NOT MEASUREMENT SENSITIVE

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02 April 1992

DEPARTMENT OF DEFENSE HANDBOOK

MASS PROPERTIES CONTROL FOR SPACE VEHICLES

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Do not cite this document as a requirement

AMSC N/A

FSC 1810

FOREWORD

This handbook is approved for use by all Departments and Agencies of the Department of Defense. This handbook replaces MIL-STD-1811, 02 April 92, Mass Properties Control For Space Vehicles

This handbook is for guidance only. This handbook should not be cited as a requirement. If it is cited as a requirement, the contractor is not compelled to comply.

This handbook is intended for use in preparing acquisition and study contracts for selected space systems and space vehicles. The handbook should be used to determine mass properties control requirements to be cited in the contract statement of work as appropriate to the acquisition. Additional guidance may be found in the Mass Properties CPAT and the Guide Specification Space System documents.

The handbook may also be used by the contractors mass properties managers and engineers to provide guidance in developing and implementing a sound mass properties control program for space vehicles.

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

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by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

CONTENTS

1 SCOPE - This handbook provides guidance for establishing uniform procedures for the control, determination, and documentation of mass properties of space vehicles and their subsystems and components.

1.1 Purpose. The general purpose of this handbook is to describe terminology, processes and procedures for developing sound mass properties engineering practices. This handbook is derived from the applicable documents References 1 and 2. Reference 1 has been incorporated into the main body of this handbook. Reference 2 was modified and incorporated as Appendix E. As such, the handbook contains some sections which are applicable primarily to United States Government space vehicle development and acquisition programs. Other sections are more general in nature, describing terminology, processes, and procedures which are generally accepted in the industry, and reflect sound mass properties engineering practices in the development and production of space vehicles. Its applicability may therefore be extended to commercial contracts and company internal space vehicle development programs as deemed appropriate. An industry standard, incorporating the intent of Reference 1,has been developed and maintained by the Society of Allied Weight Engineers (S.A.W.E.) as a recommended practice (Reference 4 of applicable documents).

1.2 Application. This handbook is intended for use in acquisition and study contracts for selected space systems and space vehicles. This handbook may also be used as a reference document to specify mass properties control requirements for upper stage vehicles, injection stages, satellite payloads, reentry vehicles, launch vehicles, ballistic vehicles, or for other vehicles. For these applications the term “space vehicle” is to be interpreted as the applicable vehicle.

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 in this handbook.

1.MIL-STD-1811 (USAF) “Military Standard - Mass Properties Control for Space Vehicles”, 12 August 1991.

2. MIL-M-38310B (USAF), Amendment 2 “Military Specification - Mass Properties Control Requirements for Missile and Space Vehicles”, 15 June 1974.

3. SAWE Recommended Practice No. 6 Issue No. 1 dated 3 January 1995.

4. SAWE Recommended Practice No. 11 Revision A, dated 20 May 1997.

2.2 Government documents.

2.2.1 Specifications, standards, 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 issue of the Department of Defense Index of Specifications and Standards (DoDISS) and supplements thereto, cited in the solicitation.

2.3 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 DEFINITIONS

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

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

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

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

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

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

4 GENERAL REQUIREMENTS

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

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

5 DETAIL REQUIREMENTS

5.1 Control program.

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

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

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

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

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

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

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

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

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

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

5.2 Determination..

5.2.1 Changes. A documented accounting of all weight changes should be maintained throughout the contract. For all weight changes the accounting should include the magnitude of the change and the reasons for the changes. Each weight change in the accounting should be identified as being the responsibility of the contractor or the contracting officer (if due to a change in the contract requirements). This accounting should be updated when the mass properties are updated (See 5.1.7). Appendix D provides recommended weight change codes and a general description of the types of changes for each category. It is recommended that, as a minimum, the weight changes be gathered into these categories and accumulated throughout the Program.

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

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

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

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

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

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

5.2.6.2 Contents. The uncertainty analysis should include a detailed analysis of each uncertainty source with a description of the derivation of the uncertainties. The uncertainties should include, but are not limited to, measurement uncertainties, manufacturing variations, environmental effects, and uncertainties derived or assumed for mass properties estimations or calculations. If weight growth is included in the analysis, an explanation of how it is combined with the other sources of uncertainty is required. Documentation of the analysis should be available for review by the contracting officer.

5.2.7 Verification.

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

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

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

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

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

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

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

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

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

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

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

5.3 DOCUMENTATION SUMMARY.

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

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

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

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

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

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

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

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

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

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

5.3.3.7.1 Recommended Practice. Guidelines for reporting the mass properties of flight vehicles have been developed by the Society of Allied Weight Engineers (S.A.W.E.) in applicable document Reference 3. It is recommended that these guidelines be utilized when developing a reference axis system.

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

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

5.3.4.1 Detail Weight Statement. The detail weight statement should tabulate the current weights by subsystem (See 5.2.8) to a level of detail as described in paragraph B.3.2 of Appendix B.

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

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

6 NOTES

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

6.2 Subject term (key word) listing

Mass Properties
Mass Properties Control
Weight Growth
Basic Mass Properties

6.3 Supersession data.

This issue of MIL-HDBK-1811 is a complete revision.

APPENDIX A

MASS PROPERTIES VERIFICATION PLAN

A.1 SCOPE - This Appendix is a guide for preparing a Mass Properties Verification Plan. The purpose of the verification Plan is to provide a document which the contracting officer can use to review the contractor's planned methods for verifying the space vehicle mass properties. This review includes assessing the acceptability of the planned methods and the availability of acceptable mass properties measurement equipment and measurement sites.

A.2 REFERENCED DOCUMENTS

(Not Applicable).

A.3 REQUIREMENTS

A.3.1 Selected Methods Description. The Verification Plan should include a general description of the method selected to verify each mass property which is to be used in performance analyses, stability and control analyses, or other analyses which require mass properties data as an input. The element of the space vehicle for which the mass properties data have been developed should be described. For example, if the mass moments of inertia about the hinge line of a deployable element have been specified or established by design limits, the Verification Plan should describe the element being deployed and state if the mass moment of inertia is to be verified by test or analysis. If a combination of methods is planned, state the portions to be verified by each method.

A.3.2 Substantiation of Method Selection. Analyses should be made to substantiate the methods selected to verify the mass properties. Technically logical explanations of the methods selected, particularly for analytical verifications, should be included in the contractor's substantiation of the methods selected.

A.3.3 Test Plans. General test plans should be prepared. The plans should include a description of the item or items to be tested and the mass properties limits. A general description of the testing equipment, including its accuracy, and a calibration schedule should be included. A test schedule showing the planned test site, planned schedule, and articles to be tested should be included. The use of mass simulators instead of flight items in any test should be accurately documented.

APPENDIX A

MASS PROPERTIES VERIFICATION PLAN

A.10.0 GENERAL - This section is another guide for preparing the mass properties verification plan discussed in par. 5.2.7.1 and 5.3.2 The following items should be included.

a. Analytical Verification Items.

1. Items

2. Analytical substantiation that test is not required for these items.

b. Experimental Verification Items.

1. Items to be verified by experiment.

2. Analytical substantiation that test is required for these items.

3. Estimated costs of proposed tests.

A.20.0 TEST PLAN - For each item to be tested, or for each block of tests, list the following:

a. Measurement objectives, including measurement to be performed and overall accuracy required.

b. Description of the test setup, including the location, measurement system proposed, equipment, fixtures, pertinent dimensions and reference datum locations, and environmental control provisions.

c. Measurement procedures, number of successful runs required, the use of average readings from a number of independent measurements, and the requirements for complete unloading, unbalance or shutdown of equipment between measurement readings.

d. Instrumentation calibration procedure and schedule.

e. Statement of overall uncertainty of the measurement system, with supporting analysis of the system showing calibration and systematic error analysis. The measurement system analysis should indicate possible sources of random error, their method of estimation, and their possible effect on the precision of measurement, and should show the method of combining different sources of error to obtain a value for overall uncertainty of the measurement process. The analysis also should indicate the relationship of the uncertainty with the required accuracy.

f. Schedule, including equipment availability dates and test start and completion dates.

g. Test reporting plan, including submittal schedules, for reports containing the following minimum information:

1. Explanation of deviations from test plan.

2. Summary of data.

3. Evaluation of results.

4. Final conclusion of results.

5. Recommendations.

APPENDIX B

FUNCTIONAL BREAKDOWN OF WEIGHT

B.1 SCOPE- -Space vehicles are comprised of subsystems which perform specific functions. Examples of two subsystems are structural support for equipment and electrical power. Useful subsystem information is generated when component weights are accumulated on a functional basis. The uses of functional subsystem weights include the tracking of functional weight during design for weights proposed for new vehicles, and the improvement of the database used for the refinement of weight-estimating methods. It is necessary to strive for consistency regarding which components comprise each subsystem if the objectives of subsystem weight estimation and evaluation are to be achieved. Consideration should also be given to the configuration for which actual weight data will be obtained. The following sections provide guidelines for achieving this consistency.

B.2 REFERENCED DOCUMENTS - JSC-23303 "Design Mass Properties, Guidelines and Formats for Aerospace Vehicles", dated March 1989, (NASA Johnson Space Center)

B.3 REQUIREMENTS

B.3.1 Establishment of a Subsystem List. In accordance with Section B.1, wherein the functional basis is discussed, a list should be established which names each of the subsystems comprising the space vehicle. Since the term "space vehicle" is representative of a large variety of vehicles with a wide range of complexities, specifying a comprehensive subsystem list in this Appendix is not considered advisable. However, two subsystem lists are given in Tables B-I and B-II which are intended to serve as guides. Additional guidelines can be found in JSC 23303. The contractor should develop a subsystem list suitable for the space vehicle being developed. This contractor's list should contain subsystems in at least as much detail as represented in Tables B-I and B-II.

B.3.2 Subsystem Breakdown.

B.3.2.1 Second Level of Detail. Each subsystem total weight should be broken down to a second level of detail. This second level of detail should be constructed to provide useful information for weight estimation and evaluation. For example, useful information is provided when a satellite electrical power subsystem is broken down into components of solar array, batteries, and power conditioning. Representative subsystem breakdowns to a second level of detail are shown in Tables B-I and B-II. The information in Tables B-I and B-II is intended to be a guide. The contractor should establish the applicable second level weight breakdown and it should be at least to the level of detail represented in Tables B-I and B-II.

B.3.2.2 Subsequent Levels of Detail. A breakdown of the second level of detail to a third level may be useful. Examples of this are shown in Tables B-I and B-II. As in the case of the second level of detail, the third level may be needed for weight evaluation and estimation. The Contract Data Requirements List (CDRL), incorporated into the contract, may require the contractors subsystem list, the second-level-of-detail list, and any subsequent level-of-detail lists, to be prepared for review and approval by the contracting officer.

APPENDIX B

B.3.3 Functional Coding. The contractor should develop a functional code which is consistent with the subsystem list and level of detail lists described in Sections B.3.1 and B.3.2 of this Appendix B. The code format is not specified. As weights are determined they should be coded and accumulated by the codes.

B.3.3.1 Ambiguities. In the process of coding items to a function, ambiguities are likely to occur. For example, a solid propellant motor case may have two functions; propulsion and basic structure. A cylindrical portion of a motor case may be partially designed by the loads produced by the payload the launch vehicle carries and partially designed by the case internal pressure. The domes are designed by the internal pressure and the motor case skirts are designed by axial and bending loads. Another example would be the structure used to support the solar cells on a deployable solar array panel. Arguments can be made for either a structure or electrical power functional code. The numerous small equipment support provisions can be coded to either structure or the function of the equipment supported. Similar ambiguities arise in the case of wiring, plumbing, or thermal doublers.

B.3.3.2 Resolution of Ambiguities. For those items which have more than one function, the contractor should code them to the primary function. If the choice is not obvious, the contractor may make an arbitrary decision. When arbitrary decisions are made for items constituting at least 10 percent of the subsystem weight, the contractor should maintain descriptive titles in the mass properties records of the space vehicle. This permits the transfer of these items from one function to another at the discretion of the contracting officer.

APPENDIX B

TABLE B-I

SAMPLE FUNCTIONAL BREAKDOWN (SATELLITE)

1. Payload

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

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

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

5. Guidance, Navigation

6. Data Management

7. Telemetry, Tracking, Command

8. Orientation Control

9. Reaction Control

10. Propulsion

11. Weight Growth Allowance

12. Fluids

APPENDIX B

TABLE B-II

SAMPLE FUNCTIONAL BREAKDOWN (Liquid Propulsion Stage)

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

2. Thermal Control

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

4. Orientation Control (Thrust Vector Control)

5. Secondary Power
   - 5.1 Electrical
   - 5.2 Hydraulic

6. Instrumentation

7. Range Safety and Abort

8. Weight Growth Allowance

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

APPENDIX B

TABLE B-III

SAMPLE FUNCTIONAL BREAKDOWN (REENTRY SYSTEM)

1. Aerodynamic Surfaces
2. Body Structure
3. Induced Environment Protection
4. Launch, Recovery and Docking
5. Main Propulsion
6. Orientation Controls, Separation and Ullage
7. Prime Power Source
8. Power Conversion and Distribution
9. Guidance and Navigation
10. Instrumentation
11. Communication
12. Environmental Control
13. Armament
14. Personnel Provisions
15. Crew Station Controls and Panels
16. Range Safety and Abort
    16a. Weight Growth Allowance
17. Personnel
18. Cargo
19. Ordnance
20. Ballast
21. Residual Propellant and Service Items
22. Reserve Propellant and Service Items
23. Inflight Losses (Liftoff to Separation)
24. Thrust Decay Propellant
25. Full Thrust Propellant
26. Thrust Propellant Buildup
27. Pre-Ignition Loses

Appendix B

TABLE B-III FUNCTIONAL CODE

FIRST GENERATION	1. AERODYNAMIC SURFACES
SECOND GENERATION	THIRD GENERATION
1.1 Fixed Surfaces	Basic structure Leading edge Trailing edge Secondary structure Trim devices Insulation Exterior finish and sealer
1.2 Movable Surfaces	Basic structure Leading edge Trailing edge Secondary structure Trim devices Insulation Exterior finish and sealer
1.3 Fairings and Associated Structure (Including Insulation)	Forward fairings Center Fairings Tail fairings Air intakes Cable conduits Ice shields Equipment fairings Exterior finish and sealer

Appendix B

TABLE B-III FUNCTIONAL CODE

FIRST GENERATION	2. BODY STRUCTURE
SECOND GENERATION	THIRD GENERATION
2.1 Structural Fuel Tank	Skin (including welds) Ring frames, stringers, longerons, struts, and tie rods Beams and shear panels Forward bulkhead Aft bulkhead Fittings Bracket, doublers, gussets, etc. Cutouts and associated structure Container wall insulation - inner Container wall insulation - outer Forward bulkhead insulation - inner Forward bulkhead insulation - outer Aft bulkhead insulation - inner Aft bulkhead insulation - outer Antislosh devices
2.2 Structural Oxidizer Tank	Skin (including welds Ring frames, stringers, longerons, struts, and tie rods Beams and shear panels Forward bulkhead Aft bulkhead Fittings Bracket, doublers, gussets, etc. Cutouts and associated structure Container wall insulation - inner Container wall insulation - outer Forward bulkhead insulation - inner Forward bulkhead insulation - outer Aft bulkhead insulation - inner Aft bulkhead insulation - outer Antislosh devices
2.3 Structural Propellant Tank (Common Bulkhead)	Skin (including welds Ring frames, stringers, longerons, struts, and tie rods Beams and shear panels Forward bulkhead Common bulkhead (including insulation) Aft bulkhead Fittings Bracket, doublers, gussets, etc. Cutouts and associated structure Container wall insulation - inner Container wall insulation - outer Forward bulkhead insulation - inner Forward bulkhead insulation - outer Aft bulkhead insulation - inner Aft bulkhead insulation - outer Antislosh devices

Appendix B

TABLE B-III FUNCTIONAL CODE

FIRST GENERATION	2. BODY STRUCTURE Cont'd)
SECOND GENERATION	THIRD GENERATION
2.4 Structural Solid Propellant Case or Tank	Forward closure assembly Cylinder assembly Aft closure assembly Nozzle adapter Attaching assemblies Insulation
2.5 Structural Enclosing Nonintegral Tank	Skin (including welds Ring frames, stringers, longerons, struts, and tie rods Beams and shear panels Bulkheads Fittings Bracket, doublers, gussets, etc. Cutouts and associated structure Insulation - inner Insulation - outer Platforms and catwalks
2.6 Structural Forward of Integral Tank	Skin (including welds) Ring frames, stringers, longerons, struts, and tie rods Beams and shear panels Bulkheads Fittings Bracket, doublers, gussets, etc. Cutouts and associated structure Insulation - inner Insulation - outer Platforms and catwalks
2.7 Structural Between Integral Tank	Skin (including welds) Ring frames, stringers, longerons, struts, and tie rods Beams and shear panels Bulkheads Fittings Bracket, doublers, gussets, etc. Cutouts and associated structure Insulation - inner Insulation - outer Platforms and catwalks
2.8 Structural Aft of Integral Tanks	Skin (including welds) Ring frames, stringers, longerons, struts, and tie rods Beams and shear panels Bulkheads Fittings Bracket, doublers, gussets, etc.

Appendix B

TABLE B-III FUNCTIONAL CODE

FIRST GENERATION	2. BODY STRUCTURE Cont'd)
SECOND GENERATION	THIRD GENERATION
2.8 Structural Aft of Integral Tanks (cont'd)	Cutouts and associated structure Insulation - inner Insulation - outer Platforms and catwalks Skin (including welds) Ring frames, stringers, longerons, struts, and tie rods
2.9 Thrust Structure	Beams and shear panels Bulkheads Fittings Bracket, doublers, gussets, etc. Cutouts and associated structure Hold-down posts Insulation
2.10 Interstage/Spacer/ Vehicle Instrument Unit Structure	Skin (including welds) Ring frames, stringers, longerons, struts, and tie rods Beams and shear panels Bulkheads Fittings Bracket, doublers, gussets, etc. Cutouts and associated structure Insulation - inner Insulation - outer Platforms and catwalks
2.11 Pressurized Compartment	Bulkheads Rings Webs Frames Longerons Stringers Covering (skin, including welds) Reinforcements Partitions Floor (acting as structural member) Hatches and airlocks Windows and ports Firewalls Pressure seals Brackets, doublers, gussets, etc.
2.12 Nonpressurized Compartment	Bulkheads Rings Webs Frames Longerons Stringers Covering (skin, including welds)

Appendix B

TABLE B-III FUNCTIONAL CODE

FIRST GENERATION	2. BODY STRUCTURE Cont'd)
SECOND GENERATION	THIRD GENERATION
2.12 Nonpressurized Compartment (cont'd)	Reinforcements Partitions Floors (acting as structural member) Hatches and airlocks Windows and ports Firewalls Pressure seals Brackets, doublers, gussets, etc.
2.13 Ballast	Ballast for longitudinal center of gravity control Ballast for radial center of gravity control Ballast for weight simulation
2.14 Multipurpose Equipment-Containers, Panels Supports	
2.15 Exterior Finish and Sealer	

Appendix B

TABLE B-III FUNCTIONAL CODE

FIRST GENERATION	3. INDUCED ENVIRONMENT PROTECTION
SECOND GENERATION	THIRD GENERATION
3.1 Thermal Protection (Active)	Ablator Insulation Reinforcements Release mechanism Fairings Attaching structure Bonding material
3.2 Thermal Protection (Passive)	Insulation Reinforcements Release mechanism Fairings Attaching structure Bonding material
3.3 Noise Protection	Insulation Attaching structure Bonding material
3.4 Meteorite Protection	Bumper Supports Stiffeners Filler Shield Attaching structure
3.5 Radiation Protection	Shielding Attaching structure

Appendix B

TABLE B-III FUNCTIONAL CODE

FIRST GENERATION	4. LAUNCH, RECOVERY, AND DOCKING
SECOND GENERATION	THIRD GENERATION
4.1 Launch Gear	Struts Pads Fittings Deploying devices Sequencing devices Controls Braces Power source Shock attenuation devices Structure Attachment fittings Tie-down fittings
4.2 Deployable Aerodynamic Devices	Droque parachute Main parachute Pilot parachute Paraglider Structure Sequencing controls
4.3 Landing Gear	Struts Pads Fittings Deploying devices Sequencing devices Controls Braces Power source Shock attenuation devices Solid brake rocket cases Liquid brake rockets Structures
4.4 Flotation Gear	Container Flotation devices Power Source Control devices Sequencing devices Deployment devices Structure
4.5 Docking Structure	Rings Seals Latching mechanisms Repositioning devices Separation devices Fairings

Appendix B

TABLE B-III FUNCTIONAL CODE

FIRST GENERATION	4. LAUNCH, RECOVERY, AND DOCKING (Cont'd)
SECOND GENERATION	THIRD GENERATION
4.6 Recovery Aids	Visual Communication Tracking Landing Structure

Appendix B

TABLE B-III FUNCTIONAL CODE

FIRST GENERATION	5. MAIN PROPULSION
SECOND GENERATION	THIRD GENERATION
5..1 Liquid Rocket Engine and Accessories	Thrust chamber Turbopump Engine mounts (attached to engine) Gimbal mounts and thrust frame (attached to engine) Propellant plumbing (attached to engine) Gas generator and igniter (less ordnance) Lubrication system Controls Hydraulic system Pneumatic system Electrical system Heat exchangers and exhaust ducts Purge system
5.2 Solid Propellant Engine and Accessories	Nozzle - fixed Nozzle - movable Propellant container (nonstructural) Engine attachment fittings Igniter (less ordnance) Controls Insulation - inner Insulation - outer Safe and arm system (less ordnance) Thrust termination system (less ordnance)
5.3 Nuclear Power Plant and Accessories	Propellant feed system (including turbopump attached to engine) Reactor (including shielding) Thrust chamber (including nozzle) Thrust structure (attached to engine) Cooling system Controls Pneumatic system Hydraulic system Destruct system (less ordnance)
5.4 Ion Engine and Accessories	Propellant feed system (including turbopump including turbopump)) Reactor (including shielding) Thrust chamber (including nozzle) Thrust structure (attached to engine) Cooling system Pneumatic system Hydraulic system Turbine Power generating system Destruct system (less ordnance)

Appendix B

TABLE B-III FUNCTIONAL CODE

FIRST GENERATION	5. MAIN PROPULSION Cont'd)
SECOND GENERATION	THIRD GENERATION
5.5 Photon Engine and Accessories	Power source Light source Reflector Destruct system (less ordnance) Controls
5.6 Air Breathing Engine and Accessories	Propellant feed system Thrust structure Thrust chamber Turbine Compressor Controls Air induction
5.7 Purge System for Stage Chilldown	Bottles and supports Valves and nozzles Controls Plumbing and fittings Manifolds Ducts for chilldown or purge gas (including brackets and attaching hardware) Buckets or collectors for disposal
5.8 Fuel Container (Nonstructural)	Structure Baffling and antivortex webs Liners Bladders Fill and drain provisions Vents Sumps Sensors Supports Insulation
5.9 Fuel System	Pump installation (including power supply attached to engine) Fill and drain system Distribution or suction system Replenishing system (if separate) Transfer system Vent system Purge system Antivortex devices Exclusion risers Sensing controls
5.10 Pressurization System - Fuel	Tank structure Supports Fill and drain provisions Vents Sumps

Appendix B

TABLE B-III FUNCTIONAL CODE

FIRST GENERATION	5. MAIN PROPULSION Cont'd)
SECOND GENERATION	THIRD GENERATION
5.10 Pressurization System - Fuel (cont'd)	Sensors Plumbing Valves and regulators Insulation Heat exchanger Sensing controls
5.11 Oxidizer Container (Nonstructural)	Structure Baffling and antivortex webs Liners Bladders Fill and drain provisions Vents Sumps Sensors Support Insulation
5.12 Oxidizer System	Pump installation including power supply (not attached to engine) Fill and drain system Distribution or suction system Replenishing system (if separate) Transfer system Vent system Purge system (if separate) Antivortex devices Exclusion risers Sensing controls
5.13 Pressurization System - Oxidizer	Tank structures Supports Fill and drain provisions Vents Sumps Sensors Plumbing Valves and regulators Insulation Heat exchanger Sensing controls
5.14 Auxiliary Fluids System	Tanks and Supports (not integral with structure) Pump installation including power supply (not attached to engine) Fill and drain system Distribution or suction system Replenishing system (if separate) Transfer system Vent system

Appendix B

TABLE B-III FUNCTIONAL CODE

FIRST GENERATION	5. MAIN PROPULSION Cont'd)
SECOND GENERATION	THIRD GENERATION
5.14 Auxiliary Fluids System (cont'd)	Tank pressurization system Purge system (if separate) Antivortex devices Exclusion risers Sensing controls
5.15 Propellant Utilization system	Plumbing Valves Regulators Supports

Appendix B

TABLE B-III FUNCTIONAL CODE

FIRST GENERATION	6. ORIENTATION CONTROLS, SEPARATION, AND ULLAGE
SECOND GENERATION	THIRD GENERATION
6.1 Thrust System (Main)	Thruster Injection system Gimbal system (if not integral) Insulation Protective devices Case Liner Ignition system (less ordnance) Nozzles Structure
6.2 Thrust System (Auxiliary)	Thruster Injection system Gimbal system (if not integral) Insulation Protective devices Case Liner Ignition system (less ordnance) Nozzles Structure
6.3 Aerodynamic Control	Roll Pitch Yaw
6.4 Spatial Control	Roll Pitch Yaw Stabilizing electronics
6.5 Separation	Structure Rocket Cases Fairings Controls, sequencing equipment, and wiring Jettison system Power supply
6.6 Ullage (Separate from 6,4,6.5)	Structure Rocket Cases Fairings Controls, sequencing equipment, and wiring
6.7 Fuel Containers	Tanks Bladders Baffles Fill and drain provisions Sensors and valves Insulation Structure

Appendix B

TABLE B-III FUNCTIONAL CODE

FIRST GENERATION	6. ORIENTATION CONTROLS, SEPARATION, AND ULLAGE (Cont'd)
SECOND GENERATION	THIRD GENERATION
6.8 Oxidizer Containers	Tanks Bladders Baffles Fill and drain provisions Sensors and valves Insulation Structure
6.9 Pressurization	Tanks Liners Fill and drain provisions Insulation Plumbing Sensors and valves Sequencing Structure
6.10 Distribution and Control - Fuel	Plumbing Valves and regulators (indicate injection valves) Insulation Structure
6.11 Distribution and Control - Oxidizer	Plumbing Valves and regulators (indicate injection valves) Insulation Structure
6.12 Thrust Structure	Ring Frame Supports Fittings Skin Insulation Stringers
6.13 Artificial Gravity	

Appendix B

TABLE B-III FUNCTIONAL CODE

FIRST GENERATION	7. PRIME POWER SOURCE
SECOND GENERATION	THIRD GENERATION
7.1 Power Source -	Engine Engine pump unit Engine generator unit Gas Generator unit Gas generator Fuel storage Plumbing Valves and pumps
7.2 Power Source - Fuel Cell	Fuel cell - nonregenerative modules and internal voltage controls Fuel container Oxidizer container Reactant controls - H_2 (including plumbing, heat exchangers, etc.) Reactant controls - O_2 (includes plumbing, heat exchangers, etc.) Plumbing and valves Radiator, nonstructural (area) Electrical controls - coolant, reactant Pumps - coolant Structure Purge system Electrical coupling system (integral)
7.3 Power Source - Batteries	Battery (quantity)* Battery container and supports Voltage controls Recharge controls Structure Electrical coupling system (integral) Emergency *Identify system usage
7.4 Power Source - Solar Cell	Solar cell Internal wiring Protective diodes (short regulators, etc.) Protective covers and filters Insulation and coatings Reflector Mounting panel or structure (solar paddle, etc.) Structure (including deployment devices) Orienting devices and controls Voltage controls Cooling system Electrical coupling system (integral) Photometric monitoring device

Appendix B

TABLE B-III FUNCTIONAL CODE

FIRST GENERATION	7. PRIME POWER SOURCE Cont'd)
SECOND GENERATION	THIRD GENERATION
7.5 Power Source - Nuclear	Reactor or isotope source Radiation shield Primary systems (tubing, heaters, pumps) Power converter (rotating unit, boiler, structure, regulator, radiator) Heat rejection structure Electrical startup and controls Flight instrumentation (speed, etc.) Destruct system (less ordnance) Structure
7.6 Power Source - Gas Generator	Pressurization tank (force feed system) Pressurization controls (force feed system) Fuel containers Fuel controls Plumbing Valves and controls Decomposition chamber Speed regulator Gas bearing Gear box Turbine Heat exchanger Structure Purge system Voltage control Electrical coupling system (integral)

Appendix B

TABLE B-III FUNCTIONAL CODE

FIRST GENERATION	8. POWER CONVERSION AND DISTRIBUTION
SECOND GENERATION	THIRD GENERATION
8.1 Power Conversion - Electrical (AC)	Generator Transformers Inverters Phase adapters Frequency converters Voltage regulators Constant speed drive Supports
8.2 Power Conversion - Electrical (DC)	Generator Converters Voltage regulators Rectifiers Supports
8.3 Power Conversion - Hydraulic/Pneumatic	Motor pump or compressor Pump or compressor unit (unless integral) Reservoirs Accumulators Filters Pressure regulator Supports
8.4 Power Distribution - Electrical (AC)	Buses Isolation diode system Circuit breakers and switches Relays Electrical coupling Supports
8.5 Power Distribution - Electrical (DC)	Buse Isolator assembly Circuit breakers and switches Relays Electrical coupling Supports
8.6 Power Distribution - Hydraulic/Pneumatic	Valves Controls Plumbing Fluid Supports
8.7 Unity Provisions - Electrical	Pyrotechnic initiator Lights Signal Device
8.8 External Service Provisions	

Appendix B

TABLE B-III FUNCTIONAL CODE

FIRST GENERATION	9. GUIDANCE AND NAVIGATION
SECOND GENERATION	THIRD GENERATION
9.1 Guidance Source - Inertial Reference Stellar Reference Planetary Reference Relative Reference	Programmer Accelerometers Gyros Telescope Sextant Horizon sensor Radar altimeter Rendezvous radar Rendezvous laser Optical sightline sensor Supports
9.2 Guidance Evaluation	Computer Computer keyboard Inertial platform Coupling unit Power and servo assembly Time base selector Gyro electronics Supports
9.3 Output	Electronics package Rate gyros Accelerometers Servo amplifiers Power supply Electrical coupling Supports
9.4 Spares	

Appendix B

TABLE B-III FUNCTIONAL CODE

FIRST GENERATION	10. INSTRUMENTATION
SECOND GENERATION	THIRD GENERATION
10.1 Sensors	Temperature Pressure Flow Volume Leak rate Acceleration Force Vibration Displacement Angular velocity Gas partial pressure Acoustic noise Strain Char and ablation Contamination Bio-medical Structure
10.2 Signal Conditioning	Analog commutator Analog-digital converter Digital commutator Programmer Calibrator Signal conditioning Data storage Structure
10.3 Signal Transmission	Antenna Waveguides Coax Transmitters Structure
10.4 Electrical Coupling	Junction box Cable harness Wire Coax Conduit Clips, clamps, etc. structure
10.5 Support Items	
10.6 Spares	

Appendix B

TABLE B-III FUNCTIONAL CODE

FIRST GENERATION	11. COMMUNICATION
SECOND GENERATION	THIRD GENERATION
11.1 Intercommunication	Transceiver equipment Antenna system structure
11.2 Near Earth Communication	VHF FM transmitter equipment VHF AM transceiver equipment VHF antenna system Structure
11.3 Deep Space Communication	DSIF receiver equipment DSIF transmitter equipment DSIF power amplifier equipment DSIF antenna system Structure
11.4 TV Systems	Cameras Monitor Control equipment and components Structure
11.5 Tracking System	
11.6 Spares	Intercommunication Near earth Deep space Tracking system Television
11.7 Electrical Coupling	Junction box Cable harness Wire Coax Conduit Clips, clamps, etc.
11.8 Racks & Supports	

Appendix B

TABLE B-III FUNCTIONAL CODE

FIRST GENERATION	12. ENVIRONMENTAL CONTROL
SECOND GENERATION	THIRD GENERATION
12.1 ECS - Equipment	Insulation Instrument temperature control system Electronic equipment temperature control system Compartment temperature control system Compartment pressurization system Engine cooling system (separate from engine) Fire control system Electrical coupling system Supports
12.2 ECS - Personnel	Insulation Temperature control system Atmosphere control system Pressurization control system Fire control system Electrical coupling system CO_2 and odor removal system Supports
12.3 Coolant System	Insulation Radiator Fluid boiler Plumbing and valves Blowers Heat exchangers Pumps Containers Supports
12.4 Multipurpose Equipment - Containers, Panels, etc.	Supports

Appendix B

TABLE B-III FUNCTIONAL CODE

FIRST GENERATION	13. ARMAMENT
SECOND GENERATION	THIRD GENERATION
13.1 Safety and Arming	Devices (less ordnance) Supports
13.2 Detonating	Devices (less ordnance) Supports
13.3 Warhead Provisions	Supports Checks Accessories

Appendix B

TABLE B-III FUNCTIONAL CODE

FIRST GENERATION	14. PERSONNEL PROVISIONS
SECOND GENERATOIN	THIRD GENERATION
14.1 Accommodations for Personnel	Seats Supports Restraints - seat Liners shock absorbers Adjustment mechanisms Bunks Sleeping restraints
14.2 Fixed Life Support Equipment	Food containers Water containers Waste management Hygiene equipment Galley equipment
14.3 Cargo Handling	Rails Attachment fittings
14.4 Furnishings	Partitions Soundproofing Flooring (nonstructural) Lifts and hoist Stairs and ladders Platforms Catwalks
14.5 Emergency Equipment	Fire extinguisher (build-in_ Fire detection Life raft provisions Life raft (built-in)

Appendix B

TABLE B-III FUNCTIONAL CODE

15. CREW STATION CONTROLS AND PANELS	
SECOND GENERATION	THIRD GENERATION
15.1 Pedestal	Orientation, separation and ullage Propulsion Environment Navigation and guidance Prime power source Communication Instrumentation Range safety and abort
15.2 Control Stands	Orientation, separation and ullage Propulsion Environment Navigation and guidance Prime power source Communication Instrumentation Range safety and abort
15.3 Instrument Panels	Orientation, separation and ullage Propulsion Environment Navigation and guidance Prime power source Communication Instrumentation Range safety and abort
15.4 Crew Station Controls (Flight)	Control - roll - pitch - yaw Connecting members for above Supports

Appendix B

TABLE B-III FUNCTIONAL CODE

FIRST GENERATION	16. RANGE SAFETY AND ABORT
SECOND GENERATION	THIRD GENERATION
16.1 Sensors	
16.2 Signal Conditioning	
16.3 Signal Transmission	
16.4 Signal Evaluation	
16.5 Destruct System	Destruct receiver Range safety beacon Power supply Controls Supports
16.6 Electrical Coupling System	
16.7 Service Items	
16.8 Spares	
16.9 Debris, Re-entry	

FIRST GENERATION	16A. WEIGHT GROWTH ALLOWANCE
SECOND GENERATION	THIRD GENERATION

Appendix B

TABLE B-III FUNCTIONAL CODE

FIRST GENERATION	17. PERSONNEL
SECOND GENERATION	THIRD GENERATION
17.1 Crew	Crew Constant wear garments Personnel comm. headset and belt pack Pressure suit
17.2 Personal Gear	Portable life support system Garments - protective Personal parachutes Hygienic equipment Privacy curtains
17.3 Life support	Food Food containers (portable) Water Water drinking device Galley equipment (portable) Recreation equipment. Exercise equipment Medical and first aid equipment Survival kit (portable)
17.4 Crew Accessories	Maps and manuals Log book Maintenance tools Fire extinguisher (portable)

Appendix B

TABLE B-III FUNCTIONAL CODE

FIRST GENERATION	18. CARGO
SECOND GENERATION	THIRD GENERATION
18.1 Scientific Instruments	
18.2 Experiments	
18.3 Cargo	

Appendix B

TABLE B-III FUNCTIONAL CODE

FIRST GENERATION	19. ORDNANCE
SECOND GENERATION	THIRD GENERATION
19.1 Propulsion Ordnance	Igniters Safe and arm Thrust termination Destruct
19.2 Orientation Controls, Separation and Ullage	Igniters (thrust systems) Separation
19.3 Prime Power Source	Destruct (nuclear systems)
19.4 Armament	Safe and arm Detonating Warhead
19.5 Range Safety and Abort	Destruct (vehicle)

Appendix B

TABLE B-III FUNCTIONAL CODE

FIRST GENERATION	21. RESIDUAL PROPELLANT AND SERVICE ITEMS
SECOND GENERATION	THIRD GENERATION
21.1 Fuel Pressurizing Gas - As Container Residual	
21.2 Oxidizer Pressurizing Gas - As Container Residual	
21.3 Fuel Trapped - Main Engine	Tank Lines - between sump and engine pumps Engine - below pump inlet Sump Fill lines
21.4 Oxidizer Trapped - Main Engine	Tank Lines - between sump and engine pumps Engine - below pump lines Sump Fill lines
21.5 Fuel - Outage Main Engine	
21.6 Oxidizer - Outage Main Engine	
21.7 Fuel Trapped - Auxiliary Propulsion System	Tank Lines Engine
21.8 Oxidizer Trapped - Auxiliary Propulsion System	Tank Lines Engine
21.9 Fuel - Outage Auxiliary Propulsion System	
21.10 Oxidizer - Outage Auxiliary Propulsion System	

Appendix B

TABLE B-III FUNCTIONAL CODE

FIRST GENERATION	21. RESIDUAL PROPELLANT AND SERVICE ITEMS (Cont'd
SECOND GENERATION	THIRD GENERATION
21.11 Fuel Trapped - Electrical Power	Tank Lines Converter
21.12 Oxidizer Trapped - Electrical Power	Tank Lines Converter
21.13 Service Items Trapped - Including Non-expendables	Pressurizing gases (not inpropellant tanks) Purge system gases Pneumatic system gases Air-bearing system gases Ejection system gases Hydraulic fluid Lubricants Fuel additives Environment control fluids Spatial attitude control propellants Propellants for landing or recovery

Appendix B

TABLE B-III FUNCTIONAL CODE

FIRST GENERATION	22. RESERVE PROPELLANT AND SERVICE ITEMS
SECOND GENERATION	THIRD GENERATION
22.1 Fuel Pressurizing Gas Reserves	
22.2 Oxidizer Pressurizing Gas reserves	
22.3 Fuel - Main Engine Reserve	
22.4 Oxidizer - Main Engine Reserve	
22.5 Fuel Pressurizing Gas Reserves Auxiliary Propulsion Systems	
22.6 Oxidizer Pressurizing Gas Reserve - Auxiliary Propulsion Systems	
22.7 Fuel Reserves - Auxiliary propulsion Systems	
22.8 Oxidizer Reserves - Auxiliary Propulsion Systems	
22.9 Fuel - Electrical Power Reserve	
22.10 Oxidizer - Electrical Power Reserve	
22.11 Fuel - Atmospheric Cruise	

Appendix B

TABLE B-III FUNCTIONAL CODE

FIRST GENERATION	22. RESERVE PROPELLANT AND SERVICE ITEMS (Cont'd)
SECOND GENERATION	THIRD GENERATION
22.12 Oxidizer - Atmospheric Cruise	
22.13 Service Item Reserves	

Appendix B

TABLE B-III FUNCTIONAL CODE

FIRST GENERATION	23. INFLIGHT LOSSES (LIFTOFF TO SEPARATION)
SECOND GENERATION	THIRD GENERATION
23.1 Vented pressuring Gas-Fuel system	
23.2 Vented Pressuring Gas-Oxidizer system	
23.3 Fuel - Auxiliary Pro-pulsion System	Pressure relief losses Normal burning
23.4 Oxidizer - Auxiliary Propulsion system	Pressure relief losses Normal burning
23.5 Fuel - Electrical System	Pressure relief losses Normal burning
23.6 Oxidizer - Electrical System	Pressure relief losses Normal burning
23.7 Service Items	Pressurizing gasses (not in propellant tanks) Purge system gases Pneumatic system gases Air-bearing system gases Ejection system gases Hydraulic fluid Lubricants Fuel additives Environmental control fluids Spatial attitude control propellants Frost Separation system propellants Ullage system propellants

Appendix B

TABLE B-III FUNCTIONAL CODE

FIRST GENERATION	24. THRUST DECAY PROPELLANT
SECOND GENERATION	THRID GENERATION
24.1 Fuel - consumed During Thrust Decay	Container Sumps Lines Engines
24.2 Oxidizer - Consumed During Thrust Decay	Container Sumps Lines Engines
24.3 Solid Propellant - Consumed During Thrust Decay	
24.4 After-Cooling Propellants (Nuclear)	Container Sumps Lines Engines
24.5 Service Items	Pressurizing gases (not in propellant tanks) Purge system gases Pneumatic system gases Air-bearing system gases Ejection system gases Hydraulic fluid Lubricants Fuel additives Environmental control fluids Spatial attitude control propellants Frost Separation system propellants Ullage system propellants

Appendix B

TABLE B-III FUNCTIONAL CODE

FIRST GENERATION	25. FULL THRUST PROPELLANT
SECOND GENERATION	THIRD GENERATION
25.1 Fuel	
25.2 Oxidizer	
25.3 Solid Propellants	

Appendix B

TABLE B-III FUNCTIONAL CODE

FIRST GENERATION	26. THRUST BUILDUP PROPELLANT
SECOND GENERATION	THIRD GENERATION
26.1 Fuel	Pressurizing gases Fuel
26.2 Oxidizer	Pressurizing gases Oxidizer
26,3 Solid propellants	
26.4 Auxiliary Propulsion System	
26.5 Service Items	

Appendix B

TABLE B-III FUNCTIONAL CODE

FIRST GENERATION	27. PRE-IGNITION LOSSES
SECOND GENERATION	THIRD GENERATION
27.1 Fuel	Pressurizing gases Fuel
27.2 Oxidizer	Pressurizing gases Oxidizer
27.3 Prime Power Source	
27.4 Service Items	Purge system gases Pneumatic system gases Air-bearing system gases Ejection system gases Hydraulic fluid Lubricants Fuel additives Environmental control fluids Spatial attitude control propellants Frost Emergency abort system propellants

APPENDIX C

DESIGN DATA

C.1 SCOPE. This appendix is a guide for reporting design parameters which have major influences on space vehicle subsystem weights.

C.2 REFERENCED DOCUMENTS.

(Not Applicable).

C.3 MAJOR REPORTING PARAMETERS. The following categories of data are useful for evaluating subsystem weights during the early design phase and for the improvement of weight estimating techniques.

C.3.1 Unmanned Satellite

a. Vehicle sketch giving major dimensions

b. Design Life

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

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

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

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

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

APPENDIX C

C.3.2 Liquid Propellant Stage

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

b. Structural materials and types

c. Tank design pressures

d. Safety factor

e. Structural design conditions, loads

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

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

C.3.3 Solid Propellant Stage

a. Vehicle sketch giving major dimensions.

b. Chamber pressure - average and maximum expected

c. Safety factor

d. Case structural material, number of segment joints

e. Burn time

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

g. Thrust vector control type

h. Propellant density, loading fraction

a. Specific impulse - sea level, vacuum

C.3.4 Reentry Vehicle

a. Vehicle sketch giving major dimensions

b. Lift to drag ratio

APPENDIX C

c. Thermal protection system type

d. Wetted area (total)

e. Pressurized volume

f. Mission duration

g. Structural materials and types

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

i. Safety factor

j Ultimate load factor and associated weight

k. Stabilizing and control surface areas

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

m. Propellant type, mixture ratio, densities

n. Reaction control system type, propellant type

o. Auxiliary propulsion system type, propellant type

p. Crew size

APPENDIX C

MASS PROPERTIES DEPENDENT DESIGN INFORMATION

C.10.0 GENERAL DESIGN INFORMATION This section lists the major dimensional factors and design criteria used in the development of mass properties estimating techniques and comparative studies. The following criteria are general design items.

Ballistic coefficient (W/C_dA)
Actual drag coefficient
Mach number
Reynolds number
Lift-to-drag ratio
Type of guidance
Length
Maximum diameter
Width
Depth
Nose radius
Cross sectional area (maximum)
Wetted area
Pressurized body area
Window area
Drag and lift reference area
Total volume
Body volume pressurized
Cone half angle(s)
Stage weight-carrying limitations
Mission duration
Orbit altitudes
Total velocity increment required

C.11.0 FUNCTIONAL DESIGN INFORMATION The following list of design information is intended as a guide for data submittal. Vehicle items are listed in accordance with the first-generation functional code (discussed in Appendix B).

1. Aerodynamic Surfaces (for each surface type)

Type
Material(s), types and properties
Aspect ratio
Fineness ratio
Safety factor
span
Theoretical root chord - length
Theoretical root chord - thickness

APPENDIX C

Tip chord - length
Tip chord - thickness
Mean aerodynamic chord
Projected area
wetted area
Sweepback at leading edge
Sweepback at 25% chord
Surface loading
Critical design conditions and resulting critical design loads

2. Body Structure (for each major structural entity)

Type of structure (pressurized, monocoque, skin, stringer, etc.)
Material(s), types and properties
Safety factor
Length
Diameter
Skin thickness
Gross tank volumes
Tank design pressures
Maximum available volume for ballast
Design temperature
Maximum expected operating pressure
Center of pressure location and static margin
Critical design conditions and resulting critical design loads

3. Induced Environmental Protection (for each major environmental entity)

Material(s), types and properties
Manufacturing technique
Application method
Safety factor (value and definition)
Thickness
Gross area
Critical design conditions and resulting critical loads

4. Launch, Recovery and Docking

Design and operating parameters governing weight
Critical design conditions and resulting critical design loads

5.0 Propulsion

5.1 Main Propulsion

Number
Material(s), types and properties

APPENDIX C

Types of construction
Expansion ratio
Port-to-throat ratio
% of nozzle submerged
Shape of nozzle
Motor mass fraction (total propellant weight divided by total motor weight)
specific impulse - sea level
Specific impulse - vacuum
Characteristic exhaust velocity
Throat action time
Wet action time
Thrust coefficient (C_f)
type of thrust vector control
Total impulse
Chamber pressure (P_c) - average
Chamber pressure (P_c) - maximum
Critical design conditions and resulting critical design loads

5.2 Liquid Engines

Number
Material(s), types and properties
Type of propellant feed
Type of construction
Type of cooling - thrust chamber
Type of cooling - nozzle extension
Number of starts
Throttling ratio
Expansion ratio
Characteristic exhaust velocity
Mixture ratio
Ignition type
Specific impulse - sea level
Specific impulse - vacuum
Thrust coefficient
Design burn time
Thrust - sea level
Thrust - vacuum
Throat area
Exit area
Chamber pressure (P_c) - average
Chamber pressure (P_c) - maximum
Net positive suction head
Propellant flow rte - total and components
Design propellant temperature range

Critical design conditions and resulting critical design loads

5.3 Thrust Vector Control

Type
Roll control thrust
Roll angular acceleration requirement
Maximum axial thrust misalignment
Longitudinal angular acceleration requirement
Normal force produced
Critical design conditions and resulting critical design loads

5.4 Other Propulsion Subsystems

Design and operating parameters governing weight
Critical design conditions and resulting critical design loads

6-20 Orientation Control, Separation and Ullage Through Ballast

Design and operating parameters governing weight
Critical design conditions and resulting critical loads

21-27 Propellants and Service Items

Solid Propellant(s)
Composition and properties
Loading ration - propellant volume to case volume
Web traction
Web Thickness to propellant radius
Specific heat ratio
Storage/operating temperatures
Flame temperature
Characteristic exhaust velocity
Burning rate
Sliver percentage
Burning surface area

APPENDIX C

PARAMETERS AND INVENTORY OF FLUIDS AND PROPELLANTS LOADED

C.20.0 GENERAL This section is intended as a guide for the presentation of data required for establishing the parameters and inventory of fluids and propellants loaded.

C.20.0 FLUID PROPELLANTS - MAIN ENGINE

C.20.1 Parameters of Maximum Loadable Weight. The following parameters are for the total load limited by the engine inflight mixture ratio (MR) requirement on effective burning propellants.

a. Engine number(s)

b. MR of engine(s) - (indicate actual or specified).

1. Acceptance MR at standard conditions.

2. Average inflight MR (indicate whether inclusive of consumption by gas generators, vernier engines, etc. and include reference to the current MR production analysis).

c. Tankage volumes at loading and at total gross weight conditions for each propellant (indicate actual or specified).

1. Gross tankage (total cavity above letdown valve).

2. Required ullage volume (include reference to the current ullage analysis).

3. Net maximum loadable volume (c1 - c2).

4. Volume below each discrete tank level which is significant in establishing the loaded or terminal weight of propellant.

d. Propellant bulk temperature - each propellant (highest assumed before ignition).

e. Ullage pressure at loading and tanking secure.

f. Propellant bulk density - each propellant (lowest assumed before ignition).

g. Maximum loadable weight vs average inflight MR - each propellant and total propellant.

C.20.2 Inventory of Load. The following inventory is for each propellant and total (lb).

a. Total nominal propellant loaded.

b. Propellant expanded before liftoff (total and details of bleed, leakage, venting, start, holdown, etc.).

c. Total propellant aboard at liftoff (a - b).

d. Propellant expanded during flight (total and details of bleed leakage, venting, effective burning, shutdown, etc. For each major flight stage before separation of stage being reported).

e. Total propellant aboard at the end of each major flight stage.

f. Propellant aboard at separation of stage (total and details of trapped propellants and other system unusables), and reserve propellants (including propellant vapor retained).

C.20.3 Outage. State any outage parameters, biases for outage if used, and indicate the mean and maximum probable outage. Account for these factors as used in the inventory. Include reference to the current outage prediction analysis.

C.20.4 Temperature and Density. Present the variations of loading bias, mean outage, maximum outage, average inflight mixture ratio, and propellant density with temperatures in the range around that assumed for loading at the scheduled launch period. Include reference to the current temperature prediction analysis.

C.21.0 OTHER FLUID LOADS For all other fluid loads (nonpropellant), the following parameters and inventory apply.

C.21.1 Parameters of Maximum Loadable Weight. State the parameters defining maxi-mum loadable weight of each fluid, including, as applicable, gross volumes, limiting and net volumes, pressures, temperatures, gas constants or density.

C.21.2 Inventory of Load. State the inventory of each fluid as loaded, and details of utilization, trapped and reserve quantities during the major flight stages and at separation of the stage.

C.22.0 SOLID PROPELLANTS LOADED

C.22.1 Parameters of Maximum Loadable Weight. Identify the total case volume, the total volume occupied by the maximum loadable propellant, and the remaining volumes unoccupied by propellant. State all parameters which directly limit and establish the maxi-mum loadable propellant.

C.22.2 Inventory of Propellant Loaded. Inventory the propellant weights assigned to each principal phase of propellant utilization during flight and total same to the total propellant loaded in each solid motor segment or case.

C.22.3 Sliverage. State values of the parameters used to establish the sliverage and indicate the mean and maximum sliverage. Include reference to the current sliverage prediction analysis.

C.22.4 Thrust/Time Curve. Provide the current thrust/time curve which matches the weight of the propellant loaded.

APPENDIX C

CAPACITY AND LOADING INFORMATION FOR FLUIDS AND PROPELLANTS

C.30.0 GENERAL This section lists the nominal information required to determine the parameters and procedures for pre- and post-flight evaluation of the loaded and unexpended fluid and propellant mass properties.

C.31.0 FLUID SYSTEMS For fluid systems, provide the following information:

a. Sketches of liquid propellant and fluid system, on which are noted such items as tank and plumbing volumes, loading volumes, sensors, ports, net positive suction head (NPSH), vortex levels, “letdown” valve levels and other significant discrete level locations.

b. Derivation of total usable and trapped volumes; presentation of nominal liquid volumes vs station levels for the various temperature, pressure and acceleration conditions expected.

c. Synoptic derivation and discussion of minimum ullage volumes, with reference to the basic ullage analysis documents.

d. Synoptic derivation and discussion of techniques for predicting the mean and maximum propellant outage, with reference to the basic outage prediction analysis.

e. Synoptic description and discussion of anticipated propellant temperature and rise rates at the launch site for each calendar month, with reference to the basic temperature prediction program.

f. Synoptic descriptions of loading methods and procedures for control of the fluid weight as loaded, with reference to the basic methods and procedures documents.

g. Presentation of gas constants (R), propellant and liquid densities vs temperature, pressure and other environments expected.

h. Synoptic descriptions of test and flight instrumentation and procedures to deter-mine the initial loadings and unexpended propellant and fluid weights from flight and static tests.

C.32.0 SOLID SYSTEMS For solid systems, provide the following information:

a. Sketches of propellant system in plan, and significant cross-sections showing stations and dimensions for:

1. Grain configuration at initial loading and ignition.

2. Significant burntime grain configurations.

3. Typical terminal configurations of sliverage at end of web action time and end of action time.

4. Liner, insulation and bonding.

5. Igniter and thrust termination systems.

b. Volumetric data for:

1. Total case capacity.

2. Propellant, insulation and liner for conditions (a-1), (a-2), and (a-3) above.

c. Densities of propellants, insulation, linear and bonding materials.

d. Synoptic description of loading methods and procedures for control of the solid weight as loaded.

APPENDIX D

Weight Change Codes and General Description

Code	Description
1	**Better definition of the design** (Design maturation) As the design progresses beyond the proposal stage the design criteria and requirements become better defined and optimistic assumptions made during the proposal cannot be justified. These changes are generally early in the program but prior to drawing release.
2	**Out of scope changes** These are new scope changes caused by the customer adding or changing the requirements for the contracted vehicle beyond that of its original proposal.
3	**Redesign** When the original component or subsystem design criteria need to be changed due to: repackaging, failure of a component during testing, impact of other subsystem changes, etc.
4	**Maturing component design** Improvements in weight analysis due to updates in drawings after original release. (Item #1 generally relates to weight analysis prior to drawing release.)
5	**Error in previous estimate** The reason for change is an error in the weight calculations for an original or later estimate.
6	**Uncontrolled vendor changes** If none of the other change codes apply then this category is a catch all for vendor weight changes over which you have very little control.
7	**Weight reduction activity** Changes due to official weight reduction efforts.
8	**Measured vs. calculated** The differences caused by actual measured weights of components as opposed to the latest calculated value.
9	**Cost reduction, added weight** Where weight increases were incurred to save money, i.e., substitution for expensive exotic materials, machinery costs reduced by eliminating elaborate machined parts and cutouts, etc.

APPENDIX E

MIL-M-3810B
AMENDMENT 2
15 January 1976
Modified to be incorporated
as an Appendix E of Dept. of
Defense Handbook MIL-HDBK-
1811 26 November 1997

MASS PROPERTIES CONTROL REQUIREMENTS
FOR MISSILE AND SPACE VEHICLES

1. SCOPE

1.1 General. This document originally provided a means to establish a system for the management of mass properties during the conceptual, validation, (full scale) development production, and deployment for surface-to-surface ballistic vehicles, space launch vehicles, spacecraft, satellites and reentry vehicles, or portions thereof. It was designed to facilitate rapid establishment and reporting of data for the weight/performance relationship critical to validation and full-scale development; to permit the acquisition of systematized, traceable, verifiable, and controllable mass properties of these systems and subsystems during the production and deployment phases for use in operational integrated system targeting and planning or R&D and to enable parametric extrapolation from the reported systems to newly evolving systems. This document was superseded by Mil-Std-1811.

1.2 Limitations. The elements of this document are not to be placed on contract, but are listed to provide a comprehensive collection of elements from which selection may be made as appropriate for the discrete requirements of each program.

7 Index for Appendix E

7.1 Index

3. REQUIREMENTS

3.1 Objectives

3.1.1 General. A system of mass properties management should be established to ensure fulfillment of the program mass properties objectives and compliance with contractual requirements.

3.1.2 Development of Objectives. The contractor should develop achievable mass properties objectives and should assist the procuring activity in specifying General System Specification mass properties requirements, and their proper allocation to the Configuration Element(s) Specifications(s) requirements. During the initial development of, or any subsequent change to, mass properties objectives, the contractor should give particular attention to substantiating data, mass properties dependent design performance information and the critical mass properties uncertainties analysis.

3.1.3 Development of Limits. Throughout the contract, the contractor should develop and maintain cognizance of the vehicle mass properties limits whether established by contract, system performance or by subsystem design. The compatibility of total system mass properties requirements with the configuration element(s) requirements should be assessed to assure that the program objectives are met.

3.1.4 Specified Mass Properties Base. The specified mass properties base should be as approved by the procuring activity.

3.1.5 Weight Growth Allowances. The contractor should develop and substantiate appropriate weight growth allowances consistent with prior experience.

3.2 Studies, Planning, Cognizance and Control

3.2.1 Studies

3.2.1.1 Trade Studies Methodology. Adequate methodology and tools should be developed, or existing methodology and tools adapted, to support trade studies involving mass properties inputs. Such methodology and tools may be curves, computer programs, or any suitable means for relating major design parameters to significant mass properties and providing parametric assessment of inter-system and intra-system mass properties during trade studies leading to item selection.

3.2.2 Planning

3.2.2.1 Program Plan. The contractor should develop a master plan for a system of mass properties control which will ensure fulfillment of the program mass properties objectives. Both technical and organizational needs should be considered. Necessary supporting plans should be identified.

3.2.2.2 Supporting Plans. The contractor should develop supporting plans for the system of mass properties control to ensure the effective execution of control functions such as analysis, verification, improvement, reporting and operational field support. The impact of changes to critical mass properties on these plans should be assessed and changes to the plans should be formulated.

3.2.2.3 Plan Review. The contractor should be prepared to review any plan concerning the program system of mass properties control with the procuring activity.

3.2.2.4 Coordination. After go-ahead and prior to first report submittal, the contractor should be prepared to review with the procuring activity:

(a) The interpretation of contractual requirements.

(b) The planned mass properties management program.

3.2.2.5 Personnel. Qualified personnel should be assigned the responsibility and authority to assure the establishment and maintenance of mass properties objectives, and the effective planning and execution of mass properties control functions.

3.2.2.7 Weight Growth Allowance Depletion. The contractor should develop a planned approach for the control and reporting of the depletion of weight growth allowances over the time period from contract authority to proceed to contract completion.

3.2.3 Cognizance

3.2.3.1 Monitoring. Each item, and the operating characteristics of transfer, loading, and utilization systems should be analyzed and monitored continuously to establish current mass properties and their trend.

3.2.3.2 Uncertainty Analyses. The uncertainty associated with each of the Critical Mass Properties should be established by analytical methods. These established uncertainties should be used in dispersion studies, for analytical verification of computed nominal values, and in the identification of system elements which warrant verification by experimental methods.

3.2.3.3 Subcontractor Surveillance. The contractor should be responsible for the adequacy of each subcontractor's system of mass properties control. An appropriate mass properties section, comparable to and compatible with the contractual requirements, should be incorporated in each procurement document affecting system mass properties.

3.2.3.4 Associate Design Activity and GFE Suppliers Interfaces. Associate Design Activities and GFE Suppliers should be responsible for the interchange of sufficient mass properties data to support the integration of sub-unit mass properties into the complete unit mass properties and should promptly respond to requests from the interfacing and integrating contractors for information required by them in satisfaction of contractual requirements.

3.2.3.5 Supplemental Data. The contractor should be prepared to provide, in an expeditious manner, existing supplemental data or informal inputs for any report.

3.2.3.6 Trade Studies Inputs. The contractor should determine and maintain, in a form available for review by the procuring activity, the following:

(a) System mass properties inputs used in trade studies and other screening processes for including or excluding designs for future study.

(b) The effect on system mass properties of each trade study, whether or not performed as a mass properties trade.

3.2.3.7 Identification of Changes. The contractor should provide and maintain in a form available for review by the procuring activity, an account which identifies the nature, magnitude and sequence of each change in proposed mass properties from the initiation to the termination of the program.

3.2.3.8 Review Meeting Support. - Technical support should be provided for review meetings involving system mass properties, viz:

(a) In-house management review meetings.

(b) Associate contractor and/or sub-contractor interface meetings.

(c) Review meetings with the procuring activity.

3.2.3.9 Relationships. Mass properties data provided by the contractor in response to contractual requirements should employ the definitions of paragraph 6.3 and the functional code of Appendix B, and should be presented in a manner which will facilitate the rapid establishment of their relationship to current performance, design and mission functions of the item.

3.2.3.10 Interface with Associate and Integrating Contractors. The contractor should be responsible for the timely interchange of sufficient mass properties information to support the integration of subsystem mass properties into system level mass properties by requesting needed information from the pertinent contractor(s) and agency and by responding promptly to like requests for information from the contractor(s) and agency.

3.2.3.11 System Engineering. All Associate Contractors' reported mass properties should be evaluated by the contractor and integrated to provide management visibility of system level mass properties status, of major problems encountered, and/or progress made in the mass properties management program. The contractor's evaluation of reported system mass properties should ensure the technical accuracy of these inputs for integration purposes and their compatibility with current program baselines and objectives. When the interests of program data currency and compatibility require adjustments to these inputs prior to system level integration such adjustments should be made and the affected supplier of the data should be notified promptly of the change, the reason for the change, and the proposed manner of incorporation. Every effort should be made to obtain approval from the affected supplier for such adjustment prior to incorporation, however approval must be obtained in all cases.

3.2.3.12 Reference Base. The system mass properties base at the initiation of the contract should be defined for reference purposes only. This base has no control implications.

3.2.4 Control

3.2.4.1 Control Parameters. The time projected weight should be used as weight control parameter; all other mass properties should utilize the specified mass properties base for control and reporting.

3.2.4.2 Improvement Action

3.2.4.2.1 Means to Meet Specified Mass Properties. Mass properties control personnel, working with analytical, design and management personnel, and considering such constraints as reliability, performance, schedule and cost, should determine means to insure that specified mass properties are met or bettered.

3.2.4.2.2 Improvement Potentials. A summary of all improvement potentials which could be used to offset mass properties or performance degradation should be established and maintained. Mass properties analyses for all alternative design configurations should be conducted.

3.2.4.2.3 Problem Definition. The procuring activity should be notified immediately of any problem requiring improvement action, with a statement of the problem and the potential effect on mass properties and performance when:

(a) Program objectives are endangered.

(b) Established control parameters have been reached or exceeded.

3.2.4.2.4 Corrective Action. The contractor should take, or recommend to the procuring activity, actions which will correct the recognized deficiencies.

3.2.4.2.5 Limiting Condition Analyses. Analyses should be performed to assist the procuring activity in the establishment and maintenance of mass properties limits. Analyses should be performed to establish and maintain other mass properties limits created by mandatory and acceptable system objectives and functions. Analyses should consider current system design and operating characteristics.

3.2.4.2.6 Document Release. Documents controlling the design, manufacture and procurement of system components should be approved, prior to release, by personnel responsible for the contractor's mass properties control effort. Such approval should signify component acceptability in satisfaction of system mass properties objectives and the currency of the mass properties accounting system. Release without approval should be so noted.

3.3 Verification

3.3.1 Verification of Critical Mass Properties. Each Critical Mass Property and its conformance to limits should be verified by the contractor. Verification should be performed by approved analytical or experimental methods, or by a combination of both.

3.3.2 Configuration Item Verification. Configuration Item mass properties should be verified by approved analytical or experimental methods, or by a combination of both.

3.3.3 Detail Part Verification. Detail part mass properties should be verified by approved analytical or experimental methods, or by a combination of both.

3.3.4 Measurement Conditions. Item measurements performed in accordance with procuring activity approved procedures should satisfy the following conditions at the time of measurement:

(a) The item should simulate the dry flight condition and be at least 95 percent complete by weight, excluding hazardous components or components not normally installed at the measurement site.

(b) The manufacturing status of the item should be documented.

(c) A representative of the contractor's mass properties control section should be present.

3.3.5 Notification of Measurement. In all cases of measurements to be performed in accordance with procuring activity approved procedures, the contractor should notify the procuring activity of the time and place at least one week in advance.

3.3.6 Data Records. Mass properties verification data should be recorded and maintained in a form available for review by the procuring activity. Actual mass properties data records should be provided, in accordance with approved procedures for each major measurement performed.

3.3.7 Post-Flight Analyses. The contractor should determine, by analysis of post-flight data, the actual system mass properties for the initial and terminal conditions of flight and compare these actual conditions to the planned conditions. Each difference in mass properties should be itemized, explained and the effect on system performance capability defined. Adequate instrumentation and procedures should be provided, subject to approval by the procuring activity, to ensure the capability for post-flight determination of system mass properties.

3.3.8 Field Support of Launch Operations. The contractor should provide adequate mass properties support to launch operations. This support should maintain mass properties inputs to flight planning which are in agreement with the actual vehicle configuration and the planned loading and utilization of fluids.

3.4 Documentation. Data that are submitted in accordance with any Contract Data Requirements List (CDRL) should conform to the requirements of this document, unless otherwise specified by the procuring activity.

3.4.1 Types of Reports Required. The required reports are described by the following general types. Their specific composition is set forth in a CDRL and may vary according to the phase of procurement. The report elements should be as described in paragraph 3.4.3 unless otherwise specified by the procuring activity.

3.4.1.1 Detail Mass Properties Reports. Reports in this category provide comprehensive detail reference documentation of the mass properties as they exist at initial, intermediate and final stages of procurement. Submittals occur at specified times in the Conceptual, Validation, Development and Production phases. Vehicles or vehicle blocks reported upon should be those specified by the procuring activity.

3.4.1.2 Mass Properties Status Reports. Reports in this category provide a current status of the mass properties, of changes since the last report, and of problems encountered and progress made in tasks associated with the mass properties control program. Submittals occur at specified intervals during the Conceptual, Validation. Full Scale Development, Production and Deployment phases. Submittals also occur at specified events during flight preparation and launch of each vehicle. Vehicles or vehicle blocks reported upon should be those specified by the procuring activity.

3.4.1.3 Procedural Reports. - Reports in this category provide outlines of the contractor's approach for satisfying the requirements of this document. Initial submittals occur sufficiently in advance of implementation to permit their review and approval.

3.4.1.4 Miscellaneous Reports. Submittal dates for the following reports in this category cannot be specified in this document.

3.4.1.4.1 Contract Change Proposals. Information to evaluate and substantiate the effect on vehicle mass properties from proposed changes. Submittal occurs with the Change Proposal.

3.4.1.4.2 Test Results. Results of testing to verify parameters for the mass properties of fluids or propellants submitted in accordance with the design activity's Mass Properties Verification Plan.

3.4.1.4.3 Operational Targeting Data. Mass Properties targeting information submitted in accordance with the Operational Support Plan for Targeting.

3.4.2 Report Format

3.4.2.1 General. This section recommends the basic format requirements for reports.

3.4.2.1.1 Unit System of Measure. Data contained in the required mass properties reports should be in the unit system specified by the procuring activity.

3.4.2.1.3 Coding. Unless otherwise specified or approved by the procuring activity, the definitions in paragraph 6.3 of this Appendix and the functional code in Appendix B can be used to provide a uniform basis for mass properties comparisons and to facilitate preparation of mass properties summaries. Where contract responsibility includes items comprising more than one step, the components for each step should be tabulated separately in each report.

3.4.2.1.4 Coordinate Axes. To provide a common reference basis for all mass properties, performance and design data, the coordinate axes and notation system from Reference 3 should be used.

3.4.2.2 Report Elements. Unless otherwise specified by the procuring activity, reports should be composed of those applicable described in Section 3.4.3.

3.4.3 Report Element Description

3.4.3.1 Title Page. A title page should contain the following information, as applicable:

(a) Report number.

(b) Type of submittal,

(c) Vehicle flight number.

(d) Step, stage or module.

(e) Applicable serial numbers.

(f) Date of issuance.

(g) Actual date of data reported.

(h) Contractor's name.

(i) Mission identification.

3.4.3.2 Table of Contents. - A Table of Contents is a listing of the report elements and their location within the report.

3.4.3.3 Review for Management. - The Review for Management should present a summary of the significant material contained in the report.

3.4.3.3.1 Management Review Tabulations. - Reports containing a Mass Properties Summary should include a concise management review tabulation presenting the following, as applicable:

(a) Weights - revised Specified Weight Base, last current status and current status, together with the change from last to current for:

(1) Total dry weight.

(2) Residuals and reserves.

(3) Dry weight items jettisoned and ablated during flight.

(4) Subtotal of (1) less (3) (minimum burn-out weight).

(5) Total available design thrust propellants.

(6) Ignition weight.

(7) Maximum loadable tank capacity (main propellants).

(b) Control Parameter Encroachment - for each mass property which has reached or exceeded its control parameter, specify the following:

(1) Control parameter and its associated limit.

(2) Current mass property value.

(3) Accuracy or uncertainty of the current value.

(c) Highlights of newly encountered problems.

(d) Graphs presenting the current weight with respect to the time projected weight and the specified weight as typified in Figure 3.

3.4.3.4 Organization. Furnish organization charts and descriptive material to identify the key personnel responsible for mass properties control, their relationship to other elements of the organization and the percentage of their time devoted to the contract. These data should be up-dated whenever changes occur.

3.4.3.5 Mass Properties Summary. Summarize current mass properties detail data in an orderly build-up to the dry, terminal, lift-off ignition, and gross weight conditions, as applicable. Expenditures, reserves and residuals should be clearly identified in the build-up. The minimum acceptable amount of information reported should be as follows:

(a) Code - first and second generation functional code, except for propulsion systems which should be carried to at least the third generation. See Appendix B.

(b) Description - appropriate functional code nomenclature or summary title.

(c) Specified Weight Base - original specified weight base.

(d) Procuring Activity and Government Furnished Equipment (GFE). Out of scope changes resulting from procuring activity initiated changes and /or GFE changes.

(e) Revised Specified Weight Base - The sum of (c) and (d).

(f) Current Weight.

(g) Changes, last to current, Contractor Responsibility in-scope changes in current weight since last report.

(h) Changes, last to current, procuring activity responsibility out of scope changes in current weight since last report.

(i) Percentage Breakdown of Current Weight - Percent of reported current weight which was based on estimates, drawing calculations, or actual weights.

(j) Note Number - Reference numbers for explanatory notes, remarks, or change identification.

(k) Center of Gravity - current centers of gravity.

(l) Moment of Inertia - current moments of inertia.

3.4.3.6 Detail Mass Properties. Provide a complete breakdown of the item's current mass properties. These data should include, but not be limited to, the following:

(a) Code - Applicable first, second and third generation functional code, except for propulsion systems which should be carried to at least the fourth generation.

(b) Description - applicable functional; code and summary titles.

(c) Class - third generation weight as estimated, calculated or actual.

(d) Current Mass Properties.

3.4.3.7 Change Analysis and Improvement Potentials

3.4.3.7.1 Mass Properties Change Analysis. An explanation of significant changes in current mass properties data and of all changes in the Specified Weight Base. All changes in Government Furnished Equipment should be identified and explained.

Each change should be cross-referenced to the Mass Properties Summary Report Element (Paragraph 3.4.3.5) and the Sequenced Mass Properties Data Element (Paragraph 3.4.3.10) as applicable. The minimum acceptable amount of information shown in this element should be as follows:

(a) Note Number - reference number corresponding to the note number in the Mass Properties Summary Element or the Sequenced Mass Properties Data Element.

(b) Code - Recommended change codes are shown in Appendix D

(c) Change, Total - total change in mass properties for each functional code.

(d) Effective Point - vehicle effectivity point, as applicable.

(e) Change, Contractor Responsibility - change in mass properties as a result of in-scope changes.

(f) Change, Procuring Activity Responsibility - change in mass properties resulting from out of scope changes.

(g) Remarks - Description of each change, the authority for the change and the effects of the change on the mass properties dependent design information. Changes that result from reconciliation of predicted values with actual measurement of configuration elements, or major portions thereof, should be fully identified.

3.4.3.7.2 Pending Mass Properties Change Analysis. Each significant pending change in mass properties, including contract change proposals, should be reported. The following minimum information should be submitted with each pending change.

(a) Change Identification - case number assigned by the contractor or the customer.

(b) Code - see Appendix D

(c) Change - current and pending mass properties for each affected code together with the total mass properties change.

(d) Effective Point - vehicle number or approximate data when pending change will be incorporated.

(e) Remarks - explanation of each change, including reference correspondence, change order number, drawing number and other pertinent data.

3.4.3.7.3 Summary of Improvement Potentials. Tabulate all mass property improvement potentials which could be used to offset degradations. Include Identification or Case Number and best estimates of effects on mass properties, schedules, costs, reliability and effectivity, when available. Indicate whether technical feasibility is established or requires further study. Items which have been rejected should be accumulated separately, together with the reasons for rejection.

3.4.3.8 Unresolved Problems. All problems that may affect mass properties should be reported at the earliest possible time including the system affected, action being taken and an estimate of when the problem will be resolved.

3.4.3.9 Historical Log. Provide a record of the item's mass properties configuration at the time of the first major measurement and for each subsequent change. The first log entry should record the "as measured condition" mass properties of the item and identify the Actual Mass Properties Data Record (3.4.3.18) from which the data were extracted. A copy of the shortage list contained in the variance items (3.4.3.18.2c) should accompany each copy of the log from the time of the first entry. Subsequent log entries should be recorded each time a part is added, removed or relocated, with corresponding adjustments made in the shortage lists, when applicable. If the procuring activity has not established measurement requirements for center of gravity and inertia data, calculated data may be used. Log sheets should be sequentially numbered. Log entries should be in chronological order.

3.4.3.10 Sequenced Data. This report element should contain weight, balance and inertia data on the step/stage/vehicle for each major event of the mission and should be reported. The contractor should use current detail data and engineering information to develop mass properties for each mission event. These data should start with the step/stage/vehicle at ground ignition and continue throughout the mission to separation, impact and recovery, as applicable. The mass properties and code numbers of items subtracted from

the totals in getting from one event to another should be shown. The information reported in this section should be the following, as applicable:

(a) Code - functional code number.

(b) Description - functional code title or mission event.

(c) Weight - current weight. Significant changes since the previous report should be underlined and cross-referenced to the change analysis element (Paragraph 3.4.3.7).

(d) Center of Gravity - center of gravity location measured from the reference datum. Significant changes since the previous report should be underlined and cross-referenced to the change analysis element.

(e) Moment of Inertia - current moment of inertia. Significant changes since the previous report should be underlined and cross-referenced to the change analysis element.

(f) Product of Inertia - where required, columns may be added for the presentation of products of inertia.

(g) Angels of Intersection - where required, between the principal and geometric axes.

3.4.3.11 Powered Flight Data. This report element should contain mass properties data used to derive performance information. It should include, but not be limited to, the following:

(a) Tabulation or plot of weight, center of gravity, pitch, yaw and roll moments of inertia versus mission time.

(b) Assumptions made and data used to derive these mass properties (propellant weights, propellant duration, liquid inertias during flight, engine parameters, ejection time on all items, stage burning time).

(c) Reference should be made as applicable to other report elements from which the above data may be extracted or based upon.

3.4.3.12 Diagrams. Include sketches, curves and drawings (elevation and plan) sufficient to supply the following minimum information:

(a) Principal structural stations and structural interface locations.

(b) Reference datum for the 3-axes moment arms, showing quadrant numbers and gimbal plane stations.

(c) Significant lengths, heights, widths and diameters.

(d) Sections of the vehicle as sectionalized for shipping and handling.

(e) Locations of jig, leveling and weighing points.

(f) Thrust reaction stations, giving direction of thrust and points of application.Where the thrust direction is not fixed the maximum angle of variation should be specified

(g) Center of gravity envelope for stages and the complete vehicle, as applicable.

3.4.3.13 Substantiating Data. Validate the reported mass properties values, and weight growth allowance, by including the analytical, statistical or empirical methods used in their derivations. When the complexity of the equations and computer programs prevents inclusion in the document, a summary should be presented and the detail methods should be readily available for review by the procuring activity. Where values are determined by an accumulation of separate equipment groups, values should be given for each component. These data should be updated whenever changes occur.

3.4.3.14 Government Furnished Equipment. A separate tabulation of all GFE should be prepared for each vehicle step or module of each flight number showing the drawing number and description, serial number where applicable, number required, and the unit, total dry and total wet specified mass properties. Provisions should be included to record the actual unit weight and total weight, and the difference between total specified and total actual weights. Changes to the specified weights of GFE items should be listed.

3.4.3.15 Computer Disks. These are detail mass properties to be prepared in accordance with the procuring activity's instructions.

3.4.3.16 Mass Distribution. Data should be prepared for all critical conditions which depend on mass distribution for their analyses and should be in tabular or graphical form presenting the following information, including supporting calculations:

(a) Weight per unit of longitudinal length representing distributed loads.

(b) Concentrated loads and related reaction points.

(c) Cantilevered loads and related reaction points, moments and moment direction (plus or minus).

3.4.3.17 Design Data for Mass Properties Analysis

3.4.3.17.1 Mass Properties Dependent Design Information. These data include major dimensional factors and design criteria used in the development of the reported mass properties. Appendix C presents a list which should be used as a guide for data submitted.

3.4.3.17.2 Structural Increments for Design Features. Net structural increments for special functions, installations and other design features considered to be other than basic on any major design group should be included. Insofar as practicable, the amount buried or masked in "basic structure" and quantitatively evaluated by some rational procedure should be listed for such items as body joints, major cutouts, removable structural panels, etc. Values should be accompanied by amplifying and clarifying remarks or data verifying the means of determination.

3.4.3.18 Actual Data Records

3.4.3.18.1 General. Records for each major mass properties measurement performed in accordance with the procedures approved by the procuring activity should include:

(a) Location where measurements were performed, signature of authorized individual responsible for the entries, date and time of entries, date of last equipment calibration, document number of the approved measuring procedures and identification of the item measured.

(b) (Provision for the signature of a procuring activity witness on each page of the data record that includes measured data.

3.4.3.18.2 Records for Dry Mass Properties Measurements. Records for dry mass properties measurements should include:

(a) Tables showing the applicable scale readings: tare; net weight; moment arm; moment for longitudinal, vertical and lateral center of gravity; and calculations showing the derivation of the “as measured” weight and center of gravity condition from the measurements.

(b) Measurements taken for the determination of moment and product of inertia and calculations showing the derivation of the “as measured” inertias from the measurements.

(c) Variance Items - A list of items, including a Shortage List, for the weight, center of gravity and inertia data to be added to or subtracted from the “as measured” condition to obtain the actual “dry weight” determination for launch condition.

(d) Diagrams of measuring equipment and related fixtures showing pertinent dimensions and other data required for the determination of the “as measured” weight, center of gravity, and moment and product of inertia.

3.4.3.18.3 Records for Fluid Mass Properties Measurements. Records for fluid mass properties measurements should included:

(a) Explanation of deviations from test plan.

(b) Summary of data.

(c) Evaluation of results.

(d) Final conclusion of results.

(e) Recommendations.

3.4.3.19 Summary of Critical Mass Properties. - Provide a table stating the relationship between the current value and its limiting value for all of the Critical Mass Properties for each mission, including at least the following:

(a) Limiting mass property value.

(b) Current mass property value.

(c) Uncertainty of the current value.

(d) The difference between the limiting mass property value (b) with it's most adversely (plus or minus) uncertainty from (c).

(e) Reference to the current Critical Mass Property Uncertainties analysis and to the current Mass Properties Limits analysis.

3.4.3.20 Evaluation of Flight. Compare the actual launch mass properties and the actual mass properties variations throughout the flight with the predicted mass properties flight data. In liquid propellant systems the evaluation should include analytical extrapolation from the actual propellants at thrust termination to the outage condition which would have existed had burning been to depletion. An evaluation of the critical mass properties, uncertainties and other pertinent data should be included in the final post flight reports to substantiate mass properties contained in the contractor's Final Flight Evaluation Report. Quick Look reports should be confined to gross information and analysis based on the best available sources to confirm either normal flight mass properties conditions or apparent anomalies.

3.4.3.21 Uncertainties. Provide sufficient data for, and analysis of the critical mass property uncertainties to be used in association with studies of trajectory dispersions and other limiting conditions. The information is to be organized to permit determination of those sources of error which are large enough to warrant test verification of nominals and uncertainties and to serve as a guide in the approach to any testing required. This analysis should include at least the following for each mission:

(a) Uncertainties in the critical mass property conditions of the system should be summarized and substantiated by detailed analysis of each contributing error source. Each quantity for which uncertainties are summarized should be broken down to a level corresponding with its principal elements.

(b) Analysis or discussion to describe the derivation of each measured, calculated or otherwise assigned uncertainty along with the nominal value assumed for the analysis. When included in the nominals being subjected to analyses weight growth allowances should be identified.

(c) Error sources selected should be described and should include uncertainties anticipated or indicated by analysis of the following, as applicable:

(1) Nominal inert and fluid weights together with the launch procedures, ambient conditions, in-flight changes and manufacturing variations affecting same.

(2) Instrumentation performance associated with verification or testing of the above. All uncertainties stated as errors or dispersions should be accompanied by statements of the confidence of achieving the particular level of error. If the distribution of the uncertainties is known to be a normal distribution, then the confidence may be stated in terms of a multiple of the standard deviation. Otherwise, the probability of not exceeding the particular error value must be stated.

3.4.3.22 Limits. Mass Properties Limits should include the following:

(a) A tabulation of the limiting conditions and the associated mass properties limits which are established by contract. Include reference to the contract document and page where the requirement is placed.

(b) A tabulation of the limiting conditions and the associated mass properties limits which are established by mandatory and acceptable system objectives and functions under the current design and operating characteristics.

(c) Analyses supporting and establishing the allowable limiting values of each mass property condition tabulated in (b) above.

3.4.3.23 Fluid and Propellant Loads. For each fluid and propellant load reported, present an inventory of the load and the maximum loaded weight together with a statement of the parameters and other criteria employed in their derivation, sufficient to substantiate the reported values. A guide for presenting the required data is shown in Appendix C.

3.4.3.24 Capacity and Loading Information. For each fluid and propellant, provide system capacity data, loading and associated information required to predict the loaded, expended and unexpended values for mission planning. A guide for presenting the required data is shown in Appendix C.

3.4.3.25 Verification Plan. Provide the plan for contractor verification of all system mass properties which are critical. A guide for the verification plan is shown in Appendix A. The plan should include the following:

(a) Identification of the system mass properties, and elements thereof, for which experimental verification is, or is not, proposed. Justification should be provided for either case Test plans for proposed experimental measurements should be provided, incorporating an error analysis of the equipment and procedures to be used. Appendix F is a guide for preparing the required information.

(b) Description of the planned procedures to determine, record and report all post-measurement mass property changes resulting from changes in configuration and in operating conditions affecting the loading and utilization of propellants and fluids. Description of planned communication methods to assure rapid pre- and post-flight reporting of these changes to the procuring activity and the contractor's principal points of contact in the field and at the home plant should be indicated.

(c) Description of the planned procedures to assure that inflight mass property changes are promptly detected and determined during flight and that any decision for inflight change to mission performance objectives is based on correct mass properties. This part of the plan should include an examination of contingencies which may logically cause significant deviations in system mass characteristics, provisions for improving mass characteristics by emergency jettison or load transfer, and provisions for rapidly displaying results to the crew or controlling station.

(d) Proposed procedures for the identification and maintenance of valid performance mass property inputs to system targeting parameters. These procedures should be conceived to be implements by the procuring activity of the appropriate Engineering Service Agency.

3.4.3.26 Operational Targeting Data. Submit mass properties targeting data in accordance with the proposal of 3.4.3.25(d). Present the actual and statistical mass properties data which are required to support the operational targeting concept. Accompanying these data should be the maintenance procedures and specifications to insure its upkeep by the appropriate Service Engineering Agency.

3.4.3.28 Program Plan. Present a master plan of a system of tasks that describes how the requirements of the Statement of Work will be implemented. The plan will consider all mass properties tasks, either implied or stated, to the lowest level of paragraph within the Statement of Work and should respond by either:

(a) Stating how the task will be performed.

(b) Referencing the appropriate paragraph within the plan where description of the implementation function is made. This may be done where operations are repetitive or where centralization of all mass properties functions makes for a more cohesive and comprehensive plan. The paragraph numbering and content should agree with that of the Statement of Work. Conformance to, or deviations from, a Contract Data Requirements List should be stated together with the rationale for any desired variance.

3.4.3.29 Trade Study Data. Trade study data should include the following where applicable:

(a) A list of the effect on mass properties of each trade study whether or not performed directly as a mass properties trade.

(b) Identification of each listed trade study by title.

(c) Description of the methodology and tools employed in deriving the results of the trade.

(d) Any mass properties criteria used in system screening or selection.

3.4.3.30 Weight Growth Allowance Depletion. - Present, either graphically or in tabular form, the proposed approach to depletion of the total growth allowance. The growth remaining at significant points in the contract life cycle should be identified. See Figure 2.

3.4.3.31 Data Sources. - All reports should include a listing of the pertinent references, such as data sources, reports correspondence, substantiating documents and any other material germane to the report.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for Inspection. Unless otherwise specified in the contract or purchase order the contractor is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified, the contractor may utilize his own facilities or any commercial laboratory acceptable to the customer. The customer may reserve the right to perform inspections deemed necessary to assure supplies and services conform to prescribed requirements.

4.2 Inspection Methods

4.2.1 Examination. The mass property control data should be thoroughly examined to determine conformance with respect to all the requirements specified.

6. NOTES

6.1 Evaluation of Contractor's Mass Properties Control Capability The procuring activity's mass properties personnel may be evaluating each contractor's mass properties control capability and effectiveness. The results of the evaluation may be summarized and documented within the procuring activity as frequently as conditions (overweight, incomplete reports, late submittals, etc.) warrant. However, each contractor will be completely evaluated after being awarded a contract and periodically thereafter. These reports will be for the customer internal use only and will not be provided for contractor information. The evaluation will be based upon, but not limited to, the following:

(a) Trend relationship between contractor's mass properties summaries and specified mass properties requirements.

(b) Completeness of data submitted.

(c) Compatibility of measured data with estimated and calculated data.

(d) Compliance with data submittal schedules.

6.1.1 Independent Analysis of Mass Properties data. Contractor data may be reviewed and, where appropriate, independently verified by the procuring activity or it's designated representative. In particular, this effort will provide input data to the independent stability and control analysis that is intended to be conducted on all programs to verify the equivalent contractor generated analysis. The fact that these independent analysis are being performed, or the results of such analyses, will not relieve the contractor of any contractual responsibilities.

6.2 Information for Contracting Officer

6.2.1 Procurement Document. Procurement documents should specify the following:

(a) Title, number and date of this specification.

(b) Selection of applicable levels of preservation, packaging and packaging required.

(c) Items of data required (see Paragraph 3.4).

(d) Additional Quality Assurance provision as applicable.

6.2.2 Classification of Data. The applicable security regulations of the procuring activity should control the processing and distribution of classified data.

6.3 Definitions

6.3.2 Angles of Intersection. - The angles between the geometric axes and the principal axes of the item.

6.3.3 Critical Mass Properties. - Those mass properties which have limits.

6.3.4 Current Mass Properties. - The current value of mass properties based on all known elements of the item but excluding any growth allowance.

6.3.5 Conceptual Phase. - The first phase of the System Acquisition Life Cycle. It represents the period extending from the determination of a needed operational capability to the Program Decision which authorizes the accomplishment of the Validation Phase for a proposed acquisition program. The objective of the Conceptual Phase is to define and select the system(s) which warrants continued development.

6.3.6 Deployment Phase. - The final phase of the System Acquisition Life Cycle. During this phase, the systems are provided to and used by operational units.

6.3.7 Full Scale Development Phase. - The third phase of the System Acquisition Life Cycle during which the system, including all of the items necessary for its support, is designed, fabricated and tested.

6.3.9 Ignition Weight. - The total weight of a stage, module or combinations thereof including propellants, fluids and items which vary in weight and location at the time of initiation of the ignition sequence.

6.3.10 Improvement Potentials. - Alternate configurations or design changes which, if incorporated into the basic design, would result in improved vehicle characteristics.

6.3.13 Limiting Conditions. - Any system operating, handling, transfer, acceptance or other conditions to which any of the following apply:

(a) Mass properties of the conditions have been established by contract as the allowable limits for satisfaction of performance incentive other system objectives.

(b) Mass properties of the conditions are decisively constrained by limiting values outside of which the mandatory system objectives or functions will not be achieved under the current design or operating characteristics.

(c) Mass properties of the conditions exercise a decisive influence upon the acceptable system objectives or functions under the current design or operating characteristics.

6.3.14 Specified Weight. The maximum weight allowed by the procuring activity, usually a contractual requirement.

6.3.15 Manufacturing Variation. - A random uncertainty resulting from the effects of manufacturing process of an item.

6.3.16 Mass Properties. - The physical characteristics of weight, center of gravity, mass distribution, moments of inertia and principal axes orientation.

6.3.17 Minimum Burnout Weight. - The weight at the end of effective action time for each stage where burning is to depletion of all main impulse propellants and fluids assumed to be available for expenditure

6.3.19 Outage. - The allowance for mean propellant-utilization system error.

6.3.20 Phase. - A period of time which denotes program progression.

6.3.22 Procuring Activity. - Any agency which maintains administrative control of a contract entered into by the agency and contractor.

6.3.23 Production Phase.- The fourth phase of the System Acquisition Life Cycle during which the system, including training equipment, spares, facilities, etc., is produced for operational use.

6.3.24 Random Error. - Error of a measurement method which fluctuates irregularly from observation to observation and which is caused by conditions that cannot be controlled completely.

6.3.25 Reference Datum. - A theoretical plane, assumed to be exact for purposes of computation or reference, from which the location of vehicle features may be established.

6.3.26 Sliverage. - That portion of the solid propellant which is unburned at the end of action time.

6.3.27 Stage. - That portion of a vehicle consisting of a step plus all steps above (see Figure 1).

6.3.28 Step. - That portion of a vehicle which may be physically separated from other portions by staging interfaces.(see Figure 1)

6.3.29 Time Projected Weight. The projection of the weight with respect to time beginning with the negotiated weight as authority to proceed and to time beginning with the negotiated weight as authority to proceed and extending to contract completion.

6.3.30 Total Gross Weight. - The weight of the vehicle after loading is complete and prior to ignition.

6.3.31 Uncertainty. - A general term for the estimated amount by which the observed or calculated value of a quantity may depart from the value accepted as true.

6.3.32 Validation Phase. - The second phase of the System Acquisition Life Cycle. Here the major program characteristics (technical, cost and schedule) are validated and refined through extensive study and analysis, hardware development or prototype testing, leading to the ratification decision which permits the Full-scale Development Phase. Analyses and/or test hardware and/or prototype hardware are the output of the Validation Phase.

6.3.33 Vehicle. - The entire assembly which is launched from the earth’s surface.

6.3.34 Verification Uncertainties. - The root sum square of the random errors associated with the analysis technique and/or measurement technique and inventory.

6.3.35 Weight Growth allowance. The weight allowance to account for weight changes due to development and manufacturing problems, changes in design requirements and other in-scope that are not identifiable at that time.

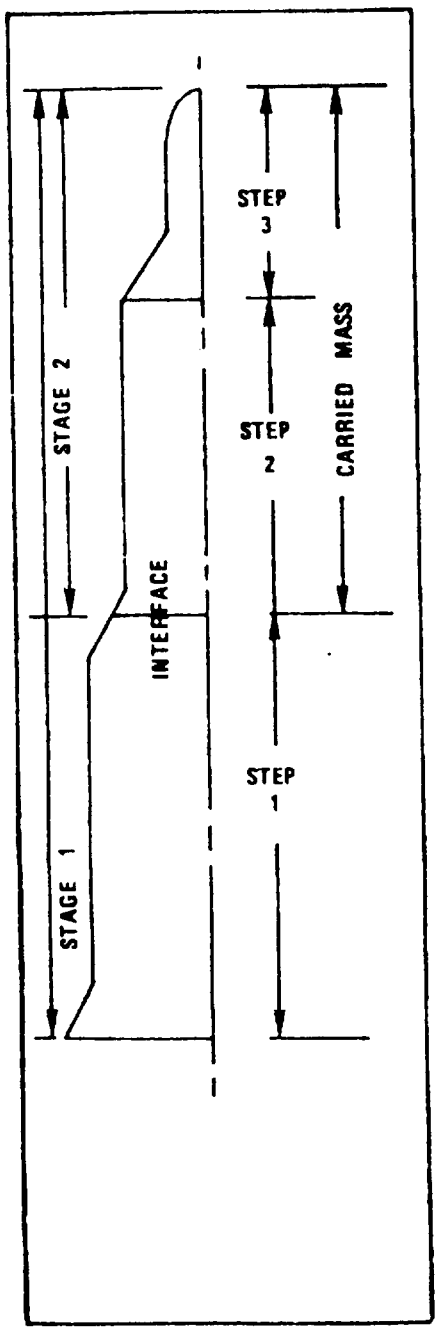

Figure 1. Example of Missile Step-Stage Relationship

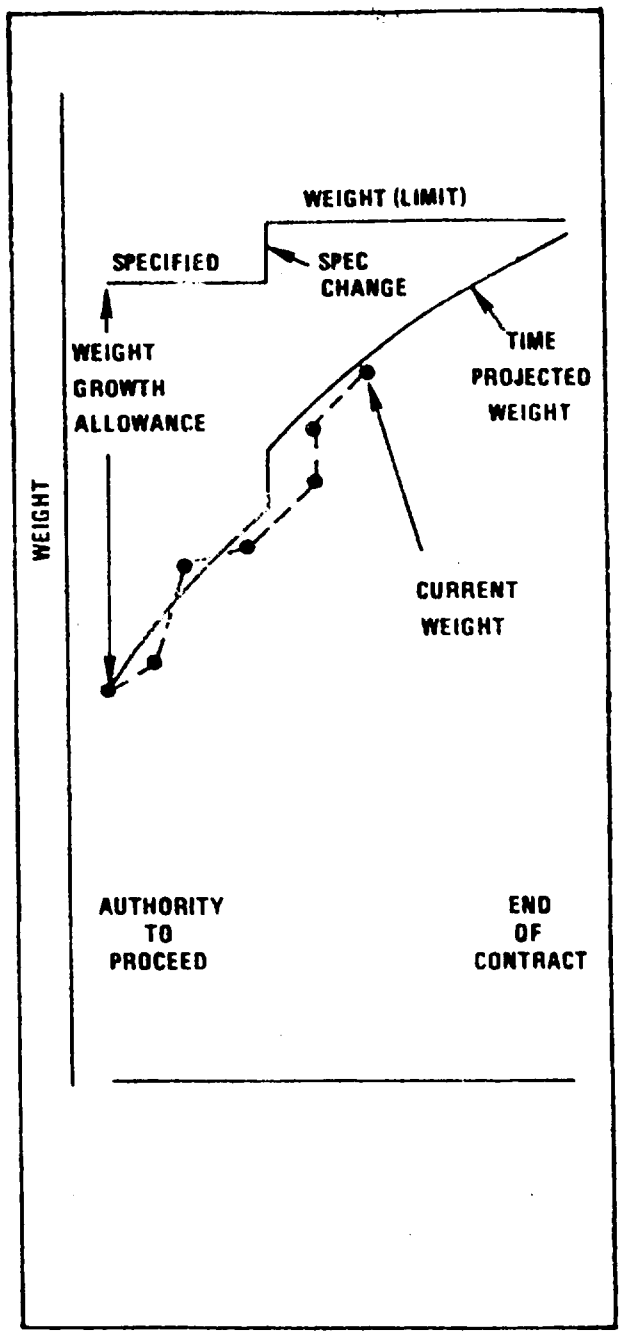

Figure 2. Example of a Weight Control Graph

CONCLUDING MATERIAL

Custodians:
Air Force - 19
Navy - AS

Review activities:
Air Force - 33, 99
NORAD - US
NASA - NA

Preparing Activity:
Air Force 19
(Project 1810-9804)

STANDARDIZATION DOCUMENT IMPROVEMENT PROPOSAL

INSTRUCTIONS

1. The preparing activity must complete blocks 1, 2, 3, and 8. In block 1, both the document number and revision letter should be given.

2. The submitter of this form must complete blocks 4, 5, 6, and 7.

3. The preparing activity must provide a reply within 30 days from receipt of the form.

NOTE: This form may not be used to request copies of documents, nor to request waivers, or clarification of requirements on current contracts. Comments submitted on this form do not constitute or imply authorization to waive any portion of the referenced document(s) or to amend contractual requirements.

I RECOMMEND A CHANGE:	**1. DOCUMENT NUMBER** MIL-HDBK-1811	**2. DOCUMENT DATE (YYMMDD)** 980812

3. DOCUMENT TITLE MASS PROPERTIES CONTROL FOR SPACE VEHICLES

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

5. REASON FOR RECOMMENDATION

6. SUBMITTER

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

8. PREPARING ACTIVITY

a. NAME SMC/AXMP	b. TELEPHONE *Include Area Code)* (1) Commercial 310-363-1744 (2) AUTOVON 833-1744
c. ADDRESS *(Include Zip Code)* 160 SKYNET STREET, SUITE 2315 LOS ANGELES AIR FORCE BASE EL SEGUNDO, CA 90245-4683	**IF YOU DO NOT RECEIVE A REPLY WITHIN 45 DAYS, CONTACT:** DEFENSE QUALITY AND STANDARDIZATION OFFICE 5203 Leesburg Pike, Suite 1403, Falls Church, VA 22401-3466 Telephone (703) 756-2340 AUTOVON 289-2340