



Long-Term Orbital Debris Prediction Uncertainty Modeling

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Environment Projection Uncertainties

- **Sources of uncertainties**

- Initial population
- Future launches
 - **Orbits, dimensions, masses, material, mission lifetimes, *etc***
 - **Proliferation of CubeSats, Mega-constellations**
- Orbit propagation and solar activity projection
- Breakup frequency and outcome
 - **Explosions, collisions**
- Mitigation
 - **The 25-year rule compliance, *etc***

Two general approaches for future projection

- Examine the extreme cases to bound the problem
- Analyze the nominal cases based on reasonable assumptions



On-Going IADC Studies (1/2)

- **NASA is contributing to an on-going IADC study to characterize the uncertainties associated with future launches**
 - The initial population consists of the LEO-crossing, 10 cm and larger objects as of 1 January 2013, based on the ESA population file
 - Vary launch rate, masses and areas of intact objects
 - Use a constant solar flux (100 SFU)
 - Assume 8-year mission lifetime for future spacecraft.
 - Set future explosions to zero.
 - Allow no station keeping and no collision avoidance maneuvers
 - Project the environment for 200 years
 - Run at least 100 Monte Carlo simulations.



On-Going IADC Studies (2/2)

- **NASA is contributing to an on-going IADC study to characterize the uncertainties associated with**
 - Solar activity projection
 - Orbit propagation
 - Breakup model
 - **Fragment distributions**
 - **Catastrophic versus non-catastrophic collisions**
 - **Collision cross sectional areas associated with appendages**



CubeSats and Mega-Constellations

- **The proliferation of CubeSats and the proposed mega-constellations present new challenges to the space environment and to other operational spacecraft**
 - Increased collision risk to other operational spacecraft
 - Potential of a collision cascade effect at the mega-constellation mission altitude
 - Higher debris population growth in the environment
- **NASA is currently conducting two parametric studies to quantify the potential negative environmental impacts of CubeSats and mega-constellations in low Earth orbit**
 - Long-term population increase
 - Collision activities