Spacecraft & Upper-Stage Passivation: Propellant Venting, Battery Isolation & 1:1,000 Risk

Pillar: Disposal Regime | **Basis:** FCC / NASA-STD-8719.14C / ODMSP | **Primary Source:** NASA ODPO / FCC | **As Of:** Active Nov 2026 (ESA 2026 Report: >660 Historical Breakups)

Passivation removes all stored internal energy—residual propellants, pressurants, batteries, and momentum wheels—at end of mission to keep accidental breakup probability below 0.001 (1 in 1,000) across more than 660 historical fragmentation events recorded through end of 2025.

Documented Instrument & Engineering Record

• Why passivation is enforced: ESA's 2026 Space Environment Report (data through end of 2025) documents more than 660 historical breakups, explosions, and fragmentation events—including a 2024 spike of >3,000 tracked fragments driven by propulsion-related breakups.

• Propulsion passivation: Operators must burn or vent residual fuel, oxidizer, and pressurant gases (e.g., helium, nitrogen, krypton) to prevent tank over-pressurization from solar heating.

• Electrical passivation: Batteries must be discharged and permanently isolated from solar arrays (disconnect relays or bleed resistors) so internal cell shorts cannot trigger thermal runaway.

• Kinetic & thermal stores: Reaction wheels must be spun down and pressurized heat pipes or cryocoolers accounted for in the ODAR.

Passivation Engineering Checklist by Subsystem

Subsystem	Stored Energy Hazard	Required EOL Action
Liquid / Cold-Gas Propulsion	Hypergolic/pressurant tank rupture	Depletion burn + latch-open vent valves
Electric Propulsion (Hall/Ion)	High-pressure xenon/krypton tank	Bleed residual gas through thruster/valves
Power / Batteries	Thermal runaway & cell explosion	Full discharge + permanent charge-path open
ADCS Momentum Wheels	Rotor burst on structural fatigue	Active spin-down before bus shutdown

Mission Designer, Compliance Lead & Founder Takeaways

• Designing latch-open pyro or solenoid vent valves adds minimal mass early in CDR but is nearly impossible to retrofit after integration.

• Upper-stage propulsion firms in WA (Blue Origin, Stoke Space, Aerojet Rocketdyne Redmond) must verify passivation sequences under both FAA Part 450 and NASA ODAR deliverables.

• Passivation sequencing matters: telemetry must confirm disposal burn completion *before* permanent battery disconnect cuts communications.

Cross-Cluster Links & Primary Sources

• **Stoke Space (Kent) Census Profile:** https://bcesg.org/stoke-space-washington-space-cluster-profile/

• **Blue Origin (Kent) Census Profile:** https://bcesg.org/blue-origin-washington-space-cluster-profile/

• **WA Space Cluster Hub:** https://bcesg.org/washington-space-cluster-census/

• **NASA ODPO: Orbital Debris Mitigation:** https://orbitaldebris.jsc.nasa.gov/mitigation/

• **ESA Space Debris Office (2026 Environment Context):**
https://www.esa.int/about-us/directorates/operations/space-safety/space-debris

• **eCFR: 47 CFR § 25.283:** https://www.ecfr.gov/current/title-47/chapter-I/subchapter-B/part-25/subpart-D/section-25.283

Provenance Note: Breakup count (>660) and 2024 propulsion spike (>3,000 fragments) cited from ESA 2026 Space Environment Report (data through end of 2025).