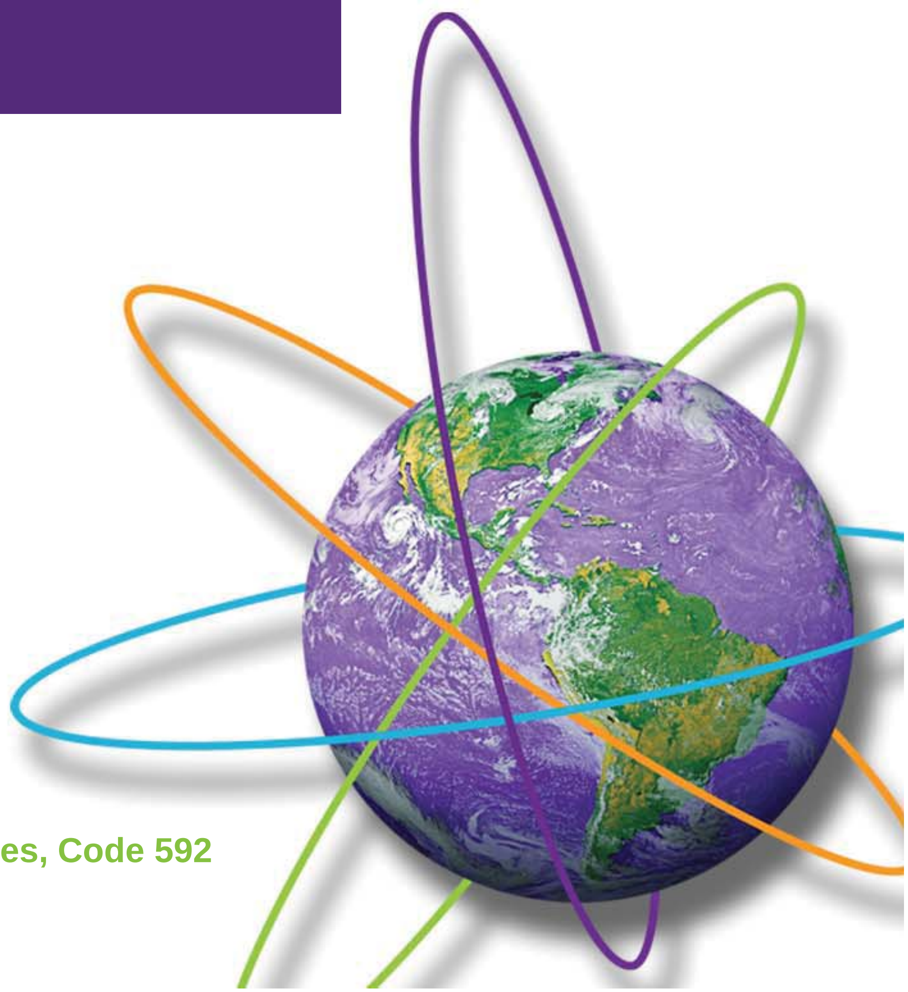
National Aeronautics and Space Administration

NASA Orbital Debris Requirements and Best Practices



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Outline

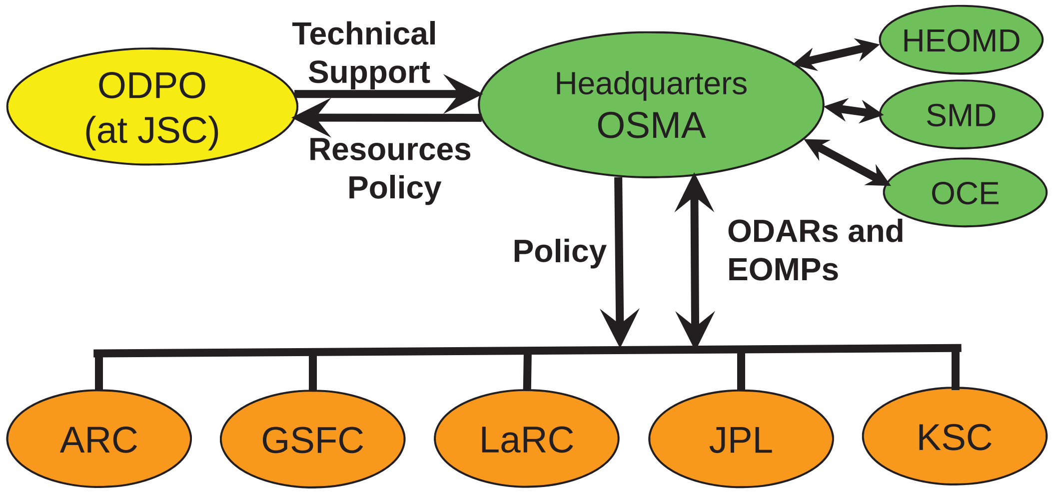
NASA Requirements
- Origin
- Policy
- Technical Standards

Best Practices
- Mission Design Considerations
- Protecting the Spacecraft from Existing Debris
- Design Approaches for Passivation

NASA ORBITAL DEBRIS REQUIREMENTS

Drawing the lines

NASA Orbital Debris Structure



NASA's orbital debris requirements are driven by the National Space Policy of the United States – 2010

- Development and adoption of international and industry standards
- "Continue to follow the <u>United States Government Orbital Debris Mitigation Standard Practices</u>, consistent with mission requirements and cost effectiveness …"
- Notify the Secretary of State of exceptions

NASA Orbital Debris Policy

NPR 8715.6, "NASA Procedural Requirements for Limiting Orbital Debris"

- Designed to meet the guidelines and intent of U.S. Government and international agreements including IADC Space Debris Mitigation Guidelines
- Spells out roles and responsibilities across the Agency
- References NASA-STD 8719.14 for technical requirements
- Orbital Debris Assessments are conducted from proposal through launch at scheduled milestones
- End of Mission Plans are updated throughout operations until decommissioning
- Requires Conjunction Assessments to help prevent collisions

NASA-STD-8719.14
Technical Requirements

Section 4.3	(2)	Operational Debris
Section 4.4	(4)	Explosions, Passivation, Intentional Break-up
Section 4.5	(2)	Collisions with Large and Small Objects
Section 4.6	(4)	Postmission Disposal
Section 4.7	(1)	Reentry Risk
Section 4.8	(1)	Tethers
	14	Total Requirements

The NASA requirements generally **exceed** the guidelines

Requirement Group 4.3
Operational Debris

Operational debris are objects intentionally separated from the spacecraft (instrument covers, de-spin devices, etc)

Req. 4.3-1: Debris Passing Through LEO (> 1 mm)

– Maximum orbital lifetime of 25 years
– Maximum of 100 object-years below 2000 km

Req. 4.3-2: Debris Passing Near GEO (> 5 cm)

– Below GEO – 200 km within 25 years

Requirement Group 4.4
Accidental Explosions and Intentional Breakup

Req. 4.4-1: Risk of Explosions During the Mission

- Need to assess and report a quantitative estimate for explosion risk
- < 0.001 probability for all credible failure modes

Req. 4.4-2: Risk of Accidental Postmission Explosions

- "Deplete all onboard sources of stored energy"
- Also referred to as **passivation**
- Disconnect battery from charging circuit
- Vent pressure

Req. 4.4-3: Planned Breakup, Long-term Risks

- > 10 cm orbital lifetime < 100 object-years

Req. 4.4-3: Planned Breakup, Short-term Risks

- Collision probability for > 1mm objects < 10^{-6} for 24 hours

Requirement Group 4.5
Collisions

Req. 4.5-1: Risk of Large Object Collision

- Catastrophic impacts over the orbital lifetime
- Driven by spacecraft area and orbit
- < 0.001 probability of random collision with >10 cm objects
- Can be mitigated by Conjunction Assessment for some missions

Req. 4.5-2: Risk of Small Object Collision

- < 0.01 probability of a small object penetration during the mission lifetime that prevents the planned disposal
- Driven by component placement and shielding

Requirement Group 4.6
Postmission Disposal

Req. 4.6-1: Disposal from LEO

- Atmospheric reentry
  - Orbit decay within 25 years after end of mission
  - No more than 30 years total orbital lifetime
  - Can be Uncontrolled Reentry or Controlled Reentry
- Maneuver to a storage orbit
  - Perigee > 2000 km, Apogee < GEO – 500km
- Direct retrieval

Req. 4.6-2: Disposal from GEO

- Maneuver to > GEO + 200 km or < GEO - 200 km

Req. 4.6-3: Disposal from Between LEO and GEO

- Maneuver to a storage orbit (19,200 km to 20,700 km excluded)

Req. 4.6-4: Disposal Reliability

- Disposal hardware designed for $\geq$ 0.90 at the end of the mission

Postmission Disposal Options

Storage Orbits

– Above GEO+200 km

– 2000 km to GEO-200 km

– Excluding 19,200 – 20,700 km

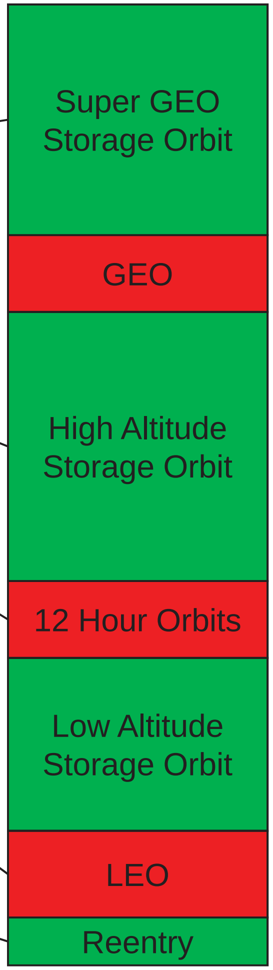
– Can stay in LEO up to 25 years, or 30 years after launch

Reentry

– Controlled or uncontrolled

– With or without orbit lowering

– Depends on reentry risk, orbit, propulsion capacity, guidance capability



Requirement Group 4.7
Reentry Risk

- Risk of casualty must be < 0.0001 (1 in 10,000)
  - Casualty defined as impact energy > 15 J
  - Includes any risk from hazardous materials

- Controlled Reentry additional requirements
  - Composite risk < 0.0001

    P_f x (Uncontrolled Reentry Risk) < 0.001
  - > 370 km from foreign land masses
  - > 50 km from the US or Antarctica

Requirement Group 4.8
Tethers

Req. 4.8-1: Tethers

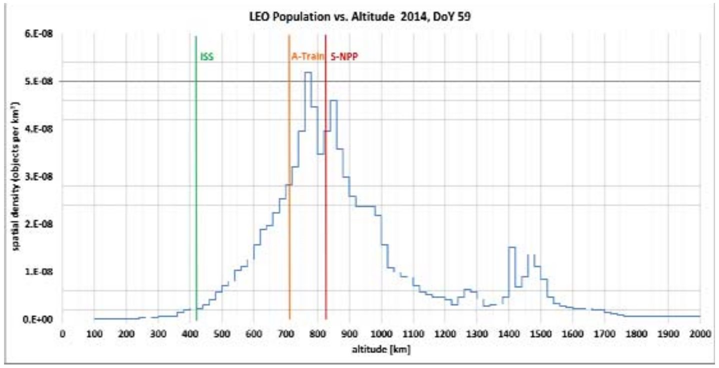
– All intact tethers or possible fragments must meet the requirements in Groups 4.5 and 4.6 (Collisions and Disposal)

BEST PRACTICES

Coloring inside the lines

Mission Design and Ops Considerations

- **<u>Orbital debris needs to be considered early</u>**
  - Prevent generation of new debris
  - Consider effects of existing debris on your mission
  - Identify the disposal method early, and design around it
- **Orbit Selection**
  - Debris peaks at ~750, 900, and 1400 km
  - Orbit selection is usually driven by science needs, but science can be difficult in a minefield



- **Operations**
  - Orbit change maneuvers to avoid predicted close approaches
  - Reorient the spacecraft during meteor showers or close approaches
  - Have plans in place to help diagnose and/or respond to potential debris hits

Hardware Design Considerations for Penetration Protection

- Component location
  - If possible, locate critical bus components inside the structure
  - Nadir and zenith are lowest exposure
  - Ram direction and sides are highest exposure
  - Take advantage of shadowing
- Wall thickness
- Add shielding
- Redundancy

Design for Safety
During and After the Mission

- Pressure tank design
  - Burst strength ≥2X MEOP recommended
- Battery selection
  - Usually driven by power demands
  - $Ni\text{-}H_2$ can be an explosion risk if overcharged
  - Li-ion less susceptible, but has strict charging considerations
- Locate pressurized components near center of spacecraft
  - Protection against debris strikes
  - Any fragmentation is more contained
- Passivation commands not available until EOM
- Design for proper disposal

Power System Passivation

- Requires designing in an “off-switch” early

- Disconnect solar arrays (preferred)
  - Can be easier/safer to achieve
  - Passivates all electronic equipment at once
- Disconnect the battery from the charging circuit
  - Relays, instead of logic
  - Reducing charging rate is not enough
- Leave loads attached to the bus
- Disable failure detection and correction modes at EOM
- Prevent recharging Li-ion after a deep discharge
- Disable transmitter to prevent RF interference

Pressure Vessels Passivation

- Venting hardware needed early in the design

- Venting design options
  - Add vent lines for isolated pressurant
  - Bypass around diaphragms
  - Redundant valves in series on vent lines
  - Consider the disturbance effects of vent thrust

- Vent pressure as much as practical
  - Latching valves left open if possible

Conclusions

- NASA takes orbital debris prevention seriously, and has requirements in place to limit or prevent debris generation
- The NASA orbital debris requirements generally exceed the US Government Standard Practices and international guidelines
- It is important to consider disposal and passivation early in the mission design, in order to prevent debris generation
- With early consideration, it is possible to design for adequate passivation at the end of the mission

NASA