Appendix A — Regulatory & Technical References (for Celestia Certification / Space Sustainability Score)

Key foundational documents (primary, load-bearing references)

1. **ISO 24113:2023 — Space systems — Space debris mitigation requirements**. Core international standard for debris mitigation, post-mission disposal, passivation and design requirements. Iteh Standards
   Link (ISO abstract / purchase): https://www.iso.org/standard/83494.html
   Direct sample PDF: https://cdn.standards.iteh.ai/samples/83494/dcb00a9e0adf4e9399dae46af3aac277/ISO-24113-2023.pdf

2. **IADC — Space Debris Mitigation Guidelines (IADC Guidelines, Rev)**. Inter-agency guidance used as technical baseline for post-mission disposal, fragmentation prevention and mitigation measures. orbitaldebris.jsc.nasa.gov
   Link (IADC / NASA mirror PDF): https://orbitaldebris.jsc.nasa.gov/library/iadc-space-debris-guidelines-revision-2.pdf

3. **UNOOSA / COPUOS — Space Debris Mitigation Guidelines (United Nations)** — Consolidation of IADC guidance and UN recommendations for universal adoption. unoosa.org
   Link (UNOOSA PDF): https://www.unoosa.org/pdf/publications/st_space_49E.pdf

4. **U.S. Government — Orbital Debris Mitigation Standard Practices (ODMSP), 2019 (USG)** — U.S. national practice document aligning with ISO/IADC and addressing large constellations, RPO, smallsats and mission ops. orbitaldebris.jsc.nasa.gov
   Link (NASA / ODMSP PDF): https://orbitaldebris.jsc.nasa.gov/library/usg_orbital_debris_mitigation_standard_practices_november_2019.pdf

5. **ESA — Zero Debris Charter & ESA Space Debris Mitigation Requirements** — European approach/ambition (Zero Debris approach) and ESA-specific mitigation requirements / ECSS alignment. esoc.esa.int+1
   Links:
   - Zero Debris Charter (ESOC PDF): https://esoc.esa.int/sites/default/files/Zero_Debris_Charter_EN.pdf

    - ESA mitigation standard: https://technology.esa.int/upload/media/ESA-Space-Debris-Mitigation-Requirements-ESSB-ST-U-007-Issue1.pdf

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Supporting standards, best-practice frameworks and industry guidance

- **Space Safety Coalition — Best Practices for the Sustainability of Space Operations (SSC)** — industry living document compiling ISO/IADC/UNOOSA principles into recommended operator practices. PDF: https://spacesafety.org/wp-content/uploads/2023/04/SSC_Best_Practices_for_Space_Operations_Sustainability_v29.pdf. spacesafety.org
- **World Economic Forum — Space Industry Debris Mitigation Recommendations / Space Economy Reports** — industry recommendations and economic context for sustainable space operations. Example: WEF Space Industry Debris Mitigation Recommendations (2023): https://www3.weforum.org/docs/WEF_Space_Industry_Debris_Mitigation_Recommendations_2023.pdf. www3.weforum.org
- **NASA — Orbital Debris Management & Risk Mitigation (Technical handbook & reference docs)** — breakup models, casualty risk guidance, and technical analysis methods. NASA doc: https://www.nasa.gov/wp-content/uploads/2018/12/692076main_orbital_debris_management_and_risk_mitigation.pdf. NASA
- **IADC / UNOOSA Compendia** — UNOOSA compendium of national policies and IADC public files (useful for jurisdictional alignment and best-practice examples). UNOOSA compendium (2024): https://www.unoosa.org/documents/pdf/spacelaw/sd/Space_Debris_Compendium_COPUOS_09_April_2024.pdf
- **ECSS / ESA adoption notices (ECSS-U-AS-10C adoption of ISO 24113)** — for European contractor alignment and ECSS cross-reference. ECSS adoption page: https://ecss.nl/standard/ecss-u-as-10c-rev-2-adoption-notice-of-iso-24113-space-systems-space-debris-mitigation-requirements-9-february-2024/
- **ESA Zero Debris technical papers and conference proceedings** — technical rationale and target-setting (e.g., “Zero Debris approach” aiming to eliminate new debris in certain orbits).

Overview:
https://www.esa.int/Space_Safety/Clean_Space/ESA_s_Zero_Debris_approach

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Technical models, simulation tools and datasets (for score calibration)

These are the primary technical resources we will rely on for modelling Residual Orbital Lifetime (ROL), fragmentation behaviour, reentry survivability and collision probability:

- **NASA breakup models & reentry survivability tools** (NASA ODPO references and technical papers).
  Example: NASA reference docs and modelling guidelines (ODPO):
  https://orbitaldebris.jsc.nasa.gov
- **LeoLabs / commercial SSA providers** (data feeds for tracked objects, conjunction history, density maps).
  LeoLabs info: https://www.leolabs.space (private/commercial data access; used in prototype visualization).
- **USSTRATCOM / Space-Track TLE catalogue** (public TLE catalogue for verification and historical conjunction data).
  https://www.space-track.org
- **ESA CLEAN-Space and ECSS modeling guidance** for fragmentation and disposal modelling.
  ESA tech pages: https://technology.esa.int

Regulatory & spectrum / coordination references (operational context)

- **UNOOSA / National Registration Convention (UN Register of Objects Launched into Outer Space)** — registration responsibilities and transparency obligations.
  https://www.unoosa.org/oosa/en/ourwork/spacelaw/registration/index.html
- **ITU Recommendations (spectrum & orbital slots coordination)** — coordination of communication payloads and spectrum obligations (relevant for comm satellites and operational constraints).
  https://www.itu.int

- **National licensing frameworks (examples)** — FCC (USA) and national space agency licensing guidance (for integration into operator compliance checks).
    - FCC (U.S.) space/earth station licensing: https://www.fcc.gov/wireless/bureau-divisions/icom/space-communications

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Academic literature and risk analyses (for fragment-size and casualty risk modelling)

- Papers and conference proceedings used for fragmentation size distribution, collision cascades and Kessler syndrome modelling. Representative sources include: NASA technical reports, USRA/URSA conference papers, Orbital Debris conferences (examples below):
    - TRIS / NASA technical references search (recent NASA presentations): https://ntrs.nasa.gov
    - Orbital Debris conference proceedings (USRA/Houston): https://www.hou.usra.edu/meetings/orbitaldebris2023/

Annex — quick mapping of standards → scoring inputs

Standard / Guideline	**Direct metric(s) used in Celestia Score**
ISO 24113	Post-mission disposal deadline (≤ 25 years), fragmentation control, passivation verification
IADC Guidelines	Fragmentation prevention, debris release limits, design practices
UNOOSA (COPUOS)	Global baseline for transparency / registration / good practice
USG ODMSP (2019)	Conjunction thresholds, risk modelling, recommended P(disposal) practices
ESA Zero Debris / ECSS	Aggressive ROL targets, design-for-disposal, “zero new debris” ambition

Standard / Guideline	Direct metric(s) used in Celestia Score
SSC Best Practices / WEF	Industry endorsement, operational best practices and stakeholder adoption pathways

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How these references will be used in the white paper & score calibration

1. **Normative thresholds** (e.g., the 25-year disposal rule; acceptable casualty risk on reentry) will be taken from ISO 24113, IADC and NASA/USG ODMSP and encoded as score bands. Iteh Standards+2orbitaldebris.jsc.nasa.gov+2
2. **Fragmentation and particle-size modelling** will reference NASA breakup models and IADC guidance to assign penalties for high fragmentation risk (e.g., probability of releasing >1 cm fragments). NASA+1
3. **Operational transparency** metrics will be aligned with UNOOSA registration / data-sharing expectations and SSC best practices. unoosa.org+1
4. **European alignment** (where applicable) will reference ESA Zero Debris targets and ECSS adoption of ISO 24113 for contractors and procurement preferences. esoc.esa.int+1

Files & PDFs (direct links) — ready for export into white paper appendix

- ISO 24113 sample PDF: https://cdn.standards.iteh.ai/samples/83494/dcb00a9e0adf4e9399dae46af3aac277/ISO-24113-2023.pdf. Iteh Standards
- IADC Space Debris Mitigation Guidelines (PDF): https://orbitaldebris.jsc.nasa.gov/library/iadc-space-debris-guidelines-revision-2.pdf. orbitaldebris.jsc.nasa.gov
- UNOOSA / COPUOS — Space Debris Mitigation Guidelines (PDF): https://www.unoosa.org/pdf/publications/st_space_49E.pdf. unoosa.org
- USG ODMSP (2019) PDF: https://orbitaldebris.jsc.nasa.gov/library/usg_orbital_debris_mitigation_standard_practices_november_2019.pdf. orbitaldebris.jsc.nasa.gov
- ESA Zero Debris Charter (PDF): https://esoc.esa.int/sites/default/files/Zero_Debris_Charter_EN.pdf. esoc.esa.int

- SSC Best Practices PDF: https://spacesafety.org/wp-content/uploads/2023/04/SSC_Best_Practices_for_Space_Operations_Sustainability_v29.pdf. spacesafety.org
- WEF Space Industry Debris Mitigation Recommendations: https://www3.weforum.org/docs/WEF_Space_Industry_Debris_Mitigation_Recommendations_2023.pdf.