BY ORDER OF THE COMMANDER

SMC Tailoring SMC-T-003
19 March 2010

Supersedes:
New issue

Air Force Space Command

SPACE AND MISSILE SYSTEMS CENTER TAILORING

LIMITING ORBITAL DEBRIS

SMC TAILORING OF NASA-STD-8719.14

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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 new-issue SMC tailoring comprises the text of The Aerospace Corporation report number TOR-2009(8506)-5, entitled *SMC Tailoring of NASA-STD-8719.14, Process for Limiting Orbital Debris*.

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

1. Introduction

This document shall be used as the SMC tailoring of NASA-STD 8719.14 and provides a contractual Compliance Document listing that cites the NASA standard and an annex with tailoring instructions.

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2. Compliance Document and SMC Tailoring

The following section shows an example Compliance Document List entry for the NASA standard indicating that tailoring is to be applied as described in the annex below. Portions of the NASA-STD-8719.14 that do not need SMC tailoring have not been included even though they provide required guidance.

2.1 Core Compliance Document

Document Number	Title	Pub Date
NASA-STD-8719.14	Process for Limiting Orbital Debris	28 Aug 07

2.2 Tailoring Annex

The following section describes the SMC tailoring for NASA-STD-8719.14, *Process for Limiting Orbital Debris*. The numbering in the tailoring below are the paragraph numbers from the NASA standard.

The U.S. Government requirements from the U.S. Government Orbital Debris Mitigation Standard Practices are contained in the Department of Defense Instruction (DoDI), DoDI 3100.12, Space Support, which is the source authority for the derived requirements of U.S. Strategic Command (STRATCOM), Air Force Space Command (AFSPC), and the National Reconnaissance Office (NRO) for debris mitigation. References to these requirements may be found in TOR-2007(8506)-6693, SMC Space Debris Mitigation Handbook Revision 2.0, 30 June 2007.

1.1.4 Replace with: "This SMC-tailored NASA-STD establishes requirements for (1) limiting the generation of orbital debris, (2) assessing the risk of collision with existing space debris, (3) assessing the potential of space structures to impact the surface of the Earth, and (4) assessing and limiting the risk associated with the end of mission (EOM) or end of life (EOL) of a space object. In addition to requirements in Section 4 and methods for assessment, this tailored NASA-STD provides the format for the required debris assessment and reports that must be submitted to SMC/EA."

1.2.a Replace with: "This SMC-tailored NASA-STD is applicable to all objects launched into space in which SMC has lead involvement and control, or has partial involvement with control over design or operations via U.S. internal or international partnership agreements, including the launch vehicle. This document has no automatic exclusions for any program or project due to limited funding, responsibility, or involvement of SMC in the program or project. SMC involvement includes design, manufacture, or funding of instruments, spacecraft bus, spacecraft systems, the launch vehicle, and launch processing. The use of this tailored NASA-STD is only required for those portions of a space mission under SMC control. This tailored NASA-STD defines being in "space" as exceeding 100 km (~62 mi) in altitude and achieving or exceeding Earth orbital velocity."

1.2.c Replace with: "Any decision to waive or vary from the requirements in this SMC-tailored NASA-STD requires the concurrence of the SMC Chief Engineer (SMC/EA).

1.2.e Replace with: "Spacecraft, launch vehicles, and instruments that passed Systems Requirements Review (SRR) prior to September 2000 (release of DoDI 3100.12, Space Support) are not required to perform an orbital debris assessment (ODA) unless a large change in design or changes in space object capability or risk affect the ability to achieve compliance with the requirements. If one or more of these conditions occur, an ODA Report (ODAR) shall be performed."

1.2.f, g, and h Remove these sections in their entirety.

2.1.3 Non-Government Documents

Replace reference with "Inter-Agency Space Debris Coordination Committee (IADC) Space Debris Mitigation Guidelines, Revision 1, September 2007 (http://www.iadc-online.org/index.cgi?item=docs_pub)."

2.2 Reference Documents

Replace reference to "U.S. Air Force Space and Missile Center (SMC) Orbital Debris Handbook, (July, 2002)" with "TOR-2007(8506)-6693, SMC Space Debris Mitigation Handbook Revision 2.0, 30 June 2007"

4.1.b Replace with: "Each SMC program or project should attempt to meet all pertinent requirements for its spacecraft, launch vehicle orbital stage(s), and objects released during nominal operations. It is understood, however, that satisfying these requirements must be balanced with the necessity to meet mission requirements and to control costs. If a requirement cannot be met because of an overriding conflict with mission requirements, technical capabilities, or prohibitive cost impact, then a waiver can be requested through the SMC Chief Engineer or the appropriate authority for risk acceptance per MIL-STD 882C with the SMC ODAR containing the appropriate rationale and justification."

4.1.c Replace with: "SMC/EAF is staffed and funded to provide support to programs, and SMC/SE can also assist programs and projects with the preparation of the required ODARs and End of Life Plans (EOLP). Programs/projects may use the orbital debris modeling tools provided by the NASA Orbital Debris Program Office (ODPO) in assessing orbital debris generation and risk in Earth orbit."

4.2.1.g Replace with: "The ODAR shall be delivered in accordance with the requirements specified below. The nominal schedule is:

- **i. PDR Draft ODAR:** 30 days prior to the SMC program Preliminary Design Review (PDR) for the spacecraft or equivalent program/project development milestone. This draft is submitted to the Contracting Officer, who will make distribution to SMC/EAF and any other offices as needed. The purpose of preparing the report early in the design and development process is to ensure that orbital debris issues are identified early when resolutions are least costly to implement. Any orbital debris mitigation compliance issues not resolved by PDR shall be addressed and resolved no later than the Critical Design Review (CDR) or equivalent program/project development milestone.

ii. CDR Draft ODAR: 45 days prior to the SMC program or project CDR for the spacecraft or equivalent program/project development milestone. This Draft is submitted to the Contracting Officer, who will make distribution as with the PDR Draft ODAR. The purpose of the CDR Draft is to update and clarify the issues and changes to the PDR Draft. Any noncompliances that remain prior to beginning the launch approval process will require formal risk acceptance by the SMC Chief Engineer.

iii. FINAL ODAR: shall be submitted to the Contracting Officer for approval and signature prior to the beginning of the launch approval process but no later than the program's Flight Readiness Review (FRR). Formal acceptance of the risk associated with the noncompliances remaining in the ODAR shall accompany the delivery of the Final ODAR."

Note: Each ODAR delivered will be reviewed by the SMC Chief Engineer with technical assistance from SMC/EAF. After the review, results will be provided to the SMC Program Manager."

4.2.2.a Replace with: "The EOLP is a living document. It is developed during the later stages of SMC mission development to ensure that design and operational use do not preclude a safe decommissioning and disposal. The EOLP identifies milestones in the operational life of the mission that affect the EOL process. After those milestones, the EOLP and the health of the critical items defined in the EOLP shall be evaluated and updated so that SMC management understands the constraints and options available at EOL for limiting orbital debris."

4.2.2.e Replace with: "End of Life Plans shall be delivered in accordance with the requirements specified below. The nominal schedule is:

i. Preliminary End of Life Plan: 45 days prior to the program CDR for the spacecraft or equivalent SMC program/project development milestone. This Preliminary Draft is submitted to the Contracting Officer, who will make distribution to SMC/EAF and any other offices as needed. The purpose of preparing the plan early in the operational development process is to ensure that EOL issues are identified early when resolutions are least costly to implement.

ii. Prelaunch End of Life Plan: 30 days prior to the launch of the mission. The prelaunch End of Life Plan shall be submitted to the Contracting Officer who will make distribution to SMC/EAF and any other offices as needed. Formal acceptance of the risk associated with any noncompliances remaining in the End of Life Plan shall be included in the approval process.

iii. Updates to the End of Life Plan (titled: "*[date]* Update to the End of Life Plan"): to be made at the major program operational milestones identified in the End of Life Plan.

iv. **Final End of Life Plan:** shall be delivered 3 months prior to the expected implementation of the End of Life Plan for spacecraft decommissioning/ disposal.

Note: Each End of Life Plan delivered will be reviewed by SMC/EAF and SE. The draft End of Life Plans may be submitted in electronic form only. Signed End of Life Plans shall be delivered in both electronic and paper copies. Note that programs are encouraged to use existing program documentation and the ODAR for mission and spacecraft descriptions and identification of EOL decommissioning issues. A copy of the Final ODAR shall be included in the delivery of the Final End of Life Plan."

4.2.4 Deviations to ODARs and EOMPs

Replace with: "Deviations from the requirements for ODARs and EOLPs stated in this tailored NASA-STD requires approval by the SMC Chief Engineer."

4.3.2.1 *Requirement 4.3-1: Debris passing through LEO:*

Replace with: "For SMC missions leaving debris in orbits passing through LEO, released debris with diameters of 5 mm or larger shall satisfy both Requirement 4.3-1a and Requirement 4.3-1b."

4.3.4 Methods to Assess Compliance

Replace with: "Compliance to section 4.3 requirements shall be documented in the ODAR and EOLP for all items/objects larger than 5 mm in LEO and 5 cm in GEO planned for release during all phases of flight."

4.3.4.1.b (2) Replace with: "With the debris orbital parameters, area-to-mass ratio, and year of release into orbit, use the NASA Debris Assessment Software (DAS 2.01 or most current version) to determine the orbital lifetime. If the apogee of the debris is greater than 5000 km, then additional orbital data will be needed. DAS will prompt the user for this information. Assistance can also be obtained from SMC/EAF."

4.4.4.1.2.i. Replace with: "The ODAR and EOLP contain a full description of the passivation actions to be employed for all sources of stored energy and a notional timeline of when the actions take place. This plan identifies all passivation measures to include, at a minimum, spacecraft fuel depletion, propellant venting, disabling of battery charging systems, safing of bus and payloads, and any sources of stored energy that will remain. For example, an orbital stage main propulsion system depletion burn may be scheduled 15 minutes after separation of the payload, followed by a sequenced venting of the propellant and pressurant tanks thereafter."

4.4.4.2.b (1) Replace with: "Define a breakup model for the test. A breakup model describes the debris created in the breakup process in terms of the distributions in size, mass, area-to-mass ratio, and velocity imparted at breakup. A standard breakup model used for debris environment evolution calculations may be acceptable for a test, or the breakup model may require taking into account specific characteristics of the planned test. Standard breakup models or support for defining specific breakup models for a given test may be obtained from SMC/EAF."

4.4.4.2.b (4) Replace with: "No later than 30 days prior to the planned breakup, SMC will coordinate with the Department of Defense (specifically, U.S. Strategic Command) to verify that immediately after the breakup no operating spacecraft will have a probability of collision greater than 10^{-6} with debris larger than 1 mm. Special software is generally required to analyze the debris cloud characteristics immediately after breakup. Contact SMC/EAF for assistance."

4.5.2 Requirements for the Collision-induced Risk to Disposal Area: Replace with: "The contractor shall assess and limit the probability that the operating space system becomes a source of debris if it collides with orbital debris or meteoroids."

4.5.4 Methods to Assess Compliance. Replace with: "Compliance to Section 4.5 requirements shall be documented in the ODAR and EOLP for all phases of flight including the launch phase per applicability in Section 4.5 introduction.

The analyses documented in the ODAR and EOLP need to include not only collisions that produce large amounts of debris, but also collisions that will terminate a spacecraft's capability to perform post-mission disposal. This documentation should also address methods being used to reduce risk, such as mission re-selection or operational collision avoidance and any trade-offs between cost, mission requirements, and risk reduction for each method."

4.5.4.2.d. Replace with: "Determining the vulnerability of a space system to impact with orbital debris or meteoroids can be a very complex process, in some cases requiring hypervelocity impact testing of components and materials that have been designed into the system. The objective of the following evaluation process is to help the SMC user determine (1) whether there may be a significant vulnerability to meteoroid or orbital debris impact, (2) which components are likely to be the most vulnerable, and (3) what simple design changes may be made to reduce vulnerability. DAS can provide insight into these issues. If necessary, higher fidelity assessments may be warranted. SMC/EAF can assist programs or projects with any questions in this area."

4.5.5.b. Replace with: "There are many mitigation measures to reduce the probability that collisions with small debris will disable the spacecraft and prevent successful post-mission disposal. These measures use the fact that the debris threat is directional (for orbital debris, highly directional) and that the directional distribution can be predicted with confidence. Design responses to reduce failure probability include addition of component and/or structural shielding, rearrangement of components to let less sensitive components shield more sensitive components, use of redundant components or systems, and compartmentalizing to confine damage. Since there are many alternatives to pursue for reducing vulnerability to impact with small debris, some of them requiring in-depth familiarity with hypervelocity impact effects, they will not be discussed further in this document. If a significant reduction in failure probability is required, it is advisable to contact SMC/EAF."

4.6.1.f. Replace with: "The contractor shall support the SMC space programs and projects in planning for the disposal of spacecraft and launch vehicle orbital stages and space structures at the end of their respective missions. Post-mission disposal shall be used to remove a space structure from Earth orbit in a timely manner or to leave a space structure in a disposal orbit where the structure will pose as small a threat as practical to other space systems."

4.6.2.4. Replace with: "*Requirement 4.6-4. Reliability of post-mission disposal operations in Earth orbit*: The contractor shall ensure that all post-mission disposal operations are designed for a probability of success as follows:"

4.6.2.5. Replace with: "Requirement 4.6-5. Operational design for EOM passivation:

(a) All SMC spacecraft and launch vehicles in Earth and lunar orbit shall be passivated at EOL to the extent necessary to prevent breakup or further generation of orbital debris.

(b) The timing, order, procedures, and verification methods for performing all depletions identified for Requirement 4.4-2 shall have been developed prior to launch.

(c) The level of passivation shall be updated prior to implementation of the EOLP."

4.6.3.f. Replace with: "SMC spacecraft that have terminated their mission shall be maneuvered far enough away from GEO so as not to cause interference with space systems still in geostationary orbit (Requirement 56583). The minimum increase in perigee altitude at the end of re-orbiting shall ensure that the space structure does not come within GEO + 200 km for the next 100 years. A selected perigee of GEO +235 km + $(1000 \cdot C_R \cdot A/m)$ and an eccentricity of less than 0.003 ($e<0.003$) will ensure that the space structure does not come within 200 km of GEO altitude (35,786 km) for at least 100 years (Figure 4.6-1 of NASA-STD-8719.14). [C_R = solar radiation pressure coefficient, typical values: 1-2, A = area in m^2, and m = mass in kg]"

4.6.3.i. Replace with: "Recent studies have also indicated that disposal orbits with modest eccentricities near GEO can be perturbed over long periods into more elliptical orbits with perigees less than 200 km above GEO. Therefore, the initial eccentricity of an SMC GEO disposal orbit should be less than 0.003. In selecting a disposal orbit, the specific initial orbital conditions can be evaluated to determine the long-term perturbative effects and consequent limitations on initial eccentricity."

4.6.3.m. Replace with: "When selecting a disposal orbit between LEO and GEO, a long-term (at least 100-year) orbital perturbation analysis shall be conducted (and documented in the ODAR/EOLP) to ensure that the disposal orbit is not altered, particularly by solar or lunar gravitational forces, in such a way that the disposed space structure will later penetrate LEO or GEO. Even nearly circular orbits in MEO can, under certain initial conditions, later experience severe changes in eccentricity, resulting in perigees within LEO or apogees within GEO."

4.6.3.o. Replace with: "All planned post-mission maneuvers, including large, discrete maneuvers and continuous low-thrust maneuvers shall be evaluated for potential collision risks with other resident space objects tracked by the U.S. Space Surveillance Network."

4.6.3.q. Delete.

4.6.4.1.a. Replace with: "The amount of time an SMC space structure will remain in orbit depends on its orbit, on the final area-to-mass ratio of the space structure, and on solar activity. For an orbit with apogee altitude above 5,000 km, the orbital lifetime will also be affected by lunar and solar gravitational perturbations. Follow the directions in Section 4.3 of this tailored NASA-STD (as well as in DAS documentation) to determine the optimum disposal orbit. Assistance is also available from SMC/EAF."

4.6.4.1.b. Replace with: "Drag augmentation devices, such as inflatable balloons, increase the area-to-mass ratio of a space structure and, consequently, reduce its orbital lifetime. However, the use of such a device results in a larger collision cross-section, thereby increasing the probability of a collision during natural orbital decay. The increased collision probability should be documented in the ODAR/EOLP. This assessment needs to include the probable consequence of a hypervelocity impact between a resident space object, operational or non-operational, and the drag augmentation device."

4.6.4.1.d. Replace with: "A general plan for performing all post-mission disposal maneuvers is to be included in the ODAR/EOLP."

4.6.4.2. Replace with: "Other Post-Mission Disposal Options (Requirements 4.6-1b, 4.6-2 and 4.6-3)

Disposal options resulting in the space structure being left in long-lifetime orbits that will limit interference with future space operations are described in Requirements 4.6-1b, 4.6-2, and 4.6-3. DAS can be used to help design disposal orbits in accordance with Requirements 4.6-1b and 4.6-3. Whenever possible, disposal orbits should avoid the creation of a concentration of orbital debris. Between LEO and GEO, disposal orbits need to be chosen to reduce potential interference with operational satellite constellations. Long-term analysis of orbital stability for the selection of disposal orbit parameters needs to be documented in the EOLP. DAS will measure compliance with Requirement 4.6-3 by evaluating whether or not the orbit will reenter the GEO - 500 km within 100 years from EOM. As noted earlier in this Chapter, propellant gauging is an issue of particular importance for space structures in orbits near GEO."

4.6.4.4. Replace with: "Development of an EOLP (Requirement 4.6-5)

a. Compliance with Requirement 4.6-5 will be based on the completeness of the document with regards to the data required per Appendix B.

b. The ODARs are considered as design documents and are basically final when the mission is launched. The EOLP is considered as an operational document and will need to be updated periodically until it is implemented at EOL.

c. As a living document, the EOLP will need to identify events/milestones in the operational life of the mission that affect end of life processing for disposal. Those events/milestones include:

- Any event affecting the reliability of the space vehicle control systems. This includes the vehicle's ability to maintain a safe/controllable attitude and flight path such as the proper operation of flywheels, solar arrays, and flight control computers.

- Any event affecting the reliability of the systems needed to passivate the vehicle upon decommissioning, such as thrusters required to deplete fuel.
- Any event affecting the reliability of critical instruments to support the mission. For example, the primary mission requires photography, and when the camera fails, the spacecraft can be decommissioned.
- Budgetary timelines/milestones.

d. An EOLP is required for all spacecraft being launched, and is to be updated periodically during the mission per Appendix B.

e. EOLPs are not considered complete until they are reviewed and signed by the SMC Program Executive Officer (PEO) for Space."

4.6.4.5. Delete.

4.6.5. Replace with: "Brief Summary of Mitigation Measures Used for this Area

a. For a program or project that elects to limit orbital lifetime using atmospheric drag and re-entry, several options are available:

- Lower the initial perigee altitude for the disposal orbit;
- When deploying LEO spacecraft to altitudes above 700 km, utilize a lower altitude staging orbit, followed by spacecraft raising maneuvers, to accelerate the orbital decay of launch vehicle stages, in particular those with no re-start capability;
- Increase the area-to-mass ratio for the structure using drag augmentation, but be aware of the issues regarding collision potential with resident space objects;
- For highly elliptical orbits, restrict the initial right ascension of ascending node of the orbit plane relative to the initial right ascension of the Sun so that the average perigee altitude is lowered naturally; and/or
- To increase the probability that the post-mission disposal maneuver will be successful, consider incorporating redundancy into the post-mission disposal system.

b. Additional options and more detailed descriptions can be found in the SMC Debris Mitigation Handbook. Many of these options are also applicable for the disposal of spacecraft.

c. The review of SMC EOLPs during the program's operational life will help meet the goals and intent of this tailored NASA-STD while keeping AF management aware of the associated risks and EOL constraints."

4.7.2 Replace with: "Requirements for the Area

SMC space programs and projects that use atmospheric re-entry as a means of disposal for space structures need to limit the amount of debris that can survive re-entry and pose a threat to people on the surface of the Earth. This area applies to spacecraft and launch vehicles as well as jettisoned components.

Requirement 4.7-1. Limit the risk of human casualty: The potential for human casualty is assumed for any object with an impacting kinetic energy in excess of 15 joules:

(a) For uncontrolled re-entry, the risk of human casualty from surviving debris shall not exceed 0.0001 (1:10,000).

(b) For controlled re-entry, the selected trajectory shall ensure that no surviving debris impact with a kinetic energy greater than 15 joules is closer than 370 km from foreign landmasses, or is within 50 km from the continental U.S., territories of the U.S., or the permanent ice pack of Antarctica.

(c) For controlled reentries, the product of the probability of failure of the re-entry burn (from Requirement 4.6-4.b) and the risk of human casualty assuming uncontrolled re-entry shall not exceed 0.0001 (1:10,000)."

4.7.4.d. Replace with: "Due to the complexity of satellite re-entry physics and aerothermal responses, SMC programs and projects shall employ either DAS or a higher fidelity model such as AHaB (Atmospheric Heating and Breakup) to determine compliance with Requirement 4.7-1. The re-entry risk assessment portion of DAS contains a simplified ORSAT (Object Re-entry Survival Analysis Tool) model that does not require expert knowledge in satellite re-entry analyses. Due to the need to make simplifications, ORSAT is designed to be somewhat conservative. The degree of conservatism is a function of the space vehicle and the materials under evaluation."

4.7.4.e. Replace with: "If a properly performed DAS re-entry risk assessment indicates that the risk is less than 0.0001, then the vehicle is compliant with Requirement 4.7-1. If the DAS result indicates a risk greater than 0.0001, the vehicle may still be compliant, but a higher fidelity assessment will be needed. AHaB is maintained and operated by The Aerospace Corporation, while ORSAT is maintained and operated by trained personnel at JSC. In addition, AHaB and ORSAT have been validated using comparisons with recovered satellite debris as well as comparisons with each other and the European SCARAB (Spacecraft Atmospheric Re-entry and Aerothermal Breakup) model."

4.7.4.f. Replace with: "For a controlled re-entry, the result of the DAS or higher fidelity casualty expectation risk assessment is multiplied by the failure probability of the controlled re-entry (from Requirement 4.6-4) in order to determine whether the overall risk of human casualty is less than 0.0001 (1:10,000). For example, if a failure modes and effects analysis determines that there exists a 10% probability of failure of the controlled re-entry maneuver, then the risk to human casualty must be less than 0.001 (0.1 x 0.001 = 0.0001). If the probability of failure is 20%, the risk to human casualty must be less than 0.0005 (0.2 x 0.0005 = 0.0001). For both controlled and uncontrolled re-entry, the DAS or higher fidelity evaluation must be performed to determine compliance with Requirement 4.7-1."

4.7.4.g. Replace with: "In the DAS or higher fidelity casualty expectation risk assessment, the assumptions used to model the re-entry shall be documented in the ODAR and include the explanation of which items are assemblies and subassemblies and which items, resulting in >15 J impacts have been included."

4.8.4. Replace "EOMP" with "EOLP."

Appendix A—Orbital Debris Assessment Reports (ODAR)

A.1.1 Delivery Requirements

Replace with: "The ODAR shall be delivered in accordance with the requirements specified below. The nominal schedule is:

- **a. PDR Draft ODAR:** 30 days prior to the program Preliminary Design Review (PDR) for the SMC spacecraft or equivalent program/project development milestone. This draft is submitted to the Contracting Officer, who will make distribution to SMC/EAF and any other offices as needed. The purpose of preparing the report early in the design and development process is to ensure that orbital debris issues are identified early when resolutions are least costly to implement. Any SMC orbital debris mitigation compliance issues not resolved by PDR shall be addressed and resolved no later than the Critical Design Review (CDR) or equivalent program/project development milestone.

- **b. CDR Draft ODAR:** 45 days prior to the program or project CDR for the SMC spacecraft or equivalent program/project development milestone. This Draft is submitted to the Contracting Officer, who will distribute to the SMC Chief Engineer and others, as with the PDR Draft ODAR. The purpose of the CDR Draft is to update and clarify the issues and changes to the PDR Draft. Any noncompliances that remain prior to beginning the launch approval process will require formal risk acceptance by the SMC Chief Engineer.

- **c. FINAL ODAR:** shall be submitted to the Contracting Officer, who will distribute to the SMC Chief Engineer for approval and signature prior to the beginning of the launch approval process but no later than the program's Flight Readiness Review (FRR). Formal acceptance of the risk associated with the noncompliances remaining in the ODAR shall accompany the delivery of the Final ODAR."

A.1.4 and A.1.5. Delete.

A.1.6. Replace with: "Each ODAR shall follow the format shown in the table below and, at a minimum, include the content indicated to the extent possible for the SMC acquisition phase. Note that orbital debris mitigation requirements for the SMC spacecraft and launch vehicle shall be addressed in separate ODAR sections (Sections 2 through 8 for spacecraft and Sections 9 through 14 for launch vehicles) for the ease of preparing the assessment report. The draft ODAR may be submitted in electronic form only. Programs are encouraged to use existing program documentation for mission and spacecraft descriptions."

ODAR Cover and Front Matter, and ODAR Sections 1 through 14. Replace with:

Cover and Front Matter

- Cover showing the document version and date of delivery
- Inside cover signed by (at a minimum): document preparer(s), program management, and SMC/EAF office reviewer.
- Statement of any restrictions on the data in the Orbital Debris Assessment Report (ODAR) such as Limited/Government Purpose/Special License Rights; Distribution Statements D or X for technical data subject expert controls. If the document does not contain any restrictions, then a statement to that effect shall be included. If the document does contain restricted information, the restricted information shall be summarized and marked clearly on the page(s) where it occurs and on the cover.
- Document history page showing each version of the report. Reviews of the previous versions by SMC/EAF shall be included on this page.

Section 1: Program Management and Mission Overview

- Identification of the SMC program sponsoring the mission and the Program Manager
- Schedule of mission design and development milestones through proposed launch date, including spacecraft PDR and CDR (or equivalent) dates
- Summary table indicating compliance or noncompliance with each debris mitigation requirement of DoDI 3100.12
- Brief description of the mission
- Identification of the anticipated launch vehicle and launch site
- Identification of the proposed launch date and mission duration
- Description of the launch and deployment profile, including all parking, transfer, and operational orbits with apogee, perigee, and inclination
- Identification of all SMC spacecraft, launch vehicle orbital stages, and all other released objects (>5 mm in diameter), including their orbital parameters following insertion of the spacecraft into a mission orbit
- Identification of any interaction or potential physical interference with other operational spacecraft

Section 2: Spacecraft Description

- Physical description of the spacecraft, including spacecraft bus, payload instrumentation, and all appendages, such as solar arrays, antennas, and instrument or attitude control booms
- Detailed illustration of the entire spacecraft in the mission operation configuration with clear overall dimensional markings and marked internal component locations
- Total spacecraft mass at launch, including all propellants and fluids
- Dry mass of spacecraft at launch, excluding solid rocket motor propellants
- Description of all propulsion systems (cold gas, monopropellant, bipropellant, electric, nuclear)
- Identification, including mass and pressure, of all fluids (liquids and gases) planned to be on board and a description of the fluid loading plan or strategies, excluding fluids in sealed heat pipes
- Description of all fluid systems, including size, type, and qualifications of fluid containers such as propellant and pressurization tanks
- Description of all active and/or passive attitude control systems with an indication of the normal attitude of the spacecraft with respect to the velocity vector
- Description of any range safety or other pyrotechnic devices
- Description of the electrical generation and storage system
- Identification of any other sources of stored energy not noted above
- Identification of any radioactive materials on board

Section 3: Assessment of Spacecraft Debris Released during Normal Operations

- Identification of any object (>5 mm) expected to be released from the spacecraft any time after launch, including object dimensions, mass, and material
- Rationale/necessity for release of each object
- Time of release of each object, relative to launch time
- Release velocity of each object with respect to spacecraft
- Expected orbital parameters (apogee, perigee, and inclination) of each object after release
- Calculated orbital lifetime of each object, including time spent in Low Earth Orbit (LEO)
- Assessment of spacecraft compliance with DoDI 3100.12 paragraph 6.3.1

Section 4: Assessment of Spacecraft Potential for Explosions and Intentional Breakups

- Identification of all potential causes of spacecraft breakup during deployment and mission operations
- Summary of failure modes and effects analyses of all credible failure modes that may lead to an accidental explosion
- Detailed plan for any designed spacecraft breakup, including explosions and intentional collisions
- List of components that shall be passivated at End of Life (EOL). List shall include method of passivation and amount that cannot be passivated.
- Rationale for all items that shall be passivated but are not designed to be passivated
- Assessment of spacecraft compliance with DoDI 3100.12 paragraph 6.3.2.

Section 5: Assessment of Spacecraft Potential for On-Orbit Collisions

- Calculation of spacecraft probability of collision with known space objects larger than 10 cm in diameter during the orbital lifetime of the spacecraft
- Identification of all systems or components required to accomplish any post-mission disposal operation, including passivation and maneuvering
- Calculation of spacecraft probability of collision with space objects, including orbital debris and meteoroids, of sufficient size to prevent post-mission disposal
- Assessment of spacecraft compliance with DoDI 3100.12 paragraph 6.3.3.

Section 6: Assessment of Spacecraft Post-mission Disposal Plans and Procedures

- Description of spacecraft disposal option selected
- Plan for any spacecraft maneuvers required to accomplish post-mission disposal
- Calculation of area-to-mass ratio after post-mission disposal, if the controlled re-entry option is not selected
- Assessment of spacecraft compliance with DoDI 3100.12 paragraphs 6.3.2.2 and 6.4

Section 7: Assessment of Spacecraft Re-entry Hazards

- Detailed description of spacecraft components by size, mass, material, and shape if the atmospheric re-entry option is selected or if launch failure could lead to atmospheric re-entry. For re-entry survivability analysis, the following data is required: a parts list (e.g., a master equipment list); masses for each part (e.g., a spacecraft mass statement); material for each part (e.g., 2042 Al, 410 SS, Kevlar, graphite-epoxy, Ti-6Al-4V); physical dimensions for each part (height, width, length, wall thickness, honeycomb density, etc.); briefing charts, schematics, and drawings illustrating the shape of each part; briefing charts, schematics, and drawings showing the placement of parts in relationship to each other; and the initial orbital state vector for re-entry.
- Summary of objects expected to survive an uncontrolled re-entry, specifying the software analysis tool(s) used for the analysis
- Calculation of probability of human casualty for the expected year of uncontrolled re-entry and the spacecraft orbital inclination
- If appropriate, preliminary plan for spacecraft controlled re-entry
- Assessment of spacecraft compliance with DoDI 3100.12 paragraph 6.4.

Section 8: Assessment for Tether Missions

- Type of tether; e.g., momentum or electrodynamic
- Description of tether system, including (1) tether length, diameter, materials, and design (single strand, ribbon, multistrand mesh), at a minimum and (2) end-mass size and mass
- Determination of minimum size of object that will cause the tether to be severed
- Tether mission plan, including duration and post-mission disposal
- Probability of tether colliding with large space objects
- Probability of tether being severed during mission or after post-mission disposal
- Maximum orbital lifetime of a severed tether fragment
- Assessment of compliance with DoDI 3100.12 paragraph 6.3.3.

Section 9: Launch Vehicle Description

- Identification of launch vehicle to be used
- Identification of any non-basic upper stages to be used
- Identification of any launch vehicle stage that will be inserted into Earth orbit and left there
- Dry mass of each orbital stage after spacecraft deployment
- Detailed illustration of each orbital stage with clear dimensional markings and marked internal component locations

Section 10: Assessment of Launch Vehicle Debris Released during Normal Operations

- Identification of any object greater than 5 mm that will be released into Earth orbit from any stage, including, but not limited to, dual-payload attachment fittings and stage separation devices
- Rationale/necessity for release of each object
- Time of release of each object relative to launch time
- Release velocity of each object with respect to orbital stage
- Expected orbital parameters (apogee, perigee, and inclination) of each object after release
- Calculated orbital lifetime of each object, including time spent in Low Earth Orbit (LEO)
- Assessment of launch vehicle compliance with DoDI 3100.12 paragraph 6.3.1.

Section 11: Assessment of Launch Vehicle Potential for Explosions and Intentional Breakups

- Identification of all potential causes of launch vehicle orbital stage breakup during all operations
- Summary of failure modes and effects analyses of all credible failure modes which may lead to an orbital stage accidental explosion
- Detailed plan for any designed orbital stage breakup, including explosions and intentional collisions
- Detailed plan, under normal EOL conditions and deployment malfunction scenario, for passivating (depleting all energy sources) each orbital stage, including the burning or release of all propellants and fluids
- Assessment of launch vehicle compliance with DoDI 3100.12 paragraph 6.3.1.

Section 12: Assessment of Launch Vehicle Potential for On-orbit Collisions

- Calculation of each orbital stage probability of collision with known space objects larger than 10 cm in diameter during the orbital lifetime of the stage
- Assessment of launch vehicle compliance with DoDI 3100.12 paragraph 6.3.3.

Section 13: Assessment of Launch Vehicle Post-mission Disposal Plans and Procedures

- Description of orbital stage disposal option selected
- Plan for any orbital stage maneuvers required to accomplish disposal after end of orbital stage mission
- Calculation of area-to-mass ratio after completion of all orbital stage operations, including disposal maneuvers, if the controlled re-entry option is not selected
- Procedure for executing orbital stage disposal plan, including timeline from final shutdown of each orbital stage to completion of passivation and disposal operations
- Demonstration of reliability of orbital stage disposal operations
- Assessment of launch vehicle compliance with DoDI 3100.12 paragraph 6.3.4.

Section 14: Assessment of Launch Vehicle Re-entry Hazards

[Note: if a re-entry hazard assessment has already been performed for an orbital stage, simply refer to that report and make any necessary adjustments for orbital inclination and year of re-entry]

- Detailed description of launch vehicle components by size, mass, material, and shape if the atmospheric re-entry option is selected. For re-entry survivability analysis, the following data is required: a parts list (e.g., a master equipment list); masses for each part (e.g., a stage mass statement); material for each part (e.g., 2042 Al, 410 SS, Kevlar, graphite-epoxy, Ti-6Al-4V); physical dimensions for each part (height, width, length, wall thickness, honeycomb density, etc.); briefing charts, schematics, and drawings illustrating the shape of each part; briefing charts, schematics, and drawings showing the placement of parts in relationship to each other; and the initial orbital state vector for re-entry.
- Summary of objects expected to survive an uncontrolled re-entry, specifying the software tool(s) used for the analysis
- Calculation of probability of human casualty for the expected year of uncontrolled re-entry and the orbital stage inclination
- If appropriate, preliminary plan for launch vehicle controlled re-entry
- Assessment of launch vehicle compliance with DoDI 3100.12 paragraph 6.3.4.

A.2 Review of ODARs

Replace with: "Each ODAR delivered will be reviewed by the SMC Chief Engineer with technical assistance from SMC/EAF. After the review, results will be provided to the Program Manager." Delete Figure A.2-1.

A.3 Abbreviated ODARs

Delete.

Appendix B—Replace with: "End of Mission (EOL) Plans (EOLP)

B.1 Format for EOLPs

B.1.1 Replace with: "End of Life Plans shall be delivered in accordance with the requirements specified below. The nominal schedule is:

- **a. Preliminary End of Life Plan:** 45 days prior to the program CDR for the spacecraft or equivalent program/project development milestone. This Preliminary Draft is submitted to the Contracting Officer, who will make distribution to SMC/EAF, SE, and any other offices as needed. The purpose of preparing the plan early in the operational development process is to ensure that EOL issues are identified early when resolutions are least costly to implement.
- **b. Prelaunch End of Life Plan:** 30 days prior to the launch of the mission. The prelaunch End of Life Plan shall be submitted to the Contracting Officer, who will distribute to the Chief Engineer for review and subsequent submission to SMC/CV for approval and signature prior to beginning the launch approval process but no later than the program's FRR. Formal acceptance of the risk associated with any noncompliances remaining in the End of Life Plan shall be included in the approval process.
- **c. Updates to the End of Life Plan (titled: "*[date]* Update to the End of Life Plan"):** to be made at the major program operational milestones identified in the End of Life Plan.
- **d. Final End of Life Plan:** shall be delivered at 3 months prior to the expected implementation of the End of Life Plan for spacecraft decommissioning/disposal.

Each End of Life Plan delivered will be reviewed by SMC/EAF and SMC/SE. The approving authority for Final End of Life Plans is SMC/CC, who is the Program Executive Officer (PEO) for Space. The draft End of Life Plans may be submitted in electronic form only. Signed End of Life Plans shall be delivered in both electronic and paper copies. Note that programs are encouraged to use existing program documentation and the ODAR for mission and spacecraft descriptions and identification of the EOL decommissioning issues. A copy of the Final ODAR shall be included in the delivery of the Final End of Life Plan."

B.1.4. Delete.

B.1.6. Delete.

Replace with: "EOLP Cover and Front Matter, EOLP Sections 1 through 8, EOLP Appendices, and EOLP Addendum.

Cover and Front Matter (*all data is needed prior to launch*)

- Cover showing the document version and date of delivery.
- Inside cover showing the signatures on that report. This shall include as a minimum: Document preparer(s), program management, SMC/EAF and SE office reviewers, and SMC management signatures.
- Statement of any restrictions on the data in the End of Life Plan such as Limited/Government Purpose/Special License Rights; Distribution Statements D or X for technical data subject expert controls. If the document does not contain any restrictions, then a statement to that effect shall be included. If the document does contain restricted information, the restricted information shall be summarized and marked clearly on the page(s) where it occurs and on the cover.
- Document history page showing each version of the report. Reviews of the previous versions by SMC/EAF shall be included in this page.

Section 1: Program Management and Mission Overview (*data needed prior to launch*)

- Identification of the Program sponsoring the mission and the Program Manager
- Schedule of mission operational milestones from launch through EOL
- Summary table indicating compliance or noncompliance with each debris mitigation requirement of DoDI 3100.12
- Brief description of the mission (single paragraph)
- Description of operational orbits with apogee, perigee, and inclination (data added during operations)
- Chronology of management reviews of the End of Life Plan to include changes in spacecraft operability which may affect the ability to passivate and dispose per the plan in Section 6 of the End of Life Plan

Section 2: Spacecraft Description (*data needed prior to launch*)

- The ODAR Section 2 contains a full description of the spacecraft. Since the ODAR remains a reference, it does not need to be repeated here.
- Table of the following onboard the spacecraft at time of issue of End of Life Plan version, expected at commencement of passivation, and expected at completion of passivation.
    - Fluids
    - Pyrotechnic devices
    - Electrical generation and storage system
    - Identification of any other sources of stored energy not noted above
    - Any radioactive materials
- List of changes in the propulsion systems and energy systems that have occurred since launch. Include a detailed illustration of the entire spacecraft in the EOL configuration with clear dimensional markings and marked internal component locations (*data added during operations*)
- Total mass of post-passivation spacecraft, including all propellants and fluids
- Status of the major systems on board the spacecraft, including any changes in redundancy

Section 3: Assessment of Spacecraft Debris Released During and After Passivation (*data needed prior to launch, reference ODAR Section 3*)

- Identification of any solid object (>5 mm) expected to be released during passivation
- Identification of all objects (>1 mm) expected to be released (including fluids)
- Rationale/necessity for release of each object
- Time of release of each object relative to passivation
- Release velocity of each object with respect to spacecraft
- Expected orbital parameters (apogee, perigee, and inclination) of each object after release
- Calculated orbital lifetime of each object, including time spent in Low Earth Orbit (LEO)
- Assessment of spacecraft compliance with DoDI 3100.12 paragraph 6.3.1.

Section 4: Assessment of Spacecraft Potential for Explosions and Intentional Breakups (data needed prior to launch, reference ODAR Section 4)

- Identification of all potential causes of spacecraft breakup during passivation and post passivation
- Summary of remaining failure modes and effects analyses of all credible failure modes that may lead to an accidental explosion during passivation and after passivation.
- Assessment of spacecraft compliance with DoDI 3100.12 paragraph 6.3.2.

Section 5: Assessment of Spacecraft Potential for On-orbit Collisions (*data needed prior to launch, reference ODAR Section 5*)

- Identification of all systems or components required to accomplish any post-mission disposal operation, including passivation and maneuvering
- Evaluation of the vulnerability of systems required for post-mission disposal to impacts by space objects smaller than 10 cm in diameter
- Assessment of EOL spacecraft compliance with DoDI 3100.12 paragraph 6.3.3 (*data added during operations*)
- Calculation of spacecraft probability of collision with space objects larger than 10 cm in diameter during the orbital lifetime of the spacecraft after passivation
- Assessment of EOL spacecraft compliance with DoDI 3100.12 paragraph 6.3.3 (*data added during operations*)

Section 6: Assessment of Spacecraft Post-mission End of Life Plans and Procedures (*data needed prior to launch, reference ODAR Section 6***)**

- Demonstration of reliability of post-mission disposal operations
- Description of spacecraft disposal option selected
- Plan for any spacecraft maneuvers required to accomplish post-mission disposal
- Calculation of area-to-mass ratio after post-mission disposal if the controlled re-entry option is not selected
- Procedure for executing post-mission End of Life Plan
- Detailed plan for passivating (depleting all energy sources) the spacecraft, including the burning or release of all propellants and fluids, the discharge of batteries, the disabling of charging circuits, and the de-energizing of rotational energy sources
- Assessment of spacecraft compliance with DoDI 3100.12 paragraphs 6.3.2.2 and 6.4

Section 7: Assessment of Spacecraft Re-entry Hazards (*reference ODAR Section 7, all data added during operations*)

- Detailed description of spacecraft components by size, mass, material, and shape if the atmospheric re-entry option is selected or if launch failure could lead to atmospheric re-entry
- Summary of objects expected to survive an uncontrolled re-entry, specifying software tool(s) used for the analysis
- Calculation of probability of human casualty for the expected year of uncontrolled re-entry and the spacecraft orbital inclination
- If appropriate, preliminary plan for spacecraft controlled re-entry
- Assessment of spacecraft compliance with DoDI 3100.12 paragraph 6.4

Section 8: Assessment for Tether Missions (all data added during operations)

- Description of tether system, including (1) tether length, diameter, materials, and design (single strand, ribbon, multi-strand mesh) at a minimum and (2) end-mass size and mass remaining at EOL
- Assessment of compliance with DoDI 3100.12 paragraph 6.3.3

End of Life Plan Addendum: Final ODAR

For the Final End of Life Plan, a copy of the final ODAR shall be included for reference.

B.2 Review of EOLPs

Each End of Life Plan delivered will be reviewed by the SMC Chief Engineer with technical assistance from SMC/EAF and SMC/SE. After review, results will be returned to the Program Manager. The Program Manager will forward the final ODAR and prelaunch EOLP to the Risk Acceptance Authority required by the severity of the identified risks.” Delete Figures B.2-1 and B.2-2.

Appendix F—Delete.

Acronyms

AHaB	Atmospheric Heating and Breakup re-entry survivability analysis model
AFI	Air Force Instruction
AFSPC	Air Force Space Command
Al	aluminum
CDR	Critical Design Review
CDRL	Contract Data Requirements List
CONOPS	concept of operations
DAS	Debris Assessment Software, NASA tool for assessing compliance
DoD	Department of Defense
DoDI	DoD Instruction
ECP	Engineering Change Proposal
EOL	End of Life
EOLP	End of Life Plan
EOM	End of Mission
EOMP	End of Mission Plan
FMEA	Failure Modes and Effects Analysis
FRR	Flight Readiness Review
GEO	geosynchronous Earth orbit
JSC	Johnson Space Center
LEO	low Earth orbit
MEO	medium Earth orbit
MRAR	Mishaps Risk Assessment Reports
NASA	National Aeronautics and Space Administration
NEPA	National Environmental Policy Act
NRO	National Reconnaissance Office
O&SHA	Occupational and Safety Health Act
ODAR	Orbital Debris Assessment Report
ODPO	Orbital Debris Program Office at NASA Johnson Space Center
ORSAT	NASA Object Re-entry Survival Analysis Tool
PDR	Preliminary Design Review
PEO	Program Executive Officer
PESHE	Programmatic Environmental, Safety and Health Evaluation
PHA	Preliminary Hazard Analysis
SCARAB	European Spacecraft Atmospheric Re-entry and Aerothermal Breakup model
SDR	System Design Review
SHA	system Hazard Analysis
SMC	U.S. Air Force Space and Missile Systems Center
SOW	Statement of Work
SRCA	Safety Requirements Criteria Analysis
SRR	System Requirements Review
SS	stainless steel
SSHA	Subsystem Hazard Analysis

STD	standard
STRATCOM	U.S. Strategic Command
Ti	titanium
TOR	Aerospace Technical Operating Report

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

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