DEPARTMENT OF DEFENSE

JOINT SERVICE SPECIFICATION GUIDE

CREW SYSTEMS

DEPLOYABLE AERODYNAMIC DECELERATOR (DAD) SYSTEMS HANDBOOK

This specification guide handbook is for guidance only.
Do not cite this document as a requirement.

AMSC   15GP

JSSG-2010-12

FOREWORD

JSSG RELEASE NOTE

The specification guides support the acquisition reform initiative, and is predicated on a performance based business environment approach to product development. As such it is intended to be used in the preparation of performance specifications. It is one of a set of specification guides. It is the initial release of this guide. In this sense this document will continue to be improved as the development program is accomplished.

1. This specification guide handbook is approved for use by all Departments and Agencies of the Department of Defense (DoD).

2. This Joint Service Specification Guide (JSSG) handbook, in conjunction with its companion JSSGs handbooks, is intended for use by Government and Industry program teams as guidance in developing program unique specifications. This handbook is for guidance only. This handbook cannot be cited as a requirement. If it is, the contractor does not have to comply. This document may not be placed on contract.

3. The complete set of JSSGs, and their respective handbooks, establish a common framework to be used by Government-Industry Program Teams in the Aviation Sector for developing program unique requirements documents for Air Systems, Air Vehicles, and major Subsystems. Each JSSG contains a compilation of candidate references, generically stated requirements, verification criteria, and associated rationale, guidance, and lessons learned for program team consideration. The JSSGs identify typical requirements for a variety of aviation roles and missions. By design, the JSSG sample language for "requirements" and "verification criteria" are written as generic templates, with blanks that need to be completed in order to make the requirements meaningful. Program teams need to review the JSSG rationale, guidance, and lessons learned to: (1) determine which requirements are relevant to their application; and (2) fill in the blanks with appropriate, program-specific requirements.

4. This document is Part 2 of two parts. Part 1 of the JSSG-2010 is a template for developing the program unique performance specification. As a generic document, it contains requirement statements for the full range of aviation sector applications. It must be tailored to delete non-applicable requirements to form the program unique specification. In addition, where blanks exist, these blanks must be filled in for the program unique specification to form a complete and consistent set of requirements to meet program objectives. Part 2 of the JSSG-2010 is a handbook which provides the rationale, guidance, and lessons learned relative to each statement in Part 1. The section 4, verification requirements, must be tailored to reflect an understanding of: (1) the design solution; (2) the identified program milestones; (3) the associated level of maturity which is expected to be achieved at those milestones; and (4) the specific approach to be used in the design and verification of the required products and processes. It must be recognized that the rationale, guidance, and lessons learned are not only generic in nature, but also document what has been successful in past programs and practices. This must not be interpreted to limit new practices, processes, methodologies, or tools.

5. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: ASC/ENSID, Bldg. 560, 2530 Loop Road West, Wright-Patterson AFB OH 45433-7101, by using the Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

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1. SCOPE

1.1 Scope.

This handbook provides the guidance for the development requirements and verifications for deployable aerodynamic decelerator (DAD) system or subsystem. Previously these requirements have been applied strictly to parachute systems however, the term DAD has been used to encompass any deployable aerodynamic decelerator, flexible or rigid. However, since many of the requirements and guidance have been developed for specific parachute applications, the term "parachute" is still used frequently throughout the text. For the purposes of the generic requirements and guidance, the terms "decelerator" and "parachute" are synonymous. This handbook is for guidance only. This handbook cannot be cited as a requirement. If it is, the contractor does not have to comply.

2. APPLICABLE DOCUMENTS

2.1 General.

The documents listed below are not necessarily all of the documents referenced herein, but are the ones that are needed in order to fully understand the information provided by this handbook.

2.2 Government documents.

2.2.1 Specifications, standards, and handbooks.

The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those listed in the latest issue of the Department of Defense Index of Specifications and Standards (DoDISS) and supplement thereto.

SPECIFICATIONS

FEDERAL

A-A-59291	Ink, Marking (for Parachutes and Other Textile Items)
QQ-A-367	Aluminum Alloy Forgings **(Inactive for New Design)**
QQ-C-320	Chromium Plating (Electrodeposited)
DDD-L-20	Labels: For Clothing, Equipage, and Tentage (General Use)

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MIL-S-5002	Surface Treatments and Inorganic Coatings for Metal Surfaces of Weapons Systems **(Inactive for New Design)**
MIL-C-5541	Chemical Conversion Coatings on Aluminum and Aluminum Alloys

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MIL-E-6051	Electromagnetic Compatibility Requirements, System **(Canceled; s/s by MIL-STD-464)**
MIL-H-6088	Heat Treatment of Aluminum Alloys **(Canceled, s/s by SAE AMS-H-6088)**
MIL-H-6875	Heat Treatment of Steel, Process For
MIL-I-6903	Ink, Marking (for Parachutes and Other Textile Items) **(Canceled, s/s by A-A-59291)**
MIL-F-7179	Finishes, Coatings, and Sealants for the Protection of Aerospace Weapons Systems **(Canceled, s/s by MIL-STD-7179)**
MIL-F-7190	Forging, Steel, for Aircraft/Aerospace Equipment and Special Ordnance Applications
MIL-P-7567	Parachutes, Personnel, Detail Manufacturing Instructions For
MIL-B-7883	Brazing of Steels, Copper Alloys, Nickel Alloys, Aluminum and Aluminum Allows **(Canceled; future acquisitions should specify one: AWS-C3.4, AWS-C3.5, AWS-C3.6, AWS-C3.7)**
MIL-I-8500	Interchangeability and Replaceability of Component Parts for Aerospace Vehicles **(Canceled)**
MIL-W-8611	Welding, Metal Arc and Gas, Steels and Corrosion and Heat Resistant Alloys **(Canceled; s/s by MIL-STD-2219)**
MIL-A-8625	Anodic Coatings for Aluminum and Aluminum Alloys
DOD-D-1000	Drawings, Engineering and Associated Lists **(Inactive for New Design; use MIL-DTL-31000)**
MIL-F-18264	Finishes: Organic, Weapons Systems, Application and Control Of
MIL-A-21180	Aluminum Alloy Castings, High Strength
MIL-D-21265	Cartridges for Cartridge Actuated Devices, Design and Evaluation Of
MIL-A-22771	Aluminum Alloy Forgings, Heat Treated
MIL-D-23615	Design and Evaluation of Cartridge Actuated Devices
MIL-I-23659	Initiators, Electrical, General Design Specification For
MIL-DTL-31000	Technical Data Packages

MIL-PRF-55110	Printed Wiring Board, Rigid, General Specification For
MIL-H-81200	Heat Treatment of Titanium and Titanium Alloys
MIL-C-83488	Coating, Aluminum, Ion Vapor Deposited
MIL-S-85076	System, Automatic, Water Activated Parachute Release, Detail Specification For **(Canceled)**
MIL-P-85710	Parachutes, Personnel Emergency Escape General Design Specification For
MIL-C-87115	Coating, Immersion Zinc Flake/Chromate Dispersion **(Inactive for New Design)**

STANDARDS

  FEDERAL

FED-STD-H28	Screw Thread Standards for Federal Services
FED-STD-191	Textile Test Methods
FED-STD-595	Colors Used in Government Procurement
FED-STD-751	Stitches, Seams, and Stitching

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MIL-STD-130	Identification Marking of U.S. Military Property
MIL-STD-461	Requirements for the Control of Electromagnetic Interference Emissions and Susceptibility
MIL-STD-462	Measurement of Electromagnetic Interference Characteristics, Test Method Standard For
MIL-STD-464	Electromagnetic Environmental Effects Requirements for Systems
MIL-STD-470	Maintainability Program for Systems and Equipment **(Canceled, s/s by MIL-HDBK-470)**
MIL-STD-756	Reliability Modeling and Prediction **Canceled)**
MIL-STD-785	Reliability Program for Systems and Equipment Development and Production **(Canceled)**
MIL-STD-810	Test Method Standard for Environmental Engineering Considerations and Laboratory Tests
MIL-STD-858	Testing Standard for Personnel Parachutes **(Canceled)**
MIL-STD-882	System Safety Program Requirements
MIL-STD-889	Dissimilar Metals

MIL-STD-1252	Inertia Friction Welding Process, Procedure and Performance Qualification **Inactive for New Design)**
MIL-STD-1385	Preclusion of Ordnance Hazards in Electromagnetic Fields, General Requirements For **(Canceled, s/s by MIL-STD-464)**
MIL-STD-1472	Human Engineering
DOD-STD-1866	Soldering Process General (Non-Electrical) **(Canceled)**
MIL-STD-2067	Aircrew Automated Escape Systems Reliability and Maintainability (R/M) Program Requirements For
MIL-STD-2175	Castings, Classification and Inspection Of
MIL-STD-2219	Fusion Welding for Aerospace Applications
MIL-STD-7179	Finishes, Coatings, and Sealants for the Protection of Aerospace Weapons Systems

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MIL-HDBK-5	Metallic Materials and Elements for Aerospace Structures
MIL-HDBK-132	Protective Finishes for Metal and Wood Surfaces of Weapons Systems **(Canceled)**
MIL-HDBK-470	Maintainability Program for Systems and Equipment

(Unless otherwise indicated, copies of the above specifications, standards, and handbooks are available from the Standardization Document Order Desk, 700 Robbins Ave., Bldg 4D, Philadelphia PA 19111-5094.)

2.2.2 Other Government documents, drawings, and publications.

The following other Government documents, drawings, and publications form a part of this document to the extent specified herein.

DEPARTMENT OF TRANSPORTATION

49 CFR 171-178	Transportation
FAA TSO-C23	

(Copies of 49 CFR are available from the Government Printing Office (GPO), P.O. Box 371954, Pittsburgh PA 15250-7954 and copies of FAA TSO-C23 are available from the Department of Transportation, FAA Aeronautical Center, AML-611, P.O. Box 25082, Oklahoma City OK 73125-5082.)

NAVAL WEAPONS CENTER (NWC)

SK 13-018-001-85	Parachute Volume Measurement Fixture
NWC TP 6575	Parachute Recovery Systems Design Manual

NAVAL AIR SYSTEMS COMMAND (NAVAIR)

NAVAIR 13-1-6.2	Aviation-Crew Systems Manual-Organization, Intermediate and Depot Level Maintenance with Illustrated Parts Breakdown for Emergency Personnel and Drogue Parachute Systems
AS-4613	Application and Derating Requirements for Electronic Components, General Specification For
WS-6536	Procedures and Requirements for Preparation and Soldering of Electrical Connections

(Copies are available from the Naval Weapons Center (NWC), ATTN: Technical Library, Code 3432, China Lake CA 93555-6001. Copies of the Aeronautical Specifications (AS) are available from the Naval Inventory Control Point (NAVICP), Code 33343.10, 700 robbins Ave., Phiadelphia PA 19111-5098 and copies of the Weapons Specifications (WS) are available from the Defense Automated Printing Service (DAPS), ATTN: DoDSSP, Code NPP-9, Bldg 4/D, 700 Robbins Ave., Philadelphia PA 19111-5094.

AIR FORCE

AFFDL-TR-78-151	Recovery Systems Design Guide
T.O. 14D3-11-1	Operation, Inspection, Maintenance, and Packing Instructions for Emergency Personnel Recovery Parachute (Chest, Back, Seat Style, and Torso Harness)
T.O. 14D1-3-316	Inspection, Repair, and Packing Instructions, Drogue Parachute Assembly, Part Numbers: J114712-501, J114712-503, and J114712-505

(Copies of TRs are available from the Defense Technical Information Center (DTIC), 8725 John J. Kingman Rd., Ste 0944, Fort Belvoir VA 22060-6218. Copies of TOs are available from OC-ALC/TILUB, 7851 Arnold St., Ste 209, Tinker AFB OK 73145-9147.)

INTERRANGE INSTRUMENTATION GROUP (IRIG)

IRIG 106	Telemetry Standards
IRIG 118	Test Methods for Telemetry Systems and Subsystems

(Copies are available from: Range Commanders Council, ATTN: STEWS-SA-R, White Sands Missile Range NM 88002-5110.)

2.3 Non-Government publications.

The following document(s) form a part of this document to the extent specified herein. Unless otherwise specified, the issue of the documents which are DoD adopted are those listed in the issue of the DoDISS, and supplement thereto.

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

ASTM D 2261	Standard Test Method for Tearing Strength of Fabrics by the Tongue (Single Rip) Procedure (Constant-Rate-of-Extension Tensile Testing Machine)
ASTM D 2262	Standard Test Method for Tearing Strength of Woven Fabrics by the Tongue (Single Rip) Method (Constant-Rate-of-Traverse Tensile Testing Machine) (DoD adopted)

(Application for copies should be addressed to the American Society for Testing and Materials, 100 Barr Harbor Dr., West Conshohocken PA 19428-2959.)

AMERICAN WELDING SOCIETY (AWS)

AWS-C3.4	Torch Brazing (DoD adopted)
AWS-C3.5	Brazing, Induction (DoD adopted)
AWS-C3.6	Furnace Brazing (DoD adopted)
AWS-C3.7	Aluminum Brazing, Specification For (DoD adopted)

(Application for copies should be addressed to the American Welding Society, 550 N. LeJeune Rd., Ste 100, Miami FL 33126-5699.)

SOCIETY OF AUTOMOTIVE ENGINEERS (SAE)

AMS-H-6088	Heat Teatment of Aluminum Alloys
AS 8015	Minimum Performance Standards for Parachute Assemblies and Components, Personnel

(Application for copies should be addressed to the Society of Automotive Engineers, Inc, 400 Commonwealth Dr., Warrendale PA 15096-0001.)

2.4 Order of precedence.

In the event of a conflict between the text of this document and the references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

3. REQUIREMENTS

3.1 Crew Systems Engineering (see JSSG-2010-1).

3.2 Crew Systems Automation, Information, and Control/Display Management (see JSSG-2010-2).

3.3 Cockpit/Crew Station/Cabin (see JSSG-2010-3).

3.4 Aircrew Alerting (see JSSG-2010-4).

3.5 Aircraft Lighting (see JSSG-2010-5).

3.6 Sustenance and Waste Management (S&WM) Systems (see JSSG-2010-6).

3.7 Crash Survivability (see JSSG-2010-7).

3.8 Energetics (see JSSG-2010-8).

3.9 Life Support/Personal Protection (see JSSG-2010-9).

3.10 Oxygen System (see JSSG-2010-10).

3.11 Emergency Egress (see JSSG-2010-11).

3.12 Deployable Aerodynamic Decelerator (DAD) Systems.
The decelerator or parachute shall be used to affect stabilization, deceleration, and/or safe recovery for the following application: _____. The term "decelerator" or "parachute" as used throughout this specification shall apply to the system consisting of the following: _____ (This section is for parachute and other deployable decelerator subsystem requirements including personnel recovery, seat deceleration/stabilization, crew module deceleration/stabilization and recovery, and other subsystem applications as required. This section should be tailored as the JSSG-2010 decelerator subsection or as a stand alone specification for a decelerator system with consideration of the guidance in the companion handbook: JSSG-2010-12. If a system includes more than one decelerator subsystem this section should be tailored separately for each different application).

<div align="center">REQUIREMENT RATIONALE (3.12)</div>

Parachutes and other decelerators are used in a broad spectrum of applications. Each parachute must be designed for a specific application to meet criteria such as deployment speed, deployment altitude, desirable stability characteristics during descent, steady state rate of descent, and weight to be recovered. The functional definition of the "decelerator or parachute" assembly being developed is also required to clarify the scope of the effort.

<div align="center">REQUIREMENT GUIDANCE (3.12)</div>

The precise application and purpose for which the parachute is to be developed and the aircraft or the major system or subsystem on which the parachute or component thereof will be installed should be clearly stated in the first blank; for example: "The parachute shall be designed for auxiliary deceleration of the F-1000 aircraft during landing roll out." The functional definition of the parachute or decelerator subassembly should be stated in the second blank to define the scope of the effort. For example: In the case of a personnel parachute, the acquisition may be only for a new parachute canopy, in another case, it may be for a canopy, and container, in another case it may be for a complete system of harness, container, and canopy. A functional definition should reflect the scope of the acquisition, i.e., The term "parachute" as used throughout this document shall apply to the system consisting of the following: a complete assembly including a suspension/attachment mechanism (harness), decelerator, and decelerator stowage container. General guidance for design considerations of various decelerator applications are given below.

Personnel parachute considerations.

Emergency escape personnel parachutes are classified as one of two major types as follows:

a. Type 1 - Ejection seat parachute. The ejection seat parachute (or recovery subsystem) is for use by an aircrew member after exiting the aircraft via an ejection seat, or aircrew automated escape system (AAES).

b. Type 2 - Bailout parachute. The bailout parachute is for use by an aircrew member after manually exiting the aircraft and may be worn during flight or donned immediately prior to egress or bailout.

Emergency escape personnel parachutes have traditionally been fabric devices used by aircrew members for making a safe descent from an aircraft following ejection (type 1) or bailout (type 2). Requirements for both types are generally similar, and steady state requirements are usually identical.

Desirable design features. Recommended design features that are desirable for premeditated and emergency escape personnel parachutes are as follows:

a. Low bulk and weight.

b. Comfortable, light weight, and properly designed harness.

c. Provision for fast release of canopy from harness or person. Standard canopy release hardware should be used as applicable. Automatic release when landing in water is also desirable.

d. A pack that will not have any corners or protuberances and that is properly positioned in order not to be subject to damage or snagging preceding or during deployment. Emergency escape personnel parachutes should also be packed or stowed in a container that will not hinder aircrew field of vision (particularly type 1 parachutes).

e. Adaptability to automatic operation.

f. Resistance to damage during use and recovery.

g. Ease of repair.

h. Ease of packing.

i. Low initial cost.

j. Low life-cycle and maintenance costs.

Seat stabilization. An important part of an ejection seat or AAES system is stabilization of the seat. Seat ejection at high subsonic and supersonic speeds poses a stabilization problem, because aerodynamic forces can cause such abrupt and rapid tumbling of the seat that a person's physical and mental control can be degraded. Tumbling of a seat or capsule can also interfere with clean deployment of the recovery parachute. Stabilization of the crew member in a high altitude manual bailout situation can be just as critical. Auxiliary stabilization parachutes are often used to stabilize the crew member, the crew/seat combination, or an escape capsule, prior to deployment of the main recovery parachute.

The following requirements apply to the stabilization of personnel, an ejection seat, and an escape capsule by parachute.

a. The deployment of the stabilization parachute must be extremely rapid to avoid canopy fouling on personnel, gyrating seat, or capsule.

b. The opening at subsonic and supersonic airspeeds must be rapid and reliable.

c. Parachute deployment must be positive; static line or forced ejection to deploy the parachute into a region not appreciably affected by the wake of the aircraft seat or the capsule.

d. The drag must be sufficient to control personnel, seat, or capsule tumbling to prevent or preclude disorderly deployment of the parachute.

e. Manual control for any individual operation during the sequence prior to the deployment of the recovery parachute must be available. If the automatic manual control fails, there should be a manual backup.

f. Adequate clearance of the aircraft structure must be assured.

g. Acceleration must be kept within the acceptable human tolerances (see 3.12.2.2 Dynamic Operation guidance).

Vehicle Recovery Parachute Considerations

Overall design. The basic purpose in designing any vehicle recovery parachute is to decelerate the recoverable body from the speed and the altitude at which it is traveling prior to recovery to a low vertical speed at a low altitude, at which ground impact will not cause any damage or only minimal damage. Vehicle recovery parachutes must be individually designed to obtain the desired performance applicable to a specific vehicle, a specific flight, and a specific desired performance. The design of the vehicle recovery parachute must be complete (as applicable to the body to be recovered), with a number of stages, parachute types and sizes, location and configuration of stowage compartment, deployment system and procedure, release and control system, and a shock absorbing or flotation method of landing. The overall requirements and conditions imposed by the recoverable body design and the flight regime in which it is to be operated must be considered before any stage or component of the vehicle recovery parachute can be designed. The final design of the vehicle recovery parachute must reflect the best possible compromise between the size, the cost, the impact damage factor to the vehicle, and the effect on the performance of the vehicle caused by the weight and the bulk of the parachute.

General design considerations. The designer of a vehicle recovery parachute should consider the following:

a. Possible range of speed at initial deployment.

b. Possible range of altitude at initial deployment.

c. Type of recovery such as rapid, stabilized descent; delayed descent; or free descent in which final impact is the only consideration.

d. Allowable weight and space available for deployable aerodynamic decelerator and impact attenuation system.

e. Location of decelerator or decelerators, which may affect the installation required and the type of deployment such as pilot parachute, static line, or forced ejection equipment.

f. Bridle design.

(1) Desirable angle for vehicle support.

(2) Center of gravity at time of deployment and descent.

(3) Force limitations of vehicle at load connections.

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g. Direction of G and maximum G tolerance for unmanned vehicles or rate of G onset and maximum G tolerance of humans for manned vehicles.

h. Desirable stability and angle of descent at final impact.

i. Shock attenuation system to be used for final impact.

j. Geographical and physiographical area in which vehicle is expected to operate.

k. Weight of vehicle at anticipated recovery time.

l. Position of first stage parachute at inflation, as influenced by motor blast heat and pressure and by wake effect.

m. Aerodynamic heating.

n. Vehicle configuration (stable or unstable in descent).

Major design problems. Problems in designing a satisfactory vehicle recovery parachute can be grouped into four major categories as follows:

a. Overall design consideration based on anticipated flight conditions and environments.

b. Detailed design layout based on number of deceleration stages and components required.

c. Requirement for repeated use of recovered items.

d. Fabrication of vehicle recovery parachute and free–flight testing under simulated or actual recovery conditions.

Phases of recovery. The recovery of vehicles from atmospheric and space flight by a parachute consists of all or some of the following phases:

a. Atmospheric re-entry and hypersonic-speed deceleration

b. Supersonic deceleration and stabilization

c. Final recovery

d. Ground or water impact

e. Location and retrieval.

Aerodynamic drag shapes. Comparison of the drag, the heating, and the static stability of the various aerodynamic drag shapes obtained by analytical calculations and shock-tube tunnel tests has shown that a 70° cone is the optimal configuration. The 70° cone, with a length to diameter ratio of 0.3 and a drag device to capsule area ratio of 50, has a C_D of approximately 1.5 at Mach 8. Deviation from the optimal configuration is often necessary in the development of exploratory test models because of structural problems and the complexity of a parachute.

Inflatable conical shape. The flexible, inflatable conical shape has been subjected to wind tunnel tests up to Mach 10 and has shown C_D that is compatible with data that was obtained from solid models. The shock-tube tunnel tests and the tests on the conical shape have shown static stability for cone angles up to 70°. The questionable part of the performance of the conical shape is the stability of the cone when cone angles that are greater than 70° are considered.

Inflatable spherical balloons (ballutes). For the sake of the structural simplicity of the model, inflatable spherical balloons, or ballutes, have been subjected to numerous wind tunnel tests up to Mach 3.5 and to numerous free flight tests above Mach 2 at an altitude of 150,000 feet. The

results of the wind tunnel tests and the free flight tests have indicated that an inflatable spherical balloon, utilizing readily available material and present day methods of manufacturing, is feasible and is a practical method of decelerating and stabilizing a recoverable payload from high altitude and high speed flight regimes. The use of an inflatable torus around the inflatable spherical balloon as a boundary-layer trap was found necessary to obtain static stability in the low subsonic speed regime. The spherical balloons have supersonic C_D that is slightly less than unity (0.93).

Expandable structures. The pace and speed at which aerospace vehicles have been developed have forced deviations from an analytical step progression to orbital velocities. A mechanically expandable re-entry vehicle with a light, flexible, foldable skin and a low W/C_DA was investigated on a competitive basis with retro-rockets, heat-sink, and parachute final recovery. This high drag device became known as the AVCO drag brake. The drag brake has sufficient area in low altitude orbits (150 nautical miles or lower) to produce a drag force large enough to circularize or make in-plane orbit corrections and de-orbit. The drag brake is radiation cooled with the temperature remaining below 1,300 °F at all times and at all points. The drag brake does not require any additional drag producing body for final recovery over water. The multiple use of the drag brake aerodynamic surfaces eliminates the requirement for a retro-rocket, an attitude control system, or a final recovery parachute and results in a significant weight saving. An expandable structure decelerator will be between 25 percent and 50 percent lighter than a rigid re-entry vehicle. The missions that are possible with the drag brake area are limited to orbital-plane re-entries and orbital altitudes below 150 nautical miles. The drag brake has a much lower total heat ratio than rigid vehicles that have a constant L/D ratio (see table I). The maximum benefit of lift in controlling deceleration and heating rate is obtained from L/D ratios between zero and one–half. The control of deceleration and heating rate is not greatly improved for vehicles with higher L/D ratios, but the altitude range and the horizontal travel capability (cross–range capability) increase proportionally with the square of the L/D ratio. The base for the preceding comparison is an expandable structure, zero-lift decelerator. Lift, in addition to permitting cross-range maneuverability, also decreases the heating rate and peak deceleration (see table I).

The conclusion is that a lightweight expandable structure with zero lift and a rigid structure with lift have desirable features that are not obtainable by the other and that the desirable re-entry decelerator should possess the desirable qualities of both. The desirable features of a lightweight expandable structure with zero lift are high weight efficiency (relative weight for the same payload), compact launch vehicle, low ballistic coefficient (W/C_DA), high operational altitude (above 200,000 feet), high emissivity, low total heat, and reduced communication problem through the ionized flow. The desirable features of a rigid structure with lift are maneuverability, lower heating rates, lower deceleration, and confidence in the design and the fabrication gained from years of aircraft experience.

Supersonic speed deceleration and stability. Aerodynamic decelerators are essential for the initial deceleration and stabilization of aerospace vehicles to reduce their velocity for the safe initiation of final recovery by a large parachute. Aerodynamic decelerator devices are also required for the initial deceleration or initial stabilization (or both) of missiles, drones, boosters, space capsules, data capsules, and a variety of other re-entry vehicles. The self-inflating trailing aerodynamic decelerators are considered to be the most suitable decelerators in the transonic and supersonic flight regimes because of the relative simplicity of their design and operation.

TABLE I. Variation of factors with L/D ratios.

L/D ratios	Relative weight for equal payload	Heating rate ratio	Total heat ratio	Peak deceleration for entry at -3°	Gross range
Expandable structure: 0	1	1.0	1.0	8	0
Rigid structure: 0.5	1.5	0.44	1.85	3.3	135
1.0	1.6	0.32	2.60	2.25	540
1.5	1.7	0.26	3.10	1.85	1200
2.0	1.8	0.22	3.50	1.70	2140
2.5	1.9	0.20	3.85	1.60	3340

Aircraft Deceleration and Spin Stabilization Parachute Considerations

Parachutes have proven to be very effective for decelerating aircraft during landing approach and landing roll and for recovering aircraft from spins and stalls. The first known test that used a parachute as a landing brake was conducted in 1923 at McCook Field, Dayton OH. A conventional man-carrying parachute was used to reduce the landing roll of a DeHavilland biplane.

Ribbon parachutes. In 1933 the Germans investigated the feasibility of developing parachutes suitable for in–flight and landing deceleration of aircraft. As a result of these investigations, the ribbon parachute was developed and successfully tested in 1937 as a landing brake for a Junker's W-34 aircraft. The ribbon parachute was adequately stable, opened reliably, had a low opening shock, and did not interfere with the controllability of the aircraft. The Germans, during World War II, used ribbon parachutes as landing deceleration parachutes and retractable dive brakes.

Drag parachutes. The development of jet aircraft has resulted in high landing speeds and in associated long landing rolls. The B-47 bomber aircraft was the first USAF aircraft to be equipped with a landing deceleration drag parachute and soon was followed by the F-84 fighter aircraft and the B-52 bomber aircraft. The drag parachute of the B-47 bomber aircraft decreased the landing roll by 25 to 40 percent, depending on touchdown speed and runway conditions. Drag parachutes are most effective on wet or icy runways and for high speed emergency landings. The drag parachute, which originally was intended to be used as an emergency device, soon proved to be effective for saving tires and brakes and is in general use for all landings. Figure 1 shows landing roll reduction as a function of parachute diameter and ground friction coefficient. Table II shows a variety of deceleration parachute systems.

Approach parachutes. The B-47 bomber aircraft used an approach parachute as well as a landing drag parachute. The approach parachute, which was deployed at altitude, steepened the descent and approach angle and improved the landing accuracy.

Drag and approach parachutes. Reefed drag parachutes have been deployed during approach followed by disreef at touchdown, serving both as an approach and a deceleration landing brake; however, no operational use of this concept is known.

Design requirements. The design of aircraft deceleration parachutes must include the following requirements:

    a. No oscillation to avoid interference with control of the aircraft.

    b. Reliable opening in the wake of the aircraft.

    c. High drag but low opening peak load.

    d. Low weight and volume.

    e. Suitability for repeated use.

    f. Ease of maintenance and installation.

    g. Low cost.

Ribbon parachutes. The ribbon parachute was specifically developed as a stable parachute that would not interfere with aircraft control. Added benefits of the ribbon parachute are its low opening load factor and its insensitiveness to local damage. Ribbon parachutes were the first drag parachutes for the B-47 and the B-52 bomber aircraft.
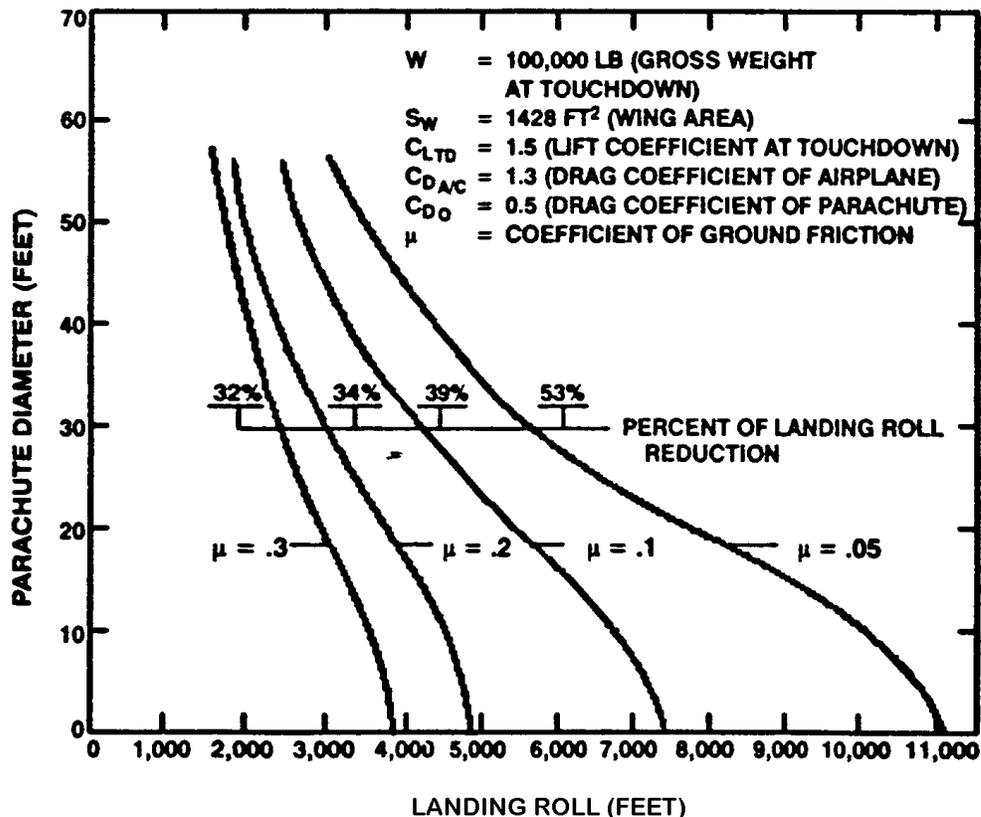
FIGURE 1. Landing roll reduction versus parachute diameter and μ factor.

Ringslot parachutes. The ringslot parachute was developed in 1951 at Wright Field as a low cost replacement of the ribbon parachute. The ringslot parachute is used today on several U.S. and foreign fighter aircraft.

Cross and varied porosity parachutes. Several foreign countries are using the Cross parachute. The Cross parachute is employed in this country as a drag brake for automobile dragsters. A varied porosity version of the conical ribbon parachute type, using continuous ribbons, has been introduced as an aircraft drag parachute. The Cross and the varied porosity parachutes have the same drag as a ringslot parachute of equivalent size but have a slightly higher opening load factor. The Cross parachute is relatively inexpensive to manufacture.

Spin and deep stall recovery parachutes. Parachutes for spin and deep stall recovery are used today on prototypes of most military aircraft and some civilian aircraft. Many aircraft during the flight test phase must demonstrate spin and deep stall recovery characteristics. Parachutes that are installed in the tail of the aircraft have been used successfully for termination of the spin and for stall recovery.

Spin recovery parachute configurations. A typical spin recovery parachute system consists of a riser, a spin recovery parachute, a deployment bag, and the components that provide deployment of the main parachute. The parachute riser that connects the parachute to the aircraft must be able to move freely in all directions without hang-up.

TABLE II. Aircraft deceleration parachutes.

Aircraft	Type	Type designation	Nominal diameter (ft)	Number of gores	Deployment velocity (in knots)
F-100	ringslot	MB-5	16	20	190
F-101	ringslot	MB-6	15.5	20	200
F-4	ringslot	MB-6	15.5	20	200
F-104	ringslot	MB-7	16	20	200
F-105	ribbon	MB-8	20	24	225
F-106	ringslot	A-28A-1	14.5	20	220
F-5	ringslot		15	20	180
B-47 Approach	ringslot	MB-1	16	20	195
B-47	ribbon	D-1	32	36	160
B-52	ribbon	D-2	44	48	170
B-58	ringslot		24	28	190
F-16[1]	ribbon[2]		23	24	200
TA-7E	ringslot		15	20	180

[1] The aircraft is a Norwegian version of the F-16 aircraft.

[2] The parachute is a varied porosity continuous ribbon parachute.

Design considerations. Design considerations for the spin recovery parachutes involve the size of the parachute, the type of the parachute, the length of the connecting riser, the deployment method for getting the parachute into good airflow, and the pilot controlled mechanism for deploying and jettisoning the parachute. The size of the parachute is best determined by model spin tests. The pertinent data for several spin recovery parachutes that are listed in table III can be used as an alternative to the model spin tests. Using the relationship of the parachute drag area to the wing area gives a ratio of 0.5 to 0.7 for aircraft that are in the weight class of 70,000 pounds and a ratio of 0.8 to 1.0 for aircraft that are in the weight class of about 20,000 pounds. The spin recovery parachute should be stable, have high drag, and have a low opening load factor in order to obtain the maximum drag force with a minimum required weight and stowage volume. The distance from the leading edge of the canopy to the rear of the aircraft fuselage is important to ensure parachute inflation in the wake of the spinning aircraft. The ratio of this distance for the parachutes listed in table III divided by the nominal parachute diameter varies between 2.8 and 3.8 with the high ratio used for the most recent aircraft.

TABLE III. Parachutes for spin and stall recovery.

Types and function of parachute	Gross weight (in lbs)	Deployment velocity (in knots)	Parachute size (D_o) (in ft)	Line length (in ft)	Riser length (in ft)	Trailing distance (D_o)	Deployment method (see fig 17)
Ribbon chute for stall recovery of DC-9 aircraft	108,000	210	24	24	136	6.3	A
Ribbon chute for spin recovery of T-38 aircraft	11,000	185	24.8	35	45	3.2	C
Ringslot chute for spin recovery of F-105 aircraft	50,000	200	21	21	45	3.7	C
Ribbon chute for spin recovery of F-14 aircraft	53,000	185	26	26	74	3.8	A
Ribbon chute for spin recovery of S-3A aircraft	42,500	140	28	28	47	2.7	A
Ribbon chute for spin recovery of F-16 aircraft	20,000	188	28	28	50	2.8	A
Ribbon chute for spin recovery of F-5E aircraft	15,000	185	24.8	25	45	3.2	B
Ribbon chute for spin recovery of F-17 aircraft	22,000	188	26	26	76	3.9	A

Components. Only the ribbon and the ringslot parachutes have been used for spin recovery parachutes. If properly designed their oscillation is less than 3°, which is more important for the runway and in-flight deployment tests prior to spin tests. Performance and design data for landing drag parachutes apply equally well to spin recovery parachutes. A varied porosity ribbon parachute, which was used as a drogue parachute for the crew module of the B-1 bomber aircraft and has been used as an aircraft drag parachute, may be considered for future spin recovery uses.

Airdrop Parachute Considerations

Airdrop concepts require the use of parachutes for aerial delivery of vital supplies and equipment in an operational condition in support of combat operations and in supply missions. Present standard airdrop systems are designed for unit cargo loads weighing up to 35,000 pounds. The primary objective of the airdrop systems is to deliver a variety of vehicles, weapons, heavy cargo, and miscellaneous supplies to any strategic locality in a usable condition within a minimum time and with a minimum hazard to the personnel involved.

Types of airdrops. The types of airdrops are free fall, aerial supply, heavy drop, and extreme low level delivery and are defined as follows:

a. A free fall airdrop is any subsystem that does not require or use a descent-control device or retardation technique to reduce the effect of gravity on the rate of descent.

b. An aerial supply airdrop is any subsystem that utilizes a descent-control device or retardation technique but does not utilize a platform for mounting the load.

c. A heavy drop airdrop is any subsystem that uses both a descent-control device or retardation technique and a platform for mounting the load. Normally, the term "heavy drop" is associated with heavy equipment such as wheel or track vehicles.

d. An extreme low level delivery airdrop is any subsystem that does not use a descent-control device but does utilize a retardation technique to arrest the load velocities in the horizontal plane with respect to the ground.

Components of airdrop systems. The components that are common to these four types of airdrop systems or subsystems include extraction and ejection devices, containers, energy absorbers, and techniques for attitude and accuracy control. Components that are unique to the aerial supply and the heavy drop subsystems include platforms and descent-control devices and retardation methods. Combinations of these subsystems, particularly the aerial supply and the heavy drop subsystems, are sometimes used for specific missions.

Airdrop techniques. The aircraft cargo is restrained from extraction by latches and lock settings of the cargo rail system which provides 1/2 G of aft restraint at a given gross weight of the platform. This extraction restraint is overcome by the aft directed force of the extraction parachute and an airdrop occurs. The platform detents disengage at the time of restraint release. A lockout pin keeps the detents fully retracted and locked out of position.

Airdrop aircraft. The aircraft that are presently used for airdrop have a large opening at the aft end of the fuselage through which the loads leave the aircraft. The standard airdrop aircraft are the C-130, the C-141, C-17 and C-5 cargo aircraft. A force is required to extract or eject a load from these airdrop aircraft. This force is supplied by ejection or extraction devices.

Design objectives. The design of an airdrop system is based on getting the cargo to the ground, in the least possible time without damage to the aircraft or the cargo, by applying the most economical and practical methods. The least possible drop time is desirable for maximum

drop accuracy, the minimum dispersion of the drop loads, and the minimum effect of the wind drift. Theoretically, the ideal airdrop system would let the equipment free fall, without employing any type of deceleration device, but would absorb the landing shock to prevent damage to the cargo. Practically, the use of the ideal airdrop system, particularly for bulky or heavy objects, is prohibited by the size, the weight, and the cost of the shock-absorbing devices that would be required. The shock-absorbing devices on the platforms and the containers, in conjunction with the parachutes, have great advantages. The stabilizing effect of the canopy permits the cargo to absorb impact shock in essentially only one direction. Airdrop systems are designed, in general, to achieve the best possible compromise between a system for landing-impact absorption and a rate of descent low enough to hold the design of the shock-absorbing devices to reasonable size, weight, and cost and in proportion to the fragility of a specific item.

Design considerations. The designer of the airdrop parachute should consider the following:

a. The maximum tolerable shock loads during deployment and the direction of these shock loads in relation to the cargo.

b. The maximum vertical fall distance permissible before terminal velocity is reached.

c. Suspension design in relation to center of gravity of the load and its attitude for landing.

d. Conformation to available space in aircraft prior to and during exit.

e. The anticipated range of launching speed and altitude for drop.

f. The anticipated aircraft to be utilized and its characteristics and capabilities in regard to load extraction or ejection.

g. The minimum weight possible for the system, including platforms or containers and parachutes.

h. The determination of whether to use expendable or reusable containers or platforms.

i. The location of the center of gravity of the aircraft within controllable limits.

j. The provision for rapid exit to keep the drop dispersion area to a minimum.

k. The point of attachment to the structure of the platform or cargo for the absorption of opening shock.

l. A deployment system designed so that the load will not have a chance to overturn completely after exit.

m. The attitude of the load prior to main canopy deployment.

n. Reliable deployment without a complicated deployment system.

o. Ease of packing and handling.

p. Low cost of maintenance.

q. The specific stability requirements for the particular cargo being dropped.

r. The rate of descent desirable during any staged or reefed canopy condition.

s. The selection of proper materials in relation to cost and strength.

t. Maintenance and logistic support.

u. Ease of manufacture and low cost.

v. Reliability of inflation.

    w. Opening shock.

    x. Bulk and weight.

    y. Environment.

Accuracy. Accuracy is the capability of an airdrop system to deposit the load at a predetermined spot on the ground in the drop zone from an aircraft over the drop zone. Accuracy does not include the problems associated with getting to a particular drop zone or identifying a drop zone as the correct drop zone. The most important element that detracts from accuracy is the effect of wind drift during descent. A computed air release point (CARP) method is utilized in determining the point at which the airdrop loads should be released in order to impact on the desired area. Wind velocity and direction at the drop zone are determined, relayed to the delivery aircraft, and used to compute the proper release point. A shortcoming of this method is that it does not consider wind velocity and direction changes with altitude. This shortcoming can seriously affect the accuracy of high altitude drops because of the possibility of changing wind conditions. One way to overcome the resultant inaccuracies from wind conditions is to increase the rates of descent for the supplies and the equipment being dropped. This increased rate of descent tends to reduce the effect of various wind conditions that can exist in a particular area. This theory should hold true, and the same degree of accuracy should exist, at any given altitude provided the pilot has the proper sighting instruments for determining his release point. The increased rate of descent requires more stringent energy absorption at impact. Recently, newer methods are being developed to allow real-time measurement of winds at different altitudes along the trajectory to allow a more accurate CARP calculation. Accuracy is not dependent on rate of descent alone. The means of extracting or ejecting aerial supply equipment or bundles from the aircraft must be positive so that a firm basis from which to compute exit time will be established. The deployment time of the retarding device must be constant. Finally, before the entire system can be effectively utilized, an accurate aerial supply drop sight must be provided for the pilot.

Environment. The airdrop canopies are often packed and stored for a considerable time in areas of high humidity, relatively high temperature, or extreme low temperature. If the environmental conditions for a specific design are expected to be unusual, the selection of proper material or provisions for special protective packing, or both, will be necessary.

Weapons Parachute Considerations

The basic reason for the development of retardation parachutes for special weapons is to control the trajectory of the weapon. The parachutes for weapons are usually of very heavy duty construction, because of the high dynamic pressures that are frequently encountered during deployment. Parachutes for each weapon usually must be tailor-made to specific requirements, which generally precludes the use of off-the-shelf components from any other weapons parachutes. The main objective in the design of a special weapons parachute is to produce a parachute that will meet the delivery requirements, will have a high degree of reliability, will be as lightweight as possible, and will fit the stowage volume in the weapon.

Delivery requirements. The delivery requirements that the retardation parachute must meet are of prime importance. The delivery requirements include velocity; delivery altitude; weapon weight; stability; and impact conditions, which include impact angle and velocity, time of fall, range, and delivery mode. A stringent requirement for stability introduces unforeseen design problems. Retardation parachutes should not induce a roll of the weapon during deployment or descent. Stability requirements vary from no restriction in oscillation to $\pm 10°$. Impact requirements are usually given as an angle that is measured between the longitudinal axis of

the weapon and the horizontal and maximum vertical velocity. A minimum impact velocity and a maximum impact velocity in some applications may be imposed. Computer studies are normally run, prior to actual drop testing, to determine as nearly as possible the proper configuration of the parachute to meet all the delivery requirements. The drop testing program is used to determine the effect of the variables that are impossible to predict and cannot be programmed in the computer studies.

Types of retardation parachutes. The configurations that are used for retardation parachutes are single stage, multi-stage, reefed, or unreefed. A single-stage retardation parachute uses only one parachute or a cluster of parachutes to provide retardation. A single-stage retardation parachute can be reefed, either permanently or for some specific time delay, or can be unreefed. A lightweight single-stage or a cluster system normally contains a pilot parachute and one or more main parachutes. A heavier weight single-stage system contains either a single parachute or a cluster of parachutes and usually incorporates an extraction parachute in addition to the pilot parachute, because the pilot parachute cannot generate sufficient force for the proper deployment of the main parachute or parachutes. A multi-stage system has components that are similar to the components of single-stage systems that use an extraction parachute. Multiple-stage retardation parachutes could conceivably be made up of any number of stages, with each stage acting independently in sequence to stabilize and retard the weapon. The attachment of the extraction parachute in a multi–stage retardation parachute is to the weapon as well as to the second-stage parachute or parachutes. When the extraction parachute or (more properly) the first stage parachute is deployed, it does not immediately extract the main canopy or canopies but instead retards the weapon to a predetermined velocity where the main parachute or parachutes can be safely deployed. If this sequence of deploying he second-stage parachute is used, the main canopy or canopies may be light/weight construction. A multi-stage retardation parachute invariably requires more altitude to accomplish the same results as a single-stage retardation parachute.

Aerial Pickup/Mid Air Retrieval Parachute Considerations

The aerial pickup parachutes are developed to recover RPV, missiles, and similar type vehicles upon termination of flight. Because of the high dynamic pressures that can be encountered during deployment, aerial pickup parachutes usually have a heavy duty, stable, first-stage decelerator to decelerate the vehicle to conditions that are suitable for deployment of the main recovery parachutes. The main recovery parachute for aerial pickup can be developed based on the guidelines for vehicle recovery parachutes. The aerial pickup parachute as a backup or secondary capability must be capable of making a surface landing, although impact requirements may not be as stringent as for vehicle recovery applications.

Components. The main components of a retardation parachute are the canopy and the deployment bag in which the canopy is packed. Other components are lanyards and bridles. The deployment bag is tailor-made to insure that the parachute will fit in the space provided in the weapon. The deployment bag must be strong to withstand the shock of accelerating the packed parachute. A typical midair retrieval system includes a drag parachute for decelerating the vehicle to conditions that are suitable for main parachute deployment. The drag parachute is also often used to assist in the deployment of the main parachute and engagement target. The main parachute is generally designed to decelerate the vehicle to conditions that are suitable for air pickup or surface impact. The aerial pickup parachute usually includes, but is not limited to, a main recovery parachute, an engagement target, and a load-bearing structure to transfer the aerial pickup loads from the engagement target to the vehicle being recovered.

REQUIREMENT LESSONS LEARNED (3.13)

The type of parachute most appropriate for the particular application depends upon the type of body or vehicle to be recovered, the recovery operational envelope, the experience available with recovery systems in the applicable technical field, and the time and the funds available for development. The latter may dictate the use of a proven conventional system in preference to a higher performance (i.e., lower weight, volume, loads) unproven system. It is extremely important to conduct an in-depth study to determine what is needed from the total system standpoint and then to design the parachute with that concept in mind. Many times the designer has started with a simple recovery system in mind but ended with a complicated multiple-role recovery system. The requirements for each application of a recovery parachute will have a different priority rating; for example: The top priority for a recovery parachute providing the primary means of landing personnel will be reliability. An airdrop parachute, where the payload may cost less than the airdrop parachute, will stress acquisition cost and reuse for multiple operations.

Some past applications of aircraft deceleration have subsequently been applied to landing approach. These applications generally result in higher-than-designed-for deployment conditions (dynamic pressure); consequently, the safety factors must be reduced accordingly. The type of dynamic pressure (compressive "q_c or incompressible "q") must be specified. Major errors in predicting parachute forces and deployment characteristics may result when operating at M 0.5 and above. Likewise, an aircraft deceleration parachute could be used in a spin recovery application with the safety factors adjusted accordingly.

The manufacturer should be told the range of performance required of the parachute and what is required of the parachute if a related system fails; for example: The drogue parachute (stabilization) for the B-1 aircraft crew escape module development program had to work through the full escape envelope with other stabilizing devices such as fins, spoilers, and a maneuvering rocket control system. Failure of one fin during a particular test resulted in tumbling of the module which the drogue parachute was not able to stabilize fully. The main canopies eventually wrapped up during deployment resulting in loss of the test module.

4.12 Deployable Aerodynamic Decelerator Subsystem Performance Verifications.

Analysis, inspection, demonstration, and/or test shall be used to verify that the design is suitable for the application specified in 3.12.

In the course of system development there are various program milestones that help chart the course of the program and ensure that it is progressing as planned. Each program is unique and may be set up with different milestones as is applicable to the particular effort. No matter how the program is set up, the important thing is to have specific expectations in place for each milestone and not to move on past a particular milestone unless all the requirements and expectations of that milestone have been met. Table IV presents a sample program structure with typical milestones and the recommended data and verifications required to meet each milestone.

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TABLE IV. Program milestone data and verification requirements.

MILESTONE	DATA/VERIFICATION REQUIRED TO PROCEED
System Requirements Review (SRR)	1. Decelerator subsystem performance specification tailored from JSSG-2010-12. JSSG-2010, 3.12 and 4.12. 2. Preliminary quality assurance plan. 3. Preliminary Test and Evaluation Master Plan (TEMP).
System Functional Review (SFR)	1. Draft allocated configuration data. JSSG-2010, 3.12.1.3 and 4.12.1.3 2. Audit trail from SRR changes/revisions.
Preliminary Design Review (PDR)	1. Preliminary design drawings. JSSG-2010, 3.12.1 and 3.12.2 2. Critical technologies/processes identified (risk management plan); Failure Modes Effects and Criticality Analysis (FMECA), Preliminary Stress Analysis. 3. Quality assurance plan complete. 4. Audit trail from SFR changes/revisions.
Critical Design Review (CDR)	1. Component development analysis & test data (deployment hardware, pyros, materials, sub-assemblies). JSSG-2010, 3.12.2 and 4.12.2 2. Preliminary interface fit check analysis/demonstration data. JSSG-2010, 3.12.1 and 4.12.1 3. Draft detailed design drawings, complete set. 4. Audit trail from PDR changes/revisions.
Test Readiness Review (TRR)	1. Component test/qualification data. JSSG-2010, 3.12.2 and 4.12.2 2. Bench deployment test data. JSSG-2010, 3.12.2.2 and 4.12.2.2 3. Interface fit check data. JSSG-2010, 3.12.1 and 4.12.1 4. Audit trail from CDR changes/revisions. 5. Completed TEMP & Test Plans. JSSG-2010, 4.12.1 and 4.12.2 6. Test Procedures (including safety/emergency procedures as applicable).
Functional Configuration Audit (FCA)	1. Component qualification test data. 2. Complete system/subsystem qualification test data (final test report) including bench deployment tests, drop tower tests, inflight/airdrop tests, live jump tests, environmental tests, etc. JSSG-2010, 3.12 and 4.12
Physical Configuration Audit (PCA)	1. Complete, detailed, final manufacturing drawings. 2. Completed acceptance test plans/procedures. 3. Pre/Initial production prototype system/subsystem hardware. JSSG-2010, 3.12 and 4.12

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VERIFICATION RATIONALE (4.12)

For a requirement to be meaningful it must be verifiable, otherwise it adds no value to the design effort. Analysis, inspection, demonstration, and test are the four methods available to verify a requirement. Every requirement should be verifiable using one or more of these methods.

VERIFICATION GUIDANCE (4.12)

Many of the critical performance requirements of a system can only be verified by test. In the case of parachute system, these are often flight or airdrop tests. Some general testing guidelines are given below.

Classification of test results. Test results shall be classified or ranked into one of the following categories, as applicable:

 a. No test. Test results shall be classified "no test" when it is determined by analysis that the test failure was caused by personnel actions or that a failure of the support equipment prevented the valid measurement of the parameter under test.

 b. System success. Test results shall be classified "system success" when the parachute meets without failure, all performance requirements of this specification, the associated specification sheet, and the contract or purchase order.

 c. System failure. Except as defined in a. above, test results should be classified "system failure" when the parachute fails to meet any of the performance requirements of the specification, the associated specification sheet, and/or the contract or purchase order. Each failure should then be further categorized as either catastrophic, critical, marginal, or negligible in accordance with the definitions (see 5).

NOTE: Because multiple tests may be included in each live jump, sled run, or airdrop, test results could be classified into more than one category. For example, a "no test" of descent rate due to a trajectory data failure, along with a "system failure", or "success", for acceleration of force levels.

Recording of test data. Data measured on board the parachute should be recorded using either 1) telemetry which transmits the data to a remote receiving station where it is recorded, or 2) a digital solid state recorder carried aboard the parachute/test vehicle system. When telemetry is used, the data should be transmitted in digital form using pulse-code modulation (pcm) in accordance with the requirements of IRIG document 106 and IRIG document 118. When an onboard solid state recorder is used, the data should be stored in nonvolatile solid state memory. The minimum data sample rate should be 1000 samples per second for each channel of data. The minimum data word size should be 10 bits. Transducers should have a minimum passband of 0 to 200 hertz and should be free of resonances in the 0 to 300 hertz range. Filtering of the analog signal should be used to prevent aliasing of digital data. No filtering should be used that affects the minimum passband.

Photographic coverage. The value of photographic coverage should not be underestimated. Often, photo data is the primary information used to analyze and solve problems. Photographic coverage should include sequence stills and telescopic tracking via video or motion picture cameras, or both, with a capability of 100 to 400 frames per second. Both onboard and ground based cameras can be valuable. Motion picture, sequence still, and video timing marks should be coordinated with the telemetry and trajectory data timing.

International Civil Aviation Organization (ICAO) standard atmosphere conditions. Standard atmosphere conditions shall be the sea level values of the ICAO.   Rate of descent

data should be converted as specified below to ICAO standard atmosphere sea level conditions prior to the rate of descent calculations (see 4.12.2.3,Steady state operation guidance).

$$V_c = V_v \, (\rho/\rho_o)^{\wedge(1/2)}$$

Where:

V_c = corrected rate of descent

V_v = measured rate of descent

ρ_o = ICAO sea level density

ρ = density at altitude where V_v is measured

Wind conditions. Maximum allowable surface wind speed may vary depending on the particular system. In general, surface wind speed during field testing should be no greater than 15 knots.

Parachute reuse. Unless otherwise specified in the contractual documents, at the contractor's discretion, a parachute may be reused for subsequent field and laboratory tests. A parachute should not be reused for any test when greater than 2 percent of the canopy area has been repaired. A parachute or any component thereof which has been subjected to age life projection, structural strength, environmental, or dummy airdrop tests should not be reused for live jump tests. A clear understanding between the contractor and procuring activity as to the reuse of parachutes should be in place prior to testing.

QUALIFICATION TESTING GUIDANCE

Qualification testing of military parachute systems have historically been governed by Military specifications and Military standards, all of which are outdated and/or have been canceled. Perhaps the most extensive of these documents was MIL-STD-858, Testing Standard for Personnel Parachutes. MIL-STD-858 has been canceled, primarily due to the fact that it is outdated. Some of the technical details and methods used are out of date. Also, MIL-STD-858 relied heavily on shear numbers of tests to obtain consistency and verify reliability. Although it is still desirable to conduct as many tests as possible, today's program budgets do not normally allow it. For example, following MIL-STD-858, qualifying a complete manual bailout parachute would require hundreds, perhaps approximately 1000 tests; many of which are airdrop or flight tests. Clearly, this type of program is beyond the funding available to most contemporary program budgets. Analytical methods have improved over the years, but accurately modeling the dynamics of deployment and opening is still difficult, and can only really be done on a generic basis. No analytical method can account for the physical details of how a parachute is packed, and deployed from a container. Consequently, testing is still necessary, but due to budget constraints, must be kept to a minimum. This can only be done by designing smarter from the start, and ultimately, by accepting more operational risk.

One approach to qualification testing is using a civilian standard to qualify, or certify, a military system for operational use. Federal Aviation Administration (FAA) Technical Standard Order C23 (TSO-C23) is an FAA civil regulation that dictates minimum standards for personnel parachutes. These standards are based on requirements provided in the Society of Automotive Engineers (SAE) Aerospace Standard AS8015. Certification based on successful compliance with TSO-C23 is typically used for light aircraft emergency bailout parachutes and skydiving parachutes. TSO-C23 has been proposed as a minimum requirement for military systems also. Unfortunately, many military systems require operation outside the boundaries of the TSO standards. In some cases, the TSO may be considered minimum acceptable testing for a military system, but more than likely, more testing is necessary. A hybrid TSO/military

qualification test program is another alternative which has also been considered on some programs. TSO testing is first completed, followed by additional testing needed to qualify a system for a unique military capability.

Qualification for other parachutes, other than personnel, are not necessarily covered by TSO-C23 and are usually dependent on the complexity of the system and the value of the payload.

Types of testing. There are various methods available for testing parachute systems and components. Ultimately, every parachute needs to demonstrate reliable dynamic operation and there are various ways to do this. Also, there are different methods for testing components and major subassemblies. All these test methods are very useful, the important thing is to consider what is being tested, and what the limitations of the test method are relative to the desired results.

a. Wind tunnel testing. Wind tunnel testing has been conducted for many years, but has primarily been used as a research tool to evaluate general behavior of a given canopy configuration. There are several problems with wind tunnel testing for qualification. For most systems, the complete full scale item will not fit into a wind tunnel, so a scale model must be used. This introduces the problem of model fidelity and proper scaling considerations. Generally, small scale models can not be made as flexible as full scale parachutes, which means that dynamic behavior of the model may not be an accurate representation of the full scale item. Wind tunnel tests can show trends, and can be used for comparison of one configuration versus another. Wind tunnels can also be used to evaluate steady state conditions such as oscillation and steady state drag coefficient. Since qualification tests usually mean dynamic deployment, wind tunnels generally are not suitable for this. Except for small parachutes, most wind tunnels are not big enough for a dynamic deployment. Also, since the flow can not be quickly reduced in most wind tunnels, finite mass conditions can not be duplicated. A small parachute intended for operational deployment in an infinite mass condition could possibly be qualified in a wind tunnel.

b. Windblast testing. Similar to wind tunnel testing is windblast testing. A typical windblast facility is an open air facility which creates a local airflow over the test item. Since it is open air, the atmospheric conditions can not be controlled, but it may allow for testing of larger parachutes since there are no, or fewer, constraining tunnel walls. Dynamic qualification of the first stage of an ejection seat stabilization parachute was recently conducted in an open air windblast facility. Some windblast facilities have short duration airflow from gas storage tanks, which may be acceptable for a finite mass situation. Other facilities, powered by jet engine air, may only be suitable for infinite mass testing.

c. Tower drop testing. Drop testing from a tower, or platform is often used for testing of personnel parachute harnesses, or may be used for evaluating steady state rate of descent and oscillation parameters. Tower testing may also be used for scale model testing, but scaling factors must be considered carefully.

d. Bench/truck deployment testing. A low cost test method for evaluating packing and deployment configuration is bench deployment tests and truck deployment tests. A bench deployment is simply deploying a packed parachute from its container on a packing table or bench to evaluate how it comes out of the pack, and to see if any obvious potential problems appear. Bench testing does not account for the true dynamics of deployment but allows an analysis of the deployment sequence. The next step is a more dynamic test often done from the back of a truck. This amounts to a low speed dynamic deployment of the system. For force deployed systems, a force deployment from the ground, a bench, or a truck with not airflow will also help evaluate the deployment configuration. While all the dynamics of a high speed operational test may not be present, these inexpensive test methods go a long way to trouble

shoot a design before subjecting it to a more expensive test. Another advantage to this type of testing is that motion picture or video data can be obtained easily for detailed study.

e. Sled testing. Sled testing is a method often used for stabilization and vehicle recovery parachutes in an infinite mass condition. A typical example would be a ribbon stabilization parachute mounted on a sting, attached to a rocket sled. When the sled is accelerated to the appropriate speed, the parachute is deployed. This type of testing can provide dynamic operational data such as opening shock. Cameras mounted on the sled can provide high speed motion picture or video data. Velocity can be controlled, but other atmospheric parameters can not be controlled and all testing is in close proximity to the ground. Also, it normally is not possible to duplicate fore body wake effects.

f. "Whirl tower" testing. "Whirl tower" testing is included as an example of a generic low cost dynamic test method. In the past, whirl towers have been used as a cheap method of conducting large numbers of repetitive tests for development or qualification testing. A typical whirl tower is a large tower structure with a long rotating arm at the top. On the end of the arm typically is a hanging cable with a gondola or test fixture on the end. The arm is spun to achieve a desired velocity and the parachute is launched or deployed from the end of the cable. This type of testing can provide a great deal of data at relatively low cost, and can be repeated consistently. Unfortunately there are no operating whirl towers in the U.S. at this time, but it is the type of testing that can be used to great advantage. Similarly, other methods have been used to provide repeatable dynamic tests at low cost compared to airdrop or sled test. Examples include guns or catapults which can be used to fire a test vehicle at a given velocity.

g. Airdrop/flight testing. For most parachute systems, the ultimate qualification test is a full system flight test. Depending on the system, this can be accomplished by airdrop, or by other means, such as the actual launch of a missile or payload. It is always best to test with the actual primary body configuration when ever possible, however this is not always an option. For safety reasons, or budgetary constraints, test vehicles (or manikins in the case of personnel parachutes) must be used. Critical to the success of these tests is to make sure the testing is representative of the actual configuration, or as close as possible. For qualification, the way the parachute is deployed is critical. A parachute that operationally, will be deployed cross wind, should not be qualification tested by a direct downwind test method. There have been many cases where parachute performance varies significantly based on how it is deployed. An example is testing of an ejection seat recovery parachute. Since it is expensive to conduct a large number of ejection seat sled tests, or in flight seat tests, a test vehicle is sometimes used as a substitute for the ejection seat. Previous programs have used cylindrical test vehicles with the recovery parachute deployed from the test vehicle. In some cases, a down wind deployment from the test vehicle has been used to test a parachute designed to operate cross wind from an ejection seat. A parachute may perform well when deployed one way, but not even open, when deployed another way. Also, even if the deployment method is "the same" the attitude of the vehicle, or the wake of a non representative vehicle could have unseen effects. Previously, ejection seat recovery parachutes were tested from a cylindrical test vehicle, using the same cross wind method as the operational system, except that when the parachute was deployed, the vehicle was always traveling straight down, so there was an added gravity component not typically seen when the system deploys horizontally. Test results have been shown to vary from horizontal versus vertical deployments.

Number of tests required. As stated previously, today's budget environment often dictates, or at least limits, the type and amount of testing that can be done. For qualification testing, the number of tests needed relates directly to the level of reliability required to be demonstrated. Table VII indicates the number of tests required to demonstrate a given reliability level with a given confidence. Strictly speaking, this chart refers to reliability at a single given condition. It

has typically been used to represent the total number of tests required over a complete performance envelope, at various conditions. In reality, this "waters down" the reliability requirement, but there is still something to be said for successfully completing the total number of dynamic deployments, even if the conditions vary. Each program must struggle with the amount of risk it can afford to determine the acceptable number of tests. Manned systems must attempt to maintain as high a demonstrated reliability as possible. Other systems may be able to cut test requirements to the absolute minimum.

VERIFICATION LESSONS LEARNED (4.12)
(Lessons learned will be added as acquired.)

3.12.1 Interface.
The parachute or decelerator subsystem shall be designed to physically and functionally interface with the prime system and other systems as applicable.

3.12.1.1 Primary body characteristics.
The primary body characteristics that affect the design and performance of the decelerator are as follows: _____.

REQUIREMENT RATIONALE (3.12.1.1)
Primary body characteristics affect the performance of the parachute. Characteristics such as weight at initiation, weight during descent, center of gravity, and moments of inertia are necessary to determine strength requirements, loading patterns, and detailed structural design and to define the deployment system.

REQUIREMENT GUIDANCE (3.12.1.1)
The primary body characteristics that should be specified include weight, weight range, and any variances in weight from parachute deployment initiation through recovery and descent. If the elimination of as much weight as possible prior to impact to improve the descent or impact situation is desirable, a weight breakdown of the primary body parts (if applicable) may be provided. Often the aerodynamic characteristics of the primary body should be specified. These characteristics should provide information about the airflow that affects parachute initiation and deployment and information that will help in estimating the primary body deceleration characteristics and free fall equilibrium rate of descent. Normally, an estimated average drag area for a tumbling primary body should be provided; however, if the primary body will remain oriented in a certain plane, the frontal drag area should also be provided. Often, information on the center of gravity and the moments of inertia of the primary body should be provided to enable the parachute designer to determine their effects on the parachute deployment, the free flight characteristics of the primary body, and the orientation of the primary body during descent to assess the impact situation.

Recovery weight of an aerospace vehicle. The recovery weight is the weight of the missile, the drone, the escape capsule with occupant, or the aerospace vehicle or components of any of the preceding vehicles and should be the maximum weight under which recovery is to be made. Reducing this value by dumping fuel or jettisoning parts of the primary body that is to be recovered must be given consideration.

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REQUIREMENT LESSONS LEARNED (3.12.1.1)

Behavior of the primary body must be known at the time of deployment to determine how to design the deployment system. A stable primary body is highly desirable. If a stable primary body is not possible, the designer should plan on the worst conditions (tumbling, et cetera) at the time of deployment. The primary body drag in some cases may provide some deceleration to reduce dynamic pressure at the time of recovery parachute deployment.

Utilization of the primary body as the test bed for all parachutes such as in the case of a personnel emergency escape parachute is not practical. A personnel emergency escape parachute in a new design must be proven to be reliable and qualified to certain minimum standards before a human subject can be used to test it. Since a human subject is more flexible than a dummy, the loading that is encountered by a human subject is not the same as the loading that is encountered by a dummy. Determining the loading that is encountered by a human subject versus a dummy could be a problem.

One peculiar problem that occurred during parachute deployment of a dummy but not in actual service use was the opening of a particular canopy release. The successive oscillations of the webbing and the canopy releases are felt to have caused the opening of the safety cover and the subsequent releasing of the latch during dummy parachute drops. The inherent flexibility of the human subject that attenuates these oscillations is felt to be the reason that the opening of the safety cover and the subsequent releasing of the latch did not occur during the actual service use. The repetitive oscillations on the dummy were probably of the correct period and amplitude to cause opening of the release.

The primary body characteristics may need to be altered to enhance the performance of a parachute such as the lifting parachute that was being developed for weapon stabilization by the Sandia Laboratories. The primary body characteristics in this case were changed to include controls to assure proper orientation so that the lift provided by the lifting parachute will be upward and not sideways or downward.

If the aerodynamic characteristics of the primary body are not provided, the recovery parachute cannot be designed adequately to meet the performance requirements, resulting in lengthy testing or program cancellation.

4.12.1 Interface.

The physical and functional interface of the parachute or decelerator subsystem with the prime system and other systems specified in 3.12.1 shall be verified as specified below.

4.12.1.1 Primary body characteristics.

Accommodation of the primary body characteristics specified in 3.12.1.1 in the design of the decelerator shall be verified as follows: _____.

VERIFICATION RATIONALE (4.12.1.1)

Since the primary body characteristics are specified, testing can and should be conducted with a test vehicle that is as representative of the primary body as possible so that the parachute can be tested in a realistic environment.

VERIFICATION GUIDANCE (4.12.1.1)

Specify whether a primary body, a representative (dummy) of the primary body, or other test vehicle is to be used for the reliability demonstration tests.

VERIFICATION LESSONS LEARNED (4.12.1.1)

The use of a test vehicle that is not representative of the primary body can provide misleading results; for example: The crew module of the F-111 aircraft has a unique deployment system, which is a catapult propelled deployment bag in a crosswind direction. A cylindrical test vehicle (CTV), which did not duplicate this deployment system, was used to obtain performance data for the first thirty tests of the recovery parachute for the crew module of the F-111 aircraft. All of the results of the tests using the CTV were good; however, the first test using a test vehicle that was representative of the stability, the drag, and the deployment of the crew module of the F-111 aircraft was a catastrophic failure. The anomalies of the crosswind deployment, which had been noted prior to the start of the testing, were verified. The parachute had to be redesigned, and all of the tests had to be repeated to obtain the applicable performance data.

3.12.1.2 Stowed interface.

The interface characteristics and requirements of the stowed decelerator subsystem shall be as follows: _____.

REQUIREMENT RATIONALE (3.12.1.2)

Stowed interface requirements can be broken down into the following lower level requirement considerations: dimensions/volume, weight, mounting/installation, Government furnished equipment (GFE), standard parts/materials, packing/maintainability and logistics, and environmental conditions.

Dimensions/volume.   Dimensional limitations must be defined so that the parachute will physically fit into the compartment or location provided on the primary body, will be a size and a shape that are practical for handling and packing, and will not interfere with the mission of the primary body (an oversize man mounted parachute could hinder the aircrew member in the performance of his/her normal duties in the crew station). Pack expansion and contraction must be considered in establishing the stowage envelope.

Weight. The weight of the parachute can adversely affect (limit) crewmember mobility, can make the parachute impractical for ground handling, or can adversely affect the center of gravity envelope of the primary body. The weight of the parachute is also directly related to the snatch force of the parachute.

Mounting/installation.   A precise definition of the interface is required to assure that the parachute or component thereof mates with the primary body or equipment in a manner so that the operation of the primary body or equipment will not be impaired and so that any special requirements for the proper operation of the primary body or equipment are provided. The parachute should be considered during the design phase of the vehicle or primary body (if appropriate) to avoid a less than ideal interface.

a. Installation. Installation considerations need to be specified to assure that the parachute is designed to be practical and to meet the specified performance requirements. The performance requirements are the primary concern. The more complicated the installation of the parachute will be the more likely the reliability of the parachute will be degraded.

GFE. A listing of all Government furnished equipment (GFE) and a detailed description of all GFE are necessary so that the designer can properly assess the interface of the GFE with the remainder of the parachute system. Information in the detailed description of the GFE such as size, shape, weight, and function may dictate the design approach for the parachute.

Standard parts/materials. The requirement to specify standard parts and standard materials in some cases is necessary for standardization or is dictated by the interface requirements. Standard materials such as threads, tapes, cords, webbings, and cloths are covered by Government specifications and are stocked by the Government for economical repairing or refurbishing of existing parachutes. Nonstandard or proprietary materials that are used in parachutes must also be stocked to repair or refurbish parachutes, or the parachutes must be returned to the contractor for repair or refurbishment.

Packing/maintainability and logistics. Maintenance and logistic support is a composite of all the considerations that are necessary to ensure effective and economical operation and support of the parachute throughout its programmed life cycle. These considerations include test and support equipment, spares and repair parts, personnel and training, safety considerations, transportation and handling, facilities, and technical data.

Service/shelf life. Life requirements or limits must be imposed to assure the availability at all times of a reliable parachute. Parachute materials are subject to strength losses and other changes due to age, environment, contaminants, and use.

Packing. Packing considerations need to be specified to assure that the design of the parachute will be practical and will meet the operational envelope requirements as specified. The more complicated the packing procedure will be, the more likely the reliability of the parachute will be degraded.

Environmental conditions. The parachute is exposed throughout its useful life to certain environments such as temperature, pressure, rain, sand, dust, vibration, noise, shock, acceleration, and wind blast. The parachute must operate satisfactorily after or during exposure to these environments.

REQUIREMENT GUIDANCE (3.12.1.2)

Interface. The parachute should be designed to physically and functionally interface with the prime system and other systems as applicable. Interface control drawings and other engineering data required to define all physical and functional interfaces and to ensure parachute compatibility with the prime system and other applicable systems should be as specified in the contractual documents.

Dimensions/volume:

Weapons Parachute Considerations

Volume and weight of weapons retardation parachutes. The weight of a canopy can be predicted, by detailed calculations, to within three percent of the actual weight. The other components of the retardation parachute can be accurately estimated from past experience so that the weight of the total retardation parachute can be predicted with an accuracy of approximately five percent. This predicted total weight can be used to determine the volume that will be needed in the weapon for the total retardation parachute.

Weight. All weight limitations on the packed or stowed parachute should be specified. A listing of the portions of the parachute to which the weight limitations apply should be provided.

Aircraft Deceleration Parachute Considerations

The aircraft manufacturer determines the required parachute drag for a given maximum landing velocity. This in turn determines the diameter of the parachute. Parachute size, opening load factor, applied factor of safety, and design factors for abrasion, multiple use, and connection efficiencies between canopy and suspension lines and suspension lines and riser determine the required material strength and thereby the weight of the parachute assembly.

Mounting/installation. Detailed envelope and interface definitions should be provided through sketches or drawings of the primary body or equipment showing dimensions, attachment locations, compartment size, compartment location, and any protrusion that may interfere with parachute deployment or operation.

Personnel Parachute Considerations

Parachute pack. The parachute pack must suitably house and protect the canopy and, if applicable, must mount the canopy on the person (type 2). The pack must reliably open, both automatically and manually, at the time the ripcord is actuated and must permit uninterrupted deployment of the canopy. Such operation must take place under the extremes of environmental and handling conditions imposed in service. The use of ribs or stiffeners in the parachute pack design should be minimized to reduce the weight and to maintain wearing comfort. The parachute pack should mount firmly and form–fit the body to minimize fouling on the aircraft equipment and the seats. The integration of the parachute pack with any other personal equipment the person is required to wear is highly important and will influence the design and the configuration of the parachute pack.

Purpose of parachute harness. The parachute harness is employed first to transmit the parachute opening forces to the crewmember to preclude injury and second to support the crewmember during descent. The support provided by the parachute harness during descent should be such that the crewmember's vertical axis will be approximately perpendicular to the surface of the earth.

Design of parachute harness. The parachute harness, consisting primarily of webbing and associated hardware, can be connected directly to the suspension lines by the use of links; however, the use of risers to connect the suspension lines to the parachute harness is preferred. The parachute harness, the personnel parachute, and the parachute pack are sometimes designed as an assembly so that the crewmember, while on the ground, will carry the parachute harness, the personnel parachute, and certain attached personal equipment. Another arrangement is for the parachute harness to be separated from the parachute pack and the other attached personal equipment while the crew member is on the ground. The personnel parachute and the ancillary personal equipment are kept in the aircraft. The crewmember, while on the ground, wears the parachute harness. When the crewmember enters the aircraft, he attaches the personnel parachute and the personal equipment to the parachute harness. The portion of the parachute that remains in the cockpit at all times can be hooked up for automatic disconnection from the seat during an ejection. Survival kits and other personal equipment can also be attached to the portion of the parachute that will remain in the aircraft.

Harness. When design of the parachute includes the harness, the following requirements should apply.

   a. The harness should preclude injury to the aircrew member during transfer of the opening forces from the main canopy to the aircrew member, and must safely and securely support the aircrew member during all phases of operation without damage to the harness.

b. Webbing straps should not slip greater than 0.5 inch through the hardware when subjected to a pull force from 0 to 6500 lbf.

c. For type 1 parachutes, the harness must interface with the ejection seat AAES as specified.

Other design considerations for parachute harness. The designer of a parachute harness should consider the following:

a. Construct the harness so that adjustments can be made by the user and repairs can easily be made by personnel at all operating levels.

b. Maintain a safety factor of 1.5 (minimum).

c. Minimize any temporary sewing or tacking.

d. Design the parachute harness to fit the body so that it will perform its basic function of retaining the body at the end of the parachute suspension system in an inherently secure manner.

e. Assure that the risers, the harness, or the ancillary equipment will not interfere with normal vision and will not seriously hamper the movement required for canopy manipulation during descent or at ground impact.

f.   Design the harness so that it will have a suitable connection for a canopy and so that the connection of the riser straps and the harness will be located one inch to two inches below the collarbone of the crew member.

g. Keep the design of the harness simple, with a minimum of parts that can become entangled or twisted or can interfere with one another, which would force the crewmember to readjust the parts in order to don the harness.

h. Design the harness so that an individual can don and adjust the assembly while standing or sitting.

i.   Incorporate a method whereby the crew member, by operating each connector with one hand, can remove the harness quickly and easily.

j.   Design the harness so that the number of adjustment points required to make the harness fit will be kept to a minimum and the adjustment points will be accessible, preferably visible, to the crew member when seated.

k. Design the harness so that the adjustment points will not hamper or prevent actuation of a manual ripcord or automatic parachute arming knob on the accessible front area of the harness when worn.

l.   Design the harness so that even after faulty or careless adjustment it will not fall or slip from the crew member's shoulders during canopy deployment or opening.

m. Design the harness so that it can be adjusted quickly and easily without roping or jamming of the webbing in the adjustment fittings. Mark the harness (if desired) to indicate its size so that the size to which the harness can be adjusted will be seen at a glance.

n. Design the harness, unless individually sized, so that it can readily and quickly be adjusted to a suitable fit for the entire aircrew population as required, with or without standard winter clothing.

o. Design the harness so that it will not cause discomfort to the crew member as a result of limited–area body contact and pressure points and will not cause uncomfortable restrictions as

a result of bulky protrusions that may invite snagging on other personal equipment, the aircraft doors, or the aircraft seat.

p. Design the harness so that there will not be any strap adjuster, connector, or metal fitting directly against the crew member's back when the harness is worn and so that no metal fitting will contact the crew member's face or head during opening or descent of the canopy.

Vehicle Recovery Parachute Considerations

Compartment. Since reliable recovery operations depend upon a minimum of interference with the deployable aerodynamic decelerator during the deployment procedure, the compartment should not have any projections or sharp edges that will be in the way of the deploying decelerator and must be positioned so that the deployment path will pass between any protrusions such as tail surfaces. If possible, the aft wall of the compartment should have a considerable slope to aid in extracting the packed parachute. The outer edges of the compartment should be rounded so that nothing will tear or snag the bag in which the decelerator is packed.

Compartment location. The motion of a deploying aerodynamic decelerator will generally be straight aft in relation to the flight path of the body; therefore, the best location for the compartment in most cases will be in the extreme tail of the vehicle. The best location for the compartment in some cases where a missile is expected to be tumbling at the time of deployment will not necessarily be in the tail of the vehicle but must be a location that will accommodate the special deployment. If the compartment is located in the tail of the vehicle, the compartment in many cases may have excessive temperature because of the proximity of the power plant. If the temperature of the compartment will be excessive, the possibility of insulating or cooling the compartment must be considered. If insulating or cooling the compartment is not practical, the compartment must be located in an area where excessive heating will not be encountered. (NOTE: The thermal properties of some parachute textile fibers are specified in table V.)

TABLE V. Thermal properties of parachute textile fibers.

Parachute textile fibers [1]	Temperature at loss of 50 percent of strength: °F [2]	Temperature at loss of 50 percent of strength: °C [2]	Exposure time (hours)
Nomex T-430 aramid	425	218	More than 3000
	500	260	Approx. 2000
	580	304	Approx. 250
Kevlar 29 aramid	392	200	Approx. 320
	482	250	Approx. 70
Dacron Polyester	350	177	Approx. 320
	500 [3]	260 [3]	
Nylon 66	350	177	Approx. 100
	500 [3]	260 [3]	

[1] These parachute textile fibers are manufactured by E.I. DuPont deNemours & Co, Inc; Wilmington, Delaware.
[2] The strength was measured at 70 °F at 50 percent relative humidity.
[3] Nylon 66 and Dacron polyester will melt at this temperature.

Installation. Installation requirements are a secondary concern. Performance of the parachute should not be jeopardized for easier installation. Although a short installation time with a low number of personnel required to accomplish installation is desirable, the user should be willing to accept whatever reasonable time and effort are required to avoid sacrificing the reliable performance of the parachute.

Aircraft Deceleration Parachute Considerations

Pilot parachute and deployment bag. It is of utmost importance that the pilot parachute is ejected into good airflow, that it is able to open quickly, and that it is able to extract the deployment bag. If the pilot parachute is too small, the deployment bag may fall to the runway and be damaged. If the pilot chute is too large, it will delay or prevent the opening of the drag parachute. The deployment bag should closely contain the drag parachute and the riser. The packed shape of the deployment bag should conform to the aircraft compartment outline. The deployment bag should be large enough to prevent movement in the aircraft compartment and loose enough to ensure easy extraction of the deployment bag. Normally, a two-compartment deployment bag that separates the parachute canopy from the suspension lines and the riser is used. Components of a typical drag parachute assembly are shown on figure 2.

Stow loops and tie cords. Stow loops and tie cords are used to hold components in place and subsequently to deploy them in an orderly fashion such as the riser–first deployment. (The riser–first deployment is a concept in which the following components are deployed in the sequence listed: riser, suspension lines, and canopy.) Good stowage provisions and sequential deployment of the components is especially important for large bomber aircraft that employ parachutes with diameters of more than 20 to 30 feet.

Risers. The risers are formed either from multiple layers of textile webbing or from bundled continuous suspension lines. The latter approach is used on the drag parachute riser of the B-52 bomber aircraft, because the designing of a webbing riser with sufficient strength and flexibility proved to be impossible. Risers frequently need protection from the heat of jet exhaust. This protection is provided by the use of Nomex sleeves, coated braided metal sleeves, and similar techniques. The riser connection to the aircraft is either a metal fitting or a loop formed by the textile riser that engages a release mechanism in the aircraft.
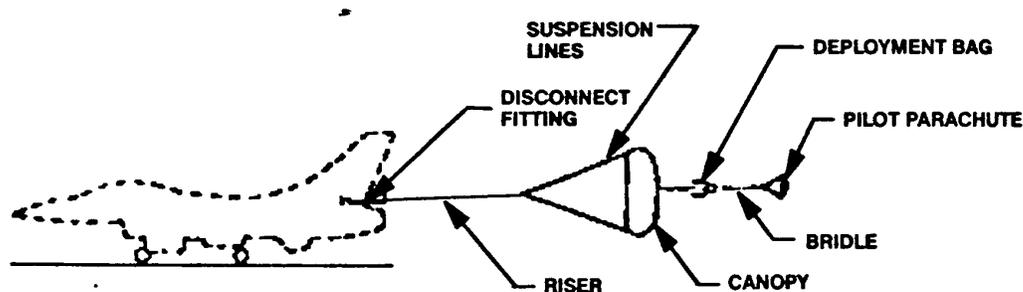

FIGURE 2. Typical landing drag parachute assembly.

Parachute installation. The parachute installation must conform to the aircraft and should comply with the following:

a. Suitable drag parachute compartment location.

b. Suitable drag parachute compartment configuration.

c. Safe drag parachute "lock, deploy and jettison" mechanism.

Parachute compartment. The parachute compartment should be located on the upper side and to the rear of the fuselage. The parachute compartment should be smooth on the inside with rounded corners and a sloped rear wall to facilitate extraction of the drag parachute deployment bag by the pilot parachute. The deployment path of the drag parachute deployment bag should be clear of protrusions and obstacles that can cause hang-ups of the pilot parachute or the drag parachute deployment bag. The pilot parachute installation should ensure immediate ejection after the parachute compartment door is opened. A good pilot parachute location is on the inside of the parachute compartment door or on the top of the drag parachute deployment bag, with the pilot parachute held in place with flaps actuated by the opening of the parachute compartment door. If the parachute compartment is on the side of the fuselage, the drag parachute deployment bag must be positioned and held in place by the flaps that are opened by the deploying pilot parachute. Locating the parachute compartment under the fuselage as in the case of the B-47 bomber aircraft should be avoided, because the parachutes are difficult to install in the overhead location and require the undesirable canopy-first deployment concept. The location of the parachute compartment should permit easy access and simple installation of the parachute assembly by maintenance personnel. The parachute compartment must be insulated against engine heat and humidity. The parachute compartment door must open when it is covered with ice. If the parachute is made of nylon, the temperature of the parachute compartments should not exceed 250 °F; however, limiting the temperature of the parachute compartments to 200 °F is preferable. The use of Kevlar material for parachutes will result in a higher allowable temperature for the parachute compartments and in smaller parachute compartments.

Aircraft installation. The data contained herein that applies to the installation of the landing drag parachutes will apply equally well for the installation of the spin recovery parachutes, but the assurance of a free path for the ejected and extracted pilot parachute or main parachute deployment bag is more important for the spin recovery parachute. The riser attachment fitting must be located so that the riser can rotate in a 360-degree circle through a 75-degree arc around the tail of the aircraft. The aircraft must be stressed for accepting the parachute loads in the same directions. The riser attachment mechanism should comply with the requirements specified herein for the landing drag parachutes. The riser attachment mechanism should be disengaged in flight, should be engaged prior to parachute deployment, and should be positive in jettisoning after use. The spin recovery parachute in several instances has disconnected on deployment, resulting in the loss of the aircraft in at least one instance. The cause of this failure was the inability of the release to handle the side loads.

GFE. A list of all Government Furnished Equipment (GFE) and appropriate drawings or detailed information for each item should be provided. Applicable GFE should be clearly specified in the contractual documents. The contractor is normally responsible for the integration of GFE into the parachute and for interfacing with GFE external to the parachute.

GFE conformance to specification. In the event of a conflict or inconsistency between the performance or other critical parameter requirements of the contract GFE specification and the delivered GFE component, the contractor should immediately notify the contracting activity.

Changes to GFE. Changes to the GFE to meet requirements peculiar to a specific application may be proposed by the contractor but must be approved by the contracting activity prior to implementation.

Standard parts/materials. All standard parts and standard materials, which are required by standardization or are dictated by the interface requirements but which are not provided as GFE, should be listed and accurately described (part number, drawing number, specification number, type, etc.) to avoid possible confusion or error. Proprietary designs and parts should be avoided.

Materials and standard parts selection. Materials, including textiles, and standard parts should conform to Government specifications and standards as applicable. Materials or parts not covered by Government specifications or standards should be suitable for the purpose intended, should be of the best quality and the lightest practical weight, and should be approved by the contracting activity prior to use. The following order of precedence should be used for the selection of materials and standard parts:

a. Materials and parts specified in the contractual documents.

b. Materials and parts specified in this specification.

c. Other materials and parts covered by military specifications and standards.

d. Materials and parts specified in NWC TP 6575.

e. Materials and parts specified n AFFDL-TR-78-151

f. Other materials and parts covered by industry specifications and standards and approved by the contracting activity.

g. Other materials and parts not covered by Government or industry specifications and standards, but approved by the contracting activity.

Fungus proof materials. Materials that are nutrients for fungi should not be used without prior approval from the contracting activity. When such materials must be used and approval for use has been obtained, they should be treated with a fungicidal agent which has been approved by the contracting activity and meet the fungus growth environmental requirements.

Reclaimed, recycled, or reused parts and materials. No reclaimed, recycled, or reused parts or materials should be used except for raw steel, aluminum, or other metals which are the result of normal recycling processes.

Textiles. Textiles should be resistant to damage caused from exposure to solar radiation, atmospheric contaminants, including smog, and shipboard environments. Textiles that become unserviceable under conditions of service- or storage-use should not be used.

Age of textiles. The contractor should have available for Government review, records from the textile manufacturer which validate the age of all textiles used in the design. The date of manufacture and the name of the textile manufacturer for each material lot should be recorded on the inspection record for each parachute produced. The maximum allowable age should be specified.

Electronic components. The use of electronic components in the design should be approved by the contracting activity prior to implementation. Electronic components should be selected from existing DoD standards and specifications to the fullest extent possible. Components conforming to accepted commercial or industry standards may also be used as specified in the contractual documents. Component application and derating should be in accordance with AS-4613. Component quality levels should be capable of achieving the required performance and reliability level.

Printed wiring boards. Printed wiring boards should be in accordance with MIL-P-55110.

Wiring.   Wiring and terminal design should include protection against environmental and mechanical hazards to prevent corrosion and shorting of circuits.   Electrical connectors should be capable of being connected and disconnected and the cables flexed without damage within the expected operational temperature range.   Past environments have used a temperature range of -54 to +74 °C (-65 to +165 °F) but each application requires it own analysis of the potential extremes.

Nonmetallic parts.   Nonmetallic parts should be of a type that minimize deterioration caused by abrasion or exposure to solar radiation, micro-organisms, moisture, heat, fuel, hydraulic and lubricating oil, grease, and salt spray.   Nonmetallic materials should have chemical properties appropriate for the environmental conditions specified herein.   In addition, any nonmetallic parts used in the design should not outgas corrosively, creep under an applied load, nor crack due to aging.   Aging of nonmetallic parts for up to ten years should not cause performance degradation in any service use environment.

Metallic parts.   The selection of metals and their properties should be in accordance with MIL-HDBK-5.   Magnesium and magnesium alloys should not be used.

Cables.   Metal cables may be used in the design contingent upon approval by the contracting activity.

Dissimilar metals and organic matrix composites.   Dissimilar metals and organic matrix composites, as defined and classified in MIL-STD-889, should not be used unless suitably protected against electrolytic and galvanic corrosion in accordance with MIL-F-7179 or equivalent protection.

Corrosion protection.   All metal parts should be the corrosion resistant type, or should be treated in accordance with MIL-F-7179 or equivalent protection, as applicable, to render them corrosion resistant.

Finishes.   The selection of protective finishes should be in accordance with MIL-HDBK-132.   Protective coatings and finishes should be acceptable as moisture, fungus, and corrosion preventatives, and should not crack, chip, nor scale during the normal course of inspection and operation or during exposure to the required environmental conditions.   Inorganic coatings, surface treatments, and finishes should be in accordance with MIL-S-5002.   Application and control of organic finishes should be in accordance with MIL-F-18264.

Anodizing, coating, and plating of aluminum parts.   Aluminum and aluminum alloy parts not subject to wear, abrasion, erosion, or corrosion conditions should be either anodized in accordance with MIL-A-8625, type II, anodic coating, or treated with a chemical conversion coating in accordance with MIL-C-5541.   Parts subject to normal wear, abrasion, erosion, or corrosion conditions should be anodized in accordance with MIL-A-8625, type II, anodic coating.   Parts subject to severe wear, except for those normally reworked during overhaul, should be anodized in accordance with MIL-A-8625, type III.   Parts subject to severe wear and which will normally be reworked during overhaul should be chromium plated in accordance with QQ-C-320, class 2.   Intermediate nickel plating may be used, as required, to render parts corrosion resistant.

Plating of steel parts.   Steel parts in contact with aluminum or aluminum alloy parts should be protected in accordance with MIL-C-87115 or coated with aluminum by ion vapor deposition in accordance with MIL-C-83488, type II, class 1.

Stainless steel.   Stainless steel has been used to manufacture parts subject to harsh environments and may be considered for selected parts.

Heat treatment. Heat treatment of aluminum and aluminum alloy parts should be in accordance with MIL-H-6088. Heat treatment of steel and steel alloy parts should be in accordance with MIL-H-6875. Heat treatment of titanium and titanium alloy parts should be in accordance with MIL-H-81200.

Castings. Castings should not be used for parts which are stressed more than 50 percent of the material yield strength. Ferrous and nonferrous raw metal castings used in the design should be in accordance with MIL-STD-2175. Aluminum alloy castings should be in accordance with MIL-A-21180.

Forgings. Steel forgings should be in accordance with MIL-F-7190, grade A. Aluminum forgings should be in accordance with MIL-A-22771. Requirements of QQ-A-367, which is now inactive for new design, were also used in the past.

Welding. Welding should be in accordance with or MIL-STD-1252, or MIL-STD-2219 which has superseded MIL-W-8611, used previously.

Brazing. Brazing should be in accordance with MIL-B-7883.

Mechanical soldering. Mechanical soldering should be in accordance with DOD-STD-1866.

Electrical soldering. Procedures and requirements for preparation and soldering of electrical connections should be in accordance with WS-6536.

Screw threads. Screw threads and the go/no-go gauging practice should be in accordance with FED-STD-H28.

Fabrication procedures, textile components. Detail manufacturing instructions should be in accordance with MIL-P-7567. Fabrication procedures should be documented by the contractor and, when required in the contractual documents, should be included in the data package as part of the design disclosure.

Stitches, seams, and stitchings. Stitches, seams, and stitchings should be in accordance with FED-STD-751 whenever possible.

Suspension lines. Unless otherwise prescribed by unique design requirements, all suspension lines should be continuous and without splice or knots. All lines for one canopy should be made from the same continuous length of cord. Lines damaged during parachute construction should be replaced with lines from the same line production lot whenever possible and, in any case, by lines from the same manufacturer.

Tensioning of suspension lines. After 24 hours of ambient conditioning of suspension line material under zero tension and at a temperature of 20 $\pm$3 °C (68 $\pm$5 °F) and RH from 40 to 80 percent, the suspension lines should be marked for cutting under applied tension as specified in table VI. Within 30 $\pm$5 seconds after applying tension, the lines should be either marked and released from tension or locked in place under the applicable tension until markings can be performed. Lines tensioned on multiple pulley systems should be measured and marked as one continuous length and should not be anchored at any intermediate points between the ends.

TABLE VI. Tension requirements for marking and cutting suspension lines.

Rated tensile strength of suspension line material (pounds) [1]	Tension to be applied (pounds)
100 to 499	10.0 ±0.5
500 to 1000	20.0 ±1.0
Greater than 1000	40.0 ±2.0

[1] Ranges are inclusive.

Nameplates and product marking. Non-GFE items, assemblies, subassemblies, and components should be marked for identification in accordance with MIL-STD-130 and as specified in the contractual documents. (GFE components will be marked by the original manufacturer in accordance with their respective drawings prior to delivery.) The date of manufacture should be shown for each fabric component, and should be indicated by the month and year of delivery to the contracting activity. Space should also be provided for entering the date the equipment, assembly, or subassembly is placed in service, to be filled in by the using activity. Parachutes manufactured for use by agencies other than the U.S. Government should be identified and marked as specified in the contractual documents. Unless otherwise specified, marking ink should be in accordance with MIL-I-6903, type I, II, III, or IV as applicable, color generic black or blue. All marking should be applied in a manner which will ensure clear legibility throughout the service life of the parachute.

Marking of canopy. Unless otherwise required all canopies, including pilot and drogue, should be marked as specified on figure 3 or 4, as applicable. Marking characters should be not less than 0.5 inch high. Where applicable, the type designation should precede the drawing number. For round canopies less than 36 inches in diameter, the date of manufacture and serial number may be specified only once (instead of twice), but in the top center gore as shown on figure 3; and marking characters may be reduced to not less than 0.375 inch high, provided legibility is not adversely affected.

Marking of hardware. The part number should be marked on each metal part large enough to allow legible marking. If possible, the manufacturer's Federal Supply Code for Manufacturers (FSCM) or symbol and year of manufacture should also be marked on each metal part. Marking should be applied by etching or die-stamping into the metal before the part is anodized or plated, or for larger parts, by a pre-printed metal-foil label.

Marking of harnesses. When the harness is included in the design and unless otherwise required, a label in accordance with DDD-L-20, type IV, class 11, should be affixed to each harness. The label should contain the following information: design activity code identification number, part/drawing number, contract number, manufacturer's FSCM or symbol, date of manufacture, and space for date placed in service to be filled in by the using activity.

Marking of risers. When risers are included in the design which are not an integral part of the harness, each riser should be marked in the same manner as recommended for marking harnesses and should be clearly identified as the right or left riser, as applicable.

Marking of cross connector straps. When cross-connector straps are included in the design which are not an integral part of the riser or harness, each cross connector strap should be marked in the same manner as recommended for marking harnesses and should be clearly identified as the front or back strap, if applicable.

Marking of deployment bag. When a deployment bag is included in the design, the bag should be marked in the same manner as recommended for marking harnesses.

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FIGURE 3. Round canopy marking requirements, view looking down on outside of canopy.

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FIGURE 4. Ram-air-inflated canopy marking requirements, view looking down on upper surface of canopy.
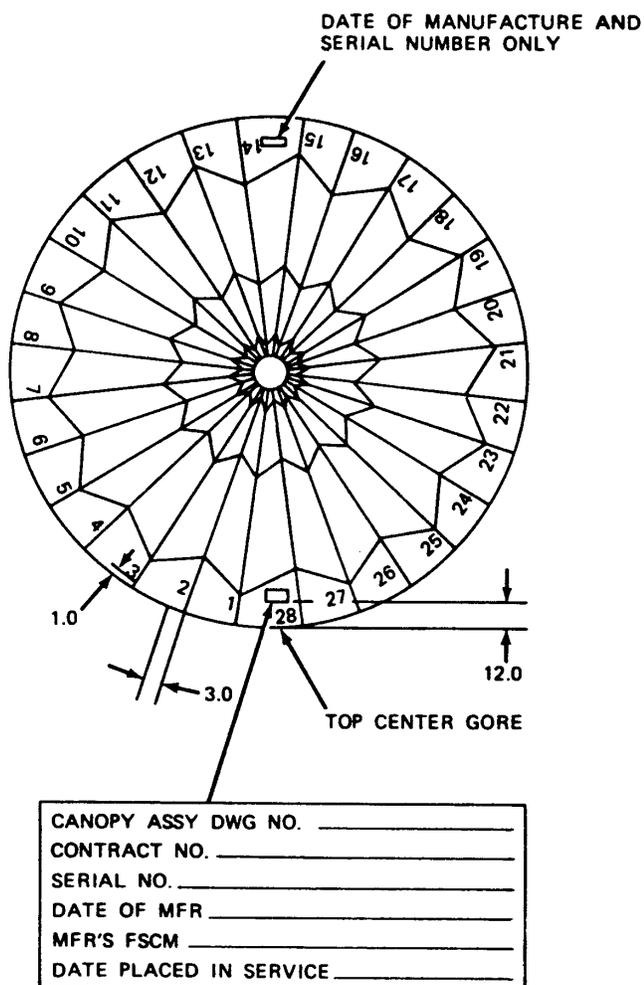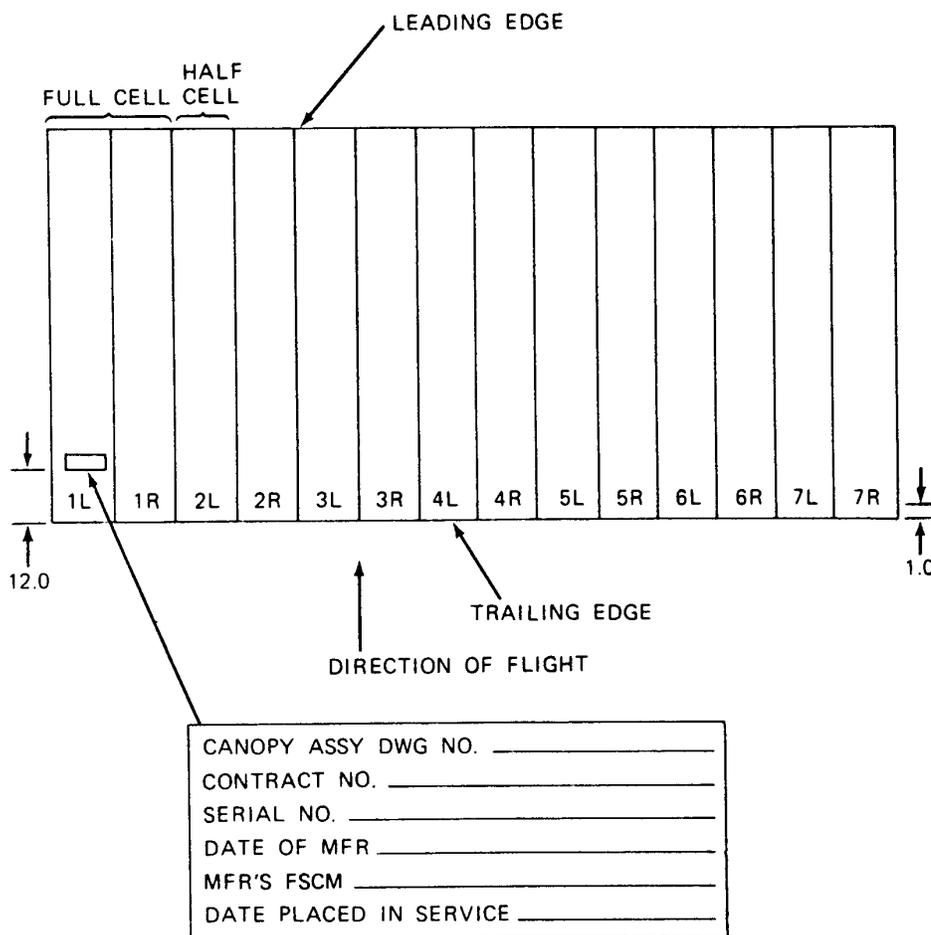
NOTES:

1. Dimensions are in inches, ±0.25 inch.

2. As shown above, cells should be numbered/marked from left to right along the trailing edge of the canopy referenced to the direction of flight. Cell numbers should be marked on the upper surface in the center of each half cell using "L" (left) and "R" (right) to designate the appropriate half cell.

3. Canopy diagram is for reference only. Canopy shape and number of cells may vary according to design requirements.

Marking of container/pack. The outside on the container/pack should be marked in the same manner as recommended for marking harnesses. If the parachute contains ballistic or pyrotechnic components, appropriate warning labels should be affixed to both the outside and the inside of the container/pack. In addition, the information shown on figure 5 should be marked on the outside of the container/pack, separate and apart from the label showing the container/pack part number and manufacturing information.

Interchangeability and replaceability. Similar parts, subassemblies, and assemblies of the parachute should be interchangeable or replaceable. Criteria from MIL-I-8500, which has been cancelled, has been used in the past for interchangeability and replaceability.

Workmanship. Workmanship should be of the highest quality to ensure optimum performance, reliability, and service life. All components and assemblies should be free from defects, such as burrs, cracks, dents, sharp edges, snags, snares, tears, loose or hanging threads, chipped paint, contamination, corrosion, evidence of excessive wear, and foreign material.

Cleanup. Prior to and after final assembly, all subassembly parts and the completely assembled parachute should be thoroughly cleaned of loose threads and other foreign material. Solvents which emit toxic fumes or which may degrade any plastics or textiles used in the parachute should not be used to clean metal parts.

```
NOMENCLATURE: _____
DESIGN ACTIVITY CODE IDENT: _____
PARACHUTE ASSY PART/DWG NO.: _____
PARACHUTE ASSY CONTRACT NO.: _____
MANUFACTURER'S FSCM: _____
ASSEMBLY ACTIVITY: _____
DATE OF ASSEMBLY: _____
CANOPY SERIAL NO.: _____
DATE CANOPY PLACED IN SERVICE: _____
                RECORD OF MODIFICATIONS
```

NOTES:

1. Information may be printed or stamped thereon, or may be affixed by label in accordance with DDD-L-20, type IV, class 11.

2. Nomenclature includes item name and type designation as defined in MIL-STD-130.

FIGURE 5. Container/pack marking requirements for parachute identification.

Packing/maintainability and logistics. Maintenance and logistic support must be initially planned and developed as part of the overall parachute development process to ensure the optimum balance between the parachute and its maintenance and logistic support. The balance considers the performance characteristics of the parachute, the input resources required, and the evaluation of the results in terms of effectiveness and cost. If alternative design approaches are considered in some areas, each alternative design approach must be evaluated on the basis of cost effectiveness of the parachute, including its maintenance and logistic support, thereby leading to the selection of an overall preferred parachute configuration. The objective is to provide the optimum level of support at the proper location and at the right time. Consideration should be given to qualifying alternate suppliers during the development cycle.

Parachute life. The useful life of the parachute should be defined. This definition may include limits on storage after manufacture but prior to installation, any limits on installed life including inspection and repack cycles, and a definition of the parachute service life. The definition of the parachute service life may be one use or multiple uses, depending upon the particular parachute that is involved. An overall time limit is usually imposed on the parachute. A target service life and shelf/total life for the parachute should be designated to aid the designer in determining the amount of environmental protection required. If service/shelf/total life are critical to the application, they should be made a firm requirement.

Packing. All packing considerations including time limits, special tools or equipment, number of packers required to accomplish the packing, skill level required of the packers, and any reference to auxiliary methods of volume reduction such as pressure, autoclave, or vacuum packing should be specified. If auxiliary methods of volume reduction are used, x-ray inspection of the pack should be required to reveal damaged, bent, or broken reefing rings, cutters, or other hardware before the packed parachute is placed in service. The packing procedures must be described step by step to assure that the packing performed by all packers will be the same.

The parachute should be packed in a manner which prevents deploying parachute components from striking the aircrew member and from damaging garments or equipment. Special rigging and packing tooling peculiar to a specific design should be kept to a minimum. The rigging and packing procedures should be documented by the contractor and when specified in the contractual documents should be included in the data package as part of the design disclosure. Prior to live jump testing, the rigging and packing procedures must be validated/certified by the certification group specified in the contractual documents. When specified in the contractual documents, the validation/certification should be documented in a certification/data report. Rigging and packing procedures for current in service parachutes are specified in Navy manual NAVAIR 13-1-6.2 or several Air Force technical orders such as T.O. 14D3-11-1, or T.O. 14D1-3-316, which may be used for guidance.

All installation considerations including time limits, special tools or equipment, manpower requirements, and skill level required of the installers should be specified.

Maintainability program. When specified in the contractual documents, the contractor should establish and maintain an effective maintainability program that is planned, integrated, prepared, and reported in accordance with MIL-STD-2067 (for type 1 only) and MIL-STD-470, task 101. The maintainability program plan should be developed in conjunction with other design and development functions to permit the most cost effective achievement of overall program objectives. The maintainability program plan is used by the contracting activity to improve operational readiness, reduce maintenance manpower needs, reduce life cycle costs, and for effective management through the data provided.

Maintainability, non-sealed parachute. The non-sealed parachute should be designed to be maintained at the organizational (O) and intermediate (I) levels of maintenance and should meet the following minimum maintainability requirements:

a. Based upon a flying hour rate of 35 hours per month, the direct maintenance man hour per flight hour (DMMH/FH) at the O and I levels for corrective and preventative maintenance shall be not greater than 0.05, including time for preparation of components to be installed in the parachute.

b. The mean-time to repair (MTTR) shall be not greater than 0.4 hour.

c. The maximum corrective maintenance time ($M_{max\ ct}$) for the 95th percentile individual maintenance action, ranked on the basis of corrective times, shall be not greater than 1.2 hours, excluding time for rigging and packing.

d. At least 95 percent of the total maintenance actions can be performed by maintenance personnel within the Navy Aviation Structural Mechanic (AME) or Aircrew Survival Equipmentman (PR) rating at pay grade E-4 or below, or the civilian equivalent or by qualified level 3 Air Force technicians.

Maintainability, sealed parachute. Except for external components, the sealed parachute should be designed for zero maintenance at the O and I levels. The replaceable textile and hardware components external to the sealed parachute should be designed to be maintained at the O and I levels as stated above.

Transportability. The parachute should be designed to be transportable by any appropriate transportation method suitable for explosives, if applicable, and which conforms to 49 CFR 171-178.

Ease of manufacture and low cost. Wherever possible, parachute design should be simple for ease of manufacture. Low cost designs adapt to a high rate of production.

Human performance/human engineering. The human performance/human engineering requirements for the parachute shall conform to MIL-STD-1472 to the extent applicable to the parachute and its intended environment. For parachutes incorporating pyrotechnic or ballistic components, engineering practices should include those applicable to working with hazardous materials. Failure to perform an operation in the specified manner should not pose a threat to human life. Personnel-to-equipment interface should be optimized to achieve maximum effectiveness of personnel during handling, rigging, packing, operation, and control, and to minimize demands upon personnel resources, skills, training, and costs.

System safety program. The parachute should be designed to meet the system safety requirements of MIL-STD-882. The contractor should conduct a system safety program in accordance with MIL-STD-882 to ensure that adequate consideration is given to safety during all life cycle phases of the program and to establish a formal, disciplined program to achieve system safety objectives. When specified in the contractual documents, the system safety program should be documented in a plan which must be approved by the contracting activity prior to use.

System safety hazard analysis. When specified in the contractual documents, a hazard analysis should be performed and documented by the contractor to systematically identify and evaluate hazards, both real and potential, for their elimination or control.

Health and safety criteria. The parachute should not contain any part or component that provides adverse explosive, mechanical, or biological, including toxicological and carcinogenic, effects on the handler or aircrew member when handled or used in accordance with approved

procedures. In some cases where hazardous conditions may be unavoidable, such as aircraft deceleration parachutes which over time, pick up hazardous exhaust chemicals, procedures must be developed for working with hazardous items.

Documentation/drawings. The design and all elements of the design should be documented by the contractor as required for configuration control and production. When specified in the contractual documents, design approval drawings shall be prepared by the contractor in accordance with MIL-T-31000. DOD-D-1000, which is now inactive for new design, provides additional criteria for consideration.

Supply. The parachute should be capable of being supplied to using activities through the normal supply chain, either by component part, subassembly, or complete assembly as determined by the Government.

Facilities and facility equipment. The parachute shall be designed for maintenance (inspection, rigging, packing, repairing, and modifying) in a parachute loft which meets the requirements of NAVAIR 13-1-6.2 for Navy. Air Force T.O. 14D3-11-1 also provides some guidance on parachute loft requirements. In some cases, a particular parachute system may also have additional unique requirements, although these should be minimized as much as possible.

Personnel and training. Personnel and training requirements for maintenance of the parachute shall be in accordance with NAVAIR 13-1-6.2 for Navy.

Personnel Parachute Considerations

Parachute life. The total life imposed by the Air Force on the emergency escape parachute is 13 years from date of manufacture. Sometimes separate service and shelf lives are specified. A personnel emergency escape parachute is removed from service after one use. A personnel emergency escape parachute, even if it has not been used, is removed from service at the end of the overall time limit.

Vehicle Recovery and Deceleration Parachute Considerations

Reuse of drag parachutes and vehicle recovery parachutes. Single drag parachutes have been used more than 150 times. The normal life span of single drag parachutes is 25 to 50 cycles. Parachutes should be inspected and approved or rejected for further use by qualified maintenance personnel. The parachute assembly must be designed with multiple use in mind. All parts of the parachute assembly should be designed for and protected against abrasion and rough handling. The major components of the parachute assembly should be easily attachable to, and detachable from, each other to facilitate replacement. Keeping the components of the parachute assembly connected to each other serves two purposes:

a. All components are retained for easy retrieval and repacking.

b. The pilot parachute keeps tension on all parts of the parachute assembly during deployment, thereby preventing sloppy deployment and parts of the parachute assembly from falling on the runway and incurring damage.

Parachute packing. Pressure packing, which is a technique extensively used in vehicle recovery parachutes, is avoided for drag parachutes to minimize the need for support equipment and to decrease the packing time and complexity.

Maintenance and cost of vehicle deceleration and recovery parachutes. The design requirements of the parachute that pertain to suitability for aircraft operational environment;

ease of maintenance and operation; and low cost involve minimum support equipment and ease of repair, packing, storage, and installation. Electrical or electronic control circuits, switches, and initiator circuits must be designed for ease of access and testing for verification of circuit/component continuity and integrity. Built in test capability for verification of system readiness is highly desirable. The total cost of the parachute includes acquisition cost, refurbishment cost, and number of possible reuses. No valid data are available for comparing the low cost ringslot and the cross parachutes with the longer life ribbon parachutes.

Safety precautions for aircraft deceleration chutes. Safety precautions to prevent ground personnel injuries from inadvertent opening of the parachute compartment doors and pilot parachute being ejected are required. The sometimes primitive conditions of combat operations should be considered. Two approaches to prevent the problems that are caused by inadvertent in-flight deployment of the drag parachute are used. The first approach listed herein is generally preferred. The two approaches are as follows:

    a. The hook of the release mechanism that connects the parachute to the aircraft is not engaged until the pilot is ready to deploy the drag parachute.

    b. If the parachute is deployed above a safe velocity, a fail-safe break link in the riser fitting separates.

Airdrop Parachute Considerations

Ease of maintenance is principally a result of design simplicity. Airdrop canopies are subject to damage not only by ground and object contact but also by lack of attention after completion of the drop or through mishandling by personnel. Since many airdrops will take place in areas where the parachute can be recovered for reuse, parachutes and hardware that will resist damage under ordinary anticipated conditions are desirable.

Bulk and weight. Bulk and weight are of particular importance for ease of handling by ground personnel. The bulk of the parachute may or may not be critical depending on the application. For example, lightweight and small bulk are desirable for the airdrop parachute provided the economy and the design criteria of the airdrop system can be met.

Weapons Parachute Considerations

Pressure packing. Pressure packing in one form or another is used in most retardation parachutes for special weapons. This pressure packing sometimes takes the form of a localized high pressure and is sometimes applied by large hydraulic presses. Pressure packing must be used to achieve the high pack densities that are required so that the retardation parachute will fit in the space provided in the weapon.

Storage environment of weapons chutes. The storage environment is important to the retardation parachute. If nylon is damp, it tends to adhere to itself; hence, adequate precautions must be taken to protect the retardation parachute, while it is in storage, from environmental conditions such as rain, snow, and humidity.

Environmental conditions. All the environments that could affect the performance of the parachute when it is operated during its useful life should be listed. Guidance is provided below on criteria that have been used in the past. Each application, however, must be analyzed to determine appropriate criteria and levels of exposure.

Cartridge actuated devices. Cartridge actuated devices used in the design should meet the requirements of MIL-D-23615. Internal cartridges for the cartridge actuated devices shall meet the requirements of MIL-D-21625.

Electric Initiators. Electric initiators used in the cartridge actuated devices and elsewhere in the design should meet the requirements of MIL-I-23659.

Gas actuated devices. Gas actuated devices used in the design should meet the requirements of MIL-D-23615.

Rain. The parachute should perform as required after exposure, in the packed condition, to a rain environment consisting of a rainfall rate up to 0.8 millimeters per minute, droplet sizes from 2.0 to 4.5 millimeters, wind velocities up to 64 km/hr, and water temperatures from +5 to +45 °C (+40 to +115 °F) for 30 minutes per parachute container/pack side.

Salt fog. The parachute should perform as required after exposure, in the packed condition, to a salt fog environment consisting of salt concentrations up to 5 percent, atomized at 2.8 liters of salt solution per 0.28 cubic meters and temperatures up to +35 °C (+95 °F) for 48 hours.

Sand and dust. The parachute should perform as required after exposure, in the packed condition, to a sand and dust environment consisting of temperatures up to +49 °C (+120 °F) air velocities up to 5700 feet per minute, dust concentrations up to 0.5 grams per cubic foot for 12 hours minimum, and sand concentrations up to 0.0773 grams per cubic foot for 1.5 hours.

Pressure/altitude cycling. The parachute should perform as required after exposure, in packed condition, to a pressure/altitude environment cycling from 5 pound-force per square inch absolute (psia) for 1 minute minimum to 15 psia for 1 minute minimum (one cycle) for 5000 cycles.

High temperature/humidity. The parachute should perform as required after exposure, in the packed condition, to a high temperature environment of +74 °C (+165 °F) with the humidity levels at 5 percent relative humidity maximum for 500 hours and 90 percent RH minimum for 500 hours.

High temperature cycling. The parachute should perform as required after exposure, in the packed condition, to a high temperature environment cycling from +20 to +74 °C (+68 to +165 °F) in 1 hour, remaining at +74 °C (+165 °F) for 5 hours, then back down to +20 °C (+68 °F) in 1 hour and remaining at +20 °C (+68 °F) for 3 hours (one cycle) for 100 cycles. High temperature exposure may vary a great deal depending on the application. Parachutes stored in fighter cockpits may see temperatures over 200 °F, spin or drag parachutes located near engine compartments may see even higher temperature. Each application must be examined closely to insure the service environment is well understood and defined.

Temperature/humidity shock. The parachute should perform as required after exposure, in the packed condition, to temperature/humidity shock beginning at +74 °C (+165 °F) and 90 percent RH for 2 hours, then within one minute, down to -54 °C (-65 °F) at 5 percent RH for 2 hours (one cycle) for 50 cycles.

Solar radiation. The parachute should perform as required after exposure, in the packed condition, to noonday sun solar radiation equivalent to 1120 watts per square meter for 1440 hours.

Fungus. When the design includes fungi-nutrient materials, the parachute, in the packed condition and the exposed condition should not support fungi growth when exposed to United States Department of Agriculture (USDA) fungi QM 386, QM 380, QM 432, QM 474, and QM 459 for 672 continuous hours and should perform as required after exposure.

Acceleration, shock and vibration. The parachute should perform as required after exposure, in the packed condition, to the acceleration, shock, and vibration levels specified in

the contractual documents. Typically, these requirements may have been derived from the prime system detail specification or other data on the operational shock, acceleration, and vibration environment.

Depressurization. The parachute should perform as required after exposure, in the packed condition, to rapid decompression from 15 psia to 1 psia within 0.1 second.

Toxic or corrosive emissions. Materials should not generate toxic or corrosive emissions when exposed to temperatures from -54 to +74 °C (-65 to +165 °F) or higher if applicable. In the event of any uncertainty with regard to this requirement, the contractor should immediately notify the contracting activity.

EMR hazard. For designs incorporating electrically-initiated explosive, propellant, or pyrotechnic subsystems or components, the parachute should be designed to preclude hazards from electromagnetic radiation to ordnance (HERO) in accordance with MIL-STD-464. MIL-STD-1385 has been used in the past but has been superceded by MIL-STD-464.

Electromagnetic interference and electromagnetic compatibility (EMI/EMC). For designs incorporating electronic, electrical, or electromechanical subsystems or components, the parachute should be designed to be compatible with the applicable aircraft EMI/EMC environment specified in MIL-STD-464, MIL-STD-461, and MIL-STD-462. MIL-E-6051 has been used in the past but has been superceded by MIL-STD-464.

Electromagnetic effects. For designs incorporating electronic, electrical, electro-pyrotechnic, or electro-mechanical systems or components, the parachute circuitry should be designed to withstand, without damage or disruption, either one of the following:

a. An open-circuit voltage of 1500 ±50 volts (V), with a rise time of 20 nanoseconds (ns) maximum as driven by a 50 ohm source, applied across each connector pin and its return path for 125 ±5 ns.

b. A short-circuit current of 10.0 ±0.5 amperes (A), with a rise time of 20 ns maximum as driven by a 50 ohm source injected through each connector pin and its return path for 125 ±5 ns.

REQUIREMENT LESSONS LEARNED (3.12.1.2)

Dimensions/volume. The compartment size should be defined so that any expansion or change of shape of the parachute will not result in binding that will prevent the deployment of the parachute.

Autoclave and pressure packing techniques had to be employed to reduce the volume of the recovery parachute of the F-111 aircraft escape module, resulting in a non-growth pack with a density of approximately 42 pounds per cubic foot.

The need for non-growth packs should be studied from design inception. If non-growth packs are required, autoclave and pressure packing techniques as well as the pre-stretching of pack materials, cloths, and webbing prior to parachute stowage should be considered.

Weight. The parachutes on most RPV are located at the tail. This requires that ballast be added to the forward end of the RPV or that lighter weight materials be used for the parachute to maintain the proper RPV center of gravity. Another possibility might be to develop a deployment system allowing the parachute to be placed closer to the center of gravity.

Measures have been taken to control and reduce weight in many parachute applications. These measures have included reducing the safety factors as a means to reduce weight, using

slotted ribbons along with continuous ribbon construction on special weapons parachutes, and reducing the length of the suspension lines. If the length of the suspension lines is reduced, care must be taken not to reduce the length to the extent that the drag characteristics of the parachute are changed.

Mounting/installation. Most of the design problems and the high cost of developing and testing parachutes are the result of afterthought. Every effort should be made to include the parachute as a part of the original vehicle design and not as an afterthought when the design is "locked in concrete."

Space availability (volume), location of available space, and shape of space are some of the potential problem areas to be considered in designing the installation and mounting interface.

The installed or mounted parachute should not interfere with the normal functioning of the primary body or related equipment prior to parachute initiation. Deployment paths should be in line with the relative air stream to avoid crosswind deployments and associated problems such as line sail during deployment and the potential for entanglement. The attachment point should be free and clear of any obstruction to prevent riser abrasion or tension pull over any edge.

The parachute during deployment sometimes initiates other functions that are associated with the primary body. Care should be taken to assure that these other functions will not impair the functioning of the parachute such as happened during the deployment of a recording system from a high speed aircraft. The parachute, an afterthought, was tasked with pulling a number of pins that were supposed to initiate other devices in the recording system. Improper functioning of the interface devices resulted in hang up of the parachute deployment and failure to recover the recording system.

Detailed stowage envelope definitions are generally incomplete. In many instances the primary body contractor provides the preliminary drawings of the parachute compartment, which are accepted by the parachute subcontractor. The primary body contractor eventually changes the parachute compartment design as the program progresses. These changes often have an adverse effect on the parachute design.

GFE. The availability of the GFE is of prime importance and should coincide with the contractor's schedule. The performance characteristics and tolerances of each lot of the GFE should be provided to the contractor.

Some specific national stock numbers (NSN) that have been listed in the past were out of date or did not have the proper change letter; consequently, the parachute designer had to spend time in determining the proper configuration. This type of information should be thoroughly researched before it is included in a specification.

Standard parts/materials. The Air Force inventory already contains a wide range of parachute hardware and parachute textiles such as cloths, webbing, tapes, ribbons, cords, and threads. Most of the parachute hardware and the parachute textiles in the Air Force inventory have been used in the past and will be used in the future for more than one parachute.

If an application in the parachute technology is found for new materials, these new materials must be standardized over a range of strengths and other characteristics. Whenever practical and economical, Government specifications should be written to cover these new materials to avoid procurement problems and to assure uniform products.

Packing/maintainability and logistics. The design of the parachutes in some instances was fixed before the development of the maintenance and logistic support elements; consequently, the design of the parachute was not supported with maintenance and logistic support elements that were compatible with each other or the parachutes. The maintenance and logistic support

elements included improper types and quantities of test and support equipment, spares and repair parts, personnel, data, etc. The various maintenance and logistic support elements were not always available on a timely basis; that is, delivery was too early or too late, which can be costly.

Nylon parachute materials are not fully stable with respect to age and the influence of light, heat, certain environments, and contaminants. Their performance capabilities degrade according to individual circumstances, and the reliability of the equipment population decreases with time and service. Because of a lack of feasible means to determine the condition of each unit, service life limits are prescribed on a wholesale basis. The present limits imposed by the Air Force were established based upon experienced opinion with minimal supporting data.

These service life limits have apparently been satisfactory in that no service failures have been attributed to deteriorated materials; however, actual uses of the personnel emergency escape and premeditated troop parachutes represent a very small sampling of older units and do not indicate the remaining margin of safety. Under the existing repair cost formula, which is heavily weighted by attained age and jump history, premeditated troop parachutes have seldom reached the overall age limits. Survey projects have been very restricted in scope. In consequence, there has been no valid measure of the reliability of the older equipment population on hand.

In 1974 the Army extended the total age limit of the T-10 main parachute to 12 years. The Army presently has a total age limit of 13 years for the harness and the risers and of 12 years for the T-10 chest reserve parachute assembly. Data were insufficient to provide a basis for establishing limits for initial storage life and service or installed life as distinguished from total life. Again, nylon materials are used in the fabrication of these items of equipment.

Inspection and repack intervals for parachutes vary according to their application, storage location, etc.

The type 2 personnel emergency escape parachutes of the Air Force are generally repacked at 120-day intervals. Type 2 parachutes that are stowed in a compartment as an integral part of an ejection seat are exceptions to the 120-day repack intervals. Parachutes that are stowed in a compartment as an integral part of an ejection seat receive virtually no handling on a day-to-day basis and are not repacked for one or five years.

The limiting factor in the cases of some repack intervals may be the propellant devices that are used on the parachute which could require replacements such as reefing line cutters in a time interval that is shorter than the normal repack cycle.

Since it is probably impossible to completely define the environmental use of the parachute in a specification, the designer should be allowed to contact the using command to determine where and how the parachute system is to be used.

Packing. Packing requirements are secondary. Performance of the parachute should not be jeopardized for easier packing. Although a shortened packing time with a minimum number of packers is a desirable goal, the user should be willing to accept whatever reasonable time and effort are required rather than to degrade the parachute performance.

Parachutes that require very high pressure for packing can easily be damaged by the pressure that is required to complete the packing process; for example: The relative humidity on the days some parachutes were packed was 90 percent. Because the high humidity resulted in a high moisture content in the parachutes, a significant increase in pressure was necessary to close the containers. The increased pressure damaged the parachutes. The damage to the

parachutes could have been prevented by controlling the humidity during packing to preclude the need to use excessive pressure.

Permitting the packed parachutes to soak for some period of time under a medium range pressure rather than applying additional pressure to hasten packing may be advisable, because the application of the additional pressure could damage components such as reefing rings and cutters. Soaking will also permit trapped air to escape, substantially reducing the volume.

X-ray inspection of the packed parachute has been highly successful for the escape capsule of the F-111 aircraft and may be applied to the RPV parachutes and the cruise missile recovery parachutes. A method has been developed to coat reefing lines so that they are visible under x-ray to determine if any problem with the reefing lines exists. Such x-ray inspection of all complex packs should be required from program initiation so that the contractor can include it in his costing and work efforts.

The complete packing and verification procedures must be described in detail. The simplest deviation from the established packing procedures could jeopardize the proper deployment and operation of the parachute.

Environmental conditions. The environments to which the parachute will be exposed during storage and during operation (whether imposed by the primary body, the methods of deployment, or the recovery and impact conditions) are prime considerations in design for reliable operation.

The designer must be aware of how the environmental conditions will affect materials such as a fabric or metal from which the parachute is constructed and must know the total environment to which the parachute will be exposed.

The deceleration parachute for the F-84 aircraft, which has a heat–resistant riser cover, was stored under steam heat pipes in a warehouse. The heat from the pipes over a period of time changed the chemical composition of the primary riser material and degraded the material.

Windblast conditions immediately after exiting from the cockpit in the case of personnel emergency escape parachutes can literally tear the parachute packs apart.

A problem with the emergency escape personnel parachutes in the past has been the opening of the canopy releases during deployment. The exact cause of this problem is extremely difficult to pinpoint; however, windblast, vibration, and acceleration loads in the risers have been suspected. Methods that have been used to reduce the possible opening of the canopy releases during deployment required cover plates or levers that might be susceptible to windblast to be porous; locking levers for opening the device to prevent inadvertent opening by vibration, acceleration, or windblast; and mass balancing the device to prevent opening by acceleration loads.

There is the possibility that risers and suspension lines may be exposed to excessive temperatures that may damage and eventually cause failure of the parachute in aircraft deceleration applications, in spin recovery applications, or in ejection seat applications in which the parachute may be exposed to the rocket exhaust plume. This possibility may be overcome by the use of steel cable risers provided that the limited bending radius of the steel cable will not create a stowage problem. If the risers are made of nylon or any other relatively low temperature resistant material, the short distance of the riser that will be exposed to the high temperature may be covered by a flexible high heat resistant material.

Parachute systems often contain electronic or electroexplosive devices. The devices can range from small automatic actuation devices (AAD) for personnel parachutes to mortar deployed systems for vehicle recovery or stabilization. These devices may be subjected to

electromagnetic interference (EMI) and must be tested to determine if adequate shielding and safeguards are in place to prevent inadvertent activation during flight or on the ground. If there is a potential for the use of electronic/electroexplosive devices on a system, the EMI environment should be included as one of the environmental requirements.

4.12.1.2 Stowed Interface.

The interface characteristics and requirements specified in 3.12.1.2 shall be verified as follows: _____.

VERIFICATION RATIONALE (4.12.1.2)

Dimensions/volume. The measurement and analysis are necessary to determine if the dimensions of the parachute conform to the specified requirements.

Weight. The parachute must be weighed to assure that the weight of the parachute conforms to the specified requirements.

Mounting. Installation and mounting characteristics of the parachute on the primary body can be determined by physically measuring the mating surfaces, by demonstrating the installation and mounting, by analyzing the drawings of the mating surfaces, or by reviewing test results for any irregularities due to the installation and mounting. The installation of the parachute into its stowage compartment should always be demonstrated to assure conformance to the specified requirements.

GFE. If a parachute includes GFE, a representative configuration that includes GFE should be used to conduct the testing. Using a representative configuration that includes GFE for testing should help to provide a realistic environment for operation and to identify any interface problems that may exist between the GFE and the parachute.

Standard parts/materials. The parachute or the drawings thereof must be inspected to assure conformance to the specified requirements.

Packing/maintainability and logistics. Although the effects of environment, contaminants, and use on the parachute can usually be evaluated, this review is necessary because time does not permit the actual life testing of the new parachutes prior to use and the accelerated aging of the materials is not totally predictable.

Packing. This demonstration of packing is required to determine conformance to the requirements as specified.

Environmental conditions. The tests specified in 4.12.1.2 are required to verify that the parachute can withstand the environmental conditions specified in 3.12.1.2.

VERIFICATION GUIDANCE (4.12.1.2)

Interface. The stowed interface requirements of 3.12.1.2 should be verified by documentation comparison, analysis, inspection, government final acceptance gauges, and field tests as required.

Dimensions/volume. The dimension requirements should be verified by measuring the physical dimensions of the parachute. The following method is recommended to determine the volume of canopies up to 800 cubic inches in size:

a. Except for deployment devices sewn to the canopy (for example, diapers) and the connector links and sliders on ram air inflated parachutes, strip the canopy of all extraneous items such as risers/harness, steering toggles, and deployment bags.

b. Fluff the canopy.

c. Using the parachute volume measurement fixture of drawing SK 13-018-001-85 shown on figure 6, place the canopy into the fixture chamber, distributing the material as evenly as possible and as follows:

   (1) Place the round canopy into the chamber apex first, suspension lines last.

   (2) Place the ram-air inflated (or "square") canopy into the chamber tail first, suspension lines last.

d. Insert the piston into the cylinder, and manually press down the piston to compact the canopy as much as possible.

e. Using weight bags or equivalent devices, apply enough weight to the top of the piston that, when combined with the weight of the piston, will place a total of 3 pound force per square inch on the canopy, or a total of 210 $\pm$0.25 pounds calculated as follows: 70 square inches of piston surface area x 3 psi = 210.

f. Remove 140 $\pm$0.25 pounds from the top of the piston. Allow the remaining 70 pounds to compress the canopy for an additional 30 seconds minimum.

g. As shown on figure 6, measure the height from the bottom of the cylinder to the bottom of the piston. Measurements shall be $\pm$0.0625 inch.

h. Repeat steps b through g five times. Average the results.

Weight. The weight requirements should be verified by weighing the parachute. Ensure the assembly being weighed includes all the appropriate components and subassemblies as specified in the requirement.

Mounting/installation. The number of installation trials that must be accomplished to demonstrate the installation process must be specified. The installation time, the manpower, the skill level, and the tools or equipment, which are required for these installation trials, must be specified.

Harness. When the harness is included in the design of the parachute, the harness requirements should be verified by field tests. The test requirements should include a minimum of five drop tests per harness prior to field tests. The following conditions apply:

a. The harness to be tested should be constructed of all new textile and hardware components.

b. No repairs should be made during the drop test series.

c. Any major change in design during testing (for example, stitch pattern variations, changes in textile or hardware components, rerouting of straps, relocation of hardware) should invalidate all previous tests.

d. The risers, or harness attachment points, should be attached to a snubbing cable which is attached to a fixed point on the drop tower. The forces in each riser should be measured by a force transducer. The total load in the snubbing cable should be measured by a single force transducer.

e. The harness should be tested on a torso dummy weighing 300 +0, −5 pounds. The dummy should be dropped from a sufficient height to produce a force from 0 to 6500 pounds.

f. To measure webbing strap slippage through the hardware, each side of the webbing strap should be marked with a contrasting color thread at a convenient reference point (for example, edge of a slide bar). After each drop test, the straps should be examined for slippage.

g. After the drop test series, the harness should be examined for evidence of damage. Any hardware yield or damage to primary load carrying structure should be considered a test failure.
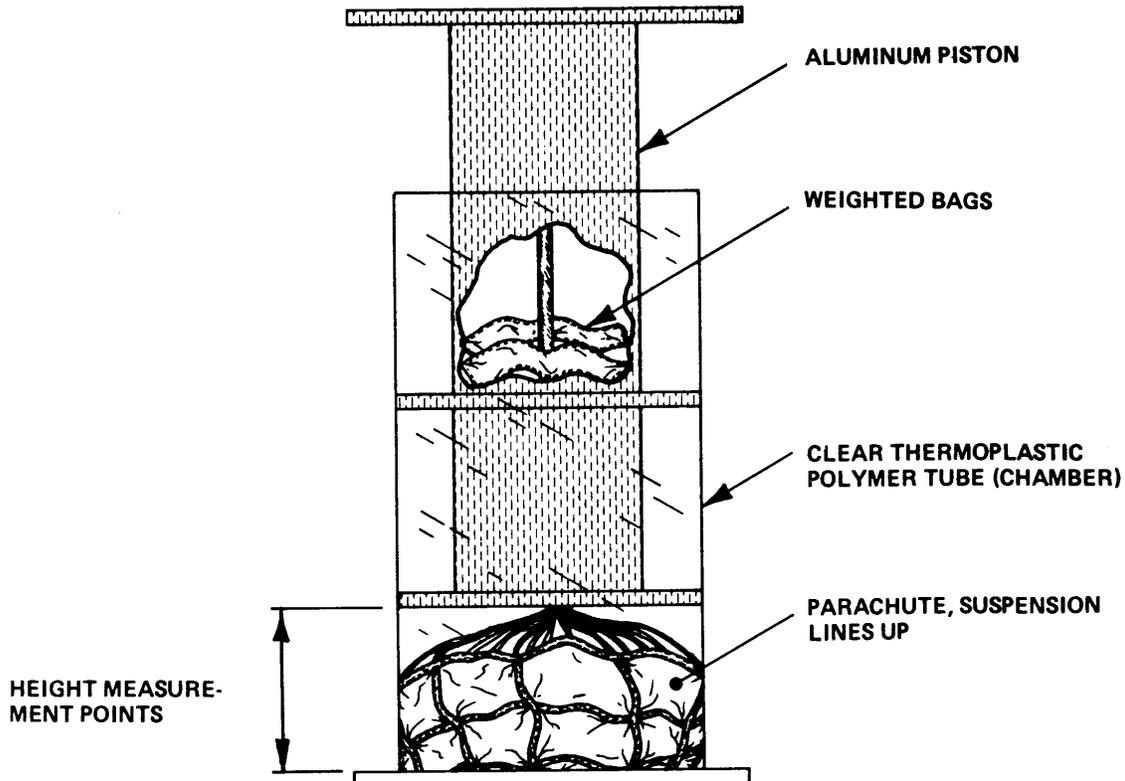
NOTE: Fixture is in accordance with drawing SK 13-018-001-85.

FIGURE 6. Parachute volume measurement fixture.

GFE. Analysis of drawings and/or inspection of actual hardware should be conducted to insure use proper use of GFE as required.

Standard parts/materials. Textile integrity evaluation. When specified in the contractual documents, the integrity of the textiles used in the design should be evaluated by the evaluation group identified in the contractual documents. Detailed test plans, describing the tests, test sequences, test conditions, and number of prototypes or textile samples required for complete

evaluation, should be prepared by the evaluation group. As a minimum, and unless otherwise specified in the contractual documents, the design evaluation should include but may not be limited to, the following test from FED-STD-191:

  a. Cloth. Test methods 5104, 5122, 5134 (replaced by ASTM D 2261 and ASTM D 2262), 5450

  b. Cordage. Test method 6016.

  c. Webbing and tape. Test method 4108.

  d. Thread. Test method 4100.

Materials, processes, and parts. The materials, processes, and parts requirements should be verified by visual examination, verification of conformance to applicable documents, and as specified in the contractual documents.

Fabrication procedures, textile components. The fabrication procedures and textile component requirements should be verified by visual examination, verification of conformance to applicable documents, and as specified in the contractual documents.

Interchangeability and replaceability. The interchangeability and replaceability requirements should be verified by visual examination and documentation reviews. MIL-I-8500, which has been canceled, contains guidance previously used.

Workmanship. The workmanship requirements should be verified by visual examination.

Packing/maintainability and logistics. After the planning has been completed and the maintenance and logistic support has been adequately considered in the developmental process, the requirements for the specific elements of the maintenance and logistic support that have been identified through analyses must be verified through compatibility testing. Problems that are identified as a result of the compatibility testing must be corrected so that the maintenance and logistic support items will be satisfactory for operational use and support of the parachutes in the field throughout their life cycle.

Useful service life records pertaining to specific parachutes that are similar in application, materials used, performance requirements, packing characteristics, and installation characteristics should be researched thoroughly. A conservative limit based on this review can usually be established to determine if the specified limits reasonable. Age data on the parachute should then be accumulated throughout its life and periodic evaluation should be conducted to determine if the life conditions specified based on the initial review can be extended. This effort should be part of the development contract.

Packing: The number of packing trials that must be accomplished to demonstrate the packing process must be specified. The packing time, the number of packers, the skill level, and the tools or equipment, which are required for the packing trials, must be specified.

Rigging and packing. The rigging and packing requirements should be verified during field testing following certification.

Maintainability. Unless otherwise specified in the contractual documents, the contractor should provide a maintainability article for evaluation by the contracting activity to determine whether the parachute design meets all the maintainability requirements. All ballistic and pyrotechnic components of the prototype parachute maintainability article should be inert; all mechanical firing mechanisms should be operable. Applicable maintenance instructions and peculiar support equipment evaluation articles needed to accomplish and evaluate all maintenance requirements and actions at each maintenance level should be provided with the

maintainability article. The peculiar support equipment evaluation articles should be of the proposed final design, but need not be manufactured by planned production processes. The maintainability article will be subjected to field maintainability review/evaluation by the contracting activity to:

a. Ensure system and component maintainability.

b. Develop information for evaluating contractor recommended maintenance procedures and practices.

c. Determine support equipment and peculiar support equipment suitability for performing the required maintenance tasks in a fleet maintenance environment.

d. Type I personnel parachutes. Evaluate the susceptibility of parachute components to damage during aircraft cockpit and recovery system (ejection seat) maintenance.

e. Type I personnel parachutes. Determine adequacy of the design to meet the requirements of MIL-STD-2067.

Human performance/human engineering. The human performance/human engineering requirements should be verified in accordance with MIL-STD-1472.

Safety. The safety requirements should be verified in accordance with MIL-STD-882.

Packaging. The packaging requirements should be verified by visual examination and documentation comparison prior to shipment.

Environmental conditions. The minimum number of parachutes to be subjected to the environmental tests and subsequently operated must be specified. The environmental tests must be explained in detail. The operation of the parachutes should be fully detailed in terms of test conditions. The criteria given below have been used in the past, however, a thorough understanding of the environmental conditions is needed to establish the proper criteria for a given program.

Cartridge-actuated devices. The requirements for cartridge actuated devices should be verified in accordance with MIL-D-23615. The internal cartridges should be verified in accordance with MIL-D-21625.

Electric initiators. The requirements for electric initiators should be verified in accordance with MIL-D-23615.

Gas actuated devices. The requirements for gas actuated devices should be verified in accordance with MIL-D-23615.

Rain. The rain requirements should be verified in accordance with MIL-STD-810, Method 506.3, procedure I, and as follows:

a. Test item configuration   packed condition

b. Rain fall rate   equivalent to 0.8mm/min

c. Droplet size   from 2.0 to 4.5 mm

d. Test item preheat temp   room ambient

e. Exposure   30 minutes per parachute container/pack side

f. Wind velocity   52 $\pm$12 km/hr

g. Water temperature   Cycling from 5 - 45 °C (40 - 115 °F)

Salt fog.   The salt fog requirements should be verified in accordance with MIL-STD-810, Method 509.3, procedure I, and as follows:

    a. Test item configuration   packed condition

    b. Test duration   48 hours

Sand and dust.   The sand and dust requirements should be verified in accordance with MIL-STD-810, method 510.3, procedures I and II, and as follows:

    a. Test item configuration   packed condition

    b. Test temperature   46 $\pm$3 °C (115 $\pm$5 °F)

    c. Relative humidity   30 +0, $-$5 percent

    d. Air Velocity, procedure I   1750 $\pm$100 ft/min

    e. Air velocity, procedure II   3540 to 5700 ft/min

    f. Sand composition   silica type

    g. Sand concentration   0.0623 $\pm$0.0150 g/ft^3

    h. Dust composition   Red China type

    i. Dust concentration   0.3 $\pm$0.2 g/ft^3

Pressure/altitude cycling.   The pressure/altitude cycling requirements should be verified by subjecting the parachute, in the packed condition, to pressure/altitude cycling beginning from 5 psia maximum for 1 minute minimum to 15 psia minimum for 1 minute minimum (one cycle) for 5000 cycles. Test apparatus should be in accordance with MIL-STD-810, method 500.3.

High temperature/humidity.   The high temperature/humidity requirements should be verified by subjecting the parachute, in the packed condition, to a high temperature environment of +74 +0, $-$3 °C (+165 +0, $-$5 °F) at 5 percent RH maximum for 500 hours minimum and then 90 percent RH minimum for 500 hours minimum. Test apparatus should be in accordance with MIL-STD-810, method 501.3.

High temperature cycling.   The high temperature requirements should be verified by subjecting the parachute, in the packed condition, to a high temperature environment cycling from +20 to +74 °C (+68 to +165 °F) in 1 hour minimum, remaining at +74 +0 $-$3 °C (+165 +0 $-$5 °F) for 5 hours minimum, then back down to +20 +3, $-$0 °C (+68 +5, $-$0 °F) in 1 hour minimum and remaining at +20 +3, $-$0 °C (+68 +5, $-$0 °F) for 3 hours (one cycle) for 100 cycles. Test apparatus should be in accordance with MIL-STD-810, method 501.3.

Temperature/humidity shock.   The temperature/humidity shock requirements should be verified by subjecting the parachute in the packed condition, to temperature/humidity shock beginning at +74 +0, $-$3 °C (+165 +0, $-$5 °F) and 90 percent RH minimum for 2 hours minimum, then, within 1 minute, down to $-$54 +3, $-$0 °C ($-$65 +5, $-$0 °F) at 5 percent RH maximum for 2 hours minimum (one cycle) for 50 cycles. Test apparatus should be in accordance with MIL-STD-810, method 507.3.

Solar radiation.   The solar radiation requirements should be verified by subjecting the parachute, in the packed condition, to the test of MIL-STD-810, method 505.3, procedure II, 60 cycles, except the radiant energy rate in step 1 shall be 1120 W/m^2.

Fungus.   The fungus requirements should be verified by subjecting the parachute, in the packed condition and then in the exposed condition, to the test of MIL-STD-810, method 508.4,

duration of 672 continuous hours. Note, this testing is only required when the parachute contains fungus nutritive materials.

Acceleration, shock and vibration. The acceleration requirements should be verified by subjecting the parachute in the packed condition, to the acceleration, shock, and vibration levels specified in the contractual documents. Test apparatus should be in accordance with MIL-STD-810, methods 513.4, 514.4, and 516.4.

Depressurization. The depressurization requirements should be verified by subjecting the parachute, in the packed condition, to rapid depressurization from 15 psia minimum to 1 psia maximum within 0.1 second.

Service life and shelf/total life. The service life and shelf/total life requirements may be verified by analysis, or in accordance with the age life projection test specified in the appendix of MIL-P-85710. Often, a surveillance test program is established to periodically test equipment to see if it is meeting the expected age life requirement, and/or to see if the service life can be extended.

Electromagnetic radiation (EMR) hazard. The EMR hazard requirements should be verified in accordance with MIL-STD-464. MIL-STD-1385, which has been superceded by MIL-STD-464 also has guidance on this requirement.

Electromagnetic interference/electromagnetic compatibility (EMI/EMC). The EMI/EMC requirements should be verified in accordance with MIL-STD-464 (which supersedes MIL-E-6051), and the applicable procedures of MIL-STD-462 at the limits specified in MIL-STD-461.

Electromagnetic effects. The electromagnetic effects requirements should be verified by subjecting the parachute to either one of the following electrical tests, as applicable:

a. An open circuit voltage of 1500 $\pm$50 V with a rise time of 20 ns maximum, as driven by a 50 ohm source, should be applied across each connector pin an its return path for 125 $\pm$5 ns.

b. A short circuit current of 10.0 $\pm$0.5 A with a rise time of 20 ns maximum, as driven by a 50 ohm source, should be injected through each connector pin and its return path for 125 $\pm$5 ns.

VERIFICATION LESSONS LEARNED (4.12.1.2)

Dimensions/volume. (Lessons learned to be added as acquired.)

Weight. The weight of the packed parachute can vary according to the humidity that was present during the packing of the parachute or the moisture that was absorbed by the parachute after packing.

Mounting/installation. The installation and mounting should be checked on a regular basis as the design progresses to assure compliance with the specified requirements. The installation time for the installation trials will understandably be longer than for the installation accomplished after experience has been gained with the parachute. The installation time may be reduced considerably as the personnel involved in the installation process become more familiar with the parachute.

GFE. (Lessons learned to be added as acquired.)

Standard parts/materials. (Lessons learned to be added as acquired.)

Packing/maintainability and logistics. A proven reliable means does not exist for accelerating the aging process of a parachute to determine a true total life. The age life

projection test in the appendix of MIL-P-85710 may be used to gain insight into the age performance of a material. Typically, true age life information is obtained only as experience is gained over the years, which is a slow process.

Packing. The packing time for the initial packing trials will understandably be longer than for the packing accomplished after experience has been gained with the parachute. The packing time may be reduced considerably as the personnel involved in the packing process become more familiar with the parachute.

Differences in the difficulty and the time required for packing new parachutes and previously packed parachutes have been noticed. The flexing and the stretching of the parachutes during previous packing possibly contributed to the ease of packing; therefore, a new parachute should be used to develop procedural packing instructions.

Environmental conditions. If a parachute is exposed to the laboratory test conditions as specified above and continues to operate satisfactorily, a high degree of confidence that the parachute could survive in the field environment during its expected life will have been established. However, the specified tests cannot be interpreted to be an exact and conclusive representation of actual service operation.

3.12.1.3 Operational Interface.

The interface characteristics of the decelerator for functional/operational use shall be as follows: _____

REQUIREMENT RATIONALE (3.12.1.3)

The operational interface requirement can be broken down into the following lower level requirement considerations: functional interface with the primary body, and the functional interface with unattached auxiliary equipment.

Functional interface with primary body. Functions that depend on the primary body for their accomplishment such as parachute deployment initiation must be considered in the design of the interface between the primary body and the parachute. These functions can involve interconnecting cables, cords, electrical connections, and similar items necessary for the functioning of the parachute or a portion thereof.

Functional interface with unattached auxiliary equipment. The parachute and the primary body combination must interface in certain cases with an unattached auxiliary item. Such is the case with a midair retrieval parachute system in which a helicopter outfitted with retrieval equipment is used to snatch a descending vehicle with a parachute prior to ground impact. A parachute that is not properly designed may not mate with the retrieval equipment of the helicopter, resulting in ground impact and damage to the vehicle; or may lead to overload of the helicopter and to failure of the helicopter or failure to recover the vehicle. Likewise, the extraction parachutes in some airdrop systems must mate with the aircraft pendulum release system.

REQUIREMENT GUIDANCE (3.12.1.3)

Interface. The parachute should be designed to physically and functionally interface with the prime system and other systems, as applicable. The interface control drawings and other engineering data required to define all physical and functional interfaces and to ensure parachute compatibility with the prime system and other applicable systems should be provided.

Functional interface with primary body. Parachute functions that require a direct interface with the primary body to effect their accomplishment should be listed. If facilities exist on the primary body for any of the functions listed, a description of these facilities (possibly drawings) should be provided to assure the proper interface between these facilities and the parachute. Any redundancy that is required of any function should be stated.

Personnel Parachute Considerations

Automatic opening parachutes. All premeditated and type 2 emergency escape personnel parachutes should be designed for the installation of an automatic ripcord release so that the parachutes will open automatically. The automatic opening parachutes will enable the crewmember to escape above a preset altitude and arm his automatic release so that the deployment of the parachute will be automatically initiated at a safe and predetermined altitude. If the crewmember escapes from the aircraft below an altitude equivalent of the preset altitude value of the automatic release, the deployment of the parachute should be initiated automatically after a predetermined delay time to allow for sufficient speed decay and avoid high or excessive opening shock forces. Type 1 emergency personnel parachutes should also function automatically. The automatic ripcord release for type 2 emergency escape personnel parachutes should be mounted inside the parachute pack in a manner that will comply with the following requirements:

   a. The comfort of the crewmember of the parachute must not be affected.

   b. The release must be easily accessible for inspection, servicing, and installation.

   c. The automatic actuation of the ripcord must be very reliable.

   d. The arming knob or handle of the release must be suitably mounted and accessible to either hand of the crewmember.

Automatic releases should be designed for ease of inspection and testing to verify system readiness. Interface with test equipment should be designed to reduce or eliminate the need to remove the release from the pack for testing (particularly for electronic systems). When practical, built in test capability should be designed into the release to reduce or eliminate the need for additional test equipment. Electronic releases must be protected from the effects of electromagnetic radiation (EMR) to prevent inadvertent activation.

Container/pack manual opening system. The type 2 parachute should include a manually activated container/pack opening system designed for operation by either hand. When the type 1 parachute includes a backup manually activated container/pack opening system it should also be designed for operation by either hand.

Manual operation force. For both type 1 and type 2 parachutes, the container/pack manual opening system should be designed for operation with a pull force not less than 10 nor greater than 27 pound force. The minimum and maximum forces required for an aircrew member to manually activate other design features of the parachute which required a pull force to invoke operation should also be specified.

Canopy/risers release system. The parachute should incorporate a canopy/risers release system to detach the canopy or risers from the aircrew member. The canopy/risers release system should be designed to preclude inadvertent operation and should have no more than two points of release, each operable with either hand and by two separate and different motions. The canopy/risers release system should also function automatically upon contact with seawater. Although MIL-S-85076 has been canceled, it was used to develop past water activated releases and may still contain some useful guidance.

Inadvertent canopy/risers release. The parachute should be designed to maintain the integrity of the main canopy in the event of the inadvertent functioning of one side of a dual canopy/risers release system. Cross connector straps have typically been used for this in the past. The parachute should sustain no damage nor exhibit performance degradation worse than for a marginal failure as defined in the reliability requirement guidance and section 5.

Vehicle Recovery Parachute Considerations

Compartment door release. The reliable opening of a decelerator compartment door, or the release of the whole door, at high speeds is essential in a successful aerospace vehicle recovery operation but is usually not as simple to achieve as it appears. The unlatching mechanisms must function under various environmental extremes such as low temperature (65 °F), high altitude, high positive acceleration, high negative acceleration, and extreme vibrations. The unlatching mechanisms must not have an adverse effect on the performance of the vehicle. Two of the most commonly used unlatching mechanisms are explosive bolts and Primacord.

Controls. The functioning of the vehicle recovery system must be controlled by time, altitude, or pressure, or a combination of these, arranged to deploy the different aerodynamic decelerators in the order desired. The devices for controlling the functioning of the vehicle recovery system may perform their function either by direct mechanical linkage or through electrical circuits. If electrical circuits are utilized, two independent parallel electrical circuits that are complete with timers or other controls and batteries must be provided. The two electrical circuits must be arranged so that the failure of one electrical circuit will not prevent the proper functioning of the vehicle recovery system as a whole. Electrical or electronic control circuits, switches, and initiator circuits must be designed for ease of access and testing for verification of circuit/component continuity and integrity. Built in test capability for verification of system readiness is highly desirable.

Canopy disconnect. Generally, all canopy disconnects should be mechanical and are actuated by either springs or propellant devices. A suitable device for releasing the final stage canopy from the recoverable body after ground or water impact must be incorporated in the canopy disconnects to prevent the final stage canopy from dragging the vehicle as a result of surface winds.

Aircraft Deceleration and Spin Stabilization Parachute Considerations

Operation. The pilot in the operation of the aircraft makes a normal approach and landing and deploys the drag parachute at, or immediately after, touchdown. The pilot applies the brakes at a speed of approximately 80 knots. The pilot keeps the drag parachute inflated and off the runway, at the end of landing roll, by rolling at low speed to a designated parachute drop-off area that is generally located near the end of the runway where the pilot jettisons the drag parachute. The pilot should not try to reinflate the parachute after collapse or drag it to the hangar area, because reinflating or dragging the parachute can result in damage to the parachute due to ground friction and in soiling of the parachute by the exhaust of the jet engines. The pilot can control inflation by applying enough engine power to keep the parachute inflated even at very low speeds. The parachute, independent of the location of the aircraft attachment point, will ride above the ground due to the airflow around the canopy. Drag parachutes help to prevent ground loops and sudden pitch ups, thereby assisting in control of the aircraft. Ground personnel should retrieve the jettisoned parachute and return it to the packing loft for inspection, repair, repacking, and storage for reuse.

Handle operation. A single handle that is accessible to the pilot and the copilot provides the three functions that are required for parachute operation. The first 3 to 4 inches of the handle pull engages the hook that connects the parachute riser to the aircraft. Pulling beyond the first stop will open the parachute compartment door, eject the pilot parachute, and start the deployment of the drag parachute. Turning the handle 90 degrees and completing the pull will jettison the drag parachute. (An up and down movement of the handle is used for some aircraft.) These three distinctly different movements of the handle are required in every case of parachute operation. The parachute compartment door opening at pilot action should automatically eject the spring-loaded pilot parachute.

Aerial Pickup/Mid Air Retrieval Parachute Considerations

Aerial pickup techniques. Experience with aerial pickup parachutes has involved both helicopter and fixed wing aircraft with aft opening cargo doors. Details of the aerial pickup parachutes vary somewhat but are basically the same. The helicopter has equipment for engaging the target of the aerial pickup parachute. Once engaged, the vehicle is reeled up near the underside of the helicopter by a winch and towed in that position until set down at a preselected recovery site. The fixed wing aircraft are likewise equipped to snag the engagement target. Once engagement has been made, the vehicle is reeled into the cargo compartment of the aircraft and is offloaded upon landing.

Airdrop Parachute Considerations

Airdrop aircraft. The aircraft that are presently used for airdrop have a large opening at the aft end of the fuselage through which the loads leave the aircraft. The standard airdrop aircraft are the C-130, the C-141, C-17, and the C-5 cargo aircraft. A force is required to extract or eject a load from these airdrop aircraft. This force is supplied by ejection or extraction devices.

Ground disconnect. Parachute release devices are used to release the parachutes from the load on contact with the ground to prevent high surface winds from dragging the parachutes, which could damage the cargo.

Weapons Parachute Considerations

Automatic deployment. Automatic deployment is required when the weapon is carried externally on the aircraft or when free fall is desired prior to deployment of the parachutes. The sequence of an automatic deployment is as follows:

a. After the weapon is released from the aircraft, the weapon falls free for some specific length of time; then the tail of the weapon or the cover of the parachute compartment is removed, usually by explosives.

b. The pilot parachute that is connected to the tail cover is deployed as the cover moves away.

c. Once the pilot parachute reaches the airstream, the deployment of the remaining components is identical to the static line deployment.

Functional interface with unattached auxiliary equipment. All functions that require a direct interface of the parachute and the primary body combination with an unattached auxiliary item should be listed. The unattached auxiliary item should be identified. The unattached auxiliary item (if the design exists) with which the parachute and the primary body combination must mate should be described in detail. A description of the interfacing function that is as complete

as possible and any factors that limit how the interface can take place should be specified. Any redundancy or backup requirements should be stated.

Aerial Pickup/Mid Air Retrieval Parachute Considerations

Vehicle compatibility. The aerial pickup parachutes are usually designed for internal carriage in the parent vehicle. Consideration should be given to the compatibility of the aerial pickup parachute and the parent vehicle with respect to attachment and deployment.

Engagement target. An engagement target, whether it is an integral part of the main descent parachute or a separate decelerator, must be included in the design of the aerial pickup parachute. The engagement target must contain and present a load–bearing structure network capable of being snagged by the retrieval equipment on the recovery vehicle.

Main parachute disposition. Whether to jettison or retain the main parachute upon engagement must be given consideration. If the main parachute is to be released upon engagement, it should be controlled in a manner that will prevent premature release during deployment, descent, or unsuccessful attempts at engagement by the recovery vehicle. If the main parachute is to be retained upon engagement, the prevention of wind drag on the main parachute that could possibly hinder recovery vehicle reel–in procedures should be considered.

REQUIREMENT LESSONS LEARNED (3.12.1.3)

Functional interface with primary body. Extreme care should be exercised to assure that the functional interface will not affect or retard recovery system functioning in any way to prevent even, orderly operation.

Parachutes provide a range of performance (in particular, force and deployment and opening times) rather than identical performance with each operational use. If a parachute is required to perform a specified task such as arming some other device during deployment, the performance variation of the parachute should be considered in the design of the interface to assure a reliable parachute.

Functional interface with unattached auxiliary equipment. Care should be exercised to assure that the requirements for the unattached auxiliary equipment to interface with the parachute and primary body combination will not impose limitations on the performance of the parachute.

During a flight test of a drone, a failure of the main recovery parachute to release from the drone after engagement caused the failure of the engagement parachute and a ground impact. This failure was caused by a maintenance error (disconnect device not rigged correctly) and not a parachute failure. This problem has been encountered before. Recommendations were made to "Murphy" proof the disconnect link to avoid this problem in the future.

A yaw stabilized descent system for midair recovery of remotely piloted vehicles (RPV) was needed to match the capability of the retrieval aircraft. Problems were encountered with a parachute that allowed the RPV to rotate rapidly, that descended at erratic and high rates, and that oscillated at heavy suspended weights. The suspected cause of these problems was that the main parachute suspension lines (nylon) were stretched differentially during deployment, causing unequal line lengths that resulted in an unsymmetrical loading. When the nylon lines were replaced with less elastic (Dacron) lines, the problem disappeared.

4.12.1.3 Operational Interface.

The interface characteristics of the decelerator for functional/operational use specified in 3.12.1.3 shall be verified as follows: _____

VERIFICATION RATIONALE (4.12.1.3)

Functional interface with primary body. This verification is necessary to assure that the applicable parachute functional aspects allow proper interface with the primary body.

Functional interface with unattached auxiliary equipment. This verification is necessary to assure that the functional aspects of the interface of the parachute and primary body combination with the unattached auxiliary equipment conforms to the specified requirements.

VERIFICATION GUIDANCE (4.12.1.3)

Interface. The interface requirements should be verified by documentation comparison, analysis, inspection, government final acceptance gauges, and field tests as required.

Functional interface with primary body. An analysis may include a study of each function specified to assure that proper functioning will take place. The analysis should also assure that redundancy exists where required. Testing of the parachute mated with the primary body should be conducted throughout the operational envelope to verify that the parachute functions as required.

Personnel Parachute Considerations

Manual operation force. The manual operation force requirement should be verified during laboratory tests by gradually applying a pull load until release occurs.

Canopy/risers release system. The canopy/risers release system requirement should be verified by manual operation of the system under 300 +0, -5 pound suspended load

Inadvertent canopy/risers release. The inadvertent release requirements should be verified during field tests by releasing either the right or left side of a dual canopy/risers release system after full inflation of the main canopy.

Functional interface with unattached auxiliary equipment. The verification that is required to assure that the parachute conforms to the functional interface requirements throughout the operational envelope and to all redundancy requirements should be specified.

VERIFICATION LESSONS LEARNED (4.12.1.3)

Functional interface with primary body. The functional interface characteristics should be physically checked periodically throughout the development process within the constraints available to assure that design changes have not adversely affected the functional interface. This checkout should be conducted in as realistic as possible an environment.

A new rip cord release was qualified by subjecting it to extensive environmental and bench tests but was not installed on a parachute as intended in actual use. When the production item was first used, a change had to be made because a sharp bend in the cable housing could cause problems in arming the rip cord release. Since this problem would have shown up only through actual fit and function checks, the functional interface was not as simple as it had seemed to be during the bench tests.

Functional interface with unattached auxiliary equipment.   The functional interface characteristics should be physically checked periodically throughout the development process to assure that design changes have not adversely affected the functional interface.   This checkout should be conducted in a realistic environment.

3.12.2 Operational performance.

The parachute or decelerator subsystem shall meet the operational performance as specified below.

3.12.2.1 Reliability.

When the decelerator is operated under the environmental and operational conditions specified herein, it shall have a probability of success of _____.

REQUIREMENT RATIONALE (3.12.2.1)

Assurance that the parachute will function as required is necessary. The operational reliability of a parachute is the probability of the successful sequence of the necessary operations in the deployment of the parachute.   Certain minimum reliability requirements that are based on the overall effects that the failure of the parachute will have on the mission must be specified. The highest reliability is required for the safe recovery of personnel. The reliability for the airdrop of equipment or supplies is usually not as stringent as the reliability for the recovery of personnel. The highest reliability is always desirable for any parachute; however, the increase in reliability may be a higher price than is warranted by the mission or may not be practical to demonstrate.

REQUIREMENT GUIDANCE (3.12.2.1)

The probability of the successful operation of the parachute should be specified as a percentage or the decimal equivalent.

Reliability program. When specified in the contract or purchase order a reliability program should be planned, implemented, and reported by the contractor in accordance with MIL-STD-2067 (for type 1 only) and MIL-STD-785, tasks 101, 102, 104, 204, 208, 209, and 302.   The reliability program plan should be prepared for use by the contracting activity to assist in managing an effective reliability program and to evaluate the contractor's approach to, understanding of, and execution of his reliability tasks, his depth of planning to ensure that his procedures for implementing and controlling reliability tasks are adequate, and his organizational structure to ensure that appropriate attention will be focused on reliability activities and problems.

Predicted reliability. Using the methods of MIL-STD-756 and the guidelines of MIL-STD-785, task 203, or MIL-STD-2067 (for type 1 only), a reliability prediction should be performed by the contractor to estimate the basic mission and storage reliability of the parachute. The prediction should be prepared for use by the contracting activity to determine whether these reliability requirements can be achieved with the proposed design and in making program decisions regarding the feasibility and adequacy of a new design approach.   When specified in the contractual documents, all effort performed should be documented in a report prepared in accordance with MIL-STD-756.

Failure modes, effects, and criticality analysis (FMECA). When specified in the contract or purchase order, an FMECA should be performed and documented by the contractor in accordance with MIL-STD-2067 (for type 1 only) and MIL-STD-785, task 204.   The FMECA

should be performed on each level of assembly for each required environmental condition and for each operational mode, and shall identify and evaluate all failure modes. In addition, for each failure mode, the likelihood of occurrence should be determined for the failure identified, a determination should be made as to its effect and criticality upon the component or subsystem in question, and of the ultimate significance of this effect upon the parachute performance, reliability, maintainability, and safety. These analyses should include a description of the factors inherent in the design, or in the quality assurance program, that will minimize the probability of occurrence of those failures having the most significant potential adverse effect on system performance, reliability, maintainability, and safety. The criticality of the effects of each identified failure mode upon specific modes of parachute operation shall be classified or ranked into the following categories for a parachute operating at the extreme required performance envelopes.

a. Catastrophic. A catastrophic failure is defined as a design weakness, malfunction, or system damage that causes the parachute to fail to meet any of the critical performance requirements greater than 50 percent.

b. Critical. A critical failure is defined as a design weakness, malfunction, or system damage that causes the parachute to fail to meet any of the critical performance requirements by less than 50 percent with a resulting failure that cannot be counteracted or controlled by an uninjured aircrew member.

c. Marginal. A marginal failure is defined as a design weakness, malfunction, or system damage that causes the parachute to fail to meet any of the performance requirements of table 1 by less than 50 percent with a resulting failure that can be counteracted or controlled by an uninjured aircrew member.

d. Negligible. A negligible failure is defined as a design weakness, malfunction, or system damage that does not prevent the parachute from meeting any of the critical performance requirements.

Inversions. An inversion (often incorrectly called a "line over") can adversely affect the reliability of a premeditated or an emergency escape personnel parachute. An inversion is more common in a solid cloth canopy but can occur in other canopies such as a ring sail canopy or a ring slot canopy. An inversion is either a full inversion or a partial inversion. A partial inversion is usually identifiable by a pattern of friction burns. A partial inversion (see figure 7), depending on how the aerodynamic forces develop, is a permanent cross canopy partial inversion, a permanent lateral gore partial inversion, a temporary cross canopy partial inversion, or a temporary lateral gore partial inversion. The term "Mae West" is often used to describe a permanent cross canopy partial inversion or a permanent lateral gore partial inversion. The incidence of temporary cross canopy partial inversions and of temporary lateral gore partial inversions is increased markedly during high speed or over speed tests. Many temporary cross canopy partial inversions and many temporary lateral gore partial inversions occur in 0.01 second or less.
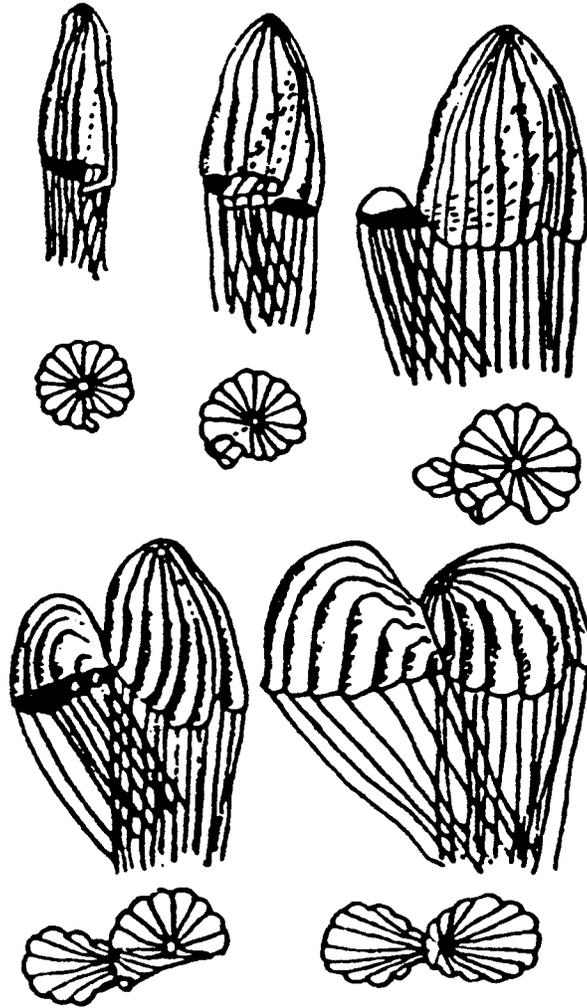
FIGURE 7. Formation of inversion.

Causes of partial inversions. The causes of partial inversions can only be properly analyzed by studying high speed motion picture coverage of partial inversions. The three causes of partial inversions that have been identified during many years of studying high speed motion picture coverage of partial inversions are as follows:

a. The random movement of the skirt during the deployment and the very early inflation of the parachute can cause one part of the skirt to move inward and into an adjacent or opposite part of the skirt and to pass under the adjacent or opposite part of the skirt. The part of the skirt that passed under the adjacent or opposite part of the skirt will be inverted or inside out.

b. The relative wind during the crosswind deployment of the parachute can push the "up wind" side of the skirt against and under the "down wind" side of the skirt. The part of the skirt that passed under the "down wind" side of the skirt will be inverted or inside out.

c. An uneven skirt as in the case of the entanglement of a group of suspension lines or of a riser can cause a part of the skirt to move inward and into an adjacent or opposite part of the skirt and to pass under the adjacent or opposite part of the skirt. The part of the skirt that passed under the adjacent or opposite part of the skirt will be inverted or inside out.

Prevention of partial inversions. The incidence of partial inversions can be reduced by preventing crosswind deployment and by controlling the skirt until line stretch. The incidence of partial inversions can be virtually eliminated by a technique that uses a barrier below the skirt to prevent one part of the canopy from moving under the skirt of another part of the canopy provided that the barrier is made of material of sufficiently high porosity so that the material will not start an inversion. The Army uses a barrier or an anti–inversion net on the 35-foot-diameter canopy of the T-10 personnel parachute. The anti–inversion net is made of mesh material with 3-3/4 inch squares and extends 18 inches below the skirt. The malfunction rate of the canopies of the T-10 personnel parachutes before the use of the anti–inversion net, between 1970 and mid-1977, is 0.33 percent.   The malfunction rate of the canopies of the T-10 personnel parachutes with the anti-inversion net, for approximately 500,000 jumps, is only 0.005 percent with only one inversion type of malfunction. The anti–-nversion net has several drawbacks such as increased weight, increased bulk, longer opening time with less consistency (larger standard deviation), and the possibility of net entanglement.

Damage caused by partial inversions. Partial inversions normally cause some damage. The typical damage that is caused by a partial inversion consists of scattered friction burn holes, 1/2 to 2 inches in diameter, in the lower one-third to as high as the lower two-thirds of several adjacent gores and of a small area of friction burn, usually on the inside edge of the skirt, in the middle of the area of the canopy under which another area of the canopy was pulled under. The damage normally starts with frictional heat melting the nylon at the point where one part of the canopy is being rapidly pulled under the skirt of another part of the canopy. The melting of the nylon leaves friction burns. The friction burns can weaken the canopy so that the portion of the canopy that contains the friction burns can fail, especially at high airspeeds. If the airspeed is high, the damage frequently includes ruptured gores, broken skirt bands, and broken suspension lines. If the canopy is multi-colored, the damage frequently includes a transfer of color between the area where the skirt was pulled through and the area of the skirt that was pulled through.

Temporary cross canopy and lateral gore partial inversions.   If the airspeed is high, temporary cross canopy partial inversions and temporary lateral gore partial inversions usually cause considerable damage.

Damage charts. Figure 8 shows a typical damage chart of a C-9 canopy having a flat diameter of 28 feet. The format and damage symbols are recommended for post test documentation of damage parachute canopies. The C-9 canopy was damaged by a temporary cross canopy partial inversion in which the area around gore 7 passed under the skirt of gore 28, leaving friction burns on the skirt and transferring color from an olive green area to the orange area around gore 7. (Note: Gores 1 through 10 are orange, and gores 25 through 28 are olive green.) The damage shown on figure 8 would not significantly affect the rate of descent of the C-9 canopy. Figure 9 shows the damage chart of a temporary cross canopy partial inversion in which the area around gore 14 passed under the skirt at gore 27, producing friction burns in the skirt. The friction burns in the skirt caused the skirt band to break. The sudden breaking of the skirt band caused the failure of the gore. The damage shown on figure 9 would cause an increase of approximately 40 percent in the rate of descent of the canopy. Figure 10 shows a damage chart of a temporary lateral gore partial inversion in which gore 19 passed under the skirt band of gore 21. As gore 19 was pulled under the skirt band of gore 21, the friction heat

melted enough of the nylon suspension line on each side of gore 21 to cause these two nylon suspension lines to break under opening loads. The damage shown on figure 10 would not significantly affect the rate of descent of the canopy.
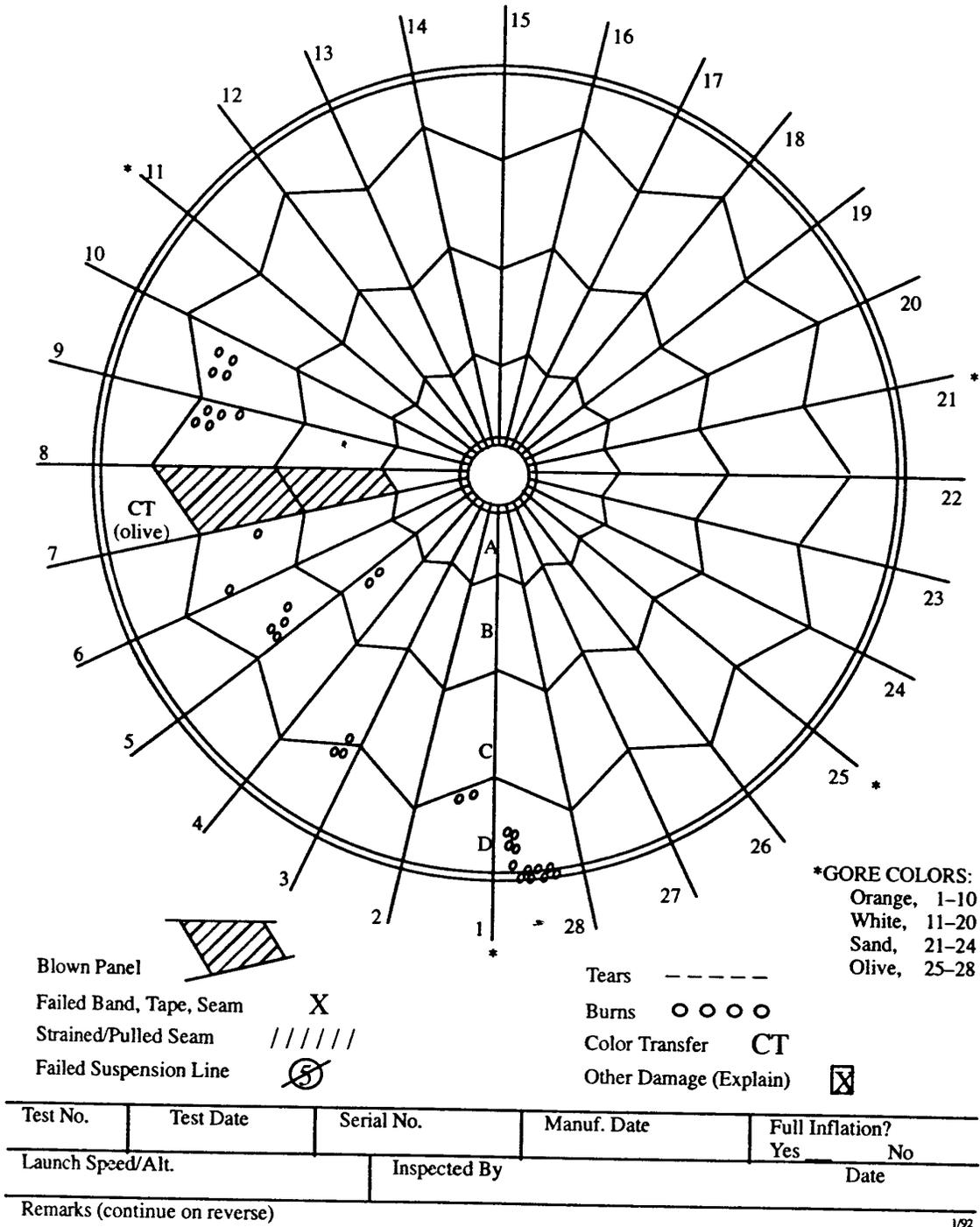

FIGURE 8. Sample 1, C-9 canopy damage chart.

Permanent cross canopy and lateral gore partial inversions. Permanent cross canopy partial inversions and permanent lateral gore partial inversions usually do not cause a great deal of damage but can cause holes in some areas of the canopy that can cause a spinning condition. The spinning condition can lead to an increase of as much as 65 percent in the rate of descent as well as a bad landing attitude. If there is no spinning condition, the increase in the rate of descent is usually low.

Personnel Parachute Considerations

Ultra high reliability, both in deployment and in opening, whether automatic, manual, or static line. The parachute should demonstrate a reliability of 0.98 minimum at the 90 percent confidence level when tested as specified. These requirements assume that system sequencing of the parachute has been designed such that any component or function that fails during operation will "fail safe" in that redundant, standby devices will automatically continue safe performance through mission completion.

Aircraft Deceleration and Spin Stabilization Parachute Considerations

Stability and opening reliability. The ribbon, the ringslot, the cross, and the varied porosity parachutes meet the stability and the opening reliability requirements for landing drag parachutes. Ribbon parachutes have a more uniform opening, which is an added benefit rather than a necessity. Reliable parachute deployment and opening will involve the total process from pilot action to main parachute full opening. Figure 2 shows a typical landing drag parachute assembly consisting of a pilot parachute, a pilot parachute bridle, a deployment bag, a drag parachute, a riser, and an aircraft attachment fitting. Upon pilot action, the aircraft drag parachute compartment door is opened and the pilot parachute is ejected. The pilot parachute bridle extracts the deployment bag from its compartment. The deployment bag opens and deploys the riser, the suspension lines, and the parachute canopy.

Single parachute versus cluster of parachutes. The 44-foot-diameter drag parachute for the B-52 bomber aircraft is the largest single deceleration parachute used. The B-70 bomber aircraft used a cluster of three 28-foot-diameter ribbon parachutes. There are two reasons for using a cluster of parachutes. The deployment and opening time for a cluster of smaller parachutes is shorter than for a single larger parachute of equal drag, assuming that all parachutes open uniformly. Experience has shown this assumption to be seldom true. A low location of the aircraft riser attachment point coupled with a large diameter drag parachute may cause the parachute force line to go below the center of gravity of the aircraft resulting in high loads on the forward landing gear. This can be alleviated by a longer riser or use of a cluster with a low resultant force line. Available test data indicate that the drag of a parachute with a short riser may be reduced by as much as 10 percent in the wake of the aircraft. A longer riser will reduce the drag loss but increase riser weight and deployment time. A riser length of 1.0 to 1.5 times the nominal parachute diameter has been used in the past; a value now considered too conservative. The riser length is determined by the riser force line to aircraft center of gravity relationship, by avoiding drag losses in the wake of the aircraft, and by protecting the drag parachute from the heat plume of the jet engine. The drag parachutes for the fighter aircraft as a rule have long risers; whereas the drag parachute for the B-52 bomber aircraft, with no center engine and a high location of the riser attachment point, has a very short riser. Several operational aircraft deceleration parachutes are listed in table II.
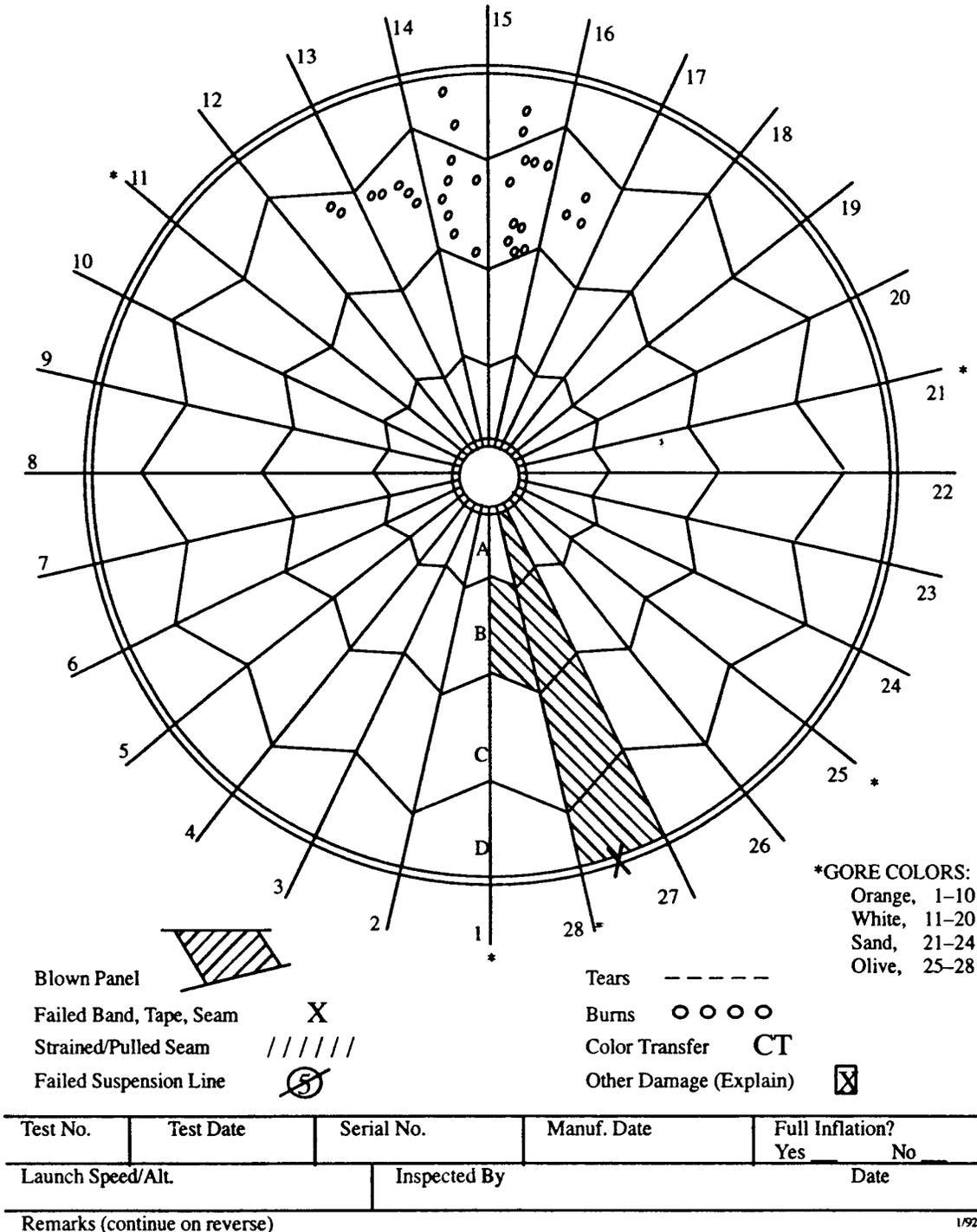
FIGURE 9. Sample 2, C-9 damage chart.
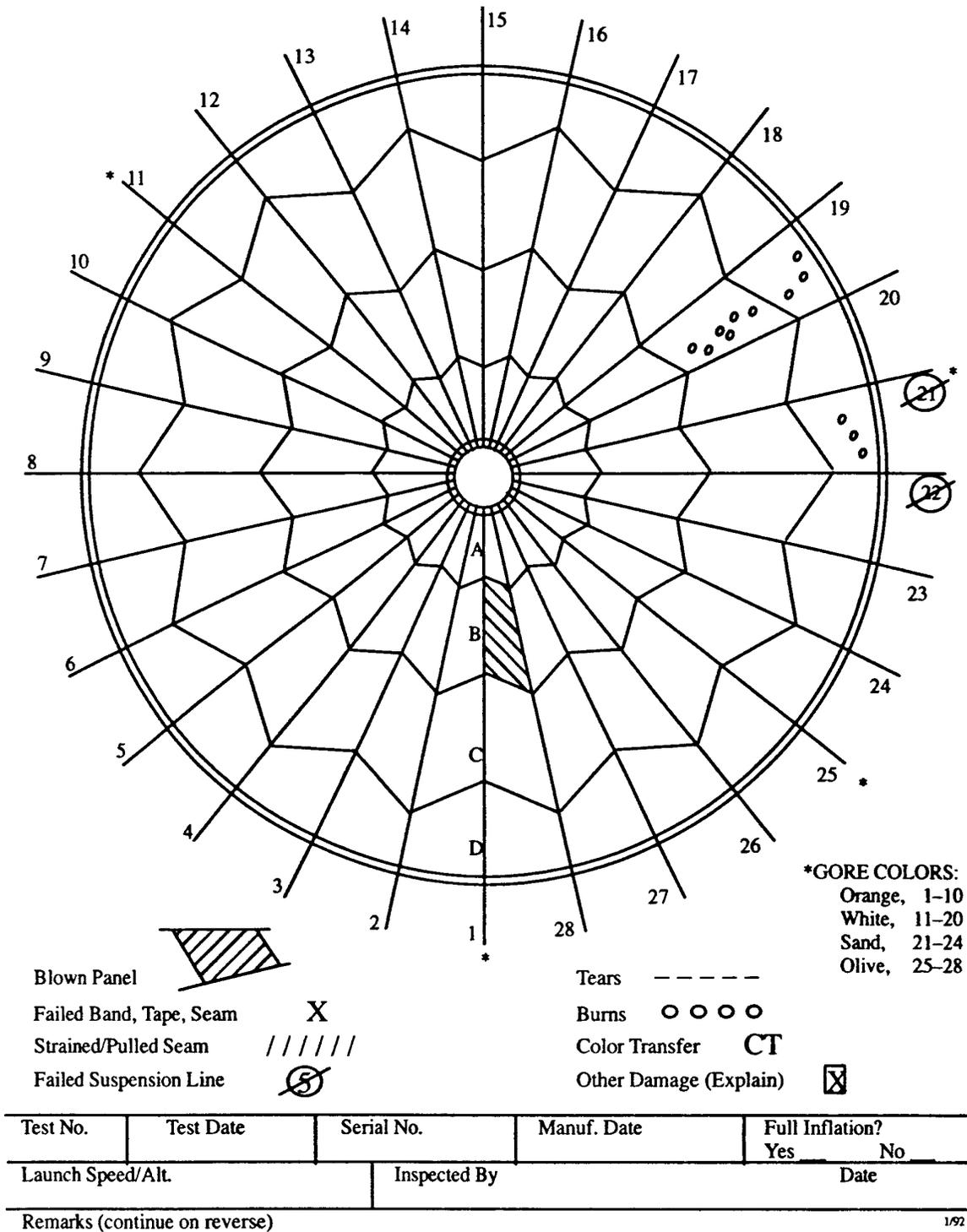
FIGURE 10. Sample 3, C-9 canopy damage chart.

Airdrop Parachute Considerations

Reliability of inflation. Airdrop canopies do not have to meet the high reliability requirements of premeditated or emergency escape personnel canopies. The airdrop canopies, for accurate dropping, must be dependable, must have predictable inflation characteristics, and must be consistent in performance.

Weapons Parachute Considerations

Reliability. Each retardation parachute must be designed to meet the reliability requirements. A retardation parachute that meets the reliability requirements will successfully retard the weapon when delivered at a dynamic pressure in excess of the dynamic pressure that is expected under the normal drop conditions. The dynamic pressure that has been used in tests in the past is 110 to 125 percent of the expected maximum dynamic pressure and is an alternative to the large numbers of tests required to establish finite reliability parameters. If the retardation parachute has functioned properly during the overtest, it should perform without failure during normal conditions.

Trajectory control. The trajectory control of the stabilized weapon is necessary to provide escape for the delivering aircraft, to allow precise control to the impact area, and to retard the weapon so that it can survive the impact. The retardation parachute in doing any or all of these things must produce a trajectory that can be accurately reproduced.

REQUIREMENT LESSONS LEARNED (3.12.2.1)

A firm basis that balances the obvious desire for maximum reliability against possible penalties in weight, bulk, cost, development time, et cetera is necessary to measure the reliability requirements for a parachute. The best approach to determine the minimum reliability required of the parachute is an analysis of its mission. This analysis can be accomplished by a study of the overall effects that the failure of the parachute will have on the mission. The entire number of the missions that are likely to be run (if applicable) and factors such as cost, time to develop the parachute, weight, and bulk must be considered and balanced against the level of reliability that can be achieved for specific levels of effort in each of these directions. A reliability level that is within the realm of practical attainment can be chosen in this way.

All reliability requirements for parachutes must be high and can be divided into two groups. The two groups are ultra reliability and very high reliability.

The ultra reliability group includes parachute applications such as personnel emergency escape, special weapons, space vehicle recovery, and similar critical applications in which costs are extremely high, assurance of mission success must be very high, or human life is involved. Reliability does not have any practical upper limit other than the perfection of 1.0. The very high reliability group includes the more usual applications of parachutes such as cargo delivery, missile and drone recovery, and weapon delivery. Some of the urgency of the factors that require virtual certainty of recovery in the cases of the very high reliability group may be tempered by overriding considerations of cost, development time, personnel training, or many other factors which are involved in the compromises required by expediency in military development. The reliability of the parachute can be adversely affected by malfunctions such as a partial inversion.

4.12.2 Operational Performance.

The operational performance of the parachute or decelerator specified in 3.12.2 shall be verified as specified below.

4.12.2.1 Reliability.

The reliability specified in 3.12.2.1 shall be verified by both analysis and the following reliability tests: _____.

VERIFICATION RATIONALE (4.12.2.1)

A parachute of new design must be tested under closely simulated operational and environmental conditions to verify its performance characteristics and to obtain a degree of confidence in its functional reliability. This testing applies in particular to parachutes that differ from standard design or that operate at high speed, at extremely low or high dynamic pressures, or at environmental conditions that are not normally encountered by parachutes and related components.

The analysis of the design of a parachute or of the actual decelerator during its development is necessary to quantify the reliability requirements. Since a firm basis for measuring the reliability of the decelerator is necessary, a statement that "high" reliability or "very high" reliability is required in not adequate to describe the performance desired for a specific design.

VERIFICATION GUIDANCE (4.12.2.1)

Laboratory and field tests should be performed to verify the adequacy of the parachute to meet the minimum requirements specified. These tests should be preceded by a prediction as required to establish that the design-to-reliability requirement is theoretically possible. When specified in the contractual documents, test plans, test levels, sample size, and other details of the reliability demonstration should be prepared by the contractor and approved by the contracting activity prior to use. Prior to the performance of any reliability tests, the reliability should be predicted in accordance with MIL-STD-756 and verified to the greatest extent possible. Often, due to funding and other program constraints, it may not be practical to demonstrate the full reliability. In this case, there may be two reliability requirements, a predicted reliability, and a demonstrated reliability. The demonstrated reliability must be verified by actual testing where as the predicted reliability may be verified by an analysis of the contractors prediction method.

The number and the type of tests that are required to demonstrate the required reliability should be specified in detail. One deployment of the packed parachute from the stowage compartment at one of the conditions specified should constitute one reliability test. If the deployment of the packed parachute from the stowage compartment complies with all of the requirements specified for the interface definition and for the operational envelope, the reliability test should be considered to be successful. Table VII provides the number of tests required to demonstrate a given reliability with a given confidence level.

VERIFICATION LESSONS LEARNED (4.12.2.1)

Although a great deal of progress has been made with analytical methods, parachute design and performance prediction remain an empirical science from which arises a steady demand for experimentally derived coefficients, factors, exponents, and base values. It should be an extra objective of test programs (where possible) to acquire and fully document test data (test items,

equipment, test conditions, procedures, and results) in a form that will add to the total data bank of recovery system knowledge. Reliable and accurate test data are being applied successfully to mathematical models that show reasonable agreement with experiment. Availability of reliable and accurate testing methods and testing equipment is essential to successful and meaningful development, but economic aspects associated with achieving close simulation of extreme environmental and operational conditions are often a major barrier. For that reason, parachute design parameters checked in wind tunnel tests or performance characteristics verified by other relatively inexpensive testing methods are useful in support of design for specific applications. Such tests may reduce the number of total systems tests required to demonstrate airworthiness or to qualify system performance. System tests should be performed with an actual or closely simulated prototype vehicle in free flight, since the dynamic and wake characteristics of the primary body tend to change the effective performance of a parachute from its characteristics in undisturbed flow.

3.12.2.2 Dynamic operation.

The decelerator shall deploy, inflate, and/or open at the specified reliability rate under the given conditions and within the given performance criteria as follows: _____.

REQUIREMENT RATIONALE (3.12.2.2)

The dynamic phase of decelerator operation including deployment and inflation (opening phase) is the most critical phase of operation in terms of design and construction of a decelerator. During the dynamic phase the decelerator is subjected to the maximum stresses, and likewise, it is transferring maximum loads and stresses to the primary body. Specific parameters must be considered to adequately define the performance required during the dynamic operation phase. The dynamic operation requirement can be broken down into the following lower level requirement considerations or parameters: the deployment envelope, opening loads, and recovery time/distance (or altitude loss).

Deployment envelope. The conditions at parachute initiation such as velocity, altitude, attitude, and flight path influence parachute structure, drag area, and drag area control considerations as well as design of the deployment system. Maximum dynamic pressure conditions can define the amount of drag area control required to comply with the specified requirements. Low dynamic pressure conditions can be critical in determining if the deployment system design is adequate to deploy the parachute. Attitude and flight path at deployment provide inputs concerning the flow pattern into which the parachute will be deployed and possible methods of deployment to be used.

Opening loads. The primary body can be damaged by excessive loads or improper load path application. The rate of onset can be excessive, thus applying loads in an unacceptable direction due to insufficient time for the primary body to attain proper orientation. Specific minimum load levels are required to perform certain functions during the operation of some parachutes; for example, specific load levels may be required to activate switches, break tackings or ties, arm pyrotechnic devices, or deploy sequential parachute subsystems. Since the drag area of flexible parachutes can vary between deployments, even at identical deployment conditions, resulting loads can vary; therefore, loads should be specified in a range giving the average value with maximum or minimum or plus or minus values.

TABLE VII. Number of successful tests vs. reliability and confidence level.

Reliability	Confidence Level (percent)											
	50	60	70	75	80	85	90	95	97.5	99	99.5	99.9
0.999999	693150	916290	1203970	1386290	1609440	1897120	2302590	2995730	3688889	4605170	5298320	6907760
0.99999	69315	91629	120397	138629	160944	189712	230259	299573	368889	460517	529832	690776
0.9999	6932	9163	12040	13863	16094	18971	23026	29957	36889	46052	52983	69078
0.999	693	916	1204	1386	1609	1897	2303	2996	3689	4605	5298	6908
0.998	347	458	602	694	805	949	1152	1498	1845	2303	2650	3454
0.997	231	305	401	462	537	632	768	999	1230	1535	1766	2303
0.996	173	229	301	346	401	473	575	747	920	1149	1322	1723
0.995	138	183	241	277	321	379	460	598	737	920	1058	1378
0.994	115	152	201	230	267	315	383	498	613	765	880	1148
0.993	99	130	174	198	229	270	328	427	526	657	755	985
0.992	86	114	150	173	200	236	287	373	460	574	660	860
0.991	77	101	134	153	178	210	255	332	408	510	586	764
0.99	69	92	120	138	160	188	229	298	367	459	527	688
0.98	34	45	60	69	80	94	114	149	183	228	263	342
0.97	23	30	40	45	53	62	76	99	121	151	174	227
0.96	17	23	30	34	39	46	57	74	91	113	130	170
0.95	14	18	24	27	31	37	45	58	72	90	103	135
0.94	11	15	20	22	26	31	37	49	60	75	86	112
0.93	10	13	17	19	22	26	32	42	51	64	74	96
0.92	9	11	15	17	19	23	28	36	45	55	64	83
0.91	8	10	13	15	17	20	25	32	39	49	57	74
0.9	7	9	12	13	15	18	22	29	35	44	51	66
0.8	3	4	6	6	7	9	11	14	17	21	24	31
0.7	2	3	4	4	5	6	7	9	11	13	15	20
0.6	2	2	3	3	4	4	5	6	8	9	11	14
0.5	1	1	2	2	3	3	4	5	6	7	8	10

Recovery time/distance. The term recovery must be quantified to facilitate determination of the successful operation of the parachute. Recovery is based upon some finite time or distance required for the parachute to perform its designed purpose. The designed purpose most generally involves the process of arresting a state of motion and bringing to rest a primary body. Both minimal damage and retrieval are implied in the recovery purpose and concept; hence, recovery often incorporates provisions to soften the impact of landing and to disconnect the parachute after landing.

REQUIREMENT GUIDANCE (3.12.2.2)

Deployment envelope. The initiation envelope in terms of velocity, altitude, attitude, and flight path or any other appropriate parameters that will fully describe the criterion for parachute recovery initiation should be specified. These parameters are normally listed as ranges rather than point values. The description of these parameters should include not only values but rates (if applicable).

Personnel Parachute Considerations

Performance. The parachute must meet all specified performance requirements when deployed throughout a given altitude and airspeed envelope. Typically these conditions must be met with a 150 to 300 pound suspended load and at a velocity at initiation of deployment up to 300 KEAS. These conditions may vary depending on the specific application of the parachute. The parachute should also be operable over a large temperature range, typically from about -54 to +74 °C(-65 to +165 °F.

Canopy deployment. The two basic methods of canopy deployment that are used with man-mounted premeditated and emergency escape personnel parachutes (type 2) are as follows:

    a. Free–type method

    b. Static line method.

Free-type method. The free-type method of canopy deployment has been used for many years for personnel parachutes. The free-type method of canopy deployment incorporates a pilot parachute which, when released into the air stream, will produce enough drag to deploy the main canopy.

Static line method. The static line method of canopy deployment is still used for air rescue service, Army paratroopers, and other premeditated jumping. The static line method of canopy deployment incorporates a direct connection between the aircraft and the main parachute to cause deployment.

Twisted line opening capability. Often it is desirable to include a twisted line opening requirement which can help provide a measure of how tolerant the design is to anomalies. With the suspension lines twisted together 360 degrees three times within 30 inches beginning immediately below the deployment back locking or emergence point, or beginning immediately below the canopy skirt for the parachute not incorporating a deployment bag, and with the parachute then packed in the approved manner, the parachute should deploy as designed, the canopy should fully inflate, and the suspension lines should completely untwist within 500 ±50 feet following initiation of deployment at a velocity not greater than 100 KEAS and with a 300 pound suspended load.

Vehicle Recovery Parachute Considerations

Deployment.   Deployment must be an orderly process. There should be no slack in the connecting line between the decelerator and the vehicle being recovered.   Some means of forceful ejection must be utilized for deployment of first-stage decelerators at speeds greater than sonic speed.   The minimum velocities required for pack ejection to insure deployment of the first-stage decelerator through the adverse wake of a vehicle are presented on figures 11 through 14 as functions of vehicle deceleration, vehicle base diameter, vehicle Mach number, and pack weight.

ALTITUDE		G	θ	CONSTANT VALUES
□	1,000	16	45°	$W_P = 50$ LB
▲	18,000	6	45°	$D_V = 5.0$ FT
○	35,000	5	45°	
△	63,000	4	10°	
●	130,000	1	5°	
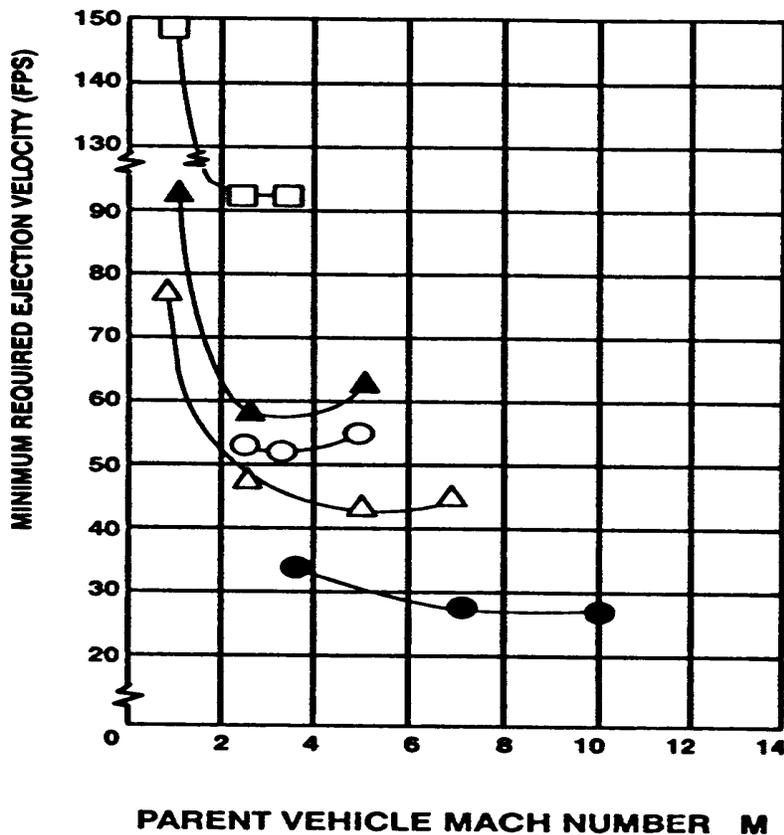
FIGURE 11. Ejection velocity vs. parent vehicle deceleration.

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	ALTITUDE	MACH NO.	θ	G
☐	1,000	2.5	45°	16
▲	18,000	2.5	45°	6
○	35,000	3.5	45°	5
△	63,000	5.0	10°	4

CONSTANT VALUES
W_P = 50 LB
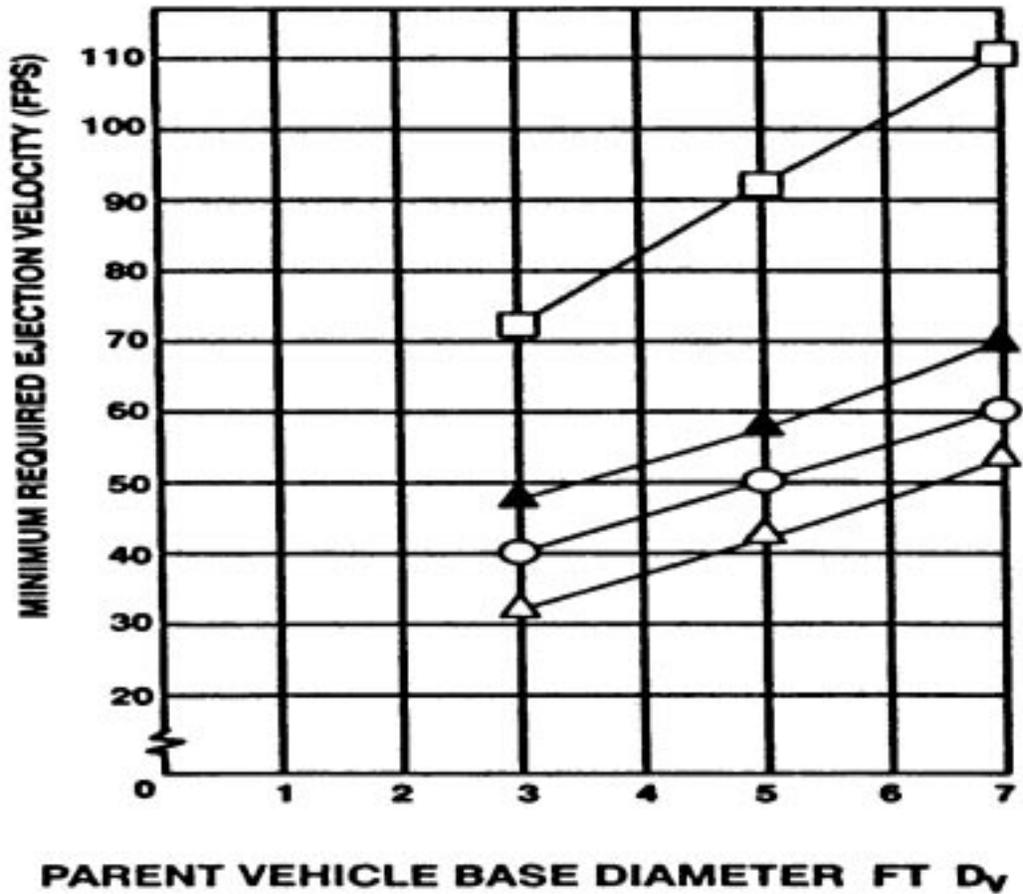
FIGURE 12. Ejection velocity vs. parent vehicle base diameter.

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ALTITUDE	G	θ
□ 1,000	16	45°
▲ 18,000	6	45°
○ 35,000	5	45°
△ 63,000	4	10°
● 130,000	1	5°

CONSTANT VALUES
$W_P = 50\ LB$
$D_V = 5.0\ FT$
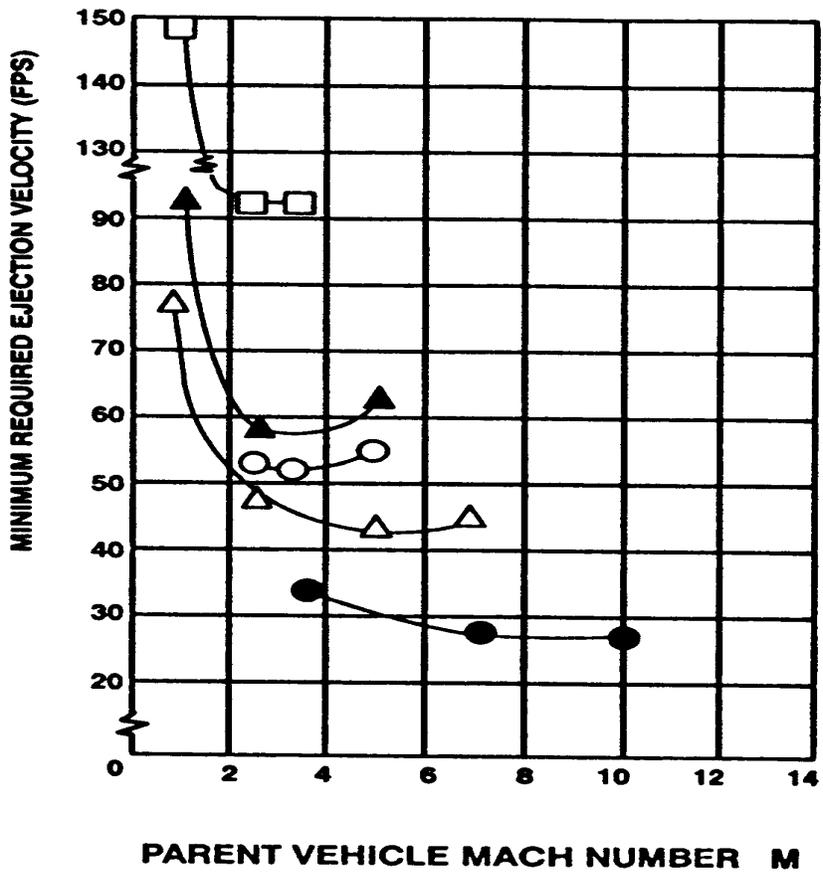
FIGURE 13. Pack ejection velocity vs. parent vehicle Mach number.

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	ALTITUDE	MACH NO.	G	θ
□	1,000	2.5	16	45°
▲	18,000	2.5	6	45°
○	35,000	3.5	5	45°
△	63,000	5.0	4	10°
●	130,000	7.0	1	5°

CONSTANT VALUES
$D_V = 5.0$ FT
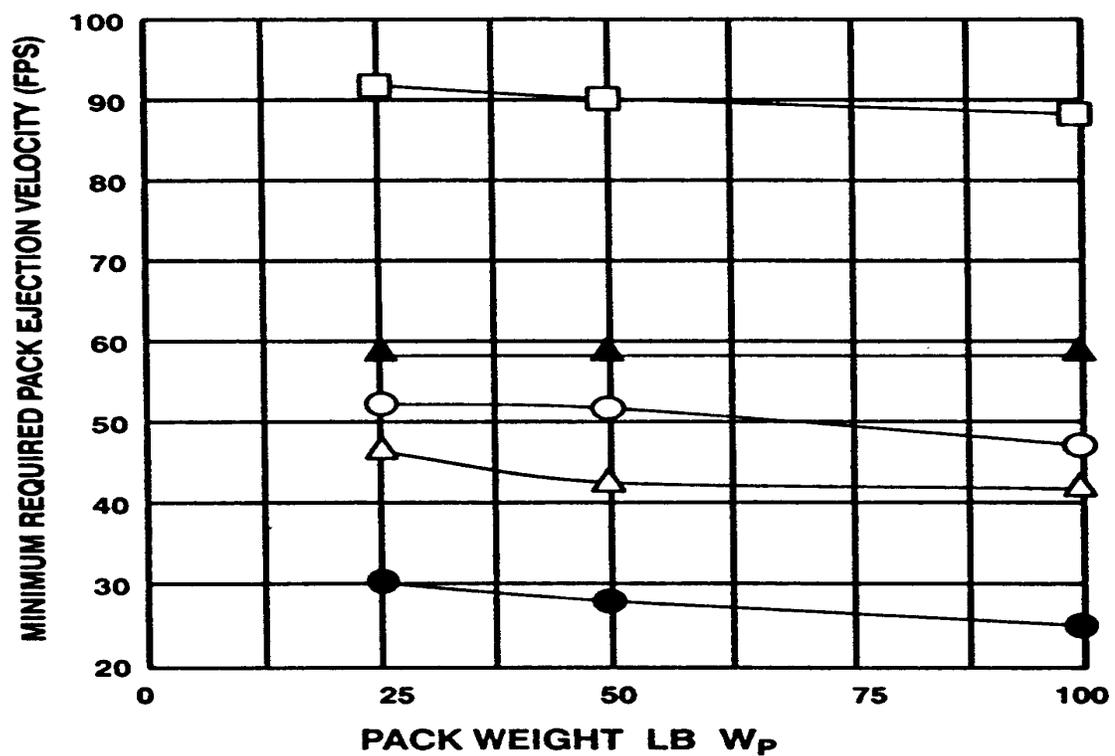
FIGURE 14. Pack ejection velocity vs. pack weight.

**Design of stabilization system**. The canopy must have very rapid opening characteristics and must be able to withstand high opening shock, because deployment can take place at supersonic airspeeds. The opening shock of the canopy must not exceed human tolerances on manned vehicles. The canopy deployment must be rapid and positive and must be accomplished in a region that is not blanketed by the aircraft seat or by the capsule. Normally, positive deployment requires forcible ejection of the parachute by means of a static line, ejector guns, blast bags, or other propellant systems. The bridle must be designed for quick stabilization of the vehicle or capsule without creating excessive snap or over-correction.

Controls. The functioning of the vehicle recovery system must be controlled by time, altitude, or pressure, or a combination of these, arranged to deploy the different aerodynamic decelerators in the order desired. The devices for controlling the functioning of the vehicle recovery system may perform their function either by direct mechanical linkage or through electrical circuits. If electrical circuits are utilized, two independent parallel electrical circuits that are complete with timers or other controls and batteries must be provided. The two electrical circuits must be arranged so that the failure of one electrical circuit will not prevent the proper functioning of the vehicle recovery system as a whole electrical or electronic control circuits, switches, and initiator circuits must be designed for ease of access and testing for verification of circuit/component continuity and integrity. Built in test capability for verification of system readiness is highly desirable.

Timers. Timers that are started with or prior to the initiation of recovery are usually used for sequencing. The timers may be mechanical, electronic, or propellant (powder–train) timers provided the timers are adaptable to the vehicle and will meet the environmental requirements of the recoverable body.

Switches. Altitude switches or ram–pressure switches, or both, may be used for sequencing the operation of the recovery system provided that a safety timer system is also incorporated. A suitable altitude control must be placed in series with the release system on the final recoverable stage so that this stage will not be actuated higher than 15,000 feet above mean sea level.

Propellant devices. Propellants may be used for powering releases, explosive bolts, and other devices provided two independent charges, either of which will accomplish the action, are used. The individual charges in these devices are ignited by either an electrical igniter or a percussion cap.

Atmospheric re-entry and hypersonic-speed deceleration. Aerospace vehicles in the outer fringes of the atmosphere introduce new phenomena and concepts that must be considered in the design philosophy of such vehicles. Considering that the returning aerospace vehicles will encounter the perceptible atmosphere almost as fast as meteors, the feasibility of safe atmospheric deceleration is by no means obvious. The terminal phase of an orbiting vehicle, when it encounters the perceptible atmosphere, can be the most critical phase of its flight . The major aspects of the atmospheric re-entry problem for the vehicle are aerodynamic heating, maneuverability, and deceleration. The lowest heating rates and the smallest decelerations are obtained from tangential (very shallow) re-entries, but the total heat absorbed is greater during a shallow re-entry than during a steep re-entry. The heating rate and the decelerations can be controlled by any method that will increase the re-entry time; for example, the re-entry angle can be held to a relatively low angle by using lift or by having surfaces whereby significant aerodynamic drag forces can be generated at high altitudes. The optimum ballistic coefficient (W/C_DA) for a constant-drag device is approximately ten. The peak decelerations with a W/C_DA of ten for re-entry angles that are less than or equal to -3 degrees are below 8 G ($G=D/W$) (see

figure 15. The following expression can be used to obtain the approximate heat–transfer rate for hypersonic flight.

$$q_s = \{17,600/(R_N)^{(1/2)}\}\{[(\rho/\rho_o)^{\wedge}(V/V_C)]^{(1/2)}\}$$

The following expression can be used to obtain the temperature in degrees Rankine.

$$T_s = (q_s/\varepsilon\ E)^{(1/4)}$$

Where:

q_s = Stagnation heating rate, BTU/sec sq ft

R_N = Nose radius

ρ/ρ_o = Local–to–sea–level density ratio

V/Vc = Local–to–circular orbital–velocity ratio

ε = Emissivity (dependent on material) between 0.7 and 0.9

E = Stefan–Boltzman constant (0.476×10^{-12} BTU/ft^2–sec–°R^4)

Low dynamic pressure. The immediate consideration in the case of decelerators for high altitude and high Mach number applications is dynamic pressure. If the dynamic pressure is too low, the parachute may not fully inflate, which could result in the twisting of the lines, thereby preventing the full inflation at a later time (even if the dynamic pressure increases). Assuming that the parachute inflates satisfactorily after deployment at these conditions, other problems can arise. One of the problems that could arise is canopy breathing; that is, the canopy will extend from over-inflation to complete collapse or any degree between these limits, while pulsing at a very rapid frequency. Canopy breathing can be reduced by choosing either a proper geometric porosity distribution or a suitable canopy shape or both.

Aerodynamic heating. Another problem is aerodynamic heating. If the expected temperature of the parachute will exceed the maximum allowable for nylon or Dacron, a material other than these materials may be required for the parachute. Time of exposure under these temperatures naturally will have a large effect.

Aerodynamic flutter. Another problem is aerodynamic flutter. Flutter is especially pronounced on ribbon parachutes where the individual ribbons experience high frequency oscillation. This flutter can cause canopy instability about its center of gravity as well as about the attachment point and can cause early material deterioration through the transformation of kinetic energy to heat. Flutter can be reduced by eliminating any excess material and arranging the ribbons to yield the least amount of flat–plate lift (considering the ribbon as a flat plate at an angle of attack to the flow).
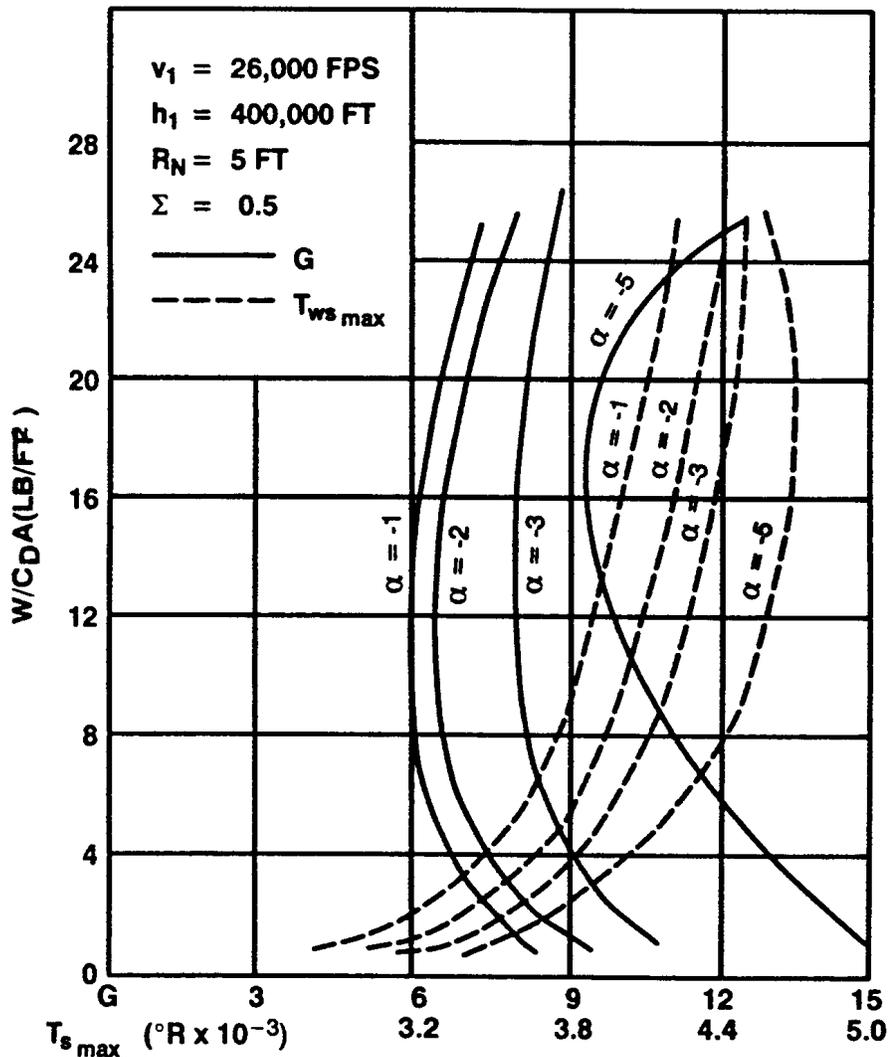
FIGURE 15. Ballistic coefficient versus maximum deceleration and stagnation point surface temperature.

Initiation. Deployment of a vehicle recovery parachute can be initiated by ground command or by flight conditions such as engine failure, loss of control signal, or loss of braking signal. The deployment of a vehicle recovery parachute in the case of an emergency escape can be initiated by an altitude velocity sensor that is armed by a timer at a predetermined interval after separation from the aircraft.

Recovery sequence. Recovery normally consists of, but is not limited to, two or more stages involving parachutes or other drag producing devices to accomplish the deceleration and subsequent descent to the ground. A plot of altitude and flight path speed for a typical five–stage vehicle recovery parachute is shown on figure 16. The number of stages and the design of the decelerator for each stage is determined by deployment speed and altitude and by the recovery weight.

Deployment speed and altitude. The requirements for the first–stage decelerator design are determined by the speed and the altitude at which it is to be deployed. The values that are selected must be the most critical (maximum and minimum) that can reasonably be expected during uncontrolled tests or operational flights of the vehicle.

Aircraft Deceleration Parachute Considerations

Application. Landing drag parachutes produce their maximum deceleration force either immediately after opening following aircraft touchdown or at a time when wheel brakes are not very effective. This fact is important for unfavorable landing conditions such as wet or icy runways and for emergencies such as aborted takeoffs, malfunctioning brakes, and overspeed landings without flaps. Figure 1 shows the relationship of aircraft landing roll versus parachute diameter and runway friction coefficient for a B-47 bomber aircraft. The 0.05 friction coefficient refers to runways that are icy or snow covered, or icy and snow covered. The 0.1 friction coefficient refers to wet runways. The 0.2 and 0.3 values refer to normal runways depending on surface conditions.
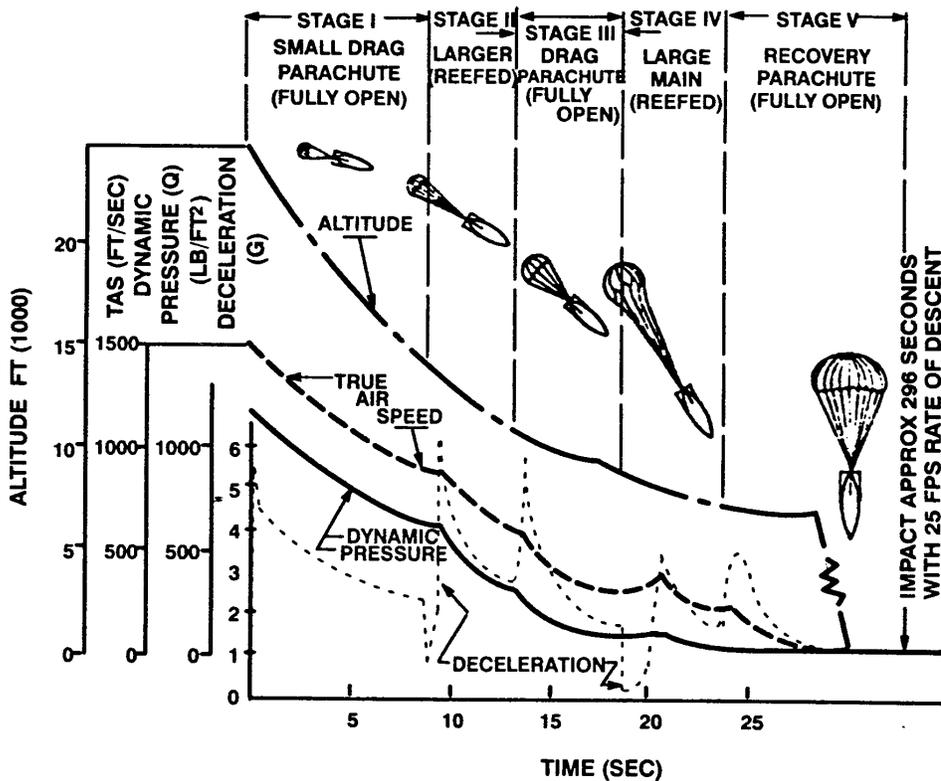
FIGURE 16. Possible operational sequence for multiple-stage parachute recovery system.

Pilot parachute and deployment bag. It is of utmost importance that the pilot parachute is ejected into good airflow, that it is able to open quickly, and that it is able to extract the deployment bag. If the pilot parachute is too small, the deployment bag may fall to the runway and be damaged. If the pilot chute is too large, it will delay or prevent the opening of the drag

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parachute. The deployment bag should closely contain the drag parachute and the riser. The packed shape of the deployment bag should conform to the aircraft compartment outline.

The deployment bag should be large enough to prevent movement in the aircraft compartment and loose enough to ensure easy extraction of the deployment bag. Normally, a two-compartment deployment bag that separates the parachute canopy from the suspension lines and the riser is used.

Aircraft Spin Stabilization Parachute Considerations

Deployment methods. Three different deployment methods for spin recovery parachutes, which have been used successfully, are illustrated on figure 17 and are as follows:

    a. Method A is mortar deployment of the main parachute.

    b. Method B is mortar deployment of a pilot parachute which in turn extracts the main parachute.

    c. Method C is drogue slug deployment of the pilot parachute.

Deployment method A. Deployment method A, which used the least number of components, ejects the main parachute. Deployment method A is considered the most positive provided the mortar ejection is powerful enough to strip off the deployment bag and the lines to canopy stretch of the parachute.

Deployment method B. Deployment method B is a better approach than deployment method C. If deployment method B is used, the pilot parachute must be ejected (mortar deployment) into good airflow with a connecting bridle that is approximately the same length as the combined main parachute riser and the suspension lines. Deployment method B requires more time for total parachute deployment.

Deployment method C. Deployment method C has been used with good results for several installations; however, it requires more components in the system and increases the possibility of interference. The pilot parachute in the spin recovery parachute for the T-38 aircraft was not spring ejected but deployed with a drogue slug. This method was changed to a mortar ejected pilot parachute on the F-5 aircraft and to a mortar deployed main parachute for the F-17 aircraft.

Risers. Risers are formed from multiple layers of webbing and stowed together with the parachute in the main deployment bag. The riser, during deployment, must be protected against contact with the parts of the aircraft or the jet engine. This protection can be provided by locating the riser attachment point at the very rear of the fuselage and by shielding the riser. Steel cables have been used effectively with spinning nose cones and the Apollo command modules but are difficult to stow and to deploy without kinking.

Deployment bag. The data contained herein that applies to the landing drag parachutes will also apply to the spin recovery parachutes. The riser-first deployment concept should be used. The spin recovery parachutes have been stowed also in sleeves. Stowage of the spin recovery parachute in a sleeve in the case of the F-5 and the T-38 aircraft was necessitated by the very flat compartment located above and between the engines.

Pilot parachute. Vane pilot parachutes are excellent to ensure orientation of the pilot parachute in the direction of the airflow. The drag area of the pilot parachutes should be about 3 percent of the drag area of the main parachute.

METHOD A ⎫
METHOD B ⎬ DEPLOYMENT CONCEPTS
METHOD C ⎭

1	Deployment Bag	5	Pilot Parachute Bag
2	Mortar	6	Pilot Parachute Mortar
3	Pilot Parachute Bridle	7	Pilot Parachute Slug
4	Pilot Parachute	8	Drogue Gun
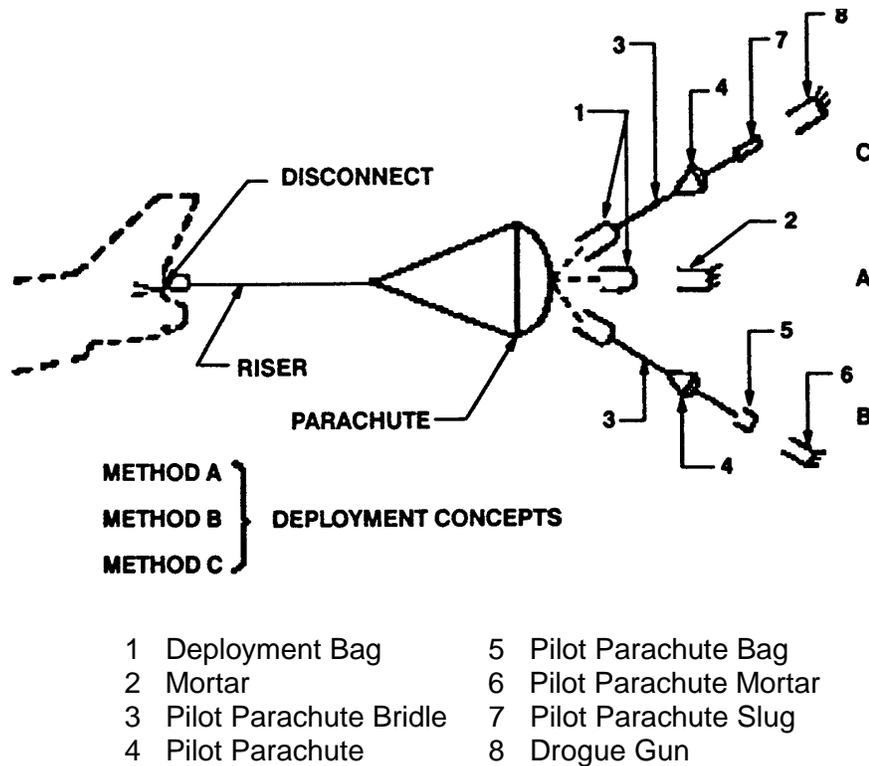
FIGURE 17. Spin recovery parachute and deployment sequence.

Airdrop Parachute Considerations

Techniques to eject or extract loads. The methods used to eject and extract loads are as follows:

    a. Gravity exit

    b. Parachute extraction

    c. Rack release

    d. Manual ejection

    e. Ground–based arrester.

Gravity exit. If the gravity exit method is used, the cargo or cargo container rolls from the aircraft utilizing the dual rail cargo handling system that is incorporated into the cargo compartment. The dual rail cargo handling system is sloped by a change of attitude of the aircraft, nose up, to permit the cargo to move by gravity when the restraint is removed.

Parachute extraction. If the parachute extraction method is used, the extraction parachutes are deployed to pull the load from the aircraft. The parachute extraction method is used primarily for heavy loads on platforms.

Rack release. The rack release method permits the release of relatively small containers from the racks which are mounted internally in the cargo compartment or the bomb bay or which are mounted externally under the wings or fuselage.

Manual ejection. The manual ejection method is applicable to all cabin or cargo type aircraft and consists of manually pushing the cargo out the doorway of the compartment.

Ground-based arrester. If the ground-based arrester method is used, the load is extracted by a ground-based arrester engaging a hook affixed to the load with a ground-based energy absorber.

Aircraft restraining systems. The design of the aircraft restraining systems must be based on the aircraft design load factors. If the skid-type platforms are used, the primary restraints are applied and removed manually by releasing the tiedowns shortly before the drop. The platforms that are used with the dual rail cargo handling systems are automatically released from the restraint by action of the extraction parachute.

Retardation parachutes. The major operational retardation devices that are used in airdrops at present are parachutes. The retardation parachutes are used singly or in clusters, depending on the weight of the load and the desired rate of descent.

Deployment. Any method of deploying retardation parachutes that are used for airdrop must be as simple as possible. Complicated methods are not desirable, since they increase cost, maintenance, and rigging time. Normally, small loads for manual release are thrown or dropped from the aircraft, using a simple static line to open the parachute. The static line can be attached directly either to the canopy or to a deployment bag. The extraction parachute for a heavy drop can also be used as a pilot parachute to deploy the main parachute or the cluster of parachutes. This function can be done by diverting the extraction line from the load to the main parachute by means of a static line and knives or a breakcord. A mechanical force transfer device that greatly reduces the number of rigging intricacies common to the static line system has been developed. A simple and reliable platform mounted force transfer system is more desirable in heavy airdrop. If the platform mounted force transfer system is used, deployment bags are used to deploy the parachute.

Weapons Parachute Considerations

Deployment methods. The three common methods of parachute deployment are static line, automatic, and forced ejection.

Static line deployment. A static line with the free end of the line connected to the aircraft will initiate deployment at the same time and place relative to the delivering aircraft. When the weapon has fallen the distance equal to the length of the static line, the pilot parachute is deployed by the static line and deployment of all remaining parachutes follows in the required order. The use of a static line is limited because it fixes the length of free fall before any drag–producing surface deploys and creates the problem of a loose, flailing line on the carrier aircraft.

Automatic deployment. Automatic deployment is required when the weapon is carried externally on the aircraft or when free fall is desired prior to deployment of the parachutes. The sequence of an automatic deployment is as follows:

a. After the weapon is released from the aircraft, the weapon falls free for some specific length of time; then the tail of the weapon or the cover of the parachute compartment is removed, usually by explosives.

b. The pilot parachute that is connected to the tail cover is deployed as the cover moves away.

c. Once the pilot parachute reaches the airstream, the deployment of the remaining components is identical to the static line deployment.

Forced ejection. Forced ejection is a method of deploying a canopy where other methods may not work or may be too erratic. Forced ejection is usually accomplished by packing the parachute around a tube filled with a propellant. As the propellant burns, the tube pulls or pushes the parachute out.

Opening loads. All loading restrictions, including load levels, duration, rate of onset, and load paths, must be specified. Load levels should be specified as an average or expected value with the acceptable range specified in terms of standard deviation. All factors will not apply in all cases, but should be considered.

Personnel Parachute Considerations

Canopy overload. With a 300 pound suspended load and upon inflation of the main canopy, the parachute should be capable of withstanding a total riser force of 6000 lbf minimum and a single riser force of 4500 lbf minimum. The parachute should sustain no damage nor exhibit performance degradation worse than for a critical failure as defined in section 5.

Tolerable snatch and opening forces at anticipated maximum speed and altitude of deployment. For emergency escape parachutes, maximum acceleration measured through the parachute risers should be as follows:

a. No more than 15 G (vector sum) if the direction of force applied to the body is random and unpredictable as in a typical type 2 bailout system.

b. No more than 25 G (vector sum) if the system is controlled so the force is applied while the body is in an optimum position (inertial resultant in $+z$ to $-x$ direction or "eyeballs out" to "eyeballs down.").

For premeditated personnel parachutes, maximum acceleration measured through the parachute risers should be no more than 15 G (vector sum).

For all cases, G onset rate over the entire T rise portion of the force/time curve should be limited to 100 G/sec.

Vehicle Recovery Parachute Considerations

Maximum deceleration. Knowledge of the magnitude of the G imposed on a vehicle or its contents as well as knowledge of the rate of application of the G imposed on vehicle or its contents in case of emergency escape is required to determine the number of stages required, the decelerator sizes, and the timing of the recovery sequence. The power plant, the instruments, the control system, and other accessories as well as the limit of the vehicle structure must be considered in determining the allowable G. If the parachute recovered vehicle will contain a human occupant, the human acceleration exposure limits must be considered in determining the allowable G.

Human acceleration exposure limits in an escape capsule. The human acceleration exposure limits defined herein are measured at or near a seat bucket or are analytically predicted in the design phase at or near a seat bucket. The acceleration vector directions are defined with respect to an axis determined by the intersection of the plane of the crew seat back and the median sagittal plane of the crew member (the y-z plane of symmetry of the man–

seat). The x-axis, the y-axis, and the z-axis or the spinal axis are shown on figure 18. The sign of the vector is defined with respect to the inertial response of the crew member; for example, plus G_z denotes the inertial response in spinal axis in footward (eyeballs–down) direction. The application and the computation methodology of the human acceleration exposure limits herein are based on, and restricted to, assumptions that concern the escape environment, the risk of injury, the condition of the crew member, and the characteristics of the personal equipment.
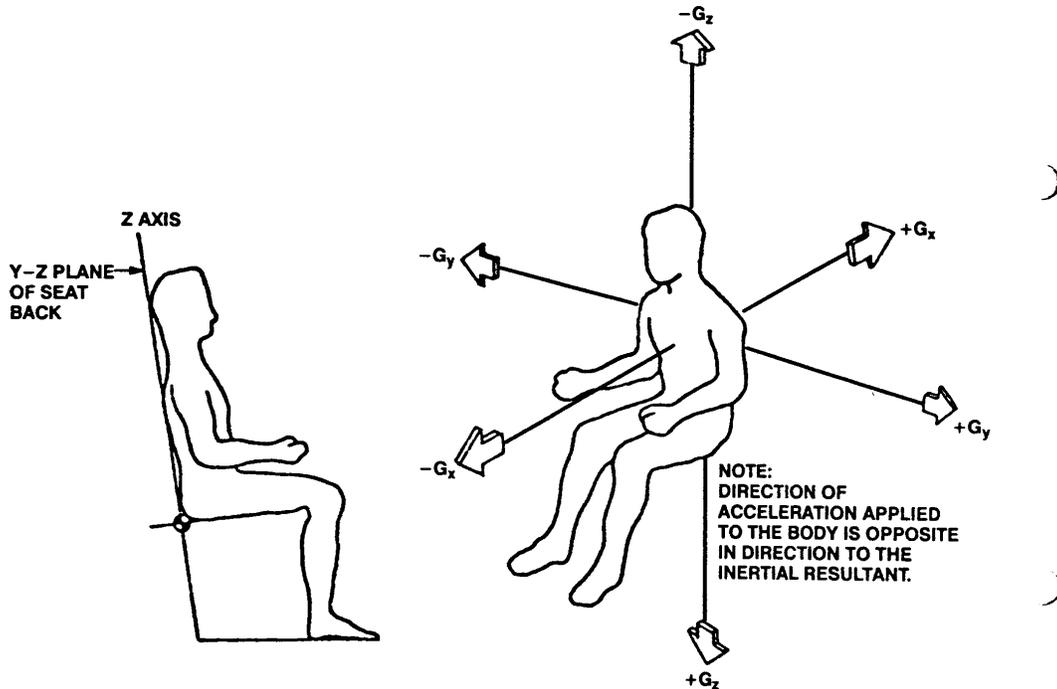

FIGURE 18. Inertial resultants for body acceleration.

Environment. The evaluation of multiple, successive acceleration pulses is based on the assumption that no detectable skeletal or visceral injury has occurred as a result of the acceleration environment.

Risk of injury. The limits specified for plus or minus G_x, plus or minus G_y, and plus or minus G_z are not nominal limits for no injury but are the maximum limits beyond which disabling injury can be expected. The plus G_z limits are defined for a probability of spinal injury (compression fracture of the vertebral bodies) of 5 percent or less.

Crew member and equipment. The restraint and body support system is assumed to be designed to maintain the crew member (occupant) in a normal seated posture during exposure to the acceleration environment and to prevent amplification of the acceleration transmitted to the crew member. The use of these limits is also based on the assumption that the crew member must wear a helmet with padding for acceleration protection.

Dynamic response index.   The dynamic response index (DRI) is representative of the maximum dynamic compression of the vertebral column.   The DRI in physical terms is calculated by describing the human body in terms of an analogous, lumped parameter, mechanical model consisting of a mass, a spring, and a damper.   The application of the model facilitates assessment of the response of the human body to accelerations having irregular waveforms.

The following equations can be used to calculate the response of the model or the DRI.

$$d^2\delta/dt^2 + 2\zeta\omega_n(d\delta/dt) + \omega_n^2\delta = d^2Z/dt^2$$

$$DRI = (\omega^2\delta_{max})/g$$

Where:

δ 　　　　=　 compression of spring in feet

ζ 　　　　=　 0.224 (damping ratio of model)

ω_n 　　　=　 52.9 radians/sec (undamped natural frequency of the model)

d^2Z/dt^2 　=　 z axis input acceleration to the human body in ft/sec^2

t 　　　　=　 time in seconds

g 　　　　=　 32.2 ft/sec^2 (acceleration due to gravity)

The model coefficients (ζ and ω_n) are for the positive spinal case (eyeballs down) for the mean age of the Air Force flying population (at the time this method was developed), 27.9 years, substituting given numerical values:

$d^2\delta/dt^2 + 23.7(d\delta/dt) + 2798(\delta) = d^2Z/dt^2$

$DRI = 86.9(\delta)$ maximum

Large structural loading.   Another problem is large structural loading.   The requirement that parachutes operating at high Mach numbers and high dynamic pressures, such as sea level, must be capable of withstanding large structural loadings can contribute to, aggravate, or make more critical the other design requirements.   Large structural loading will necessitate judicious design and fabrication of the canopy including the selection of the type of fabric, the location of the heaviest construction ("beefing up" the expected high load and high temperature areas), and the choice of canopy component junctions.

Aircraft Deceleration Parachute Considerations

Parachute maximum opening force.   The following equation can be used to determine the parachute maximum opening force.   An opening load factor (C_X value) that is close to unity is desirable for limiting the opening load to the steady state drag load with no force overshoot due to inflation of the parachute.

F_o = C_{Do} S_o q C_X

C_{Do} S_o = Drag area of full open parachute

q = Dynamic pressure of maximum deployment velocity

C_X = Opening load factor of the particular parachute type used

Landing approach parachutes. The B-47 bomber aircraft used a 16-feet-diameter ringslot parachute for descent from high altitude and for landing approach. The aerodynamically clean B-47 bomber aircraft surpassed the allowable speed limits during a steep descent and had difficulties in making a touchdown at the beginning of the runway in a ground-controlled approach. This problem was overcome by using the approach parachute which increased the aircraft drag and steepened the glide angle. The parachute could be deployed at an altitude of 40,000 feet and was often used for descent, approach, and during touchdown and roll out in place of the landing drag parachute. The use of the approach parachute is more of a historic interest, because subsequent aircraft used more effective flaps and spoilers.

Airdrop Parachute Considerations

Opening shock. Opening shock for most airdrop parachutes is not of primary concern except that it should be low enough so that it will be within the design limitations of the parachute and will not overstress the equipment that is to be dropped.

Extraction parachutes. Parachutes are predominantly used to extract heavy airdrop loads from the aircraft. Extraction parachutes are effective, relatively simple, and dependable and use the relative energy of the airstream to accomplish movement of the load. The initial action of the extraction parachute is to remove or release the restraints which secure the load in the cargo compartment of the aircraft. The force is then applied to the load to withdraw it from the cargo compartment. Once the load has reached the end of the aircraft cargo compartment (load out or nearly out), the extraction line is released from the load and diverted to deploy the main retardation parachutes. This diversion is usually accomplished by cut knives attached to static lines or by a mechanical force transfer device. Extraction canopies must be of simple and dependable design, perform reliably in the wake of the aircraft, and have high stability. The size of the extraction canopy is determined by the force required to remove the load from the aircraft compartment in the desired time. The force required for cargo extraction generally ranges from 50 to 150 percent of the load being extracted. The higher figure is recommended for important stability problems of the aircraft or for extreme low level delivery techniques. If the extraction force is too low, severe tipoff of the load during its emergence from the aircraft may follow, causing it to overturn, rotate, and tumble. Other important considerations in choosing the extraction force include the airframe capability, the type of restraint and release subsystem used, and the effect of the extraction load range on drop accuracy. The peak force of the extraction parachute will vary due to the effects of the aircraft wake. The effect of the aircraft wake is the final consideration in the selection of an extraction parachute. To minimize the effects of the aircraft wake once the extraction parachute has been released from the cargo compartment, the extraction line and the risers must be of sufficient length to ensure proper inflation.

Opening shock and reefing. Parachute opening shock in airdrop is second in intensity to landing shock. Reefing can be used to lessen the opening shock. Reefing is not generally used on cargo canopies that are used individually, because cargo canopies are designed to withstand opening shock forces at normal deployment velocities. Reefing is used at present mostly with parachute clusters to ensure that all canopies reach the same stage of inflation at the same time of disreefing, which results in even deployment and minimizes canopy damage.

Prolonged reefing can be employed to achieve better accuracy in a high altitude drop. If prolonged reefing is employed, stage reefing may be desirable. An increase in reefing time automatically raises the minimum altitude at which the drop can be accomplished successfully. Reefing design and fabrication must be simple to permit local installation.

Recovery time/distance. Time, altitude loss, flight path distance, or any other quantitative measure for the accomplishment of primary body recovery by the parachute should be specified and may not be a single value but is probably a series of values over the total range of initiation conditions.

Personnel Parachute Considerations

Rapid opening in emergency parachutes is essential. Recommended time from initiation of deployment to point of last full open at true airspeed at initiation of 100 ± 10 ft/sec and density altitude of 8000 ± 500 ft should be 2 seconds maximum.

REQUIREMENT LESSONS LEARNED (3.12.2.2)

Deployment envelope. Deployment systems should provide for the controlled movement of the deploying canopy to prevent side loads on the skirt area before completion of suspension line extension and to allow orderly deployment of the canopy along the path of the primary body travel. A crosswind deployment, which is contrary to the controlled deployment, should be avoided. If the crosswind deployment is the only reasonable choice, this fact should be set forth in the beginning so that the designer will know exactly what he must face.

Large speed ranges for deployment can present serious problems. A systematic arrangement of break ties is very helpful in assuring an orderly deployment at 300 knots and above but may be detrimental in the low speed range. Sizing (in regard to breaking strength) of the break ties is very critical to providing an orderly deployment at low, medium, and high speeds.

Added functions are often required of the parachute and may complicate the deployment system; for example: A parachute was to be the supporting body for an emitting radar wire pattern. The wires presented deployment problems by changing the flexibility characteristics of the canopy and by restricting the loading in the canopy to levels that could be tolerated by the wire pattern.

The flow field around the primary body has a bearing on the deployment system design such as was encountered with the drogue parachute of the B-1 aircraft. The drogue parachute was affected by the flow field of the crew escape module during high speed deployment, resulting in the pack tumbling and hesitating in clearing the module despite an approximately 80 feet per second velocity mortar. If the module concept had not been discarded, the designers probably would have switched from the mortar to a tractor rocket deployment. The tractor rocket deployment would have provided a positive pulling force on the drogue parachute throughout the adverse flow field behind the module and would have been beneficial in crosswind deployment systems.

The deployment system should have provisions for reducing the snatch force. The snatch force is directly proportional to the effective drag area of the pilot parachute and the main canopy; for example, a partially open canopy with a drag area of 20 square feet will impose a considerably higher snatch force on a suspended load than a deployed but uninflated canopy with a drag area of 2 square feet. Good high speed deployment must present the smallest system drag area that is consistent with orderly deployment and inflation. Low bulk and weight of the parachute are also desirable for the reduction of the snatch force.

It is important that all extremes of the initiation envelope, including their tolerances, be defined to assure that limit or overtest conditions can be met for total system reliability evaluation. Initiation conditions usually include dynamic pressure or airspeed. Dynamic pressure, impact pressure (compressible flow), knots indicated airspeed, knots calibrated airspeed, knots equivalent airspeed, and knots true airspeed can be used; however, the different types of airspeed can lead to different results. If airspeed is used, the altitude or the atmospheric conditions as well as the airspeed value must be specified. A parachute that will perform acceptably at one airspeed and altitude will not necessarily perform acceptably at the same airspeed at another altitude. Parachutes, unlike aircraft, do not behave the same at different altitudes with the same dynamic pressure or knots equivalent airspeed.

Opening loads. All deployments of trailing parachutes create a force known as "snatch force" which arises from the differential deceleration rates of the primary body and the deploying parachute. Snatch forces can be reduced by controlled deployment, by reduction of the uninflated canopy drag area, and by reduction in the pilot parachute drag area. If the deployment system must be used over a large range of speed, the controlled deployment is a very difficult process. The reduction of the uninflated canopy drag area and the reduction in the pilot parachute drag area have a greater effect on proper deployment and opening than the controlled deployment and cannot be reduced beyond a certain limit without adverse results on deployment and reliability.

Opening shock, which is the maximum force that is developed during inflation of the canopy, can be reduced by special reefing, venting, collapsing, or squidding canopy designs.

Every aspect of the parachute operation should be carefully analyzed to assure that unexpected loads will not be applied to the primary body. An example of anticipated repositioning cable loads is the crew escape module of the B-1 aircraft. The transfer loads that the parachute gave to the repositioning cables exceeded their design strength, resulting in the loss of a very expensive prototype module.

Recovery time/distance. Because a recovery parachute cannot always meet all of the user's requirements, the designer should be given latitude to make trade-offs to achieve the best possible parachute for the particular application.

4.12.2.2 Dynamic operation.

The dynamic operation requirements specified in 3.12.2.2 shall be verified as follows: _____.

VERIFICATION RATIONALE (4.12.2.2)

Critical parameters of the dynamic operation phase of the decelerator must be measured to determine compliance with the required performance. These parameters should be measured throughout the required deployment envelope, and they should be measured during operation of the parachute after exposure to critical environmental conditions as required.

Deployment envelope. Unforeseen problems can arise due to the dynamic condition at initiation and the difficulty in totally predicting deployment behavior. Initiation of the parachute at the specified conditions is necessary to demonstrate its capability and reliability.

Opening loads. Parachute loads must be measured to assure that the parachute will not allow load levels that could be detrimental to the primary body.

Recovery time/distance. This analysis is necessary to determine compliance with the recovery characteristics as specified. Parameters such as timing, displacement, velocity, and

stability characteristics can be determined precisely due to the capabilities of photographic coverage, thus providing the information that is necessary for this analysis and determination.

VERIFICATION GUIDANCE (4.12.2.2)

Deployment envelope. Tests that will investigate deployment throughout the initiation envelope, including deployment at the envelope extremes as well as at intermediate points, should be specified. The selection of the intermediate points may be based on the crossover points dividing a high speed mode and a low speed mode or some other defined critical point.

Personnel Parachute Considerations

Container/pack manual opening system. A container/pack manual opening system should be verified during field tests by manually activating the system using one hand for one test and then the other for a subsequent test.

Twisted line opening capability. Twisted line opening capability requirements should be verified by field tests. The following recommended conditions should apply:

a. A minimum of five aircraft drop tests should be conducted. Initiation of deployment should be at 500 ±50 feet AGL, a velocity no greater than 100 KEAS, and with a 300 +0, −5 pound suspended load.

b. The suspension lines should be twisted together 360 degrees three times within 30 inches beginning immediately below the deployment bag locking or emergence point. For the parachute assembly not incorporating a deployment bag, the twists should begin immediately below the canopy skirt.

c. The parachute should be rigged and packed in the approved manner.

NOTE: If difficulty is encountered in stowage of the twisted portion because of the increased girth, the line retaining member may be modified to obtain the desired retention characteristics, but should be returned to its normal configuration prior to subsequent tests.

Aircraft Spin Stabilization Parachute Considerations

Aircraft flight test program. Most military and some civilian aircraft must be subjected to spin tests as part of the flight test program. An aircraft in a spin descends vertically with the wing fully stalled at an angle of attack ranging from 30 to 75 degrees while rotating around a vertical axis at a high rate of turn. The aircraft may have additional motions in pitch and roll and may change from right side up to an inverted position and return. Film records have shown an aircraft making six turns in 7 seconds and changing to inverted spin and back before the spin recovery parachute was deployed ending this wild gyration. These violent aircraft motions require positive parachute deployment away from the wake of the spinning aircraft and into good airflow. A short flight test program of the spin recovery parachute is mandatory.

Deep stall tests. Two large commercial aircraft had parachutes installed for emergency recovery during deep stall tests. The purpose of the parachutes was to support stall recovery by decreasing the angle of attack in case of emergency.

Opening loads. Load levels, duration, onset rates, and point of application of loads (including direction) that must not be exceeded during parachute operation should be measured during tests for verification.

Riser force measurement. When required, the force in each parachute riser should be measured as a function of time by an appropriate force transducer. These forces should be algebraically summed to produce total riser force as a function of time. Peak riser forces should be determined from the total riser force data.

Acceleration. Acceleration during deployment (opening shock) should be measured at the anticipated worst case density altitude and velocity. Acceleration should be determined by dividing the total riser force data by the suspended weight.

Riser force data. The methods of reducing the parachute performance data, which are described herein, can be used to obtain the riser force data that is required to accomplish the following:

   a. Determine the impulse, the force rise, the dwell, and the force decay.

   b. Correlate the telemetry data with the cinetheodolite tabular data.

   c. Construct the characteristic force versus time profiles.

Basic concept of riser forces. The riser forces during the opening of the canopy are a function of the velocity, the free stream air density, the dynamic pressure, the effective canopy porosity, and the differential drag areas.

Differential drag areas. The pilot parachute, upon deployment from the parachute pack, will create a drag area that is proportionally larger than the drag area of the suspended load and the deploying main canopy. Upon the parachute moving aft a distance that is equal to the length of the suspension lines and the drag surface, the differential velocity between the suspended load and the pilot parachute will be at its maximum. The suspension lines and the drag surface will be stretched (elastic elongation) to their maximum length. The pilot parachute will accelerate to the common speed of the total system. This acceleration will cause an inertial force (snatch force) to be transmitted to the suspended load.

Opening force rise. If the speed of the total system is less than the critical opening speed, the canopy drag area will begin to increase. If the speed of the total system is more than the critical opening speed, the opening of the canopy will be delayed until the speed of the total system is less than the critical opening speed. As the canopy drag area increases, an increasing mass of air will be captured by the canopy and will be forced to accelerate to a speed that is common to the total system. Since the total system is a finite mass, a simultaneous acceleration (opening force rise) will occur.

Over-inflation of canopy. As the total system is accelerated, the canopy drag area will increase. The canopy may continue to accelerate through the maximum stable design canopy drag area after the maximum force has been reached. This continuation of the acceleration will result in the hyper-extension or the over-inflation of the skirt of the canopy.

Symbols. The following symbols can be used to simplify the reduction of the parachute performance data:

   a. T_{IS} is the time of the force onset at snatch and is the first occurrence of the positive slope of force versus time profile.

   b. T_{LS} is the time of line stretch and is the occurrence of peak snatch force.

   c. T_{IC} is the time of the force onset during the canopy opening and occurs subsequent to T_{LS}.

   d. T_C is the time the maximum individual riser (right or left) force occurs.

e. T_{CMAX} is the time of the total maximum opening force (summation of the left and the right risers).

f. T_F is the time of the return of the steady state force value (the weight of the suspended load).

g. F_S is the maximum snatch force (per riser).

h. F_C is the maximum canopy opening force (per riser).

i. F_{SR} is the snatch recovery force and is the lowest force between F_S and F_C.

j. F_L is the force on the left riser at T_{CMAX}.

k. F_R is the force on the right riser at T_{CMAX}.

l. F_{CMAX} is the total maximum opening force ($F_L + F_R$).

Equations. The following equations for obtaining riser force data are referenced below under "Methods to reduce parachute performance data". NOTE: The quantities that are derived by using equations 1 through 5 below are vector quantities. It should be recognized that, in addition to the equality of $\Sigma F_n dT$ and impulse (see equations 1 through 5), the direction of the resultant force coincides with the direction of the change in velocity (acceleration).

Equation 1

$$\Sigma\, F_n = MA_n = M(DV_n/dT)$$

Where:

ΣF_n = Sum of all N components of force

A_n = Sum of all N components of acceleration

V_n = Sum of all N components of velocity

Equation 2

$$\Sigma F_n = (d/dT)\,(MV_n)$$

Equation 3

$$\Sigma F_n dT = d(MV_n)$$

Equation 4

$$\oint_{T_o}^{T_f} \Sigma\, F_n dT + M\oint_{V_n}^{V_f} dV_n$$

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Equation 5

$$\sum F_n T_f = MV_{fn} - MV_{on}$$

Equation 6

$$I_{TM} = (a_I SF)_L + (a_I SF)_R$$

Where:

I_{TM} = Total linear impulse from telemetry data

a_I = Area under respective force versus time profile

SF = Scale factor

Subscript L = Left channel force data

Subscript R = Right channel force data

Equation 7

$$I_T = M(V_{IS} - V_F)$$

Equation 8

$$\text{Error (percent)} = \{(I_{TM} - I_T)/I_{TM}\} (100)$$

Equation 9

$$R_{SN} = F_S/(T_{LS} - T_{IS})$$

Methods to reduce parachute performance data. The following methods can be used to reduce parachute performance data to obtain riser force data. (NOTE: The equations that are referenced in these methods are shown above).

a. The particle of a mass (M) in any N direction can be derived from equation 1.

b. Assuming a constant mass (M), equation 1 can be stated in two forms in accordance with equations 2 and 3.

(1) Equation 2 states that the resultant force in any N direction on a particle of mass (M) equals the time rate of the change in its linear momentum (its mass and its linear velocity) in that direction.

(2) Equation 3 states that the linear impulse of $\sum F_n$ of M during time dT equals the change in the linear momentum.

c. The total impulse (area that is determined by F_n versus T curve) can be determined by test data and is usually more precise than attempting to determine the exact functional relationship between F_n and T.

d. Where subscripts 0 and F indicate the initial and the final conditions, equation 4 is an integral of equation 3 and a more usable form of equation 3.

e. Equation 4 can be integrated, resulting in equation 5.

f. The acceleration and the applied force to the load and the parachute in the case of a two–riser parachute are assumed to be along a "straight line" flight path as shown on figure 19.

g. The resultant riser force measurements are shown on figure 20.

h. The total linear impulse is the area (I) that is contained within the force versus time profiles shown in figure 20 less the steady state forces as shown below the dashed lines and bounded by T_{IS} and T_F (see equation 6).

i. The total linear impulse can be determined from the tabular data by stating equation 5 in accordance with equation 7. V_{IS} and V_F in equation 7 correspond to T_{IS} and T_F, respectively.

j. A comparison of the total linear impulse that is derived from the telemetry data (I_{TM}) in accordance with equation 6 and the total linear impulse that is derived from the tabular data (I_T) in accordance with equation 7 can be compared in accordance with equation 8.

k. The snatch force rise approximation can be expressed in accordance with equation 9.

l. Force versus time profile models can be developed to determine characteristic trapezoidal and triangular force versus time profiles as shown on figures 6 and 7.

m. A trapezoidal or a triangular force approximation of the force versus time profile after snatch force has occurred can be constructed and used to measure rise, dwell, and decay characteristics as shown below.
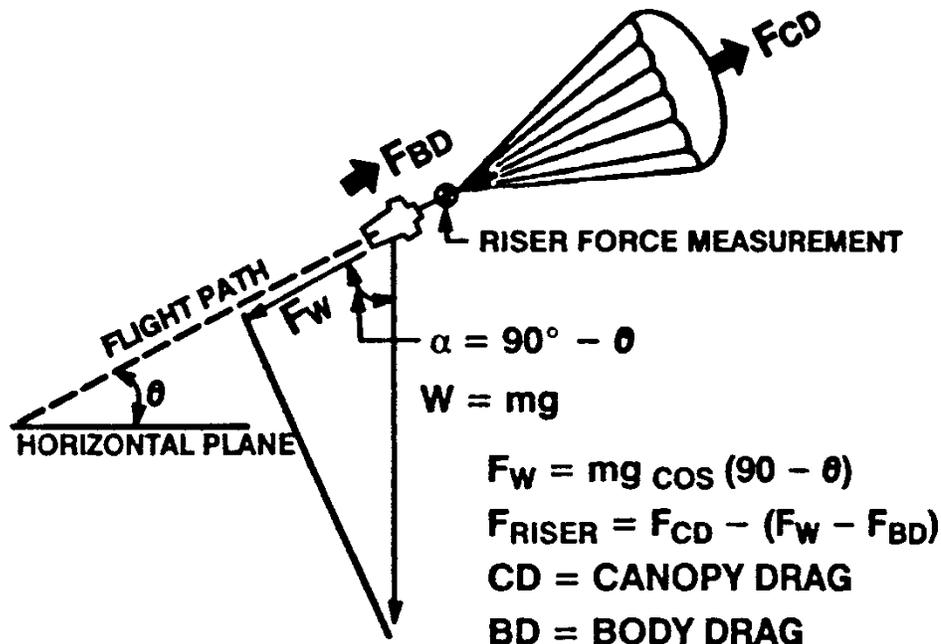
FIGURE 19. Straight line acceleration and force.

Trapezoidal or triangular force approximation.   A trapezoidal or a triangular force approximation of the force versus time profile after snatch force has occurred can be constructed and used to measure rise, dwell, and decay characteristics as follows:

a. Establish the baseline, and correct the force readings for any baseline shifts during opening.

b. Establish the maximum (peak) force magnitude (excluding snatch force).

c. Construct a reference line parallel to the baseline at a magnitude level that is equal to 10 percent of the peak level.

d. Construct a second reference line parallel the baseline at a magnitude level that is 10 percent below the peak level.

e. Locate the four extreme points of the intersection of the two reference lines with the measured force time profile of the opening sequence (see points 1, 2, 3, and 4 on figures 21 and 22). (NOTE: If the opening force rise begins above the 10 percent level, point 1 (see figure 22) will be the point where the opening rise begins.)

f. Construct a rise line, which is a straight line passing through points 1 and 2 as shown on figures 21 and 22. (NOTE: The horizontal distance between points 1 and 2 is the rise time. The slope of the rise line is the rate of rise.)

g. Construct a decay line, which is a straight line passing through points 3 and 4 as shown on figures 21 and 22. (NOTE: The horizontal distance between points 3 and 4 is the decay time. The slope of the decay line is the rate of decay.)

h. Locate the intersection of the rise line and the decay line, which is shown as point 9 on figures 21 and 22.

(1) If the intersection of these lines (point 9) occurs above the peak, construct a line from point 5 to point 6 as shown on figure 21 at the peak level (F_C) of the measured force versus time profile, which will result in a trapezoidal plateau (dwell time).

(2) If the intersection of these lines (point 9) falls below the peak level (F_C), a triangular approximation remains. Neglect the small increment of the measured force versus time profile, and measure between points 2 and 3 as shown on figure 22 to determine dwell time.

Rise time, plateau duration, and G values. Based upon acceleration–time plots from measurements or computations, rise time, plateau duration, and G values in the x-axis and the y-axis at a specific time (see figure 23) may be obtained using the graphic approximation technique described above.

Multi-axial acceleration environment.   The specific G values for a given plot of accelerations in the x-axis and the y-axis can be graphically obtained from the constructed onset and offset lines for the specific time at which the summation vector of acceleration is the greatest (see figure 24).
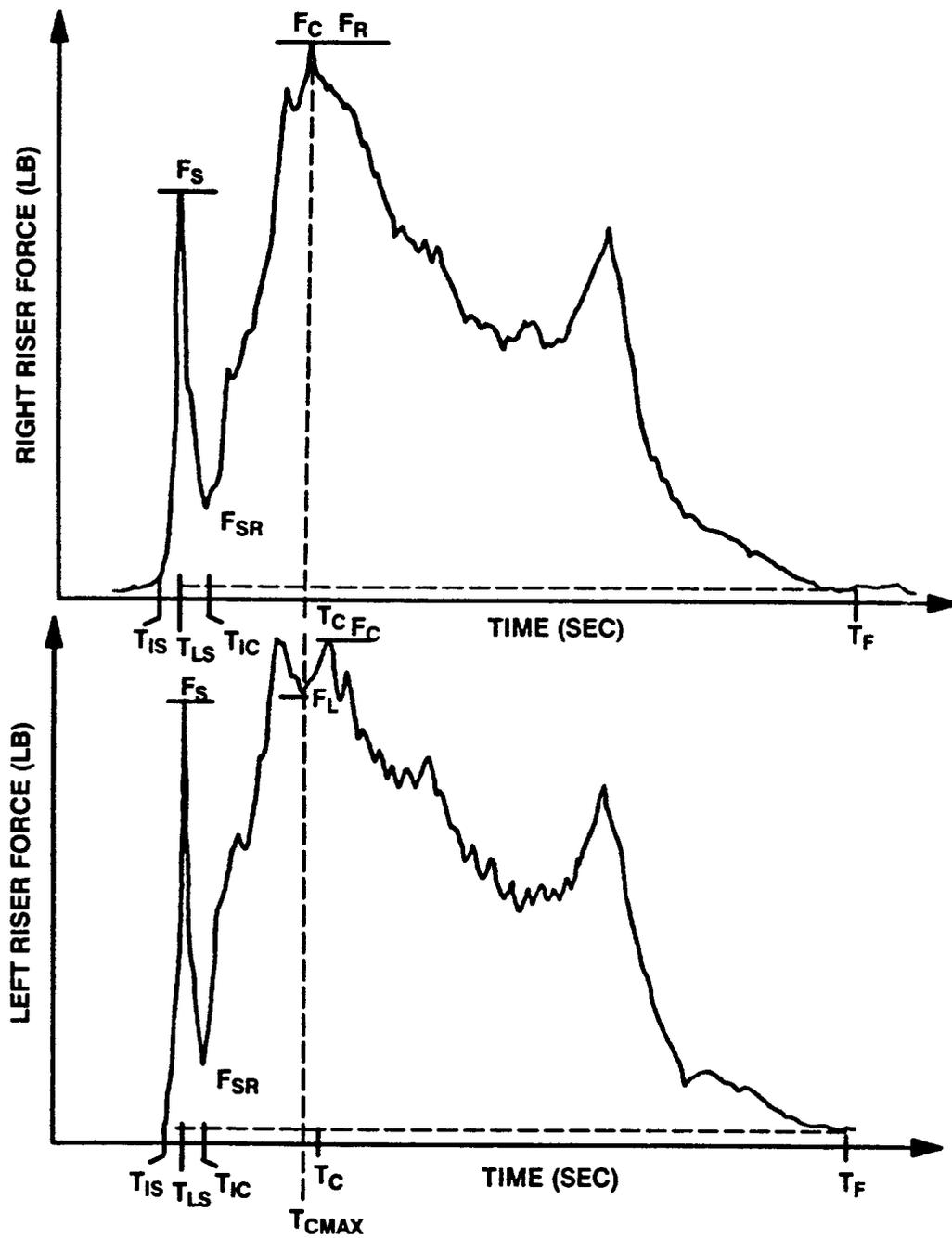
**FIGURE 20. Resultant riser force.**
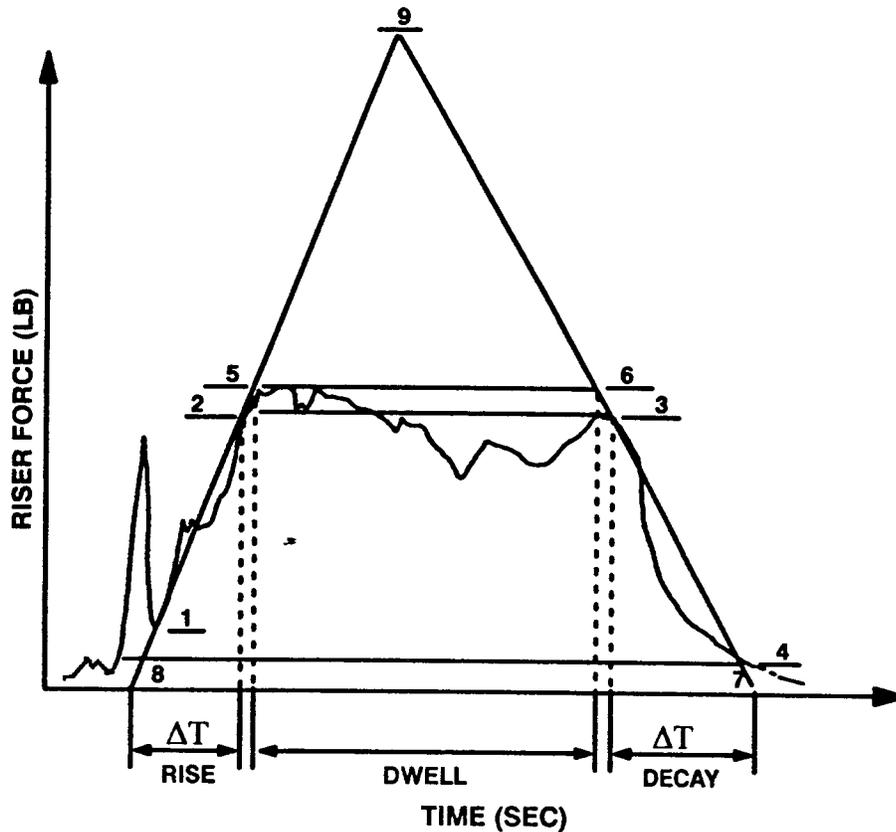
FIGURE 21. Trapezoidal force versus time profile.

Personnel Parachute Considerations

Acceleration. Acceleration during deployment (opening shock) should be measured at the anticipated worst case density altitude and velocity. Acceleration should be determined by dividing the total riser force data by the suspended weight. For each test, acceleration should be within the specified limits except:

   a. Accelerations with a duration less than 0.002 second may be disregarded.

   b. Accelerations limits may be exceeded by 5 gravity units (g) for peak accelerations with a duration of 0.04 second or less.

Canopy overload. Canopy overload requirements should be verified by field tests. With a 300 +0, −5 pound suspended load, the parachute should be dropped at the airspeed required to achieve a total riser force of 6000 pounds minimum and a single riser force of 4500 pounds minimum.
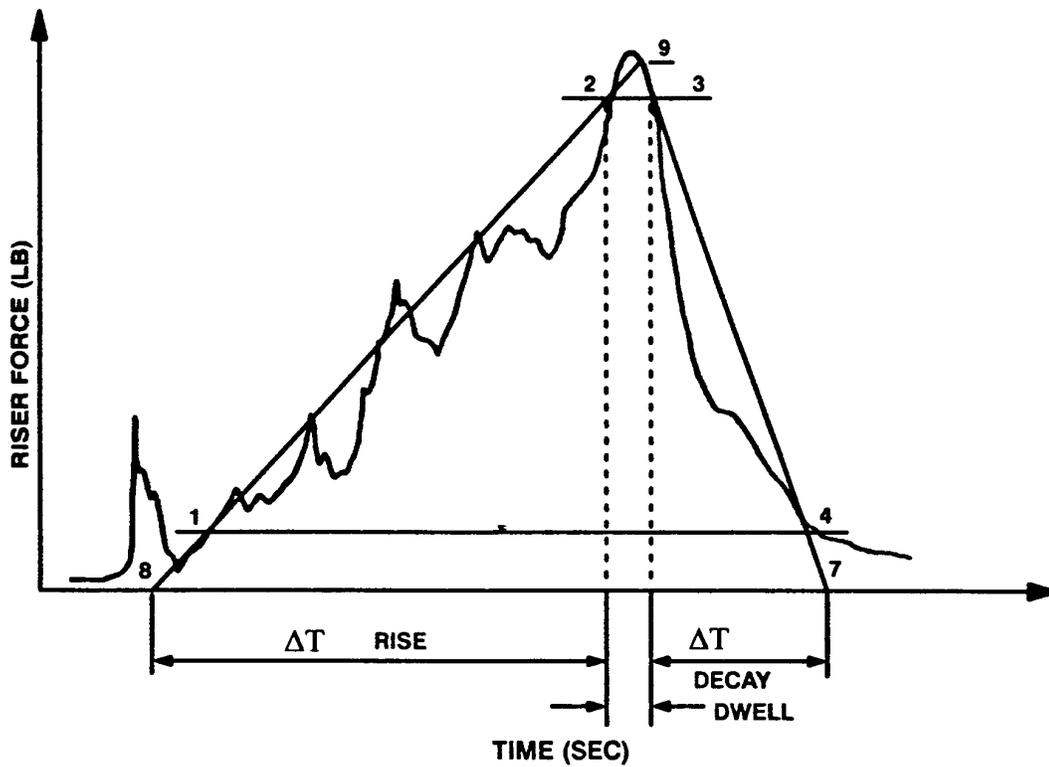
**FIGURE 22. Triangular force versus time profile.**
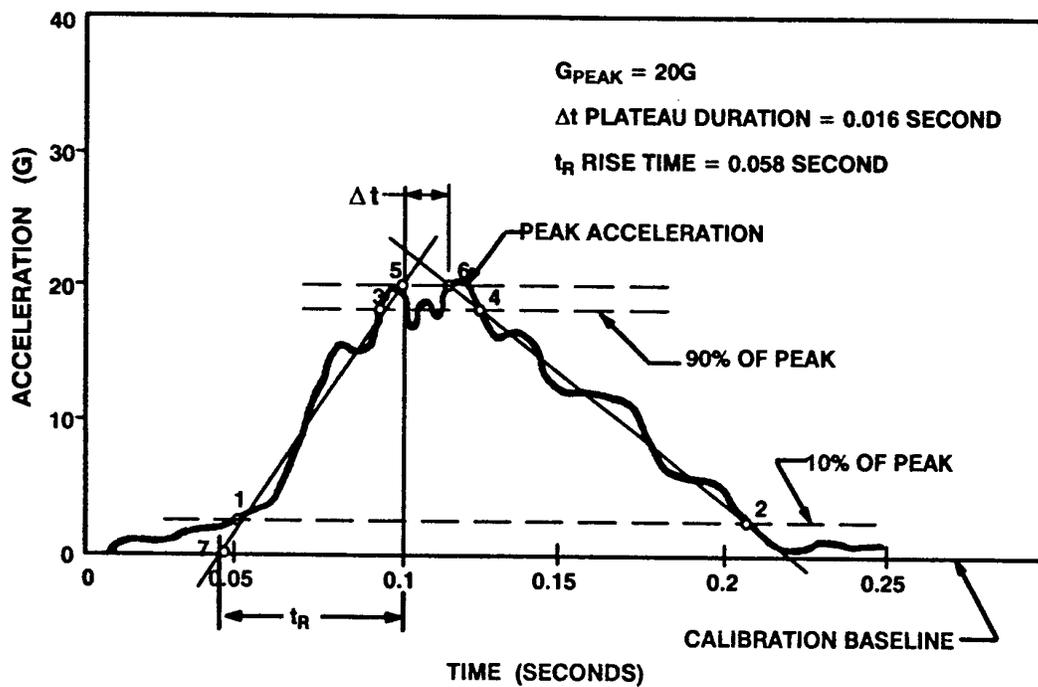
**FIGURE 23. Example of graphic approximation.**
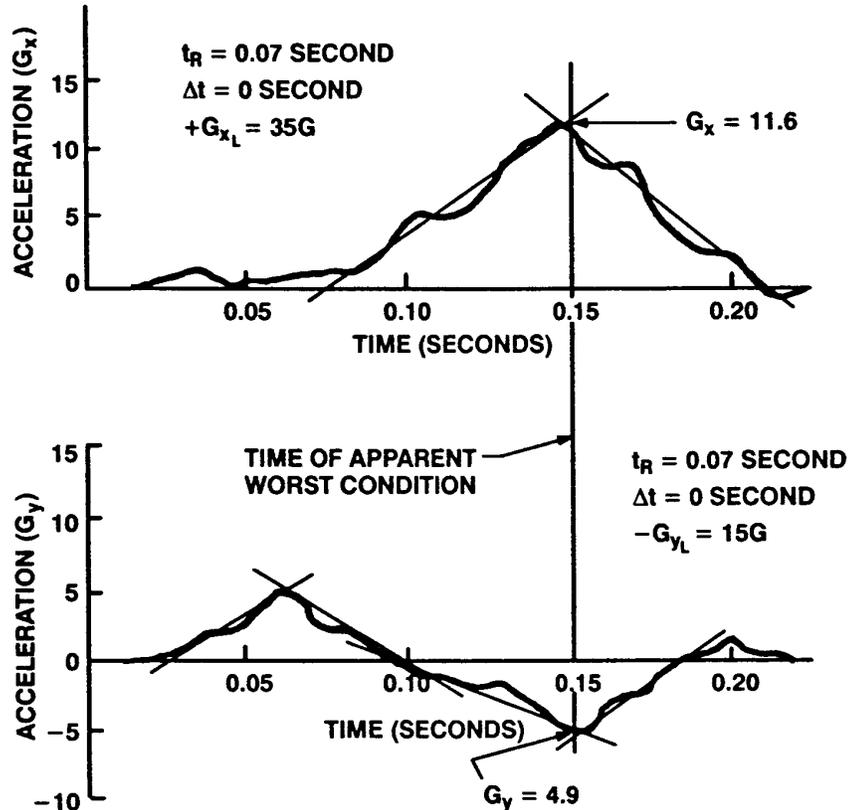
FIGURE 24. Example of multi-axial acceleration environment.

Recovery Time/Distance.

Trajectory data. When required, trajectory data should be obtained by a tracking system approved by the contracting activity. The tracking system shall measure the position of the parachute as a function of time with respect to a known reference point. The velocity of the parachute shall be obtained from these data by a method approved by the contracting activity. Trajectory data alone shall not be used to obtain the velocity of the parachute until 10 seconds minimum have elapsed after the parachute reaches full open, unless it can be demonstrated to the satisfaction of the contracting activity that the sample rate and position accuracy of the data are adequate to produce accurate results during the opening process.

Personnel Parachute Considerations

Time from initiation of deployment to the point of last full open of emergency personnel parachutes. The time from initiation of deployment (instant of container/pack opening activation) to the point of last full open should be measured at a true airspeed at initiation of 100 $\pm$10 ft/sec and a density altitude of 8000 $\pm$ 500 feet.

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VERIFICATION LESSONS LEARNED (4.12.2.2)

Deployment envelope. Since parachute testing can be very expensive, it is usually limited to essential testing. Essential testing normally involves testing only at the envelope extremes and any midpoints of particular interest such as crossover speeds for variations in deployment. Bench tests are sometimes used to check out functioning prior to more expensive airdrop testing or sled testing. Deployment tests off a moving truck bed have also proven useful and inexpensive.

Opening loads. The measured loads are only as accurate as the measuring equipment. Measuring equipment that will provide the most accurate measurements-especially where loading is critical-is desirable. Care should be exercised in the setup of the measuring equipment. The anticipated forces should be estimated so that a setup that is in error will be obvious.

The force/time curves from a parachute test program did not lend themselves to standard data reduction methods given above for trapezoidal or triangular force approximation. This led to some difficulty in interpreting the data. If a characteristic force/time curve does not conform well to the standard methods, it may require development of a unique method which makes sense for the particular data being evaluated. For example, if there are two distinct major peaks of significant duration following snatch force, such as reefed open and disreefed open, it may make sense to evaluate each peak separately using either the trapezoidal or triangular method. Any deviations from the standard methods should be well documented in test reports.

Recovery time/distance. The determination of the recovery characteristics of the parachute depends upon the definition of recovery that is specified. Data requirements can vary greatly due to the variation in the definition of recovery. The data requirements should be tailored to the particular recovery definition to reduce complexity and cost of testing.

3.12.2.3 Steady state operation.

Once inflated or opened to the steady state operational configuration, the decelerator operational performance criteria shall be as follows: _____.

REQUIREMENT RATIONALE (3.12.2.3)

The steady state operation requirement can be broken down into the following lower level requirement considerations: rate of descent, oscillation, directional mobility, color, and surface impact.

Rate of descent. The maximum rate of descent, along with the maximum primary body weight, is needed to determine the drag area requirements for the parachute. The standard day atmospheric conditions and the altitude or the time span for the stated rate of descent must be specified. The rate of descent in cases in which the equilibrium rate of descent is identical to impact velocity is necessary to determine the loads and the accelerations the primary body will receive on impact. The equilibrium rate of descent in the case of a midair retrieval system must match the descent capability of the retrieval vehicle. The time that is required for a solid flat circular parachute to reach equilibrium will differ considerably from the time that is required for a ring slot or a ribbon parachute to reach equilibrium.

Oscillation. A limit on the amplitude and frequency of oscillation permitted during descent must be imposed due to the incidence of damage and injury caused by swinging impact with the ground. Limits on the parachute oscillation characteristics for cases in which trajectory

control is extremely critical, such as bomb stabilization, must be imposed to assure reliable mission accomplishment.

Directional mobility. Directional mobility is required of many parachutes for mission accomplishment. The directional movement need not be controlled in some cases such as in a midair retrieval system. The lateral motion of the descending parachute and the primary body combination in the case of a midair retrieval parachute may need to be stabilized or directionalized (the particular direction is not critical) so that the retrieval aircraft can properly track and snatch it. The directional movement in other cases must be controlled in a particular direction and possibly at a particular offset rate or lift to drag (L/D) ratio to offset a head wind, land at a preselected landing site, or achieve precision landing accuracy. Generally, the higher the glide ratio of the flexible gliding parachutes is, the more complicated and challenging are the devices and procedures used to control the opening and deployment characteristics. The proper landing flight procedures of all flexible gliding parachutes are very critical.

Color. Some parachutes require a specific color or color pattern for camouflage or detection of the primary body. The coloring of the various components of the parachute can be an aid in packing or installing the parachute but should only be a secondary consideration. Color schemes can be used for visual reference such as in testing or midair retrieval applications.

Surface impact. Surface impact conditions define the requirements for successful mission completion of most parachutes. The objective of many parachutes that are designed for lowering a primary body to a surface impact is to arrest the descent of the primary body without exceeding the allowable load factors and without inducing excessive rolling and pitching moments upon impact. Other parachutes may be required to allow the primary body to impact in a particular velocity range at a specified angle with the impact surface.

REQUIREMENT GUIDANCE (3.12.2.3)

Rate of descent. The equilibrium rate of descent (along with altitude) that must not be exceeded for the particular application should be specified. If there is a range of possible recovery weights, there will be a range of descent velocities depending on the particular weight. The best approach in such a case may be simply to state the maximum allowable descent velocity for the maximum allowable weight or to provide a graph of the allowable descent velocities versus the range of possible recovery weights. Where practical, minimum and maximum rates of descent or tolerance on a mean value rate of descent should be defined.

Personnel Parachute Considerations

Recommended rate of descent of not more than 20 feet per second for a 360-pound gross weight for premeditated personnel parachutes and of not more than 24 feet per second for a 300-pound gross weight for emergency escape personnel parachutes at standard sea level conditions. (NOTE: This rate of descent is usually achieved by high drag coefficient to keep bulk to a minimum. The rate of descent of escape capsules is dependent upon weapon system requirements and design attenuation of ground impact loads.

Vehicle Recovery Parachute Considerations

Final recovery. After the vehicle has been decelerated to an equilibrium condition, the final parachute will be deployed. A deployment altitude below 15,000 feet is desirable for the final parachute to limit the opening forces and to restrict the drift of the vehicle during final descent. The final parachute should provide a large drag area and should limit oscillation to ±10 degrees. These characteristics have been obtained successfully in some instances by clustering the final

stage recovery parachutes. Allowable terminal velocities depend on the G limitations of the vehicle structure or its most fragile components such as a human occupant in the case of a space vehicle or aircraft escape capsule.

Airdrop Parachute Considerations

Rate of descent. In general, a rate of descent of 30 feet per second or less should be the goal. A higher rate of descent may be used for cargo that can resist damage at higher impact shocks and for special airdrop applications.

Parachute canopies. Single canopies or canopy clusters can be used either for extraction or for vertical descent. In general, it is desirable to have canopies with a high drag coefficient, which has a direct bearing on the weight and bulk of the airdrop parachute.

Oscillation. Since the requirements for oscillatory characteristics vary according to parachute application, the oscillation limits (amplitude and frequency) necessary for reliable mission accomplishment should be specified for the particular parachute application.

Personnel Parachute Considerations

Stability within plus or minus 15 degrees for emergency use and ± 10 degrees for premeditated use.

Vehicle Recovery Parachute Considerations

Instability. An additional problem, which is related to canopy breathing, is parachute instability about the attachment point due to the fluctuation of the canopy bow-shock wave. This fluctuation is the change of the direction, the force, and the shape of the shock wave brought about by the spilling and the recapturing of air within the canopy, the interactions with the wake and the suspension line boundary layers, and any other small disturbance in the flow field ahead of the canopy. This effect can be reduced by suitable canopy shape, proper magnitude and distribution of porosity, and prevention of any induced flow field disturbance.

Aircraft Deceleration Parachute Considerations

Stability and opening reliability. The ribbon, the ringslot, the Cross, and the varied porosity parachutes meet the stability and the opening reliability requirements for landing drag parachutes. Ribbon parachutes have a more uniform opening, which is an added benefit rather than a necessity. Reliable parachute deployment and opening will involve the total process from pilot action to main parachute full opening. Figure 2 shows a typical landing drag parachute assembly consisting of a pilot parachute, a pilot parachute bridle, a deployment bag, a drag parachute, a riser, and an aircraft attachment fitting. Upon pilot action, the aircraft drag parachute compartment door is opened and the pilot parachute is ejected. The pilot parachute bridle extracts the deployment bag from its compartment. The deployment bag opens and deploys the riser, the suspension lines, and the parachute canopy.

Stabilization of towed vehicle. If recovery will be made by a helicopter, the inclusion of some method of stabilization on the vehicle being recovered is often necessary to stabilize its motion while being towed.

Airdrop Parachute Considerations

Stability. An oscillation of ±10 degrees is permissible for most cargo container drops. Airdrop systems that are equipped with pneumatic shock absorbers require a higher degree of stability such as achieved with clusters of canopies.

Directional mobility. The purpose of the directional mobility requirements should be stated. The principle consideration in the case of a particular flexible gliding parachute is the end use such as for personnel (premeditated, emergency, et cetera) or for cargo. All applicable directional mobility requirements such as direction of flight, turn rate, glide range from a specified altitude, rate of horizontal travel, change in L/D ratio in flight, response time to control inputs, and control force limitations should be specified and quantified. Directional mobility should include hands-off glide.

Personnel Parachute Considerations

Flight control features. Unless otherwise specified in the contractual documents, the flight control system of an emergency personnel parachute should include two modes: (1) the "hands off" mode, and (2) the controlled gliding mode. The flight control system should minimize the possibility of inadvertently stalling the canopy during maneuvering, and should provide the capability of modulating the forward speed of the canopy using simultaneous left and right control inputs.

Hands off mode. The parachute should include a low gliding hands off mode to accommodate an injured or unconscious aircrew member. The parachute should deploy in the hands off mode with selection of the controlled gliding capability at the option of the aircrew member. Horizontal velocity in the hands off mode should not exceed 8 ft/sec and the turn rate should not exceed 5 degrees/sec.

Controlled gliding mode. The controlled gliding mode or "hands on" mode should provide a horizontal velocity in excess of 8 feet per second, or as required for the specific application (current Air Force parachutes approach 18 ft/sec max). The rate of turn in the controlled gliding mode should be 20 to 90 degrees/sec at full control stroke. The controlled gliding mode should be capable of manual activation/selection and manual deactivation/deselection by the aircrew member. Within a 200 foot altitude loss following deactivation/deselection by the aircrew member, the parachute should return to the hands off mode.

Color. All requirements relating to the color or color pattern of the parachute should be specified.

Personnel Parachute Considerations

Color. The color scheme of the parachute, other than the canopy, shall be determined by the contracting activity and shall be as specified in the associated specification sheet. Unless otherwise specified in the specification sheet, the canopy shall be color coded and the colors shall be sequenced as follows:

   a. 36 percent international orange in accordance with FED-STD-595, color number 12246; then

   b. 36 percent natural white; then

   c. 14 percent sand shade in accordance with FED-STD-595, color number 30450; then

   d. 14 percent olive green in accordance with FED-STD-595, color number 34094.

Surface impact. Specific impact conditions that are required for successful mission completion should be specified and may include allowable velocity, trajectory angle, load factors, and moments. Descriptions of the types of surfaces onto which the primary body is to impact, which may be helpful to the designer, should be specified. Any wind conditions that may affect successful mission completion should be specified.

Personnel Parachute Considerations

Canopy deflation features. To hinder the parachute's proclivity to drag the aircrew member across the surface of the water, the parachute shall incorporate features (such as water deflation pockets) which will aid in canopy deflation after a water landing.

Vehicle Recovery Parachute Considerations

Shock absorbing devices. The use of devices to absorb landing-impact shock must be considered to permit a higher rate of descent with the final stage parachute and to reduce to a great extent the weight and the volume of the entire system. Investigations have shown that retro-rockets, when considered for use with heavy loads which require low impact decelerations, may be effective as impact attenuators.

Flotation equipment. Reliable flotation equipment is essential to accomplish over-water recovery. Two methods of vehicle flotation have been utilized Both methods of vehicle flotation utilize balloons. The difference in the two methods is that in one method the balloon inflates during vehicle descent and in the other method the balloon inflates under water. The latter method appears to be the more reliable method for the following reasons:

    a. If the vehicle impacts at a high rate of descent due to failure of the final recovery aerodynamic decelerator, the vehicle can still be recovered.

    b. The possibility of the balloon entangling with the suspension system of the final recovery aerodynamic decelerator is eliminated.

REQUIREMENT LESSONS LEARNED (3.12.2.3)

Rate of descent. The recovery rate of descent is an important design parameter. The effects of wind which can at times easily reduce the total system effectiveness must also be considered for cases in which very low rates of descent are specified to eliminate or minimize damage to the primary body such as in the case of a multiple canopy vehicle recovery system for surface landing of an RPV with minimum or no damage. The multiple canopy vehicle recovery system attained the specified acceptable rate of descent; however, the surface winds at the low rate of descent had a much greater effect, sometimes causing tumbling and shearing that resulted in major damage to the RPV.

Oscillation. An oscillating or coning canopy generally adjusts to the same angle of attack as a gliding canopy. The zones of separation and attachment of the airflow on the drag producing surface of an oscillating or coning canopy are not necessarily the same as a gliding canopy because of the transverse motion of the canopy with respect to the airflow. A variation of the aerodynamic coefficients, depending on the gliding or oscillating motion of the canopy, is the logical consequence. Experimental test results have substantiated this conclusion and have proven that an oscillating or coning canopy has a lower effective drag coefficient, or effective drag, than the same canopy under gliding conditions.

The conditions under which a particular canopy will glide or oscillate, in theory, are governed primarily by its dynamic stability characteristics. It is well known that the same canopy, in actual

practice, may glide under conditions of low canopy loading and will usually descend with an oscillating or coning motion under conditions of high canopy loading. The area of transition from a gliding descent to an oscillating descent or vice versa will vary for different canopy types, depending upon the static stability characteristics of the particular canopy; for example: The statically unstable flat circular cloth canopy will change its stability behavior markedly within a relatively small range of canopy loading values The statically stable guide surface and ribbon canopies will descend almost vertically, independent of canopy loading. This phenomenon is understandable, because stability under static conditions is one of the requirements for dynamic parachute stability. Because of this difference in stability behavior, the effective drag will change over a considerable range for statically unstable canopies but will be practically constant for statically stable canopies.

The type of motion during descent to a certain extent will also depend upon the size of the canopy. This change in motion is related to a stronger damping because of the larger mass of air included by the drag producing surface of the larger canopies

Directional mobility. Directional stability is occasionally required for successful operation of a parachute such as a midair recovery system in which a retrieval aircraft must track and snatch a vehicle during its steady state descent.

Obtaining a perfectly directionalized system is impossible, because some random turning or coning is always present in flexible fabric parachutes. This random turning or coning is probably caused by some asymmetry in the parachute such as unequal length suspension lines due to manufacturing tolerances or differential stretching during deployment and opening.

Conventional circular canopies have been modified in the past to provide some glide and steerability to the parachute. This modification has usually been accomplished by venting the canopy surface to the rear. Highly porous fabrics have been used to cover the vented areas to give some structural stability to these areas or to prevent the entanglement of the drogue or the pilot parachute while still providing the venting desired. Glide and steerability have also been obtained by releasing a small number of adjacent suspension lines (four of 28 on the standard Type C-9 emergency escape parachute) to the aft, providing a forward thrust.

High glide canopies are widely used in sports parachuting but not in military applications, except for personnel premeditated parachuting, due to the limitations in the deployment speeds and the complexity of drag area control on the high glide canopies. Gliding maneuvering canopies have been and are being investigated for various military applications that include non–personnel missions such as offset aerial delivery of cargo and recovery of space satellite payloads and RPV.

Highly reliable, air deployable, ram air inflated, flexible parachutes that have a glide ratio of 3 to 1 (3 feet horizontal to 1 foot vertical) are currently being used by sports parachutists and special military activities. Total airspeeds of approximately 40 to 60 feet per second are well within the present state-of-the-art. No limitation on the use of the glide ratio for personnel or cargo is foreseen provided that the use or nonuse of the full glide ratio capability is optional.

Wind effect on parachutes cannot be accurately accounted for and contributes to landing inaccuracies, since only limited control can be attained to offset this effect.

As a general rule, the higher the total flight airspeed, the more sensitive are the directional mobility characteristics. Fast or abrupt maneuvers such as turns and brakes, particularly for personnel, should not be attempted below 500 feet above ground level.

Color. The color scheme of a round canopy for personnel emergency escape parachutes is based upon extensive evaluation of signaling and camouflage requirements. The color scheme

of the canopy should be one–third white (natural), one–third international orange, one–sixth sand, and one–sixth olive green. The colors of the canopy should be in the sequence listed herein; should be clockwise, when the canopy is viewed from above; and should radiate from a central point on the canopy. This pattern is used for signaling or detection. Individually, the white is for camouflage in snow; the sand color is for camouflage in desert areas; the olive green is for camouflage in vegetated areas. The orange in combination with the other colors, is for signaling.

The standard color scheme as given above was specified for a personnel emergency escape parachute. The terms "clockwise" and "radiate from a central point" led an offeror to believe that a round canopy configuration was required, when actually, no specific configuration requirement was intended. When specifying any color scheme or pattern, consider the implications it may have with regard to the canopy configuration. If the configuration is still TBD, specify the colors only and require that the color arrangement or pattern be approved by the procuring activity.

Surface impact. The lessons learned that are specified for rate of descent apply to surface impact.

Equipment that is part of the parachute or certain equipment in addition to the parachute can be used to reduce the momentum of the primary body to zero. Penetration spikes, air bags, crushable portions of the primary body, and retro-rockets have been used for contact and pre-contact retardation. The application of retro-rockets as practical landing decelerators has been restricted because of the disadvantages of actuation, timing, and close quality control required if more than one rocket is used.

Rates of descent for proper load recovery are generally less than 30 feet per second without shock absorption devices, about 50 feet per second with shock absorbers, and about 50 feet per second for water recovery.

4.12.2.3 Steady state operation.

The steady state operation requirements specified in 3.12.2.3 shall be verified as follows: _____.

VERIFICATION RATIONALE (4.12.2.3)

Rate of descent. The equilibrium rate of descent of the parachute must be measured to determine its capability and to determine if its capability conforms to the specified requirements. The rate of descent must be measured under the specified conditions at a particular altitude or under conditions calculated for that altitude on the basis of conducted tests to determine the drag area characteristics of the parachute. The rate of descent of the parachute can vary considerably depending upon the particular altitude.

Oscillation. Oscillation of the parachute must be measured under the specified condition to determine if the oscillatory characteristics of the parachute conform to the specified requirements.

Directional mobility. Determining the directional mobility characteristics of the parachute is necessary to verify compliance with the specified requirements.

Color. The parachute must be inspected to assure the color scheme conforms to the specified requirements.

Surface impact. Testing is required to determine if the surface impact characteristics of the parachute conform to the specified requirements.

VERIFICATION GUIDANCE (4.12.2.3)

Rate of descent. The rate of descent of the parachute is usually measured when recovering the maximum weight primary body configuration. The rate of descent of the parachute at the lower weights will be considerably lower. Photographic techniques are usually employed to measure the rate of descent during the reliability testing. The rate of descent of the parachute should be corrected to standard day conditions.

Personnel Parachute Considerations

Vertical descent velocity. The vertical descent velocity (rate of descent) should be measured during steady state descent with no canopy manipulation. A minimum of five separate tests should be performed. All test data should be converted to ICAO standards as shown under 4.13 verification guidance. For each test, a minimum of 100 data points (N) should be used for the following calculations:

a. The mean corrected vertical velocity (V_c) should be calculated for each test as follows:

$$V'_c = (\sum V_c)/N$$

Where V'_c = individual instantaneous vertical velocity point.

b. A weighted mean rate of descent should be calculated for all tests as follows:

$$V''_c = [\sum \text{ (from m=1 to M) } N_m V'_{cm}] / [\sum \text{ (from m=1 to M) } N_m]$$

Where M = the number of tests

c. A weighted standard deviation, S, of the rate of descent of all tests should be calculated as follows:

$$S = \{[\sum \text{ (from m=1 to M) } N_m(V'_{cm} - V''_c)^2 / [\sum \text{ (from m=1 to M) } N_m - 1]\}^{1/2}$$

d. A statistical t-test should be used to demonstrate that V_c does not exceed the limit specified, with a single-sided probability of occurrence of 90 percent, calculated as follows:

$$t = [V''_c - L] / [S/(M)^{1/2}] \quad \text{where L = specified limit.}$$

Oscillation. Photographic techniques are necessary to measure the oscillatory characteristics of the parachute. Weight conditions such as minimum, maximum, and nominal weight should be specified, because of the variance in oscillatory characteristics that is attributable to the weight of the primary body. The precise method of measuring oscillation (selection of the precise points on the parachute and body combination) should be specified.

Personnel Parachute Considerations

Oscillation. Oscillation angle (or the deviation of the central axis of the parachute from the vertical) as measured in degrees, should be measured by a trajectory data system or other system approved by the contracting activity. Oscillation shall be measured during steady state descent, hands-off mode, from 1000 feet above ground level until ground contact. The specified oscillation limit should not be exceeded more than twice during the 1000 foot measurement distance. The density altitude during testing should be not greater than 5000 feet.

Directional mobility.

Trajectory data. When required, trajectory data shall be obtained by a tracking system approved by the contracting activity. The tracking system shall measure the position of the parachute as a function of time with respect to a known reference point. The velocity of the parachute shall be obtained from these data by a method approved by the contracting activity. Trajectory data alone shall not be used to obtain the velocity of the parachute until 10 seconds minimum have elapsed after the parachute reaches full open, unless it can be demonstrated to the satisfaction of the contracting activity that the sample rate and position accuracy of the data are adequate to produce accurate results during the opening process.

Personnel Parachute Considerations

Horizontal velocity, hands-off mode. The horizontal velocity in the hands-off mode should be measured by deploying the parachute from a stationary location of sufficient height to ensure a descent duration of 10 seconds minimum, such as from a drop tower. Each test should be comprised of two drops minimum and for each subsequent drop, the parachute should be rotated about its central axis 180 degrees from the previous drop position. Not greater than 15 minutes should elapse between drops in each test. Not less than 10 tests should be conducted a the minimum suspended weight of 150 +5, −0 pounds and not less than 10 tests should be conducted at the maximum suspended weight of 300 +0, −5 pounds. Surface winds should not exceed 5 ft/sec during the tests. If the parachute exhibits any drive (the inherent tendency of a parachute to glide horizontally), it should be positioned such that it will drive into the wind on the first drop and with the wind on the second drop.

Rate of turn. Rate of turn shall be measured in both the hands-off mode and the controlled gliding mode. The rate of turn shall be measured by timing three 360 degree turns in each mode and calculating the average.

Flight control features. The flight control features should be verified during live jump tests. Horizontal velocity, in both the hands-off mode and the controlled gliding mode shall be measured using circular trajectory analyses. To perform tests for circular trajectory analysis, the parachute shall be trimmed to descend with a constant turn. The turn rate shall be from 5 to 12 degrees per second. During the portion of a test for which circular trajectory data are obtained, the canopy shall not be manipulated in any way which could affect or control the turn rate, horizontal velocity, or rate of descent.

Color. The color requirements should be verified by visual examination.

Surface Impact.

Personnel Parachute Considerations

Canopy deflation features. The canopy deflation features should be verified by field tests over a water source.

VERIFICATION LESSONS LEARNED (4.12.2.3)

Rate of descent. The problems in measuring the rate of descent of the parachute in free flight are related to difficulties in correcting data for updrafts and downdrafts, which cannot be reliably accounted for or predicted. Updrafts such as thermal updrafts are normally more frequent near ground level, and the effects can be reconciled for the most part by measuring the rate of descent at altitude and discounting measurements near the ground.

Oscillation. (Lessons learned will be added as acquired.)

Directional mobility. Phototheodolite coverage of airdrop tests of the parachute has been used to evaluate the directional mobility characteristics of the parachute.

Color. (Lessons learned will be added as acquired.)

Surface impact. The parachute may perform satisfactorily during testing because of the controlled landing surface conditions. In practice, the type of surface or terrain may vary to the extent that surface impact without damage exceeding the acceptable levels as specified is impossible.

3.13 Survival, Search and Rescue (SSAR) (see JSSG-2010-13).

3.14 Aircraft Windshield/Canopy Systems and Transparent Enclosures (see JSSG-2010-14).

4. VERIFICATION (with REQUIREMENTS)

5. DEFINITIONS AND ABBREVIATIONS

5.1 Definitions.
The following definitions are applicable for the purposes of this handbook.

5.1.1 Aerial delivery (airdrop).
An aerial delivery (airdrop) is an operation that involves the delivery of a variety of vehicles, weapons, heavy cargo, or miscellaneous supplies to any strategic locality in such a manner that they will be usable within a minimum amount of time and with a minimum hazard to the personnel involved.

5.1.2 Aerial engagement.
An aerial engagement is the snagging of an engagement target by the midair retrieval equipment onboard the recovery aircraft.

5.1.3 Aerial retrieval.
An aerial retrieval (midair retrieval) is the aerial engagement of a payload and the reeling of the payload in proximity to or into the recovery aircraft.

5.1.4 Canopy.
A canopy is the portion of a parachute that consists of the surface producing the aerodynamic forces and the suspension lines extended to one or more mutual confluence points.

5.1.5 Contracting activity.
The contracting activity is the Government procuring activity and the Government cognizant design activity.

5.1.6 Contractor.

The contractor is any corporation, company, association, or individual which undertakes performance under the terms of a contract, letter contract, letter of intent or purchase order, project order, and allotment, in which this document may be incorporated by reference. For the purpose of this specification, the term "contractor" also includes Government operated activities undertaking performance by assigned airtask, project order, or allotment.

5.1.7 Contractual documents.

Any document that contractually binds the contractor to the customer (Government in most cases) in the performance of the contract. This may include the contract as a whole, purchase orders, Statements of Work (SOW), specifications, specification sheets, drawings, etc.

5.1.8 Decelerator.

A decelerator (deployable aerodynamic decelerator) is a device that, by virtue of its design configuration and performance characteristics, augments the basic drag and in some cases the stability of the payload to which it is attached.

5.1.9 Demonstrated reliability.

The system reliability level that must be demonstrated through actual testing.

5.1.10 Density altitude.

Density altitude is the altitude in the standard atmosphere corresponding to a particular value of air density.

5.1.11 Deployment.

Deployment is that portion of a parachute's operation occurring from the instant of container/pack opening to the instant the suspension lines and main canopy are fully stretched, but prior to inflation of the canopy.

5.1.12 Deployment bag or sleeve.

A deployment bag or a deployment sleeve is a container, usually of fabric, for retaining the drag-producing surface of the canopy to assure controlled deployment until the suspension lines are deployed. This method reduces the snatch force by allowing the acceleration of the canopy mass in small increments only. The lines may be or may not be stowed in the deployment bag or the deployment sleeve, depending on the intended use.

5.1.13 Development.

Development is the portion of the operation of a parachute that occurs from the moment of the completion of the suspension line stretch to the moment of the full inflation of the canopy. The terms development and inflation are used synonymously.

5.1.14 Drag area.

Drag area is the drag coefficient of the canopy multiplied by the reference area (C_DS) and is obtained by dividing the instantaneous force by the instantaneous dynamic pressure.

5.1.15 Engagement target.

An engagement target is the target that the pilot of the recovery aircraft attempts to snag with the retrieval equipment during an aerial engagement. The engagement target normally consists of a parachute that is separate from the main descent parachute but can be the main descent parachute providing it mates with the retrieval equipment.

5.1.16 Equilibrium.

A parachute, when open and descending with an aerodynamic drag equaling the parachute and the primary body combined weight, is in equilibrium.

5.1.17 Exposed condition.

For the environmental requirements and inspections specified herein, the exposed condition is the parachute out of its container and with as much component surface exposure as possible.

5.1.18 Failure, test.

Test failures may be categorized as follows:

a. Catastrophic. A catastrophic failure is defined as a design weakness, malfunction, or system damage that causes the parachute to fail to meet any of the performance requirements of table 1 by greater than 50 percent.

b. Critical. A critical failure is defined as a design weakness, malfunction, or system damage that causes the parachute to fail to meet any of the performance requirements of table 1 by less than 50 percent with a resulting failure that cannot be counteracted or controlled by an uninjured aircrew member.

c. Marginal. A marginal failure is defined as a design weakness, malfunction, or system damage that causes the parachute to fail to meet any of the performance requirements of table 1 by less than 50 percent with a resulting failure that can be counteracted or controlled by an uninjured aircrew member.

d. Negligible. A negligible failure is defined as a design weakness, malfunction, or system damage that does not prevent the parachute from meeting any of the performance requirements of table 1.

5.1.19 Finite mass condition.

The deployment condition in which the velocity of the parachute/primary body combination decays substantially during deployment and inflation.

5.1.20 Full control stroke.

In the controlled gliding mode, the full control stroke is the minimum amount of movement of both sides of the control mechanism required to achieve a steady-state stall with a suspended load of 150 pounds. For parachutes where steady state stall is prevented by the design, the full control stroke is the maximum amount of movement allowed by the design.

5.1.21 Full inversion.

A full inversion occurs when the part of the canopy that is starting to turn inside out during the opening of the parachute passes under another part of the canopy and continues to pull through until the entire canopy is completely inside out.

5.1.22 Glide ratio.

Glide ratio is the ratio of the horizontal velocity to the vertical velocity under zero wind conditions. Glide ratios for parachutes within the scope of this specification are categorized as follows:

a. Low gliding parachute   less than 1:1

b. Medium gliding parachute   1:1 to 2:1

c. High gliding parachute   Greater than 2:1

5.1.23 Ground roll canopy.

A ground roll canopy (landing deceleration canopy) is a canopy that is generally used on jet aircraft to decrease the aircraft landing–roll distance. The term drag parachute is used as an alternate term for ground roll canopy.

5.1.24 Hands off operation.

A situation in which a jumper or servo motor is not attempting any control of the parachute descent trajectory and any active steering mechanisms (i.e., 4-line release) are not engaged.

5.1.25 Hands on operation.

A situation in which a jumper or servo motor is actively controlling the parachute descent trajectory and any active steering mechanisms (i.e., 4-line release) are engaged.

5.1.26 Infinite mass condition.

The deployment condition in which the parachute acts as if it is attached to an infinite mass. In other words, the velocity of the parachute/primary body combination does not decay, or decays only slightly, during deployment and inflation of the parachute.

5.1.27 Inflation.

Inflation describes the process the canopy goes through to achieve a full or reefed open configuration at the time it was initially exposed to the airstream in an unrestrained condition. The terms canopy filling and canopy development are also used to describe inflation.

5.1.28 Interchangeability and replaceability.

Interchangeability and replaceability are the substitution of similar parts, subassemblies, or assemblies without physical modification to any part of the component, including cabling, wiring, or mounting.

5.1.29 Inversion.

An inversion occurs when one part of the parachute passes through the lines of another part of the parachute on the same half and/or the opposite half of the parachute and opens inside out. The part of the parachute that is inside out may reach a point of equilibrium and remain inside out, may pull back through and turn right side out, or may continue to pull through until the entire parachute is inside out.

5.1.30 Landing approach canopy.

A landing approach canopy is a canopy that is used in flight to improve jet aircraft flight characteristics during normal landing approach or in approach under marginal weather conditions.

5.1.31 Lift to drag ratio.

The lift to drag (L/D) ratio is the quotient that is obtained by dividing the measured lift by the measured drag or is obtained by dividing the horizontal distance or velocity by the vertical distance or velocity, respectively, under equilibrium glide conditions. Distances and velocities must be corrected to zero wind conditions.

5.1.32 Non-sealed parachute.

A non-sealed parachute is a parachute not enclosed within an environmentally sealed container.

5.1.33 Opening.

Opening is the portion of the operation of a parachute that occurs from the instant the parachute is exposed to the air flow (pack open) to the moment of full inflation. The first phase of opening is deployment, the second phase is inflation or development.

5.1.34 Opening shock.

Opening shock is the maximum force that is developed during inflation of the canopy.

5.1.35 Packed condition.

For the environmental requirements and inspections specified herein, the packed condition is the completely rigged parachute packed in its appropriate container, including if applicable, protective coverings.

5.1.36 Parachute.

A parachute is an assembly that consists of canopy, risers, bridles, and a deployment bag or sleeve and in some cases a pilot parachute. The pack and the attaching webbing (harness), if not built into the suspended load as an integral part of the load, are considered to be part of the parachute.

5.1.37 Parachute pack.

The term pack usually denotes the container that encloses the canopy or the deployment bag or sleeve and provides for a means of opening to allow deployment of the canopy.

5.1.38 Partial inversion.

A partial inversion occurs when part of the canopy is inside out and part of the canopy is right side out.

5.1.39 Permanent cross canopy partial inversion.

A permanent cross canopy partial inversion occurs when the part of the skirt that is starting to turn inside out during the opening of the parachute passes under another part of the skirt on the opposite half of the canopy and reaches a point of equilibrium so that the canopy will remain partially inside out.

5.1.40 Permanent lateral gore partial inversion.

A permanent lateral gore partial inversion occurs when the part of the skirt that is starting to turn inside out during the opening of the parachute passes under another part of the skirt on the same half of the canopy and reaches a point of equilibrium so that the canopy will remain partially inside out.

5.1.41 Point of last full open.

The point of last full open is the first point where the projected area of the parachute exceeds the mean projected area of the fully open parachute minus one standard deviation of the projected area of the fully open parachute, and where no subsequent projected area falls below 75 percent of the mean projected area of the fully open parachute.

5.1.42 Predicted reliability.

The reliability of a system based on analytical prediction methods, but not actual tests or operational experience.

5.1.43 Primary body.

A primary body is a valuable object that is upstream of, and acted upon by, the parachute in flight or on the ground. The primary body may be an airborne crewmember, a data capsule, a supply package, or an entire air vehicle. The primary body is also referred to as suspended load, payload, and forebody.

5.1.44 Prime system.

The prime system is the system for which the parachute is an immediate subsystem; for example, the prime system for a type 1 parachute is an ejection seat.

5.1.45 Recovery parachute.

A recovery parachute includes all the items that are required to recover an object from flight and to deliver it safely on the ground or on the water with a minimum of damage or to terminate with aerial retrieval. The recovery parachute generally includes a first-stage parachute, an intermediate parachute, and a final recovery parachute; controlling devices; actuating devices; and landing or flotation devices, or both.

5.1.46 Reefing.

Reefing is a restriction of a drag-producing surface (usually at the skirt) to a diameter that is less than its diameter when it is fully inflated. Reefing is used to decrease the opening shock, to decrease the drag area, and to enhance stability.

5.1.47 Remotely piloted vehicles.

Remotely piloted vehicles (RPV) are ground launched or air launched air vehicles that use ground control or autonomous navigation; weigh up to 7,000 pounds; and perform reconnaissance, electronic countermeasure, strike, or other mission functions in support of operational aircraft. The velocities for RPV range from 50 knots to high subsonic speeds.

5.1.48 Sealed parachute.

A sealed parachute is a parachute enclosed in an environmentally sealed container.

5.1.49 Service life.

Service life of a parachute or component begins on the date when the parachute or component is first placed in service (or upon opening of manufacturer's package) and ends when a predetermined time period has elapsed.

5.1.50 Shelf/total life.

Shelf/total life of a parachute or component begins on the date of manufacture and ends when a predetermined time period has elapsed.

5.1.51 Snatch force.

Snatch force is a force of short duration that is imposed by the sudden acceleration of the canopy mass at the instant of complete extension of the suspension lines or similar components of a parachute prior to inflation of the canopy.

5.1.52 Standard conditions.

The standard conditions for this specification are :

    a. Temperature   15 ^{o}C (59 ^{o}F)

    b. Pressure   1.01325 bars

    c. Density   1.2250 kilograms per cubic meter (kg/m^3)

5.1.53 Static line.

A static line is a line, a cable, or a webbing, with one end fastened to the pack, the canopy, or the deployment bag and the other end fastened to the launching aircraft. The static line is used to open a pack or to deploy a canopy.

5.1.54 Suspended load.

The suspended load is all weight suspended below the risers.

5.1.55 Temporary cross canopy partial inversion.

A temporary cross canopy partial inversion occurs when the part of the skirt that is starting to turn inside out during the opening of the parachute passes under another part of the skirt on the opposite half of the canopy and then pulls back through so that the canopy will be completely right side out.

5.1.56 Temporary lateral gore partial inversion.

A temporary lateral gore partial inversion occurs when the part of the skirt that is starting to turn inside out during the opening of the parachute passes under another part of the skirt on the same half of the canopy and then pulls back through so that the canopy will be completely right side out.

5.1.57 Touchdown canopy.

Touchdown canopy is a term that is used as an alternate for ground roll canopy.

5.1.58 Unattached auxiliary equipment.

Unattached auxiliary equipment is equipment that must interface with the parachute during parachute operation but is not attached to the parachute and primary body combination at the time of initiation; that is, retrieval equipment used to snatch a vehicle that is descending by parachute prior to ground impact.

5.2 Acronyms, abbreviations, and symbols.

The acronyms, abbreviations, and symbols used in this handbook are defined as follows:

A	amperes
AAES	Aircrew Automated Escape System
AGL	above ground level
AME	Aviation Structural Mechanic (US Navy rating)
AMSDL	Acquisition Management Systems and Data Requirements Control List
^{o}C	degrees Celsius
CDRL	Contract Data Requirements List
CFR	Code of Federal Regulations
deg	degrees
deg/s	degrees per second
DID	Data Item Description
DMMH/FH	direct maintenance man hour per flight hour
DoD	Department of Defense
DoDISS	Department of Defense Index of Specifications and Standards
EMC	electromagnetic compatibility

EMI	electromagnetic interference
EMR	electromagnetic radiation
^{o}F	degrees Fahrenheit
FAR	Federal Acquisition Regulations
FMECA	failure modes, effects, and criticality analysis
FSCM	Federal Supply Code for Manufacturers
ft	feet
ft/min	feet per minute
ft/s	feet per second
g	gravity units
GFE	Government furnished equipment
g/ft^3	grams per cubic foot
HERO	hazards from electromagnetic radiation to ordnance
hrs	hours
Hz	hertz
I	Intermediate level of maintenance
ICAO	International Civil Aviation Organization
in^2	square inches
in^3	cubic inches
IRIG	Inter-range Instrumentation Group
K	degrees Kelvin
KEAS	knots equivalent airspeed
kg/m^3	kilograms per cubic meter
km/hr	kilometers per hour
lb	pounds
lbf	pound-force
lbf/day	pound-force per day
m^3	cubic meters
max	maximum
min	minimum
$M_{max.ct}$	maximum corrective maintenance time

mm/min	millimeters per minute
MTTR	mean time to repair
NAVAIR	Naval Air Systems Command
ns	nanoseconds
NWC	Naval Weapons Center, China Lake, CA 93555-6001
O	Organizational level of maintenance
pcm	pulse code modulation
PR	Aircrew Survival Equipmentman (US Navy rating)
psi	pound-force per square inch
psia	pound-force per square inch absolute
RH	relative humidity
R/M	reliability/maintainability
sec	seconds
V	volts
W/m^2	watts per square meter
s	standard deviation

6. NOTES

(This section contains information of a general or explanatory nature that may be helpful, but is not mandatory.)

6.1 Intended use.

This handbook is intended to be used for guidance in the development of any deployable aerodynamic decelerator (DAD) system or subsystem. The term DAD encompasses any deployable aerodynamic decelerator, flexible or rigid.

6.2 Subject term (key word) listing.

aerial pickup parachute

aircraft deceleration parachutes

airdrop systems

body acceleration

canopy damage

decelerator

parachute

personnel parachute

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vehicle recovery parachute

weapons parachute

CONCLUDING MATERIAL

Custodians: Preparing activity:

    Army - AV   Air Force - 11

    Navy - AS

    Air Force - 11

Review activities: (Project No. 15GP-0013-12)

    Air Force - 82, 99

STANDARDIZATION DOCUMENT IMPROVEMENT PROPOSAL

I RECOMMEND A CHANGE:	1. DOCUMENT NUMBER JSSG-2010-12	2. DOCUMENT DATE (YYMMDD) 981030

3. DOCUMENT TITLE

Crew Systems Deployable Aerodynamic Decelerator (DAD) Systems Handbook

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, Middle Initial)	b. ORGANIZATION	

c. ADDRESS (include Zip Code)	d. TELEPHONE (Include Area Code
	(1) Commercial
	
	(2) AUTOVON
	  (If applicable)
		e. DATE SUBMITTED
		  (YYMMDD)

8. PREPARING ACTIVITY

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c. ADDRESS (Include Zip Code)
BLDG 560
2530 LOOP ROAD W
WRIGHT-PATTERSON AFB OH 45433-7101
	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	

DD FORM 1426, OCT 89 (EF-V1)   PREVIOUS EDITIONS ARE OBSOLETE