and is linked with a recording instrument (leak detector); whereas the candidate locationsof the leaks on the structural element being tested are blasted with the test gas. The locations of the leaks are determined from the response of the leakdetector. The method has a sensitivity of at least 5˚10^{-3} l˚m Torr/s
				Vacuum Chamber Method	The essence of the vacuum chamber method is following: the test object is placed in a vacuum chamber that is connected to a recording instrument (a leak detector). The chamber is evacuated to a residual pressure of l˚10^{-3} - 10^{-4} Torr, and the test object is filled with the teat fas. The value of the leakage rate is determined from the change in the concentration of the tracer gas inside the vacuum chamber. The sensitivity of the method is 1˚10^{-3} l˚m Torr/s (1 m Torr = 10^{-3} Torr)
				Leak-in method	The essence of the leak-in method is as follows: the internal cavity of the test object is evacuated and the leakage rate is determined from the rate of pressure rise or value of steady pressure in the test object. The method has a sensitivity of 1˚10^{-2} l˚m Torr/s
				Detachable vacuum chamber method	Detachable vacuum chamber method differs from the analogous method that employs vacuum chamber in that it uses devices that form a closed envelope (I. e. a local vacuum chamber) immediately around the sealed loop element (or assembly) being tested and the value of leak rate is determined for that element (or assembly) only. The method has a sensitivity of down to 1˚10^{-4} l˚m Torr/s.
2	After welding and assembly of the presurized compartment shells, before the installation of the completing	Pressur-ized compart-ment shell	Bubble test		See prior description

	Stages of Testing	Test Object	Leak Testing Method		Brief Description of Test Method
	assemblies and units				
			"Sniffer" method		See prior description
				Vacuum chamber method	See prior description
				Leak in method	See prior description
				Detachable vacuum chamber method	See prior description
3	After welding and assembly of individual units and assemblies of the fluid systems	Assem-blies and units of the fluid systems	"Sniffer" method		See prior description
			Bubble test		See prior description
			Evacuation with external blasting with test gas		See prior description
				Vacuum chamber method	See prior description
				Leak-in method	See prior description
				Detachable vacuum chamber method	See prior description

8.4.1.8.4 ADDITIONAL REQUIREMENTS

1. The leak test methods shall be chosen on the basis of the need to expose the sealed loop structure element being tested to the operational pressure of the proper direction and provision of the necessary sensitivity for the testing (of allowable leakage rate) at a given stage of manufacture or assembly.

2. The set of leak test methods, that is used in order to verify the pressure integrity of sealed loop structure during manufacture and component acceptance tests at the factory, must provide significant margins for structure reliability with respect to the pressure integrity. It is achieved by strengthening of requirements for allowable leakage rates of sealed loops in the earlier stages of manufacture and assembly in comparison with design value, and the set of leak test methods provides detection of through defects of constituent parts (assembled units) by the usage of high-sensitive

test methods in above mentioned stages. As a result, as the assembly of components and flight elements promotes and in the final stages of ground processing, including processing on the launch pad, the margins achieved for structure reliability allow make it possible to use the methods having lower sensitivity owing to lowering of requirements for allowable leakage rates of sealed loops down to design value.

3. During manufacture and preparation, in the event of the detection of the leakage rate of the pressurized compartment component more than 1 l˚m Torr/s, no matter what the leakage rate of the sealed loop is allowable, a search for local leakage must be done, with confirmation of the absence of a concentrated leak more than 1 l˚m Torr/s, in order to reduce the possibility of a through microdefect propagation to a catastrophic level in the process of ground processing and flight operation. Through defects with a leakage rate more than 1 l˚m Torr/s must be eliminated..

The allowable localized leak rate shall not exceed $1˚10^{-3}$ - 1 l˚m Torr/s

The allowable total leak rate range is $1˚10^{-2}$ - 1 l˚m Torr/s (for different sealed loops).

8.4.1.9 MASS CHECK - COMPONENT ACCEPTANCE TEST

8.4.1.9.1 PURPOSE

The mass of each fabricated component sample is checked to verify that it does not exceed the actual mass specified in the assembly drawing for the component.

8.4.1.9.2 DESCRIPTION

The check is performed via weighing on scales.

The metrological characteristics of the scales are selected based on the standards.

8.4.1.9.3 SUPPLEMENTARY REQUIREMENTS

The first three component samples can be subjected to acceptance tests based on the actual mass. If necessary, the results obtained from weighing these samples are used to correct the values for mass in the assembly drawing.

8.4.2 FLIGHT ELEMENT ACCEPTANCE TESTS

The required tests for Flight Element Acceptance are (1) Functional Tests, (2) EMC Test, (3) Pressure/Leak Test, and (4) Mass Properties Measurement. The following apply to the flight element acceptance tests:

Functional Tests shall be conducted prior to and following EMC and Pressure/Leak environmental tests.

Where it is impractical to test flight elements as a single entity, testing of major assemblies that constitute the flight element may be utilized with the appropriate analyses, simulations, and/or simulators to satisfy this requirement. If the flight element is controlled by on-board data processing, the flight software shall be resident in the on-board computer for these tests. The verification of the operational requirements shall be demonstrated.

8.4.2.1 FUNCTIONAL TEST, FLIGHT ELEMENT ACCEPTANCE

8.4.2.1.1 PURPOSE

The Functional Test verifies that the electrical and mechanical performance of the flight element meets the performance requirements and detects any anomalous condition.

8.4.2.1.2 MECHANICAL FUNCTIONAL TEST

The Mechanical Functional test for flight element acceptance is the same as for flight element qualification testing, defined in the following paragraphs, except tests are necessary only at nominal performance requirements and ambient environment, unless flight environment is specified in applicable Prime Item Development Specification. Ambient conditions shall be demonstrated during acceptance testing.

Mechanical functional testing shall be performed on mechanical devices, valves, deployables and separate entities with the flight element in the ascent, orbital, or recovery configuration appropriate to the function. Alignment checks shall be made where appropriate. Maximum and minimum limits of acceptable performance shall be determined with respect to mechanics, time, and other applicable requirements in accordance with PP and TS for the test. Where operation in a 1-G environment cannot be performed, a suitable ground-test fixture may be utilized to permit operation and evaluation of the devices. Fit checks shall be made of the flight element physical interfaces with other flight elements and the launch vehicle by means of master gauges or interface assemblies.

8.4.2.1.3 ELECTRICAL FUNCTIONAL TEST

The Electrical Functional Test for Flight Element Acceptance is the same as for flight element qualification testing, defined in the following paragraphs, except tests are necessary only at nominal performance requirements and ambient environment, unless flight environment is specified in applicable Prime Item development Specification. Ambient conditions shall be demonstrated during acceptance testing.

Electrical functional testing shall be performed with all components and subsystems connected except pyrotechnic devices. The test shall verify the integrity of all electrical circuits, including redundant paths, by application of an initiating stimulus and the confirmation of the successful completion of the event. The test shall be designed to operate all components, primary and redundant. All commands shall be exercised. Operation of all thermal control components, such as heaters and thermostats, shall be verified by tests. The test shall demonstrate that all commands having preconditioning requirements (such as enable, disable, specific equipment configuration, specific command sequence, etc.) cannot be executed unless the preconditions are satisfied. Autonomous functions shall be verified to occur when the conditions exist for which they are designed. Equipment performance parameters (such as power, voltage, gain, frequency, command, and data rates) shall be varied over specification ranges to demonstrate the performance margins. The flight element main bus shall be continuously monitored by a power transient monitor system. All telemetry monitors shall be verified, and pyrotechnic circuits shall be energized and monitored. A segment of the electrical functional test shall operate the flight element through an ascent and mission profile with all events occurring in actual flight sequence.

8.4.2.1.4 SUPPLEMENTARY REQUIREMENTS

Data analysis to verify the adequacy of testing and the validity of the data shall be completed before disconnection from a particular environmental test configuration so that any required retesting can be accomplished.

8.4.2.2 ~~ELECTROMAGNETIC COMPATIBILITY~~EMC TEST, FLIGHT ELEMENT ACCEPTANCE

Limited EMC acceptance testing shall be accomplished on flight elements to check on EMC compliance indicated during flight element EMC qualification testing and to verify that changes have not occurred on successive production equipment. The limited tests shall include measurements of power bus ripple, peak transients, and monitoring of critical circuit parameters.

8.4.2.3 LEAK TESTS, FLIGHT ELEMENT ACCEPTANCE

8.4.2.3.1 PURPOSE

Leak tests shall be performed in order to assess the quality of manufacturing and assembly of actual structure of flight element sealed loops (i~~I~~. e., pressurized compartments and systems) comprising spacecraft for the purpose of providing the capability to store working gases or liquids within specified limits during flight as well as for the purpose of detecting the possible propagation of the structure through microdefects during manufacture and ground processing to ensure spacecraft ground and flight operations safety.

8.4.2.3.2 TEST DESCRIPTION

In keeping with the objective of acceptance tests, the flight element sealed loops are subjected to leak tests during the manufacture, assembly and pre-launch processing.

Test methods for either local or total (overall) leakage may be used, depending on the stage of manufacture or assembly of the spacecraft structure. Testing for local leaks shall screen specific areas of the surface of the sealed loop structure (e. g. welds, sealed joints of fluid manifolds and compartments), and there is the possibility of defects being missed (due to a lack of access to the search area or low qualification of operator). These tests are as a rule, a component of the preliminary inspection that is performed just before the assessment of total leakage rate of the sealed loop structure. Testing for total leakage is the most objective tool of screening for products that are not suitable for use and makes it possible to evaluate the changes of the sealed loop's leakage rates beginning with manufacture and ending with the final stages of ground processing.

The sensitivity of the methods used for the leak tests shall be chosen in such a manner that it ensures certain detection of leakage rate that is less than or equal to the half that allowed for the sealed loop structure of the flight element being tested.

For leak tests of the flight element structure sealed loop, as a rule, gas-based leak testing methods are used exposing the sealed loop structure to the maximum flight operational pressure of the proper direction

The use of methods that employ fluids or special detecting coating as the test medium is limited to the preliminary stages of leak testing, because of low sensitivity and the possibility of the test medium to close the structure through microdefects (due to capillary action).

8.4.2.3.3 TEST SCOPE AND METHODS

All spacecraft undergo leakage tests in the subsequent stages of the manufacture and preparation at the factory and launch complex.

The specific scope of tests and leak test methods are selected from the list of methods shown on Table 8.4.2.3.3-1 in a view of technical characteristics and requirements to the test object.

Table 8.4.2.3.3-1 –Flight Element Acceptance Leak Tests

No.	Stages of Testing	Test object	Leak testing method: local	Leak testing method: total	Method sensitivity
1.	After assembly of pressurized compartment and installation of units complement and fluid systems assemblies	Pressurized shell of the pressurized compartment and fluid systems lines	"Sniffer" method Evacuation with external blasing with test gas	Vacuum chamber method Leak-in method	"Sniffer" method: $5 \cdot 10^{-4}$ l·m Torr/s Evacuation with external blasting with test gas. $5 \cdot 10^{-3}$ l·m Torr/s
2.	After assembly of pressurized modules and systems comprising the spacecraft	Pressurized shells of the pressurized modules and sealed loops of the FS lines in the spacecraft configuration	"Sniffer" method Evacuation with external blasting with test gas	Vacuum chamber method Leak-in method Accumula-tion method at atmos-pheric pressure	Leak-in method: $1 \cdot 10^{-2}$ l·m Torr/s Vacuuming chamber method $1 \cdot 10^{-2}$ - $1 \cdot 10^{-3}$ l·m Torr/s
3.	After function checks and Integrated Electrical Tests (IET) on the spacecraft, in outgoing inspections stage	Pressurized shells of the pressurized modules and sealed loops of the FS lines in the spacecraft configuration	"Sniffer" method Evacuation with external blasing with test gas	Vacuum chamber method Leak-in method Accumulation method at atmospheric pressure Pressure decay method	Accumulation method at atmospheric pressure: 0.25 l·mm Torr/s for 1 m^3 envelope per one hour test

Note: Table 8.4.1.8.3-1 contains brief descriptions of the leak test methods specified on this table.

Table 8.4.2.3.3-1 (cont.)

No.	Stages of testing	Test object	Leak test methods		Method sensitivity
			local	total	
4.	During spacecraft ground processing at the launch complex	FS lines in the spacecraft configuration	“Sniffer” method Evacuation with external blasting with test gas	Leak-in method Accumulation method at atmospheric pressure Pressure decay method	
5.	In the stage of final operations with the spacecraft after completionof IET at the launch complex	Pressurized shells of the pressurized modules and sealed loops of the FS lines in the spacecraft configuration	“Sniffer” method Evacuation with external blasting with test gas	Vacuum chamber method Leak-in method Accumulation method at atmospheric pressure	
6.	At launch pad after final closure of entry (cargo) hatch of the pressurized compartment	Pressure integrity of hatch sealing and filling valves		Leak-in method Pressure decay method	

Note: Table 8.4.1.8.3-1 contains brief descriptions of the leak test methods specified on this table.

8.4.2.3.4 ADDITIONAL REQUIREMENTS

Leak test methods are selected based on the necessity of exposing the sealed loop structure element being tested to the operational pressure of the proper direction, and with the aim of ensuring the required leak test sensitivity (allowable leakage rate) in the respective stage of the flight elements' manufacture assembly or ground processing.

A design analysis is performed on the allowable overall leakage rate for the flight unit sealed loop based on the root-mean-square dependence for allowable leakage rate in the assemblies and units comprising the sealed loop, along with the joints between these assemblies and units.

The set of leak test methods, that is used in order to verify the pressure integrity of sealed loop structure for compartments and systems of flight elements during manufacture and component acceptance tests at the factory, must provide significant margins for structure reliability with respect to the pressure integrity. It is achieved by strengthening of requirements for allowable leakage rates of sealed loops in the earlier stages of manufacture and assembly in comparison with design value, and the set of leak test methods provides detection of through defects of constituent parts (assembled units) by the usage of high-sensitive test methods in above-mentioned stages. As a result, as the assembly of flight elements promotes and in the final stages of ground processing, including processing on the launch pad, the margins achieved for structure reliability allow make it possible to use the methods having lower sensitivity owing to lowering of requirements for allowable leakage rates of sealed loops down to design value.

The figures below reflect the requirements to allowable overall structural leakage values for flight element sealed loops (i. e., spacecraft/orbital station analogs), based on the set of the structural pressure integrity experimental development, as well as acceptance leak tests during manufacture, ground processing and flight operation.

Pressurized shells of the pressurized compartments:	volume up to 10 m^3 -	up to 5 l·mTorr/s
	volume below 100 m^3 -	up to 10 l·mTorr/s
	volume greater than 100 m^3 -	up to 15 l·mTorr/s
FS sealed loops:	lines that determine the capability to store working components	- from 0.01 to 1 l·mTor/rs
	other lines (including rocket engine propellant oxidizer manifolds)	- from 0.1 to 50 l·mTorr/s

Additional requirement is imposed on the pressurized compartment as a flight element. During manufacture and preparation, in the event of the detection of the leakage rate of the pressurized compartment more than 1 l˚mTorr/s, a search for local leakage must be done. with confirmation of the absence of a concentrated leak more than 1 l˚mTorr/s, in order to reduce the possibility of a through microdefect propagation to a catastrophic level in the process of ground processing and flight operation. Through defects with a leakage rate exceeding 1 l˚mTorr/s must be eliminated, or may be accepted upon analysis if they were detected in the rigid structural joints not permitting their subsequent propagation (development) to impermissible levels on exposure to conditions associated with ground processing, launch and on-orbit operation.

8.4.2.4 RESERVED

8.4.2.5 RESERVED

8.4.2.6 MASS PROPERTIES, FLIGHT ELEMENT ACCEPTANCE

8.4.2.6.1 PURPOSE

The Mass Properties Test provides recorded data for the analysis required to ensure the mass properties, to be included in the launch package, are calculated within the tolerances described in the documents containing mass characteristics of the hardware.

8.4.2.6.2 TEST DESCRIPTION

Each integrated subelement shall be weight verified by actual measurement with an accuracy of not more than +/-0.1% of actual measured weight. Each integrated subelement shall be 2 axis (minimum) center of gravity verified by actual measurement with an accuracy of not more than +/-10 mm as measured from coordinate origin.

8.4.2.6.3 SUPPLEMENTARY REQUIREMENTS

After test completion an error analysis shall be conducted to document the accuracy of the measurements.

8.5 USE OF QUALIFICATION COMPONENTS/ASSEMBLIES FOR FLIGHT

Russian industry standards do not allow usage of tested qualification components/assemblies for flight. If necessary, this requirement can be waived by a special decision document approved by management.

8.6 RESERVED

8.7 RETEST

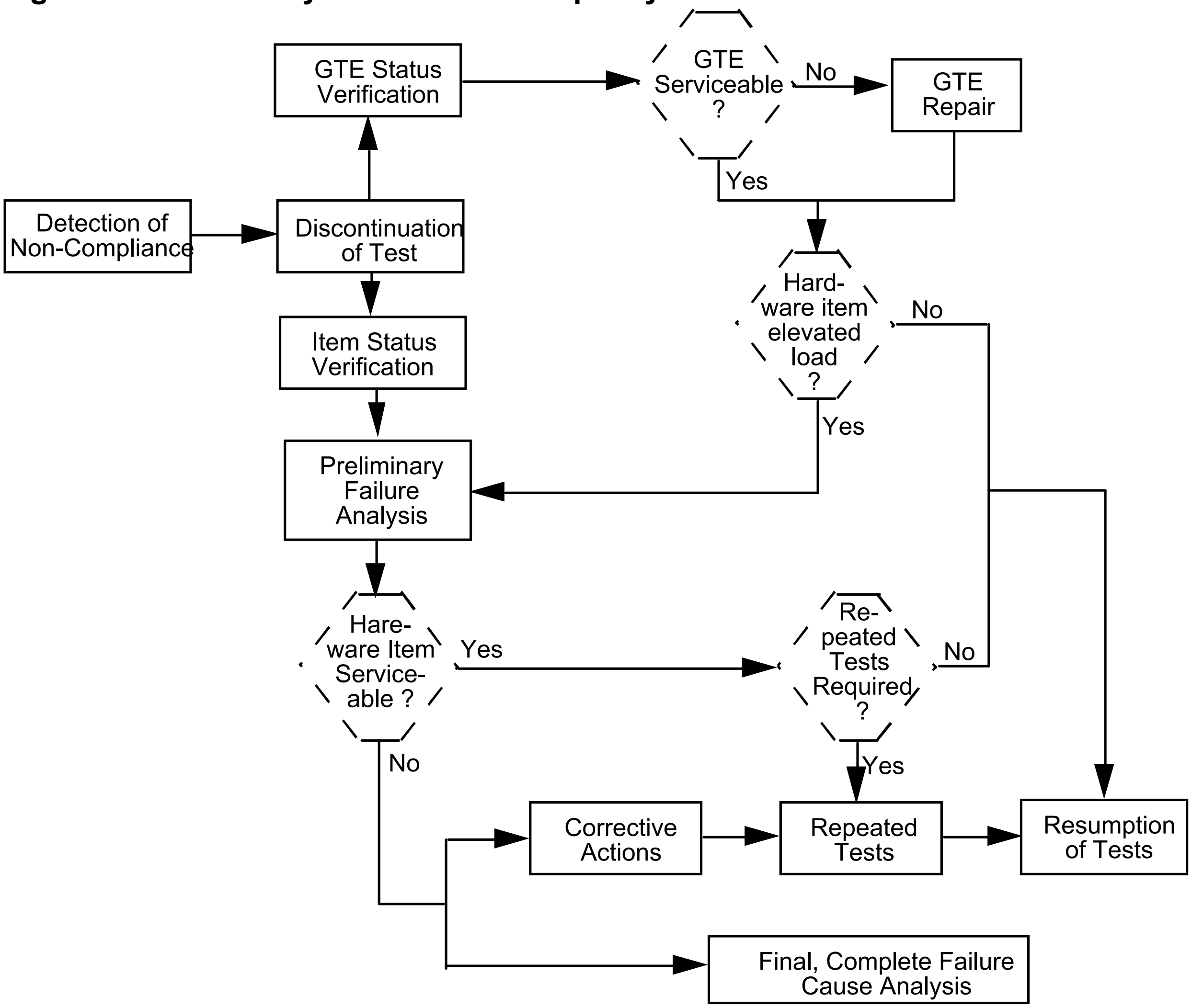
In repeated tests, previously executed tests are performed again for lack of compliance by the hardware item with existing requirements and other reasons, e.g., modifications to an already tested sample. Non-compliance of the tested hardware item with existing requirements can be discovered in any stage of qualification and acceptance tests. If a discrepancy is found, an analysis must be performed to pinpoint the cause of failure and determine whether there are any other problems, either general in nature or impacting a specific lot of hardware items, that can influence other qualification or flight samples. A cause analysis must be performed for any negative test results.

Fig. 8.7-1 presents specifically required measures that are taken immediately after it is discovered that a tested hardware item does not comply with the applicable requirements. If it is found that a hardware item does not comply with the existing requirements, the tests are suspended, and an analysis is performed on the serviceability of the hardware item itself and ground test equipment (test preparations, software, equipment) in order to determine the cause of failure.

If the hardware item itself is in good working order, it is possible that it was subjected to an elevated load due to malfunctioning ground test equipment. After it has been determined that no such elevated load exists, the tests can be continued upon completion of repairs on the ground test equipment. If the hardware item is not serviceable, either because it has malfunctioned or due to an elevated load triggered by malfunctioning ground test equipment, the tests will only be resumed after a preliminary analysis and determination of what caused the failure, and after measures have been taken to eliminate the malfunction. An additional (final) failure analysis may become necessary, since the initial analysis results are sometimes inadequate, and might require additional actions, in particular given problems either of a general nature or specifically impacting the lot of hardware items. Any decision to implement long-term corrective actions requires a determination of the possibility (and consequently, necessity) to detect a malfunction at an earlier stage of assembly or in the course of preceding tests.

The scope of repeated tests will be determined in accordance with the results obtained from failure analysis. If the tested hardware item has to be modified or repaired, already performed tests must be repeated to confirm its functional parameters and environmental parameters.

Figure 8.7.-1 Activity After Test Discrepancy



GTE = Ground Test Equipment

9 NEWLY DEVELOPED SOFTWARE

9.1 SOFTWARE DESIGN AND VALIDATION

9.1.1 GENERAL REQUIREMENTS

~~9.1.1.1~~A. The software developer shall identify, analyze, prioritize, and monitor the areas of the software development project that involve potential technical, cost, or schedule risks.

~~9.1.1.2~~B. Developmental flight software should be partitioned into Computer Software Configuration Items (CSCI~~s~~).

~~9.1.1.3~~C. The software developer shall implement a process for managing the development of the deliverable software.

~~9.1.1.4~~D. The software developer shall document and implement procedures for risk management. The software developer shall implement a risk management approach. The software risk management approach shall be documented in the software development plan.

~~9.1.1.5~~E. The software developer shall use systematic and well documented software development methods to perform requirements analysis, design, coding, integration, and testing of the deliverable software.

~~9.1.1.6~~F. The software developer shall perform the analysis necessary to ensure that the software requirements, design, and operating procedures minimize the potential for hazardous conditions during the operational mission.

~~9.1.1.7~~G. The software developer shall clearly identify and document all potentially hazardous conditions or operating procedures.

~~9.1.1.8~~H. The software developer shall consider incorporating non-developmental software (reused) into the deliverable software.

~~9.1.1.9~~I. The software developer shall document plans for using non-developmental software in the software development plan.

~~9.1.1.10~~J. Reserved

~~9.1.1.11~~K. The software developer shall decompose and partition each CSCI into Computer Software Components (CSC~~s~~) and Computer Software Units (CSU~~s~~) in accordance with the development method(s) documented in the software development plan.

~~9.1.1.12~~L. The software developer shall ensure that the requirements for the CSCI are completely allocated and further refined to facilitate the design and test of each CSC and CSU.

~~9.1.1.13~~M. The software developer shall use the high level language(s) specified in the ~~ISSA~~ISS program to code the deliverable software.

~~9.1.1.14~~N. The software developer shall monitor the utilization of processing resources for the duration of the Program and shall reallocate the resources as necessary to satisfy the reserve requirements.

~~9.1.1.15~~O. The software developer shall provide to ~~ISSA~~ISS Program deliverable code, associated with integration and joint operations, that can be regenerated and maintained using commercially available, ~~ISSA~~ISS Program-owned, or RSA deliverable support software and hardware that has been identified by the ~~ISSA~~ISS Program.

~~9.1.1.16~~P. The software developer shall prepare plans for transitioning the deliverable software from development to support. These plans shall be documented in the RSA Software Development Plan.

~~9.1.1.17~~Q. The software developer shall perform installation and checkout of the deliverable software in the support environment designed by RSA and/or NASA. The software developer shall provide training and continuing support to NASA and RSA's activities as specified by the ~~ISSA~~ISS Program.

~~9.1.1.18~~R. The software developer shall incorporate the updated Software Product Specifications and source code listings for each successfully tested and evaluated CSU into the appropriate developmental configuration.

~~9.1.1.19~~S. Detailed software schedule information and implementation plans shall be documented and maintained by the software developer and made available for review by the ~~ISSA~~ISS Program.

~~9.1.1.20~~T. The software developer shall be responsible for providing deliverables as specified by the ~~ISSA~~ISS Program, including released software and software documentation to the ~~ISSA~~ISS Program. The software deliverables will include all software and software documentation required for the ~~ISSA~~ISS Program.

~~9.1.1.21~~U. The software developer shall be responsible for providing the resources (i.e. software tools and software documentation) required to support integration activities as specified by the ~~ISSA~~ISS Program.

~~9.1.1.22~~V. The software developer shall report the following software metrics to the ~~ISSA~~ISS Program at stage completion and formal reviews. These metrics shall be reported at the CSCI and major CSC level. The software metrics are:

a. General data including reporting period, CSCI/CSC name, developer
b. Software size
c. Design and code progress
d. Software volatility
e. Formal test progress
f. Computer resource utilization
g. Software development schedules

~~9.1.1.23~~W. The software developer shall provide all flight software builds for the purposes of integration and joint operations to the ~~ISSA~~ISS Program. The software and documentation delivered to the ~~ISSA~~ISS Program shall contain:

~~a~~1. Source Code
~~b~~2. Object code
3~~c~~. Data tables
4~~d~~. Version descriptions
5~~e~~. Loader instructions for creating an executable of the software from the delivered source

~~9.1.1.24~~X. The software developer shall use Ada and/or C as the primary Programming languages for developing all ~~ISSA~~ISS software.

~~9.1.1.25~~Y. All data and commands that cross a Russian Space Agency to NASA software interface, onboard and on the ground, shall meet or contain the Program Unique Identifiers defined by the ~~ISSA~~ISS Program.

~~9.1.1.26~~Z. The software developer shall use the Program Unique Requirements Identifiers to document the software requirements in the Interface Control Document. The fixed format Program Unique Requirements Identifier shall be assigned to all of the Interface Control Document (ICD) software requirements and shall be traceable to all ICD Program Unique Signal Data Identifiers.

~~9.1.1.27~~AA. The software developer shall apply to software component naming:

~~a~~1. CSCI(s) shall have a unique character Configuration Item identifier to support Program Unique Interface Identifier naming conventions.
2~~b~~. CSC names shall be specified by the software developer.
3~~c~~. CSU names shall be specified by the software developer.

~~9.1.1.28~~AB. The software developer shall follow the following rules when defining Program Unique Interface Identifiers:

~~a~~1. The names of all interfaces shall indicate the direction of the data flow.
~~b~~2. All external interfaces between a CSCI and a Hardware Configuration Item (HWCI), FWCI, or another CSCI, and all external interfaces between CSCs that cross

RSA to NASA boundaries shall be assigned a mnemonic identifier specifying source and destination.

~~9.1.1.29~~AC. Data elements that are external to the CSCI, or internal to the CSCI but cross RSA to NASA boundaries shall follow the following standards:

~~a~~1.~~-~~ For each data identified in the software requirements specification, the software coded name shall be traceable from interface requirements to design and from design to code in the software product specification. The traceability from code to the assignment of Program Unique Signal Data Identifiers shall be documented in the software product specification.

~~b~~2.~~-~~ All adaptation data, both installation dependent data and operational parameter data specified in the software requirements specification shall have Program Unique Signal Data Identifiers assigned to it.

~~9.1.1.30~~AD. The software developer shall follow the following rules and guidelines when providing the calibration data for sensors and effectors:

~~a~~1. The techniques for generation of calibration curves (e.g., curve types, number of points, etc.) for all applicable sensors and effectors for a particular software development shall be documented.

~~b~~2. Once the calibration curve has been established for the sensor or effector, the units of measure shall be determined and used whenever that sensor/effector data is referenced.

~~c~~3. A set of inverse calibration coefficients shall be provided with each set of forward calibration coefficients in support of the ~~ISSA~~ISS Program simulation facilities.

~~d~~4. The sensor and effector calibration curve data and its inverse shall be delivered to the ~~ISSA~~ISS Program.

9.2 SOFTWARE DOCUMENTATION

9.2.1 SOFTWARE DEVELOPMENT LIFECYCLE

~~9.2.1.1~~A. The software developer shall document the traceability of the requirements allocated from the system specification to each CSCI, its CSCs and CSUs, and from the CSU level to the software requirements specifications document(s).

~~9.2.1.2~~B. The software developer shall document and implement design and coding standards to be used in the development of deliverable software. Software coding standards shall comply with the requirements specified in RSA rules and guidelines.

~~9.2.1.3~~C. The software developer shall analyze the processing resource and reserve requirements, such as timing, memory utilization, I/O channel utilization, identified by the Program and shall allocate these resources among the CSCIs. The allocation of these resources to a CSCI shall be documented in the software requirements specification for the CSCI.

~~9.2.1.4~~D. Measured resource utilization at the time of delivery shall be documented in the software product specification for each CSCI.

~~9.2.1.5~~E. The software developer shall analyze the preliminary system specification and shall determine whether the software requirements are consistent and complete.

~~9.2.1.6~~F. The software developer shall conduct analysis to determine the best allocation of system requirements between hardware, software, and personnel in order to partition the system into HWCIs, CSCIs, and manual operations. The software developer shall document the allocation in a RSA preliminary draft of the technical assignment document.

~~9.2.1.7~~G. The software developer shall define a complete set of engineering requirements for each CSCI. The software developer shall document these requirements in the Software Requirements Specification (SRS) for each CSCI.

~~9.2.1.8~~H. The software developer shall define a complete set of interface requirements for each interface external to each CSCI. The software developer shall document these requirements in the SRS.

~~9.2.1.9~~I. The software developer shall define a complete set of qualification requirements for each CSCI. The software developer shall document these requirements in the SRS for each CSCI.

~~9.2.1.10~~J. The software developer shall develop a preliminary design for each CSCI, shall allocate requirements from the SRSs to the CSCs of each CSCI, and shall establish design requirements for each CSC. The software developer shall document this information in the Software Product Specification for each CSCI.

~~9.2.1.11~~K. The software developer shall develop a preliminary design for the interfaces external to each CSCI documented in the SRS. The software developer shall document this information in a preliminary Software Product Specification.

~~9.2.1.12~~L. The software developer shall document in the Software Product Specification for each CSCI additional engineering information generated during the preliminary design process that is essential to understand the design. The engineering information may include rationale, results of analyses, and trade-off studies, and other information that aids in understanding the preliminary design.

~~9.2.1.13~~M. The software developer shall identify the formal qualification tests to be conducted to comply with the qualification requirements identified in the SRSs. The software developer shall document this information for each CSCI in the Software Test Plan (STP) or Software Development Plan.

9.2.1.14N. The software developer shall incorporate the Software Product Specification for each CSCI into the CSCI's Developmental Configuration prior to delivery to ISSAISS program.

9.2.1.15O. The software developer shall develop a detailed design for each CSCI, shall allocate requirements from the CSCs to the CSUs of each CSCI, and shall establish design requirements for each CSU. The software developer shall document this information in the Software Product Specification for each CSCI.

9.2.1.16P. The software developer shall develop the detailed design of the CSCI external interfaces documented in the Software Requirements Specification. The software developer shall document this information in the Software Product Specification.

9.2.1.17Q. The software developer shall document in the Software Product Specification for each CSCI additional engineering information generated during the detailed design process that is essential to understand the design. The engineering information may include rationale, results of analyses and trade-off studies, and other information that aids in understanding the detailed design.

9.2.1.18R. The software developer shall identify and describe the test cases for the formal qualification tests identified in the software test plans. The software developer shall document this information in the Software Test Description (STD) for each CSCI.

9.2.1.19S. The software developer shall incorporate the updated Software Product Specification for each CSCI into the CSCI's Developmental Configuration prior to delivery to the ISSAISS Program.

9.2.1.20T. The software developer shall develop a documentation set, in accordance with GOST Uniform System Program Software Documentation Standards that includes:

a1. Software Development Plan, to cover all software products being delivered or used by the ISSAISS Program.
b2. Software Test Plan (STP), to cover all the formal software test to be performed for the ISSAISS Program.
c3. Software User's Manual, for ground CSCIs which include man-machine interfaces.
d4. Software Programmer's Manual, only from processor hardware developers.
e5. Software Status Reports, in RSA format, to include the metrics, information for all software products to be developed under the ISSAISS Program.

9.2.1.21U. The software developer shall develop a documentation set for each CSCI, in accordance with RSA's GOST Uniform System Program Software Documentation Standards that includes:

a1. Software Requirements Specifications, for software and interface requirements and should include the requirements to be verified in the software formal qualification test.
b2. Interface Control Document, in the format specified by the ISSAISS Program, to include protocol and transaction sequences with word and bit level data content specified for all external processor input/output.
3c. Software Product Specification, to document the software design, requirements allocation and as-build software product. The software product specification combined with the software development folders will represent the total software design.
d4. Software Test DescriptionSTD to document the formal software test cases, requirements allocations and test procedures.
e5. Software Test Report, for each formal software test completed. This report will include the "as-run" test procedures.
f6. Version Description Document, for each software delivery. The source and executable code for the CSCI being delivered will be included with the Version Description Document.

9.2.1.22V. The following document will be maintained by the software developer for each CSCI and made available for review by NASA and RSA upon request, but are not formal deliverables:

a1. Software Development Files to include the detailed design, test, and other information.

9.2.1.23W. The software developer shall provide a separate revision of their documents for each change in Assembly Sequence or use an appendix to map each requirement to the Assembly Build flights in which the requirement's capability will be activated.

9.2.1.24X. The software standards and procedures to be used by the software developer in performing their software development shall be defined in a Software Specifications and Procedures Standard document. The Software Specifications and Procedures Standard document will provide the document standards, including the tailored data item description and contents for the software development files.

9.2.1.25Y. The software developer shall use the ISSAISS standard set of units of measure in describing the referenced data elements. The standard set of units of measure used by RSA will be defined in RSA's software specifications and standards document. The standard set will be based on the units defined in appendix F of the ISSAISS Prime Contractor Software Standards and Procedures Specification, D684-10056.-

9.2.1.26Z. The software developer shall use the ISSAISS table of standard short words and abbreviations and acronym list in the descriptive text titles for hardware, software and associated data. The table of standard short words and abbreviations will be defined in an appendix of the RSA Software Standards and Procedures

Specification. The acronym list will be defined in an appendix of the RSA Software Standards and Procedures Specification.

~~9.2.1.27~~AA. The software developer shall use the ~~ISSA~~ISS Standard Engineering Constants in the development of software and data. The standard engineering constants used by RSA will be defined in an appendix of the RSA software specification and procedures specification. The Standard Engineering Constants used by RSA will be based on the standard engineering constants defined in appendix I of the ~~ISSA~~ISS Prime Contractor Software Standards and Procedures Specification, D684-10056-1.

~~9.2.1.28~~AB. The software developer shall use the ~~ISSA~~ISS 1553 Data Types in the development of external software data types. The 1553 Data Types are defined in an appendix of the ~~ISSA~~ISS Prime Contractor Software Standards and Procedures Specification, D684-10056-1.

~~9.2.1.29~~AC The software developer shall follow the ~~ISSA~~ISS Program data encoding standards. RSA will define the data encoding standards used by RSA in RSA software documentation. The ~~ISSA~~ISS Program data encoding standards are defined in section 3.4 of the ~~ISSA~~ISS Prime Contractor Software Standards and Procedures Specification, D684-10056-1.

~~9.2.1.30~~AD. The software developer shall follow the ~~ISSA~~ISS Program software coding standards. RSA will document the coding standards used by RSA in RSA software documentation. The ~~ISSA~~ISS Program software coding standards are defined in section 3.5 of the ~~ISSA~~ISS Prime Contractor Software Standards and Procedures Specification, D684-10056-1.

9.2.2 SOFTWARE DEVELOPMENT LIBRARY

~~9.2.2.1~~A. The software developer shall establish a software development library.

~~9.2.2.2~~B. The software developer shall document and implement procedures for controlling software and associated documentation residing within the software development library. The software developer shall maintain all software and documentation under configuration control in a software development library system.

~~9.2.2.3~~C. The software developer shall maintain the software development library for the duration of the ~~ISSA~~ISS program.

9.2.3 SOFTWARE DEVELOPMENT FILES

~~9.2.3.1~~A. The software developer shall document the development of each Computer Software Unit, Computer Software Component, and CSCI in software development files.

~~9.2.3.2~~B. The software developer shall establish a separate software development file for each CSU or logically related group of CSUs; each CSC or logically related group of CSCs; and each CSCI.

~~9.2.3.3~~C. The software developer shall document and implement procedures for establishing and maintaining software development files.

~~9.2.3.4~~D. The software developer shall maintain the software development files for the duration of the ~~ISSA~~ISS Program.

~~9.2.3.5~~E. The software developer's software development files shall include (directly or by reference) the following information:

1~~a~~. Design considerations and constraints
2~~b~~. Design documentation and data
3~~c~~. Schedule and status information
4~~d~~. Test requirements and responsibilities
5~~e~~. Test cases, procedures, and results
6~~f~~. Sizing and timing estimates
7~~g~~. Problem reports and software change log

~~9.2.3.6~~F. The software developer shall establish test requirements for conducting CSC integration and testing. The software developer's CSC integration and testing shall include stressing the software at the limits of its specified requirements. The software developer shall record the test requirements (directly or by reference) in the CSC software development files.

~~9.2.3.7~~G. The software developer shall establish test responsibilities, test cases (in terms of inputs, expected results, and evaluation criteria), and schedules for CSC integration and testing. The software developer shall record this information (directly or by reference) in the CSC software development files.

~~9.2.3.8~~H. The software developer shall establish test requirements, test responsibilities, test cases (in terms of inputs, expected results, and evaluation criteria), and schedules for testing all CSCIs. The software developer's CSCI testing shall include stressing the software at the limits of its specified requirements. The software developer shall record this information (directly or by reference) in the CSCI software development files.

~~9.2.3.9~~I. The software developer shall develop test procedures for conducting each CSU test. The software developer shall record these procedures in the corresponding CSU Software Development Files (SDFs).

~~9.2.3.10~~J. The software developer shall code and test each CSU ensuring that the algorithms and logic employed by each CSU are correct and that the CSU satisfies its specified requirements. The software developer shall record the test results of all CSU testing in the corresponding CSU SDFs.

~~9.2.3.11~~K. The software developer shall make all necessary revisions to the design documentation and code, perform all necessary retesting, and shall update the SDFs of all CSUs that undergo design or coding changes based on CSU tests.

~~9.2.3.12~~L. The software developer shall develop test procedures for conducting each CSC test. The software developer shall record these procedures in the CSC SDFs.

9.3 FORMAL REVIEWS

~~9.3.1~~A. The software development process for each CSCI shall be compatible with the ~~ISSA~~ISS Program schedule for formal reviews and audits.

~~9.3.2~~B. During the software development process, the software developer shall conduct or support formal reviews and audits as required by the ~~ISSA~~ISS Program.

~~9.3.3~~C. The software developer shall develop plans for conducting the activities required. These plans shall be documented in a Software Development Plan.

~~9.3.4~~D. The software development process, as defined in RSA's GOST 19.102-77, shall include the following major activities, which may overlap and may be applied iteratively or recursively:

a. Technical Specification Stage
b. Preliminary Design Stage
c. Technical Design Stage
d. Working Draft Stage
e. Performance Stage.

~~9.3.5~~E. The ~~ISSA~~ISS Program shall review the progress of the software development at several formal reviews. These reviews will serve as milestones marking the transition of the engineering products into subsequent phases of the development cycle. RSA rules and guidelines shall be used as a guide to establish the criteria which will be applied to each review. Specific criteria for each review shall be established prior to the review with the ~~ISSA~~ISS Program. The formal reviews required are as follows:

a. Technical Specification Stage
b. Preliminary Design Stage
c. Technical Design Stage
d. Working Draft Stage
e. Performance Stage.

~~9.3.6~~F. The ~~ISSA~~ISS Program shall review the progress of the software development at several formal reviews. These reviews will serve as milestones marking the transition of the engineering products into subsequent phases of the development cycle. RSA rules and standards shall be used as a guide to establish the criteria which will be applied to each review. Specific criteria for each review shall be established prior to the review with ~~ISSA~~ISS program. The formal reviews required are as follows:

1~~a~~. Stage review of Technical Specification Stage
2~~b~~. Stage review of Preliminary Design Stage
3~~c~~. Stage review of Technical Design Stage
4~~d~~. Stage review of Working Draft Stage
5~~e~~. Stage review of Performance Stage.

~~9.3.7~~G. The software developer shall conduct one or more Technical Specification Review(s) (TSR). Following successful completion of a TSR and when authenticated by RSA and NASA, the SRSs will establish the requirements for the CSCIs.

~~9.3.8~~H. The persons conducting the evaluation of a product shall not be the persons who developed the product or are responsible for the product. This does not preclude members of the development team from participating in these evaluations.

~~9.3.9~~I. Responsibility for the fulfillment of the software product evaluation requirements shall be assigned and specified in the software development plan document.

~~9.3.10~~J. Prior to submitting each deliverable item to the ~~ISSA~~ISS program, the software developer shall internally coordinate the item with appropriate organizations for a final evaluation. The objective of each final evaluation shall be to ensure that the deliverable item is acceptable in terms of its ability to satisfy its requirements.

~~9.3.11~~K. The software developer shall prepare and maintain records of each software product evaluation performed. Evaluation records shall be available for ~~ISSA~~ISS program review and shall be maintained for the life of the Program.

~~9.3.12~~L. The software developer shall perform evaluations of the following products, using an evaluation criteria defined by RSA rules and guidelines:
1~~a~~. The Software Development Plan (SDP)
2~~b~~. The RSA Segment Specification

~~9.3.13~~M. The software developer shall perform evaluations of the product identified below, using the evaluation criteria specified by the RSA rules and standards. The software developer shall present a summary of the evaluation results at the Technical Specification Review(s).
~~a~~1. The Software Requirements Specification for each CSCI.

~~9.3.14~~N. The software developer shall perform evaluations of the products identified below, using the evaluation criteria specified by the RSA rules and guidelines. The software developer shall present a summary of the evaluation results at the Preliminary Design Review(s).

1a.- The Software Product Specification for each CSCI
2b.- The Software Test Plans or Software Development Plan which includes the software test plans
3c.- The CSC test requirements.

9.3.15O. The software developer shall perform evaluations of the products identified below, using the evaluation criteria specified in RSA rules and guidelines. The software developer shall present a summary of the evaluation results at the Technical Design review and at the Working Draft review.
1a. The updated Software Product Specification for each CSCI
2b. The updated interface design contained in the Software Product Specification Document
3c. CSC test cases
4d. CSU test requirements and test cases
5e. A set of CSCI software development files (SDFs).
6f. The Software Test Description for each CSCI.

9.3.16P. The software developer shall perform evaluations of the products identified below, using the evaluation criteria specified in RSA rules and guidelines.
a1. The source code for each CSU
b2.- The CSC test procedures
c3. The CSU test procedures and test results
d4. A set of updated software development files.

9.4 CONFIGURATION MANAGEMENT

9.4.1A. The software developer shall document and implement a corrective action process for handling all problems detected in the products under configuration control and in the software development activities required by the ISSAISS program.

9.4.2B. The software developer's corrective action process shall comply with the following requirements:

a1.- The process shall be closed-loop, ensuring that all detected problems are promptly reported and entered into the corrective action process, action is initiated on them, resolution is achieved, status is tracked and reported, and records of the problems are maintained for the life of the ISSAISS program.
b2.- Inputs to the corrective action process shall consist of problem/change reports and other discrepancy reports.
c3.- Each problem shall be classified by category and by priority.
d4.- Analysis shall be performed to detect trends in the problems reported.
e5.- Corrective actions shall be evaluated to: (1) verify that problems have been resolved, adverse trends have been reversed, and changes have been correctly implemented in the appropriate processes and products, and (2) to determine whether additional problems have been introduced.

9.4.3C. The software developer shall prepare a problem/change report to describe each problem detected in software or documentation that has been placed under configuration control.

9.4.4D. The software developer's problem/change report shall describe the corrective action needed and the actions taken to resolve the problem.

9.4.5E. The software developer shall document and implement plans for performing configuration identification. Configuration identification shall be conducted in accordance with the identification scheme specified by the ISSAISS Program. Configuration identification performed by the software developer shall accomplish the following:
1a. Identify the document that establishes the functional, allocated, and product baselines, and developmental configuration.
2b. Identify the documentation and the computer software media containing code, documentation, or both that are placed under configuration control.
3c. Identify each CSCI and its corresponding Computer Software Components and Computer Software Units.
4d. Identify the version, release, change status, and any other identification details of each deliverable item.
5e. Identify the version of each CSCI, CSC, and CSU to which the corresponding software documentation applies.
6f. Identify the specific version of software contained on a deliverable medium, including all changes incorporated since its previous release.

9.4.6F. The software developer shall document and implement plans for performing configuration control. Configuration control performed by the software developer shall accomplish the following:
a1. Establish a developmental configuration for each CSCI.
b2. Maintain current copies of the deliverable documentation and code.
3c. Provide ISSAISS Program access to documentation and code under configuration control.
4d. Control the preparation and dissemination of changes to the master copies of deliverable software and documentation that have been placed under configuration control so that they reflect only approved changes.

9.4.7G. The software developer shall document and implement plans for performing configuration status accounting. The software developer shall generate management records and status reports on all products comprising the developmental configuration and allocated and product baselines. The status reports shall:
a1. Provide traceablility of changes to controlled products.
b2. Serve as a basis for communicating the status of configuration identification and associated software.
c3. Serve as a vehicle for ensuring that delivered documents describe and represent the associated software.

~~9.4.8~~H. The software developer shall document and implement methods and procedures for the storage, handling, and delivery of software and documentation. The software developer shall maintain master copies of the delivered software and documentation.

~~9.4.9~~I. The software developer shall prepare Change Proposals (CP~~s~~) in accordance with the Program. The software developer shall prepare Specification Change Notices in accordance with the ~~ISSA~~ISS Program Configuration Management requirements.

~~9.4.10~~J. The software developer shall place the following documents under configuration control prior to delivery to the ~~ISSA~~ISS Program:
~~a~~1. The Software Development Plan
~~b~~2. The Software Requirements Specification for each CSCI

~~9.4.11~~K. The software developer shall place the software test plans under configuration control prior to delivery to the ~~ISSA~~ISS Program.

~~9.4.12~~L. The software developer shall place the Software Product Specification under configuration control prior to delivery to the ~~ISSA~~ISS Program.

~~9.4.13~~M. The software developer shall place the updated Software Product Specification under configuration control prior to delivery to the ~~ISSA~~ISS Program.

~~9.4.14~~N. The software developer shall place the STD for each CSCI under configuration control prior to delivery to the ~~ISSA~~ISS Program.

~~9.4.15~~O. The software developer shall place the source code for each successfully tested and evaluated CSU under configuration control.

9.5 SOFTWARE SUBCONTRACTOR

~~9.5.1~~A. The Russian Space Agency shall pass down to the subcontractor(s) all contractual requirements necessary to ensure that all software and associated documentation delivered to the Russian Space Agency and the ~~ISSA~~ISS Program are developed in accordance with the ~~ISSA~~ISS Program requirements. The software developer shall be responsible for implementing the flowdown of the ~~ISSA~~ISS software standards, procedures, guidelines and requirements to all software subcontractors.

~~9.5.2~~B. The Russian Space Agency shall provide to the subcontractor(s) the baselined requirements for the software to be developed by the subcontractor(s).

9.6 SOFTWARE TESTING

~~9.6.1~~A. The software developer shall conduct formal qualification testing of each CSCI on the target computer system or an equivalent system approved by the ~~ISSA~~ISS program. The software developer's formal qualification testing activities shall include stressing the software at the limits of its specified requirements. The software developer may conduct, as part of the formal qualification testing activity, testing of CSCIs integrated with other CSCIs or HWCIs that comprise the system.

~~9.6.2~~B. The software developer shall identify in the software test plans the tests that involve stressing the software and those that involve integrating CSCIs with other configuration items.

~~9.6.3~~C. The software developer shall develop plans for conducting the formal qualification testing activities required by GOST 19.301-79. These plans shall be documented in the software test plan or software development plan.

~~9.6.4~~D. Following ~~ISSA~~ISS Program approval of the software test plans, the software developer shall conduct the formal qualification testing activities in accordance with the software test plans. With the exception of scheduling information, updates to the software test plan shall be subject to ~~ISSA~~ISS Program approval.

~~9.6.5~~E. The software developer shall establish a software test environment to perform the formal qualification test effort. The software test environment shall comply with the security requirements of the ~~ISSA~~ISS Program.

~~9.6.6~~F. The software developer shall document and implement plans for the installation, test, configuration control, and maintenance of each item of the environment. Following installation, each item of the environment shall be tested to demonstrate that the item performs its intended function.

~~9.6.7~~G. The persons conducting the formal qualification testing activities shall not be the persons who developed the software or are responsible for the software.

~~9.6.8~~H. Responsibility for the fulfillment of the formal qualification testing requirements shall be assigned and specified in the software development plan.

~~9.6.9~~I. The software developer shall document the traceability of the requirements in the software requirements specification that are satisfied or partially satisfied by each test case identified in the software test description document. The software developer shall document this traceability in the software test description for each CSCI.

~~9.6.10~~J. The software developer shall interface with the software independent verification and validation agents as defined in the RSA software development plan.

~~9.6.11~~K. The test software and simulation software used on the ~~ISSA~~ISS Program for integration and verification process of flight software and avionics shall follow the same general development life cycle and configuration management controls as that established for the flight software as defined in the RSA software development plan. Test and simulation software does not require the same level of documentation as flight software.

~~9.6.12~~L. The test configuration for the formal qualification testing shall be approved by the ~~ISSA~~ISS Program.

~~9.6.13~~M. The software developer shall consider the following items during test planning:
1~~a~~. Test facilities are fully certified and current.
2~~b~~. Versions of target software are available from configuration management as required.
3~~c~~. Sufficient certified simulations are available to provide required test fidelity.
4~~d~~. Ready access to current requirements data base is available.

9.7 SOFTWARE SECURITY

The software developer shall implement and comply with the security requirements specified by the ~~ISSA~~ISS Program. The software developer shall implement an automated system security plan for all software development on the ISS~~A~~ Program. The software developer shall document the security plan in the software development plan.

9.8 SOFTWARE DEVELOPMENT ENVIRONMENT

~~9.8.1~~A. The software developer shall establish a software engineering environment to perform the software engineering effort. The software development environment description shall be contained in the RSA software development plan.

~~9.8.2~~B. The software developer's software engineering environment shall comply with the security requirements of the ISS~~A~~ program.

~~9.8.3~~C. The software developer shall document and implement plans for the installation, configuration control, and maintenance of each item of the software development environment.

9.9 COMPUTER-BASED CONTROL SYSTEM SAFETY REQUIREMENTS

Computer-based control systems use computer hardware and software as an integral part of the System Safety Program. Computer-based control system safety is the application of engineering and management principles, criteria, and techniques to provide hardware failure and software error tolerance to minimize risks associated with the use of computers to control hazards.

These requirements apply to computer-based flight systems that control flight system capabilities essential to the survival of the crew and the Space Station (this does not include simulation and training devices), and to the computer-based control system software used in the prevention of catastrophic and critical hazardous events. This includes all flight software and firmware regardless of the media the software resides on.

~~9.9.1~~A. contains the technical requirements for CBCS Safety.

~~9.9.2~~B. contains abbreviations and acronyms used in this document.

~~9.9.3~~C. provides definitions.

The purpose of section 9.9.1 is to define the requirements for computer-based control of hazards. The approaches identified provide requirements which will implement the necessary and sufficient hazard controls. These approaches are based on the type of hazard being controlled and are to be applied on a hazard-by-hazard basis. Section 9.9.1 is the top level requirement that is decomposed into the requirements in the subordinate paragraphs. Section 9.9.1.1 contains general requirements which must be met in all CBCS designs. Section 9.9.1.2 contains requirements that must be met in the control of functions that must work in order for the ISS to be safe. Section 9.9.1.3 contains requirements for functions whose inadvertent operation would cause a hazard (i.e., must-not-work functions). Within Section 9.9.1.3 either the set of requirements in 9.9.1.3.1 or the set of requirements in 9.9.1.3.2 must be met in order to control the hazard.

9.9.1 SYSTEM LEVEL CBCS SAFETY REQUIREMENTS

A CBCS shall provide hazardous function control where the inadvertent activation or deactivation of the function or capability could result in an identified critical or catastrophic hazard.

9.9.1.1 GENERAL CBCS REQUIREMENTS

This section of the computer-based control system requirements must be applied to all CBCS designs irrespective of function.

~~9.9.1.1.1~~A. The CBCS shall safely initialize to a known, safe state.

~~9.9.1.1.2~~B. The CBCS shall perform an orderly shut down of a function to a known, safe state upon receipt of a termination command or detection of a termination condition.

~~9.9.1.1.3~~C. A processor shall continue to operate safely during off-nominal power conditions, or contain design features which safe the processor during off-nominal power conditions.

~~9.9.1.1.4~~D. For hazardous functions, overrides shall require at least two independent actions by the operator.

~~9.9.1.1.5~~E. Where execution of commands out of sequence can cause a hazard, the CBCS shall reject commands received out of sequence.

~~9.9.1.1.6~~F. A CBCS shall detect and recover from inadvertent memory modification during use.

~~9.9.1.1.7~~G. A CBCS shall recover to a known safe state upon detection of an anomaly within the CBCS.

~~9.9.1.1.8~~H. The CBCS shall be capable of discriminating between valid and invalid inputs from sources external to the CBCS and remain or recover to a known safe state in the event of an invalid external input.

~~9.9.1.1.9~~I. All flight software shall be traceable to a system or software requirement.

~~9.9.1.1.10~~J. All code shall be documented.

~~9.9.1.1.11~~K. Integrity checks shall be performed when input and output data or commands are exchanged across transmission or reception lines and devices.

~~9.9.1.1.12~~L. The Space Station shall provide protection for uplinked commands to prevent unauthorized third party control of the on-orbit station.

~~9.9.1.1.13~~M. The CBCS shall reject hazardous commands which do not meet prerequisite checks for execution.

9.9.1.2 CBCS MUST WORK FUNCTION REQUIREMENTS

The requirements of this section are applicable to the design of CBCS functions whose inadvertent shutdown would cause a hazard.

9.9.1.2.1 Fault Tolerant Approach

A computer-based control system shall be designed such that no combination of two failures, or two operator actions, or one of each will cause a catastrophic hazardous event, or no single failure or operator action will cause a critical hazardous event.

~~9.9.1.2.1.1~~A. Where loss of a capability could result in a catastrophic hazard, the CBCS shall provide two independent and unique command messages to deactivate the capability.

~~9.9.1.2.1.2~~B. Where loss of a capability could result in a critical hazard, the CBCS shall provide two independent and unique command messages to deactivate the capability.

~~9.9.1.2.1.3~~C. At least one independent operator action shall be required for each operator initiated command message used in the shutdown of a capability or function that could lead to a hazard.

~~9.9.1.2.1.4~~D. Where software provides the sole control for safety critical must work on-orbit ISS assembly functions, another non-identical method for commanding the function shall be provided.

~~9.9.1.2.1.5~~E. Alternated or redundant functional paths shall be separate or protected such that any single credible event which causes the loss of one functional path will not result in the loss of the redundant functional path.

~~9.9.1.2.1.6~~F. RESPOND TO LOSS OF FUNCTION

The purpose of this capability is to respond, on-orbit, to the loss of system functions, which are required for 24 hours autonomous operations or that may manifest a catastrophic or critical hazard. The on-orbit Space Station shall automatically recover functional performance for those capabilities requiring automatic recovery, identified in column 3 of Table 9.9.2.1.6-1 (For FGB, in the scope of Table 3V in SSP50128). The on-orbit Space Station shall automatically safe in less than the time to catastrophic or f critical effect, any hazardous condition or functional operation that may, within 24 hours, manifest a catastrophic or critical hazard.

9.9.1.3 CBCS MUST-NOT WORK FUNCTION REQUIREMENTS

The requirements of this section are applicable to the design of CBCS functions whose inadvertent operation would cause a hazard.

9.9.1.3.1 FAULT CONTAINMENT APPROACH

~~9.9.1.3.1.1~~A. The CBCS shall perform prerequisite checks for the safe execution of hazardous commands.

~~9.9.1.3.1.2~~B. A unique command message shall be required to enable the removal of inhibits.

~~9.9.1.3.1.3~~C. Command messages to change the state of inhibits shall be unique for each inhibit.

~~9.9.1.3.1.4~~D. For inhibits used to control hazards, the CBCS shall make available to the crew and ground operators the status of monitored inhibits.

~~9.9.1.3.1.5~~E. Where hazardous commands can be initiated by a hard-coded failure recovery automated sequence, a separate, functionally independent parameter shall be checked before issuance or execution of each hazardous command.

F. Where hazardous commands can be initiated by a hard-coded failure recovery automated sequence, at least one of the functionally independent parameters checked before issuance or execution of a hazardous command shall be operator controllable.

9.9.1.3.1.7G. Each operator initiated command message used to remove an inhibit that controls a hazard shall be initiated by at least one independent operator action.

9.9.1.3.1.8H. A CBCS shall make available to the crew or ground operators the status of software inhibits used to disable the execution of hazardous commands.

9.9.1.3.1.9I. The CBCS shall make available to crew or ground operators the data, necessary and sufficient, for the performance of manual system safing for identified hazards.

9.9.1.3.1.10J. Individual processors within a CBCS computer (including single processor computers) shall not independently control multiple inhibits to a hazard.

9.9.1.3.2 THE CONTROL PATH SEPARATION (CPS) APPROACH

9.9.1.3.2.1A. For inhibits used to control catastrophic or critical hazards, the CBCS shall make available to the crew or ground operators the status of monitored inhibits.

9.9.1.3.2.2B. A computer-based control system shall have a Separate Control Path (SCP) for each inhibit used to control a hazard.

9.9.1.3.2.3C. Command messages to change the state of an inhibit shall be unique.

9.9.1.3.2.4D. Each SCP initiated by a hard-coded automated failure recovery sequence, shall include a check of at least one parameter functionally independent of the parameters checked by other SCPs initiated by the same sequence.

9.9.1.3.2.5E. At least one functionally independent parameter checked by an SCP initiated by a hard-coded automated failure recovery sequence shall be operator controllable.

9.9.1.3.2.6F. Each operator-initiated command message used to remove an inhibit that controls a hazard shall be initiated by at least one independent operator action.

9.9.1.3.2.7G. For the control of a hazardous function, a computer-based control system shall use SCPs with different functionality for each inhibit used to control the hazard.

9.9.1.3.2.8H. A CBCS shall make available to the crew or ground operators the status of software inhibits used to disable the execution of hazardous commands.

9.9.1.3.2.9I. Capability: Monitor system status

The purpose of this capability is to acquire performance, configuration and status data from the on-orbit Space Station. The acquired data is assessed to determine station, failure, hazard or out-of-sequence events which require operator or automated action.

The on-orbit Space Station shall generate and collect data relating to the operational performance, configuration, status, failures and hazards of all on-orbit Space Station capabilities listed in Table 9.9.2.1.6-1, column 1 (For FGB, in the scope of Table 3V in SSP50128). The on-orbit Space Station shall automatically assess the collected data to detect failures of those capabilities requiring automatic assessment, identified in Table 9.9.2.1.6-1, column 2 (For FGB, in the scope of Table 3V in SSP50128), and to detect hazards that may exhibit a time to catastrophic or critical effect of less than 24 hours.

9.9.2 ABBREVIATIONS AND ACRONYMS

A	Ampere-hour
AC	Alternating Current
AES	Artificial Earth Satellites
AFC	Amplitude Frequency Characteristics
Ah	Ampere-hour
APM	Attached Pressurized Module
ASA	Auxiliary Solar Array
AT	Acceptance Tests
atm	atmosphere
ATV	Automated Transfer Vehicle
AU	Astronomical Unit
BWAD	Bridge Wire Actuated Device
°C	degrees Centigrade
CBCS	Computer-Based Control System
CBCSSTT	Computer-Based Control System Safety Task Team
CE	conducted emissions
cm	centimeter
cm^2	square centimeter
CP	Change Proposals
CPS	Control Path Separation
CR	Cosmic Ray
CRES	Corrosion Resistant Steels
CS01	Conducted Susceptibility
CSC	Computer Software Components
CSCI	Computer Software Configuration Items
CSU	Computer Software Units
cu ft	cubic feet
CVCM	Collected Volatile Condensable Materials
CWS	caution and warning systems
dB	decible
DC	direct current
DD	Design Documentation

DDCU	Direct Current-to-Current Converter Unit
DDT	Design Developmental Test
DISU	Dual Input Switching Unit
DPAT	Developmental Preliminary and Acceptance Test
DS	Design Specification
EDM	Electrical Discharge Machining
EED	Electro-explosive Devices
EEE	Electrical, Electronic, and Electromechanical
EIF	External Influencing Factors
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EPS	Electric Power System
ERB	Earth Radiation Belt
ESA	European Space Agency
ETS	Experimental Test Site
EUT	Equipment Under Test
EVA	extravehicular activity
°F	degrees Fahrenheit
FDIR	Failure Detection, Isolation, and Recovery
FGB	Functional Cargo Block (Russian)
FS	Fluid Systems
g	gravity
g^2/Hz	spectral density of vibration acceleration
GCR	Galactic Cosmic Radiation
GDS	General Design Specification
GFCI	Ground Fault Circuit Interrupter
GHz	Gigahertz
gm	gram
GN&C	Guidance, Navigation, and Control
GSE	Ground Support Equipment
HAB	Habitation Element
HCP	Heavy Charged Particle
He	helium
HF	High Frequency
HWCI	Hardware Configuration Item
Hz	hertz
IBMP	Institute of Biomedical Problems
ICD	Interface Control Document
IET	Integrated Electrical Tests
IP	International Partner

IPT	Integrated Product Team
ISS	International Space Station
ITS	Integrated Truss Segment
IVA	Intravehicular Activity
J	Joule
J/cm^2	Joules per centimeter squared
JEM	Japanese Experiment Module
Kcal	kilocalorie
Kg	kilogram
kHz	kilohertz
km	kilometer
Kohm	kilo ohm
kPa	kiloPascal
kW	kilowatt
lbf	pounds force
LEO	Low Earth Orbit
LET	Linear Energy Transmission
LISN	Line Impedance Stabilization Network
m	meter
M&P	Materials and Processes
m^2	meter squared
MBSU	Main Bus Switching Unit
MDM	Multiplexer Mating Adapter
Mev	Microelectronvolt
MHz	Megahertz
microF	Microfarads µF
microH	Microhenry µH
min	minute
MIT	Massachusetts Institute of Technology
MLI	Multilayer Insulation
MSS	Mobile Servicing System
N	Newton
NaCI	sodium chloride
NASA	National Aeronautics and Space Administration
NDE	Nondestructive Evaluation
NDI	Nondestructive Inspection
NDI/NDT	Non-Destructive Inspection and Testing
NDT	Nondestructive Testing
Nm	Newton meter
NSTS	National Space Transportation System

OIL	Onboard Information Patch Label for the crew (Russian: БИЛ)
OILs	Onboard Information Labels
ORGN	Organization
ORU	Orbital Replacement Unit
PDMA	Pressurized Docking Module Adapter
pF	picoFarad
PG	Product Group
PMA	Pressurized Mating Adapter
POST	Power On Self Test
PP	procedure program
QA	Quality Assurance
QT	Qualification Tests
RACU	Russian American Converter Unit
rad	radiation absorbed dose
RBD	Reliability Block Diagram
REE	Radio-Electronic Equipment
RF	radio frequency
rms	root mean square (quadratic mean)
ROS	Russian Orbital Segment
RPCM	Remote Power Control Mechanism
RPM	revolutions per minute
RS	Russian Segment
RSA	Russian Space Agency
RSC-E	Rocket Space Corporation-Energia
S&MA	Safety and Mission Assurance
SAA	South Atlantic Anomaly
SCP	Separate Control Path
SCR	Solar Cosmic Ray
SDF	Software Development File
SDP	Software Development Plan
sec	second
SLM	Sound Level Meter
SLSS	System of Labor Safety Standards
SM	Service Module
SMC	Station Management and Control
SPL	Sound Pressure Level
SpS	special stability
SRP	Safety Review Panel
SRS	Software Requirements Specification
SS	Space Station

SSCB	Space Station Control Board
SSPE	Space Station Program Element
SSWG	Software Safety Working Group
STD	Software Test Description
STP	Software Test Plan
SV	Space Vehicles
SVTI	Screen-Vacuum Thermal Insulation
TBD	To Be Determined
TCS	Thermal Control System
TLV	Threshold Limit Values
TML	Total Mass Loss
TMM	Thermal Math Models
Torr	1/760 standard atmosphere
TRD	Technical Requirements of Drawings
TS	Technical Specifications
TSR	Technical Specification Review(s)
U	uranium
U.S.	United States
UPS	Uninterruptable Power Supply
USAF	United States Air Force
USGS	United States Ground Segment
USOS	United States On-orbit Segment
USS	United States Segment
UV	ULTRAViolet
V	Volts
W	Watts
w	Wolf numbers
Zc	Secondary Power Bus Source Impedance
Zm	Primary Power Bus Source Impedance

AC	Alternating Current
AES	Artificial Earth Satellites
AFC	Amplitude Frequency Characteristics
Ah	Ampere-hour
APM	Attached Pressurized Module
ASA	Auxiliary Solar Array
AT	Acceptance Test
A.U.	Astronomical Unit
BWAD	Bridge Wire Actuated Device
CBCS	Computer-Based Control System

CBCSSTT	Computer-Based Control System Safety Task Team
CPS	Control Path Separation
CR	Cosmic Ray
CRES	Corrosion Resistant Steels
CSC	Computer Software Components
CSCI	Computer Software Configuration Items
CSU	Computer Software Units
CVCM	Collected Volatile Condensable Materials
DC	Direct Current
DD	Design Documentation
DDCU	Direct Current-to-Current Converter Unit
DDT	Design Developmental Test
DISU	Dual Input Switching Unit
DPAT	Developmental Preliminary and Acceptance Test
DS	Design Specification
EDM	Electrical Discharge Machining
EED	Electro-explosive Devices
EEE	Electrical, Electronic, and Electromechanical
EIF	External Influencing Factors
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
ERB	Earth Radiation Belt
ESA	European Space Agency
EUT	Equipment Under Test
EVA	Extravehicular Activity
FDIR	Failure Detection, Isolation, and Recovery
FGB	Functional Cargo Block (Russian)
FS	Fluid Systems
GDS	General Design Specification
GFCI	Ground Fault Circuit Interrupter
GN&C	Guidance, Navigation, and Control
GSE	Ground Support Equipment
HAB	Habitation Element
HCP	Heavy Charged Particle
HF	High Frequency
HWCI	Hardware Configuration Item
IBMP	Institute of Biomedical Problems
ICD	Interface Control Document
IET	Integrated Electrical Tests
IP	International Partner

IPT Integrated Product Team
ISS International Space Station
ITS Integrated Truss Segment
IVA Intravehicular Activity

JEM Japanese Experiment Module

LET Linear Energy Transmission
LISN Line Impedance Stabilization Network

M&P Materials and Processes
MBSU Main Bus Switching Unit
MDM Multiplexer Mating Adapter
MHZ Megahertz
MLI Multilayer Insulation
MSS Mobile Servicing System

NDE Nondestructive Evaluation
NDI Nondestructive Inspection
NDT Nondestructive Testing
NSTS National Space Transportation System

OIL Onboard Information Patch Label for the crew (Russian: БИЛ)
ORGN Organization
ORU Orbital Replacement Unit

PDMA Pressurized Docking Module Adapter
PG Product Group
PMA Pressurized Mating Adapter
POST Power On Self Test
PP Program Procedures

QT Qualification Test

RACU Russian American Converter Unit
RBD Reliability Block Diagram
REE Radio-Electronic Equipment
rms root mean square (quadratic mean)
ROS Russian Orbital Segment
RPCM Remote Power Control Mechanism
RS Russian Segment

SAA South Atlantic Anomaly
S&MA Safety and Mission Assurance
SCR Solar Cosmic Ray
SDF Software Development File

~~SDP Software Development Plan~~
~~SLM Sound Level Meter~~
~~SLSS System of Labor Safety Standards~~
~~SMC Station Management and Control~~
~~SPL Sound Pressure Level~~
~~SRP Safety Review Panel~~
~~SRS Software Requirements Specification~~
~~SS Space Station~~
~~SSCB Space Sation Control Board~~
~~SSPE Space Station Program Element~~
~~SSWG Software Safety Working Group~~
~~STD Software Test Description~~
~~STP Software Test Plan~~
~~SV Space Vehicles~~
~~SVTI Screen-Vacuum Thermal Insulation~~

~~TBD To Be Determined~~
~~TCS Thermal Control System~~
~~TML Total Mass Loss~~
~~Torr 1/760 atm~~
~~TRD Technical Requirements of Drawings~~
~~TS Technical Specifications~~
~~TSR Technical Specification Review~~

~~UPS Uninterruptable Power Supply~~
~~U.S. United States~~
~~USAF United States Air Force~~
~~USS United States Segment~~
~~USGS United States Ground Segment~~
~~USOS United States On-orbit Segment~~

~~V Volts~~

~~W Watts~~

TABLE 9.9.2.1.6-1 Capabilities requiring automatic FDIR capability (if they are implemented by using a Computer)

Space Station Capability (1)	Automatic Assessment (2)	Automatic Recovery (3)
Control atmospheric pressure	X	X
Condition atmosphere	X	
Light station		
Respond to loss of function	X	X
Control station	X	X
Support crew control interface	X	

Space Station Capability (1)	Automatic Assessment (2)	Automatic Recovery (3)
Monitor system status	X	X
Respond to emergency conditions	X	X
Support user payloads	X	
Provide electrical power	X	X
Maintain thermal conditioning	X	X
Provide time reference	X	X
Support flight crew		
Control internal carbon dioxide and contaminants	X	
Provide water	X	
Provide visual access		
Facilitate internal voice communication	X	
Prepare for EVA operations	X	
Determine navigation parameters	X	X
Maintain attitude - nonpropulsive	X	X
Support on-orbit-ground communication	X	X
Support internal equipment manipulation and maintenance		
Support Space Station to external vehicle communication		
Execute translation maneuvers	X	X
Control attitude - propulsive	X	X
Support microgravity experiments	X	
Support assured crew return	X	X
Support EVA operations		
Support external robotic operations	X	
Support prelaunch and postlanding operations		
Support resupply and return		

Notes:

(1) Capabilities listed in this column are allocated to on-orbit ISS segments and require generation of performance, configuration, and status data.

(2) An "X" in this column indicates the capability requires, at a minimum, automatic failure detection.

(3) An "X" in this column indicates the capability requires automatic failure isolation and recovery (i.e., capability supports 24 hour autonomy).

9.9.3 DEFINITIONS

Anomaly - A state or condition which is not expected. It may be hazardous but it is the result of a transient hardware or coding error.

Catastrophic Hazard - Any condition which may cause a disabling or fatal personnel injury, or cause loss of one of the following: the Orbiter, ISS, or major ground facility. Loss of ISS: Loss of the ISS is to be limited to those conditions resulting from failures or damages to elements in the critical path of the ISS that render the ISS unusable for further operations, even with contingency repair or replacement of hardware, or which render the ISS in a condition which prevents further rendezvous and docking operations with ISS launch elements.

Command Message - The structure of bits within a CBCS that represent an operator or system-initiated command.

Computer-Based Control System (CBCS) - A control system which utilizes computer hardware, software, and/or firmware which accepts input information, and processes that information to provide outputs to perform a defined task.

Computer Hardware - Devices capable of accepting and storing computer data, executing a systematic sequence of operations on computer data, or producing control outputs. Such devices can perform substantial interpretation, computation, communication, control, or other logical functions.

Computer Program - A combination of computer instructions and data definitions that enable computer hardware to perform computational or control functions.

Control Path - The logical sequence of flow of a control or command message from the source to the implementing effector or function. A control path may cross the boundaries of two or more computers. Portions of multiple control paths may exist in a single computer.

Credible Failure - A condition that has a potential of occurring based on actual failure modes in similar systems.

Critical Hazard - Any condition which may cause a non-disabling personnel injury, severe occupational illness; loss of an ISS element, on-orbit life sustaining function or emergency system; or involves damage to the Orbiter or a major ground facility. For safety failure tolerance considerations, critical hazards include loss of ISS elements that are not in the critical path for station survival or damage to an element in the critical path which can be restored through contingency repair.

Database - A collection of related data stored in one or more computerized files in a manner that can be accessed by users or computer programs via a database management system.

Design for Minimum Risk - Design for minimum risk are areas where hazards are controlled by specification requirements rather than failure tolerance. Examples are structures, pressure vessels, pressurized lines and fittings, functional pyrotechnic devices, material compatibility, flammability, etc.

Error Handling - An implementation (system or compiler feature) mechanism or design technique by which software faults are detected, isolated, and recovered to allow for correct runtime program execution.

Firmware - The combination of a hardware device and computer instructions and/or computer data that reside as read-only software on the hardware device.

Hard-coded - Refers to a sequence of autonomous commands which are embedded in either software or firmware (either on-orbit or ground based).

Hazard - The presence of a potential risk situation caused by an unsafe act or condition. A condition or changing set of circumstances that presents a potential for adverse or harmful consequences; or the inherent characteristics of any activity, condition, or circumstance which can produce adverse or harmful consequences.

Hazardous Command - A command that can create an unsafe or hazardous condition which potentially endangers the crew or station safety. It is a command whose execution can lead to an identified hazard or a command whose execution can lead to a reduction in the control of a hazard.

Hazard Controls - Design or operational features used to reduce the likelihood of occurrence of a hazardous effect. Hazard controls are implemented in the following order of precedence:

A. Elimination of hazards by removal of hazardous sources and operations by appropriate design measures.

B. Prevention of hazards through the use of safety devices or features.

C. Control of hazards through the use of warning devices.

D. Special procedures and/or emergency devices.

E. Minimization of hazards through a maintainability program and adherence of adequate maintenance and repair schedule(s).

Independent Command - Two or more commands are independent if no single credible failure, event, or environment can eliminate more than one command from performing its intended function.

Independent Inhibit - Two or more inhibits are independent if no single credible failure, event, or environment can eliminate more than one inhibit.

Independent Parameter - A parameter is independent from an automated function if (a) neither the fault(s) that could initiate the automated function nor (b) the operation of the automated function itself can change the value or status of the parameter.

Independent Safing Action - Safing actions are independent if no single fault can prevent one or more of the safing actions from transitioning the system to a safe state.

Inhibit - A design feature that provides a physical interruption between an energy source and a function (e.g., a relay or transistor between a battery and a pyrotechnic initiator, a latch valve between a propellant tank and a thruster, etc.). Note: Software inhibits are not counted in meeting safety requirements for multiple inhibits.

Interlock - A design feature that ensures that any conditions prerequisite for a given function or event are met before the function or event can proceed.

Near Real Time Monitoring - Notification of changes in inhibit or safety status on a periodic basis (nominally once per orbit).

Operator Error - An inadvertent action by flight crew or ground operator that could eliminate, disable, or defeat an inhibit, redundant system, containment feature, or other design feature that is provided to control a hazard.

Override - The forced bypassing of prerequisite checks on the operator-commanded execution of a function. Execution of any command (whether designated as a “hazardous command” or not) as an override is considered to be a hazardous operation requiring strict procedural controls and operator safing.

Prerequisite Checks - The validation by the CBCS that coded states or conditions necessary for the execution of a command has been met.

Real Time Monitoring - Notification of changes in inhibit or safety status to the crew.

Reflown Hardware - Payloads or elements of payloads which are made up of hardware items that have already physically flown on the Orbiter and are being manifested for reflight.

Risk - Exposure to the chance of injury or loss. Risk is a function of the possible frequency of occurrence of an undesirable event, of the potential severity of the resulting consequences, and of the uncertainties associated with the frequency and severity.

Safe - A general term denoting an acceptable level of risk, relative freedom from and low probability of: personal injury; fatality; loss or damage to vehicles, equipment, or facilities; or loss or excessive degradation of the function of critical equipment.

Safety Critical - A condition, event, operation, process, function, equipment or system (including software and firmware) with potential for personnel injury or loss, or with potential for loss or damage to vehicles, equipment, or facilities, loss or excessive degradation of the function of critical equipment, or which is necessary to control a hazard.

Safety Critical Software - Software which:

A. Exercises direct command and control over the condition or state of hardware components or software functions and, if not performed or if performed out of sequence or incorrectly, could result in control function loss or error which could cause a hazard.

B. Monitors the condition or state of hardware components and, if monitoring is not performed or is performed incorrectly, could provide data which results in erroneous operator or companion system decisions which could cause a hazard.

C. Exercises direct command and control over the condition or state of hardware components or software functions and, if not performed or if performed out of sequence or incorrectly in conjunction with human error or hardware failure, could cause a hazard.

Separate Control Path (SCP) - A control path which provides functional independence to a command used to control an inhibit to an identified critical or catastrophic hazard. Functional independence exists when no other control path exists which can remove a hazard's inhibit belonging to this SCP. SCPs controlling different inhibits for the same hazard may co-exist within the same processor.

Software - Computer programs and computer databases. As used in a CBCS, "software" refers to all flight software regardless of the media on which the software resides, including software that resides on hardware devices (i.e., firmware).

Software Controllable Inhibit - A system-level "hardware" inhibit whose state is controllable by software commands.

Software Error - The difference between a computed, observed, or measured value or condition and the true, specified, or theoretically correct value or condition.

Software Fault - An incorrect step, process, or data definition in a computer system.

Software Inhibit - A software or firmware feature that prevents a specific software event from occurring or a specific software function form being available.

Time to Criticality - The time between the occurrence of a failure, event, or condition and the subsequent occurrence of a hazard or other undesired outcome. Time to criticality will be established by engineering or operational analysis.

10 PROPULSION

10.1 PROPELLANT

10.1.1 NONSYMMETRICAL DIMETHYLHYDRAZINE (NSDH) (UDMH).

This propellant is used in all Russian Orbital Segment (ROS) propulsion systems. This propellant must satisfy the requirements and composition specified in Table 10.1.1-1. The composition "during fabrication" is verified while the propellant is being manufactured at the plant, while the composition "during use" is verified while the propellant is being loaded into the space vehicle prior to launch.

Table 10.1.1-1 Composition of NSDH (UDMH) used on the ROS

Component	Composition		
	Unit of measurement	During fabrication	During use
NSDH[1] (UDMH)	% w/w	≥99.0	≥98.6
H_2O	% w/w	≤0.2	≤0.35
Dimethylamine	% w/w	≤0.5	not determined
Methanol	% w/w	≤0.4	not determined
Dissolved iron	% w/w	<0.00005	≤0.0001
Density	g/cm^3	0.787-0.797	0.787-0.797
Particles	% w/w	≤0.001	≤0.001

10.1.2 NITROGEN TETROXIDE

Nitrogen tetroxide is the oxidant used in ROS propulsion systems. This liquid must satisfy the requirements specified in Table 10.1.2-1; and requirements "during use" are verified while loading on the space vehicle.Nitrogen tetroxide is the oxidant used in ROS propulsion systems. This liquid must satisfy the requirements specified in Table 10.1.2-1; requirements "during fabrication" are verified at the manufacturing plant, and requirements "during use" are verified while loading on the space vehicle.

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Table 10.1.2-1 Composition of nitrogen tetroxide (N_2O_4) used on the ROS

Component	Composition		
	Unit of measurement	During fabrication	During use
N_2O_4	% w/w	≥98.7	≥98.2
NO	% w/w	0.5-0.8	0.2-0.8
Dry residue [1]	% w/w	≤5 x 10^{-4}	≤5 x 10^{-4}
Process impurities	% w/w	0.5	1.0

Component	Composition	
	Unit of measurement	During use
N_2O_4	% w/w	≥98.2
NO	% w/w	0.2 - 0.8
Dry residue [1]	% w/w	≤2 x 10^{-4}
Process impurities	% w/w	≤0.5

NDC 023

Note: [1] Percent by weight of dry residue describes the total amount of inorganic and organic impurities in the oxidant.

10.2 PRESSURIZATION GAS

10.2.1 HELIUM GAS

Gaseous helium satisfying the requirements specified in Table 10.2.1-1 is used to generate pressure in the Russian propulsion system.

Table 10.2.1-1 Composition of helium gas used to generate pressure in the ROS propulsion system [1]

Component	Purified helium, B grade [2]
Helium + neon, min. 3	99.99
Hydrogen, max.	0.0025
Nitrogen, max.	0.004
Oxygen + argon, max.	0.002
CO2 + CO. max.	0.001
Hydrocarbons, max.	0.003
Neon, max.	0.04
Dew point, °C, max.	minus 55 [4]

Notes:
[1] Taken from Table 1, TU-51-940-80
[2] Values given in percent by volume.
[3] Percent by volume for helium as calculated for dry substance
[4] Per operating documentation

10.2.2 NITROGEN GAS

Gaseous nitrogen satisfying the requirements specified in Table 10.2.2-1 per OST 92-1577-78, Category I is used as the gas for pressurizing the ROS propulsion system.

Table 10.2.2-1 Composition of gaseous nitrogen used for pressurizing the ROS propulsion system [1]

Admixture type	Verified purity index	Gaseous nitrogen, Category 1
Water	Dew point, °C, max., at pressure of 1 atm, physical	minus 55
Oil	Content as vapors, aerosols, liquids, mg/m3. max.	3
Mechanical impurities	Content as vapors, aerosols, liquids, mg/m3, max.	0.1
Oxygen in nitrogen	Content, % v/v,. max.	1.0*

Note: *Taken from GOST 9293-74, Table 1, industrial, 2nd grade.

11 RESERVED

12 ——— 12 STANDARD DEFINITION OF COORDINATE SYSTEMS

The standard coordinate systems are defined is SSP 30219, Space Station Reference Coordinate Systems.

NDC 022

Figure 12-1 Russian Segment (SM) Coordinate System Definition

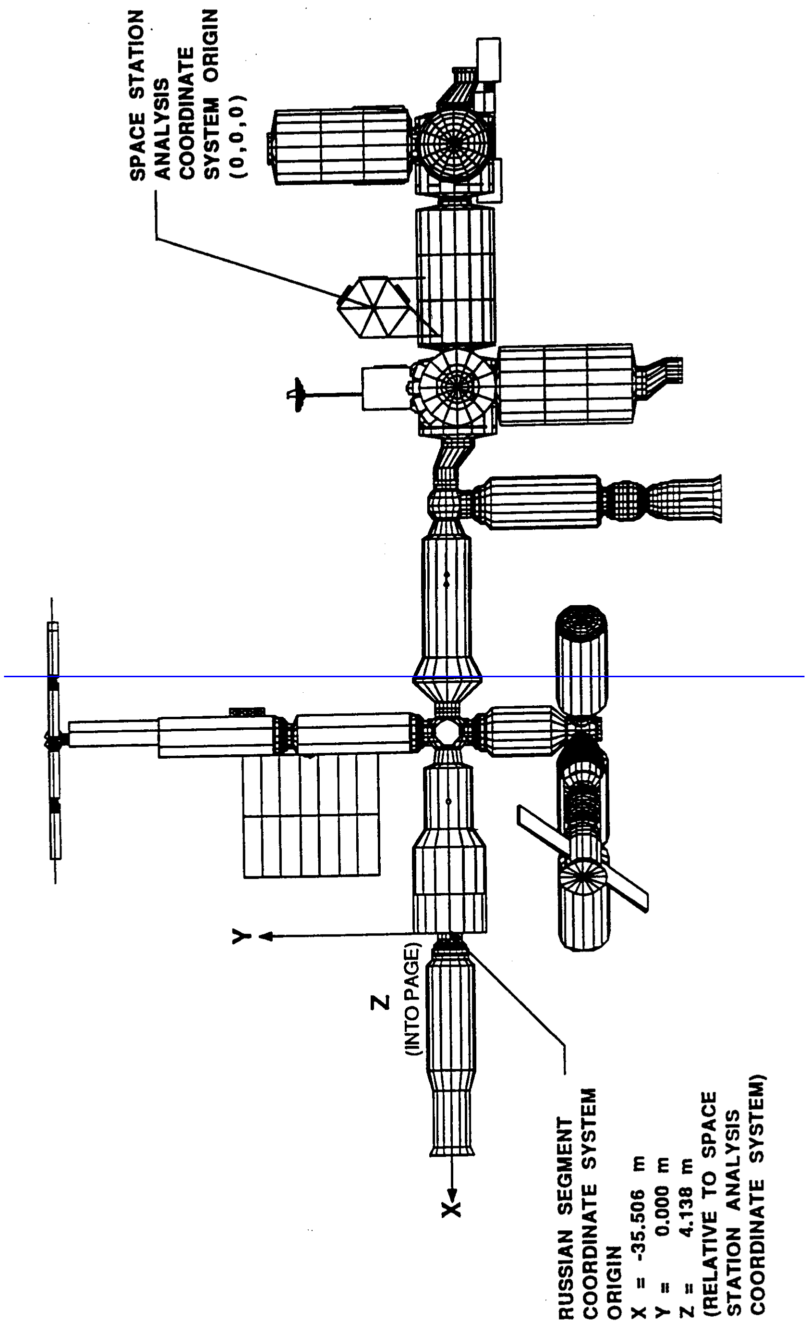
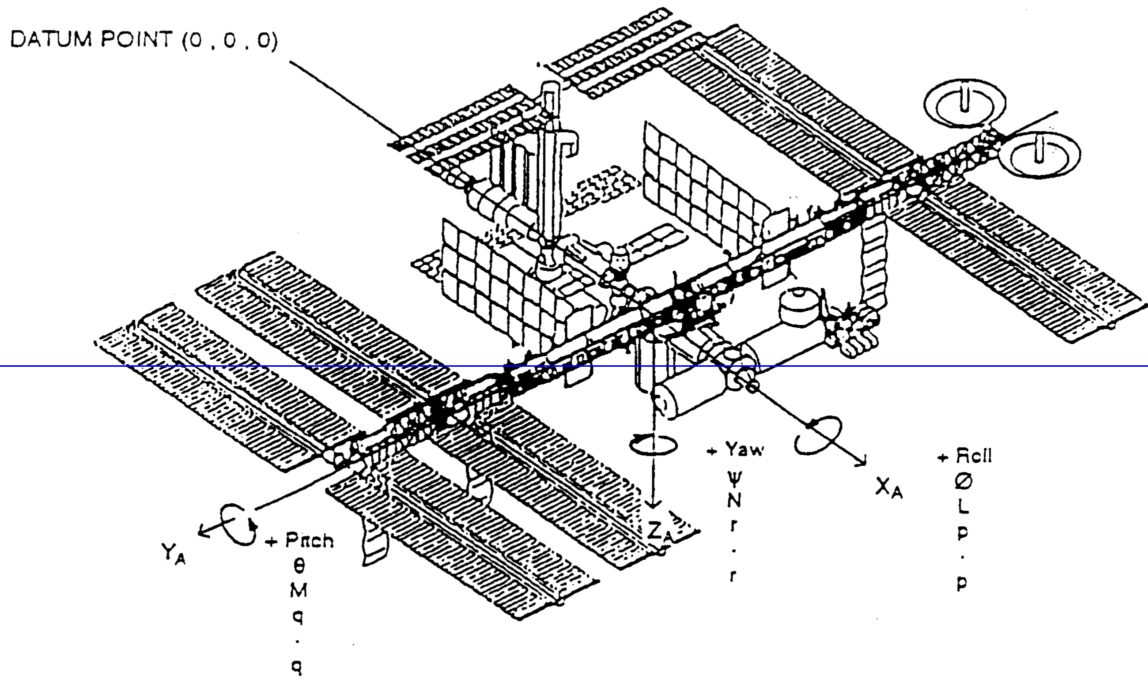


Figure 12-2 Space Station Analysis Coordinate System



NAME: Space Station Analysis Coordinate System

TYPE: Rotating Right-Handed Cartesian, Body-Fixed

DESCRIPTION: This coordinate system is derived using the Local Vertical Local Horizontal (LVLH) flight orientation. When defining the relationship between this coordinate system and another, the Euler angle sequence to be used is a yaw, pitch, roll sequence around the Z_A, Y_A and X_A axes, respectively.

ORIGIN: The origin is located at the geometric center of Integrated Truss Segment (ITS) S0 an is coincident with the datum point.

ORIENTATION: X_A The X-axis is parallel to the longitudinal axis of the module cluster. The positive X-axis is in the forward direction.

Y_A The Y-axis is coincident with the alpha joint rotational axis. The positive Y-axis is in the starboard direction.

Z_A The positive Z-axis is in the direction of nadir and completes the rotating right-handed Cartesian system.

L, M, N: Moments about X_A, Y_A and Z_A axes, respectively.

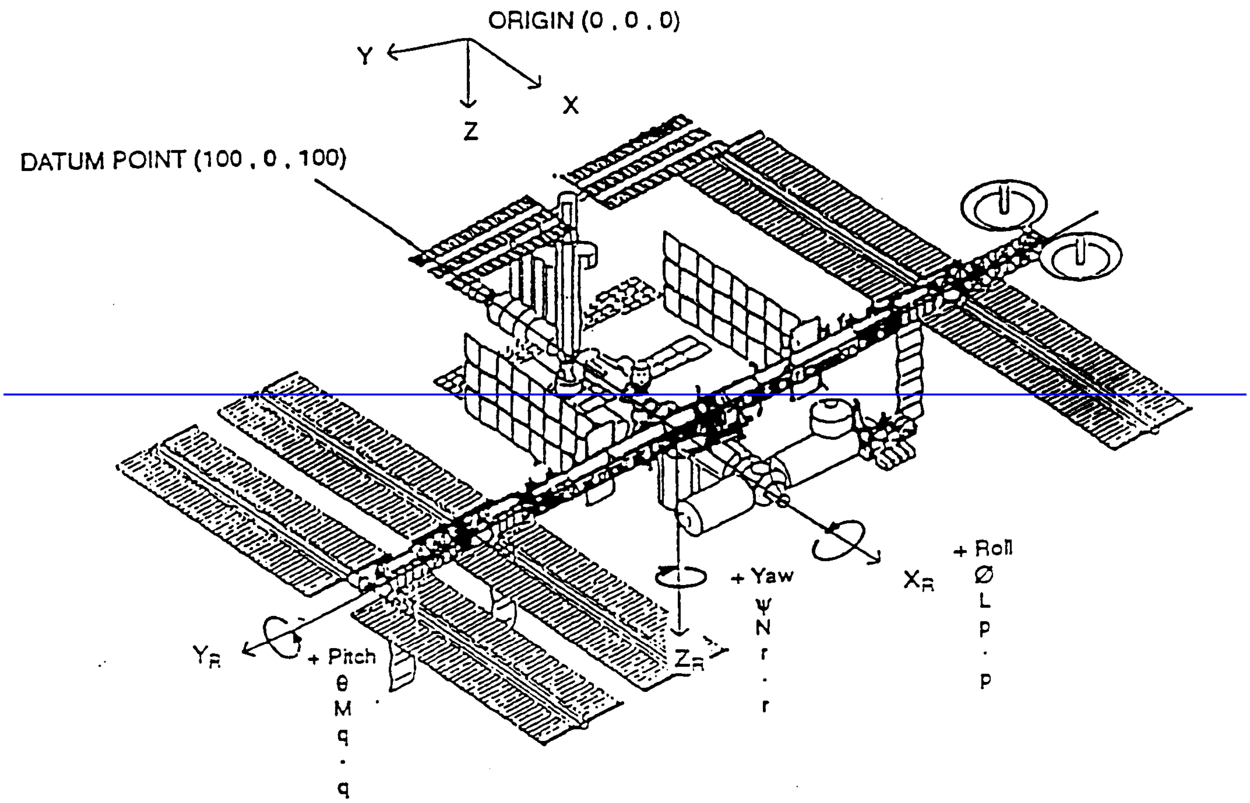
p, q, r: Body rates about X_A, Y_A and Z_A axes respectively.

p. q. r: Angular body acceleration about X_A, Y_A and Z_A axes respectively

SUBSCRIPT: A

- Based on Reference Coordinate System

Figure 12-3 Space Station Reference Coordinate System



~~**NAME:** **Space Station Reference Coordinate System**~~

~~**TYPE: Rotating Right-Handed Cartesian, Body Fixed**~~

~~**DESCRIPTION:** **This coordinate system is derived using the LVLH flight orientation. When defining the relationship between this coordinate system and another, the Euler angle sequence to be usedis a yaw, pitch, roll sequence around the Z_R, Y_R, and X_R axes, respectively.**~~

~~**ORIGIN:** **The datum point is located at the geometric center of ITS S0. The origin is located such that the datum point is located at X_R=100, Y_R=0, and Z_R=100 meters.**~~

~~**ORIENTATION:** **X_R The X-axis is parallel to the longitudinal axis of the U. S. Laboratory. The positive X-axis is in the forward direction.**~~

~~**Y_R The Y-axis is coincident with the alpha joint rotational axis. The positive Y-axis is in the starboard direction.**~~

~~**Z_R The positive Z-axis is in the direction of nadir and completes the rotating right-handed Cartesian system.**~~

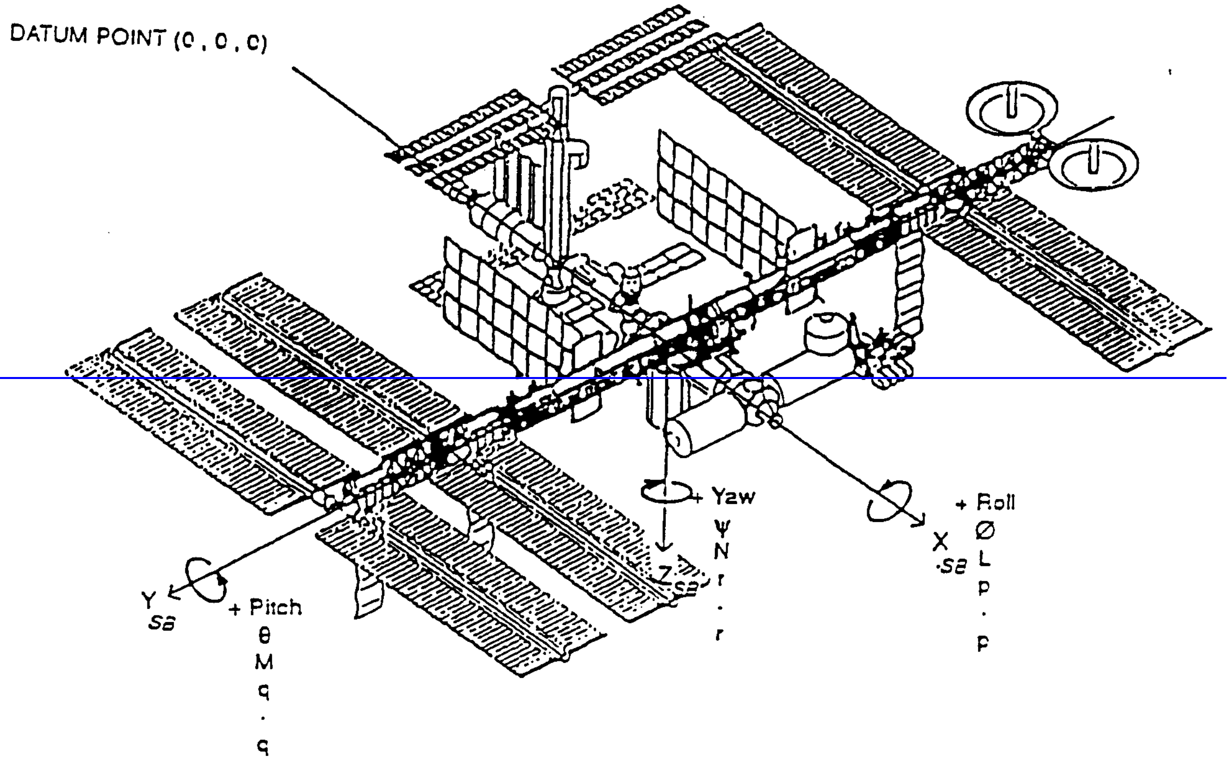
~~**L, M, N: Moments about X_R, Y_R and Z_R axes, respectively.**~~

~~**p, q, r: Body rates about X_R, Y_R, and Z_R axes, respectively**~~

~~**p. q. r: Angular body acceleration about X_R, Y_R, and Z_R axes, respectively**~~

~~**SUBSCRIPT:** **R**~~

Figure 12-4 Space Station Body Coordinate System



NAME: **Space Station body Coordinate System ***

ORIENTATION AND DEFINITIONS:

The origin is located at the Space Station center of mass.

The X_{SB} axis is perpendicular to the keels and booms. Positive X_{SB} is in the forward flight direction.

The Y_{SB} axis is parallel to the transverse boom and perpendicular to the X_{SB} axis. Positive Y_{SB} is toward starboard.

The Z_{SB} axis is parallel with the Keels. Positive Z_{SB} is approximately toward nadir and completes the right-handed system, X_{SB}, Y_{SB}, Z_{SB}.

CHARACTERISTICS:

Rotating right-handed Cartesian system.

When defining the relationship between this coordinate system and another, the Euler angle sequence to be used is a yaw, pitch, roll sequence around the Z_{SB}, Y_{SB}, and X_{SB} axes, respectively.

L, M, N: Moments about X_{SB}, Y_{SB}, and Z_{SB} axes, respectively.

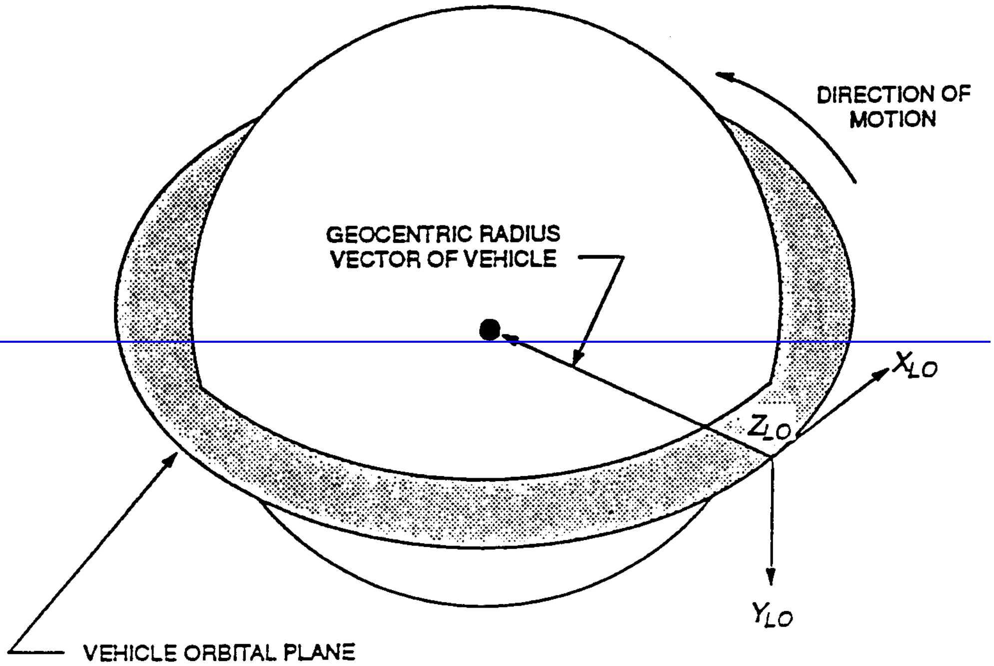
p, q, r: Body rates about X_{SB}, Y_{SB}, and Z_{SB} axes, respectively.

p, q, r: Angular body acceleration about X_{SB}, Y_{SB}, and Z_{SB} axes respectively.

SUBSCRIPT: **SB**

*** Based on Reference Coordinate System**

Figure 12-5 Local orbital: Local Vertical Local Horizontal



NAME: Local Orbital (LVLH) Coordinate System
ORIGIN: Vehicle center of mass
ORIENTATION: The X_{LO} - Z_{LO} plane is the instantaneous orbit plane at the time of interest.

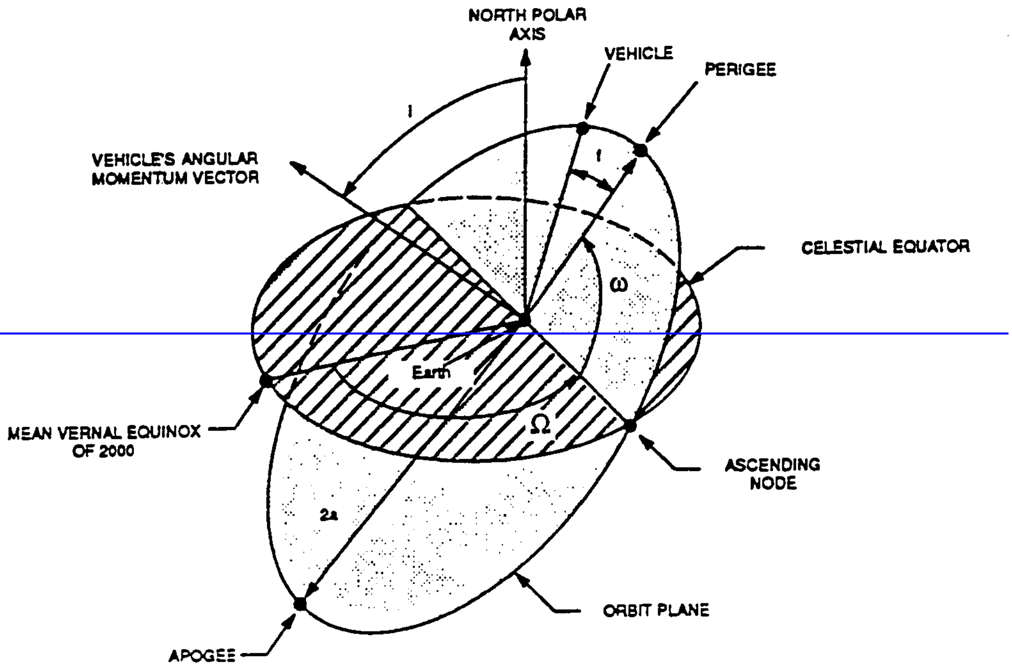
The Z_{LO} axis lies along the geocentric radius vector to the vehicle and is positive toward the center of the Earth.

The X_{LO} axis lies in the vehicle orbital plane, perpendicular to the Z_{LO} axis, and positive in the direction of vehicle motion.

The Y_{LO} axis is normal to the orbit plane and completes the right-handed orthogonal system.

CHARACTERISTICS: Quasi-inertial right-handed Cartesian Coordinate System.

Figure 12-6 Orbital Elements



NAME: Orbital Element System
ORIGIN: The center of the Earth
ORIENTATION AND DEFINITIONS:

The reference for computing osculation orbital elements is the J2000 Coordinate System.

a is the instantaneous semi-major axis of the orbit.

e is the instantaneous eccentricity of the orbit.

I, the inclination of the orbital plane, is the instantaneous angle between the mean inertial north polar axis and the orbital angular momentum vector.

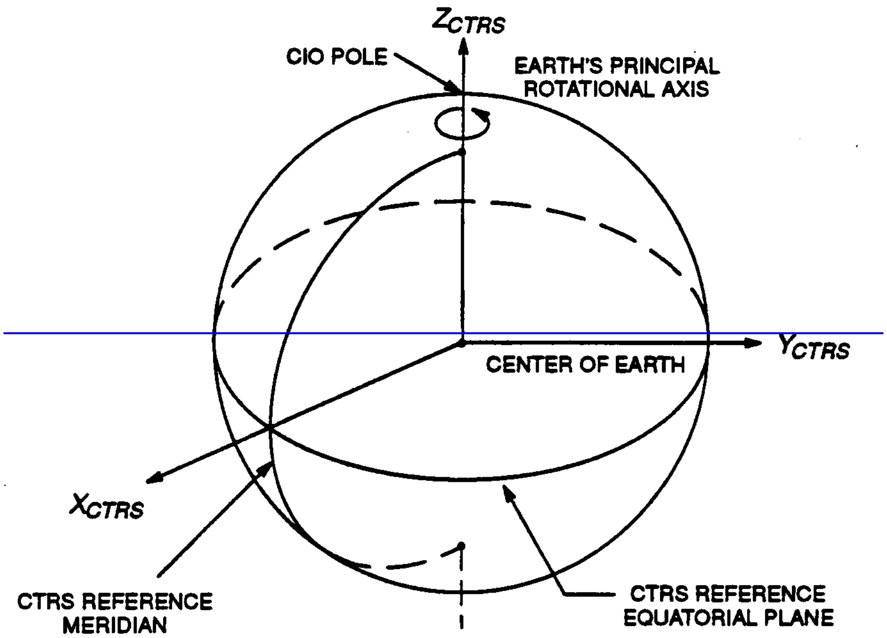
Ω, the right ascension of the ascending node, is the angle measured eastward from the vernal equinox along the equator to that intersection with the orbit plane where the vehicle passes from south to north. In the case where inclination equals zero, the ascending node is defined to be the X-axis of the inertial reference system.

□, the argument of perigee, is the angle measured in the orbit plane between the ascending node and perigee, positive in the direction of travel in the orbit. In the case where eccentricity equals zero, perigee is defined to be a the ascending node.

f, the true anomaly, is the geocentric angular displacement of the vehicle measured from perigee in the orbit plane, and positive in the direction of travel in the orbit.

CHARACTERISTICS: Quasi-inertial

Figure 12-7 Conventional Terrestrial Reference System



NAME: Conventional Terrestrial Reference System Coordinate System
TYPE: Rotating Right-Handed Cartesian
DESCRIPTION: The Convention Terrestrial Reference System (CTRS) is an updated Earth-fixed system that incorporates polar motion. The CTRS is related to the GTOD by the transformation. The CTRS assumes a spherical Earth and does not take any flatening factors into account, therefore, any definitions of altitude should be derived from the Geodetic Coordinate System.

$$\begin{pmatrix} x \\ y \\ z \end{pmatrix}_{CTRS} = \begin{bmatrix} 1 & 0 & xp \\ 0 & 1 & -yp \\ -xp & yp & 1 \end{bmatrix} \begin{pmatrix} x \\ y \\ z \end{pmatrix}_{GTOD}$$

Where xp and yp are angular coordinates (very small angles measured in tenths of an arc-second) of the Celestial Ephemeris Pole (CEP) with respect to the Conventional International Origin (CIO). This data is published weekly by the U. S. Naval Observatory in the International Earth Rotation Service Bulletin - A. The Global Positioning Satellite (GPS) ephemerides in the CTRS.

ORIGIN: The origin is located at the Earth's Center.
ORIENTATION: The pole of this system is known as the CIO.

Z_{CTRS} The Z-axis is coincident with the Earth's principal rotational axis. The positive Z-axis is directed toward the CIO.

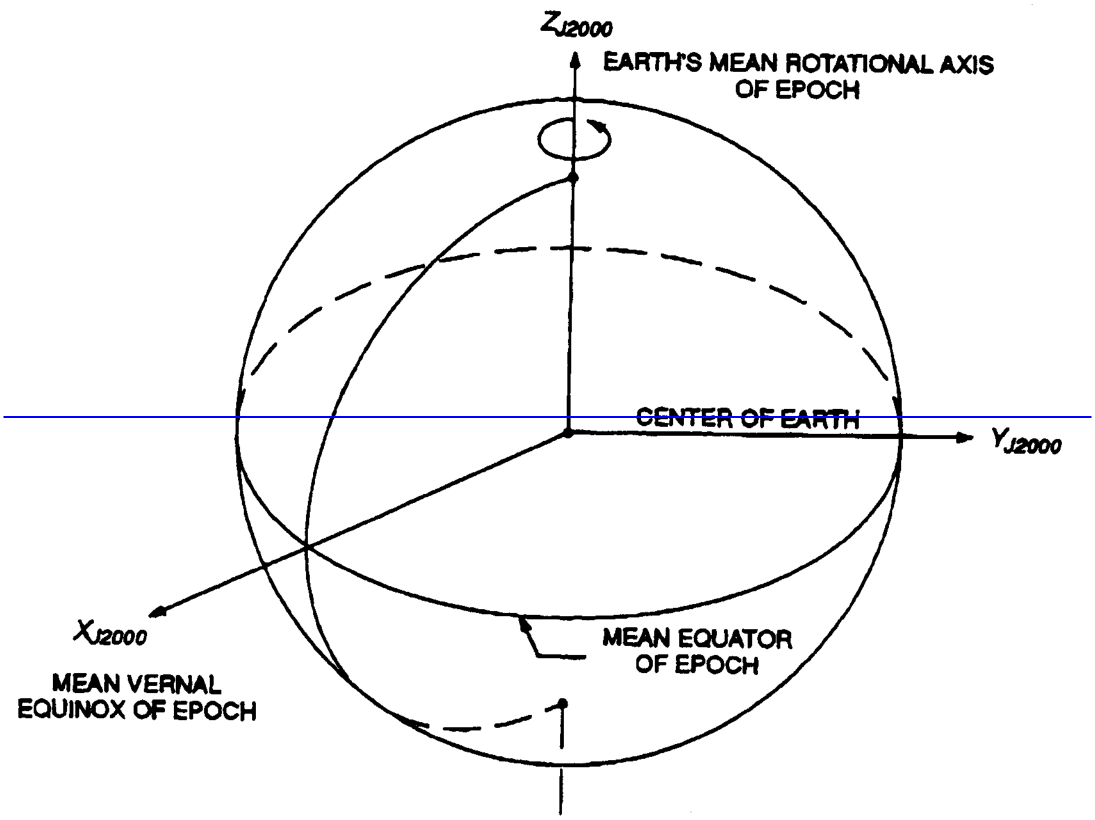
X_{CTRS} The x-axis passes through the intersection of the CTRS reference equatorial plane and the CTRS reference

~~meridian. The positive X-axis is the direction of the CTRS reference meridian.~~

~~Y_{CTRS} The positive Y-axis completes the rotating right-handed Cartesian system.~~

~~**SUBSCRIPT:** CTRS~~

Figure 12-8 J2000, Mean of 2000, Cartesian



NAME: J2000, Mean of 2000, Cartesian Coordinate System *
ORIGIN: The center of the Earth
ORIENTATION: The epoch is 2000 January 1.5 of Julian ephemeris date 2451545.0.
The X_{J2000} - Y_{J2000} is the mean Earth's equator of epoch.
The X_{J2000} axis is directed toward the mean vernal equinox of epoch
The Z_{J2000} axis is directed along the Earth's mean rotational axis of epoch and is positive north.
The Y_{J2000} axis completed a right-handed system.
CHARACTERISTICS: Inertial right-handed Cartesian system.

* A source document which discusses the expression of vectors in mean of 2000, rather than mean of 1950, coordinates is U. S. Naval observatory Circular No. 163, "The International Astronomical Union Resolutions on Astronomical Constants, Time Scales, and the Fundamental Reference Frame." Washington, D. C. 20390, December 19. 1981.

13 —13. THERMAL CONTROL

TBR

13.1 INTRODUCTION

The ISS must maintain thermal conditioning. This task of maintaining thermal conditioning includes the collection of thermal energy from internal sources, the transmission of the thermal energy and the disposal of the thermal energy. (SSP-41163, Russian Segment Specification, International Space Station Program, para.3.2.1.1.1.10)

The thermal energy disposal capability of an ISS element is determined by its individual radiation environment. However, individual elements of the ISS experience radiation interchange with other ISS elements. Individual elements also experience direct solar radiation or blockage, solar radiation reflected from other ISS elements and from the Orbiter, while the Orbiter is near the ISS or while docked at the ISS. Individual elements of the ISS experience solar reflection from the earth and earth's long wave radiation. These are the major factors in determining an individual element's radiation environment and its capability of disposing thermal energy.

The task of defining the net radiation environment for an individual element is complex and requires very detailed computations. These computations consider the view factors of surfaces to all other surfaces, the optical properties of all the surfaces and the orientation of the ISS, its orbital parameters and point on orbit, with respect to the earth and to the sun. Tools used to perform these computations use input data which describe the geometry of each surface of each element, each surface's optical properties, the location of each surface with respect to each other and the orbit and the specific orbit's parameters. These sets of input data, each describing a specific stage of the ISS build, are referred to as Thermal Math Models (TMMs).

As part of the ISS thermal control integration task, the Prime Contractor- issued SSP-50023, the ISS Thermal Control Plan. As required by the ISS Thermal Control Plan, master thermal math models of the ISS elements have been built, and integrated by the Prime Contractor. These thermal math models are maintained under configuration control as part of this Thermal Control Plan and are necessary for use in verification, as detailed in the Thermal Control Subsystem Verification Plan. The official thermal math models of the ISS are contained in SSP-50120, On-Orbit Integrated Thermal Analysis Models Report, International Space Station Program.

13.2 ON-ORBIT THERMAL RADIATION ENVIRONMENT AND PLUME HEATING ENVIRONMENT

The International Space Station shall be exposed to the hot and cold natural thermal radiation environments specified in SSP-41163, Russian Segment Specification, International Space Station Program. Note 5 referenced in the tables within the specification is noted as Table 13.2-1.

Table 13.2-1 Outgoing Longwave Radiation: top of the atmosphere, 30km, units are W/m^2

Avg. Time(s)	*Lowest Observed**	*1%*	*3%*	*5%*	*50%*	*95%*	*97%*	*99%*	*Highest Observed*
16									
64	*153*	*177*	*189*	*195*	*242*	*284*	*291*	*307*	*349*
128	*154*	*178*	*189*	*196*	*242*	*284*	*291*	*307*	*348*
256	*156*	*180*	*191*	*197*	*242*	*283*	*290*	*306*	*347*
512	*162*	*185*	*195*	*201*	*242*	*281*	*287*	*303*	*342*
896	*176*	*195*	*204*	*208*	*241*	*275*	*280*	*294*	*332*
1344	*189*	*204*	*211*	*214*	*241*	*269*	*274*	*283*	*317*
1800	*197*	*209*	*215*	*218*	*241*	*266*	*270*	*278*	*303*
2688	*199*	*212*	*217*	*220*	*241*	*265*	*269*	*276*	*296*
3600	*204*	*215*	*219*	*221*	*241*	*263*	*267*	*273*	*291*
5400	*206*	*217*	*221*	*223*	*241*	*262*	*265*	*273*	*286*
	208	*219*	*223*	*225*	*241*	*260*	*263*	*270*	*281*

* Set at 0.4 percentile, eliminating a very few unrealistically low data points.

13.3 ON-ORBIT THERMAL PLUME ENVIRONMENT

The plume heating environments applicable to the on-orbit conditions for ISS are specified in SSP-50122. These environments shall be used where applicable to determine the overall induced environments for specific vehicle configurations. Environments for cases not specified in SSP-50122 shall be discussed with NASA. NASA, upon agreement, will generate environments to satisfy the concern.

13.4 ISS RADIATION INTERCHANGE INTERFACE CONTROL

The thermal interaction between Space Station elements shall be derived in accordance with analyses performed using the official Space Station thermal math models in SSP-50120. These analyses shall address shadowing and radiant energy interaction between Space Station elements, the NSTS Orbiter and other vehicles; heating of surfaces due to Orbiter vehicle plume impingement as given in SSP-50122, Plume Heating Environments; plumes from other sources; heat from electrical power loads; parasitic losses, crew metabolic loads and electrochemical sources. The analyses shall verify element performance using configuration data, thermal interface data, material data, and equipment and test data. The Orbiter induced thermal environments shall be derived using thermal math models, as specified in the ISS Thermal Control Plan, SSP-50023.

Element configuration changes, surface optic changes and other changes which impact the energy balance of the vehicle, shall be analyzed before and after the change, using the official ISS models and impacts shall be assessed. Based upon this assessment, the vehicle integrator, in concurrence with the parties impacted by the change, shall make the final decision for the change.

APPENDIX A

50094 Specification Paragraph Number/Title	Team	NASA Contact	Contractor Contact	SSP Document Reference	SSP Reference Paragraph Number	Comments
1.0	RS AIT	R. Wang		N/A	N/A	
1.1	RS AIT	R. Wang		N/A	N/A	
1.2	RS AIT	R. Wang		N/A	N/A	
1.3	RS AIT	R. Wang		N/A	N/A	
2.0	RS AIT	R. Wang		N/A	N/A	
2.1	RS AIT	R. Wang		N/A	N/A	
3.0 (Title)	Envr.	M. Pedley		N/A	N/A	
3.1 (Reserved)	Envr.	M. Pedley		N/A	N/A	
3.2 (Title)	Envr.	M. Pedley		N/A	N/A	
3.2.1	Envr.	M. Pedley		41000	3.2.6.1.2	41000E
3.2.1	Envr.	M. Pedley		30425	4.3	30425B
3.2.1.1	Envr.	M. Pedley		30425	4.3	30425B
3.2.1.2	Envr.	M. Pedley		30425	4.3	30425B
3.2.2	Envr.	M. Pedley		41000	3.2.6.1.2	40001E
3.2.2	Envr.	M. Pedley		30425	4.5	30425B
3.3 (Title)	Envr.	M. Pedley	R. Mikatarian	30426		
3.3.1	Envr.	M. Pedley	R. Mikatarian	30426	3.3	30426D
3.3.2	Envr.	M. Pedley	R. Mikatarian	30426	3.6	30426D
3.3.3 (Title)	Envr.	M. Pedley	R. Mikaterian	30426		
3.3.3.1 (Reserved)	Envr.	M. Pedley	R. Mikatarian	30426		30426D
3.3.3.2	Envr.	M. Pedley	R. Mikatarian	30426	3.4.3	30426D
3.3.4 (Title)	Envr.	M. Pedley	R. Mikatarian	30426		
3.3.4.1 (Reserved)	Envr.	M. Pedley	R. Mikatarian	30426		30426D
3.3.4.2 (Reserved)	Envr.	M. Pedley	R. Mikatarian	30426		30426D
3.3.5 (Title)	Envr.	M. Pedley	R. Mikatarian	30426	3.3.2 & subs.	30426D
3.3.5.1	Envr.	M. Pedley	R. Mikatarian	30426		
3.3.5.2	Envr.	M. Pedley	R. Mikatarian	30426		
3.4	EMC	M. McCollum	K. Rice	30243	3.2.1	30243D
3.4.1	EMC	M. McCollum	K. Rice	No US equiv	N/A	Russian Internal Requirment
3.4.1.1	EMC	M. McCollum	K. Rice	30243	3.2.1	30243D
3.4.1.1.1	EMC	M. McCollum	K. Rice	No US equiv	N/A	
3.4.1.1.2	EMC	M. McCollum	K. Rice	No US equiv	N/A	
3.4.1.1.3	EMC	M. McCollum	K. Rice	30237	3.2.3.1.2	30237
3.4.1.2	EMC	M. McCollum	K. Rice	No US equiv	N/A	
3.4.1.2.1	EMC	M. McCollum	K. Rice	No US equiv	N/A	
3.4.1.2.2	EMC	M. McCollum	K. Rice	No US equiv	N/A	
3.4.1.2.3	EMC	M. McCollum	K. Rice	No US equiv	N/A	
3.4.1.2.4	EMC	M. McCollum	K. Rice	30237	3.2.4.2.2	30237B
3.4.1.2.5	EMC	M. McCollum	K. Rice	30237	3.2.4.2.2	30237B
3.4.2 (Title)	EMC	M. McCollum	K. Rice	30237		30237B
3.4.2.1	EMC	M. McCollum	K. Rice	30237	3.2.1.1.2	30237B
3.4.2.1.1	EMC	M. McCollum	K. Rice	30237	3.2.1.1.2, 3.2.1.2	30237B
3.4.2.1.1.1	EMC	M. McCollum	K. Rice	30482	4.1	30482
3.4.2.1.1.2	EMC	M. McCollum	K. Rice	30482	4.1	30482

50094 Specification Paragraph Number/Title	Team	NASA Contact	Contractor Contact	SSP Document Reference	SSP Reference Paragraph Number	Comments
3.4.2.1.2	EMC	M. McCollum	K. Rice	30237	3.2.4.2.2	30237B
3.4.2.2	EMC	M. McCollum	K. Rice	30237	3.2.2.1.1	30237B
3.4.2.2.1	EMC	M. McCollum	K. Rice	30237	3.2.2.2.1, 3.2.2.1.2	30237B
3.4.2.2.2	EMC	M. McCollum	K. Rice	30237	3.2.2.1.3	30237B
3.4.2.2.3	EMC	M. McCollum	K. Rice	30237	3.2.2.2.2	30237B
3.4.2.2.4	EMC	M. McCollum	K. Rice	30237	3.2.2.3.1, 3.2.2.3.2	30237B
3.4.2.2.5	EMC	M. McCollum	K. Rice	30237	3.2.4.2.2	30237B
3.4.3 (Title)	EMC	M. McCollum	K. Rice	30237		30237B
3.4.3.1	EMC	M. McCollum	K. Rice	30237	3.2.1.1.2	30237B
3.4.3.1.1	EMC	M. McCollum	K. Rice	30237	3.2.1.1.2, 3.2.1.2	30237B
3.4.3.1.1.1	EMC	M. McCollum	K. Rice	30482	4.1.1.1	30482
3.4.3.1.2	EMC	M. McCollum	K. Rice	30237	3.2.1.3.1, 3.2.1.3.2	30237B
3.4.3.1.3	EMC	M. McCollum	K. Rice	30237	3.2.3.1.2	30237B
3.4.3.2	EMC	M. McCollum	K. Rice	30237	3.2.2.1.1	30237B
3.4.3.2.1	EMC	M. McCollum	K. Rice	30237	3.2.2.2.1, 3.2.2.1.2	30237B
3.4.3.2.2.	EMC	M. McCollum	K. Rice	30237	3.4.2.2.2	30237B
3.4.3.2.3	EMC	M. McCollum	K. Rice	30237	3.2.2.2	30237B
3.4.3.2.4	EMC	M. McCollum	K. Rice	30482		30482
3.4.3.2.5	EMC	M. McCollum	K. Rice	30237	3.2.2.3.1, 3.2.2.3.2	30237B
3.4.3.2.6	EMC	M. McCollum	K. Rice	30237	3.2.4.2.2	30237B
3.4.4 (Title)	EMC	M. McCollum	K. Rice	30237		30237B
3.4.4.1	EMC	M. McCollum	K. Rice	30237	3.2.1.1.2	30237B
3.4.4.1.1	EMC	M. McCollum	K. Rice	30237	3.2.1.1.2, 3.2.1.2	30237B
3.4.4.1.1.1	EMC	M. McCollum	K. Rice	30482	4.1.1.1	30482
3.4.4.1.2	EMC	M. McCollum	K. Rice	30237	3.2.1.3.1, 3.2.1.3.2	30237B
3.4.4.1.3	EMC	M. McCollum	K. Rice	30243	3.2.3.1.2	30243D
3.4.4.2	EMC	M. McCollum	K. Rice	30240	3.2.2.1.1	30240B
3.4.5	EMC	M. McCollum	K. Rice	No US equiv	3.2.1.3.6	30245C
3.4.6 (Title)	EMC	M. McCollum	K. Rice	30242		30242C
3.4.6.1	EMC	M. McCollum	K. Rice	30242	3.1	30242C
3.4.6.2	EMC	M. McCollum	K. Rice	30242	3.2.2.3.2	30242C
3.4.6.3	EMC	M. McCollum	K. Rice	30240	3.2.2.7	30242C
3.4.6.4	EMC	M. McCollum	K. Rice	30242	3.2.2.4	30242C
3.4.7 (Title)	EMC	M. McCollum	K. Rice	30243		30243D
3.4.7.1	EMC	M. McCollum	K. Rice	30243		30243D
3.4.7.2	EMC	M. McCollum	K. Rice	30243	3.2.3, 3.2.10	30243D
3.4.7.3	EMC	M. McCollum	K. Rice	30240, 30243	3.2.2.8, 3.2.10	30240B, 30243D
3.4.7.4	EMC	M. McCollum	K. Rice	30243	3.2.10	30243D
3.4.7.5	EMC	M. McCollum	K. Rice	30243	3.2.10	30243D
3.4.8	EMC	M. McCollum	K. Rice	30245	N/A	30245B
3.4.8.1	EMC	M. McCollum	K. Rice	30245, 30243	3.2.1, 3.2.1.2.1, 3.1, 3.2.1.3.6, 3.2.1.3 and subs,	30245B, 30243D

50094 Specification Paragraph Number/Title	Team	NASA Contact	Contractor Contact	SSP Document Reference	SSP Reference Paragraph Number	Comments
					30243/3.2.9	
3.4.8.2	EMC	M. McCollum	K. Rice	30240	3.1	30240B
3.4.8.3	EMC	M. McCollum	K. Rice	30240	3.2.1.1	30240B
3.4.8.4	EMC	M. McCollum	K. Rice	30240	3.2.1.2	30240B
3.4.8.5	EMC	M. McCollum	K. Rice	30240	3.2.1.4	30240B
3.4.8.6	EMC	M. McCollum	K. Rice	30240	3.2.2.1	30240B
3.4.8.7	EMC	M. McCollum	K. Rice	30240	3.2.2.2	30240B
3.4.8.8	EMC	M. McCollum	K. Rice	30240	3.2.3	30240B
3.4.8.9	EMC	M. McCollum	K. Rice	30240	3.2.2.6	30240B
3.4.8.10	EMC	M. McCollum	K. Rice	30240	3.2.2.7	30240B
3.4.8.11	EMC	M. McCollum	K. Rice	30242	3.2.2.4.3	30240B
3.4.9	EMC	M. McCollum	K. Rice			
3.5	Envr.	M. Pedley		30420(This doc. no longer on the program)	N/A	30420B
3.5	Envr.	M. Pedley		30425	5	30426B
3.5.1 (Title)	Envr.	M. Pedley				
3.5.1.1	Envr.	M. Pedley				
3.5.1.2	Envr.	M. Pedley				
3.5.2	Envr.	M. Pedley				
3.6 (Title)	Envr.	B. Panters(?)	J. Lambert	30512		
3.6.1	Envr.	B. Panters(?)	J. Lambert	30512	3.1.1	30512C
3.6.2	Envr.	B. Panters(?)	J. Lambert	30512	3.1.2	30512C
3.7 (Reserved)						
3.8	Envr.	E. Christiansen	R. Graves	30425	8.0 and subs.	30425B
3.8.1	Envr.	E. Christiansen	R. Graves			
3.8.1.1	Envr.	E. Christiansen	R. Graves			
3.8.2 (Title)	Envr.	E. Christiansen	R. Graves			
3.8.2.1	Envr.	E. Christiansen	R. Graves			
3.8.2.2	Envr.	E. Christiansen	R. Graves			
3.8.2.3	Envr.	E. Christiansen	R. Graves			
3.8.2.4	Envr.	E. Christiansen	R. Graves			
3.8.2.5 (Title)	Envr.	E. Christiansen	R. Graves			
3.8.2.5.1	Envr.	E. Christiansen	R. Graves			
3.8.2.5.2	Envr.	E. Christiansen	R. Graves			
3.8.2.5.3	Envr.	E. Christiansen	R. Graves			
3.8.3	Envr.	E.	R. Graves			

50094 Specification Paragraph Number/Title	Team	NASA Contact	Contractor Contact	SSP Document Reference	SSP Reference Paragraph Number	Comments
		Christiansen				
4.0 (Title)	M&P	M. Pedley		N/A		
4.1 (Title)	M&P	D. Hartgerink		N/A		
4.1.1	M&P	D. Hartgerink		30312 Rev. E	3.1	30312F
4.1.1.1	M&P	D. Hartgerink		30312 Rev. E	3.2	30312F
4.1.1.1.1	M&P	D. Hartgerink		30312 Rev. E	3.2.1 and 3.2.2, 3.4	30312F
4.1.1.1.1.1	M&P	D. Hartgerink		30312 Rev. E	3.2.1.1	30312F
4.1.1.1.1.2	M&P	D. Hartgerink		30312 Rev. E	3.2.1.1	30312F
4.1.1.1.2	M&P	D. Hartgerink		30312 Rev. E	3.2.3	30312F
4.1.1.2	M&P	D. Hartgerink		30312 Rev. E	3.5	30312F
4.1.1.3	M&P	D. Hartgerink		30312 Rev. E	3.8	30312F
4.1.1.4	M&P	D. Hartgerink		30312 Rev. E	3.6	30312F
4.1.1.5	M&P	D. Hartgerink		30312 Rev. E	3.14	30312F
4.1.1.6	M&P	D. Hartgerink		30312 Rev. E	3.17, 3.18, 3.19	30312F
4.1.1.7	M&P	D. Hartgerink		30312 Rev. E	3.9	30312F
4.2 (Title)	M&P	M. Pedley, T. Vaughan	J. Golden	N/A		
4.2.1	M&P	M. Pedley, T. Vaughan	J. Golden			
4.2.2	M&P	M. Pedley, T. Vaughan	J. Golden			
4.2.3	M&P	M. Pedley, T. Vaughan, J. Chambliss	J. Golden			
4.3	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	3.0, 4.6.2	30233F
4.3.1 (Reserved)	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	3	30233F
4.3.2 (Reserved)	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	3	30233F
4.3.3 (Title)	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	3	30233F
4.3.3.1	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	3.1	30233F
4.3.3.1.1	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	3.1.1	30233F
4.3.3.1.2	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	3.1.2	30233F
4.3.3.1.3	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	3.1.3	30233F
4.3.3.1.4	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	3.1.4	30233F
4.3.3.1.4.1	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	3.1.4.1	30233F
4.3.3.1.4.2	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	3.1.4.4	30233F
4.3.3.2 (Reserved)	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	3.2	30233F
4.3.3.3 (Reserved)	M&P	M. Pedley, T.	J. Golden	30233 Rev. D	3.3	30233F

50094 Specification Paragraph Number/Title	Team	NASA Contact	Contractor Contact	SSP Document Reference	SSP Reference Paragraph Number	Comments
		Vaughan				
4.3.3.4	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	3.4	30233F
4.3.3.5	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	3.5	30233F
4.3.3.6 (Reserved)	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	3.6	30233F
4.3.3.7 (Reserved)	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	3.7 Deleted	30233F
4.3.3.8	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	3.8	30233F
4.3.4 (Title)	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4	30233F
4.3.4.1	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.1	30233F
4.3.4.1.1	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.1.1	30233F
4.3.4.1.2	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.1.2	30233F
4.3.4.1.2.1	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.1.2.1	30233F
4.3.4.1.2.2	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.1.2.2	30233F
4.3.4.1.2.3	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.1.2.3	30233F
4.3.4.1.3	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.1.3	30233F
4.3.4.1.3.1	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.1.3.1	30233F
4.3.4.1.3.2	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.1.3.2	30233F
4.3.4.1.3.3	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.1.3.3	30233F
4.3.4.1.3.4	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.1.3.4	30233F
4.3.4.1.4	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.1.4	30233F
4.3.4.1.5	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.1.5	30233F
4.3.4.1.6	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.1.6	30233F
4.3.4.1.7	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.1.7	30233F
4.3.4.1.8	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.1.8	30233F
4.3.4.1.9	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.1.9	30233F
4.3.4.2 (Title)	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.2	30233F
4.3.4.2.1	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.2.1	30233F

50094 Specification Paragraph Number/Title	Team	NASA Contact	Contractor Contact	SSP Document Reference	SSP Reference Paragraph Number	Comments
4.3.4.2.2	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.2.2	30233F
4.3.4.2.3	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.2.3	30233F
4.3.4.2.4	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.2.4	30233F
4.3.4.2.5	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.2.5	30233F
4.3.4.2.6	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.2.6	30233F
4.3.4.2.7	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.2.7	30233F
4.3.4.2.8	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.2.8	30233F
4.3.4.2.9 (Reserved)	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.2.9 Deleted	30233F
4.3.4.2.10	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.2.10	30233F
4.3.4.2.11 (Reserved)	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.2.11 Deleted	30233F
4.3.4.3 (Title)	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.3	30233F
4.3.4.3.1	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.3.1	30233F
4.3.4.3.2	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.3.2	30233F
4.3.4.3.3	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.3.3	30233F
4.3.4.3.4	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.3.4	30233F
4.3.4.3.4.1	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.3.4.1	30233F
4.3.4.3.4.2	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.3.4.2	30233F
4.3.4.3.4.3	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.3.4.3	30233F
4.3.4.3.4.4	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.3.4.4	30233F
4.3.4.3.4.5	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.3.4.5	30233F
4.3.4.3.5	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.3.5	30233F
4.3.4.3.6	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.3.6	30233F
4.3.4.3.7	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.3.7	30233F
4.3.4.4 (Title)	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.4	30233F
4.3.4.4.1	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.4.1	30233F
4.3.4.4.2	M&P	M. Pedley, T.	J. Golden	30233 Rev. D	4.4.2	30233F

50094 Specification Paragraph Number/Title	Team	NASA Contact	Contractor Contact	SSP Document Reference	SSP Reference Paragraph Number	Comments
		Vaughan				
4.3.4.5 (Title)	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.5	30233F
4.3.4.5.1	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.5.1	30233F
4.3.4.5.2	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.5.2	30233F
4.3.4.5.3 Reserved	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.5.3 Deleted	30233F
4.3.4.5.4	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.5.4, 4.5.4.1 & 4.5.4.2	30233F
4.3.4.5.5	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.5.5, 4.5.5.1	30233F
4.3.4.6 (Title)	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.6	30233F
4.3.4.6.1	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.6.5	30233F
4.3.4.6.1.1	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.6.5.1, 4.6.5.2	30233F
4.3.4.6.1.2	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.6.5.1	30233F
4.3.4.6.1.3	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.6.5.1	30233F
4.3.4.6.1.4	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.6.5.1	30233F
4.3.4.6.1.5	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.6.5.1	30233F
4.3.4.6.1.6	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.6.5.1	30233F
4.3.4.6.1.7	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.6.5.1	30233F
4.3.4.6.1.8	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.6.5.1	30233F
4.3.4.6.1.9	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.6.5.1	30233F
4.3.4.6.1.10	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.6.5.1	30233F
4.3.4.6.1.11	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.6.5.1	30233F
4.3.4.6.1.12	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.6.5.1	30233F
4.3.4.6.1.13	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.6.5.1	30233F
4.3.4.6.2	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.6.8	30233F
4.3.4.6.2.1	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.6.8	30233F
4.3.4.6.2.2	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.6.8	30233F
4.3.4.6.2.3	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.6.8	30233F

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4.3.4.6.2.4	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.6.8	30233F
4.3.4.6.2.5	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.6.8	30233F
4.3.4.6.2.6	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.6.8	30233F
4.3.4.6.2.7	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.6.8	30233F
4.3.4.6.2.8	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.6.8	30233F
4.3.4.6.2.9	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.6.8	30233F
4.3.4.6.2.10	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.6.8	30233F
4.3.4.6.2.11	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.6.8	30233F
4.3.4.6.2.12	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.6.8	30233F
4.3.4.6.2.13	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.6.8	30233F
4.3.4.6.2.14	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.6.8	30233F
4.3.4.6.2.15	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.6.8	30233F
4.3.4.6.2.16	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.6.8	30233F
4.3.4.6.2.17	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.6.8	30233F
4.3.4.6.2.18	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.6.8	30233F
4.3.4.6.3	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.6.3	30233F
4.3.4.6.4	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.6.9, 4.6.10	30233F
4.3.4.6.5	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.6.4	30233F
4.3.4.6.6	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.6.6	30233F
4.3.4.6.7	M&P	M. Pedley, T. Vaughan	J. Golden	30233 Rev. D	4.6.6.1	30233F
5.0	S&MA	B. Bragg		JSC 20793	N/A	
5.1	S&MA	B. Bragg		JSC 20793	N/A	
5.1.1 (Title)	S&MA	B. Bragg		JSC 20793	N/A	
5.1.1.1	S&MA	B. Bragg		JSC 20793	5.2.3.c	
5.1.1.2	S&MA	B. Bragg		JSC 20793	5.2.3.a	
5.1.1.3	S&MA	B. Bragg		JSC 20793	5.7.3.a	
5.1.1.4	S&MA	B. Bragg		JSC 20793	5.7.3.a	
5.1.2 (Title)	S&MA	B. Bragg		JSC 20793		
5.1.2.1	S&MA	B. Bragg		JSC 20793	5.1.3.e	
5.1.2.2	S&MA	B. Bragg		JSC 20793	5.1.3.e	
5.1.2.3	S&MA	B. Bragg		JSC 20793	5.1.3.f	

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5.1.2.4	S&MA	B. Bragg		JSC 20793	5.1.3.d	
5.1.2.5	S&MA	B. Bragg		JSC 20793	5.1.3.e	
5.1.2.6	S&MA	B. Bragg		JSC 20793	5.1.3.e	
5.1.3 (Title)	S&MA	B. Bragg		JSC 20793		
5.1.3.1	S&MA	B. Bragg		JSC 20793	5.1	
5.1.3.2	S&MA	B. Bragg		JSC 20793	5.1.3.a	
5.1.3.3	S&MA	B. Bragg		JSC 20793	5.7.3	
5.1.3.4	S&MA	B. Bragg		JSC 20793	5.1.3.a	
5.1.3.5	S&MA	B. Bragg		JSC 20793	5.7.3f	
5.1.4 (Title)	S&MA	B. Bragg		JSC 20793		
5.1.4.1	S&MA	B. Bragg		JSC 20793	5.6.3	
5.1.4.2	S&MA	B. Bragg		JSC 20793	5.2.3	
5.1.4.3	S&MA	B. Bragg		JSC 20793	5.2	
5.1.4.4	S&MA	B. Bragg		JSC 20793	5.1.3.e	
5.1.5 (Title)	S&MA	B. Bragg		JSC 20793		
5.1.5.1	S&MA	B. Bragg		JSC 20793	5.7	
5.1.5.2	S&MA	B. Bragg		JSC 20793	5.7	
5.1.5.3	S&MA	B. Bragg		JSC 20793	5.7	
5.2	S&MA	B. Bragg		JSC 20793	N/A	
5.2.1 (Title)	S&MA	B. Bragg		JSC 20793		
5.2.1.1	S&MA	B. Bragg		JSC 20793	5.2.3.b	
5.2.1.2	S&MA	B. Bragg		JSC 20793	5.2.3.c	
5.2.2 (Title)	S&MA	B. Bragg		JSC 20793		
5.2.2.1	S&MA	B. Bragg		JSC 20793	5.1.3.f	
5.2.2.2	S&MA	B. Bragg		JSC 20793	5.1.3.c	
5.2.2.3	S&MA	B. Bragg		JSC 20793	5.1.3.b	
5.2.2.4	S&MA	B. Bragg		JSC 20793	5.1.3.f	
5.2.3 (Title)	S&MA	B. Bragg		JSC 20793		
5.2.3.1	S&MA	B. Bragg		JSC 20793	5.1.3	
5.2.3.2	S&MA	B. Bragg		JSC 20793	5.1.3	
5.2.4 (Title)	S&MA	B. Bragg		JSC 20793		
5.2.4.1	S&MA	B. Bragg		JSC 20793	5.6.3	
5.2.4.2	S&MA	B. Bragg		JSC 20793	5.1.3.e	
5.2.5	S&MA	B. Bragg		JSC 20793	N/A	
5.3 (Title)	S&MA	B. Bragg		JSC 20793		
5.3.1	S&MA	B. Bragg		JSC 20793	N/A	
5.3.2 (Title)	S&MA	B. Bragg		JSC 20793		
5.3.2.1	S&MA	B. Bragg		JSC 20793	N/A	
5.3.2.2	S&MA	B. Bragg		JSC 20793	5.4.3	
5.3.2.3	S&MA	B. Bragg		JSC 20793	5.2.3.l	
5.3.2.4	S&MA	B. Bragg		JSC 20793	5.3.3.d.e	
5.3.3 (Title)	S&MA	B. Bragg		JSC 20793		
5.3.3.1	S&MA	B. Bragg		JSC 20793	5.1.3.a	
5.3.3.2	S&MA	B. Bragg		JSC 20793	5.2.3.j	
5.3.4 (Title)	S&MA	B. Bragg		JSC 20793		
5.3.4.1	S&MA	B. Bragg		JSC 20793	5.2.3.l	
5.3.4.2	S&MA	B. Bragg		JSC 20793	5.3.3.f	
5.3.5 (Title)	S&MA	B. Bragg		JSC 20793		

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5.3.5.1	S&MA	B. Bragg		JSC 20793	5.7.3.b	
5.3.5.2	S&MA	B. Bragg		JSC 20793	N/A	
5.4 (Title)	S&MA	B. Bragg		JSC 20793		
5.4.1	S&MA	B. Bragg		JSC 20793	N/A	
5.4.2 (Title)	S&MA	B. Bragg		JSC 20793		
5.4.2.1	S&MA	B. Bragg		JSC 20793	5.2.3.c	
5.4.2.2	S&MA	B. Bragg		JSC 20793	5.2.3.e	
5.4.2.3	S&MA	B. Bragg		JSC 20793	5.4.3.e	
5.4.3 (Title)	S&MA	B. Bragg		JSC 20793		
5.4.3.1	S&MA	B. Bragg		JSC 20793	5.1.3.a	
5.4.4 (Title)	S&MA	B. Bragg		JSC 20793		
5.4.4.1	S&MA	B. Bragg		JSC 20793	5.6.3.d	
5.4.4.2	S&MA	B. Bragg		JSC 20793	5.3.3.f	
5.4.5 (Title)	S&MA	B. Bragg		JSC 20793		
5.4.5.1	S&MA	B. Bragg		JSC 20793	5.5	
5.5 (Title)	S&MA	B. Bragg		JSC 20793		
5.5.1	S&MA	B. Bragg		JSC 20793	N/A	
5.5.2 (Title)	S&MA	B. Bragg		JSC 20793		
5.5.2.1	S&MA	B. Bragg		JSC 20793	5.4.3.e	
5.5.2.2	S&MA	B. Bragg		JSC 20793	5.3.3.c	
5.5.3 (Title)	S&MA	B. Bragg		JSC 20793		
5.5.3.1	S&MA	B. Bragg		JSC 20793	5.5	
5.5.4	S&MA	B. Bragg		JSC 20793	N/A	
5.5.5	S&MA	B. Bragg		JSC 20793	N/A	
5.6	S&MA	B. Bragg		JSC 20793	2,4,5,6.1	
5.6.1	S&MA	B. Bragg		JSC 20793	2,4,5,6.1	
5.6.2	S&MA	B. Bragg		JSC 20793	2,4,5,6.1	
5.6.3	S&MA	B. Bragg		JSC 20793	2,4,5,6.1	
5.6.4	S&MA	B. Bragg		JSC 20793	2,4,5,6.1	
5.6.5	S&MA	B. Bragg		JSC 20793	2,4,5,6.1	
5.6.6	S&MA	B. Bragg		JSC 20793	2,4,5,6.1	
6.0 (Title)	FCS	L. Toups		N/A		
6.1 (Title)	FCS	L. Toups		N/A		FCS & I TIM 11 Protocol
6.1.1 (Title)	FCS	L. Toups		N/A		
6.1.1.1	FCS	L. Toups				
6.1.1.2	FCS	L. Toups				
6.1.2	FCS	L. Toups				
6.1.3	FCS	L. Toups				
6.1.3.1	FCS	L. Toups				
6.1.3.1.1	FCS	L. Toups				
6.1.3.1.2	FCS	L. Toups				
6.1.3.2	FCS	L. Toups				
6.1.3.2.1	FCS	L. Toups				
6.1.3.2.1.1	FCS	L. Toups				
6.1.3.2.1.2	FCS	L. Toups				
6.1.3.3	FCS	L. Toups				
6.1.3.3.1	FCS	L. Toups				

50094 Specification Paragraph Number/Title	Team	NASA Contact	Contractor Contact	SSP Document Reference	SSP Reference Paragraph Number	Comments
6.1.3.4 (Title)	FCS	L. Toups		N/A		
6.1.3.4.1	FCS	L. Toups				
6.1.3.5 (Title)	FCS	L. Toups		N/A		
6.1.3.5.1	FCS	L. Toups				
6.1.3.6 (Title)	FCS	L. Toups		N/A		
6.1.3.6.1 (Title)	FCS	L. Toups		N/A		
6.1.3.6.1.1	FCS	L. Toups				
6.1.3.6.1.2	FCS	L. Toups				
6.1.3.6.2 (Title)	FCS	L. Toups		N/A		
6.1.3.6.2.1	FCS	L. Toups				
6.1.3.6.2.2	FCS	L. Toups				
6.1.3.6.3 (Title)	FCS	L. Toups		N/A		
6.1.3.6.3.1	FCS	L. Toups				
6.1.3.6.3.2	FCS	L. Toups				
6.2 (Title)	FCS	L. Toups		N/A		FCS & I TIM 12 Protocol
6.2.1 (Title)	FCS	L. Toups		N/A		
6.2.1.1 (Title)	FCS	L. Toups		N/A		
6.2.1.1.1	FCS	L. Toups				
6.2.1.1.2	FCS	L. Toups				
6.2.1.2	FCS	L. Toups				
6.2.1.2.1	FCS	L. Toups				
6.2.1.2.2	FCS	L. Toups				
6.2.1.3	FCS	L. Toups				
6.2.1.3.1	FCS	L. Toups				
6.2.1.3.2	FCS	L. Toups				
6.3 (Title)	FCS	L. Toups		N/A		
6.3.1 (Title)	FCS	L. Toups		N/A		
6.3.1.1.	FCS	L. Toups		SSP 50005 *	8.8.3.1 *	SSP 5005B
6.3.1.2	FCS	L. Toups		SSP 50005 *	8.8.3.2 *	SSP 5005B
6.3.1.3	FCS	L. Toups		SSP 50005 *	8.8.3.3 *	SSP 5005B
6.3.1.4	FCS	L. Toups		SSP 50005 *	8.8.3.4 *	SSP 5005B
6.3.2 (Title)	FCS	L. Toups		N/A		
6.3.2.1	FCS	L. Toups		SSP 50005 *	8.9.3.1 *	SSP 5005B
6.3.2.2	FCS	L. Toups		SSP 50005 *	8.9.3.2 *	SSP 5005B
6.3.3 (Title)	FCS	L. Toups		N/A		
6.3.3.1 (Title)	FCS	L. Toups		N/A		
6.3.3.1.1	FCS	L. Toups		SSP 50005 *	10.5.3.1 *	SSP 5005B
6.3.3.1.2	FCS	L. Toups		SSP 50005 *	10.5.3.2 *	SSP 5005B
6.3.3.1.3	FCS	L. Toups		SSP 50005 *	10.5.3.3 *	SSP 5005B
6.3.3.1.4	FCS	L. Toups		SSP 50005 *	10.5.3.4 *	SSP 5005B
6.3.3.1.5	FCS	L. Toups		SSP 50005 *	11.12.3 *	SSP 5005B
6.3.3.1.6	FCS	L. Toups				
6.3.3.1.6.1	FCS	L. Toups				
6.3.3.1.6.2	FCS	L. Toups				
6.3.3.1.6.3	FCS	L. Toups				
6.4 (Title)	FCS	L. Toups		N/A		
6.4.1	FCS	L. Toups		SSP 50005 *		SSP 5005B

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6.4.2 (Title)	FCS	L. Toups		N/A		No reference given
6.4.2.1	FCS	L. Toups				No reference given
6.4.2.2	FCS	L. Toups				No reference given
6.4.2.3	FCS	L. Toups				No reference given
6.4.2.4	FCS	L. Toups				No reference given
6.4.3 (Title)	FCS	L. Toups		N/A		No reference given
6.4.3.1	FCS	L. Toups				No reference given
6.4.3.2 (Title)	FCS	L. Toups		N/A		No reference given
6.4.3.2.1	FCS	L. Toups				No reference given
6.4.3.2.2	FCS	L. Toups				No reference given
6.4.3.2.3	FCS	L. Toups				No reference given
6.4.3.3 (Title)	FCS	L. Toups		N/A		No reference given
6.4.3.3.1	FCS	L. Toups				No reference given
6.4.3.3.2	FCS	L. Toups				No reference given
6.4.3.4	FCS	L. Toups				No reference given
6.4.4 (Title)	FCS	L. Toups		N/A		No reference given
6.4.4.1	FCS	L. Toups				No reference given
6.4.4.2	FCS	L. Toups				No reference given
6.4.4.3	FCS	L. Toups				No reference given
6.4.5 (Title)	FCS	L. Toups		N/A		No reference given
6.4.5.1	FCS	L. Toups				No reference given
6.4.5.1.1	FCS	L. Toups				No reference given
6.4.5.1.2	FCS	L. Toups				No reference given
6.4.5.1.3	FCS	L. Toups				No reference given
6.4.5.2	FCS	L. Toups				No reference given
6.4.5.3	FCS	L. Toups				No reference given
6.4.6	FCS	L. Toups				No reference given
6.4.7	FCS	L. Toups				No reference given
6.4.7.1 (Title)	FCS	L. Toups		N/A		
6.4.7.1.1	FCS	L. Toups				
6.4.7.1.2 (Title)	FCS	L. Toups		N/A		
6.4.7.1.2.1	FCS	L. Toups				
6.4.7.1.2.2	FCS	L. Toups				
6.4.7.1.2.3	FCS	L. Toups				
6.4.7.1.2.4	FCS	L. Toups				
6.4.7.1.2.5	FCS	L. Toups				
6.4.7.1.3 (Title)	FCS	L. Toups		N/A		
6.4.7.1.3.1	FCS	L. Toups				
6.4.7.1.3.2	FCS	L. Toups				
6.4.7.1.3.3	FCS	L. Toups				
6.4.7.1.3.4	FCS	L. Toups				
6.4.7.1.3.5	FCS	L. Toups				
6.4.7.1.3.6	FCS	L. Toups				
6.4.7.1.4 (Title)	FCS	L. Toups		N/A		
6.4.7.1.4.1	FCS	L. Toups				
6.4.7.1.4.2	FCS	L. Toups				
6.4.7.1.4.3	FCS	L. Toups				
6.4.7.1.4.4	FCS	L. Toups				

50094 Specification Paragraph Number/Title	Team	NASA Contact	Contractor Contact	SSP Document Reference	SSP Reference Paragraph Number	Comments
6.4.7.1.4.5 (Reserved)	FCS	L. Toups				
6.4.7.1.4.6	FCS	L. Toups				
6.4.7.1.4.7	FCS	L. Toups				
6.4.7.1.4.8	FCS	L. Toups				
6.4.7.1.5	FCS	L. Toups				
6.4.7.2	FCS	L. Toups				
6.4.7.2.1	FCS	L. Toups				
6.4.7.2.1.1	FCS	L. Toups				
6.4.7.2.1.2	FCS	L. Toups				
6.4.7.2.1.3	FCS	L. Toups				
6.4.7.2.1.4	FCS	L. Toups				
6.4.7.2.1.5	FCS	L. Toups				
6.4.7.2.1.6	FCS	L. Toups				
6.4.7.2.1.7	FCS	L. Toups				
6.4.7.2.1.8	FCS	L. Toups				
6.4.7.2.1.9	FCS	L. Toups				
6.4.7.2.1.10	FCS	L. Toups				
6.4.7.2.1.11	FCS	L. Toups				
6.4.7.2.2 (Title)	FCS	L. Toups		N/A		
6.4.7.2.2.1	FCS	L. Toups				
6.4.7.2.2.2	FCS	L. Toups				
6.4.7.2.2.3	FCS	L. Toups				
6.4.7.2.2.4	FCS	L. Toups				
6.4.7.2.2.5	FCS	L. Toups				
6.4.7.2.3	FCS	L. Toups		50253		50253
6.4.7.2.4 (Title)	FCS	L. Toups		N/A		
6.4.7.2.4.1	FCS	L. Toups				
6.4.7.2.5	FCS	L. Toups		N/A		
6.4.7.2.5.1 (Title)	FCS	L. Toups				
6.4.7.2.5.2	FCS	L. Toups				
6.4.7.2.5.3	FCS	L. Toups				
6.4.7.2.5.4	FCS	L. Toups				
6.4.7.2.5.5	FCS	L. Toups				
6.4.7.3 (Title)	FCS	L. Toups		N/A		
6.4.7.3.1	FCS	L. Toups				
6.4.7.3.2	FCS	L. Toups				
6.4.7.3.3	FCS	L. Toups				
6.4.7.3.4	FCS	L. Toups				
6.4.7.4 (Title)	FCS	L. Toups		N/A		
6.4.7.4.1	FCS	L. Toups				
6.4.7.4.2	FCS	L. Toups				
6.4.7.4.3	FCS	L. Toups				
6.4.7.4.4	FCS	L. Toups				
6.4.7.4.5	FCS	L. Toups				
6.4.7.4.6	FCS	L. Toups				
6.4.7.4.7	FCS	L. Toups				
6.4.7.4.8	FCS	L. Toups				

50094 Specification Paragraph Number/Title	Team	NASA Contact	Contractor Contact	SSP Document Reference	SSP Reference Paragraph Number	Comments
6.4.7.4.9	FCS	EVA Project				No reference given
6.4.7.4.10	FCS	L. Toups				
6.4.7.4.11	FCS	L. Toups				
6.4.7.4.12	FCS	L. Toups				
6.4.7.4.13	FCS	L. Toups				
6.4.7.4.14	FCS	L. Toups				
6.4.7.4.15	FCS	L. Toups				
6.4.7.4.16	FCS	L. Toups				
6.4.7.4.17	FCS	L. Toups				
6.4.7.4.18	FCS	L. Toups				
6.4.7.4.19	FCS	L. Toups				
6.4.7.4.20	FCS	L. Toups				
6.4.7.4.21	FCS	L. Toups				
6.4.7.4.22	FCS	L. Toups				
6.5 (Title)	FCS	L. Toups		N/A		No reference given
6.5.1	FCS	L. Toups				No reference given
6.5.1.1	FCS	V. Berend				No reference given
6.5.1.1.1	FCS	V. Berend				No reference given
6.5.1.2	FCS	V. Berend				No reference given
6.5.1.3	FCS	L. Toups				No reference given
6.5.1.4	FCS	L. Toups				No reference given
6.5.1.5	FCS	L. Toups				No reference given
6.5.1.6	FCS	L. Toups				No reference given
6.5.1.7	FCS	L. Toups				No reference given
6.5.1.8	FCS	L. Toups				No reference given
6.5.1.9	FCS	L. Toups				No reference given
6.5.1.10	FCS	L. Toups				No reference given
6.5.1.11	FCS	L. Toups				No reference given
6.5.1.11.1	FCS	L. Toups				
6.5.1.12	FCS	L. Toups				No reference given
6.5.1.13	FCS	L. Toups				No reference given
6.5.1.13.1	FCS	L. Toups				No reference given
6.5.1.14	FCS	L. Toups				No reference given
6.5.1.15	FCS	L. Toups				No reference given
6.5.1.15.1	FCS	L. Toups				No reference given
6.5.1.15.1.1	FCS	L. Toups				No reference given
6.5.1.15.1.2	FCS	L. Toups				No reference given
6.5.1.15.2	FCS	L. Toups				No reference given
6.5.1.15.2.1	FCS	L. Toups				No reference given
6.5.1.15.2.2	FCS	L. Toups				No reference given
6.5.1.15.2.3	FCS	L. Toups				No reference given
6.5.1.15.2.4	FCS	L. Toups				No reference given
6.5.1.15.2.5	FCS	L. Toups				No reference given
6.5.1.16	FCS	L. Toups				No reference given
6.5.1.17	FCS	L. Toups				No reference given
6.5.2	FCS	J. Goodman				No reference given
6.5.2.1	FCS	J. Goodman				
6.5.2.2	FCS	J. Goodman				

50094 Specification Paragraph Number/Title	Team	NASA Contact	Contractor Contact	SSP Document Reference	SSP Reference Paragraph Number	Comments
6.5.2.3 (Title)	FCS	J. Goodman		N/A		
6.5.2.3.1	FCS	J. Goodman				
6.5.2.3.2	FCS	J. Goodman				
6.5.2.3.3	FCS	J. Goodman				
6.5.2.4 (Title)	FCS	J. Goodman		N/A		
6.5.2.4.1	FCS	J. Goodman				
6.5.2.4.2	FCS	J. Goodman				
6.5.2.5 (Title)	FCS	J. Goodman		N/A		
6.5.2.5.1	FCS	J. Goodman				
6.5.2.5.2	FCS	J. Goodman				
6.5.2.5.3	FCS	J. Goodman				
6.5.2.6 (Title)	FCS	J. Goodman		N/A		
6.5.2.6.1	FCS	J. Goodman				
6.5.2.6.2	FCS	J. Goodman				
6.5.2.7	FCS	J. Goodman				
6.5.3 (Title)	FCS	F. Cucinotta	Neal Zapp			
6.5.3.1 (Title)	FCS	F. Cucinotta	Neal Zapp			
6.5.3.1.1	FCS	F. Cucinotta	Neal Zapp			
6.5.3.2 (Title)	FCS	F. Cucinotta	Neal Zapp			
6.5.3.2.1 (Title)	FCS	F. Cucinotta	Neal Zapp			
6.5.3.2.1.1	FCS	F. Cucinotta	Neal Zapp			
6.5.3.2.1.2	FCS	F. Cucinotta	Neal Zapp			
6.5.3.2.1.3	FCS	F. Cucinotta	Neal Zapp			
6.5.3.2.1.4	FCS	F. Cucinotta	Neal Zapp			
6.5.3.2.2 (Title)	FCS	F. Cucinotta	Neal Zapp			
6.5.3.2.2.1	FCS	F. Cucinotta	Neal Zapp			
6.5.3.2.2.2 (Title)	FCS	F. Cucinotta	Neal Zapp			
6.5.3.2.2.2.1	FCS	F. Cucinotta	Neal Zapp			
6.5.3.2.2.2.2	FCS	F. Cucinotta	Neal Zapp			
6.5.3.2.2.2.3	FCS	F. Cucinotta	Neal Zapp			
6.5.3.2.2.2.4	FCS	F. Cucinotta	Neal Zapp			
6.5.3.2.2.2.5	FCS	F. Cucinotta	Neal Zapp			
6.5.3.2.2.3 (Title)	FCS	F. Cucinotta	Neal Zapp			
6.5.3.2.2.3.1	FCS	F. Cucinotta	Neal Zapp			
6.5.3.2.2.3.2	FCS	F. Cucinotta	Neal Zapp			
6.5.3.2.2.3.3	FCS	F. Cucinotta	Neal Zapp			
6.5.3.2.2.4	FCS	F. Cucinotta	Neal Zapp			
6.5.3.2.2.4.1	FCS	F. Cucinotta	Neal Zapp			
6.5.3.2.2.4.2.	FCS	F. Cucinotta	Neal Zapp			
6.5.3.2.2.4.3	FCS	F. Cucinotta	Neal Zapp			
6.6 (Title)	FCS	L. Toups		N/A		
6.6.1 (Title)	FCS	L. Toups		N/A		
6.6.1.1	FCS	L. Toups				
6.6.1.1.1	FCS	L. Toups				No reference given
6.6.1.1.2	FCS	L. Toups				No reference given
6.6.1.1.3	FCS	L. Toups				No reference given
6.6.1.2	FCS	L. Toups				No reference given
6.6.1.3.	FCS	L. Toups				No reference given

50094 Specification Paragraph Number/Title	Team	NASA Contact	Contractor Contact	SSP Document Reference	SSP Reference Paragraph Number	Comments
6.6.1.4	FCS	L. Toups				No reference given
6.6.2	FCS	L. Toups		50313		50313
7.0 (Title)	STR	J. Zipay		N/A		
7.1 (Title)	STR	J. Zipay		N/A		
7.1.1 (Title)	STR	J. Zipay		N/A		
7.1.1.1	STR	J. Zipay		SSP 30559 Rev. B	3.1.3	SSP 30559B
7.1.1.2	STR	J. Zipay		SSP 30559 Rev. B	3.1.3	SSP 30559B
7.1.1.3	STR	J. Zipay		SSP 30559 Rev. B	3.3	SSP 30559B
7.1.1.4	STR	J. Zipay		SSP 30559 Rev. B	3.5.1.2	SSP 30559B
7.1.1.5	STR	J. Zipay		SSP 30559 Rev. B	3.5.2	SSP 30559B
7.1.1.6	STR	J. Zipay		SSP 30559 Rev. B	3.6	SSP 30559B
7.1.1.7	STR	J. Zipay		SSP 30559 Rev. B	3.2	SSP 30559B
7.1.1.7.1	STR	J. Zipay				
7.1.1.7.1.1	STR	J. Zipay		N/A	TITLE	
7.1.1.7.1.1.1	STR	J. Zipay		N/A	TITLE	
7.1.1.7.1.1.1.1	STR	J. Zipay				
7.1.1.7.1.1.1.2	STR	J. Zipay				
7.1.1.7.1.1.1.3	STR	J. Zipay				
7.1.1.7.1.1.1.4	STR	J. Zipay				
7.1.1.7.1.2	STR	J. Zipay				
7.1.1.7.1.2.1	STR	J. Zipay				
7.1.1.7.1.3	STR	J. Zipay				
7.1.1.7.1.3.1	STR	J. Zipay				
7.1.1.7.1.4	STR	J. Zipay				
7.1.1.7.1.4.1	STR	J. Zipay				
7.1.1.7.1.4.2	STR	J. Zipay				
7.1.1.7.1.5	STR	J. Zipay				
7.1.1.8	STR	J. Zipay		SSP 30559 Rev. B	3.1.9.1	SSP 30559B
7.1.1.8.1	STR	J. Zipay		SSP 30559 Rev. B	3.1.9.2	SSP 30559B
7.1.1.8.2	STR	J. Zipay		SSP 30559 Rev. B	3.3	SSP 30559B
7.1.1.8.3	STR	J. Zipay		SSP 30558 Rev. B	4.4.1	SSP 30558B
7.1.1.8.4	STR	J. Zipay		SSP 30558 Rev. B	4.4.1	SSP 30558B
7.1.1.8.5	STR	J. Zipay		SSP 30558 Rev. B	4.4.1	SSP 30558B
7.1.1.8.6	STR	J. Zipay		SSP 30558 Rev. B	4.4.2	SSP 30558B
7.1.1.8.7	STR	J. Zipay		SSP 30558 Rev. B		SSP 30558B

50094 Specification Paragraph Number/Title	Team	NASA Contact	Contractor Contact	SSP Document Reference	SSP Reference Paragraph Number	Comments
7.1.1.9	STR	J. Zipay		SSP 30559 Rev. B	3.1.10	SSP 30559B
7.1.2	STR	J. Zipay		SSP 30558 Rev. B	3	SSP 30558B
7.1.2.1	STR	J. Zipay		SSP 30558 Rev. B	4.1	SSP 30558B
7.1.2.1.1	STR	J. Zipay		SSP 30558 Rev. B	4.2.1	SSP 30558B
7.1.2.1.2	STR	J. Zipay		SSP 30558 Rev. B	4.2.2	SSP 30558B
7.1.2.1.3	STR	J. Zipay		SSP 30558 Rev. B	4.2.3	SSP 30558B
7.1.2.1.4	STR	J. Zipay		SSP 30558 Rev. B	4.2.4	SSP 30558B
7.1.2.2	STR	J. Zipay		SSP 30558 Rev. B	4.3	SSP 30558B
7.1.2.2.1	STR	J. Zipay		SSP 30558 Rev. B	4.3.1.3	SSP 30558B
7.1.2.3	STR	J. Zipay		SSP 30558 Rev. B	4.3.1.4	SSP 30558B
7.1.2.4	STR	J. Zipay		SSP 30558 Rev. B	4.5	SSP 30558B
7.1.2.5	STR	J. Zipay		SSP 30558 Rev. B		SSP 30558B
7.1.2.6	STR	J. Zipay				
7.1.3 (Title)	STR	J. Zipay		N/A		
7.1.3.1	STR	J. Zipay		SSP 30559 Rev. B	4.1.3	SSP 30559B
7.1.3.2	STR	J. Zipay		SSP 30559 Rev. B	4.1.2	SSP 30559B
7.1.3.3 (Title)	STR	J. Zipay		N/A		
7.1.3.3.1	STR	J. Zipay		SSP 30558 Rev. B	4.4	SSP 30558B
7.1.3.3.2	STR	J. Zipay				
7.1.3.4	STR	J. Zipay		SSP 30559 Rev. B	4.1.3.1	SSP 30559B
7.1.3.5	STR	J. Zipay		SSP 30558 Rev. B	4.3.1.3	SSP 30558B
7.1.3.6	STR	J. Zipay		SSP 30559 Rev. B	4.1.5.4	SSP 30559B
7.1.4	STR	J. Zipay		N/A	N/A	
7.1.4.1	STR	J. Zipay		SSP 30560	3.1.1	SSP 30560
7.1.4.2	STR	J. Zipay		SSP 30560	3.1.3	SSP 30560
7.1.4.3	STR	J. Zipay		SSP 30560	3.1.10	SSP 30560
7.1.4.4.	STR	J. Zipay		SSP 30560	3.1.11	SSP 30560
7.1.4.5	STR	J. Zipay		SSP 30560	3.2	SSP 30560
7.1.4.5.1	STR	J. Zipay		SSP 30560	3.2	SSP 30560
7.1.4.5.2	STR	J. Zipay		SSP 30560	3.2.2	SSP 30560
7.1.4.5.3	STR	J. Zipay		SSP 30560	3.2.3	SSP 30560
7.1.4.5.4	STR	J. Zipay		SSP 30560	3.2.4	SSP 30560

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7.1.4.5.5	STR	J. Zipay		SSP 30560	3.2.8	SSP 30560
7.1.4.6	STR	J. Zipay		SSP 30560	4	SSP 30560
7.1.4.7	STR	J. Zipay		SSP 30560	3.2.7	SSP 30560
7.1.4.8 (Title)	STR	J. Zipay		N/A		
7.1.4.8.1	STR	J. Zipay		SSP 30560	4.1	SSP 30560
7.1.4.8.1.1	STR	J. Zipay		SSP 30560	4.1.1.1	SSP 30560
7.1.4.8.1.2	STR	J. Zipay		SSP 30560	4.1.1.3	SSP 30560
7.1.4.8.2	STR	J. Zipay		SSP 30560	4.1.2.1	SSP 30560
7.1.4.8.3	STR	J. Zipay		SSP 30560	4.6	SSP 30560
7.1.4.8.4	STR	J. Zipay				
7.1.5	STR	J. Zipay				
7.1.5.1	STR	J. Zipay				
7.1.5.2	STR	J. Zipay				
7.1.5.2.1	STR	J. Zipay				
8.0 (Title)	IT & V	T. Marino		N/A		
8.1	IT & V	T. Marino		SSP 41172	3.1	SSP 41172B DCN 001,002
8.2	IT & V	T. Marino		SSP 41172	3.2	SSP 41172B DCN 001,002
8.3	IT & V	T. Marino		SSP 41172	4	SSP 41172B DCN 001,002
8.3.1	IT & V	T. Marino		SSP 41172	4.1	SSP 41172B DCN 001,002
8.3.2	IT & V	T. Marino		SSP 41172	4.2	SSP 41172B DCN 001,002
8.3.2.1	IT & V	T. Marino		SSP 41172	4.2.1	SSP 41172B DCN 001,002
8.3.2.1.1	IT & V	T. Marino				
8.3.2.1.2	IT & V	T. Marino				
8.3.2.1.3	IT & V	T. Marino				
8.3.2.2	IT & V	T. Marino		SSP 41172	4.2.2	SSP 41172B DCN 001,002
8.3.2.2.1	IT & V	T. Marino				
8.3.2.2.2	IT & V	T. Marino				
8.3.2.2.3	IT & V	T. Marino				
8.3.2.2.4	IT & V	T. Marino				
8.3.2.3	IT & V	T. Marino		SSP 41172	4.2.3	SSP 41172B DCN 001,002
8.3.2.3.1	IT & V	T. Marino				
8.3.2.3.2	IT & V	T. Marino				
8.3.2.3.3	IT & V	T. Marino				
8.3.2.3.4	IT & V	T. Marino				
8.3.2.4	IT & V	T. Marino		SSP 41172	4.2.4	SSP 41172B DCN 001,002
8.3.2.4.1	IT & V	T. Marino				
8.3.2.4.2	IT & V	T. Marino				
8.3.2.4.3	IT & V	T. Marino				
8.3.2.4.4	IT & V	T. Marino				
8.3.2.5	IT & V	T. Marino		SSP 41172	4.2.5	SSP 41172B DCN

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						001,002
8.3.2.5.1	IT & V	T. Marino				
8.3.2.5.2	IT & V	T. Marino				
8.3.2.5.3	IT & V	T. Marino				
8.3.2.5.4	IT & V	T. Marino				
8.3.2.6	IT & V	T. Marino		SSP 41172	4.2.6	SSP 41172B DCN 001,002
8.3.2.6.1	IT & V	T. Marino				
8.3.2.6.2	IT & V	T. Marino				
8.3.2.6.3	IT & V	T. Marino				
8.3.2.6.4	IT & V	T. Marino				
8.3.2.7	IT & V	T. Marino		SSP 41172	4.2.7	SSP 41172B DCN 001,002
8.3.2.7.1	IT & V	T. Marino				
8.3.2.7.2	IT & V	T. Marino				
8.3.2.7.3	IT & V	T. Marino				
8.3.2.7.4	IT & V	T. Marino				
8.3.2.8	IT & V	T. Marino		SSP 41172	4.2.8	SSP 41172B DCN 001,002
8.3.2.8.1	IT & V	T. Marino				
8.3.2.8.2	IT & V	T. Marino				
8.3.2.8.3	IT & V	T. Marino				
8.3.2.8.4	IT & V	T. Marino				
8.3.2.9	IT & V	T. Marino		SSP 41172	4.2.9	SSP 41172B DCN 001,002
8.3.2.9.1	IT & V	T. Marino				
8.3.2.9.2	IT & V	T. Marino				
8.3.2.9.3	IT & V	T. Marino				
8.3.2.9.4	IT & V	T. Marino				
8.3.2.10	IT & V	T. Marino		SSP 41172	4.2.10	SSP 41172B DCN 001,002
8.3.2.10.1	IT & V	T. Marino				
8.3.2.10.2	IT & V	T. Marino				
8.3.2.10.3	IT & V	T. Marino				
8.3.2.11	IT & V	T. Marino		SSP 41172	4.2.11	SSP 41172B DCN 001,002
8.3.2.11.1	IT & V	T. Marino				
8.3.2.11.2	IT & V	T. Marino				
8.3.2.11.3	IT & V	T. Marino				
8.3.2.11.4	IT & V	T. Marino				
8.3.2.12	IT & V	T. Marino		None	None	
8.3.2.12.1	IT & V	T. Marino				
8.3.2.12.2	IT & V	T. Marino				
8.3.2.12.3	IT & V	T. Marino				
8.3.2.12.4	IT & V	T. Marino				
8.3.2.13	IT & V	T. Marino		SSP 41172	4.2.12	SSP 41172B DCN 001,002
8.3.2.13.1	IT & V	T. Marino				
8.3.2.13.2	IT & V	T. Marino				

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8.3.2.14	IT & V	T. Marino		SSP 41172	4.2.13	SSP 41172B DCN 001,002
8.3.2.14.1	IT & V	T. Marino				
8.3.2.14.2	IT & V	T. Marino				
8.3.2.14.3	IT & V	T. Marino				
8.3.2.14.4	IT & V	T. Marino				
8.3.3	IT & V	T. Marino		SSP 41172	4.3	SSP 41172B DCN 001,002
8.3.3.1	IT & V	T. Marino		SSP 41172	4.3.1	SSP 41172B DCN 001,002
8.3.3.1.1	IT & V	T. Marino				
8.3.3.1.2	IT & V	T. Marino				
8.3.3.1.3	IT & V	T. Marino				
8.3.3.1.4	IT & V	T. Marino				
8.3.3.2	IT & V	T. Marino		SSP 41172	4.3.2	SSP 41172B DCN 001,002
8.3.4	IT & V	T. Marino		SSP 41172	4.4	SSP 41172B DCN 001,002
8.3.4.1	IT & V	T. Marino		SSP 41172	4.4.1	SSP 41172B DCN 001,002
8.3.4.1.1	IT & V	T. Marino				
8.3.4.1.2	IT & V	T. Marino				
8.3.4.1.3	IT & V	T. Marino				
8.3.4.1.4	IT & V	T. Marino				
8.3.4.2	IT & V	T. Marino		SSP 41172	4.4.2	SSP 41172B DCN 001,002
8.3.4.2.1	IT & V	T. Marino				
8.3.4.2.2	IT & V	T. Marino				
8.3.4.3 (Reserved)	IT & V	T. Marino		N/A	N/A	
8.3.4.4	IT & V	T. Marino		SSP 41172	4.4.4	SSP 41172B DCN 001,002
8.3.4.4.1	IT & V	T. Marino				
8.3.4.4.2	IT & V	T. Marino				
8.3.4.4.3	IT & V	T. Marino				
8.3.4.4.4	IT & V	T. Marino				
8.4	IT & V	T. Marino		SSP 41172	5.1	SSP 41172B DCN 001,002
8.4.1	IT & V	T. Marino		SSP 41172	5.1	SSP 41172B DCN 001,002
8.4.1.1	IT & V	T. Marino		SSP 41172	5.1.1	SSP 41172B DCN 001,002
8.4.1.1.1	IT & V	T. Marino				
8.4.1.1.2	IT & V	T. Marino				
8.4.1.1.3	IT & V	T. Marino				
8.4.1.2	IT & V	T. Marino		SSP 41172	5.1.2	SSP 41172B DCN 001,002
8.4.1.2.1	IT & V	T. Marino				
8.4.1.2.2	IT & V	T. Marino				
8.4.1.2.3	IT & V	T. Marino				
8.4.1.2.4	IT & V	T. Marino				

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8.4.1.3	IT & V	T. Marino		SSP 41172	5.1.3	SSP 41172B DCN 001,002
8.4.1.3.1	IT & V	T. Marino				
8.4.1.3.2	IT & V	T. Marino				
8.4.1.3.3	IT & V	T. Marino				
8.4.1.3.4	IT & V	T. Marino				
8.4.1.4	IT & V	T. Marino		SSP 41172	None	SSP 41172B DCN 001,002
8.4.1.4.1	IT & V	T. Marino				
8.4.1.4.2	IT & V	T. Marino				
8.4.1.4.3	IT & V	T. Marino				
8.4.1.4.4	IT & V	T. Marino				
8.4.1.5	IT & V	T. Marino		SSP 41172	5.1.4	SSP 41172B DCN 001,002
8.4.1.5.1	IT & V	T. Marino				
8.4.1.5.2	IT & V	T. Marino				
8.4.1.5.3	IT & V	T. Marino				
8.4.1.5.4	IT & V	T. Marino				
8.4.1.6	IT & V	T. Marino		SSP 41172	None	
8.4.1.6.1	IT & V	T. Marino				
8.4.1.6.2	IT & V	T. Marino				
8.4.1.6.3	IT & V	T. Marino				
8.4.1.7	IT & V	T. Marino		SSP 41172	5.1.6	SSP 41172B DCN 001,002
8.4.1.7.1	IT & V	T. Marino				
8.4.1.7.2	IT & V	T. Marino				
8.4.1.7.3	IT & V	T. Marino				
8.4.1.7.4	IT & V	T. Marino				
8.4.1.8	IT & V	T. Marino		SSP 41172	5.1.7	SSP 41172B DCN 001,002
8.4.1.8.1	IT & V	T. Marino				
8.4.1.8.2	IT & V	T. Marino				
8.4.1.8.3	IT & V	T. Marino				
8.4.1.8.4	IT & V	T. Marino				
8.4.1.9	IT & V	T. Marino		None	None	
8.4.1.9.1	IT & V	T. Marino				
8.4.1.9.2	IT & V	T. Marino				
8.4.1.9.3	IT & V	T. Marino				
8.4.2	IT & V	T. Marino		SSP 41172	5.2	SSP 41172B DCN 001,002
8.4.2.1	IT & V	T. Marino		SSP 41172	5.2.1	SSP 41172B DCN 001,002
8.4.2.1.1	IT & V	T. Marino				
8.4.2.1.2	IT & V	T. Marino				
8.4.2.1.3	IT & V	T. Marino				
8.4.2.1.4	IT & V	T. Marino				
8.4.2.2	IT & V	T. Marino		SSP 41172	5.2.2	SSP 41172B DCN 001,002
8.4.2.3	IT & V	T. Marino		SSP 41172	5.2.3	SSP 41172B DCN

50094 Specification Paragraph Number/Title	Team	NASA Contact	Contractor Contact	SSP Document Reference	SSP Reference Paragraph Number	Comments
						001,002
8.4.2.3.1	IT & V	T. Marino				
8.4.2.3.2	IT & V	T. Marino				
8.4.2.3.3	IT & V	T. Marino				
8.4.2.3.4	IT & V	T. Marino				
8.4.2.4 (Reserved)	IT & V	T. Marino		N/A	N/A	
8.4.2.5 (Reserved)	IT & V	T. Marino		N/A	N/A	
8.4.2.6	IT & V	T. Marino				
8.4.2.6.1	IT & V	T. Marino				
8.4.2.6.2	IT & V	T. Marino				
8.4.2.6.3	IT & V	T. Marino				
8.5 (Title)	IT & V	T. Marino		N/A		
8.6 (Reserved)	IT & V	T. Marino		SSP 41172	7	SSP 41172B DCN 001,002
8.7	IT & V	T. Marino		SSP 41172	8	SSP 41172B DCN 001,002
9.0 (Title)	S/W	P. Bolden, T. Crumbley		N/A		
9.1 (Title)	S/W	P. Bolden, T. Crumbley		N/A		
9.1.1 (Title)	S/W	P. Bolden, T. Crumbley		N/A		
9.1.1.1	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	4.1.4	DOD-STD-2167A
9.1.1.2	S/W	P. Bolden, T. Crumbley		D684-10056-1 Rev A	3.3.1.3A	D684-10056-1 Rev A, CN 001
9.1.1.3	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	4.1.1	DOD-STD-2167A
9.1.1.4	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	4.1.4	DOD-STD-2167A
9.1.1.5	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	4.2.1	DOD-STD-2167A
9.1.1.6	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	4.3.4	DOD-STD-2167A
9.1.1.7	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	4.3.4	DOD-STD-2167A
9.1.1.8	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	4.2.4	DOD-STD-2167A
9.1.1.9	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	4.2.4	DOD-STD-2167A
9.1.1.10	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	4.2.4	DOD-STD-2167A
9.1.1.11	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	4.2.5	DOD-STD-2167A
9.1.1.12	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	4.2.5	DOD-STD-2167A
9.1.1.13	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	4.2.7	DOD-STD-2167A
9.1.1.14	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	4.2.10	DOD-STD-2167A
9.1.1.15	S/W	P. Bolden, T.		DOD-STD-	4.6.1	DOD-STD-2167A

50094 Specification Paragraph Number/Title	Team	NASA Contact	Contractor Contact	SSP Document Reference	SSP Reference Paragraph Number	Comments
		Crumbley		2167A		
9.1.1.16	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	4.6.2	DOD-STD-2167A
9.1.1.17	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	4.6.3	DOD-STD-2167A
9.1.1.18	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	5.5.1	DOD-STD-2167A
9.1.1.19	S/W	P. Bolden, T. Crumbley		D684-10017-1	3.2	D684-10017-1
9.1.1.20	S/W	P. Bolden, T. Crumbley		D684-10017-1	3.2.3	D684-10017-1
9.1.1.21	S/W	P. Bolden, T. Crumbley		D684-10017-1	3.2.3	D684-10017-1
9.1.1.22	S/W	P. Bolden, T. Crumbley		D684-10017-1	3.12.4	D684-10017-1
9.1.1.23	S/W	P. Bolden, T. Crumbley		D684-10017-1	0.1	D684-10017-1
9.1.1.24	S/W	P. Bolden, T. Crumbley		D684-10017-1	4.2.4	D684-10017-1
9.1.1.25	S/W	P. Bolden, T. Crumbley		D684-10056-1 rev A	3.3.1	D684-10056-1 Rev A, CN 001
9.1.1.26	S/W	P. Bolden, T. Crumbley		D684-10056-1 rev A	3.3.1	D684-10056-1 Rev A, CN 001
9.1.1.27	S/W	P. Bolden, T. Crumbley		D684-10056-1 rev A	3.3.3.2	D684-10056-1 Rev A, CN 001
9.1.1.28	S/W	P. Bolden, T. Crumbley		D684-10056-1 rev A	3.3.1.3	D684-10056-1 Rev A, CN 001
9.1.1.29	S/W	P. Bolden, T. Crumbley		D684-10056-1 rev A	3.3.3.4	D684-10056-1 Rev A, CN 001
9.1.1.30	S/W	P. Bolden, T. Crumbley		D684-10056-1 rev A	3.3.4	D684-10056-1 Rev A, CN 001
9.2 (Title)	S/W	P. Bolden, T. Crumbley		N/A		
9.2.1 (Title)	S/W	P. Bolden, T. Crumbley		N/A		
9.2.1.1	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	4.2.6	DOD-STD-2167A
9.2.1.2	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	4.2.8	DOD-STD-2167A
9.2.1.3	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	4.2.10	DOD-STD-2167A
9.2.1.4	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	4.2.10	DOD-STD-2167A
9.2.1.5	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	5.1.2.1	DOD-STD-2167A
9.2.1.6	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	5.1.2.2	DOD-STD-2167A
9.2.1.7	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	5.2.2.1	DOD-STD-2167A
9.2.1.8	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	5.2.2.2	DOD-STD-2167A

50094 Specification Paragraph Number/Title	Team	NASA Contact	Contractor Contact	SSP Document Reference	SSP Reference Paragraph Number	Comments
9.2.1.9	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	5.2.3	DOD-STD-2167A
9.2.1.10	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	5.3.2.1	DOD-STD-2167A
9.2.1.11	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	5.3.2.2	DOD-STD-2167A
9.2.1.12	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	5.3.2.3	DOD-STD-2167A
9.2.1.13	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	5.3.3	DOD-STD-2167A
9.2.1.14	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	5.3.5.1	DOD-STD-2167A
9.2.1.15	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	5.4.2.1	DOD-STD-2167A
9.2.1.16	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	5.4.2.2	DOD-STD-2167A
9.2.1.17	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	5.4.2.3	DOD-STD-2167A
9.2.1.18	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	5.4.3	DOD-STD-2167A
9.2.1.19	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	5.4.5.1	DOD-STD-2167A
9.2.1.20	S/W	P. Bolden, T. Crumbley		D684-10017-1 GOST	3.0 A,B,C,F ?	D684-10017-1
9.2.1.21	S/W	P. Bolden, T. Crumbley		D684-10017-1 GOST	3.0 G, H, I, J, K, L ?	D684-10017-1
9.2.1.22	S/W	P. Bolden, T. Crumbley		D684-10017-1	3.0N	D684-10017-1
9.2.1.23	S/W	P. Bolden, T. Crumbley		D684-10017-1	3.0 paragraph 3	D684-10017-1
9.2.1.24	S/W	P. Bolden, T. Crumbley		D684-10017-1	3.0 paragraph 11	D684-10017-1
9.2.1.25	S/W	P. Bolden, T. Crumbley		D684-10056-1 Rev A	3.3.3.4.1	D684-10056-1 Rev A, CN 001
9.2.1.26	S/W	P. Bolden, T. Crumbley		D684-10056-1 Rev A	3.3.3.4.2	D684-10056-1 Rev A, CN 001
9.2.1.27	S/W	P. Bolden, T. Crumbley		D684-10056-1 Rev A	3.3.3.4.3	D684-10056-1 Rev A, CN 001
9.2.1.28	S/W	P. Bolden, T. Crumbley		D684-10056-1 Rev A	3.3.3.4.4	D684-10056-1 Rev A, CN 001
9.2.1.29	S/W	P. Bolden, T. Crumbley		D684-10056-1 Rev A	3.4	D684-10056-1 Rev A, CN 001
9.2.1.30	S/W	P. Bolden, T. Crumbley		D684-10056-1 Rev A	3.5	D684-10056-1 Rev A, CN 001
9.2.2 (Title)	S/W	P. Bolden, T. Crumbley		N/A		
9.2.2.1	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	4.1.8	DOD-STD-2167A
9.2.2.2	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	4.1.8	DOD-STD-2167A
9.2.2.3	S/W	P. Bolden, T.		DOD-STD-	4.1.8	DOD-STD-2167A

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		Crumbley		2167A		
9.2.3 (Title)	S/W	P. Bolden, T. Crumbley		N/A		
9.2.3.1	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	4.2.9	DOD-STD-2167A
9.2.3.2	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	4.2.9	DOD-STD-2167A
9.2.3.3	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	4.2.9	DOD-STD-2167A
9.2.3.4	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	4.2.9	DOD-STD-2167A
9.2.3.5	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	4.2.9	DOD-STD-2167A
9.2.3.6	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	5.3.2.4	DOD-STD-2167A
9.2.3.7	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	5.4.2.4	DOD-STD-2167A
9.2.3.8	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	5.4.2.5	DOD-STD-2167A
9.2.3.9	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	5.5.2.1	DOD-STD-2167A
9.2.3.10	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	5.5.2.2	DOD-STD-2167A
9.2.3.11	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	5.5.2.3	DOD-STD-2167A
9.2.3.12	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	5.5.2.4	DOD-STD-2167A
9.3 (Title)	S/W	P. Bolden, T. Crumbley		N/A		
9.3.1	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	4.1.1	DOD-STD-2167A
9.3.2	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	4.1.2	DOD-STD-2167A
9.3.3	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	4.1.3	DOD-STD-2167A
9.3.4	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	4.1.1	DOD-STD-2167A
9.3.5	S/W	P. Bolden, T. Crumbley		D684-10017-1	3.8	D684-10017-1
9.3.6	S/W	P. Bolden, T. Crumbley		D684-10017-1	3.8.3	D684-10017-1
9.3.7	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	5.2.1	DOD-STD-2167A
9.3.8	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	4.4.1	DOD-STD-2167A
9.3.9	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	4.4.1	DOD-STD-2167A
9.3.10	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	4.4.2	DOD-STD-2167A
9.3.11	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	4.4.3	DOD-STD-2167A

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9.3.12	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	5.1.4	DOD-STD-2167A
9.3.13	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	5.2.4	DOD-STD-2167A
9.3.14	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	5.3.4	DOD-STD-2167A
9.3.15	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	5.4.4	DOD-STD-2167A
9.3.16	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	5.5.4	DOD-STD-2167A
9.4 (Title)	S/W	P. Bolden, T. Crumbley		N/A		
9.4.1	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	4.1.9	DOD-STD-2167A
9.4.2	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	4.1.9	DOD-STD-2167A
9.4.3	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	4.1.10	DOD-STD-2167A
9.4.4	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	4.1.10	DOD-STD-2167A
9.4.5	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	4.5.1	DOD-STD-2167A
9.4.6	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	4.5.2	DOD-STD-2167A
9.4.7	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	4.5.3	DOD-STD-2167A
9.4.8	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	4.5.4	DOD-STD-2167A
9.4.9	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	4.5.5	DOD-STD-2167A
9.4.10	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	5.1.5	DOD-STD-2167A
9.4.11	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	5.3.5.2	DOD-STD-2167A
9.4.12	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	5.3.5.3	DOD-STD-2167A
9.4.13	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	5.4.5.2	DOD-STD-2167A
9.4.14	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	5.4.5.3	DOD-STD-2167A
9.4.15	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	5.5.5.2	DOD-STD-2167A
9.5 (Title)	S/W	P. Bolden, T. Crumbley		N/A		
9.5.1	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	4.1.6	DOD-STD-2167A
9.5.2	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	4.1.6	DOD-STD-2167A
9.6 (Title)	S/W	P. Bolden, T. Crumbley		N/A		
9.6.1	S/W	P. Bolden, T.		DOD-STD-	4.3	DOD-STD-2167A

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		Crumbley		2167A		
9.6.2	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	4.3.1	DOD-STD-2167A
9.6.3	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	4.3.1	DOD-STD-2167A
9.6.4	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	4.3.1	DOD-STD-2167A
9.6.5	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	4.3.2	DOD-STD-2167A
9.6.6	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	4.3.2	DOD-STD-2167A
9.6.7	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	4.3.3	DOD-STD-2167A
9.6.8	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	4.3.3	DOD-STD-2167A
9.6.9	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	4.3.4	DOD-STD-2167A
9.6.10	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	4.1.7	DOD-STD-2167A
9.6.11	S/W	P. Bolden, T. Crumbley		D684-10017-1	4.4.1	D684-10017-1
9.6.12	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	4.3	DOD-STD-2167A
9.6.13	S/W	P. Bolden, T. Crumbley		D684-10017-1	5.3.1	D684-10017-1
9.7	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	4.1.5	DOD-STD-2167A
9.8 (Title)	S/W	P. Bolden, T. Crumbley		N/A		DOD-STD-2167A
9.8.1	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	4.2.2	DOD-STD-2167A
9.8.2	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	4.2.2	DOD-STD-2167A
9.8.3	S/W	P. Bolden, T. Crumbley		DOD-STD-2167A	4.2.2	DOD-STD-2167A
9.9	S/W	V. Berend				
9.9.1	S/W	V. Berend				
9.9.1.1	S/W	V. Berend				
9.9.1.1.2	S/W	V. Berend				
9.9.1.1.3	S/W	V. Berend				
9.9.1.1.4	S/W	V. Berend				
9.9.1.1.5	S/W	V. Berend				
9.9.1.1.6	S/W	V. Berend				
9.9.1.1.7	S/W	V. Berend				
9.9.1.1.8	S/W	V. Berend				
9.9.1.1.9	S/W	V. Berend				
9.9.1.1.10	S/W	V. Berend				
9.9.1.1.11	S/W	V. Berend				
9.9.1.1.12	S/W	V. Berend				
9.9.1.1.13	S/W	V. Berend				

50094 Specification Paragraph Number/Title	Team	NASA Contact	Contractor Contact	SSP Document Reference	SSP Reference Paragraph Number	Comments
9.9.1.2	S/W	V. Berend				
9.9.1.2.1	S/W	V. Berend				
9.9.1.2.1.1	S/W	V. Berend				
9.9.1.2.1.2	S/W	V. Berend				
9.9.1.2.1.3	S/W	V. Berend				
9.9.1.2.1.4	S/W	V. Berend				
9.9.1.2.1.5	S/W	V. Berend				
9.9.1.2.1.6	S/W	V. Berend				No reference given
9.9.1.3	S/W	V. Berend				
9.9.1.3.1 (Title)	S/W	V. Berend				
9.9.1.3.1.1	S/W	V. Berend				
9.9.1.3.1.2	S/W	V. Berend				
9.9.1.3.1.3	S/W	V. Berend				
9.9.1.3.1.4	S/W	V. Berend				
9.9.1.3.1.5	S/W	V. Berend				
9.9.1.3.1.6	S/W	V. Berend				
9.9.1.3.1.7	S/W	V. Berend				
9.9.1.3.1.8	S/W	V. Berend				
9.9.1.3.1.9	S/W	V. Berend				
9.9.1.3.1.10	S/W	V. Berend				
9.9.1.3.2 (Title)	S/W	V. Berend				
9.9.1.3.2.1	S/W	V. Berend				
9.9.1.3.2.2	S/W	V. Berend				
9.9.1.3.2.3	S/W	V. Berend				
9.9.1.3.2.4	S/W	V. Berend				
9.9.1.3.2.5	S/W	V. Berend				
9.9.1.3.2.6	S/W	V. Berend				
9.9.1.3.2.7	S/W	V. Berend				
9.9.1.3.2.8	S/W	V. Berend				
9.9.1.3.2.9	S/W	V. Berend				No reference given
9.9.2	S/W	V. Berend				
9.9.3	S/W	V. Berend				
10.0 (Title)	Prop	J. Sanders, P. McRight		N/A		
10.1 (Title)	Prop	J. Sanders, P. McRight		N/A		
10.1.1	Prop	J. Sanders, P. McRight		MIL-P-25604D	N/A	Not In Program ADL
10.1.2	Prop	J. Sanders, P. McRight		MIL-P-26539D	N/A	Not In Program ADL, Could be MIL-P-26536D?
10.2 (Title)	Prop	J. Sanders, P. McRight		N/A		
10.2.1	Prop	J. Sanders, P. McRight		MIL-P-27407A	N/A	MIL-P-27407A, Amendment 1
10.2.2	Prop	J. Sanders, P. McRight		MIL-P-27401C	N/A	MIL-P-27401C, Notice 1
11.0 (Reserved)						
12.0	Std./	R. Loffi, R.		SSP 30219	3,4	Needs updating per

50094 Specification Paragraph Number/Title	Team	NASA Contact	Contractor Contact	SSP Document Reference	SSP Reference Paragraph Number	Comments
	Defin.	Lee				PIRN 68B
13.0 (Title)	TCS	J. Chambliss				
13.1	TCS	J. Chambliss				
13.2	TCS	J. Chambliss				
13.3	TCS	J. Chambliss				
13.4	TCS	J. Chambliss				
Appendix B	Joint fracture Control Plan	J. Zipay				
Appendix C	Add Infor on Russian Max Permis Expos Lvls for RF Rad	F. Cucinotta	Neal Zapp			

APPENDIX B

Joint Fracture Control Plan

Introduction

Fracture Control is the implementation of specific methodology to assure against catastrophic structural failure caused by an undetectable flaw. Flaws that are just smaller than the detection sensitivity of non-destructive inspection methods (radiography, dye penetrant, ultrasonics, etc.) used are assumed to exist in Fracture Critical Parts or Components. Fracture Critical Parts or Components are defined as Parts or Components whose single failure could potentially result in loss of life, disabling injury, or loss of launch or servicing vehicle, loss of the International Space Station or loss of a major ground facility. Such parts can include habitable modules, pressure vessels, fasteners, latches, mechanical systems and critical interface structures. The potential growth of such flaws and their final effect on the structural integrity during use will be assessed for structures of the ~~Russian Segment~~RS using the proven methods of qualification testing and fracture mechanics technology.

This plan documents a joint approach to assure that failures due to undetectable flaws will not occur in the ~~Russian Segment~~RS and all Russian-provided hardware flown on the Space Shuttle.

Foundations of Joint Approach

In those instances when the failure of ~~Russian Segment~~RS structure can lead to catastrophic consequences, the design of critical structural elements apart from the observation of the general requirements for their quality and reliability, should entail special measures to prevent the formation of cracks in them. The category of critical structural elements includes elements the failure of which would have catastrophic consequences. The following describes such special measures:

- During the design phase, the structural materials and manufacturing processes should be defined considering factors that diminish the initiation and propagation of cracks and also to assign control methods to detect and classify flaws.

- the use of non-destructive testing methods at the production and testing stages of parts and structural assemblies in order to find defects;

- the performance of qualification tests to confirm the functionality of the structure and the elements comprising it under the given conditions;

- the theoretical estimation of service life of the critical structural elements using fracture mechanics methods.

At RSC-Energia and Khrunichev Center, in addition to checking for cracks, which are excluded in principle by means of standards and control documents, primary attention is given to the method of experimental verification of the ~~Russian Segment~~RS structure service life.

When using this method, the system that has been established for testing out the strength of the spacecraft and modules and also the experience of conducting service life tests on aircraft is taken into consideration.

At NASA, the theoretical analysis of the service life of structural elements is employed using fracture mechanics methods. The NASA/FLAGRO program is considered the preferable method for calculating the safe service life.

The plan of measures for the prevention of the formation and development of cracks considers the special features of the Russian methodology and NASA and for the critical structural elements of the ~~Russian Segment~~RS it stipulates:

- checking cracks using non-destructive testing methods

- experimental verification of the durability of structural elements

- theoretical estimation of the service life of the critical structural elements using fracture mechanics methods.

Responsibilities:

Responsibilities will be shared by RSC-Energia, Khrunichev Center and NASA. Responsibilities will be defined as follows:

1. RSC-Energia and Khrunichev Center will select structural materials and perform testing and inspections in accordance with the following criteria:

- selection of materials will take into consideration the type, conditions, time of load application during operation and the working environment

- regulating and checking the parameters of the process for their manufacture of the intermediate products from these materials and also checking their mechanical properties and the presence of metallurgical defects.

- regulating and checking the parameters of the processes for the redistribution of the intermediate products during their manufacture of structural elements, in particular, checking the mechanical properties on control samples, checking for defects in the material and welded joints using non-destructive testing methods;

- individual tests of especially vital structural elements for strength.

- verification of the strength of structural elements during tests conducted on special strength mockups - static, vibration strength, acoustic

These procedures guarantee the conformity of the actual mechanical properties of the structural materials and their welded joints to the design application but also guarantee the absence of defects in the material and their welded joints, for example, cracks larger than the resolution of the non-destructive equipment or larger than the critical size of cracks, indirectly caused by the strength tests.

The critical structural elements in the manufacturing process are monitored for cracks using the non-destructive testing method. In addition to visual inspection, X-ray diffraction analysis and capillary defectoscopy (liquid penetrant method) are used.

The sensitivity of the inspection method makes it possible to estimate the maximum permissible length of a crack detected using this method and to thereby obtain the initial data concerning the "invisible" cracks to calculate the service life of critical parts using fracture mechanics methods. The sensitivity of the NDE method used for evaluation shall be provided as input data for the FLAGRO analysis.

2. RSC-Energia and Khrunichev Center will identify all parts or components of the ~~Russian Segment~~RS that could be a single point structural failure with potentially catastrophic results. These parts will be termed Fracture Critical Parts. These parts will include fasteners, latches, on-orbit interface structures, pressure vessels, components of pressurized systems, habitable modules or other structures or mechanical systems where failure of a part could result in a catastrophic hazard. For Russian-provided hardware launched on the Space Shuttle, individual parts whose failure would release a free mass in the Shuttle Cargo Bay weighing more than 277 grams (0.5 lbs.) will also be included.

3. RSC-Energia and Khrunichev Center will provide materials information for Fracture Critical Parts or Components including alloy composition, ultimate strength and yield strength and the material designation. Fracture Toughness (K_{1C}) values will be provided if available. In addition, information on the loads and the number of load cycles will be provided.

4. Where Fracture Toughness data are not available, NASA will propose the probable fracture toughness of the alloy(s) based on the comparison of strength level, by comparison to similar alloys where the data are available. This value must be agreed upon between NASA, RSC-Energia and Khrunichev Center as appropriate in order to perform life assessments. Joint testing of structural alloys to determine fracture mechanics properties can be undertaken.

5. RSC-Energia and Khrunichev Center will identify the kind of Non-Destructive Inspection(s) that have been applied to each of the fracture critical parts for detection of flaws. The flaw detection sensitivity for the inspection(s) applied will be used as the baseline for establishing the assumed flaw size(s) for fracture life analysis. A description of any strength testing performed on the part and the maximum stresses in the part will also be provided

6. NASA will provide data to RSC-Energia and Khrunichev Center, upon request, on U.S. On-orbit Segment fracture critical parts in accordance with paragraphs 1, 2, 3 and 5.

7. Loads induced by U.S. hardware on ~~Russian Segment~~RS elements will be included in the life assessments of fracture critical parts.

8. Loads induced by Russian Hardware on U.S. On-orbit Segment elements will be included in the life assessments of fracture critical parts.

Joint Approach and Criteria:

RSC-Energia, Khrunichev Center and NASA will assess the structure of the ~~Russian Segment~~RS and any Russian-provided hardware for adequate safety. Schedules and responsibilities for performing FLAGRO analysis will be determined individually for each element of the ~~Russian Segment~~RS. Testing and analysis will assess each fracture critical part or component to show that the largest undetected flaw will not grow to failure when subjected to the cyclic and sustained loads encountered in four (4) service lifetimes. If four lifetimes are not analytically available in any fracture critical part or component, the specific part(s) or component(s) will be more closely assessed by NASA, RSC-Energia and Khrunichev Center based on inspections, type of alloy used, design complexity, loading conditions ~~&~~and type of testing performed to determine the acceptability of a lesser factor not to be less than two (2) service lifetimes.

Fracture critical parts that have limit stress less than thirty percent of the ultimate strength of alloy of construction and which are inspected will be acceptable without a fracture life assessment. These will be classified as low-risk fracture parts.

For ~~Russian Segment~~RS or Russian-provided structure whose fracture control is not covered in this plan, additions to this plan will be negotiated

ACCEPTABLE HARDWARE

~~Russian Segment~~RS fracture critical hardware will comply with the intent of fracture control when:

1. Analysis and / or tests shows acceptable fracture life, or

2. Part or component qualifies as a low-risk fracture part, or

3. Other criteria for specific parts or components, acceptable to NASA and RSC-Energia and Khrunichev Center as appropriate and meeting fracture control intent are established and documented.

FRACTURE CONTROL SUMMARY REPORT

The final step in the fracture control program will be the preparation of a Fracture Control Summary Report (FCSR) for each element of the ~~Russian Segment~~RS. At a minimum, the FCSR will list all parts identified as fracture critical, the kind of non-destructive evaluation(s) used to define the assumed flaw size and the basis (analysis, test, etc.) for demonstrating four (4) service lifetimes. Parts that have been classified as low-risk fracture parts and not analyzed shall be listed. Special rationale, agreed to by NASA, RSC-Energia and Khrunichev Center as appropriate for acceptance of a part or component with less than four service lifetimes or a low-risk part will be noted and summarized.

APPENDIX C

Additional information on Russian Maximum Permissible Exposure Levels for Radio-Frequency Radiation

Permissible Energy Loads Created by Electrical and Magnetic Fields

The maximum energy load created by an electrical field shall not exceed the following in the specified frequency ranges:

.06-3.00 MHz	20,000 $(V/m)^2 \cdot hr$
3.00-30.00 MHz	7,000 $(V/m)^2 \cdot hr$
30.00-300.00 MHz	800 $(V/m)^2 \cdot hr$

The maximum magnetic field (EL) energy load shall not exceed 200 $(A/m)^2 \cdot hr$ in the frequency range .06-3 MHz.

Simultaneous exposure to electrical and magnetic fields in the frequency range .06-3 MHz shall conform to the following condition:

$EL_E / EL_{E\ Max.} + EL_H / EL_{H\ Max} \leq 1$ where:

$EL_{E\ Max.}$ and $EL_{H\ Max.}$ are the maximum allowable energy loads created by the electrical and magnetic fields.

Maximum Allowable Field Energy Flux Densities

The maximum electromagnetic field energy flux density (EFD) shall conform to (not exceed) the value derived from the following expression:

$EFD_{Max.} = K \cdot (EL_{EFD\ Max.} / T)$ where:

$EFD_{Max.}$ is the maximum allowable energy flux density, W/m2;
EL is the maximum allowable energy load
K is the biological activity attenuation factor, equaling:
 1 for all exposure cases except irradiation by rotating and scanning antennas
 10 for exposure to rotating and scanning antennas with a frequency not exceeding 1 Hz and a pulse-duty factor of at least 50.
 T is the exposure time equal to one work shift.

Serial and Parallel Radiation (300-300,000 MHz).

For Serial and parallel electromagnetic radiation in the 300-300,000 MHz frequency range, the total energy load from continuous or discrete (rotating or scanning antennas) irradiation shall be calculated using the following expression:

$EL_{EFD} = (EL_{EFD\ cont.} + EL_{EFD\ discr.}) \leq 200\ (\mu W \cdot hr)/cm^2$ where:

$EL_{EFD\ cont.}$ is the maximum allowable energy load from continuous irradiation,
$EL_{EFD\ discr.}$ is the maximum allowable energy load from discrete radiation.

When multiple pieces of on-board electronics are operating at the same time in the 300-300,000 MHz frequency range, the impact shall be assessed based on the total energy flux density (the sum of the values from each source).

APPENDIX D

NDC 031

NOISE LEVEL MEASUREMENT RESULT PROCESSING SEQUENCES

The A-weighted sound pressure level (dBA) will be calculated using the weighting A(f), which depends on the frequency f, presented in the following formula:

$$A(f) = 20 \cdot \lg\left[\frac{f_4^2 f^4}{(f^2+f_1^2)(f^2+f_2^2)^{1/2}(f^2+f_3^2)^{1/2}(f^2+f_4^2)}\right] - A_{1000}, \quad (1)$$

where $\mathbf{f_1}$ = 20.6 Hz, $\mathbf{f_2}$ = 107.7 Hz, $\mathbf{f_3}$ = 737.9 Hz, $\mathbf{f_4}$ = 12 194 Hz;
norming constant $\mathbf{A_{1000}}$ = -2.000 dB, rounded up to 0.001 dB.
The nominal geometric mean frequency of 1/3 octave bands in the range 10-20000 Hz is calculated according to the formula:

$$\mathbf{f = f_r \cdot 10^{(n-30)/10}}, \quad (2)$$

where $\mathbf{f_r}$ = 1000 Hz and whole numbers from 10-43 should be used for **n**.
Results of A(f) values according to formula (1) should be rounded up to 0.1 dB.
(1/3 octave band central frequencies calculated according to formula (2) are not in line with standard values for these frequencies usually indicated in tables; frequency values are rounded. However, when calculating A(f) according to formula (1), frequencies are plugged into this formula according to formula (2) calculations, in other words without being rounded.)

The "slow" SLM time response corresponds to the exponential averaging method in accordance with the following equation:

$$LA_\tau(t) = 20 \cdot \lg\{[(1/\tau)\int_{-\infty}^{t} p_A^2(\xi)e^{-(t-\xi)/\tau}d\xi]^{1/2}/p_o\}, \quad (3)$$

where
- **$LA_\tau(t)$** – time-weighted SPL in decibels (dBA);
- **τ** – exponential time constant in seconds (for the "slow" SLM time response, time constant τ equals 1 second);
- **ξ** – (theoretical) variable of integration within the range from a certain moment in time in the past, designated as -∞, (lower integral limit) to an observed moment in time t;
- **$p_A(\xi)$** – A-weighted pulsed SPL;
- **p_o** – threshold SPL.

In order to sample calculations according to formula (3), the integral of the corresponding value is replaced, or the following recurring ratios can be used (in dimensional values):

$$N_r = N_{r-1}\left(1-\frac{\Delta t}{\tau}\right)+\frac{\Delta t}{\tau}\left(p_A\right)_r^2 \quad (4)$$

where

- N_{r-1} and N_r — results of averaging during the previous and next steps in the calculations;

- Δt – time interval between **r-1** and **r** with consecutive sampling of values during the calculation;
- $(p_A)_r$ – impulsive level measured during the calculation at step **r**.
- τ – the same as in formula (3).

To represent the results of calculations according to formula (4) in decibels, the following well-known formula is used:

$$(LA_\tau)_r = 20\cdot \lg(N_r^{1/2}/p_o), \quad (5)$$

The equivalent level of non-stationary noise is determined according to the following formula:

$$L_{AT} = L_{A_{экв}T} = 20\lg\{[(1/T\int_{t-T}^{t} p_A^2(\xi)d\xi]^{1/2}/p_o\}, \quad (6)$$

where

- $L_{AT} = L_{A_{экв}T}$ – equivalent level of non-stationary noise in dBA;
- **T** – time interval for which the equivalent sound level is determined;
- **t** – current time;
- **ξ** – (theoretical) variable of integration;
- $p_A(\xi)$ – A-weighted impulsive sound pressure;
- p_o – threshold sound pressure.

Or, if non-stationary noise for time interval T has a step-by-step correlation, broken down into subintervals t_i, each of which has a stationary noise level (activation/deactivation of various stationary sources of noise or changing modes of noise source(s)), then the equivalent sound for this non-stationary noise is determined according to the formula:

$$L_{AэквT} = 10\cdot\lg\left(\frac{1}{T}\sum_{i=1}^{n} t_i \cdot 10^{L_i/10}\right) \quad (7)$$

Where

- $L_{AэквT}$ — equivalent non-stationary noise level in dBA;
- L_i — non-stationary noise level in dBA with a duration t_i;

-T – total duration **n** for time intervals t_i, $$T = \sum_{i=1}^{n} t_i$$.

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