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U.S. SATELLITE SERVICING POLICY– AN OVERVIEW

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Satellite Servicing- An Overview

Executive Summary

This paper provides an overview of on-orbit satellite servicing (OOS), a technology that could spur new commercial markets for robotics and human space exploration. The paper serves as an initial introduction to satellite servicing technology; how the technology has evolved, as well as previous legislation and current policy issues surrounding the topic.

On-orbit satellite servicing broadly refers to the repair, inspection, life extension, and augmentation of satellite payloads while in orbit. It also refers to the enabling of on-orbit manufacturing and assembly (OSAM), refueling, disposal, and orbital reinsertion of satellites.[1] In the United States, major satellite servicing stakeholders include commercial companies, such as Northrop Grumman (SpaceLogistics), Maxar Technologies, and Airbus; government agencies, including the DoD, DARPA, and NASA; as well as policymaking and regulatory entities, such the U.S. Congress, the FAA and the FCC. More specifically, DARPA's Robotic Servicing of Geosynchronous Satellites (RSGS) program[2] involves commercial collaboration with a wide variety of organizations such as the Naval Research Laboratory, Northrop Grumman, and Charles Draper Laboratory.

On-orbit satellite servicing is a complex topic that intersects many policy areas, such as space traffic management, space situational awareness, debris management, and the development of international standards and norms. Currently, OOS stakeholders are actively working to address a series of policy and technical concerns, including a nascent regulatory environment, the technical complexity of developing fully autonomous servicing spacecraft, and uncertain business cases given increasingly inexpensive satellite manufacturing costs and lowered launch costs.

Despite these challenges, on-orbit satellite servicing could benefit users by reducing the cost of satellite replacement and constellation replenishment, extending the life of exquisite satellites, and supporting the management of space debris created during normal satellite operations. Large satellite operators see OOS tools such as orbital adjustments, accurate pointing, and debris management as a "fleet management tool," to increase overall efficiency and effectiveness of their constellation. Ultimately, on-orbit servicing could have implications on the strategic vision of the United States space program and the future commercial space industry.

[1] Harbaugh, "Satellite Servicing TDM Project Overview." NASA, 2018.

[2] SSL, "Robotics Servicing"

How On-Orbit Satellite Servicing Works

Until recently, satellites that malfunction, deplete their fuel, or carry an obsolete payload are retired; leading to disposal in a 'graveyard orbit' or simply left to burn up in Earth's atmosphere.[3] The advent of satellite servicing missions will allow satellites to have their useful lives significantly extended. The servicing process and techniques utilized depend on multiple factors, such as the client's needs, the spacecraft's design, and orbit. Servicing could include replacing components, refueling, upgrading, relocating the satellite into a new orbit, and deploying new systems. [4]

Most satellite servicing missions would begin with rendezvousing and docking with the client's spacecraft. Next, the servicer would deploy robotic arms to perform requested tasks, such as transferring propellant to the client satellite or replacing defunct hardware elements. In the future, the development of autonomous servicing would increase the efficiency and efficacy of dexterous robotic systems in performing servicing tasks. The servicing satellite could also modify the client's orbit using a tug. Satellite servicing missions are predicted to have a duration between two to three weeks and will require approximately 50 kg of fuel for each year of life extension.[5]

In addition to refueling, on-orbit activities also could include assembly and manufacturing. On-orbit assembly involves using robotic arm or spacecraft to join components into configurations that cannot be achieved before launch due to volume limitations of launch vehicles' fairings. On-orbit manufacturing involves transforming raw materials from the ground or extracted in space into usable spacecraft components. [6] As a relatively new concept, cost-effective on-orbit manufacturing concepts will require further maturation.[7]

Benefits of Satellite Servicing

Satellite maintenance will allow operators to modify payloads and extend the life of a satellite instead of paying for a new satellite and its associated launch costs.[8] Satellite servicing will also help manage space debris as the technologies required for servicing can be used for active debris removal.[9]

On-orbit technologies also will enable the construction of complex orbital infrastructure that cannot be fully integrated before launch because of their size and complexity, such as large aperture space telescopes. NASA's Artemis program outlines a planned 2024 return date to the lunar surface as well as a call to establish a sustainable presence on the Moon by 2028.[10] In order to make lunar travel cost-effective, a significant portion of the Artemis program and Lunar Gateway will require the assembly of various components in low earth orbit or in cislunar space. The development and technical experience gained from satellite on-orbit assembly will enable more effective implementation of these plans.

Similarly, on-orbit assembly could enhance space-based reconnaissance missions by

[3] De Seiding, 2012 "Intelsat signs"
[4] Carioscia, Sara, Corbin, Benjamin, Lal, Bhavya. 2018. "Roundtable Proceedings: Ways Forward for On-Orbit Servicing, Assembly, and Manufacturing (OSAM) of Spacecrafts" *IDA*.
[5] De Seiding, 2012 "Intelsat signs"
[6] Carioscia, Sara, Corbin, Benjamin, Lal, Bhavya. 2018. "Roundtable Proceedings: Ways Forward for On-Orbit Servicing, Assembly, and Manufacturing (OSAM) of Spacecrafts"
[7] Boyd, Iain, Buenconsejo, Reina & co. 2017. "On-orbit Manufacturing and assembly of spacecraft." *IDA*.
[8] Erwin, 2017 "DARPA laying groundwork" http://spacenews.com/darpa-laying-groundwork-for-growth-in-space-robotics/
[9] NASA, 2010 "On-Orbit Satellite Servicing Study"
[10]Harbaugh, Jennifer. 2019. "Archinaut Mission."

allowing larger imagery satellites to be assembled on-orbit, leading to higher quality spatial resolution.

As on-orbit servicing becomes more common internationally, setting international norms and 'rules of the road,' participating in international dialogue, and sharing technologies when appropriate would provide the United States with soft power opportunities to lead the international space community. Reports from STPI OSAM[11] also identified that sharing the United States' technological advancement in complex systems engineering can deepen U.S. diplomatic relationships with allies.

Main Stakeholders in the United States

DARPA established and funds the Consortium for Execution of Rendezvous and Servicing Operations (CONFERS),[12] an international industry association for commercial OOS firms to create technical and operational standards and best practices, and to advocate for policies beneficial to the commercial satellite servicing industry. International government agencies also are invited to participate as subject matter experts in CONFERS activities.[13]

Another DARPA effort, the Robotic Servicing of Geosynchronous Satellites (RSGS) is the successor of previous DARPA research and development programs ranging from 2002 to 2005, including Phoenix, Spacecraft for the Universal Modification of Orbits, and the Front-end Robotics Enabling Near-term Demonstration (FREND).[14] DARPA's objective is to establish a commercial fee-for-service robotics enterprise for both military and commercial GEO satellite owners.[15] SSL won, and later withdrew from, a $15 million contract with a launch scheduled by the end of 2021.[16] Space Logistics LLC, a subsidiary of Northrop Grumman, was awarded the RSGS contract in February of 2020, with launch tentatively scheduled for 2023.

NASA's main interest in on-orbit servicing is in potential demonstrations of additive manufacturing capabilities to build and assemble complex components in space. Potential applications could enable elements of the Artemis program, as well as future planetary science and astronomy objectives. NASA Goddard Space Flight Center Satellite Servicing Capabilities Office (SSCO) develops advanced robotic technologies,[17] with projects such as RAVEN,[18] RRM-3, Restore, Hosted Payloads and Advanced Concepts project, and Vision Navigation Sensor.[19] SSCO's Restore-L program is developing a "free-flying" servicer in low earth orbit intended to refuel and repair Landsat-7 before its fuel is completely depleted. NASA's Jet Propulsion Laboratory (JPL) and the Ames Research Center collaboratively support the Archinaut on-orbit manufacturing program.[20] NASA's Langley Research Center (LaRC) develops the Commercial Infrastructure for Robotic

[11] Carioscia, Sara, Corbin, Benjamin, Lal, Bhavya. 2018.
[12] CONFERS. Website. https://www.satelliteconfers.org/
[13] DARPA, 2018 "CONFERS" https://www.darpa.mil/program/consortium-for-execution-of-rendezvous-and-servicing-operations
[14] Henry, 2017 "Congressional fire" https://spacenews.com/darpa-satellite-servicing-project-comes-under-congressional-fire/
[15] Berger & Foust, 2017. "DARPA picks SSL." http://spacenews.com/darpa-picks-ssl-as-satellite-servicing-partner-despite-orbital-atk-lawsuit/
[16] Berger & Foust, 2017 "DARPA picks SSL"
[17] SGT, "Satellite Servicing" http://www.sgt-inc.com/services-solutions/mission-operations/satellite-servicing/
[18] Masunaga, 2017 "Satellite on the fritz?" http://www.latimes.com/business/la-fi-satellite-servicing-20171116-story.html
[19] SGT, "Satellite Servicing" http://www.sgt-inc.com/services-solutions/mission-operations/satellite-servicing/
[20] Harbaugh, Jennifer. 2019. "Archinaut Mission."

Assembly and Services (CIRAS), which is part of the In-Space Robotic Manufacturing and Assembly project. [21]

In the United States, several large aerospace companies have historically been involved with the development of on-orbit servicing, notably: SSL and MDA, now subsidiaries of Maxar Technologies, and SpaceLogistics LLC, a subsidiary of Northrop Grumman. Airbus Defence and Space is developing concepts for LEO and GEO inspection with its O.CUBED services and Space Tug project, but remains generally uncertain about the commercial market. [22] [23]

Smaller commercial companies, such as Chandah Space Technologies (Insuresat) and Made in Space, Inc. (Archinaut and Vulcan), also focus on servicing and manufacturing. Made in Space received a $73.3 million contract from NASA in 2019 to build Archinaut One, which will build, assemble, and deploy its own operational solar array. The mission is slated to launch in 2022.[24] Altius Space Machines was awarded a Small Business Innovation Research (SBIR) Phase I contract by NASA to develop lightweight and low-cost 'dogtags' that are passive robotic interfaces to identify and determine the locations of objects.[25] Orbit Fab won a $250,000 grant in March 2020 to develop a cooperative docking system for refueling. [26]

<u>International Stakeholders</u>

On-orbit satellite servicing is also being pursued by international organization, often in a collaborative manner. Countries such as Luxembourg, the U.K., and U.A.E. are seen to have a more transparent regulatory environment for satellite-servicing, compared to that of the U.S.[27] In 2017, for example, the U.K. company Effective Space Solutions[28] and Israel Aerospace Industries (IAI) signed an agreement together to share technical and financial support.[29] Effective Space Solution leads the Space Drones project to perform life-extension services.[30]

Elsewhere in Europe, Thales Alenia Space is developing a concept for debris removal as their entrance to the industry.[31] Intelligent Building Blocks for On-Orbit Satellite Servicing and Assembly (iBOSS) is a German-funded initiative that focuses on introducing standard modules to make space more sustainable.[32] The European Space Agency leads the 'e.deorbit' program, which involves removing a satellite from orbit and across the Atlantic, the Canadian Space Agency awarded Neptec, later acquired by Maxar Technologies, a $11.9 million Canadian dollars contract for robotic servicing on the ISS in.[33]

In Asia, Japanese startup Astroscale has begun assembly of the 'End-of-Life Services by

[21] Damadeo, Kristyn. 2018. "NASA Puts in-space Assembly Robots to the Test." *NASA*.
[22] "O.CUBED Services" *AIRBUS*.
[23] Henry, Caleb. 2020. "Airbus Impressed by Northrop Grumman, but Remains Undecided on Satellite Servicing " *SpaceNews*
[24] Harbaugh, Jennifer. 2019. "Archinaut Mission."
[25] Messier, Doug. 2017. "Altius Space Machines DogTags Project Selected for NASA funding." *Parabolic Arc.*
[26] Foust, Jeff. 2020. "Orbit Fab gets award to test satellite refueling technology." *Spacenews.com*.
[27] Foust, 2017 "Regulatory certainty for space applications" http://www.thespacereview.com/article/3385/1
[28] Foust. 2018. "Effective Space Announces Partnership with IAI for Satellite Servicing Development." *SpaceNews.com*
[29] Henry, 2017. "MDA takes another run" http://www.spacenewsmag.com/feature/mda-corp-nearly-ready-to-take-another-run/
[30] Barnett, Danna. 2018. "Space Drone Adaptable Servicing Spacecraft." *Effective Space Solution.*
[31] Henry, 2019. "Thales Alenia Space mulls satellite servicing venture." *Spacenews*.
[32] IBOSS Satellites. *IBOSS*.
[33] Henry, 2018. "Maxar acquires robotics firm" https://spacenews.com/maxar-acquires-robotics-firm-neptec-for-32-million/

Astroscale-demonstration' (Elsa-D) spacecraft - a mission is slated for launch mid-2020. [34]

Russia and China's approach to satellite servicing is characterized for 'dual-use' purposes as inspection satellites are able to approach other nations' satellites.[35] Previously, a Russian 'inspector' satellite was deployed in 2017 with behaviors "inconsistent" with intended on-orbit servicing behaviors. [36]

The Policy History of On-orbit Servicing

In the late 1980's, NASA conducted several studies on satellite servicing and the use of the Orbital Maneuvering Vehicle (OMV) to achieve refueling, repairing, retrieving, and system upgrade objectives for Skylab, the Hubble Telescope, and the International Space Station.[37]

Later, in the 1990s and early 2000s, on-orbit satellite servicing was also demonstrated by the National Space Development Agency of Japan (NASDA[38]) Engineering Test Satellite VII, the U.S. Air Force Experimental Spacecraft System, Demonstration of Autonomous Rendezvous Technology (DART), and DARPA's Orbital Express program.[39]

DARPA's Orbital Express, launched in 2007, is considered the first demonstration of successful end-to-end robotic satellite service. The mission carried a two-part system demonstration: the prototype servicer, the Autonomous Space Transport Robotic Operations (ASTRO); and a target satellite, the NEXT-Generation Serviceable Satellite (NEXTSat).[40]

During this period, the market for satellite servicing was estimated to be worth $200 million a year in revenue.[41] Spurred by the commercial interest in satellite servicing, the 2008 NASA Authorization bill supported the development of robotic or human servicing missions. This support extended in the form of guidelines in FY2009 and FY2010 NASA Appropriations bill concerning NASA's Constellation program, providing $20 million to conduct an assessment of the Constellation program's architecture's applications to service spacecraft.[42]

Congress also authorized the NASA Advisory Council to conduct a study on on-orbit satellite servicing for high-value assets in 2010. The study examined the applicability of satellite servicing to various space architectures, such as the Thirty-Meter Space Telescope, as well as the shift toward "born-in-space" architecture.[43] The study concluded that policy maturation was required to facilitate the growth of the satellite servicing industry and to develop historic in-orbit servicing tasks performed by advanced robotics.[44] The study further stated that the type of launch vehicles chosen would largely determine the feasibility and cost effectiveness of a satellite servicing mission. For example, heavy-lift rockets would reduce the need for

[34] "ELSA-d - Astroscale, Space Debris - The Threat Hanging Over Our Heads." *Astroscale*.
[35] Strout, Nathan. 2019. "All systems 'Go': How China plans to control space. C4ISRNET.
[36] Defense Intelligence Agency. 2019. "2019 Challenges to Security in Space." Report. Pg. 28
[37] NASA, 2010 "On-Orbit Satellite Servicing Study"
[38] The National Space Development Agency of Japan (NASDA) was later merged with sister organizations to form JAXA in 2003.
[39] NASA, 2010 "On-Orbit Satellite Servicing Study"
[40] NASA, 2010 "On-Orbit Satellite Servicing Study"
[41] De Seiding, 2012 "Intelsat signs"
[42] NASA, 2010 "On-Orbit Satellite Servicing Study"
[43] NASA, 2010 "On-Orbit Satellite Servicing Study"
[44] NASA, 2010 "On-Orbit Satellite Servicing Study"

multiple small launches for refueling and on-orbit assembly.[45]

In 2018, the House considered H.R. 2809, the American Space Commerce Free Enterprise Act, which would have expanded the Office of Space Commerce's responsibilities in regulating emerging space applications such as satellite servicing.[46] While the bill was approved in the House by a voice vote, it failed to gain enough traction in the Senate to become law.[47]

The legislative debate around satellite servicing continues today. Most recently, the 2019 NASA Authorization Act requests a study on the feasibility of in-space refueling and the FY2020 Appropriations Committee Report, "encourages" the development of satellite servicing to benefit NASA, DOD, the Intelligence Community, and the private sector. [48] [49]

<u>On-orbit Satellite-servicing Regulations</u>

The licensing and regulatory process for satellite servicing is complex and involves multiple federal agencies and international coordinating bodies. The FCC and FAA hold primary authority over the licensing process for launch, deployment, docking and telemetry, tracking, and control (TT&C). [50] The State Department and Department of Commerce are stakeholders in developing consistent satellite-servicing regulations.[51] The National Oceanographic and Atmospheric Administration (NOAA) is also involved in the licensing process for Earth observation satellites,[52] as any satellite with imagery capability requires a commercial remote-sensing license.

Since satellite-servicing is a relatively new industry, there is a lack of completely understood regulatory regime for in-orbit activity and services. Additional regulatory concerns, such as Non-Earth Imaging (NEI) licensing by NOAA and debris management by FCC are driving on-orbit servicing behavior. On April 2nd, 2020, the FCC issued, and later adopted, several new rules on orbital debris (Mitigation of Orbital Debris in the new Space Age).[53][54] These regulations will have implications on the satellite industry at scale, including servicing and debris mitigation industries

As noted by Space Policy Directive-2, there remains a need to create a 'one-stop shop' for licensing. Attendees from STPI OSAM Roundtable agreed the licensing process should emphasize "efficiency, affordability, and transparency."[55] The licensing process should be designed to lower the barrier of entry to the industry and encourage non-traditional entities to pursue and develop OSAM technology.

Additionally, there is ongoing debate in the space community to modify the "25-year rule," a guideline that recommends satellites be placed in a graveyard orbit or reenter Earth's

[45] NASA, 2010 "On-Orbit Satellite Servicing Study"
[46] Foust, 2018 "House passes commercial space regulatory bill" https://spacenews.com/house-passes-commercial-space-regulatory-bill/
[47] H.R.2809 - 115th Congress (2017-2018): American Space Commerce Free Enterprise Act." *Congress.gov*, 25 Apr. 2018
[48] "NASA Authorization Act of 2019" (S. 2800.) 2019.
[49] Report: Commerce, Justice, Science, and Related Agencies Appropriations Bill, 2020. (H.Rept. 116-101)
[50] Henry, 2017. "FCC begins approval" https://spacenews.com/fcc-begins-approval-of-orbital-atk-satellite-servicing-mission-for-intelsat-901/
[51] Foust, 2017 "Regulatory certainty for space applications" http://www.thespacereview.com/article/3385/1
[52] Foust, 2017 "Regulatory certainty for space applications"
[53] The FCC adopted a small subset of proposals and is in the process of seeking additional comments on other rules.
[54] FCC Fact Sheet. April 2020. "Mitigation of Orbital Debris in the New Space Age." *FCC*.
[55] Carioscia, Sara, Corbin, Benjamin, Lal, Bhavya. 2018. "Roundtable Proceedings: Ways Forward for On-Orbit Servicing, Assembly, and Manufacturing (OSAM) of Spacecrafts" *IDA*.

atmosphere within 25 years of the end of the satellite's operational life. The guideline is intended to mitigate post-mission space debris. Many agencies, such as the Department of Defense and commercial operators, want this mandatory deadline reduced since new deadlines would impact the commercial market for satellite servicing. [56]

Currently, the broad international frameworks that guide the development on-orbit servicing norms are the Outer Space Treaty of 1967 and the Space Liability Convention of 1972. CONFERS can set industry standards to be adopted worldwide. If these standards are adopted by other nations, this could give the United States benefits in setting the rule of the road and the dialogue for on-orbit servicing for years to come. CONFERS provided Recommended Design and Operational Practices[57] and also presented OOS Guiding Principles[58] to the UN at COPUOS. The ISO Standard[59] for best practices process development is currently underway.

Main Satellite-servicing Missions

On-Orbit Servicing, Assembly and Manufacturing mission 1 (OSAM-1), formerly Restore–L, is a NASA robotic spacecraft equipped with tools to test a suite of satellite servicing technologies for telerobotic, refueling, and satellite reposition to ultimately reduce the need for crewed servicing missions. Maxar Technologies is building the spacecraft bus and robotic arms for the mission.[60] One of the attached payloads is the Space Infrastructure Dexterous Robot (SPIDER), a robotic arm also built by Maxar.[61]

Robotic Refueling Mission 3 (RRM 3) is developed on the first two phases of robotic refueling technology from the International Space Station to demonstrate the transfer of cryogenic fluid in microgravity.[62]

Mission Extension Vehicle-1 (MEV-1) was launched in October 2019 and successfully rendezvoused and docked on February 25th with Intelsat-901 in a graveyard orbit 300 kilometers above the geostationary arc.[63] This was the first successful implementation of rendezvous and proximity operations between two commercial vehicles. The accomplishment is further underscored in that the target satellite was not designed to be serviceable in orbit.

Mission Robotic Vehicle (MRV) is the planned successor mission to the MEV, as part of the RSGS program. DARPA agreed to provide the RSGS robotic payload to fly on an MEV bus.
Maxar (SSL) previously won the contract[64] to build an orbiting satellite servicing vehicle. However, Maxar withdrew from the contract, citing financial reasons.[65] SpaceLogistics replaced Maxar as DARPA's new partner for the RSGS program, following MEV-1's success. [66]

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[56] Hitchens, Theresa. 2019. "US Tightens Space Debris Standards; Keeps 25-Year Cap." *Breaking Defense*.
[57] CONFERS. Feb. 2019. "CONFERS Recommended Design and Operational Practices"
[58] CONFERS. 2018. "Guiding Principles for Commercial Rendezvous and Proximity Operations (RPO) and On-Orbit Servicing (OOS)."
[59] "ICS 49.140. Space Systems and operations." ISO.
[60] Harbaugh, "Satellite Servicing TDM Project Overview." NASA, 2018.
[61] SSL, "Robotics Servicing" https://www.sslmda.com/html/robotics_servicing.php
[62] Harbaugh, "Satellite Servicing TDM Project Overview." NASA, 2018.
[63] Henry, Caleb. "Northrop Grumman's MEV-1 Servicer Docks with Intelsat Satellite." *SpaceNews.com*, 26 Feb. 2020
[64] Spacenews, "DARPA picks SSL" 2017.
[65] Erwin, Sandra. "Maxar's Exit from DARPA Satellite Servicing Program a Cautionary Tale." *SpaceNews.com*, 2019.
[66] "Space Logistics Gets DARPA RSGS Contract." *Spacepolicyonline*,

Challenges and Opportunities

Given the ability to cheaply built and launch newer and more advanced satellites, many operators are hesitant to pay for satellite servicing if a satellite has already exceeded its 10-12 year lifespan.[67] This problem was also highlighted in the 2010 NASA Satellite Servicing Study that emphasized there is a lack of mechanisms to measure the rate of return for satellite servicing missions. Governments and commercial firms are currently undertaking market research to validate the refueling business case. Several forms have also proposed pre-positioned orbit fuel depots. However, thus far, the business case for satellite refueling failed commercially and remains under question. The business model to generate profit from on-orbit assembly or manufacturing is also uncertain in the short-term and long-term.

The STPI OSAM Roundtable outlined there is no commercial market for science missions but there could be a market to service government science assets.[68] Maxar's withdrawal from the RSGS program is viewed that on-orbit servicing is yet to be suitable for the commercial market.[69] There are additional concerns that the government and agencies are not responding as quickly to technological changes, which is a disadvantage in policy compared to that of adversaries.[70]

Technological challenges continue to include size limitations for docking and a lack of large-scale data available for training artificial intelligence that would enable full autonomy in future missions.

Despite these concerns, there are many achievements and ongoing projects in the satellite servicing industry. At Satellite 2020, panelists from SpaceLogistics and Orbit Fab discussed how refueling can enable new business models for the LEO market while geosynchronous orbit is more cost effective, as many saw MEV-1's docking a turning point for the industry. After MEV-1's successful docking, SpaceLogistics is launching MEV-2 later this year to dock with and extend the life of another Intelsat Communications Satellite.

Additionally, SpaceLogistics has partnered with DARPA's on RSGS, providing the launch, bus vehicle, integration, and operations to create the MRV for flight demonstrations with government satellites before releasing to the commercial market. In 2018, SES and Intelsat demonstrated interests in purchasing satellites with payloads that can be upgraded every five years, fitting some industry projections that payloads are becoming more standardized. SSL also discussed that satellites are projected to have more standardized payloads, which could further facilitate the growth of the satellite servicing industry.[71]

Conclusion

There are many challenges and opportunities for on-orbit servicing. While companies continue to develop technologies and demonstrate a viable market for on-orbit servicing, they cannot fully

[67] Holmes, 2011 "Satellite servicing" https://www.satellitetoday.com/innovation/2018/01/18/satellite-servicing-coming-orbital-location-near-you/
[68] Carioscia, Sara, Corbin, Benjamin, Lal, Bhavya. 2018. "Roundtable Proceedings: Ways Forward for On-Orbit Servicing, Assembly, and Manufacturing (OSAM) of Spacecrafts" *IDA*.
[69] Davis, Joshua, Mayberry, John & co. 2019. "On-Orbit Servicing: Inspection, Repair, Refuel, Upgrade, and Assembly of Satellites in Space." *The Aerospace Corporation.*
[70] Carioscia, Sara, Corbin, Benjamin, Lal, Bhavya. 2018.
[71] Russell, 2018 "Why the Market is ready" https://www.satellitetoday.com/innovation/2018/02/13/market-ready-orbit-satellite-servicing/

achieve their goals without demand, funding, standards, or regulatory support by the government. If the business case for on-orbit servicing is proven and industry standards are set, this technology can be a crucial stepping stone to achieve national strategic plans, such as Artemis' goals on time, enable a new space economy, enhance national security and international space cooperation, and increase access to a more sustainable space environment.

Frequently Used Acronyms

CCSDS – Consultative Committee for Space Data Systems
CLPS – Commercial Lunar Payload Services
CONFERS–Consortium for Execution of Rendezvous and Servicing Operations
DARPA – Defense Advanced Research Projects Agency
FCC – Federal Communications Commission
ISO – International Organization for Standardization
JSC – NASA Johnson Space Center
LaRC - NASA Langley Research Center
LEO – Low Earth Orbit
LOP-G – Lunar Orbital Platform - Gateway
MDA – MacDonald, Dettwiler, and Associates Ltd.,
MEV – Mission Extension Vehicle
MRV – Mission Robotic Vehicle
MEP – Mission Extension Pods
NOAA – National Oceanic and Atmospheric Administration
OOS – On-orbit servicing
OSAM – On-orbit Servicing, Assembly, Manufacturing
RRM – Robotic Refueling Mission
RPOD – Rendezvous, Proximity Operations and Docking
RSGS – Robotic Servicing of Geosynchronous Satellites
USG – United States Government
SIS - Space Infrastructure Services, LLC.
SSL – Space Systems Loral, LLC.
SPIDER – Space Infrastructure Dexterous Robot
SSPD – Satellite Services Projects Division

Appendices

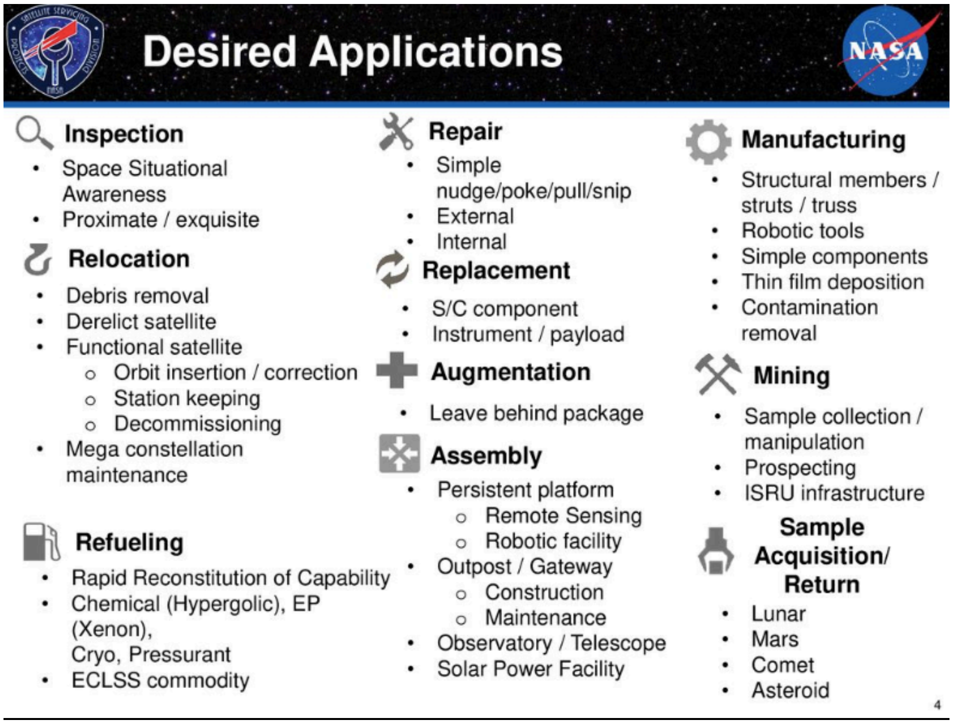

Figure 1 Source: McLaughlin, Russell. 2019.

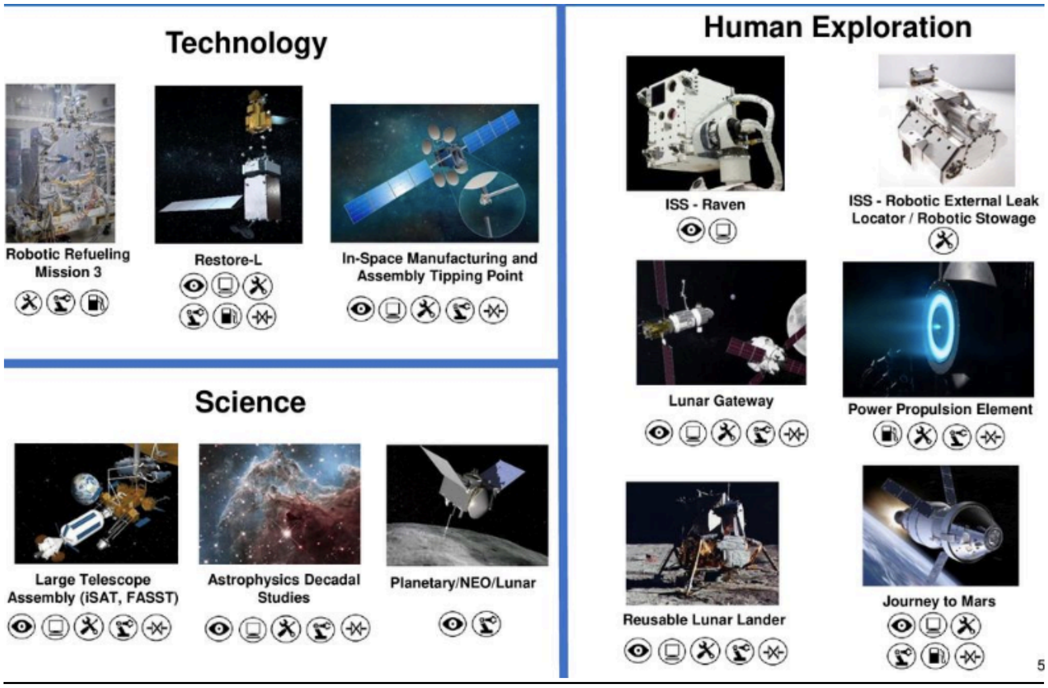

Figure 2 Source: McLaughlin, Russell. 2019.

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NOTES

The purpose of the Space Foundation's Washington, D.C., Strategic Operations is to engage with government, industry, academia, and the international space community, to advance the Space Foundation's mission and establish an environment for constructive space policy dialogue.

The Washington Strategic Operations Team conducts a broad range of programs to:

- Broaden Understanding and Develop Advocacy for the Space Foundation's Mission and Vision;
- Educate and Inform on key space and STEM related issues, policy, and legislation impacting the space community and our members;
- Develop and Maintain Relationships with key stakeholders across the Washington, D.C., space community; and
- Identify Opportunities and Initiatives to advance space related issues on behalf of the global space community.

The Space Foundation also supports its customers by providing timely reports that analyze pending legislation, as well as congressional hearings that relate to and impact all sectors of the space industry.

The Space Foundation's Washington, D.C., Strategic Operations team includes:

- Thomas Dorame, Vice President – Strategic Operations, Washington, D.C.
- Marchel Holle, Manager – Washington, D.C., Operations
- Hanh Nguyen Le, Government Affairs Associate – Washington, D.C., Operations