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Air Force Space Command

SPACE AND MISSILE SYSTEMS CENTER TAILORING

Tailoring for ANSI/AIAA S-120A-2015, Mass Properties Control for Space Systems: Space Vehicles

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FOREWORD

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

2. This revised SMC tailoring comprises the text of The Aerospace Corporation report number TR-2018-01203, entitled *Tailoring for ANSI/AIAA S-120A-2015, Mass Properties Control for Space Systems: Space Vehicles.*

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

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4. This tailoring document 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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Contents

Tables

1. Scope

1.1 Purpose

This document is to be used for tailoring the American National Standards Institute (ANSI)/American Institute of Aeronautics and Astronautics (AIAA) Standard S-120A-2015, November 23, 2015, to provide an effective space vehicle (SV) program technical baseline for mass properties control and mission success.

1.2 Application

This document is intended for use in acquisition and study contracts for SVs. The ANSI/AIAA standard tailored by this document (hereafter referred to as the “tailored ANSI/AIAA standard”) supersedes all revisions of the following documents:

- MIL-STD-1811
- MIL-HDBK-1811
- MIL-M-38310
- AIAA S-120-2006
- TOR-2005(8583)-3970
- TOR-2008(8583)-7560

This tailored ANSI/AIAA standard should be used as a compliance document to specify mass properties control requirements for SVs.

2. Tailoring

2.1 Definition

Tailoring is a process by which individual requirements from specifications, standards, or related documents are evaluated and applied to a specific program by deletion, modification, or addition of requirements. Tailoring of requirements should be undertaken with consultation and approval of the procuring authority to align the standard with the acquisition authority's requirements and the mission needs.

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

2.2 Changes from ANSI/AIAA S-120A-2015

The following is a comprehensive list of all the changes that this document imposes on ANSI/AIAA S-120A-2015.

Section	Title	Change Type
3.	Applicable Documents	Reference documents updated
4.2	Terms and Definitions	Definitions (2) added
5.	Requirements	Clarification language added
5.1.2	Mass Properties Control Plan	Clarification language added
5.1.2.1	Subcontractor Mass Properties Control Plan	Requirement added
5.1.3	Mass Properties Control Process	Clarification language added
5.1.4	Requirement Flow Down and Traceability	Clarification language added
5.1.5	Mass Maturity Assessment	Clarification language added
5.1.6	Assessment of Predicted Performance Against Requirements	Clarification language added
5.1.7	Mass Growth Allowance	Clarification language added
5.1.8	Mass Threats, Opportunities, and Probability of Occurrence	Clarification language added
5.1.10	Mass Risk Assessment	Heritage design column added
5.1.12	Mass Properties Control Board	Clarification language added
5.2.2.1	Manual Layout/Drawing Analysis	Clarification language added
5.2.2.2	Three-Dimensional (3D) Model Analysis	Clarification language added
5.2.4	Mass Properties Uncertainty Analysis	Clarification language added
5.3.1	Verification Plan	Requirement added
5.3.1.2	Verification Method Selection	Requirement added
5.3.2	Test Plan	Requirement added

Section	Title	Change Type
5.3.2.1	Test Description	Clarification language added
5.3.2.3	Measurement Uncertainty	Requirements added
5.3.2.5	Customer Witnessing of Verification Tests	Requirements added
5.3.4.3	Requirements	Clarification language added
5.3.4.4	Test Configuration	Clarification language added
5.3.4.5	Test Sequence	Clarification language added
5.3.5.1	Records for Mass Properties Measurements	Clarification language added
5.4.3	Data Organization Utility	Clarification language added
5.5.5	Test Completion Reports	Clarification language added
5.5.7	Mass Properties Status Report	Clarification language added
6.	Bibliography	References documents added
Annex C	Guidance for Compliance with Contractual Requirements (Informative)	Replaced Table C.1
Annex D	Space Vehicle Mission Risk Classes (Informative)	New annex section added
Annex E	Determining POI Sign Convention Used in CAD Software Output (Informative)	New annex section added

3. Applicable Documents

Update the references cited in ANSI/AIAA-S-120A-2015, Section 3, as described below:

ANSI/AIAA S-120A-2015	*Mass Properties Control for Space Systems*
SAWE RP A-3	Revision A, *Mass Properties Control for Space Systems*
CDS, Revision 13	*CubeSat Design Specification*
6U CDS, Revision Provisional X1	*6U CubeSat Design Specification*
ATR-2015-03151	*Mission Risk Posture Assessment Process Description*

4. Vocabulary

4.1 Acronyms and Abbreviated Terms

There are no changes to this section. Use ANSI/AIAA S-120A-2015 verbatim.

4.2 Terms and Definitions (Definitions Added)

Add the following definitions to ANSI/AIAA S-120A-2015, Section 4.2.

CubeSat
CubeSats are a subcategory of small satellites whose unit dimensions (1U) do not exceed 10.0 cm x 10.0 cm x 11.35 cm and unit mass does not exceed 1.33 kg. The CubeSat is extendable to larger sizes (1.5U, 2U, 3U, 3U+) and must adhere to the *CubeSat Design Specification*, Revision 13, Cal Poly SLO, February 20, 2014.

A 6U CubeSat is a satellite with dimensions that do not exceed 10.0 cm x 22.63 cm x 26.6 cm and whose unit mass does not exceed 12kg. 6U and 6U+ CubeSats must adhere to the *6U CubeSat Design Specification*, Revision Provisional X1, April 20, 2016.

SmallSat
Per NASA[1], a small spacecraft with mass less than 180 kg is classified as follows:

- Minisatellite: 100–180 kg
- Microsatellite: 10–100 kg
- Nanosatellite: 1–10 kg
- Picosatellite: 0.01–1 kg
- Femtosatellite: 0.001–0.01 kg

[1] https://www.nasa.gov/content/what-are-smallsats-and-cubesats

5. Requirements (Clarification Language Added)

Use ANSI/AIAA S-120A-2015 for all subsections, paragraphs, tables, and figures, except as noted below.

Insert the following paragraph into ANSI/AIAA S-120A-2015, Section 5, prior to the heading of Section 5.1:

> SAWE RP A-3, revision A is a companion document of recommended practices for the ANSI/AIAA Standard. It contains guidance and recommended practices for meeting the requirements set forth in the ANSI/AIAA Standard. Each section of RP A-3, revision A contains recommended practices for the same-numbered section in the ANSI/AIAA Standard.

5.1 Mass Properties Control

There are no changes to this section. Use ANSI/AIAA S-120A-2015 verbatim.

5.1.1 Scope

There are no changes to this section. Use ANSI/AIAA S-120A-2015 verbatim.

5.1.2 Mass Properties Control Plan (Clarification Language Added)

Append the following paragraph to the end of ANSI/AIAA S-120A-2015, Section 5.1.2:

> See SAWE RP A-3, Revision A, Section 5.1.2, for additional information on key functions of the Mass Properties Control Plan (MPCP).

5.1.2.1 Subcontractor Mass Properties Control Plan (Requirement Added)

Insert the following paragraph at the beginning of ANSI/AIAA S-120A-2015, Section 5.1.2.1:

> The contractor shall be responsible for determining and specifying the applicable and appropriate mass properties control requirements for each subcontractor- or supplier-provided components.

5.1.2.2 Supplier Interface

There are no changes to this section. Use ANSI/AIAA S-120A-2015 verbatim.

5.1.3 Mass Properties Control Process (Clarification Language Added)

Append the following sentence to the end of ANSI/AIAA S-120A-2015, Section 5.1.3:

> See SAWE RP A-3, Revision A, Section 5.1.3, for additional details on the mass properties control process.

5.1.4 Requirements Flow Down and Traceability (Clarification Language Added)

Append the following sentence to the end of ANSI/AIAA S-120A-2015 Section 5.1.4:

> See SAWE RP A-3, Revision A, Section 5.1.4, for additional information for requirements flowdown and traceability.

5.1.5 Mass Maturity Assessment (Clarification Language Added)

Append the following paragraph to the end of ANSI/AIAA S-120A-2015, Section 5.1.5:

> See SAWE RP A-3, Revision A, Sections 5.1.5 and 5.1.6, for additional guidance on assessing the mass maturity of components.

5.1.6 Assessment of Predicted Performance Against Requirements (Clarification Language Added)

Replace the first sentence in the first paragraph of ANSI/AIAA S-120A-2015, Section 5.1.6, with the sentence below:

> The system, subsystem, payload, bus, and/or vehicle aggregate Mass Growth Allowance (MGA) are strong indicators of the design maturity at each specified major milestone.

Append the following paragraphs to the end of ANSI/AIAA S-120A-2015, Section 5.1.6:

> When inertia values are derived from the basic Computer Aided Design (CAD) tools, the inertia values are based on the basic mass. If larger inertias present more adverse conditions for meeting requirements, the inertia values should be scaled by the ratio of predicted mass/basic mass to quantify inertias based on predicted mass.
>
> See SAWE RP A-3, Revision A, Section 5.1.6, for additional guidance.

5.1.7 Mass Growth Allowance (Clarification Language Added)

Append the following list to the end of the first paragraph of ANSI/AIAA S-120A-2015, Section 5.1.7:

- MGA is based on historical mass growth trends and component design maturities
- MGA is applied to mass only
- MGA always has a positive or zero value
- MGA is aggregated as a summation of MGA values for the system being assessed

5.1.8 Mass Threats, Opportunities, and Probability of Occurrence (Clarification Language Added)

Append the following sentence to the end of ANSI/AIAA S-120A-2015, Section 5.1.8:

> See SAWE RP A-3, Revision A, Section 5.1.8, for additional details.

5.1.9 Mass Margin

There are no changes to this section. Use ANSI/AIAA S-120A-2015 verbatim.

5.1.10 Mass Risk Assessment (Heritage Design Column Added)

Insert an additional column to Table 2, Mass Risk Assessment Example, listing the recommended mass margins for systems having more than 50% heritage design by mass as shown below:

Table 2 – Mass Risk Assessment Example

Program Milestone	Recommended MGA	Recommended Mass Margin	Recommended Mass Margin for More Than 50% Heritage Design by Mass[3]	MGA + Mass Margin	
	(%)[1]	(%)[1]	(%)[1]	(%)[2]	Grade
ATP	>15	>15	> 8	>30	Green
	9<MGA≤15	10<Mass Margin≤15	5.5 <Mass Margin≤ 8	19<MGA + Mass Margin≤30	Yellow
	≤9	≤10	≤ 5.5	≤19	Red
PDR	>12	>9	> 5	>21	Green
	8<MGA≤12	5<Mass Margin≤9	3 <Mass Margin≤ 5	13<MGA + Mass Margin≤21	Yellow
	≤8	≤5	≤ 3	≤13	Red
CDR	>7	>5	> 3	>12	Green
	4<MGA≤7	3<Mass Margin≤5	2<Mass Margin≤ 3	7<MGA + Mass Margin≤12	Yellow
	≤4	≤3	≤2	≤7	Red
Released Design	>3	>2	> 1.5	>5	Green
	2<MGA≤3	1<Mass Margin≤2	1<Mass Margin≤ 1.5	3<MGA + Mass Margin≤5	Yellow
	≤2	≤1	≤1	≤3	Red
Final	0	>1	>1	>1	Green

Notes:

(1) The percentages of MGA and Mass Margin in the above chart are defined as follows:

MGA = Predicted Mass - Basic Mass

% MGA = (MGA/Basic Mass) × 100

% Mass Margin = [(Allowable Mass - Predicted Mass)/Basic Mass] × 100

(2) The % (MGA + Mass Margin) is defined as:
% (MGA + Mass Margin) = [(Allowable Mass - Basic Mass)/Basic Mass] × 100

(3) Heritage Design parts and assemblies with no change to the design that meet the criteria for qualification by similarity

5.1.11 Technical Performance Measurement

There are no changes to this section. Use ANSI/AIAA S-120A-2015 verbatim.

5.1.12 Mass Properties Control Board (Clarification Language Added)

Append the following paragraph to the end of ANSI/AIAA S-120A-2015, Section 5.1.12:

> See SAWE RP A-3, revision A, Section 5.1.12, for additional information on key functions of the Mass Properties Control Board (MPCB).

5.2 Analysis

Use ANSI/AIAA-S-120A-2015 for all subsections and paragraphs, except as noted below.

5.2.1 Scope

There are no changes to this section. Use ANSI/AIAA S-120A-2015 verbatim.

5.2.2 Methods of Analysis

There are no changes to this section. Use ANSI/AIAA S-120A-2015 verbatim.

5.2.2.1 Manual Layout/Drawing Analysis (Clarification Language Added)

Append the following sentence to the end of ANSI/AIAA S-120A-2015, Section 5.2.2.1:

> See SAWE RP A-3, Revision A, Section 5.2.2.1, for additional information and guidance.

5.2.2.2 Three-Dimensional (3D) Model Analysis (Clarification Language Added)

Append the following paragraphs to the end of ANSI/AIAA S-120A-2015, Section 5.2.2.2:

> For CAD tools with a selectable setting for Product of Inertia (POI) sign convention output, select the POI sign convention that matches the mass properties database software. The process in Annex E may be used to verify the CAD's POI sign convention output after changing the setting. The matching CAD POI sign convention setting should be documented and used consistently for all mass properties data derived by the CAD tool.
>
> If the CAD tool lacks a user-specifiable setting for POI sign convention output, and its POI output sign convention is the opposite of the mass properties database, a reliable process for reversing the signs of all POI data extracted from the CAD tool prior to importing the data into the mass properties database should be implemented.

5.2.3 Flight Hardware Analysis

There are no changes to this section. Use ANSI/AIAA S-120A-2015 verbatim.

5.2.4 Mass Properties Uncertainty Analysis (Clarification Language Added)

Append the following to the end of ANSI/AIAA S-120A-2015, Section 5.2.4:

> See SAWE RP A-3, Revision A, Section 5.2.4, for additional information and guidance.
>
> Mass properties uncertainties must not be confused with MGA. Mass properties uncertainties:
>
> - Are quantified through assessment of uncertainties in the method of derivation and component variations from:
>   - Estimation or analysis uncertainties

  - Measurement uncertainties
  - Manufacturing tolerances

- Are applied to mass, Center of Mass (CM), Moment of Inertia (MOI), and POI
- Have positive or negative values
- May vary either randomly or systematically from component to component
- For the system being assessed, may be aggregated by root sum squared (RSS), Monte Carlo, or worst-case summation

5.2.5 Special Analyses

There are no changes to this section. Use ANSI/AIAA S-120A-2015 verbatim.

5.2.5.1 Balance and Ballast Mass Analysis

There are no changes to this section. Use ANSI/AIAA S-120A-2015 verbatim.

5.2.5.2 Mission and Attitude Control System Analysis

There are no changes to this section. Use ANSI/AIAA S-120A-2015 verbatim.

5.2.5.2.1 Propellant

There are no changes to this section. Use ANSI/AIAA S-120A-2015 verbatim.

5.2.5.2.2 Movable Objects

There are no changes to this section. Use ANSI/AIAA S-120A-2015 verbatim.

5.2.5.2.3 Mission Sequential Mass Properties

There are no changes to this section. Use ANSI/AIAA S-120A-2015 verbatim.

5.3 Verification

Use ANSI/AIAA-S-120A-2015 for all subsections except as noted below.

5.3.1 Verification Plan (Requirement Added)

Append the following paragraphs to the end of ANSI/AIAA S-120A-2015, Section 5.3.1:

> The Mass Properties Verification Plan (MPVP) is a document prepared for and used by engineers, managers, and the customer. The MPVP documents the method for verifying the SV's mass properties, with the objective of reducing the SV's mass properties

uncertainties. The MPVP identifies the mass properties data used for performance analyses, stability and control analyses, and other related analyses.

The contractor shall develop and document a MPVP to describe and substantiate the methods used to verify that mass properties meet requirements and/or mass properties objectives. The MPVP should be originated during the conceptual design and development stage. The MPVP should be updated and reviewed at PDR, CDR, and any other major developmental milestones such as block and/or fleet changes for which mass properties requirements and/or objectives and/or verification methods have been updated.

5.3.1.1 Verification Criteria

There are no changes to this section. Use ANSI/AIAA S-120A-2015 verbatim.

5.3.1.2 Verification Method Selection (Requirement Added)

Append the following paragraph to the end of ANSI/AIAA S-120A-2015, Section 5.3.1.2:

The verification method shall be included in the verification plan. Verification may be accomplished by analytical method(s), by measurement, or by a combination of both. Selection of the verification method(s) is/are justified by an approved verification plan (verification cross reference matrix or similar). The verification method(s) should be selected early enough in the program to provide time for the acquisition, modification, or preparation of test equipment and test site selection, or analysis tool procurement or development.

5.3.2 Test Plan (Requirement Added)

Insert the following paragraph at the beginning of ANSI/AIAA S-120A-2015, Section 5.3.2:

A test plan shall be prepared and documented for the final mass properties verification test. The test normally measures dry mass, dry CM, and/or MOI and POI.

5.3.2.1 Test Description (Clarification Language Added)

Append the following paragraph to the end of ANSI/AIAA S-120A-2015, Section 5.3.2.1:

See SAWE RP A-3, Revision A, Section 5.3.2.1, for an example outline of a test description.

5.3.2.2 Ground Support Equipment (GSE)

There are no changes to this section. Use ANSI/AIAA S-120A-2015 verbatim.

5.3.2.3 Measurement Uncertainty (Requirements Added)

Append the following paragraphs to the end of ANSI/AIAA S-120A-2015, Section 5.3.2.3:

The test plan shall include a description of the sources of measurement system error and the magnitudes of these errors. The test plan's measurement uncertainty analysis computes the predicted uncertainties in the results of the mass properties test measurement. Measurement uncertainty analysis identifies all potential sources of discrepancy between measured and true values.

The measurement uncertainty analysis computations and documentation should consider errors from:

- Measurement equipment tolerances
- Wind, ventilation system air impingement, or other environmental sources of measurement error
- Uncertainties in local gravity
- GSE mass properties uncertainties
- GSE dimensional tolerances
- Tolerances in scale leveling or vertical alignment of measured weight load paths
- Potential side loading of compression load cells and shear loading of platform scales
- Any other identifiable measurement error sources

The computed measurement uncertainty shall be included in a final system level uncertainty analysis that also includes uncertainties due to:

- Buoyancy of gases in the propellant and other closed tanks
- Measurement configuration differences from flight
- Mass properties of each overage and shortage list item
- Assessment of potential errors in methods used to reconcile overages and shortages
- Any other identifiable sources of errors in reconciling measured mass properties to flight mass properties

The resulting mass properties uncertainties of the SV are used as inputs to assess compliance and margins to mass properties requirements in the launch configuration and various flight configurations throughout the mission. If mass properties noncompliance or low margins are identified the uncertainty analysis documentation may be used to identify areas where dispersions can be reduced to improve margins.

5.3.2.4 Measurement Schedule

There are no changes to this section. Use ANSI/AIAA S-120A-2015 verbatim.

5.3.2.5 Customer Witnessing of Verification Tests (Requirements Added)

Add the following new section after ANSI/AIAA S-120A-2015, Section 5.3.2.4:

5.3.2.5 Customer Witnessing of Verification Tests

The contractor shall support witnessing of flight final mass properties measurements by the customer and/or the customer's representative.

Test plans for the flight final dry or wet mass properties measurements of SV should include provisions to support witnessing of final mass properties measurements by the customer and/or the customer's representative, at the option of the customer. The purpose of this witnessing is to verify that the test facilities, environment, measurement equipment calibration, measurement processes, test article configuration, lift rigging setup, raw data collection, and data recording will yield measurement results within accuracy requirements.

Adequate lead time and method for notifying the customer of upcoming SV final mass properties tests, and for providing a copy of the test procedures shall be negotiated with the customer and documented in the test plan.

5.3.3 Standard Work Instruction

There are no changes to this section. Use ANSI/AIAA S-120A-2015 verbatim.

5.3.4 Test Procedure (TP)

There are no changes to this section. Use ANSI/AIAA S-120A-2015 verbatim.

5.3.4.1 Test Scope

There are no changes to this section. Use ANSI/AIAA S-120A-2015 verbatim.

5.3.4.2 Applicable Documents, Equipment, GSE, and Software

There are no changes to this section. Use ANSI/AIAA S-120A-2015 verbatim.

5.3.4.3 Requirements (Clarification Language Added)

Append the following paragraph to the end of ANSI/AIAA S-120A-2015, Section 5.3.4.3:

> See SAWE RP A-3, revision A, Section 5.3.4.3, for elaboration on test requirements.

5.3.4.4 Test Configuration (Clarification Language Added)

Append the following paragraph to the end of ANSI/AIAA S-120A-2015, Section 5.3.4.4:

> See SAWE RP A-3, Revision A, Section 5.3.4.4, for elaboration on test configurations.

5.3.4.5 Test Sequence (Clarification Language Added)

Append the following paragraph to the end of ANSI/AIAA S-120A-2015, Section 5.3.4.5:

> See SAWE RP A-3, Revision A, Section 5.3.4.5, for a top-level example of a test sequence.

5.3.5 Data Record

There are no changes to this section. Use ANSI/AIAA S-120A-2015 verbatim.

5.3.5.1 Records for Mass Properties Measurements (Clarification Language Added)

Append the following to the end of ANSI/AIAA S-120A-2015, Section 5.3.5.1:

> Records for each major mass properties measurement performed in accordance with the approved procedure or detailed work/process instructions should include the following:

- A copy of the redlined test procedure with the quality engineer's approval when deviating from the approved test procedure.

- A copy of the measured raw data reduction, including the measurement uncertainty computations.

- A record of the test equipment model number, serial number, and calibration and proof-load expiration dates.

- A copy of tables and figures showing each scale reading with units and dimensions, tare, zero drifts, and the raw weight at each reaction point.

- A list of missing flight items (shortage list). This list contains data on each flight hardware item that was not present on the SV during mass properties measurement. Each record in this list should contain:

  - Identifying part number and description of each item

  - As applicable, the predicted mass, CM, MOI, and POI of each item

- A list of the non-flight items used during the measurements (overage list). This list contains data on the location, orientation, and applicable mass properties of GSE, lift riggings, any non-flight handling and lift fittings, test equipment, protective covers, tag lines, etc. Each record in this list should contain:

  - Identifying part number and/or description of each item

  - If applicable, the serial number of the GSE

  - As applicable, the measured or predicted mass, CM, MOI, and POI of each item

- If the measured SV includes propellant tanks, pressurant tanks, and/or sealed compartments that are known to, or are suspected of, containing liquids or gases with densities different from the surrounding atmosphere during weighing, the mass properties engineer should take measurements to compute tank buoyancies, and record the tank internal pressure, ambient air temperature, and barometric pressure.

- To obtain mass readings when using force measurement devices, such as load cells or electronic platform scales, include the measurement or computation of local gravitational acceleration at the weighing site so that weight measurements can be converted to corresponding mass values.

  - Note that some electronic weighing systems have software features that can adjust weight measurements in local gravity to standard gravity. The presence of such features should be verified, and, if present, the system's gravity adjustment settings during the weighing should be recorded.

- If the mass measurement is performed using mass balance systems such as balance beam scale, the use of balance beam scales should be documented, and should not need any local gravity adjustment.

5.3.5.2 Post-Test Configuration Change Log

There are no changes to this section. Use ANSI/AIAA S-120A-2015 verbatim.

5.4 Mass Properties Data Management

Use ANSI/AIAA-S-120A-2015 for all paragraphs except as noted below.

5.4.1 Scope

There are no changes to this section. Use ANSI/AIAA S-120A-2015 verbatim.

5.4.2 Data Management System

There are no changes to this section. Use ANSI/AIAA S-120A-2015 verbatim.

5.4.2.1 Database Requirements

There are no changes to this section. Use ANSI/AIAA S-120A-2015 verbatim.

5.4.2.2 Frequency of Database Updates

There are no changes to this section. Use ANSI/AIAA S-120A-2015 verbatim.

5.4.3 Data Organization Utility (Clarification Language Added)

Replace the ANSI/AIAA S-120A-2015 paragraph in Section 5.4.3 with:

> The mass properties database should have the flexibility to sort and report mass properties data in multiple formats, based on criteria from various programmatic and technical stakeholders, including work breakdown structure (WBS) and function breakdown structure (FBS).

5.4.4 Database Record Keeping

There are no changes to this section. Use ANSI/AIAA S-120A-2015 verbatim.

5.5 Documentation

Use ANSI/AIAA-S-120A-2015 for all paragraphs except as noted below.

5.5.1 Scope

There are no changes to this section. Use ANSI/AIAA S-120A-2015 verbatim.

5.5.2 Mass Properties Control Plan

There are no changes to this section. Use ANSI/AIAA S-120A-2015 verbatim.

5.5.3 Verification Plan

There are no changes to this section. Use ANSI/AIAA S-120A-2015 verbatim.

5.5.4 Mass Properties Test Plans and Procedures

There are no changes to this section. Use ANSI/AIAA S-120A-2015 verbatim.

5.5.5 Test Completion Reports (Clarification Language Added)

Append the following sentence to the end of ANSI/AIAA S-120A-2015, Section 5.5.5:

> Refer to SAWE RP A-3, Revision A, Section 5.5.5, for recommended content of a mass properties test completion report.

5.5.6 Contract Change Proposals

There are no changes to this section. Use ANSI/AIAA S-120A-2015 verbatim.

5.5.7 Mass Properties Status Report (Clarification Language Added)

Append the following paragraphs to the end of ANSI/AIAA S-120A-2015, Section 5.5.7:

> Refer to SAWE RP A-3, Revision A, Section 5.5.7, for elements of a mass properties status report.
>
> Mass properties status reports composed of those applicable elements listed in SAWE RP A-3, Revision A, Annex D, Table D.1, should be developed and documented by the contractor as specified in the contract data requirements list (CDRL) and detailed by a data item description (DID).
>
> Refer to the subsections of SAWE RP A-3, Revision A, Section 5.5.7, for recommended contents of a mass properties status report. Where variations for SV or launch vehicle (LV) are indicated, the SV variant should be used. Where subsections of Section 5.5.7 are indicated in Annex D, Table D.1, these subsection references are to subsections of Section 5.5.7 in SAWE RP A-3, Revision A, as ANSI/AIAA-S-120A-2015, Section 5.5.7, has no subsections.
>
> Mass properties data files should be provided in formatted text, spreadsheet, or other data field delimited or structured digital format. Portable document format (PDF) is discouraged for delivery of medium to large data sets.

6. Bibliography

Append the following references to the end of ANSI/AIAA S-120A-2015, Section 6:

[7] The Aerospace Corporation report number ATR-2015-03151, “Mission Risk Posture Assessment Process Description,” dated September 29, 2015

[8] Cal Poly – San Luis Obispo. CubeSat Design Specification, Revision 13, dated February 29, 2014

[9] Cal Poly – San Luis Obispo. 6U CubeSat Design Specification, Revision Provisional X1, dated April 20, 2016

Annex A. Supplemental Information for Terms and Definitions (Informative)

No change to this annex. Use ANSI/AIAA-S-120A-2015 verbatim.

Annex B. Functional Breakdown of Mass (Informative)

No change to this annex. Use ANSI/AIAA-S-120A-2015 verbatim.

Annex C. Guidance for Compliance with Contractual Requirements (Replace Table C.1)

Replace the last sentence in this section and Table C.1 with the following:

Table C.1 numbers each requirement and identifies whether the requirement is:

- Applicable (A) – required
- Conditionally Applicable (C) – evaluation by procuring authority
- Optional (O) in support of program planning

Replace Table C.1 with the following table.

Table C.1 – Numbered Requirements

Item #	Section # Description	Requirement	Applicability		
			Class A	**Class B**	**Class C/D**
1	5.1.2.1 Subcontractor Mass Properties Control Plan (Requirement Added)	The contractor SHALL be responsible for determining the applicable and appropriate mass properties control requirements for each subcontractor or supplier provided component.	A	C	O
2	5.1.2.2 Supplier Interface	The contractor SHALL structure its subcontracts to ensure suppliers provide sufficient information to support timely integration of subunit mass properties into complete unit mass properties and to ensure timely responses to information requests.	A	A	A
3	5.1.3 Mass Properties Control Process	The contractor SHALL develop achievable mass properties objectives and assist the procuring authority in specifying general system mass properties requirements and their proper allocation to the configuration element requirements.	A	A	A
4	5.1.4 Requirements Flow-down and Traceability	The contractor SHALL show traceability to its source for all system and subsystem mass properties requirements, including, but not limited to, contractual, attitude control, and mission and ground handling requirements.	A	A	A
5	5.1.6 Assessment of Predicted Mass Properties against Requirements	The contractor SHALL maintain the percentage of aggregate predicted mass in each maturity category in Table 1 and perform an analysis to show predicted performance and acceptable margins for each identified critical mass properties requirement.	A	A	O
6	5.1.7 Mass Growth Allowance	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 according to Table 1.	A	A	O
7	5.1.8 Mass Threats, Opportunities, and Probability of Occurrence	The contractor SHALL evaluate and maintain a list of all potential design changes with threats to increase and opportunities to decrease the system mass.	A	A	O
8	5.1.10 Mass Risk Assessment	The contractor SHALL monitor mass risk according to predefined criteria for margin and MGA throughout the program.	A	A	C
9	5.1.11 Technical Performance Measurement (TPM)	The contractor SHALL track and status all critical mass properties (including mass, CM, MOI, POI) using TPM charts that show basic and predicted performance against derived limits and contractual requirements.	A	A	C
10	5.1.12 Mass Properties Control Board	If program-specific mass properties margins are not acceptable or have not been assessed, the program SHALL institute an MPCB.	A	C	O

Item #	Section # Description	Requirement	Applicability Class A	Class B	Class C/D
11	5.2.1 Analysis Scope	The contractor SHALL perform mass properties analysis to support the program requirements for space system mass properties accuracy and documentation for all configurations throughout the program.	A	A	O
12	5.2.2 Methods of Analysis	During all program phases, from proposal to launch and operation, the contractor SHALL substantiate the mass properties database and MGA values by providing a maturity assessment of each subsystem and key component and document associated coordinate systems as discussed in SAWE RP-6.	A	A	O
13	5.2.2.1 Manual Layout/Drawing Analysis	If a manual layout/drawing analysis approach is used in estimating mass properties, the contractor SHALL document and maintain records of the manual calculation of mass properties data.	A	A	O
14	5.2.2.2 Three-Dimensional (3D) Model Analysis	If a 3D model analysis is used, all constituents of the parts and assemblies SHALL be accounted.	A	A	A
15	5.2.5.1 Balance and Ballast Mass Analysis	For programs where CM, static or dynamic balance, or MOI requirements are critical, and balance or ballast mass is required to meet those requirements, the contractor SHALL analyze the optimum locations and configuration of the balance and ballast mass required.	A	C	C
16	5.2.5.2 Mission and Attitude Control Systems Analysis	Mass properties analysis in support of space system launch and on-orbit operations SHALL be performed as necessary.	A	C	C
17	5.2.5.2.1 Propellant	The contractor SHALL calculate the propellant mass properties based on the system predicted dry mass.	A	A	A
18	5.2.5.2.2 Movable Objects	The mass properties of movable objects, e.g., rotating appendages, SHALL be determined for their nominal stowed and deployed conditions, as well as any intermediate positions that may be critical because of stability, control, or mission success concerns, as necessary.	A	A	C
19	5.2.5.2.3 Mission Sequential Mass Properties	The contractor SHALL perform sequential mass properties as necessary to support guidance navigation and control, jettison, and re-contact analyses.	A	C	O
20	5.3.1 Verification Plan (Requirement Added)	The contractor SHALL develop and document a MPVP to describe and substantiate the methods used to verify that mass properties meet requirements and/or mass properties objectives.	A	C	O
21	5.3.1.2 Verification Method Selection (Requirement Added)	The verification methods SHALL be included in the verification plan.	A	A	A

Item #	Section # Description	Requirement	Applicability		
			Class A	Class B	Class C/D
22	5.3.2 Test Plan Requirement Added)	A test plan SHALL be prepared and documented for the final mass properties verification test.	A	A	A
23	5.3.2.2 Ground Support Equipment	A test equipment fit check SHALL be performed on all new GSE as necessary, allowing adequate time for problem resolution so as not to impact the test schedule.	A	C	O
24	5.3.2.2 Ground Support Equipment	If GSE is attached to the unit being measured during the mass properties measurement, the test plan SHALL identify how the mass properties of the GSE will be measured and tracked.	A	A	O
25	5.3.2.3 Measurement Uncertainty (Requirement Added)	The test plan SHALL include a description of the sources of measurement system error and the magnitudes of these errors.	A	A	A
26	5.3.2.3 Measurement Uncertainty (Requirement Added)	The computed measurement uncertainty SHALL be included in a final system level uncertainty analysis.	A	A	C
27	5.3.2.5 Customer Witnessing of Verification Tests (Requirements Section Added	The contractor SHALL support witnessing of flight final mass properties measurements by the customer and/or the customer's representative.	A	C	O
28	5.3.2.5 Customer Witnessing of Verification Tests (Requirements Section Added	Adequate lead time and method for notifying the customer of upcoming SV final mass properties test, and for providing a copy of the test procedures SHALL be negotiated with the customer and documented in the test plan.	A	A	C
29	5.3.4.4 Test Configuration	The mass properties test configuration and environment SHALL be accurately documented in detail.	A	A	A
30	5.3.4.5 Test Sequence	The test procedure SHALL include a detailed step-by-step sequence to be followed.	A	C	O
31	5.3.5 Data Record	Records for each major mass properties measurement performed in accordance with approved procedures or detailed work/process instructions SHALL be documented, and these documents are made available for review by the customer and/or the customer's representative upon request, including the subcategories listed below.	A	A	A
32	5.4.2 Data Management System	The contractor SHALL develop and maintain a mass properties database of the space system with sufficient capability and accuracy to support program reporting requirements.	A	C	C
33	5.4.4 Database Record Keeping	The contractor SHALL maintain records that represent a snapshot in time of the detailed mass properties database in electronic format.	A	C	O

Item #	Section # Description	Requirement	Applicability		
			Class A	Class B	Class C/D
34	5.5.2 Mass Properties Control Plan	The contractor SHALL document an MPCP in accordance with section 5.1 in this document.	A	C	C
35	5.5.3 Verification Plan	The contractor SHALL document program-specific mass properties verification planning, as specified in section 5.3.1 of this standard, describing and substantiating the methods to be used to verify the program critical mass properties.	A	C	C
36	5.5.4 Mass Properties Test Plans and Procedures	The contractor SHALL develop formal test plans, procedures, and work/process instructions.	A	C	O
37	5.5.5 Test Completion Reports	The contractor SHALL document data records specified in section 5.3.5 of this standard for each critical mass properties test, performed in accordance with approved verification planning and released procedures, in a test completion report.	A	A	A
38	5.5.6 Contract Change Proposals	The contractor SHALL document and substantiate the effect on vehicle mass properties resulting from proposed changes submitted with the change proposal.	A	A	O
39	5.5.7 Mass Properties Status Report	The contractor SHALL develop mass properties status reports that satisfy the needs of the customer, program office, and other internal customers who rely on the timely communication of mass properties information.	A	A	A

Annex D. Space Vehicle Mission Risk Classes (Informative)

The table below is from ATR-2015-03151, *Mission Risk Posture Assessment Process Description*, dated September 29, 2015. This table provides a summary of the mission risk classes and defines top-level parameters for each risk class.

Table D.1 – Space Vehicle Acquisition Mission Risk Classes

Description	Class A	Class B	Class C	Class D
Risk Acceptance	Lowest	Low	Moderate	High
National Significance	Extremely critical	Critical	Not critical	Not critical
Payloads	Operational	Operations demonstrate Operational utility; May become operational	Typically experimental	Typically experimental
Acquisition Cost	Highest	High	Medium	Lowest
Development Time	May take 4 or more years	May take 3 or more years	May take 2 or more years	May take 1 or more years
Mission Life	Long – Greater than 5 years; typically 8-10 years	Medium – Up to 5 years	Short – Less than 2 years	Short – Less than 1 year
Launch Constraints	Critical	Medium	Few	Few to none
Specification and Standards Compliance	Specifications/standards fully incorporated as compliance documents with no or limited tailoring of requirements. All practical measures taken to minimize risk to mission success.	Specifications/standards required as compliance documents with minor tailoring in application to maintain a low risk to mission success.	Medium risk of achieving mission success may be acceptable. Reduced mission assurance requirements with tailoring acceptable.	High risk acceptance achieving mission success is permitted. Reduced set of mission assurance requirements acceptable.

Annex E. Determining POI Sign Convention Used in CAD Software Output (Informative)

The following is a sample process for determining the POI sign convention used in mass properties data output from a CAD solid modeling tool.

1. Create a solid 1 unit diameter rod with one end at X = -10, Y = -10, Z = 0 units, and the other end at X = 10, Y = 10, Z = 0 units in the work coordinate system.
    a. Units may be inches, feet, meters, or other dimensional unit of measure.
    b. Specify a density of 1 in any convenient density unit for the rod material.
2. Have the CAD software compute and output the rod's mass properties.
3. If the output Ixy value is positive, the positive integral sign convention is being used for POI output by the CAD software; otherwise, the negative integral sign convention is being used for POI output.

<table>
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<tr><td colspan="4">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.</td></tr>
<tr><td colspan="2">SMC STANDARD CHANGE RECOMMENDATION:</td><td>1. Document Number
SMC-T-002 (2018)</td><td>2. Document Date
16 July 2018</td></tr>
<tr><td>3. Document Title</td><td colspan="3">Tailoring for ANSI/AIAA S-120A-2015, Mass Properties Control for Space Systems: Space Vehicles</td></tr>
<tr><td colspan="4">4. Nature of Change
(Identify paragraph number; include proposed revision language and supporting data. Attach extra sheets as needed.)</td></tr>
<tr><td colspan="4">5. Reason for Recommendation</td></tr>
<tr><td colspan="4">6. Submitter Information</td></tr>
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<tr><td colspan="2">c. Address</td><td colspan="2">d. Telephone</td></tr>
<tr><td colspan="2">e. E-mail address</td><td colspan="2">7. Date Submitted</td></tr>
<tr><td colspan="4">8. Preparing Activity
Space and Missile Systems Center
AIR FORCE SPACE COMMAND
483 N. Aviation Blvd.
El Segundo, CA 91245
Attention: SMC/ENE</td></tr>
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February 2013