

What Do the New FCC Space Debris Rules Mean for Operations & Sustainability?

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Center for Space Standards
and Innovation

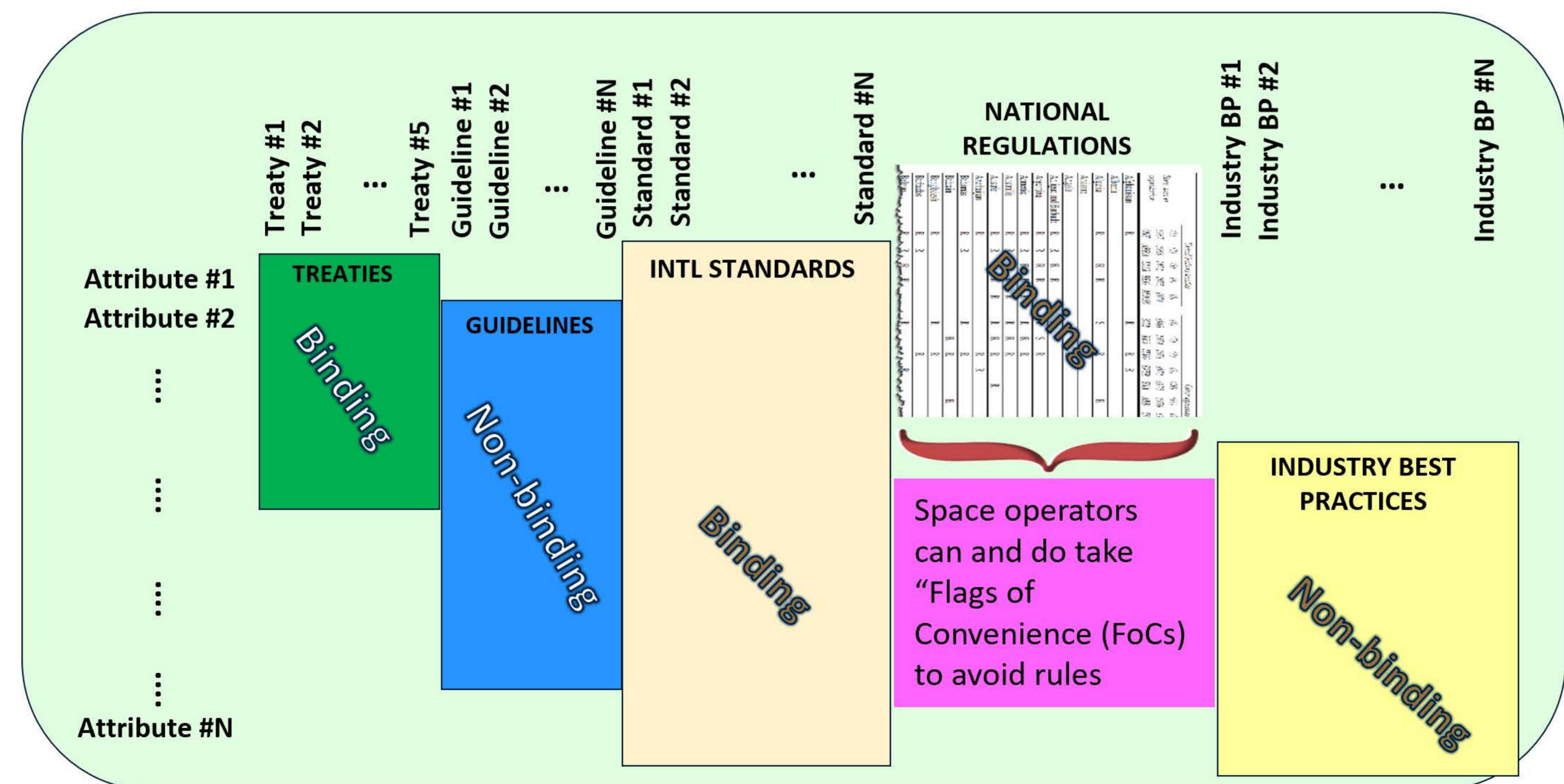
Astroscale Workshop

23 April 2020



Mapping of mandates, guidelines and practices to originating body

- We characterized wide variety of space governance documents



Prior evaluation based on the FCC NPRM

| | United Nations | International NGOs | National Regulatory | Industry Consortia |
|---|----------------|--------------------|---------------------|--------------------|
| UN COPUOS (Treaties) | ● | ○ | | |
| UN COPUOS (Excl. Treaties, SDM & LTS Guidelines) | ○ | | | |
| United Nations Space Debris Mitigation Guideline | ○ | | | |
| United Nations Long Term Sustainability Guideline | ○ | ○ | | |
| Committee on Space Research (COSPAR) | | ● | | |
| Consultative Committee for Space Data Stds | | ○ | | |
| Inter-Agency Debris Coordination Committee | | ○ | | |
| Intl Assoc for Adv of Space Safety (IAASS) | | ○ | | |
| Intl Organization for Standardization (TC20/SC14) | | ● | | |
| International Telecommunications Union (ITU) | | ○ | | |
| Canada | ● | ● | ● | ● |
| EU | | ● | ● | ● |
| France | | | ● | ● |
| Japan | | | | ● |
| South Africa | | ● | ● | ● |
| UK | | ● | ● | ● |
| USA Commercial | | | ● | ● |
| USA NASA | | | ● | ● |
| USA USAF | | | ● | ● |
| AIAA | ○ | | | |
| Association of Space Explorers (ASE) | ○ | | | |
| CubeSat Standard (Cal Poly) | ○ | | | |
| Consortium for Execution of RPO & OOS (CONFRS) | ○ | | | |
| Satellite Industry Association (SIA) | ○ | | | |
| Space Data Association (SDA) | ○ | | | |
| Space Safety Coalition (SSC) | ○ | | | |
| World Economic Forum | ○ | | | |

Normative? (●=Y ○=N ●=Mix)

Capacity building
Casualty risk
Contamination (physical)
Contamination (radiation)
Contamination (RFI)
Cooperation, inclusiveness
Exchange of space data
Health & status
Jurisdiction & ownership
Moon & celestial bodies
Registration
Responsibility/Liability
RPO/OOS
Safety
Security
Space law
Space weather effects
SSA
Standardization
TCBMs

Including FCC's latest R&O requirements

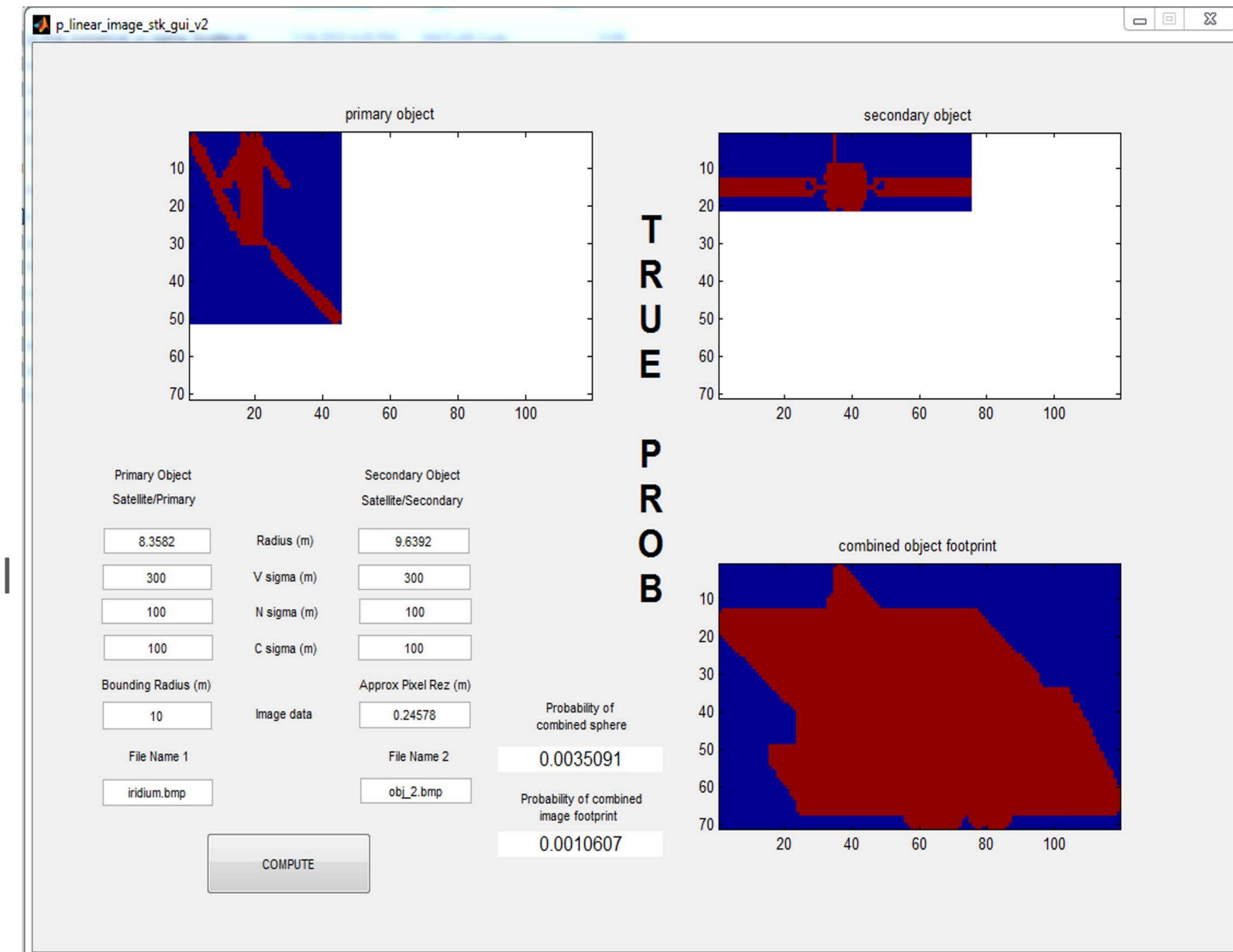
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| Safety | | | | |
| Security | | | | |
| Space law | | | | |
| Space weather effects | | | | |
| SSA | | | | |
| Standardization | | | | |
| TCBMs | | | | |

Wide-ranging Go/No-Go criteria: tradeoffs

- **“Maximum probability” metric**
 - Perfectly legitimate, mathematically rigorous
 - Provides bounding P_c limit assuming combined covariance aspect ratio \approx constant
 - Extremely conservative approach
 - Useful when fuel-rich with very few/sparse close approaches
 - Requires little or no FDS risk analysis
- **Estimated actual P_c is most representative risk metric**
 - Minimizes fuel usage
 - More complex to estimate (at least accurately)
- **Range of Go/No-Go options in between**
 - Since in-track position least well-known, some operators alter their radial position at Time of Closest Approach (TCA) to preclude chance of contact even if large in-track errors
 - Requires more avoidance maneuver fuel and may impact mission, but conservative & simplifies FDS analyses
 - Unfortunately, some operators failing to consider radial errors when selecting this radial avoidance threshold, rendering this avoidance strategy potentially problematic.

Sophistication increases risk portrayal accuracy

- Higher-fidelity conjunction modeling leads to more accurate portrayal of collision risk
 - Non-linear conjunctions
 - Asymmetric bodies
 - Rule of thumb: **3X reduction of estimated actual P_c over spherical approx.**



Ranking of warning & Go/No-Go screening criteria

- Each Go/No-Go criterion has varying levels of conservatism, fuel usage, risk portrayal accuracy, complexity and data requirements (**list below sorted on fuel usage**)

| Go/No-Go Criterion | Conservatism (10 = most conservative) | Fuel Usage (10 = uses the least fuel) | Accuracy (10 = best portrayal of risk) | Complexity & Data Req'd (10 = simple, w/little data req'd) |
|---|--|--|---|---|
| Cartesian miss distance (arbitrary user threshold) | ? | ? | 1 | 10 |
| Componentized miss distance (e.g. radial-only separation) (arbitrary user threshold) | ? | ? | 1 | 10 |
| Estimated actual probability using non-linear relative motion & asymmetric hard-body shapes | 1 | 10 | 10 | 1 |
| Estimated actual probability using linearized relative motion but with asymmetric body shapes | 6 | 9 | 9 | 2 |
| Estimated actual P_c , w/linearized relative motion and spherical hard-body shapes | 8 | 7 | 7 | 4 |
| Estimated actual probability using non-linear relative motion and spherical hard-body shapes | 3 | 7 | 7 | 3 |
| Adjusted Mahalanobis distance (requires miss distance, covariance, spherical object radius) | 7 | 5 | 5 | 4 |
| Cartesian miss distance based on P_c threshold or major eigenvalue (e.g. Sal algorithm) | 8 | 4 | 4 | 4 |
| Componentized miss distance (e.g. radial-only separation) based on all eigenvalues | 8 | 4 | 4 | 4 |
| Mahalanobis miss distance (requires miss distance & covariance) | 9 | 3 | 3 | 6 |
| Combination of miss distance and estimated actual probability (e.g., F-Factor) | ? | 3 | 7 | 4 |
| Maximum probability | 10 | 2 | 3 | 9 |

Probability is a suitable Go/No-Go metric

- Estimated actual (sometimes called “true”) collision probability (P_c) is likely the best metric available:
 - Incorporates object sizes, miss distance, and positional uncertainty in rigorous mathematical fashion
- User must understand assumptions, potential inaccuracies, & pitfalls
 - Covariance (error) information may be inaccurate or unavailable for either (both) object(s)
 - Conjunction relative motion may be “non-linear”
 - Object shapes may be aspherical or improperly sized
- Each of these concerns can lead to P_c estimates that are multiple orders-of-magnitude from the actual P_c
- Regulatory gap (including in FCC R&O and other documents) is P_c algorithm

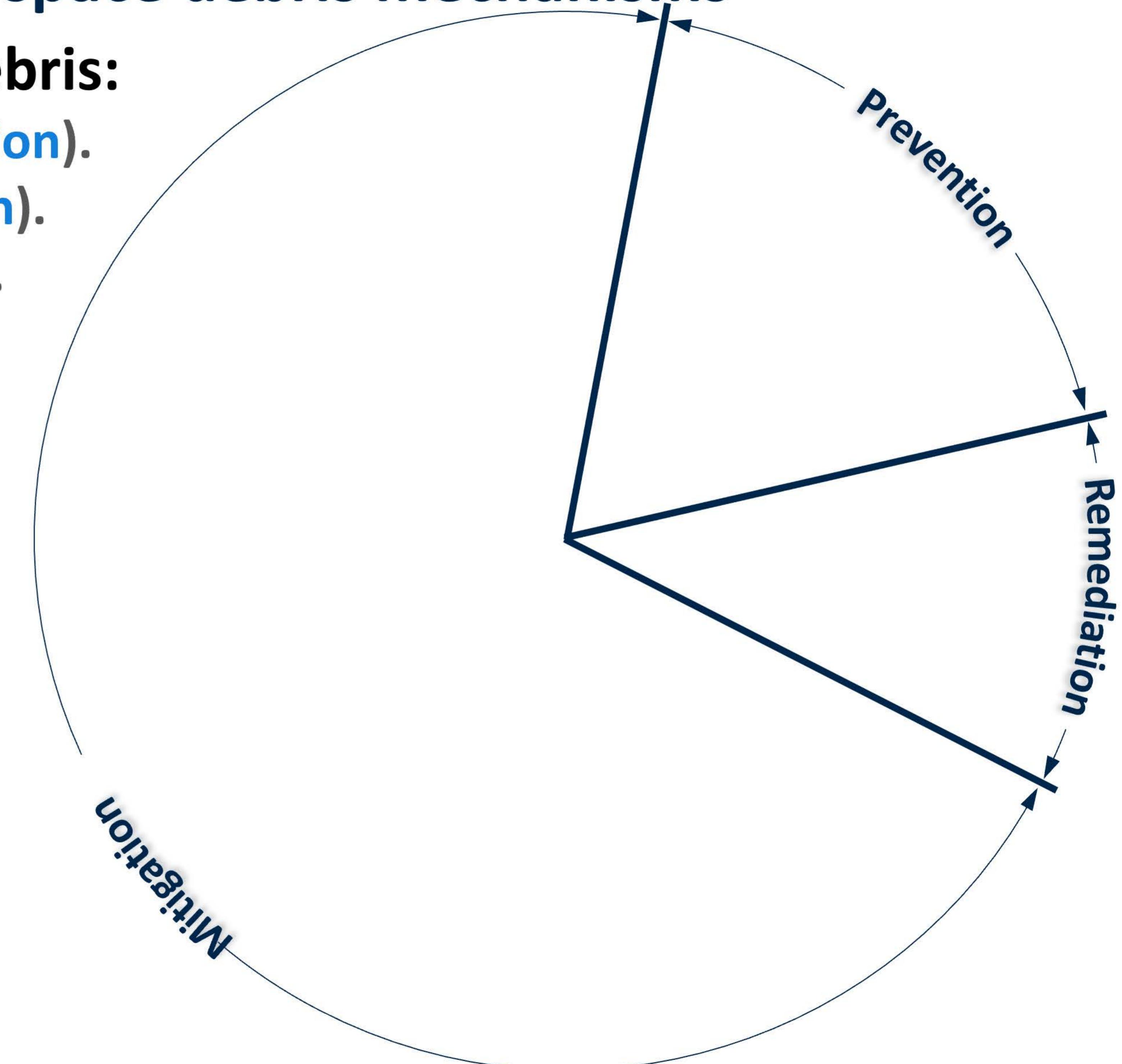
Key Long-Term Sustainability (LTS) space debris mechanisms

- Three LTS ways to address space debris:

1. Avoid predictable collisions (**Prevention**).
2. Remove massive debris (**Remediation**).
3. Don't create new debris (**Mitigation**).

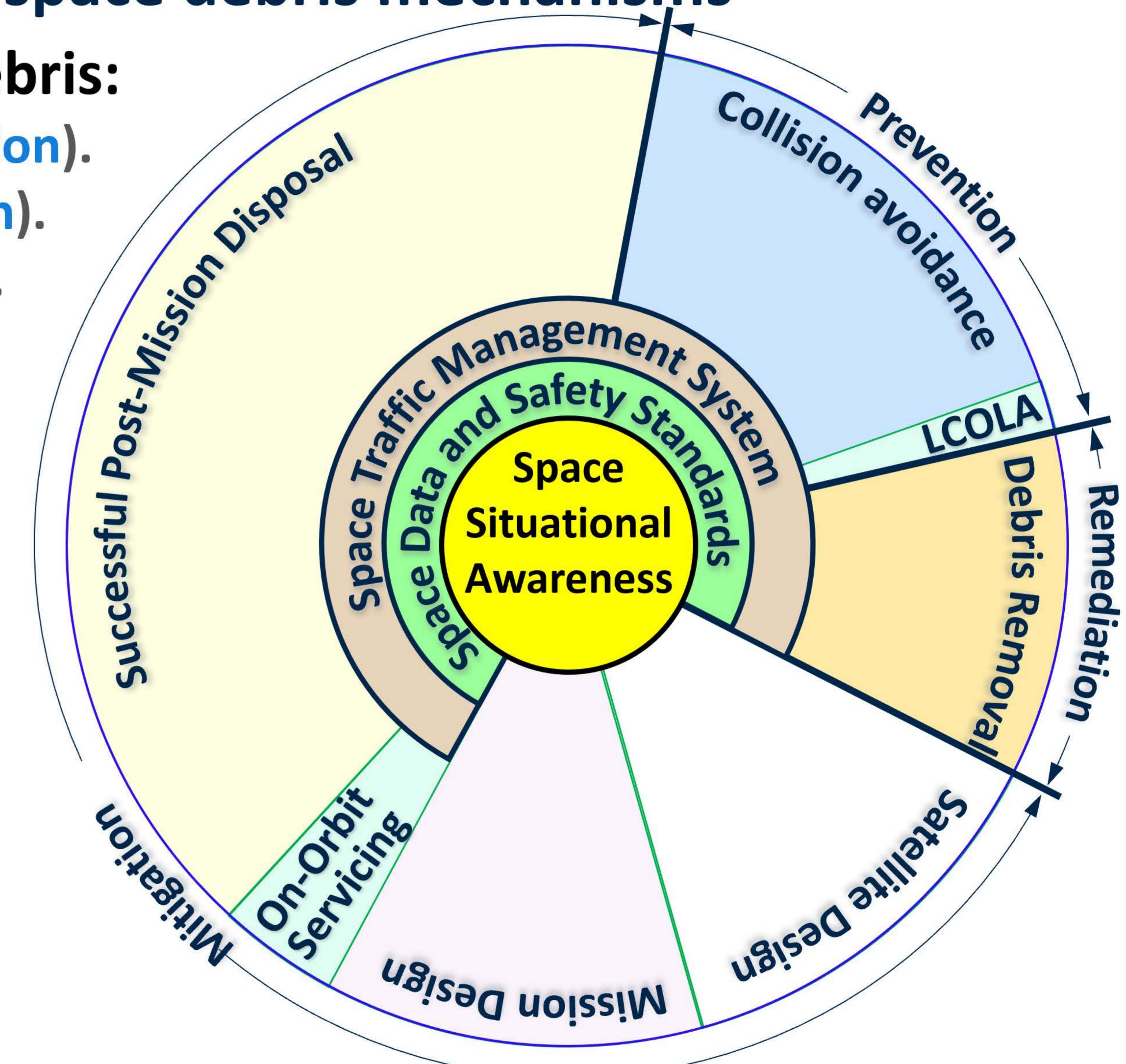
- In terms a child can understand:

1. Don't hit each other.
2. Put your toys away.
3. Play nice and don't litter.



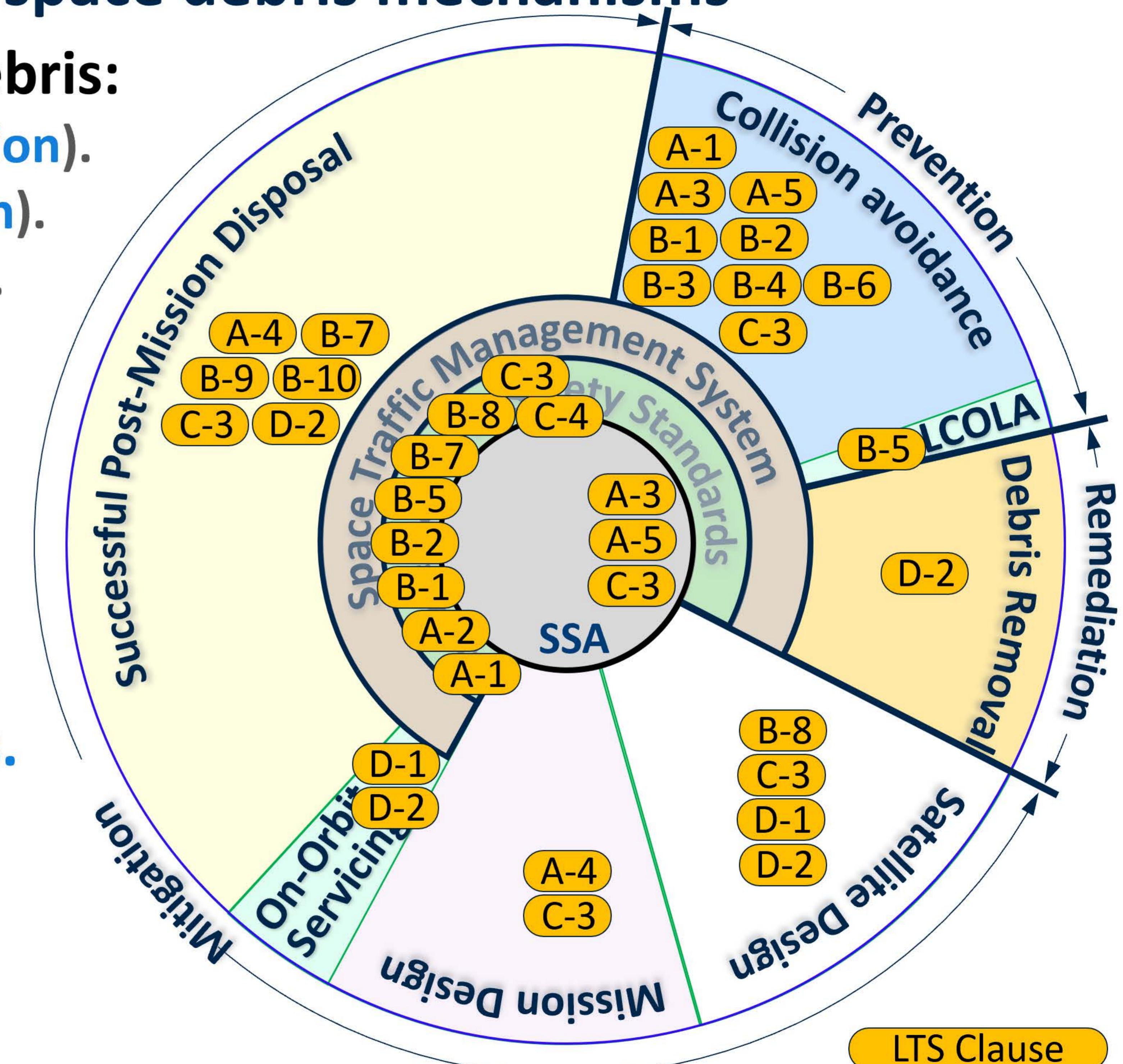
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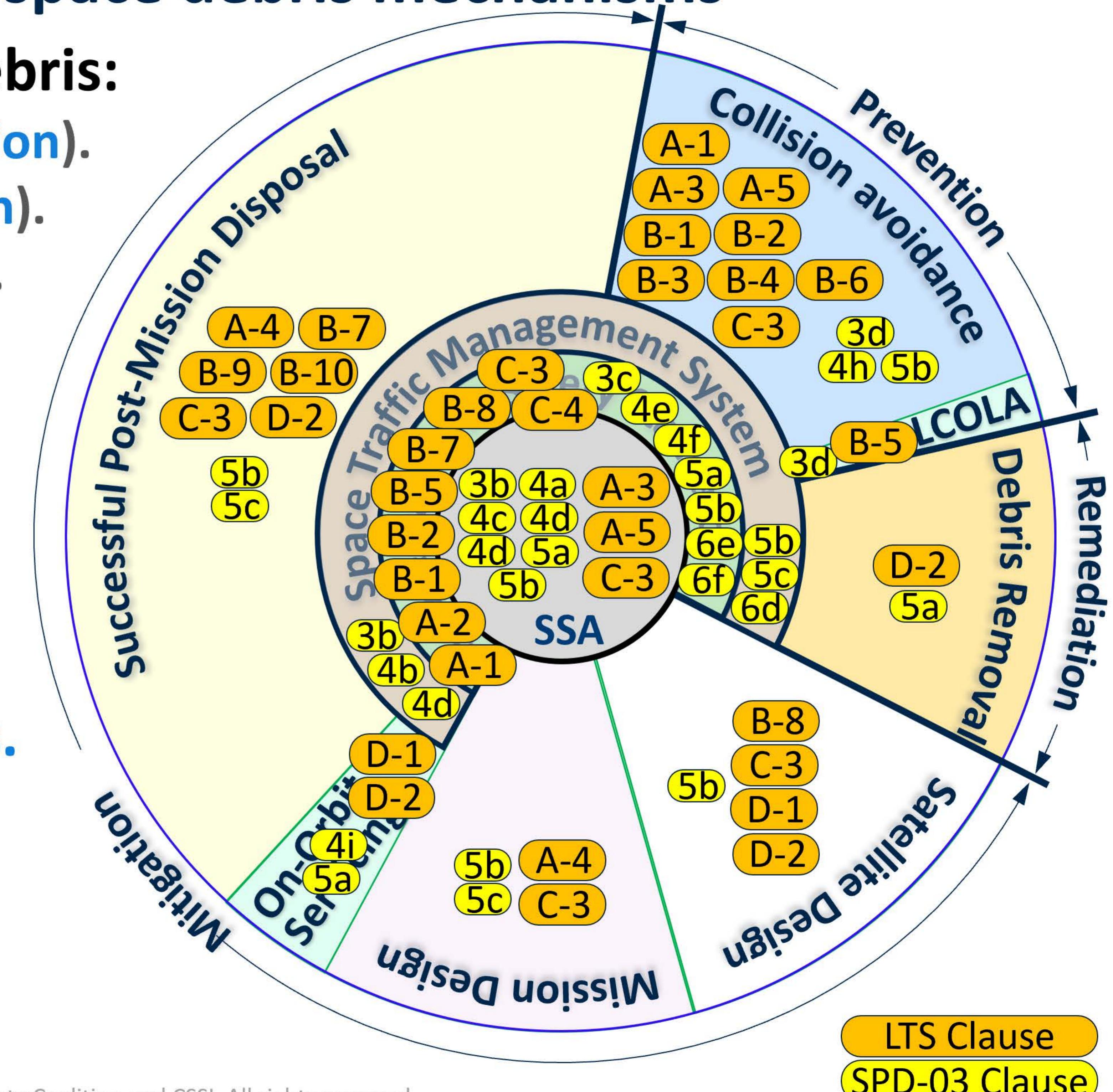
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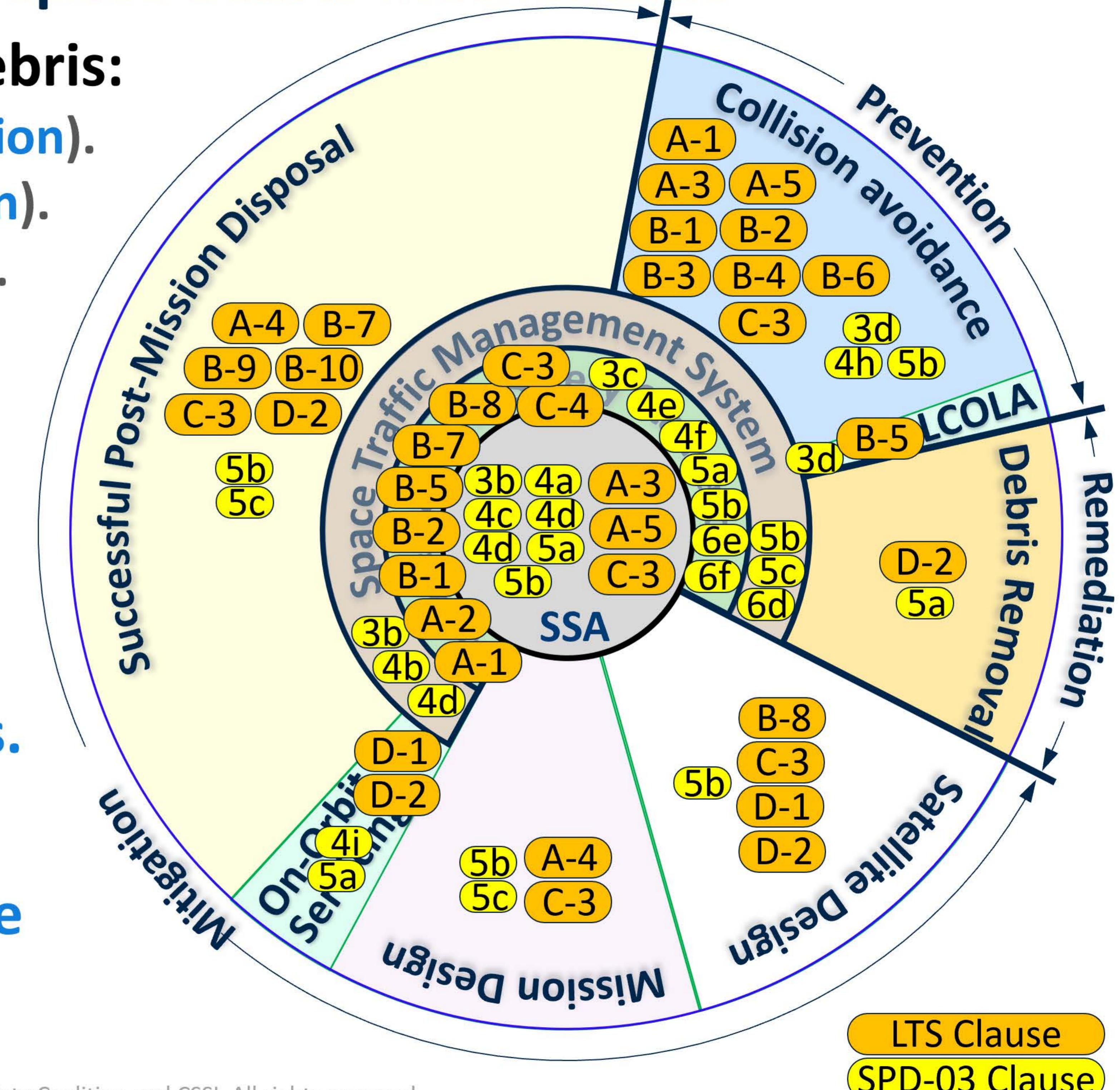
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- The FCC R&O does move the needle on many of these issues



Thank you !

