

USA Space Debris Environment, Operations, and Research Updates

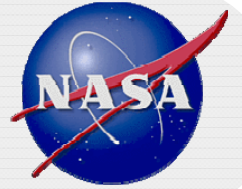
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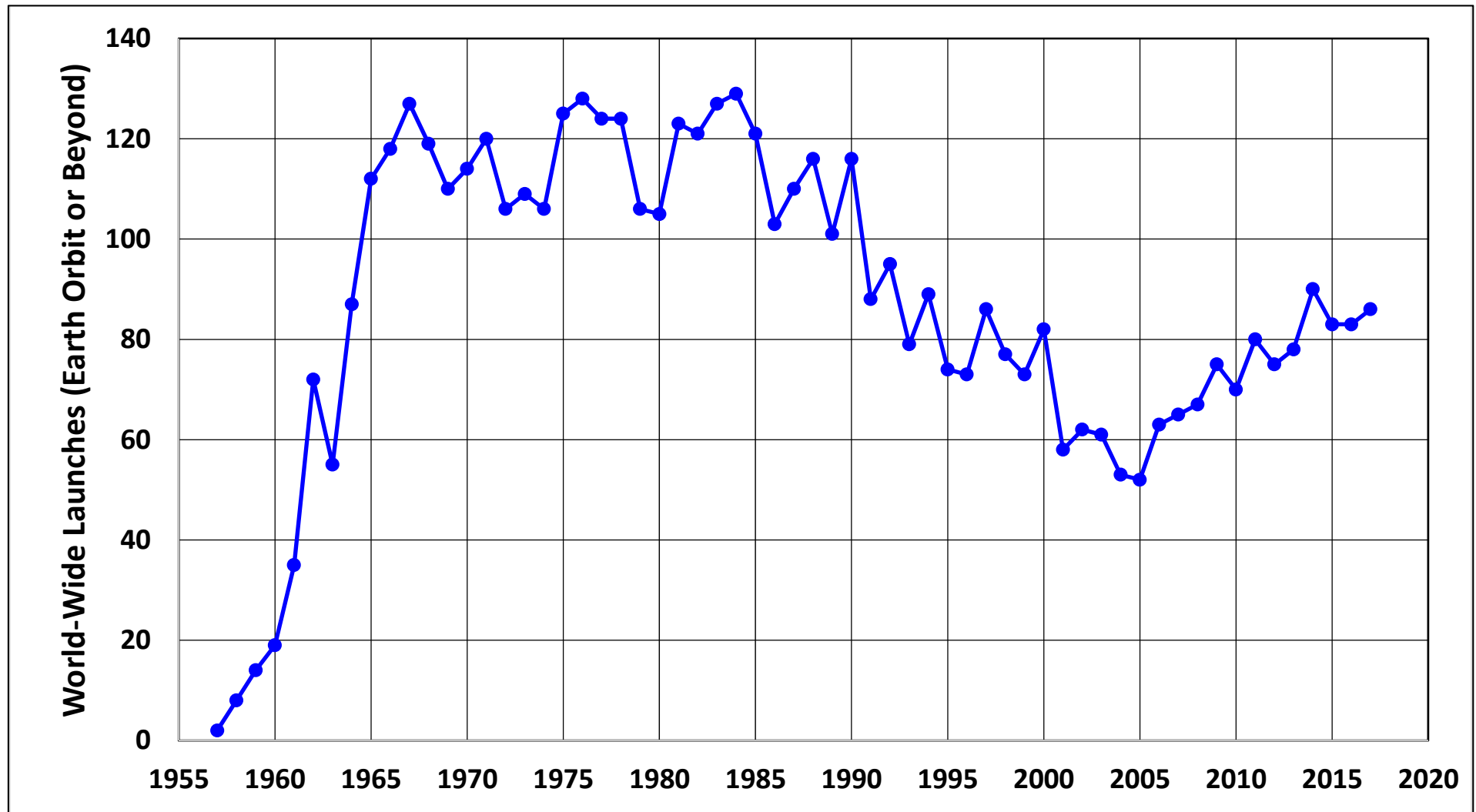
Presentation Outline

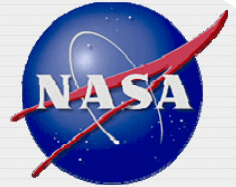
- **Space Missions in 2017**
- **Earth Satellite Population**
- **Collision Avoidance Maneuvers**
- **Postmission Disposal of U.S.A. Spacecraft**
- **Space Situational Awareness (SSA) and the Space Debris Sensor (SDS)**



World-Wide Space Activity in 2017

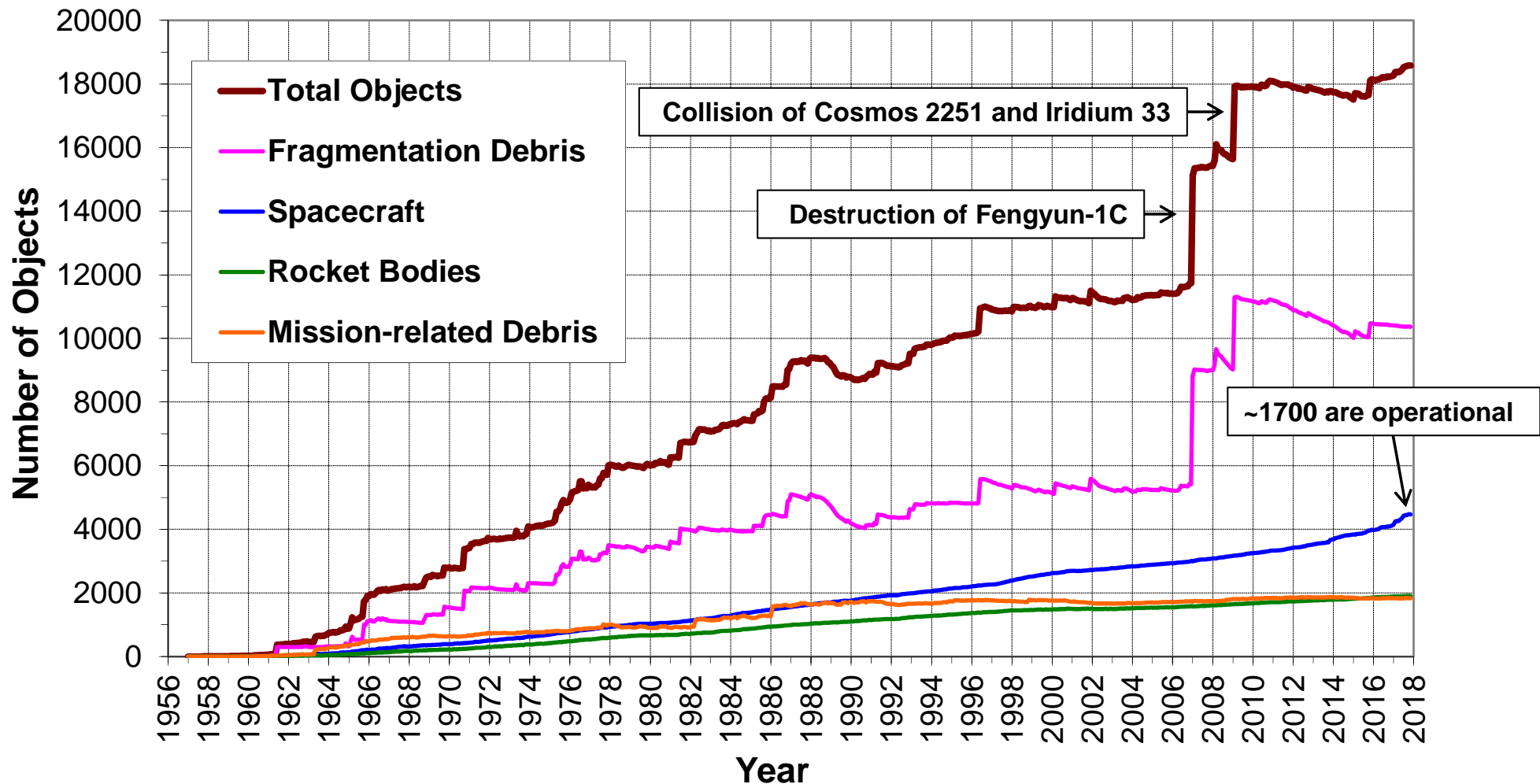
- A total of 86 space launches placed more than 400 spacecraft into Earth orbits during 2017, following the trend of increase over the past decade





Evolution of the Cataloged Satellite Population

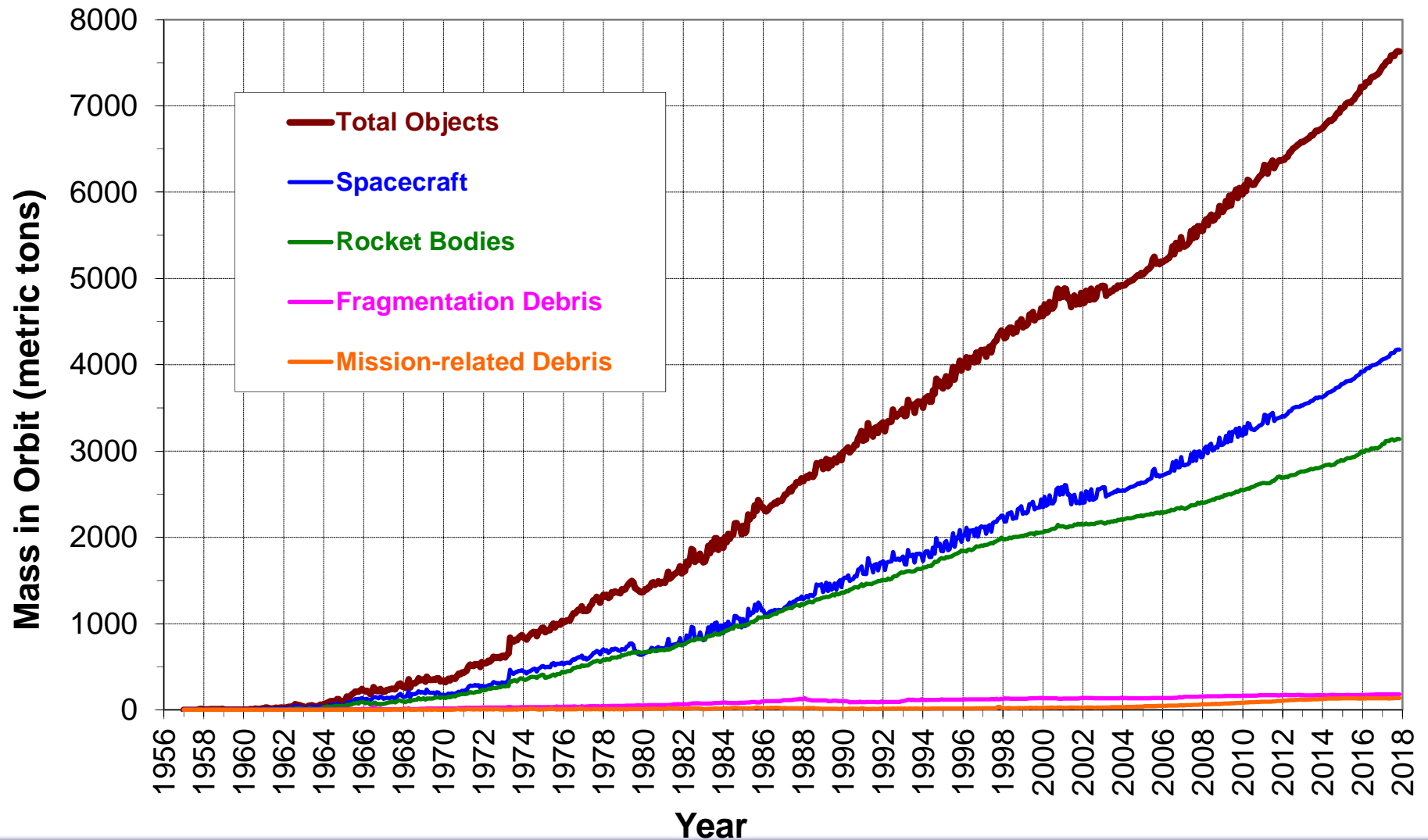
- According to the U.S. Satellite Catalog, the number of 10 cm and larger objects in Earth orbit continued to increase in 2017



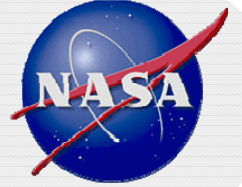


Mass in Near-Earth Space Continued to Increase

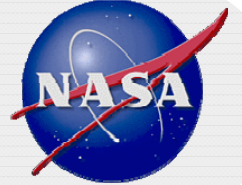
- The total mass of material exceeded 7600 metric tons in 2017



International Space Station and NASA Robotic Spacecraft Collision Avoidance Maneuvers



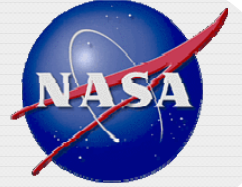
- **NASA has established conjunction assessment processes for its human spaceflight and uncrewed spacecraft to avoid accidental collisions with objects tracked by the U.S. Space Surveillance Network**
 - NASA also assists other U.S. government spacecraft owners with conjunction assessments and subsequent maneuvers
- **The ISS has conducted 25 debris collision avoidance maneuvers since 1999**
 - None in 2016-2017, but an ISS visiting vehicle had one collision avoidance maneuver in 2017
- **During 2017 NASA executed or assisted in the execution of 21 collision avoidance maneuvers by uncrewed spacecraft**
 - Four maneuvers were conducted to avoid debris from Fengyun-1C
 - Two maneuvers were conducted to avoid debris from the collision of Cosmos 2251 and Iridium 33
 - One maneuver was conducted to avoid the ISS



Disposal of USA Spacecraft in GEO

- **Two USA commercial spacecraft ended operations in GEO in 2017**
 - Intelsat 701 and EchoStar 3 were launched before the establishment of the 2007 UN COPUOS Space Debris Mitigation Guidelines
 - Both spacecraft conducted disposal maneuvers to move away from the GEO region and postmission passivation operations (fuel depletion, discharging batteries), consistent with the UN COPUOS Space Debris Mitigation Guidelines
- **A third spacecraft, AMC-9, launched in 2003, was forced to end its mission after a serious anomaly**
 - The operator was able to regain partial control of the spacecraft, raised its orbit away from GEO, and carried out several passivation operations

Spacecraft	International Designator	Minimum Height above GEO	Maximum Height above GEO
Intelsat 701	1993-066A	264 km	279 km
EchoStar 3	1997-059A	350 km	440 km
AMC-9	2003-024A	277 km	430 km

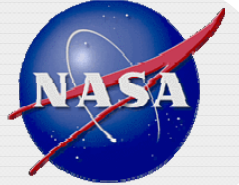


Iridium System Satellite Replacement and Disposal in LEO

- **In 2017, the operator of the 66 spacecraft Iridium constellation began replacement of spacecraft**
 - 40 new spacecraft (“Iridium NEXT”) were launched in 2017
 - 13 first-generation spacecraft were removed from operational orbits for disposal and passivation, consistent with the UN COPUOS Space Debris Mitigation Guidelines
 - **6 decayed from orbit and reentered so far, 3 are expected to reenter by 2020, and the remaining 4 are expected to reenter within 25 years**
- **As newly launched spacecraft enter into service, additional first-generation Iridium spacecraft will be removed from orbit for disposal**

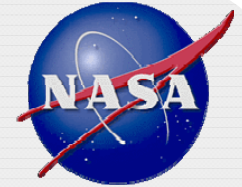


Successful launch of the 4th Iridium NEXT mission on 22 December 2017.

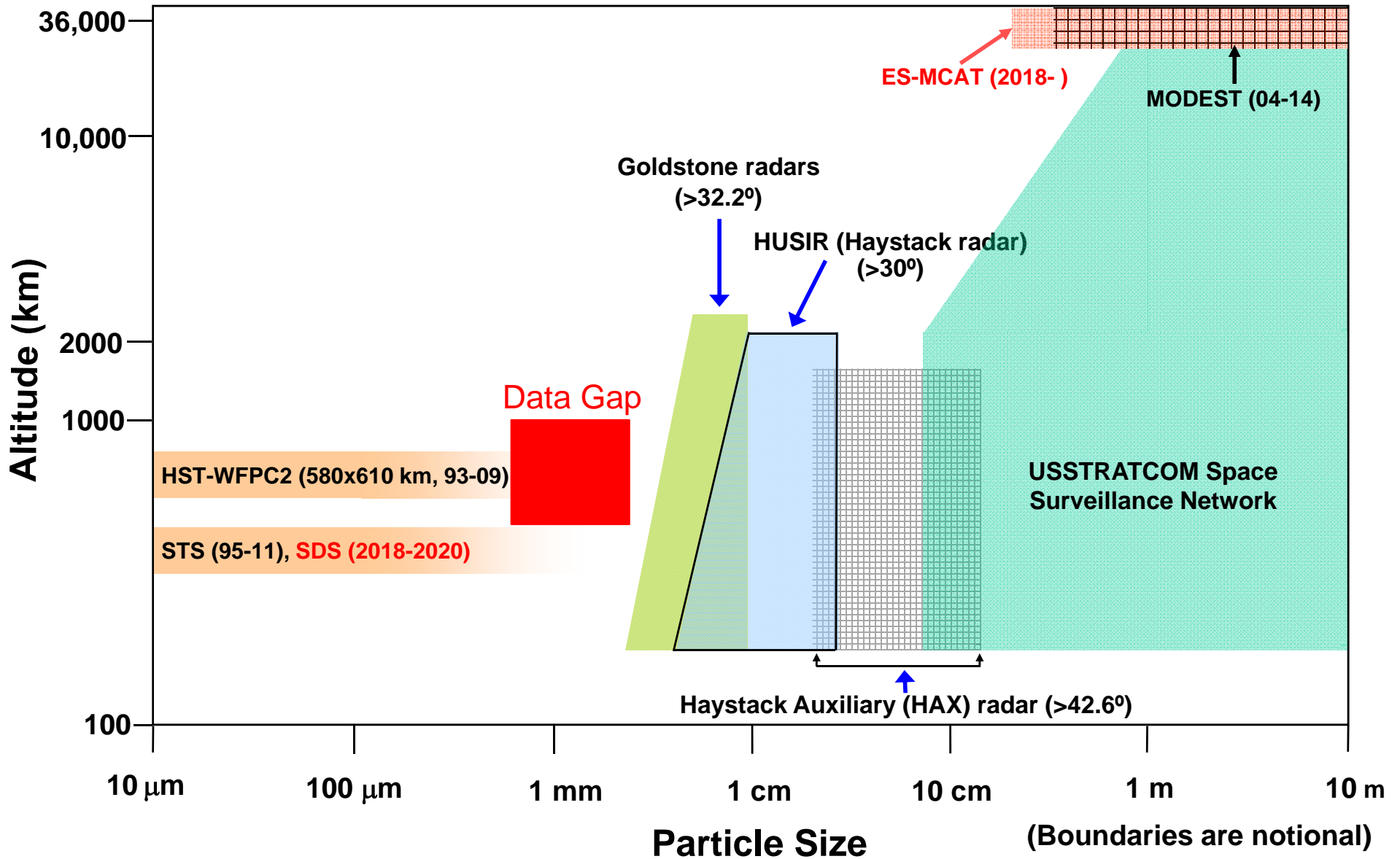


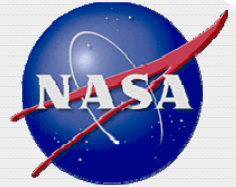
Space Situational Awareness in the United States

- **The U.S. Strategic Command (USSTRATCOM) continues to use the Space Surveillance Network (SSN) to track the largest objects in the near-Earth environment**
 - Objects approximately 10 cm and larger in low Earth orbit (LEO)
 - Objects approximately 1 m and larger in geosynchronous Earth orbit (GEO)
 - USSTRATCOM shares the SSA data with the global community via SSA Sharing Agreements and the space-track.org website
- **NASA uses additional radars, telescopes, and in-situ measurements to characterize objects too small to be tracked by the SSN, but large enough to threaten human spaceflight and robotic missions**
 - Millimeter-sized debris represent the highest penetration risk to most operational spacecraft in LEO
 - NASA uses all available measurement data to develop Orbital Debris Engineering Model (ORDEM) for mission impact risk assessments. The model is available at the NASA Orbital Debris Program Office's website



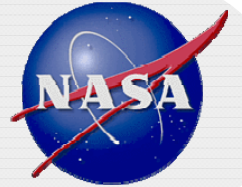
SSA Coverage in the United States





Top Risk for Operational Spacecraft in LEO

- **The 2014-15 NASA Engineering and Safety Center (NESC) study on the micrometeoroid and orbital debris (MMOD) assessment for the Joint Polar Satellite System (JPSS) provided the following findings**
 - Millimeter-sized orbital debris pose the highest penetration risk to most operational spacecraft in LEO
 - The most effective means to collect direct measurement data on millimeter-sized debris above 600 km altitude is to conduct *in situ* measurements
 - There is currently no *in situ* data on such small debris above 600 km altitude
- **Since the orbital debris population follows a power-law size distribution, there are many more millimeter-sized debris than the large tracked objects**
 - Current conjunction assessments and collision avoidance maneuvers against the tracked objects (which are typically 10 cm and larger) only address a small fraction (<1%) of the mission-ending risk from orbital debris
- **To address the millimeter-sized debris data gap above 600 km, NASA has recently developed an innovative *in situ* measurement instrument – the Space Debris Sensor (SDS)**



Measurements of Small Debris from the ISS

- **SpaceX-13, carrying resupply and NASA's SDS, was launched to the ISS on 15 December 2017**
 - The SDS mission will mature NASA's *in situ* measurement technologies and collect data on the sub-millimeter debris population at the ISS altitude
 - NASA will seek future mission opportunities to deploy SDS above 600 km altitude to fill the data gap on the millimeter-sized orbital debris for better SSA and reliable orbital debris impact risk assessments to improve the safe operations of spacecraft in LEO

