Tech Brief:
Tracking and Collision Avoidance Technologies

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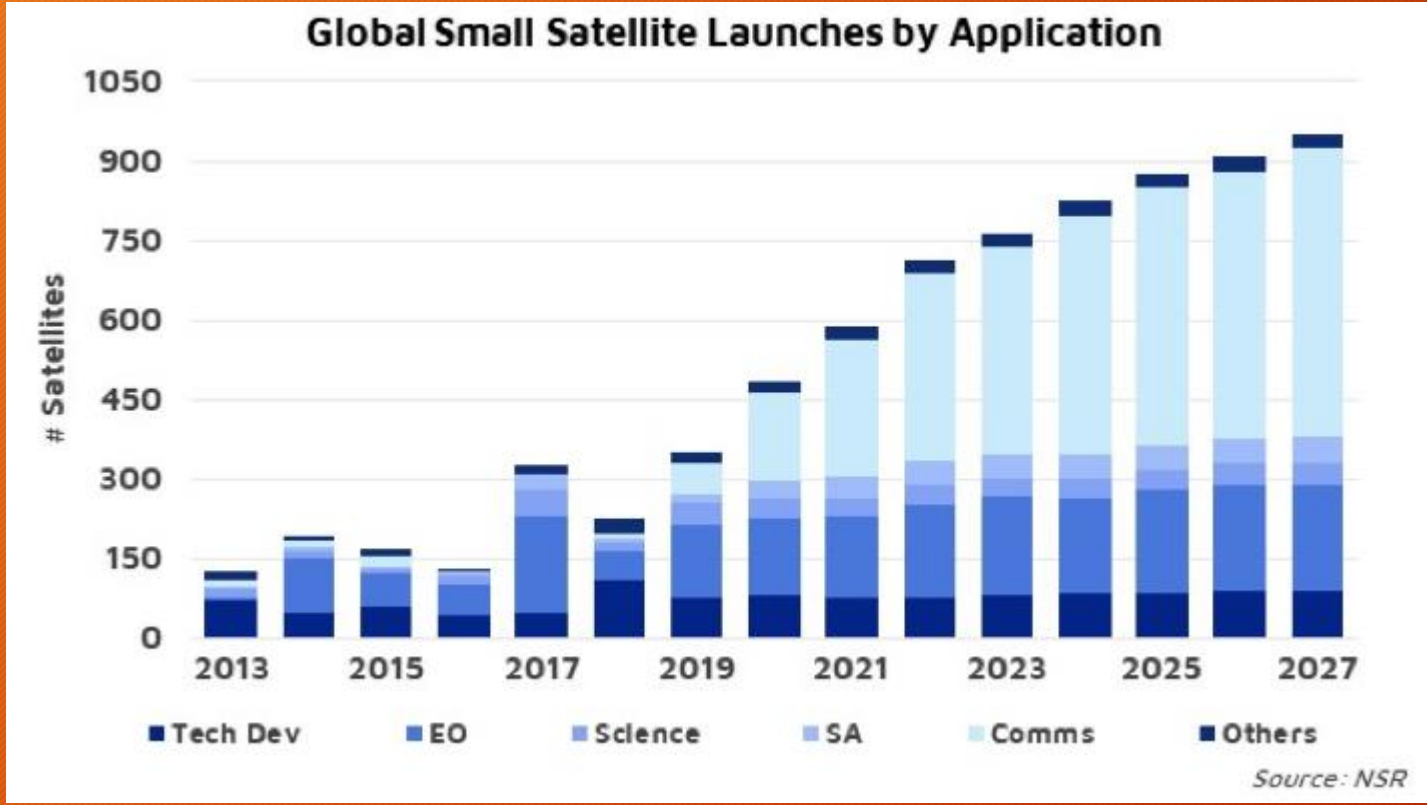
The Magnitude of the problem

Increasing Launches



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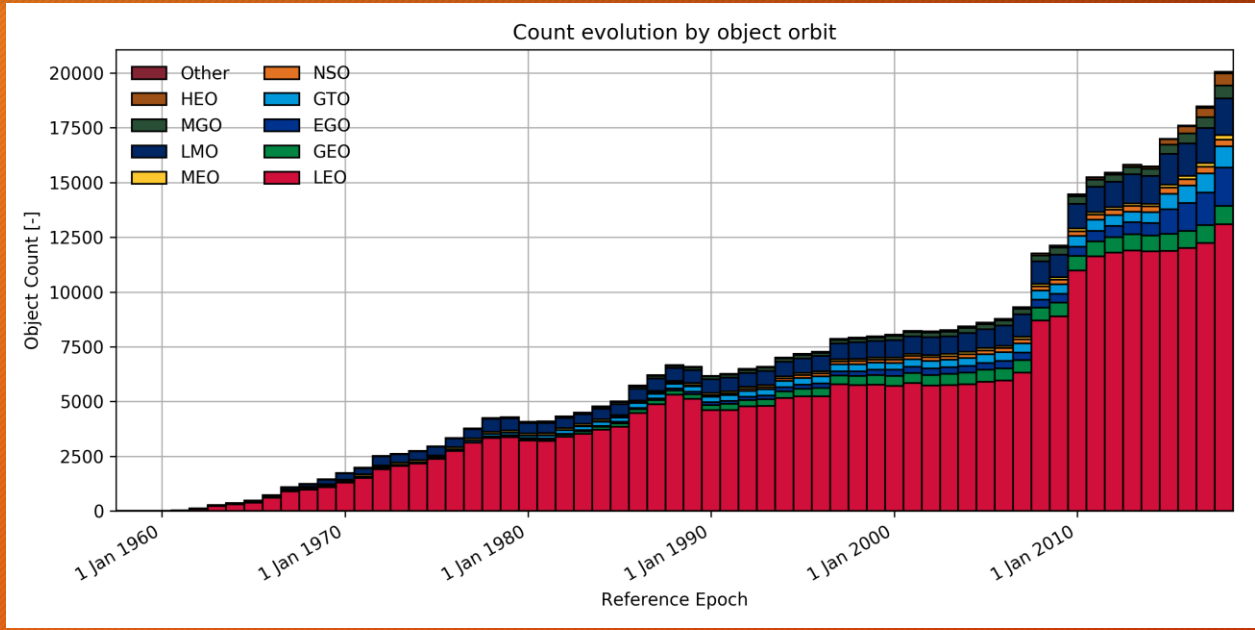
Payload Launches

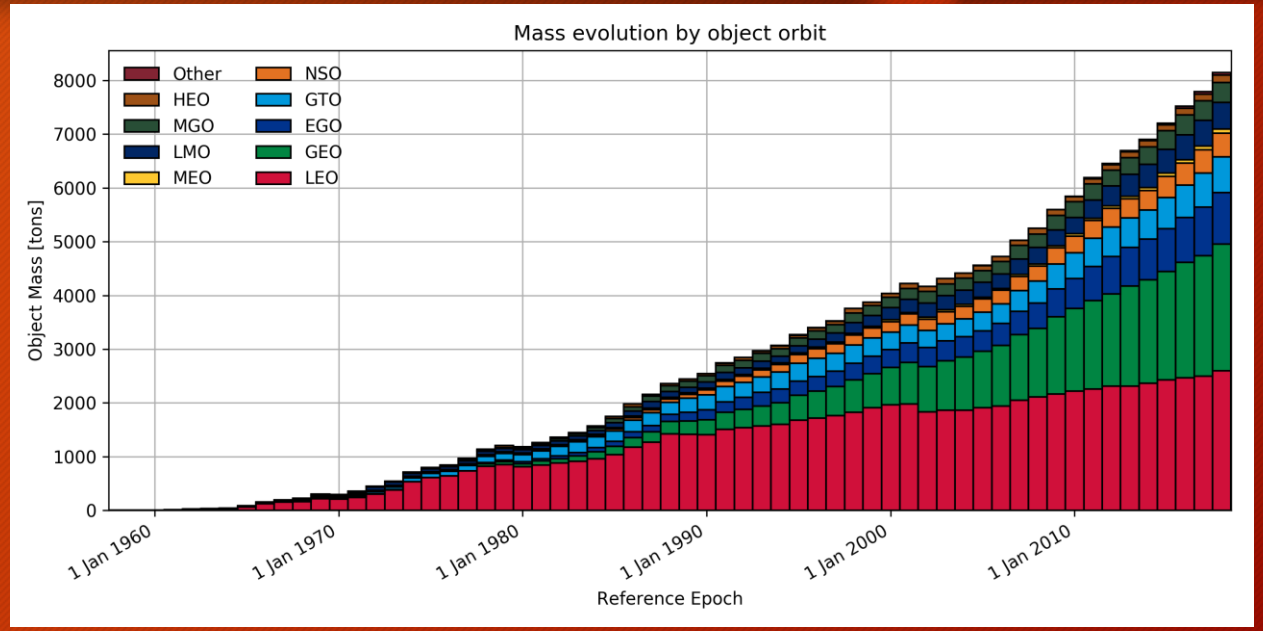
	United States	China	Russia	Total	US launch as percent/total
2019	253	49	29	331	76%
2020	959	65	23	1047	92%
2021	1215	78	16	1309	93%

Starlink as Percentage of launches

	United States	Total Number of Starlink Payloads	Starlink as % of all US payloads	Starlink as % of all payloads (US, Russia, and China)
2019	253	119	47%	36%
2020	959	832	87%	79%
2021	1215	988	81%	75%

The Growth in Space Debris





Operational changes are required to limit space debris. Failing this, debris density will grow collisions between objects could cause a cascade of collisions creating more debris.

“The Kessler Syndrome”

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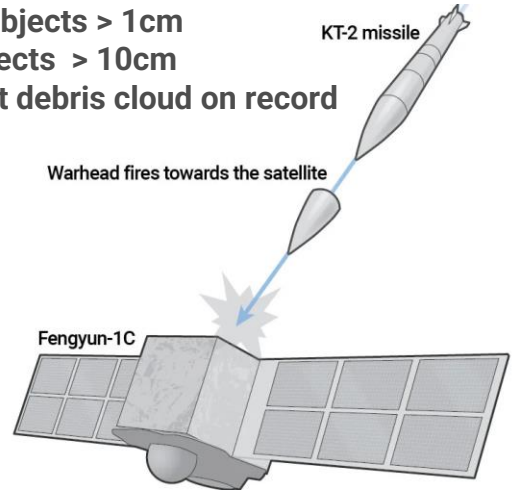
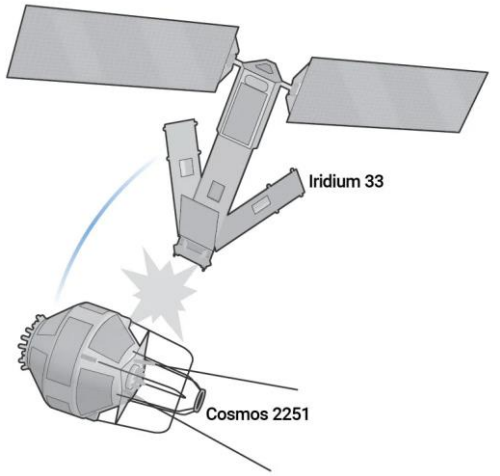
Sources of Space Debris

- The delivered payload from a successful launch
  - The Mission is the Debris unless it can be “deorbited”
- Upper stages of launch boosters and orbit transfer motors
- Other mission hardware launch adapters, lens covers, etc.
- Explosion or remnant rocket bodies and space craft
- Collison between satellites and other space debris
  - Example Iridium 33 and Cosmos 251
- Intentional anti-satellite weapons tests
  - Example KT-2 missile & Fengyun-1C weather satellite

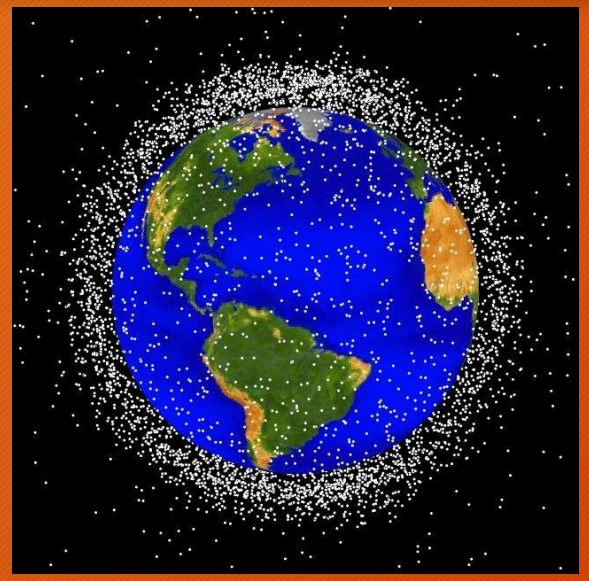
2007, China tests an anti-satellite missile
300K objects > 1cm
3K Objects > 10cm
Largest debris cloud on record



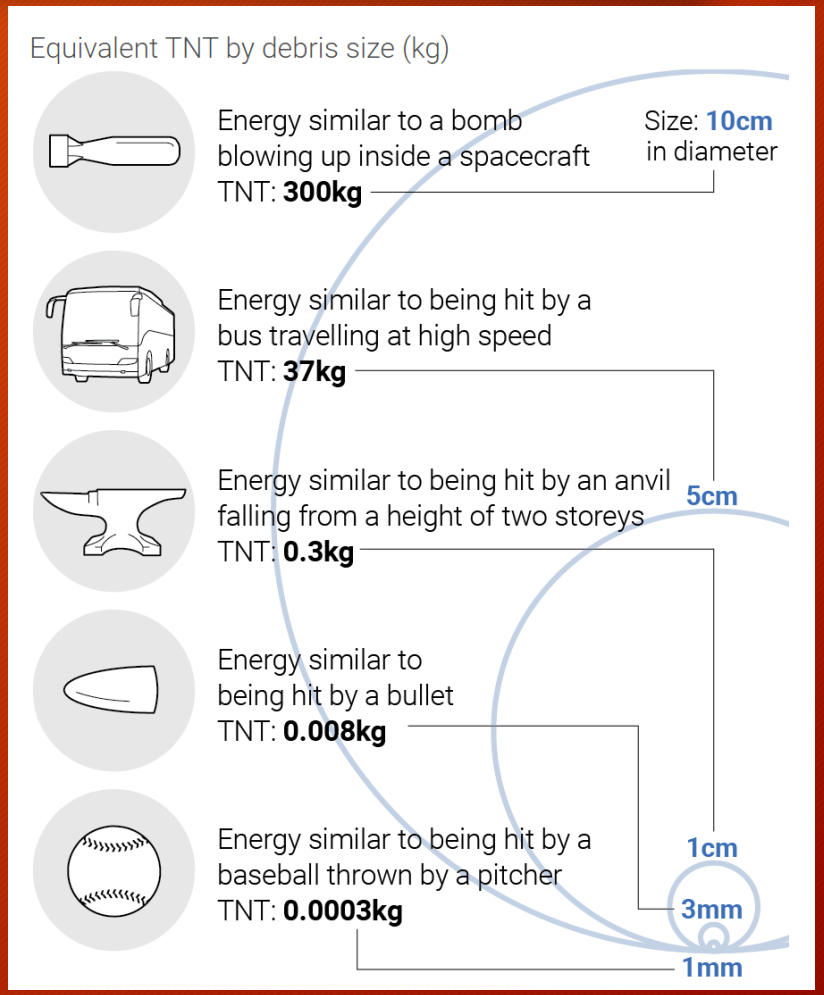
February 10, 2009 first Satellite Collision
~2k Objects > 10cm created



Mass Combined with High Velocity = High Destructive Power



- More than 27,000 pieces of orbital debris >10cm
- 500,000 pieces of debris >1cm but < 10cm
- 100 Million pieces > than 1mm
- Average velocity 28,000 km/h (17,000 mph)



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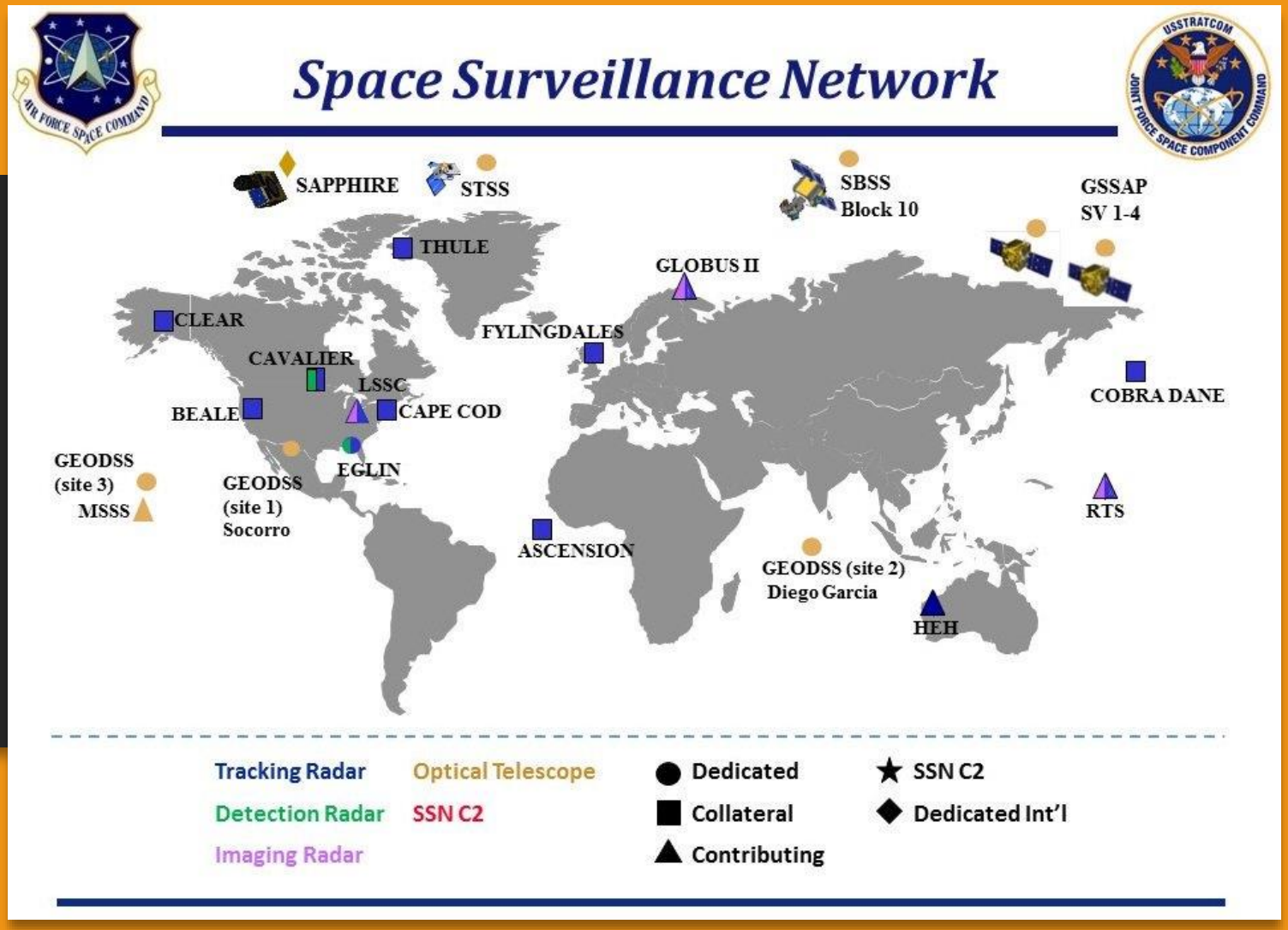
Object/Debris Tracking

Tracking Orbital Space Debries

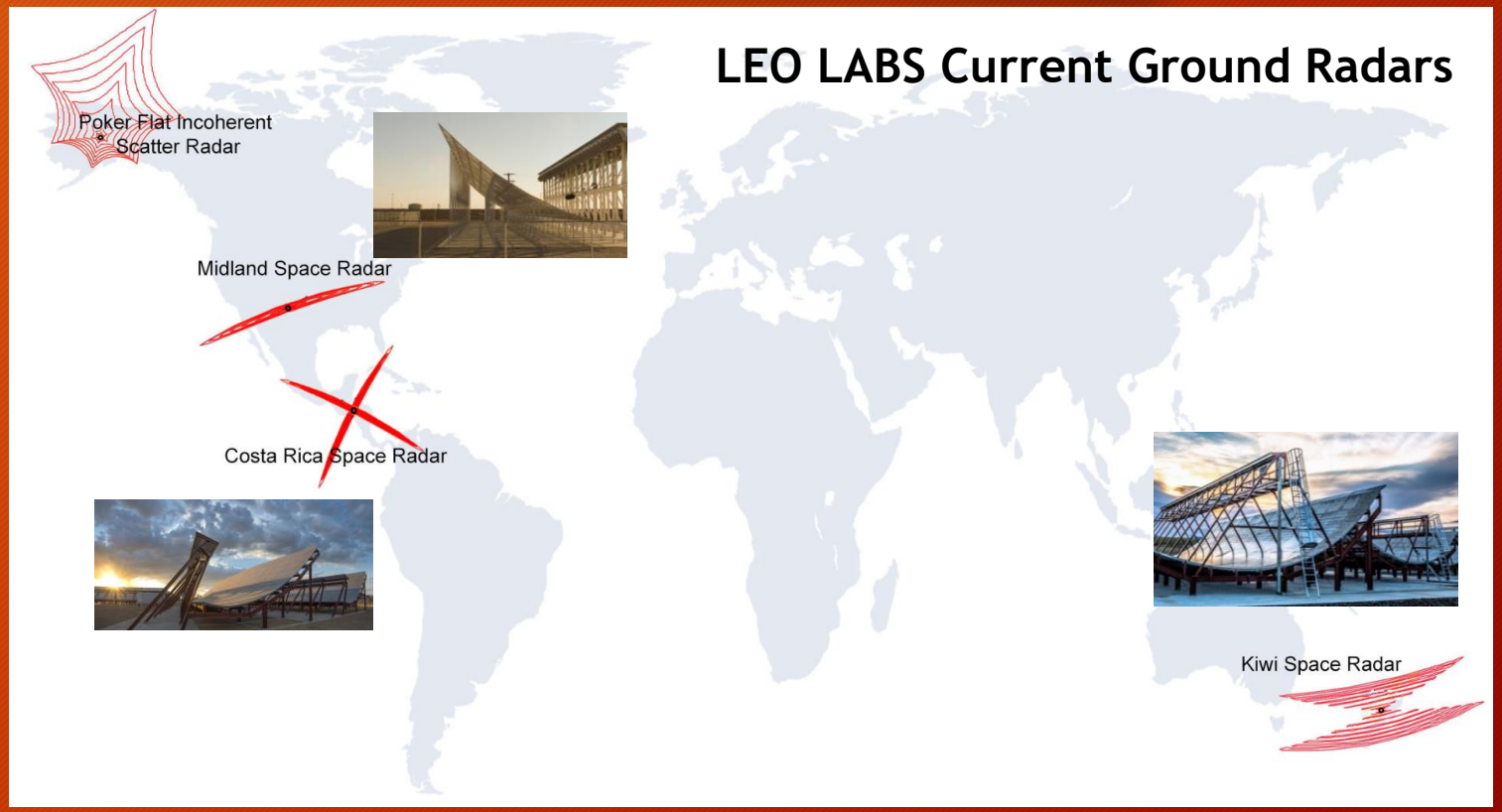
- 18th Space Defense Squadron – USSF Space Domain Awareness unit (in conjunction with NASA)
  - Operates the US Space Surveillance Network (SSN)
  - SSN is a world wide network of 30+ ground-based radars and optical telescopes, plus 6 satellites in orbit (Pathfinder SSBS)
  - Near-Earth (NE) tracking- observing satellites, space debris and other LEO objects
  - Deep Space (DS) tracking- generally for asteroids and comets
  - Cataloges and Tracks >27K near earth objects > 10cm
- China, Russia, and EU perform similar tracking functions
  - Limited sharing of object data bases (which is disappointing)

Components of the Space Surveillance Network



Commercial LEO Debris Tracking: LEO LABS

- LEO Labs provides Tracking and Collision Avoidance As A Service
  - Conjunction Alerts and post maneuver assessment
  - Mission planning and assessment
  - Space Domain Awareness
    - Tracking of any and all launches deployed objects
- Developing a network of 20 S-Band and UHF Phased Array Radars
  - Track objects as small as 2 cm
- When completed:
  - Track new satellites in orbit within hours of deployment
  - Revisit satellites multiple times a day
  - Avoidance Alerts and Risk assessment



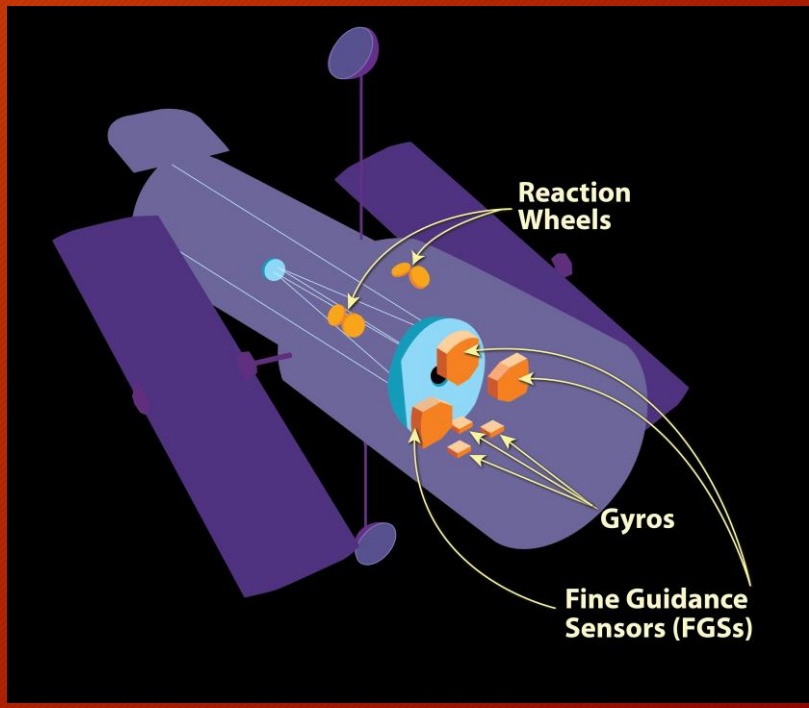
Debris Avoidance

Collision Avoidance:
Mission Planning and Non-Thruster Techniques

- A vast majority of satellites and vehicles have no thrusters
- Mission Planning and Simulation identify launch and orbit profiles that minimize probability of collision large objects in the SSN catalog
- For LEO satellites atmospheric drag can be used to alter orbit and avoid collision
  - Satellite orientation used to alter between low-drag and high-drag configurations to decelerate and avoid collision – simple rotation
- Satellite and spacecraft orientation systems like Magnetorquers, Reaction wheels, etc., can modify orbit with inertia

Orbital Changes can lead to Future Collison Events
Simulation and Planning is Advised

Satellite Orientation Control



Collision Avoidance: Spacecraft with Onboard Thruster

- Space craft with thrusters can perform debris avoidance maneuvers
  - Small manuversare executed several hours before the time of the conjunction (collision)
  - Manned space craft like the ISS require about 5 hours to plan and execute
- The International Space Station (ISS) will execute maneuvers when:
  - Probability of collision is greater than 1 in 100,000, and not result in significant impact to mission objectives.
  - If it is greater than 1 in 10,000, a maneuver will be conducted unless it will result in additional risk to the crew.
  - For small debris impact, ISS has Whipple shielding to resist damage
- ISS has conducted 29 debris avoidance maneuvers since 1999, including three in 2020.

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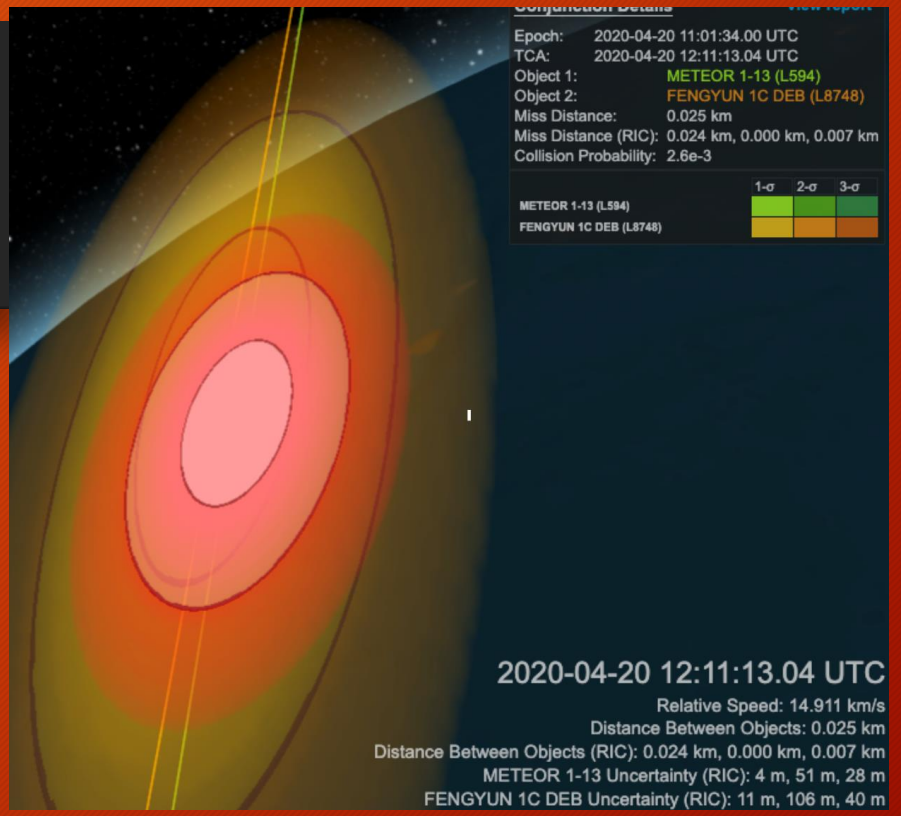
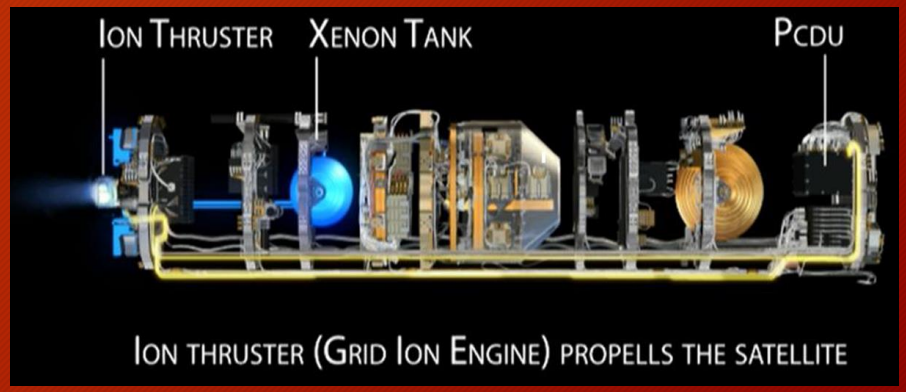
Conjunction Event Simulation





Decreasing Space Debris – New Regulation

- The United States is defining stringent limits to Space Debris especially for space craft in orbits < 2000 Km
  - 2019 update: US Government Orbital Debris Mitigation Standard Practices
  - September 20, 2022 FCC report: Space Innovation; Mitigation of Orbital Debris in the New Space Age
- Specific changes
  - **Disposal:** 25 year deorbit policy moved to **5 Years**
    - Increased requirements for thrusters of LEO space craft
  - **Operations:** Required Selection of Safe Flight Profile and operational Orbit Configuration
  - FCC will apply US standards to any LEO communications system to get US Market Access

Thank You

Questions/Comments Contact: paul@struhsaker.com
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