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MILITARY STANDARD

MASS PROPERTIES CONTROL FOR SPACE VEHICLES

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DEPARTMENT OF THE AIR FORCE
Washington, D.C. 20360

MIL-STD-1811 (USAF)

Mass Properties Control for Space Vehicles

1. This military standard is approved for use within the Department of the Air Force, and is available for use by all Departments and Agencies of the Department of Defense.

2. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to:

USAF Space Systems Division, SSD/SDFC
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by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

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SECTION 2

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(Not Applicable)

SECTION 1

SCOPE

1.1 PURPOSE

This standard establishes uniform procedures for the control, determination, and documentation of mass properties of space vehicles and their subsystems and components.

1.2 APPLICATION

This standard is intended for use in acquisition and study contracts for selected space systems and space vehicles. The standard should be cited in the contract statement of work to specify the mass properties control requirements for the space vehicles as may be applicable to the acquisition. Guidance on government tailoring of this Standard for specific acquisitions is contained in Section 6.

This standard may also be used as a reference document to specify mass properties control requirements for upper stage vehicles, injection stages, satellite payloads, reentry vehicles, launch vehicles, ballistic vehicles, or for other vehicles. For these applications the term "space vehicle" is to be interpreted as the applicable vehicle.

SECTION 2

REFERENCED DOCUMENTS

(Not Applicable)

SECTION 3

DEFINITIONS

3.1 MASS PROPERTIES.

The mass properties of an item include the item's weight (or mass), center of gravity (or center of mass), mass moments of inertia, and mass products of inertia.

3.2 CURRENT MASS PROPERTIES.

The current mass properties of an item are the mass properties data based on an assessment of the most recent baseline design. This design assessment includes the estimated, calculated, or measured mass properties, and also includes an estimate for undefined design details. The weight growth allowance and uncertainties are not included.

3.3 WEIGHT GROWTH ALLOWANCE.

The weight growth allowance is the predicted change to the mass properties of an item based on an assessment of the design and fabrication status of the item, and an estimate of the design changes that may still occur. The design changes that may occur can be both in-scope and out-of-scope.

3.3.1 In-scope Changes. In-scope design changes are changes that may be implemented by the contractor to meet design requirements. The weight growth allowance associated with in-scope design changes provides for the lack of design maturity.

3.3.2 Out-of-scope Changes. Out-of-scope design changes are changes that are out-of-scope with respect to the current contract baseline, but for any number of reasons may be considered in the future. The weight growth allowance associated with undefinitized out-of-scope design changes are based entirely on past program experience and are very difficult to predict. At the direction of the customer, the weight growth allowance for undefinitized out-of-scope design changes may be omitted. Definitized proposed changes are out-of-scope until the changes are authorized by an official contract change. The weight growth associated with a definitized proposed change is based on the proposed change.

3.4 PREDICTED MASS PROPERTIES.

The predicted mass properties of an item are the current mass properties plus the weight growth allowance.

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SECTION 4

GENERAL REQUIREMENTS

4.1 CONTROL PROGRAM.

The mass properties control program for space vehicles shall be in accordance with the requirements of this standard. The contractor shall implement and maintain the mass properties control program with the objective of meeting the space vehicle mass properties requirements. Qualified personnel shall be assigned the responsibility and authority to assure the establishment and maintenance of mass properties objectives and the effective planning and execution of mass properties control functions. The program level of effort shall be adequate to determine, control, and document the mass properties of the space vehicle, subsystems, and components. The mass properties control program includes all subcontractor items, associate contractor items, Government Furnished Equipment (GFE) items, as well as contractor furnished items.

4.2 DETERMINATION.

The space vehicle mass properties shall be determined as required for all analyses requiring mass properties data such as performance analyses, stability and control analyses, and structural dynamic and loads analyses.

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SECTION 5

DETAIL REQUIREMENTS

5.1 CONTROL PROGRAM.

5.1.1 Mass Properties Control Plan. The contractor shall develop and implement a mass properties control plan. The objective of this plan shall be to formulate an organized weight control program that can be effectively implemented early in the contract period to meet the space vehicle mass properties requirements.

5.1.2 Subcontractor Mass Properties Control. The contractor shall be responsible for the mass properties control of each subcontractor and vendor. In each procurement document for items which may significantly affect the space vehicle mass properties, a mass properties control section shall be included to impose the applicable requirements of this document on the subcontractor or vendor.

5.1.3 Associate Design Activity and GFE Suppliers Interfaces. Associate Design Activities and Government Furnished Equipment (GFE) Suppliers shall be responsible for the interchange of sufficient mass properties data to support the integration of sub-unit mass properties into the complete unit mass properties. They shall respond promptly to requests from the interfacing and integrating contractors for information required by the contractors in satisfaction of contractual requirements.

5.1.4 Management Participation. High-level management shall participate in the development and maintenance of the mass properties control program. Control of mass properties has historically been found to be proportional to the direct participation of high-level management. High-level management emphasis on weight control encourages designers to consider the trade-off of light weight design and performance margins.

5.1.5 Mass Properties Limits. The contractor shall determine and document the mass properties limits. The mass properties limits shall include those established by system, subsystem, and component performance, as well as design requirements and the mass properties limits established by contract.

5.1.6 Weight Growth. The contractor shall include in the weight data an allowance for the expected weight growth. The weight growth allowance may be depleted from the beginning to the end of the contract according to an approved plan. Weight growth allowances shall be identified in the contractor's mass properties records.

5.1.7 Current Mass Properties. The contractor's space vehicle mass properties database shall be maintained current by periodic updating using the most recent information from design data, drawings, mass properties measurements, GFE data, associate contractors, subcontractors, and vendors. These data should be updated frequently in the early developments phase; once per week is recommended. Less frequent updating is acceptable late in the development phase when mass properties changes are small; once per month is a recommended minimum. More frequent updating may be required during launch preparation. The contractor's selection of updating frequency is subject to the approval of the contracting officer. The updating frequency is not necessarily related to the frequency of submitting official mass properties reports.

5.1.8 Limit Monitoring. The contractor shall maintain a documented comparison of the predicted mass properties (See 3.4) and the limits discussed in 5.1.5. The comparison shall identify the current weight growth allowance. Mass properties uncertainties should also be included and identified.

5.1.9 Corrective Action. The contracting officer shall be notified immediately when the mass properties limits described in paragraph 5.1.5 are equaled or exceeded. The contractor shall advise the contracting officer of the resulting effects on system performance and recommend corrective action.

5.1.10 Document Release. Documents controlling the design, manufacture, and procurement of system components shall be approved, prior to release, by personnel responsible for the contractor's mass properties control.

5.2 DETERMINATION.

5.2.1 Changes. A documented accounting of all weight changes shall be maintained throughout the contract. For all weight changes the accounting shall include the magnitude of the change and the reasons for the changes. Each weight change in the accounting shall be identified as being the responsibility of the contractor or the contracting officer (if due to a change in the contract requirements). This accounting shall be updated when the mass properties are updated (See 5.1.7).

5.2.2 Sequential Mass Properties. The space vehicle mass properties shall be determined and documented as a function of time or percent of steady state thrust from mission initiation through mission completion. Time increments should be selected based on requirements of other analyses or on significant mission events. All items that are expended, jettisoned, or moved during the mission shall be identified in the contractor's mass properties records.

5.2.3 Ground Operations Support. Adequate mass properties shall be developed and documented for the support of ground and launch operations. These date shall be in agreement with the actual vehicle configuration and with the planned loading and utilization of fluids and propellants. The contractor's records of all changes to the space vehicle subsequent to final mass properties measurements and the resulting mass properties shall be made available for review by the contracting officer.

5.2.4 Postflight Analysis. Actual mass properties data shall be determined by analysis of postflight data for significant mission events. Differences from the planned conditions shall be itemized and explained.

5.2.5 Trade Studies. The contractor shall maintain, available for the contracting officer's review, mass properties data developed for trade studies or other screening processes used in the design process.

5.2.6 Mass Properties Uncertainties Analyses. Knowledge is required of the accuracies of mass properties data used in space vehicle performance, stability, control, and structural analyses. This is true not only for the total space vehicle but also for elements of the space vehicle such as fluids, deployable, and independently moving parts. Mass properties approaching a limit may require an uncertainty analysis. In some cases, the accuracy of the combination of certain mass properties may be required, such as an inertia ratio or the difference of two inertias.

5.2.6.1 Requirements for Uncertainty Analyses. Mass properties uncertainty analyses shall be conducted-when mass properties dispersions are required for other analyses, or when the uncertainties may cause mass properties limits to be exceeded.

5.2.6.2 Contents. The uncertainty analysis shall include a detailed analysis of each uncertainty source with a description of the derivation of the uncertainties. The uncertainties shall include, but are not limited to, measurement

uncertainties, manufacturing variations, environmental effects, and uncertainties derived or assumed for mass properties estimations or calculations. If weight growth is included in the analysis, an explanation of how it is combined with the other sources of uncertainty is required. Documentation of the analysis shall be available for review by the contracting officer.

5.2.7 Verification.

5.2.7.1 Requirements. Each mass property and its conformance to the limits shall be verified by the contractor. Verification shall be accomplished by approved analytical methods, by test, or by a combination of both. The selection of the verification methods shall be justified by a documented and approved verification plan. The verification methods should be selected early enough in the program to provide time for the acquisition, modification, or preparation of measurement equipment and sites. The verification plan shall also include the planned general procedures for the measurement tests. A guide for a verification plan is provided in Appendix A.

5.2.7.2 Procedures. Mass properties measurement tests shall be conducted in accordance with approved, documented procedures.

5.2.7.3 Notification of Measurement. The contractor shall notify the contracting officer of the time and place of the mass properties measurement tests at least one week prior to testing. Exceptions such as the weighing of small hardware items, may be made by mutual agreement of contractor and customer.

5.2.7.4 Test Conditions. The item shall simulate the dry flight condition and be at least 95-percent complete by weight, excluding hazardous components or components not normally installed at the measurement site. A mass properties engineer shall verify the configuration of the item and record mass properties related data for all missing items, added nonflight items, and tare items.

5.2.7.5 Data Records. Mass properties verification data shall be documented and made available for review by the contracting officer.

5.2.8 Data Organization. The mass properties data shall be organized and maintained by the contractor in accordance with the requirements stated in this standard.

5.2.8.1 Functional Organizations. To provide a uniform basis for mass properties comparisons, the space vehicle mass properties shall be categorized on a functional basis. For example, the weights of all items which function primarily as the space vehicle structure shall be accumulated for the total weight of the space vehicle structure. Appendix B provides a discussion of the need for a functional breakdown and guidelines for the functional categorization of component weights. In order to achieve functional weight breakdown consistency, the contractor shall use the guidelines in Appendix B.

5.2.8.2 Sectional Organization. When the space vehicle is comprised of sections for which knowledge of the section mass properties is required, the mass properties data for the sections shall be developed separately. Examples of this include a propulsive vehicle stage having more than one stage, or an independently movable section of a space vehicle. The functional organization shall be maintained within the mass properties data of each section.

5.2.8.3 Government Furnished Equipment. The contractor’s mass properties records shall have a separate tabulation of all Government Furnished Equipment.

5.2.8.4 Correlation of Weights and Part Numbers. The contractor’s mass properties records shall include the correlation of weights with their respective drawing numbers. This shall be done at a level of detail that permits the determination that the weights of all items on the space vehicle have been included correctly.

5.2.8.5 Basis of Current Mass Properties. The basis of space vehicle mass properties can be categorized by the methods used for their determination, for example: estimated, calculated, or measured. The measured category has historically been called "actual." The percent of the space vehicle weight that is based on each of these categories is an indication of the confidence that can be placed in reported mass properties data. Mass properties determined from preliminary data such as sketches or calculations from layout drawings are typically considered to be in the estimated category. Mass properties determined from released drawings are typically considered in the calculated category. Mass properties determined by measurement or by comparison of nearly identical components for which measured mass properties are available are in the measured category. When ambiguities occur, the most representative category should be used, keeping in mind that the purpose of this categorization is to provide an indication of the confidence of the reported mass properties. The basis (estimated, calculated, measured, etc.) of each component weight

shall be included as part of the recorded component data. As many categories as is necessary to accurately define the status of the mass properties may be used. Totals of each of these categories shall be recorded to provide an indication of the mass properties confidence at the subsystem level and for the complete vehicle.

5.3 DOCUMENTATION SUMMARY.

5.3.1 Mass Properties Control Plan. A Mass Properties Control Plan in accordance with Section 5.1.1 shall be developed and documented by the contractor. This report shall state the management program and procedures to be used for mass properties control and verification during the various procurement phases. The Contract Data Requirements List (CDRL), incorporated into the contract, may require this plan to be delivered to or approved by the contracting officer.

5.3.2 Verification Plan. A Verification Plan which describes and substantiates the methods to be used to verify the mass properties data (See 5.2.7.1) shall be developed and documented by the contractor. The Contract Data Requirements List (CDRL) incorporated into the contract, may require this plan to be delivered to or approved by the contracting officer.

5.3.3 Status Report. A Mass Properties Status Report that includes the elements described in the following subparagraphs shall be developed and documented by the contractor. The Contract Data Requirements List (CDRL) incorporated into the contract, may require this report to be delivered to or approved by the contracting officer.

5.3.3.1 Mass Properties Summary. The following mass properties summary description applies for each section of the space vehicle as discussed in 5.2.8.2. The predicted mass properties shall be tabulated by subsystem and combined for the total predicted mass properties. Items which are expended or jettisoned shall be so noted. Each section’s total predicted mass properties and the space vehicle total predicted mass properties shall be presented for the launch condition. For each weight item reported, the basis used shall be indicated (See 5.2.8.5). This may be done by percentages.

5.3.3.2 Mass Properties Limit Monitoring. As described in 5.1.8, a comparison of the predicted mass properties and the mass properties limits shall be documented.

5.3.3.3 Changes. As described in 5.2.1, all weight changes incorporated since the previous Status Report shall be documented.

5.3.3.4 Potential Changes. All pending or potential weight changes shall be documented.

5.3.3.5 Sequential Mass Properties. As described in 5.2.2, the sequential mass properties shall be documented.

5.3.3.6 Government Furnished Equipment (GFE). As described in 5.2.8.3, a tabulation of GFE and the associated mass properties shall be documented.

5.3.3.7 Reference Axes. A diagram shall be prepared which relates the location and orientation of the reference axis system used for mass properties determination to the space vehicle. The exact location of the reference axis system origin with respect to the vehicle shall be noted on the diagram. If the space vehicle is comprised of more than one section, and each section has a different reference axis system, each system shall be similarly described. Their mutual relative locations and orientations shall also be described.

5.3.3.8 Weight Growth. The current status of both the weight growth allowance and the weight growth depletion plan (See 5.1.6) shall be documented.

5.3.4 Detail Mass Properties Report. A Detail Mass Properties Report that includes the elements specified in 5.3.3 plus the elements described in the following subparagraphs shall be developed and documented by the contractor. The Contract Data Requirements List (CDRL), incorporated into the contract, may require this report to be delivered to or approved by the contracting officer.

5.3.4.1 Detail Weight Statement. The detail weight statement shall tabulate the current weights by subsystem (See 5.2.8) to a level of detail as described in paragraph 30.2 of Appendix B.

5.3.4.2 Design Data. These data include the design parameters that have major impacts on subsystem weights. The information is useful for evaluating weights in the early design phase and also for improving weight estimating methods. Appendix C presents a list of design parameters to be used as a guide for reporting the data.

5.3.5 Miscellaneous Mass Properties Report. A Miscellaneous Mass Properties Report that includes the mass properties data associated with contract changes proposals, fluid and propellant verification, or current operational data (See 5.2.3) shall be developed and documented by the contractor. The Contract Data Requirements List (CDRL), incorporated into the contract, may require this report to be delivered to or approved by the contracting officer.

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SECTION 6

NOTES

The contents of this Notes section are not compliant. The notes are intended for use by Government Acquisition personnel for guidance and information only.

6.1 INTENDED USE

This standard is intended for use in acquisition contracts for selected space systems and space vehicles. The standard should be cited in the contract statement of work to specify the mass properties control requirements for the space vehicles as may be applicable to the acquisition. The mass properties control requirements specified are generally applicable to space vehicles, upper stage vehicles, injection stages, satellite payloads, reentry vehicles, launch vehicles, ballistic vehicles, or for other vehicles. For all applications the term "space vehicle" is to be interpreted as the applicable vehicle.

6.2 TAILORED APPLICATION

The requirements in each contract should be tailored to the needs of that particular program. Military specifications and standards need not be applied in their entirety. Only the minimum requirements needed to provide the basis for achieving the program requirements should be imposed. The cost of imposing each requirement of this standard should be evaluated by the program office against the benefits that should be realized. However, the risks and potential costs of not imposing requirements shall also be considered. Improper control of the mass properties of space and launch vehicles may allow the fabrication of vehicles that cannot meet the required performance or achieve the required stability.

6.3 DATA ITEM DESCRIPTION

When this standard is used in an acquisition and data are required to be delivered, the data requirements identified below shall be developed as specified by an approved Data Item Description (DD Form 1664) and delivered in accordance with the approved Contract Data Requirements List (CDRL), incorporated into the contract. When the provisions of DOD FAR Supplement, Part 27, Sub-part 27.410-6 (DD Form 1423) are invoked and the DD Form 1423 is not used, the data specified below shall be delivered by the contractor in accordance with the contract or

purchase order requirements. Deliverable data required by this standard is cited in the following paragraphs.

Paragraph No.	Data Requirement Title	Applicable DID No.
4.1 & 5.1	Mass Properties Control Plan	DI-GDRQ-81127
4.2 & 5.2.7	Mass Properties Verification Plan	DI-GDRQ-81128
5.1 & 5.2	Detail Mass Properties Report	DI-GDRQ-81129
5.1 & 5.2	Mass Properties Status Report	DI-GDRQ-81130
5.1 & 5.2	Miscellaneous Mass Properties Report	DI-GDRQ-81131

Each data item must be specified on the DD Form 1423 to be invoked.

(Data item descriptions related to this standard, and identified in Section 6, will be approved and listed as such in DoD 5010.12-L, Acquisition Management System and Data Requirements Control List (AMSDL). Copies of data item descriptions required by the contractors in connection with specific acquisition functions should be obtained from the Naval Publications and Forms Center or as directed by the contracting officer.)

6.4 SUBJECT TERM (KEY WORD) LISTING

Mass Properties
Mass Properties Control
Weight Growth
Current Mass Properties

6.5 SUPERSESSION DATA.

This issue of MIL-STD-1811 is a complete revision that supersedes MIL-M-38310 for new designs. The previous issues of MIL-M-38310 remain in effect to cover the procurement of previously designed equipment.

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APPENDIX A

MASS PROPERTIES VERIFICATION PLAN

This Appendix is a mandatory part of the standard.

10. SCOPE .

This Appendix is a guide for preparing a Mass Properties Verification Plan. The purpose of the Verification Plan is to provide a document which the contracting officer can use to review the contractor's planned methods for verifying the space vehicle mass properties. This review includes assessing the acceptability of the planned methods and the availability of acceptable mass properties measurement equipment and measurement sites.

20. REFERENCED DOCUMENTS.

(Not Applicable).

30. REQUIREMENTS.

30.1 Selected Methods Description. The Verification Plan shall include a general description of the method selected to verify each mass property which is to be used in performance analyses, stability and control analyses, or other analyses which require mass properties data as an input. The element of the space vehicle for which the mass properties data have been developed shall be described. For example, if the mass moments of inertia about the hinge line of a deployable element have been specified or established by design limits, the Verification Plan shall describe the element being deployed and state if the mass moment of inertia is to be verified by test or analysis. If a combination of methods is planned, state the portions to be verified by each method.

30.2 Substantiation of Method Selection. Analyses shall be made to substantiate the methods selected to verify the mass properties. Technically logical explanations of the methods selected, particularly for analytical verifications, shall be included in the contractor's substantiation of the methods selected.

30.3 Test Plans. General test plans shall be prepared. The plans shall include a description of the item or items to be

tested and the mass properties limits. A general description of the testing equipment, including its accuracy, and a calibration schedule shall be included. A test schedule showing the planned test site, planned schedule, and articles to be tested shall be included. The use of mass simulators instead of flight items in any test shall be accurately documented.

APPENDIX B

FUNCTIONAL BREAKDOWN OF WEIGHT

This Appendix is a mandatory part of the standard.

10. SCOPE.

Space vehicles are comprised of subsystems which perform specific functions. Examples of two subsystems are structural support for equipment and electrical power. Useful subsystem information is generated when component weights are accumulated on a functional basis. The uses of functional subsystem weights include the tracking of functional weight during design for weights proposed for new vehicles, and the improvement of the database used for the refinement of weight-estimating methods. It is necessary to strive for consistency regarding which components comprise each subsystem if the objectives of subsystem weight estimation and evaluation are to be achieved. Consideration should also be given to the configuration for which actual weight data will be obtained. The following sections provide guidelines for achieving this consistency.

20. REFERENCED DOCUMENTS.

JSC-23303 "Design Mass Properties, Guidelines and Formats for Aerospace Vehicles", dated March 1989, (NASA Johnson Space Center)

30. REQUIREMENTS.

30.1 Establishment of a Subsystem List. In accordance with Section B10, wherein the functional basis is discussed, a list shall be established which names each of the subsystems comprising the space vehicle. Since the term "space vehicle" is representative of a large variety of vehicles with a wide range of complexities, specifying a comprehensive subsystem list in this Appendix is not considered advisable. However, two subsystem lists are given in Tables B-I and B-II which are intended to serve as guides. Additional guidelines can be found in JSC 23303. The contractor shall develop a subsystem list suitable for the space vehicle being developed. This contractor's list shall contain subsystems in at least as much detail as represented in Tables B-I and B-II.

30.2 Subsystem Breakdown.

30.2.1 Second Level of Detail. Each subsystem total weight shall be broken down to a second level of detail. This second level

of detail shall be constructed to provide useful information for weight estimation and evaluation. For example, useful information is provided when a satellite electrical power subsystem is broken down into components of solar array, batteries, and power conditioning. Representative subsystem breakdowns to a second level of detail are shown in Tables B-I and B-II. The information in Tables B-I and B-II is intended to be a guide. The contractor shall establish the applicable second level weight breakdown and it shall be at least to the level of detail represented in Tables B-I and B-II.

30.2.2 Subsequent Levels of Detail. A breakdown of the second level of detail to a third level may be-useful. Examples of this are shown in Tables B-I and B-II. As in the case of the second level of detail, the third level may be needed for weight evaluation and estimation. The Contract Data Requirements List (CDRL), incorporated into the contract, may require the contractor's subsystem list, the second-level-of-detail list, and any subsequent level-of-detail lists, be prepared for review and approval by the contracting officer.

30.3 Functional Coding. The contractor shall develop a functional code which is consistent with the subsystem list and level of detail lists described in Sections 30.1 and 30.2 of this Appendix B. The code format is not specified. As weights are determined they shall be coded and accumulated by the codes.

30.3.1 Ambiguities. In the process of coding items to a function, ambiguities are likely to occur. For example, a solid propellant motor case may have two functions; propulsion and basic structure. A cylindrical portion of a motor case may be partially designed by the loads produced by the payload the launch vehicle carries and partially designed by the case internal pressure. The domes are designed by the internal pressure and the motor case skirts are designed by axial and bending loads. Another example would be the structure used to support the solar cells on a deployable solar array panel. Arguments can be made for either a structure or electrical power functional code. The numerous small equipment support provisions can be coded to either structure or the function of the equipment supported. Similar ambiguities arise in the case of wiring, plumbing, or thermal doublers.

30.3.2 Resolution of Ambiguities. For those items which have more than one function, the contractor should code them to the primary function. If the choice is not obvious, the contractor may make an arbitrary decision. When arbitrary decisions are made for items constituting at least 10 percent of the subsystem weight, the contractor shall maintain descriptive titles in the mass properties records of the space vehicle. This permits the transfer of these items from one function to another at the discretion of the contracting officer.

TABLE B-I

SAMPLE FUNCTIONAL BREAKDOWN (SATELLITE)

1. Payload

2. Structure
   - 2.1 Basic Structure
     - 2.1.1 Main Truss
     - 2.1.2 Equipment, Bulkheads, and Platforms
     - 2.1.3 Kick Motor Support Cone
   - 2.2 Secondary Structure
     - 2.2.1 RCS Tank Supports
     - 2.2.2 Momentum Wheel Supports
     - 2.2.3 Solar Array Retention Fittings
   - 2.3 Adapter, Separation
   - 2.4 Mechanical Integration (hardware, clips, misc.)

3. Thermal Control
   - 3.1 Louvers
   - 3.2 Heat Pipes
   - 3.3 Insulation
   - 3.4 Surface Mirrors, Paint

4. Electrical Power
   - 4.1 Solar Array
     - 4.1.1 Power Source
     - 4.1.2 Substrate
     - 4.1.3 Drives
   - 4.2 Converters
   - 4.3 Power Switches
   - 4.4 Electrical Integration (harness, connectors, hardware, misc.)

5. Guidance, Navigation

6. Data Management

7. Telemetry, Tracking, Command

8. Orientation Control

9. Reaction Control

10. Propulsion

11. Weight Growth Allowance

12. Fluids

TABLE B-II

SAMPLE FUNCTIONAL BREAKDOWN (Liquid Propulsion Stage)

1. Structure
   - 1.1 Fuel Tank
     - 1.1.1 Domes
     - 1.1.2 Cylinder
     - 1.1.3 Skirts
     - 1.1.4 Anti-slosh Devices
   - 1.2 Oxidizer Tank
   - 1.3 Intertank Structure
   - 1.4 Thrust Structure
   - 1.5 Launch Supports

2. Thermal Control

3. Main Propulsion
   - 3.1 Rocket Engine
     - 3.1.1 Thrust Chambers
     - 3.1.2 Pumps
     - 3.1.3 Engine Systems
   - 3.2 Fuel Feed
   - 3.3 Oxidizer Feed
   - 3.4 Pressurization
   - 3.5 Fill, Drain, Vent

4. Orientation Control (Thrust Vector Control)

5. Secondary Power
   - 5.1 Electrical
   - 5.2 Hydraulic

6. Instrumentation

7. Range Safety and Abort

8. Weight Growth Allowance

9. Fluids
   - 9.1 Impulse Propellant
   - 9.2 Residual Propellant
   - 9.3 Reserve Propellant
   - 9.4 Bias Propellant
   - 9.5 Outage Propellant
   - 9.6 Pressurization Gas

APPENDIX C

DESIGN DATA

This Appendix is a dc no charge part of the standard. The contents are intended for guidance and information only.

10. SCOPE.

This appendix is a guide for reporting design parameters which have major influences on space vehicle subsystem weights.

20. REFERENCED DOCUMENTS.

(Not Applicable).

30. MAJOR REPORTING PARAMETERS.

The following categories of data are useful for evaluating subsystem weights during the early design phase and for the improvement of weight estimating techniques.

30.1 Unmanned Satellite

a. Vehicle sketch giving major dimensions

b. Design Life

c. Electrical power subsystem description (solar array, battery)
   - Solar array area, cell thickness, cover glass thickness., substrate type, and materials
   - Battery type, depth of discharge, capacity
   - Bus voltage, number of bus, number of battery cells

d. Attitude Control
   - Type (momentum, magnetic, mass expulsion, etc.)
   - Pointing accuracy, slew angles, and rates

e. Propulsion Subsystem - for maneuvering or orbit changes
   - Propellant Type
   - Pressurization Method
   - Number of tanks and tank size
   - Number of thrusters and thrust rating
   - Total Velocity Increment

f. Thermal Control
   Type (Paint, insulation, louvers, heat pipes, refrigerators)
   Radiator Area

g. Structure
   Material Type(s)
   Construction Type(s) (Monocoque, Skin/Stringer, etc.)

30.2 Liquid Propellant Stage

a. Vehicle sketch giving major dimensions, tank geometry, etc.

b. Structural materials and types

c. Tank design pressures

d. Safety factor

e. Structural design conditions, loads

f. Engine data
   - Thrust, Specific Impulse (Sea Level and Vacuum)
   - Expansion Ratio
   - Chamber Pressure
   - Throttling Ratio
   - Number of Engines
   - Number of Starts
   - Throat Area

g. Propellant type, mixture ratio by volume or weight, densities

30.3 Solid Propellant Stage

a. Vehicle sketch giving major dimensions.

b. Chamber pressure - average and maximum expected

c. Safety factor

d. Case structural material, number of segment joints

e. Burn time

f. Nozzle materials, throat area, expansion ratio(s)

g. Thrust vector control type

h. Propellant density, loading fraction

i. Specific impulse - sea level, vacuum

30.4 Reentry Vehicle

a. Vehicle sketch giving major dimensions

b. Lift-to-drag ratio

c. Thermal protection system type

d. Wetted area (total)

e. Pressurized volume

f. Mission duration

g. Structural materials and types

h. Wing span, root chord length and thickness, plan area (define)

i. Safety factor

j. Ultimate load factor and associated weight

k. Stabilizing and control surface areas

l. Landing system type (parachute, retro-rockets, etc.)

m. Propellant type, mixture ratio, densities

n. Reaction control system type, propellant type

o. Auxiliary propulsion system type, propellant type

p. Crew size

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STANDARDIZATION DOCUMENT IMPROVEMENT PROPOSAL

INSTRUCTIONS

1. The preparing activity must complete blocks 1, 2, 3, and 8. In block 1, both the document number and revision letter should be given.
2. The submitter of this form must complete blocks 4, 5, 6, and 7.
3. The preparing activity must provide a reply within 30 days from receipt of the form.

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I RECOMMEND A CHANGE:	1. DOCUMENT NUMBER	2. DOCUMENT DATE (YYMMDD)
	MIL-STD-1811 (USAF)	910812

3. DOCUMENT TITLE

Mass Properties Control for Space Vehicles

4. NATURE OF CHANGE *(Identify paragraph number and include proposed rewrite, if possible. Attach extra sheets as needed.)*

5. REASON FOR RECOMMENDATION

6. SUBMITTER

a. NAME (Last, First, Middle Initial)	b. ORGANIZATION	
c. ADDRESS (Include Zip Code)	d. TELEPHONE (Include Area Code) (1) Commercial (2) AUTOVON (If applicable)	7. DATE SUBMITTED (YYMMDD)

8. PREPARING ACTIVITY

a. NAME	b. TELEPHONE (Include Area Code) (1) Commercial (2) AUTOVON
USAF Space Systems Division, SSD/SDF	(310) 363-3234
c. ADDRESS (Include Zip Code) P.O. Box 92960, Worldway Postal Center Los Angeles, CA 90009-2960	IF YOU DO NOT RECEIVE A REPLY WITHIN 45 DAYS, CONTACT: Defense Quality and Standardization Office 5203 Leesburg Pike, Suite 1403, Falls Church, VA 22041-3466 Telephone (703) 756-2340 AUTOVON 289-2340