BY ORDER OF THE COMMANDER

SMC Standard SMC-T-002
2 January 2013

Supersedes:
SMC-T-002 (2008)

Air Force Space Command

SPACE AND MISSILE SYSTEMS CENTER TAILORING

TAILORING INSTRUCTIONS FOR AIAA-S-120-2006

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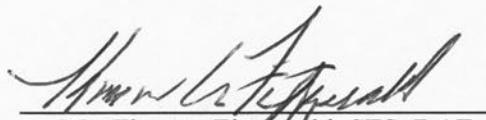
FOREWORD

1.   This standard defines the Government's requirements and expectations for contractor performance in defense system acquisitions and technology developments.

2.   This revised SMC standard comprises the text of The Aerospace Corporation report number TOR-2008(8583)-7560 REV A, entitled *Tailoring Instructions for AIAA-S-120-2006* and contains the following major changes:

- Removes the non-quantifiable term "to the maximum extent possible in Section 4.1.2.1
- Replaces the word "shall" with "should in sections where contractual requirements are not intended to be placed on the contractor as indicated in Section 2.2 of this document
- Changes from AIAA-S-120-2006 are stated in Section 2.2 of this document
- Table 2 notes 1 and 2 corrected from TOR-2008(8583)-7560, Rev A to conform with table contents

3.   Beneficial comments (recommendations, changes, additions, deletions, etc.) and any pertinent data that may be of use in improving this standard should be forwarded to the following addressee using the Standardization Document Improvement Proposal appearing at the end of this document or by letter:

<div align="center">

Division Chief, SMC/ENE
SPACE AND MISSILE SYSTEMS CENTER
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4.   This standard has been approved for use on all Space and Missile Systems Center/Air Force Program Executive Office - Space development, acquisition, and sustainment contracts.

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1. Scope

1.1 Purpose

This document shall be used for tailoring the AIAA Standard, S-120-2006 dated December 1, 2006, to provide effective program execution and mission success.

1.2 Application

This document is intended for use in acquisition and study contracts for space systems. The AIAA Standard tailored by this technical operating report (TOR) (hereafter referred to as the "Tailored AIAA Standard") supersedes all revisions of MIL-STD-1811, MIL-HDBK-1811, MIL-M-38310, and TOR-2005(8583)-3970. The AIAA Standard approved on December 1, 2006, shall be tailored by this document as an effective baseline.

The tailored AIAA Standard shall also be used as a compliance document to specify mass properties control requirements for space vehicles, upper-stage vehicles, injection stages, satellite payloads, reentry vehicles, launch vehicles, or ballistic vehicles.

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2. Tailoring

2.1   Definition

A process by which individual requirements from specifications, standards, or related documents are evaluated and applied to a specific program by selection of requirements, or in some exceptional cases, modification or addition of requirements. Tailoring of requirements shall be undertaken with consultation and approval of the procuring authority where applicable to align the standard with the government's requirements and the mission needs.

This Tailored AIAA Standard establishes a new baseline for requirements, which in turn may be tailored or revised with rationale upon approval by the procuring authority.

2.2   Changes from AIAA S-120-2006

The following is a comprehensive list of the changes that this document imposes on AIAA S-120- 2006.

Section	Page	Paragraph	Change Required/Rationale
1	1	Scope	Add paragraph 1.1 "Purpose" to define the relationship between this document and AIAA S-120-2006.
1	1	Scope	Add paragraph 1.2 "Application," which modifies the Scope section of AIAA S120 and inserts intended use and superseded documents.
2	1	Tailoring	Reword definition and add a subsection including this table.
4	5	4.1.2	Change last sentence from "…shall be to formulate…" to "…is to formulate…" to remove implied requirement
4	5	4.1.2.1	Remove phrase "…to a significant extent (as determined by the responsible MPE)…" and reword last sentence to remove implied requirement (shall).
4	5	4.1.2.3 (new)	Add a requirement for generating a mass properties milestone/delivery schedule based on a top-level program schedule.
4	5	4.1.3.1	Remove numbering in second sentence, and change "shall" to "should" in last sentence.
4	5	4.1.3.2	To second sentence, add "When comparing to requirements," and …"plus the predicted uncertainty"… to convey worst case margin.
4	5	4.1.3.2.1	Delete paragraph; non-value added statement. Re-number paragraph 4.1.3.2.3 to 4.1.3.2.1.
4	6	4.1.3.2.2	Change "shall," "may" and "shall" in sentences 1,-3, respectively, to "should" in all cases.
4	6	4.1.3.2.3	Insert as 4.1.3.2.1. In third sentence, change "shall" to "should." Reword last sentence to permit contractor to use in-house MGA algorithm only if proven and approved by contracting officer.
4	7	Table 1	Include Maturity Code 3 in the major category "E," thus removing Maturity Code 3 from major category "C." Provides better alignment with historical data. Increase wire harness MGA percent from 55 to 75 (Maturity Code 1), and from 30 to 40 (Maturity Code 2) based on recent harness weight trends.
4	8	4.1.3.2.4	Change title to include pending changes. Add two sentences at the end of the paragraph to define pending changes and how they are factored into the margin analysis.

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Section	Page	Paragraph	Change Required/Rationale
4	9	Table 2	Change table title to "TPM-Mass Risk Assessment," Change column headings to "Recommended MGA" and "Recommended Predicted Dry Mass Margin." Add a fourth column titled "Basic Dry Mass Margin," which is a sum of columns two and three. Remove color coding for all but the last column. Change notes accordingly. Remove the values associated with the row "SRR" from the table, as there is no supporting data for this program phase.
4	9	4.1.3.2.6.3	Revise the text under 4.1.3.2.6.3 for explanation of revised Table 2 color coding. Change "…should be initiated" to "…shall be initiated" (last bullet).
4	10	4.1.3.3.1	Change "The program management, or designee, shall provide…" to "The program management, or designee with sufficient authority to direct changes, should provide…"
4	10	4.1.3.3.2	In first line, change "The key MPCB functions shall include…" to "The key MPCB functions should include…"
4	10	Figure 2	Remove the line and values associated with the heading, "SRR" from the graph (system requirements review).
4	13	4.1.3.4	In sentences 1, 2, and 4, change "shall" to "should." Sentence 3 retains the word "shall." In sentence 2, remove "…and to ensure delivery…mass properties requirements." (Redundant with phrase in sentence 1)
4	13	4.1.3.5	In first sentence, remove phrase "…to a significant extent (as determined by the responsible MPE)…" and change "…shall be approved…" to "…should be approved…" In second sentence, change "Such approval shall signify component acceptability…" to "Such approval signifies component acceptance…"
4	13	4.1.3.6	Reword paragraph for clarification of "inter-system and intra-system," and change all "shall" statements to "should."
4	13	4.2.1	Delete last sentence (redundant with first sentence), and in third sentence, change "shall" to "should."
4	14	4.2.2	Insert at the beginning of the last paragraph: "During the early phases of the program... in the following categories: new, modified, or existing." In third sentence, change "shall" to "should." Add fourth bullet.
4	14	4.2.2.2	In second sentence, change "shall" to "should."
4	14	4.2.2.3	In first sentence, change "shall" to "should." Add two sentences, "Depending on the quality…process used to fabricate each part." In subsequent two sentences, change "The contractor shall document…" to "The contractor should document…" and "Special attention shall…" to "Special attention should…"
4	14	4.2.3.1	Change "shall consider" to "should include" to emphasize the desire to include all applicable mass properties parameters in analysis and reporting tasks.
4	14	4.2.3.2	Change "shall" to "should." and add second sentence, "In drawing systems…should also be included."
4	15	4.2.3.3	In second sentence, change "shall" to "should." Add "or equivalent" after reference to Table 1.
4	15	4.2.3.4 (new)	Add a paragraph, "Heritage of Hardware" to broadly classify new, modified, or existing hardware.
4	15	4.2.4.1	In second sentence, change "shall" to "should."
4	15	4.2.4.2	Rewrite sentence to clarify that the mass properties model include test instrumentation that remains on the vehicle after system tests are completed.
4	15	4.2.4.3	In third sentence, change "shall" to "should."

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Section	Page	Paragraph	Change Required/Rationale
4	17	4.2.5.1	In all three sentences in the second paragraph, change "shall" to "should."
4	17	4.2.5.2	Change "The mass properties function shall provide…" to "Mass Properties Engineering may be asked to provide…" Add a sentence at the end: "The mass properties data base and associated software tools should be flexible enough to provide this information if requested.
4	18	4.2.5.4.3	In sentences 2 and 3, change "shall" to "should."
4	18	4.2.5.4.5	In second sentence, change "shall" to "should."
4	18	4.2.5.4.6	Expand Breakup Analysis/Disposal subsection to include detailed information on components to be considered in the analysis.
4	18	4.2.5.5	In both sentences, change "shall" to "should."
4	18	4.3.1	In second sentence, change "shall" to "should."
4	19	4.3.1.2	In third sentence, change "shall" to "should."
4	22	4.3.4.4	Change first bullet from "...simulate the flight condition to the extent practical" to "...simulate the dry flight condition and be at least 90% complete by mass, excluding hazardous components or components not normally installed at the measurement site."
4	24	4.4.3	Change "shall" to "should." Delete "…as described in the following sections."
4	24	4.4.3.1	In second sentence, change "shall" to "should."
4	24	4.4.3.2	In first and third sentences, change "shall" to "should."
4	24	4.4.3.4	Change "shall" to "should."
4	25	4.5.1	After last sentence, add "A preliminary mass properties control plan shall be submitted with each proposal package, as shown in Table D.1 of Annex D."
4	26	4.5.6.4	In the first line, change "The mass properties summary shall…" to "The mass properties summary should…"
4	29	4.5.6.16	In first sentence, change "...by functional subsystem or drawing tree structure" to "...by functional subsystem, showing subsystem breakdown to the second level of detail."
4	30	4.5.6.17	In first sentence, change "...by functional subsystem or drawing tree structure" to "...by functional subsystem, showing subsystem breakdown to the second level of detail."
4	30	4.5.6.21 (new)	Add a subsection requiring reporting of propellant budget, including contingencies, for each mission phase.
5	30	5 (new)	Add a section for contractor deliverables, referencing Appendix D.
Annex A	32	A.2	Replace Space Vehicle figure with Space System figure to show relationship between launch vehicle capability and Space Vehicle margin
Annex B	33	B.1-B.3	In section title, change from (Informative) to (Normative). Change all "should"s to "shall"s.
Annex D	45-46	Table D.1	Add a line 4.5.1 "Mass Properties Control Plan (Preliminary)" and place an "x" in column 3 ("With submittal of all proposals"). On line 4.5.6.17, add an "x" to column 15. Add a line 4.5.6.21 "Fluid and Propellant Loads," and place an "x" in columns 1–6, 10–11, and 14-17. Delete column 19.

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3. Vocabulary

There are no changes to this section—use AIAA S-120-2006 verbatim.

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4. Requirements

4.1 Mass Properties Control

Use AIAA-S-120-2006 for all paragraphs, tables, and figures, except as noted below.

4.1.2 Mass Properties Control Plan

The contractor shall develop and document a mass properties control plan (MPCP) for the space system that states the management plan and the procedures for mass properties control and verification during the various procurement phases. The MPCP describes in detail the formal process for controlling mass within the Program/Project organizational structure and includes the applicable requirements specified in Section 4 of this standard. The objective of this plan is to formulate an organized mass properties control program to meet the space system mass properties requirements.

4.1.2.1 Subcontractor Mass Properties Control Plan

The contractor shall be responsible for the mass properties control of each subcontractor and supplier. In each procurement document, items which affect the space system mass properties shall include a mass properties control section to impose the applicable requirements of this document on the subcontractor or supplier. The contractor, with approval from the procuring authority, is responsible for determining how the mass properties specification limits, control process, and reporting requirements of this plan will be flowed down to each subcontractor and supplier.

Note: Mass properties control may be tailored as appropriate for items with known mass properties.

4.1.2.3 Program Schedules

A top-level program schedule showing major milestones and deliverables should be referenced in the Mass Properties Control Plan (MPCP). The contractor should derive major mass properties milestones and deliverables from the top-level schedule, and include that schedule in the MPCP.

4.1.3 Mass Properties Control Process

No change to this paragraph – title used as a placeholder only.

4.1.3.1 Requirements Flowdown and Traceability

The contractor shall perform a comprehensive review of all program system requirements and identify all the major mass properties requirements that affect space system performance. The source of the requirements starts with the contractual Technical Requirements Document (TRD) or Operational Requirements Document (ORD), followed by the flow-down of requirements to the space system's subsystems and components. Included are internally derived requirements imposed on the space system from specialty engineering functions such as Attitude Control, Mission Engineering and Ground Handling and Transportation. The contractor shall show the traceability to its source for each requirement. The contractor should prepare a verification cross-reference matrix showing the mapping between each requirement and the method(s) to be used for verification of the requirement.

4.1.3.2 Assessment of Predicted Performance Against Requirements

The contractor shall perform an analysis to show predicted performance for each identified critical mass properties requirement that affects space system performance, and shall verify margin against

the requirement. When comparing to requirements, the mass properties shall include the basic (nominal) value plus mass growth allowance plus the predicted uncertainty based on an assessment of design maturity. The contractor shall initiate a recovery plan when negative margins are predicted.

4.1.3.2.1 Mass Growth Allowance and Depletion Schedule

The contractor shall include in the mass data an allowance for the expected mass growth resulting from lack of maturity in the current design data. Mass growth varies as a function of hardware type and its design maturity. The Mass Growth Allowance (MGA) should be applied at the lowest design detail level reported in the mass properties database. Depletion of the MGA follows the design process; as the design and analyses of the hardware matures, the MGA depletes to reflect increased confidence in the predicted final mass. The contractor should use Table 1, Mass Growth Allowance and Depletion Schedule, to determine MGA. The contracting officer may grant an exception to this requirement and approve the contractor's use of their own mass growth and depletion schedule in specific cases where the contractor is able to provide past program performance data that supports successful algorithm predictions of final mass with adequate margin. The contractor's past performance data should be evaluated by the contracting officer for applicability to the current program scope (e.g., mission category and type, mass and power class, first-generation design versus generational design with increased complexity or scope, or new technology insertion).

4.1.3.2.2 Mass Properties Categorization Guidelines

Table 1 prescribes maturity codes that should be included as part of the recorded component data. As many categories as are necessary to accurately define the status of the mass properties should be used. Totals of each of these categories should be recorded to provide an indication of the mass properties confidence at the subsystem level for the bus, payload, and the complete space system.

4.1.3.2.4 Mass Threats, Opportunities, and Pending Changes

The assessment of mass properties predicted performance shall also consider potential changes to the design that may adversely impact predicted mass properties margin against requirements. The contractor shall evaluate and maintain a list of all potential design changes with threats to increase and opportunities to decrease the system mass. Each potential change shall be evaluated and assigned a percent probability of occurrence as either: "High" (H) >75%, "Medium" (M) 25% to 75% or "Low" (L) <25%. Pending changes are those known changes that have not yet been incorporated into the mass properties database due to timing or open issues requiring resolution. Threats, opportunities, and pending changes should all be factored into analyses when assessing margins.

4.1.3.2.6.3 Explanation of Table 2 Color Coding

Table 2 represents the mass risk assessment derived by comparing the allowable dry mass to the basic dry mass at each major program phase. The MGA is based on a system-level average of the values in Table 1, and is shown for reference in Table 2. The basic dry mass margin, however, is historically based, and deviations from this baseline may be granted by the contracting officer where sufficient justification is provided by the contractor for lesser margin values. An example could be a generational design that follows a previously developed concept with capability or complexity enhancements within an established design envelope (heritage bus design with extensive use of off-the-shelf hardware).

Table 1.   Mass Growth Allowance and Depletion Schedule

Major category	Maturity Code	Design Maturity (Basis for Mass Determination)	Electrical/Electronic Components 0-5 kg	Electrical/Electronic Components 5-15 kg	Electrical/Electronic Components >15 kg	Structure	Brackets, Clips, Hardware	Battery	Solar Array	Thermal Control	Mechanisms	Propulsion	Wire Harness	Instrumentation	ECLSS, Crew Systems
E	1	**Estimated** 1) An approximation based on rough sketches, parametric analysis, or undefined requirements, 2) A guess based on experience, 3) A value with unknown basis or pedigree	30	25	20	25	30	25	30	25	25	25	75	60	23
	2	**Layout** 1) A calculation or approximation based on conceptual designs (equivalent to layout drawings), 2) Major modifications to existing hardware	25	20	15	15	20	15	20	20	15	15	40	30	15
	3	**Preliminary Design** 1) Calculations based on a new design after initial sizing but prior to final structural or thermal analysis, 2) Minor modification of existing hardware	20	15	10	10	15	10	10	15	10	10	25	25	10
C	4	**Released Design** 1) Calculations based on a design after final signoff and release for procurement or production, 2) Very minor modification of existing hardware, 3) Catalog value	10	5	5	5	6	5	5	5	5	5	10	10	6
A	5	**Existing Hardware** 1) Actual mass from another program, assuming that hardware will satisfy the requirements of the current program with no changes, 2) Values based on measured masses of qualification hardware	3	3	3	3	3	3	3	2	3	3	5	5	4
	6	**Actual Mass** Measured hardware	**No mass growth allowance – use appropriate measurement uncertainty values**													
	7	**Customer Furnished Equipment or Specification Value**	**Typically a "not-to-exceed" value is provided; however, contractor has the option to include MGA if justified**													

Table 2.   TPM-Mass Risk Assessment

Program Milestone	Recommended MGA	Recommended Predicted Dry Mass Margin	Basic Dry Mass Margin	
	(%)1	(%)1	(%)2	Grade
ATP	> 15	> 15	> 30	Green
	9 < MGA ≤ 15	10 < Mass Margin ≤ 15	19 < Mass Margin ≤ 30	Yellow
	≤ 9	≤ 10	≤ 19	Red
PDR	> 12	> 9	>21	Green
	8 < MGA ≤ 12	5 < Mass Margin ≤ 9	13 < Mass Margin ≤ 21	Yellow
	≤ 8	≤ 5	≤ 13	Red
CDR	> 7	> 5	> 12	Green
	4 < MGA ≤ 7	3 < Mass Margin ≤ 5	7 < Mass Margin ≤ 12	Yellow
	≤ 4	≤ 3	≤ 7	Red
Drawing Release Complete	> 3	> 2	> 5	Green
	2 < MGA ≤ 3	1 < Mass Margin ≤ 2	3 < Mass Margin ≤ 5	Yellow
	≤ 2	≤ 1	≤ 3	Red
Final	0	> 1	> 1	
1. The percentages of MGA and predicted dry margin in the above chart are defined as follows:				
MGA = predicted dry mass − basic dry mass				
% of MGA = (MGA/basic dry mass) × 100				
% of predicted dry mass margin = [(allowable dry mass - predicted dry mass)/basic dry mass] x 100				
2. The basic dry mass margin is defined as:				
% of basic dry mass margin = [(allowable mass − basic dry mass)/basic dry mass] × 100				

Note: Table 2 motes 1 and 2 from TOR-2008(8583)-7560 REV A have been updated in this SMC document.

Color code definitions:

- **Green:** At each specific design phase (program milestone), if the combination of MGA and predicted dry mass margin is greater than the percentages shown on the first line in the green shaded areas of Table 2, mass risks are considered to be minimal. No action is required other than monitoring the mass status.

- **Yellow:** If the combination of MGA and predicted dry mass margin is in the yellow shaded percentage ranges, the mass risk is medium. A risk-handling plan should be prepared, with particular attention paid to potential design changes that would adversely affect the margin.

- **Red:** If the combination of MGA and predicted dry mass margin is in the red shaded areas, there is a high mass risk, and an immediate mass audit, mass reduction effort, or risk mitigation process shall be initiated.

The green dry mass margin listed in Table 2 shall be the minimum requirement, unless superseded by a value specified in the technical requirement document (TRD).

4.1.3.3.1 Program Management Responsibility

The MPCB, under program management leadership, is the key mass properties management decision making authority on the program, and shall administer and manage all mass properties control activities directly affecting the space system design. The program management, or designee with sufficient authority to direct changes, should provide direction to the space system teams to fully support the functions of the MPCB.

4.1.3.3.2 Key Functions of the Board

The key MPCB functions should include, but are not limited to, the following.

(Remainder of this section is unchanged)

4.1.3.4 Mass Properties Monitoring

The space systems mass properties should be monitored by all program personnel and teammates responsible for design and delivery of flight hardware, with the goal of meeting all system mass properties requirements. The contractor mass properties personnel should be assigned responsibility for accurate mass properties determination, monitoring of the design, and timely reporting to support the mass properties control tasks on the program. To achieve this goal, the MPCB shall set internal mass properties allocations at the subsystem and unit level consistent with their respective top-level mass properties allocation requirement. Each member of the program team should be aware of their mass properties allocations and limits and provide compliance status to the MPE through the design drawing release phase.
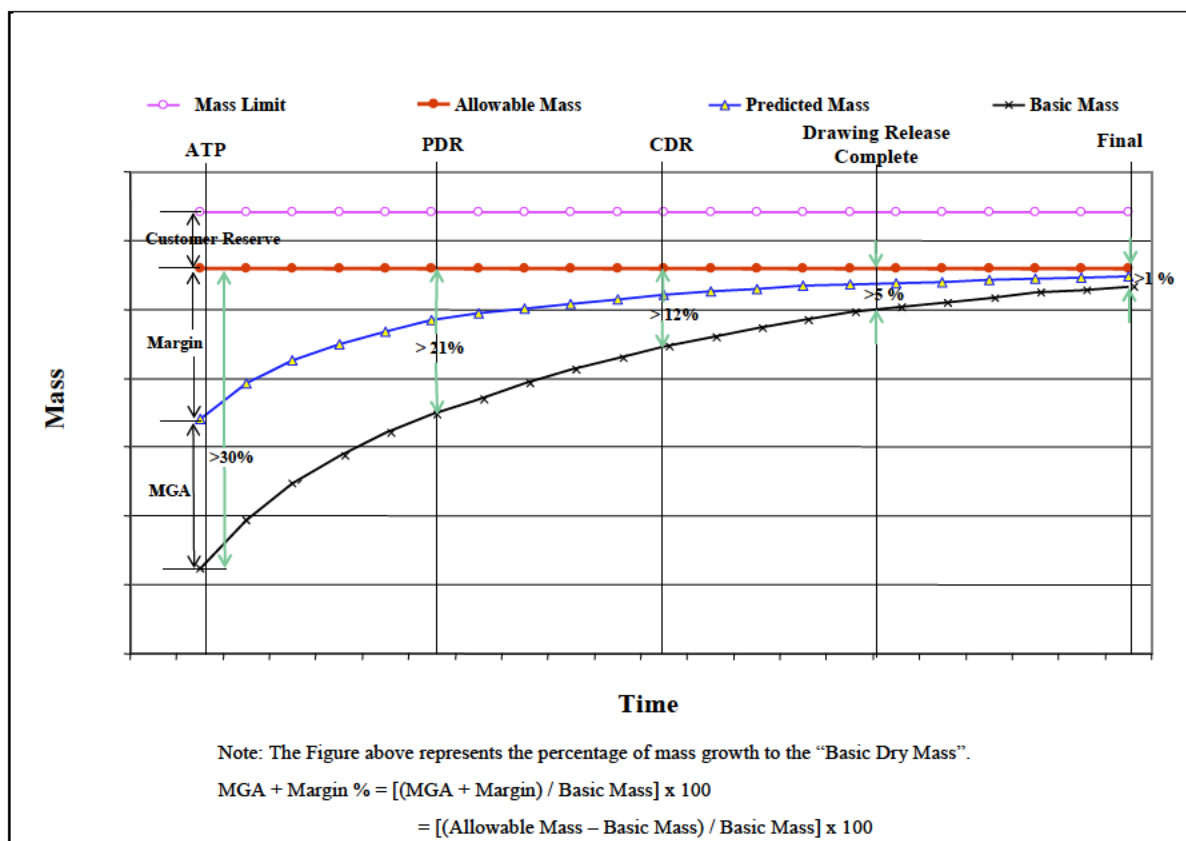
Note: The Figure above represents the percentage of mass growth to the "Basic Dry Mass".

MGA + Margin % = [(MGA + Margin) / Basic Mass] x 100

= [(Allowable Mass – Basic Mass) / Basic Mass] x 100

Figure 2.   Example plot of mass versus time.

4.1.3.5 Drawing Release Sign-off

Documents controlling the design, manufacture, and procurement of items which affect the space systems mass properties should be approved prior to release. Such approval signifies component acceptance in satisfaction of system mass properties objectives.

4.1.3.6 Trade Studies

Adequate methodology and tools should be developed, or existing methodology and tools adapted, to support trade studies involving mass properties. Such methodology and tools may be curves, computer programs, or any suitable means for relating major design parameters to relevant mass properties. Ultimate selection of design should be based on a thorough assessment of mass properties impact upon other subsystems. The contractor should determine and maintain, in a form available for review by the procuring authority, the following:

- The mass properties and limits considered in the trade studies
- The other screening processes used to include or exclude designs for future study
- The net effect on mass properties if the trade study recommendations are implemented

4.2 Analysis

Use AIAA-S-120-2006 for all paragraphs except as noted below.

4.2.1 Scope

The mass properties analysis shall support the program requirements for space system mass properties accuracy and documentation for all configurations throughout the program. The contractor shall assess the scope of the mass properties analyses required and implement a plan to satisfy compliance with all of the program mass properties requirements. The contractor should ensure that personnel with sufficient mass properties training and experience are assigned the responsibility to perform the required analyses and that adequate analysis tools are available to predict space system mass properties through all phases of the program.

4.2.2 Methods of Analysis

The primary methods of analysis are typically dictated by the program phase. During all program phases, from proposal to launch and operation, the contractor shall substantiate the mass properties model and MGA values by providing a maturity assessment of each subsystem and key component. This assessment should be accomplished by defining the heritage for each space system detail using the categories provided in Table 1 or equivalent. The early phases of program acquisition and development from authorization to proceed (ATP) through system preliminary design review (PDR) are critical because historical data indicates half of the mass growth experienced on an average program occurs during this period. The primary reasons for this observed mass growth are:

- Lack of design maturity information

- Overly optimistic assessment of the hardware maturity

- Requirements that are not fully defined or understood, or are not flowed down to the subsystem or unit levels

- Compromises to meet conflicting commonality, cost, and schedule requirements

During the early phases of the program (concept studies and concept development), the space system mass model maturity assessment may be accomplished by using the technology readiness level (TRL) method identified in the Defense Acquisition Guidebook November 2007, or by defining the heritage for each detail of the flight hardware in the following categories: new, modified, or existing. When parametric scaling techniques are used, the contractor shall provide historical data to support these methods. For detailed mass properties analysis, the coordinate system reference shall be documented.

4.2.2.2 Manual Layout/Drawing Analysis

The contractor shall document and maintain records of the manual calculation of mass properties data from design layouts and drawings. This data should be organized by drawing or part number and show rollups from lower level details to assembly and subsystem definitions.

4.2.2.3 Computer-Aided Design Analysis

The primary method for space system flight hardware mass properties analysis should be based on the available computer-aided design (CAD) tool. The contractor shall be responsible for accounting for the mass properties of all items, including those that are not modeled as solids in the CAD tool. Examples of the latter are thermal finishes (primer, paint), structural adhesives, wire harness, and fluids. Depending on the quality of the CAD models, attention should be paid to the inclusion of correct fillet radii, section thicknesses, material densities, and fastener holes. Consideration should also be given to biases in material thickness tolerances based on the manufacturing process used to fabricate each part. The contractor should document the current CAD model's mass properties at least to the level of detail in the CAD model. Special attention should be paid to understanding whether the

CAD tool uses a positive or negative integral in the determination of products of inertia. The contractor shall verify that the CAD model and mass properties model are based on a consistent definition for the products of inertia. Use of the wrong sign convention may result in principal axis errors that can affect flight dynamics.

4.2.3   Analysis Parameter Requirements and Recording of Analysis

No change to this paragraph – title used as a placeholder only.

4.2.3.1   Mass Properties Parameter Requirements

The mass properties parameters required for analysis of space system components should include mass, center of mass (CM), moments of inertia (MOI), and products of inertia (POI).

4.2.3.2   Drawing Number or Part Number

The contractor's analysis of the space system detail components, assembly, and installation level definition should include drawing number or part number. In drawing systems where the drawing revision letter or effectivity data is needed to uniquely define the part, assembly, or installation configuration, the additional information needed for unique configuration definition should also be included.

4.2.3.3   Hardware Design Maturity Assessment

The contractor shall assign a hardware maturity assessment based on the codes in Table 1 or equivalent. Mass properties personnel should be responsible for verifying that the proper maturity level is applied to each space system component.

4.2.3.4   Heritage of Hardware

The contractor shall define the heritage (new, modified, and existing) of all space system flight hardware in the request for proposal (RFP) submittal and clearly indicate hardware designs that would be considered "new technology insertion."

4.2.4   Flight Hardware Analysis

No change to this paragraph – title used as a placeholder only

4.2.4.1   Correlation to Work Breakdown Structure (WBS)

The work breakdown structure (WBS) is a hierarchical outline of the work to be done on the program or contract, along with a dictionary defining each entry in the outline. The contractor's flight hardware mass properties records should correlate to the program contract work breakdown structure.

4.2.4.2   Remaining Test Instrumentation

The contractor shall include in the space system mass properties model an allowance for the planned test instrumentation that remains with the space system after system test of the spacecraft and payload.

4.2.4.3 Mass Changes

A documented accounting of all mass changes, including part name and drawing number, shall be maintained throughout the contract. For all mass changes, the accounting shall include the "was" and "is" value of the item, the magnitude of the change, and the reasons for the changes. The mass changes should be gathered into the categories defined in Table 3 and accumulated throughout the program.

4.2.5 Special Analyses

No change to this paragraph – title used as a placeholder only.

4.2.5.1 Mass Properties Uncertainty Analysis

Mass properties uncertainty analyses shall be conducted when mass properties dispersions are required for other analyses, or when the uncertainties may cause mass properties limits to be exceeded. The accuracy of the mass properties data used in space system performance, stability, control, and structural analyses shall be documented. This is true not only for the total space system but also for elements of the space system such as fluids and deployable and independently moving parts. In some cases, the accuracy of the combination of certain mass properties may be required, such as an inertia ratio (spin to transverse moments of inertia ratio) or the inertia asymmetry, the difference of two transverse principal inertias.

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 mass growth is included in the analysis, an explanation of how it is combined with the other sources of uncertainty should be provided.

4.2.5.2 Finite Element Model Mass Distribution Analysis

Mass Properties Engineering may be asked to provide a sectional mass distribution analysis, consistent with the segment definitions set by the structural and controls systems analysis group, to support the development of the space system finite element model (FEM). The FEM supports analyses to determine dynamic response, loads distribution, stress analysis of structure and units, and control and stability limits for space system components. The mass properties database and associated software tools should be flexible enough to provide this information if requested.

4.2.5.4.3 Mission Sequential Mass Properties

The space system mass properties shall be determined and documented as a function of time or propellant fraction fill 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.

4.2.5.4.5 Post Flight Analysis

Actual mass properties data should be determined by analysis of post-flight data, where available, for significant mission events. If a post-flight analysis is performed, the differences from the planned conditions should be itemized and explained.

4.2.5.4.6   Breakup Analysis/Disposal

The mass properties database should be capable of supporting specific mission requests for both a breakup analysis and for deorbiting or repositioning the space system.

4.2.5.4.6.1   Breakup Analysis

A space system may malfunction from an anomalous ascent breakup; potential space system debris would be expected that may pose a threat to life and property. The contractor should have the capability to provide accurate mass properties data for the debris of the space system when given specific configurations to track. In addition, hazardous materials may be released during breakup. The following data are suggested for the breakup analysis:

- A detailed description of the major components and assemblies.
- Mass, center of gravity, and dimension data of the major components and assemblies.
- Ordnance device and explosive data including locations, types, part numbers, quantities, and net explosive mass.
- The amount and type of propellant mass from tanks.
- The amount of the electrolyte solutions mass from battery cells.
- The amount of ammonia mass from heat pipes.

4.2.5.4.6.2   Disposal

Mission analysis may require a plan to de-orbit or reposition a space system at the end of its operational life. The propellant required for de-orbiting or repositioning shall be included in the propellant budget.

4.2.5.5   Ground Operations Support Analysis

Mass properties should be developed and documented for the support of ground, transportation, 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.

4.3   Verification

Use AIAA-S-120-2006 for all paragraphs except as noted below.

4.3.1   Verification Plan

The contractor shall develop and document a verification plan to describe and substantiate the methods used to verify that mass properties meet requirements. The verification plan should be originated during the conceptual design and development stage, updated and reviewed at PDR, and released by CDR.

4.3.1.2   Verification Method Selection

Verification may be accomplished by analytical methods (see Section 4.2 Analysis), by measurement (see Section 4.3.2 Test Plan), or by a combination of both. The selection of the verification methods shall be justified by an approved verification plan. The verification methods should be selected early

enough in the program to provide time for the acquisition, modification, or preparation of test equipment and test site selection.

4.3.4   Test Procedure (TP)

No change to this paragraph – title used as a placeholder only.

4.3.4.4   Test Configuration

Use AIAA-S-120-2006 for all text in this section, except the first bullet shall read as follows:

- The test article shall simulate the dry flight condition and be at least 90% complete by mass, excluding hazardous components or components not normally installed at the measurement site. Deviations from the flight condition should be commensurate with test objectives such that the test results are meaningful and measurement uncertainties are within expected ranges.

4.4   Mass Properties Data Management

Use AIAA-S-120-2006 for all paragraphs except as noted below.

4.4.3   Data Organization Utility

The mass properties database should have the flexibility to sort and report mass properties data in multiple formats.

4.4.3.1   Functional Subsystem Organization

To provide a uniform basis for mass properties comparisons, the space system mass properties shall be categorized on a functional basis. For example, the mass of all items that function primarily as the space system structure should be accumulated for the total mass of the space system structure. Annex B provides a discussion of the need for a functional breakdown and guidelines for the functional categorization of component mass.

4.4.3.2   WBS Organization

The database should have the organization and sort capability to show correlation to the program contract WBS. This typically means a correlation of component masses to their respective drawing numbers. This should be done at a level of detail that permits the determination that the masses of all items on the space system have been included properly.

4.4.3.4   Customer-Furnished Equipment (CFE)

The contractor's mass properties records should have a separate tabulation of all CFE.

4.5   Documentation

Use AIAA-S-120-2006 for all paragraphs except as noted below.

4.5.1   Mass Properties Control Plan

A mass properties control plan in accordance with 4.1 shall be developed and documented by the contractor. The plan shall state the management program and procedures to be used for mass properties control, analysis, verification, and documentation of the space system. A preliminary mass properties control plan shall be submitted with each proposal package, as shown in Table D.1 of Appendix D.

4.5.6   Mass Properties Status Report

No change to this paragraph – title used as a placeholder only.

4.5.6.4   Mass Properties Summary

The mass properties summary should include the following.

(The remainder of this section is unchanged)

4.5.6.16 Detailed Mass

Prepare a tabulation of the current space system detailed mass by functional subsystem, showing subsystem breakdown to the third level of detail. Show the following for each line of detail.

- Functional Code
- Description
- Basic Mass
- Predicted Mass
- Percent of Basic Mass in Each Category as Coded in Table 1
- MGA

4.5.6.17 Detailed Mass Properties

Prepare a tabulation of the current space system detailed mass properties by functional subsystem, showing subsystem breakdown to the third level of detail. Show the following for each line of detail.

- Functional Code
- Description
- Basic Mass
- Predicted Mass
- Center of Mass (X, Y, Z)
- Moment of Inertia (Ix, Iy, Iz)
- Product of Inertia (Ixy, Ixz, Iyz)

The contractor shall stipulate whether the values used to derive CM, MOI, and POI are derived from basic or predicted mass.

4.5.6.21 Fluid and Propellant Loads

For each fluid and propellant load reported, present a detailed summary of the fluid/propellant load budget. The budget shall specify the predicted mission fluid and/or propellant allocation required for each mission phase and include appropriate contingencies (for mission design,

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thruster performance, and mission execution) based on the program acquisition phase. Specify the source for the budget that describes the parameters and criteria used to substantiate the reported values.

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5. Contractor Deliverables

Refer to Appendix D for a complete listing of contract deliverables and a submittal schedule.

Appendix A. Supplemental Information for Terms and Definitions

Use AIAA S-120-2006 except as noted.
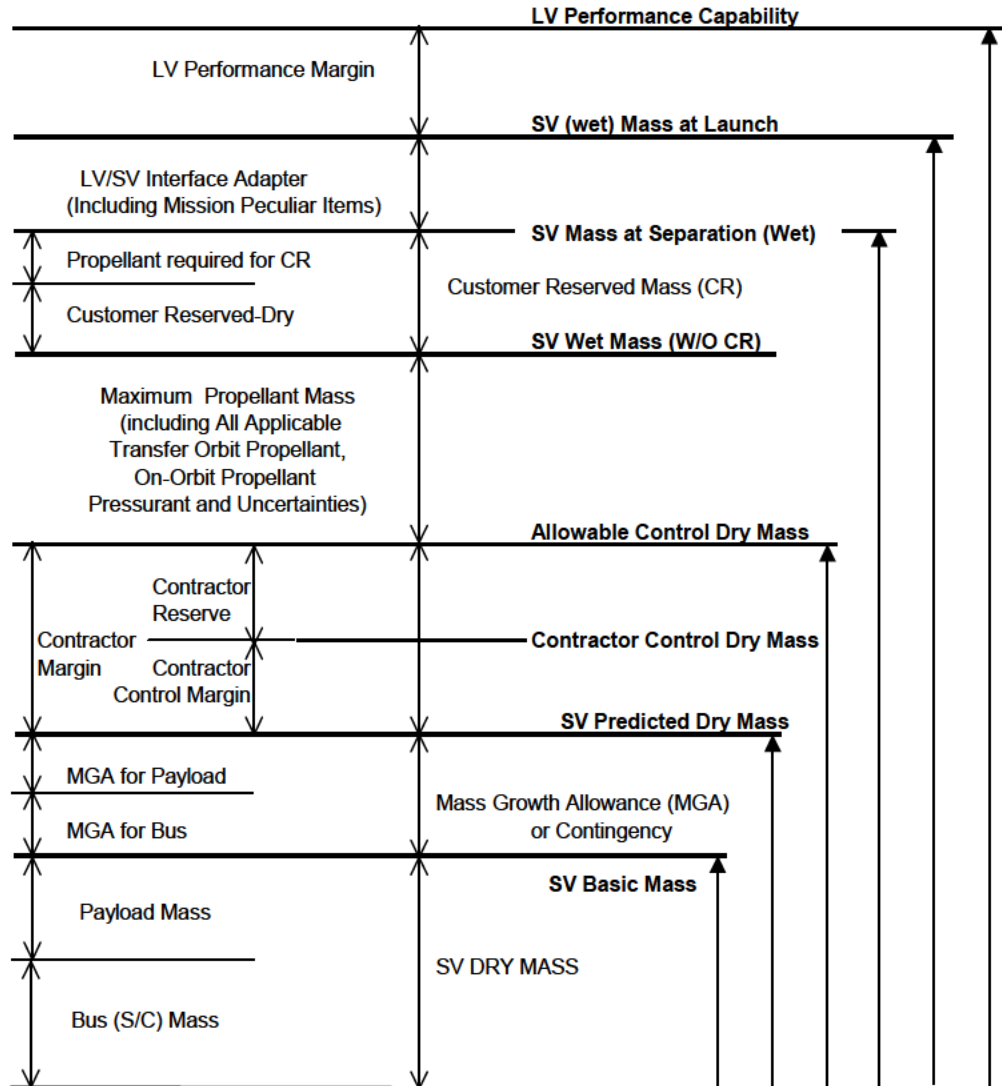
A.1 Space System Specific Mass Definitions

Figure A.1. Space system mass definitions.

Appendix B. Functional Breakdown of Mass (Normative)

B.1 Scope

Space systems comprise subsystems that perform specific functions. Examples of two subsystems are structural support for equipment and electrical power. Useful subsystem information is generated when component masses are accumulated on a functional basis. The uses of functional subsystem mass include the tracking of functional mass during design for mass proposed for new vehicles, and the improvement of the database used for the refinement of mass-estimating methods. It is necessary to strive for consistency regarding which components comprise each subsystem if the objectives of subsystem mass estimation and evaluation are to be achieved. Consideration shall also be given to the configuration for which actual mass 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 shall be established that names each of the subsystems comprising the space system. Since the term "space systems" 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, several subsystem lists are given in Tables B.1 through B.4, which are intended to serve as guides. Additional guidelines can be found in JSC 23303. The contractor shall develop a subsystem list suitable for the space system being developed. This contractor's list shall contain subsystems in at least as much detail as represented in Tables B.1 through B.4.

B.3.2 Subsystem Breakdown B.3.2.1 Second Level of Detail

Each subsystem's total mass shall be broken down to a second level of detail. This second level of detail shall be constructed to provide useful information for mass 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.1 through B.4. The contractor shall establish the applicable second-level mass breakdown and it shall be at least to the level of detail represented in Tables B.1 through B.4.

B.3.2.2 Third Level of Detail

The second level of detail shall be further broken down to a third level where applicable to facilitate a more detailed evaluation of mass and mass properties. Examples of this are shown in Tables B.1 through B.4. The third level, also known as the unit level, provides valuable information on location of individual units or subassemblies.

B.3.2.3 Subsequent Levels of Detail

A breakdown of the third level of detail to lower levels may be useful for evaluation purposes. The contract data requirements list (CDRL), incorporated into the contract, may require the

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contractor's subsystem list, the second- and third-level-of-detail list, and any subsequent level-of-detail lists, be prepared for review and approval by the contracting officer.

B.3.3 Functional Coding

The contractor shall develop a functional code that is consistent with the subsystem list and level of detail lists described in Sections B.3.1 and B.3.2 of this Appendix. The code format is not specified. As masses are determined, they shall 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.

B.3.3.2 Resolution of Ambiguities

For those items that have more than one function, the contractor shall code them to the primary function according to Table B.5. If the choice is not obvious, the contractor may choose between the two closest candidate categories. When decisions are made for items constituting at least 10% of the subsystem mass, the contractor shall maintain descriptive titles in the mass properties records of the space system. This permits the transfer of these items from one function to another at the discretion of the contracting officer.

Tables B.1 through B.5

There are no changes to these tables—use AIAA S-120-2006 verbatim.

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Appendix C.   Space System Design Features

There are no changes to this appendix—use AIAA S-120-2006 verbatim.

Appendix D. Document Content and Submittal Schedule

D.1 Schedule of Submittals

There are no changes to this paragraph—use AIAA S-120-2006 verbatim.

D.2 Distribution

There are no changes to this paragraph—use AIAA S-120-2006 verbatim.

Table D.1.   Document Content and Submittal Schedule

		PRE-SYSTEMS ACQUISITION			SYSTEMS ACQUISITION					
	PROGRAM PHASE	PRE-KDP-A	PHASE A		PHASE B					
		CONCEPT STUDIES	CONCEPT DEVELOPMENT		PRELIMINARY DESIGN					
	Column No.	1	2	3	4	5	6	7	8	9
	SCHEDULE OF SUBMITTALS	Monthly for studies < 2 months; At first of each month for studies > 2months; Semiannually for studies > 1 year or more; At completion of all studies;	Monthly for studies < 2 months; At first of each month for studies > 2 months; Semiannually for studies > 1 year; At completion of all studies; At major design reviews;	With submittal of all proposals	At Authorization To Proceed (within 30 days of ATP)	Monthly Reports - at first of each month between ATP and PDR	At PDR	Mass Properties Control Plan - within 60 days after ATP	Verification Plan - submittal with PDR package	Contract Change Proposal - with each contract change proposal
	DOCUMENT TYPES	Status Report	Status Report		Status Report			Procedural		Misc.
Section	DOCUMENT ELEMENT									
4.5.6.1	Title Page	x	x	x	x	x	x	x	x	x
4.5.6.2	Table of Contents	x	x	x	x	x	x	x	x	x
4.5.6.3	Introduction	x	x	x	x	x	x	x	x	x
4.5.6.4	Mass Properties Summary	x	x	x	x	x	x			x
4.5.6.5	Mass Change Analysis	x	x		x	x	x			x
4.5.6.6	Mass Change Summary by Change Code				x	x	x			x
4.5.6.7	Pending and Potential Changes	x	x	x	x	x	x			x
4.5.6.8	Coordinate Axes and SV Configurations	x	x	x	x	x	x			x
4.5.6.9	Sequenced Mass Properties			x	x	x	x			
4.5.6.10	Space Vehicle Movable Objects			x	x	x	x			
4.5.6.11	Mission Critical Mass Properties	x	x	x	x	x	x			
4.5.6.12	Uncertainties						x			
4.5.6.14	Mass Growth Allowance & Depletion Schedule	x	x	x	x	x	x	x		
4.5.6.15	Space Vehicle Design Features	x	x	x	x		x			
4.5.6.16	Detail Mass	x	x	x	x	x	x			
4.5.6.17	Detailed Mass Properties				x		x			
4.5.6.18	Definitions and Acronyms	x	x	x	x	x	x	x	x	
4.5.6.19	References	x	x	x	x	x	x	x	x	
4.5.6.21	Fluid and Propellant Loads	x	x	x	x	x	x			
4.5.1	Mass Properties Control Plan (Preliminary)			x						
4.5.1	Mass Properties Control Plan							x		
4.5.2	Verification Plan								x	
4.5.3	Test Procedure									
4.5.4	Test Completion Report									

Table D.1. Document Content and Submittal Schedule (continuation)

PROGRAM PHASE	SYSTEMS ACQUISITION								
	PHASE C				PHASE D				
	COMPLETE DESIGN				BUILD & OPERATIONS				
Column No.	10	11	12	13	14	15	16	17	18
SCHEDULE OF SUBMITTALS	Monthly Reports - at first of each month between PDR and CDR	AT CDR	Verification Plan Updated - submittal with CDR package	Contract Change Proposal - with each contract change proposal	Quarterly Reports - at first of each quarter between CDR and Launch	Final Mass Properties Testing - 14 days after test	At Pre-Ship Readiness Review	As-launched report within 14 days after launch	Test Procedures - 60 days in advance of the scheduled test
DOCUMENT TYPES	Status Report		Procedural	Misc.	Status Report				Miscellaneous
Section — DOCUMENT ELEMENT									
4.5.6 1 Title Page	x	x	x	x	x	x	x	x	x
4.5.6 2 Table of Contents	x	x	x	x	x	x	x	x	x
4.5.6 3 Introduction	x	x	x	x	x	x	x	x	x
4.5.6.4 Mass Properties Summary	x	x			x	x	x	x	
4.5.6 5 Mass Change Analysis	x	x			x	x	x	x	
4.5.6.6 Mass Change Summary by Change Code	x	x			x	x	x	x	
4.5.6.7 Pending and Potential Changes	x	x			x	x	x	x	
4.5.6.8 Coordinate Axes and SV Configurations	x	x	x		x	x	x	x	x
4.5.6 9 Sequenced Mass Properties	x	x			x	x	x	x	
4.5.6 10 Space Vehicle Movable Objects	x	x			x	x	x	x	
4.5.6 11 Mission Critical Mass Properties	x	x			x	x	x	x	x
4.5.6 12 Uncertainties		x				x	x	x	
4.5.6 14 Mass Growth Allowance & Depletion Schedule	x	x			x	x	x	x	
4.5.6 15 Space Vehicle Design Features	x	x			x	x	x	x	
4.5.6 16 Detail Mass	x	x			x	x	x	x	
4.5.6 17 Detailed Mass Properties		x			x	x	x	x	
4.5.6 18 Definitions and Acronyms	x	x	x		x	x	x	x	x
4.5.6 19 References	x	x	x		x	x	x	x	x
4.5.6 21 Fluid and Propellant Loads	x	x			x	x	x	x	
4 5.1 Mass Properties Control Plan (Preliminary)									
4 5.1 Mass Properties Control Plan									
4 5.2 Verification Plan			x						
4 5.3 Test Procedure									x
4 5.4 Test Completion Report						x			

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SMC Standard Improvement Proposal

INSTRUCTIONS

1. Complete blocks 1 through 7. All blocks must be completed.
2. Send to the Preparing Activity specified in block 8.

NOTE: Do not use this form to request copies of documents, or 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. Comments submitted on this form do not constitute a commitment by the Preparing Activity to implement the suggestion; the Preparing Authority will coordinate a review of the comment and provide disposition to the comment submitter specified in Block 6.

SMC STANDARD CHANGE RECOMMENDATION:	1. Document Number	2. Document Date

3. Document Title	

4. Nature of Change
(Identify paragraph number; include proposed revision language and supporting data. Attach extra sheets as needed.)

5. Reason for Recommendation

6. Submitter Information

a. Name	b. Organization
c. Address	d. Telephone
e. E-mail address	7. Date Submitted

8. Preparing Activity	Space and Missile Systems Center AIR FORCE SPACE COMMAND 483 N. Aviation Blvd. El Segundo, CA 91245 Attention: SMC/EAE

March 2008