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Statement of

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Committee on Armed Services
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and

Subcommittee on Space
Committee on Science, Space and Technology
U. S. House of Representatives

Chairman Rogers, Chairman Babin, Ranking Member Cooper, Ranking Member Bera, and Members of the Subcommittees, thank you for the opportunity to appear before you today to discuss Space Situational Awareness (SSA), particularly as it has to do with space object surveillance and tracking and orbital debris characterization. The space domain is becoming increasingly congested and contested, prompting the space community to recognize the need to establish a national space traffic management framework to enhance the safety, stability, and sustainability of operations in the space environment.

To address some of these challenges, at the February 21, 2018, meeting of the National Space Council, Vice President Pence directed the Executive Secretary of the Council to develop a whole-of-Government strategy for space traffic management. The President signed Space Policy Directive-3 on June 18, 2018. This policy will guide critical and much-needed progress for space traffic management. SPD-3 builds on our continued progress implementing SPD-1, which is galvanizing American space leadership by returning to the Moon with commercial and international partners, and SPD-2, which will create regulatory certainty for entrepreneurs to raise capital to grow the American economy in space. As we continue to thrive in space, we also have more people launching to orbit, and an increasingly complex universe of satellites overhead. SPD-3 provides guidelines and initiatives to ensure that America is a leader in providing a safe and secure environment as space traffic increases. Common sense space situational awareness and traffic management will be good for our economy and will help provide a more stable environment for the burgeoning space economy.

NASA's Current Space Situational Awareness Activities

NASA maintains a strong, cooperative relationship with the DoD on SSA issues. NASA uses SSA information from DoD to avoid collisions between its assets and other tracked objects in Earth orbit. The Conjunction Assessment Risk Analysis (CARA) office at NASA Goddard Space Flight Center and the

Human Space Flight Operations Directorate at the NASA Johnson Space Center comprise the NASA spaceflight safety functions. These NASA spaceflight safety functions currently maintain a direct interface with the U.S. Strategic Command's (USSTRATCOM) Joint Space Operations Center and the U.S. Air Force Space Command's 18th Space Control Squadron (18 SPCS), in order to ensure that the SSA needed for collision avoidance analysis is provided to NASA in a timely manner.

NASA does not create or maintain a catalog for SSA – i.e., NASA does not track detailed debris orbits, report where an object will be in the coming days, or compute close approach predictions. This activity is conducted by the DoD through the United States Space Surveillance Network (SSN), which detects, identifies, tracks, and catalogs human-made objects (e.g., active/inactive spacecraft, spent rocket bodies, or fragmentation debris) orbiting Earth as small as 10 cm in Low Earth Orbit (LEO) and objects as small as 1 m in Geosynchronous Earth Orbit (GEO). The SSN is the responsibility of the USSTRATCOM Joint Force Space Component Commander.

Collision Avoidance

NASA depends upon DoD's SSA information to prevent its spacecraft from colliding with tracked objects in Earth orbit. NASA's spaceflight safety functions are mission-funded resources that perform risk assessment for their respective missions using software suites consisting of a combination of Commercial Off-the-Shelf and custom applications to analyze the close approach data provided by the 18 SPCS. These spaceflight safety functions maintain liaison with the 18 SPCS in order to ensure that the SSA needed for proper collision avoidance analysis is provided to NASA and that information regarding upcoming NASA spacecraft maneuvers is delivered to DoD in a timely manner.

Collision avoidance is a three-step process. The first step is conjunction assessment screening, which involves computing the predicted close approaches between NASA spacecraft and the 18 SPCS catalog of space objects. This step is performed for NASA at the 18 SPCS by either the NASA Orbital Safety Analysts (OSAs) for robotic missions or by 18 SPCS Human Spaceflight (HSF) OSAs for crewed missions. The second step is a risk analysis, in which NASA analyzes results from the first step to determine the level of risk posed by predicted close approaches and to further determine whether the operational risk warrants additional investigation or mitigation. The third step, if required, is mitigation, in which the mission operator plans, and perhaps executes, a collision avoidance maneuver or other mitigating action, often in coordination with the owner of the other space object. Not all NASA spacecraft have propulsion systems and can take action in this third step. In those cases, if the close approach is with an object that can maneuver, we will negotiate with the owners of that system to do so. If neither spacecraft can alter their trajectory, we monitor the conjunction until the danger has passed.

CARA provides spaceflight safety support to all Agency robotic missions. It funds a team of contract personnel, OSAs, who are embedded within the 18 SPCS. These NASA OSAs provide dedicated and focused support, ensure mission safety, and provide timely required SSA data streams back to CARA. They represent NASA's interests and protect NASA's robotic Earth-orbiting satellites. The OSAs have access to the 18 SPCS close-approach assessment systems, and they can produce specialized products for NASA missions. The OSAs are vested with the appropriate access and proficiencies to meet NASA mission needs and exigencies in a responsive manner. The current funding line for NASA CARA is approximately $4 million per year. This covers the full CARA service for about 65 spacecraft, including operators, offline analysts, software developers, OSA staff at the Vandenberg AFB 18 SPCS facility, the hardware, the software licenses, documentation, training, system administration and IT security, and management.

For human spaceflight missions, the NASA teams in the Houston Mission Control Center perform both functions of risk assessment and operational response. Crewed spaceflight situation awareness services are provided by Human Spaceflight (HSF) OSAs. These HSF OSAs are a team of 18 SPCS-provided civilian and military personnel providing around-the-clock conjunction assessment and other operational safety support to the Mission Control Center in Houston. These HSF OSAs also support other 18 SPCS functions such as catalog maintenance. Upon receiving alerts from the HSF OSAs at 18 SPCS, personnel in Mission Control assess the associated tracking and orbit predictions to determine the collision risk, and then coordinate an appropriate mitigation plan with the operations team, including international partners, as appropriate.

Each NASA spaceflight safety function provides automated updates to their missions regarding the risk posed by close approaches each time SSA data is received from the 18 SPCS. They also perform manual analysis to determine the risk posed by each predicted close approach based on several factors, including the quality of the close approach prediction for the secondary (conjuncting) object, which depends upon the tracking data that was used to compute the trajectory and predict the close approach. NASA develops and maintains state of the art models for computing probability of collision for close approaches. This risk analysis assists the project managers in developing mitigations to avoid collisions.

Orbital Debris Characterization

While collision avoidance and catalog maintenance are important, they do not entirely address the problem of orbital debris collision risk. For every object that is currently tracked and can be avoided, there are orders-of-magnitude more orbiting objects too small to be tracked that could do serious damage to NASA spacecraft. The new Space Fence radar being constructed by DoD will help address this problem by lowering the minimum object size being tracked, but most risks from non-trackable debris will remain. In fact, millimeter-sized orbital debris represents the highest penetration risk to most operational spacecraft in LEO. In addition, while collision avoidance is prudent for operational spacecraft, it is not a solution to the long-term degradation of the space environment due to future collisions. This is because the vast majority of potential collisions are between objects that cannot maneuver to avoid collisions, especially massive spent upper stages and retired spacecraft.

The NASA Orbital Debris Program Office (ODPO) has the responsibility to define the environment for debris too small to be catalogued by 18 SPCS, but still large enough to threaten missions. These debris are not tracked, but are measured using statistical techniques based on radar, telescope, and *in situ* measurement data to understand their size and orbit distribution, and to understand where they come from. The ODPO also creates and maintains modeling tools to understand the effects of debris on spacecraft risk and the long-term evolution of the debris environment.

For understanding the present and near-term environment, the ODPO has created the Orbital Debris Engineering Model (ORDEM), an empirically-based model that predicts the orbital debris environment for the next 30-35 years and is intended to be used by spacecraft designers and mission planners to assess the impact risk from orbital debris to a spacecraft over its on-orbit lifetime. These analyses using ORDEM provide spacecraft designers/operators with quantitative results for evaluating the risk that orbital debris poses to the success of their missions as well as providing a basis for evaluating quantitative methods of the cost effectiveness of various debris shielding techniques as well as operational techniques for mitigating damage from the debris impacts. ORDEM can be used to compute the average rate at which debris of various sizes might be expected to hit a spacecraft over its mission lifetime, but is not designed to evaluate the risk a particular tracked object will hit a particular space asset at a particular time.

The ORDEM model is also used in the Debris Assessment Software, a tool to assist spacecraft and mission designers to determine compliance with orbital debris mitigation requirements in NASA's Technical Standard, NASA-STD-8719.14A. The Debris Assessment Software, along with the Object

Reentry Survival Analysis Tool software, can be used to predict reentry survivability of an upper stage or spacecraft for human casualty risk assessments.

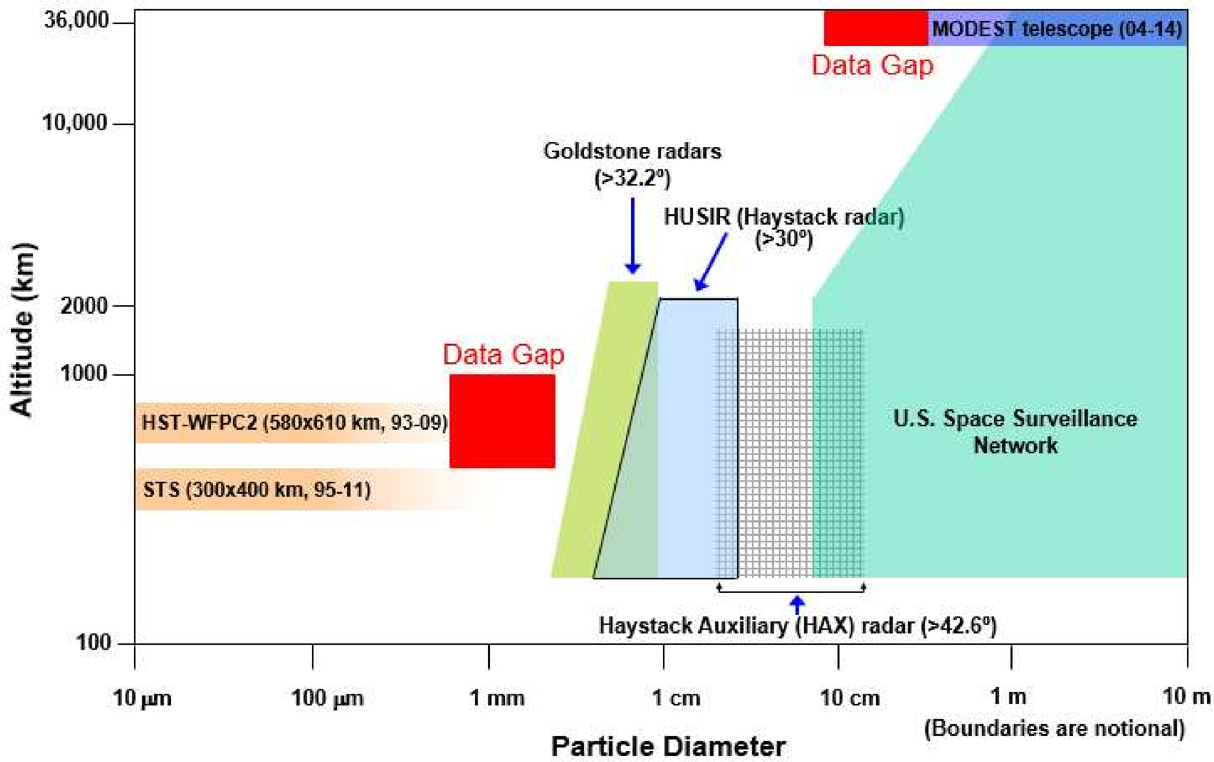
Another important ODPO tool used to understand the debris environment is the LEO-to-GEO Environment Debris (LEGEND) model. LEGEND is NASA's long-term debris evolutionary model designed to predict the environment 100-200 years into the future based on user-specified scenarios, such as future launch rates and different mitigation and remediation measures. It is often used to test the effectiveness of mitigation and remediation strategies in use by the U.S. and other spacefaring nations. It can also be used to investigate potential negative long-term effects from special classes of missions, such as the proposed large constellations, to the environment to support the development of new guidelines and best practices to mitigate such effects.

The inputs to these models are obtained by statistical measurements using ground-based radars and optical telescopes and by analysis of spacecraft surfaces that have been exposed to the space environment. None of these observations are primarily intended to provide real-time, actionable data like the collision-avoidance information from the 18 SPCS. Their goal is to monitor changes in the environment and to provide statistical data to update ODPO models, especially ORDEM, which is used to address the main orbital debris impact risks to space missions.

For radar, ODPO uses the Haystack and Haystack Auxiliary radars operated by MIT Lincoln Labs and NASA's Deep-Space Network Goldstone radars. These radars can make statistical observations of the small particle environment (in some cases objects as small as 2-3 mm) in LEO (the region below 2000 km altitude), but they are incapable of tracking individual small debris. Optical telescopes are primarily used to characterize the environment at higher altitudes, such as the geosynchronous orbit region (36,000 km altitude). ODPO, in collaboration with the Air Force, has developed and installed the Meter Class Autonomous Telescope (MCAT) on Ascension Island. MCAT is in the process of undergoing readiness reviews and testing prior to proceeding to full operation, and should be able to help characterize and monitor debris in the geosynchronous and other regions in early 2019. Note that in the future, because of its unique capabilities and location, the MCAT is expected to have the capability to aid the 18 SPCS with its cataloging and tracking function on an as-needed basis.

To improve our characterization and monitoring of the small particle (millimeter or smaller) environment, the ODPO has developed the Debris Resistive/Acoustic Grid Orbital NASA-Navy Sensor (DRAGONS). DRAGONS is a cooperative project among NASA's Orbital Debris Program Office, Naval Research Lab, and the U.S. Naval Academy. It is an *in situ* experiment designed to fly on a spacecraft host and be directly exposed to the space environment and detect debris impacts on its surface. It combines three sensor technologies, acoustic sensor, resistive grid, and dual-layer thin films to characterize the size, impact speed, impact direction, and the energy of the impacting particle. NASA has recently funded a technology demonstration mission of the sensor on the International Space Station to mature the DRAGONS technologies.

Below is an orbital debris measurement coverage chart, from LEO to GEO. MCAT, which is used by NASA as a tool for debris characterization and modeling/analysis, will address the gap in GEO (for debris down to ~15-20 cm in size). *In situ* measurements are needed to fill the millimeter sized debris gap at 600-1000 km altitude in LEO since debris in that size regime represent the highest mission-ending risk to spacecraft operating in that region. Data on such small debris could help improve the orbital debris impact risk assessments for the current missions and support the development and implementation of cost-effective debris impact protective measures for the safe operations of future missions.



To better understand the outcome of on-orbit collisions and to provide calibration data for radar and optical debris measurements, NASA and the Air Force Space and Missile Systems Center (SMC) have collaborated on a laboratory satellite impact test called DebriSat. A representative modern satellite was designed, fabricated, and then subjected to the impact of a ~10 cm projectile at close to 7 km/sec impact speed at the Air Force's Arnold Engineering Development Complex. The DebriSat fragment data will be used to improve the NASA and Air Force's satellite breakup models and be used to support other SSA applications, such as improving the debris size estimation model for radar observations and developing an optical debris size estimation model for telescope observations.

Almost all of ODPO's measurements projects are collaborations with DoD and some also have university involvement. There is a MOU between DoD and NASA for measurements from the Haystack radars. The ODPO is also collaborating with the DoD on calibration of the new Space Fence.

The ODPO is recognized worldwide as the leader in orbital debris measurements, modeling, and policy development. The NASA ODPO is located at Johnson Space Center and is funded by NASA Office of Safety and Mission Assurance at Headquarters. The current funding line for the ODPO is approximately $7 million/year.

Conclusion

NASA looks forward to continuing to collaborate with our interagency partners to ensure a safe and sustainable orbital environment. As a leading user of space situational awareness data, the world's leading organization for characterizing the orbital debris environment, and the world's leading space exploration agency, NASA is a major beneficiary of the Administration's continuing attention to these issues.

Mr. Chairman, I would be happy to respond to any questions you or the other Members of the Subcommittees may have.