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COSMIC

CONSORTIUM FOR SPACE MOBILITY AND ISAM CAPABILITIES

COST AND VALUE MODELING METHODOLOGIES FOR ON-ORBIT SERVICING WORKSHOP REPORT

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1. Workshop Summary

1.1 Workshop Overview

On September 16 and 18, 2025, the Consortium for Space Mobility and ISAM Capabilities (COSMIC) held a workshop on the topic of Cost and Value Modeling Methodologies for On-orbit Servicing (OOS). Each 3-hour session brought together users and providers of OOS and other in-space servicing, assembly, and manufacturing (ISAM) capabilities and services, in addition to mission managers, technologists, and financiers from across the space enterprise. The workshop, hosted and planned by COSMIC's Missions & Ecosystems Focus Area, brought together experts within the OOS ecosystem to discuss the current methodologies being used to articulate the value and benefit OOS capabilities bring to the space ecosystem. The workshop was open to all members of the public and space community.

The motivation for this workshop came from the COSMIC Steering Committee, who expressed the need for a better understanding of not only the cost and value models employed by industry to help pitch their services, but also the methodology behind their models. Specifically, potential government users of servicing desire more consistent and robust techniques to describe servicing and the value it could provide to their spacecraft or architectures. In order to achieve the objective of bringing awareness to the cost and value modeling methodology shortcomings for OOS, COSMIC created an agenda focused on the need for modeling, theoretical frameworks, and client-focused cost and value modeling.

This report summarizes the briefings of the workshop, identifies common themes amongst the briefings, pinpoints gaps in both methodologies and the servicing ecosystem, and proposes next steps to close these gaps. While briefers did cover modeling methodologies, the workshop covered a broad swath of challenges for successful implementation of an on-orbit servicing ecosystem. As a result, this report includes both insights into cost- and value-modeling methods and challenges faced in the adoption of servicing as a routine part of space architectures.

1.2 The Need: Workshop Motivation

Refueling and Servicing: Maneuver Warfare and a Concept of Support in the Space Domain

How does USSF view the need for on-orbit servicing and refueling in the context of maneuver warfare?

- Speaker: Lt. Col. Alexander Jehle, United States Space Force (USSF) Assured Access to Space
- Presentation slides: [COSMIC Introductory Jehle 9 16 2025 Approved Public Release.pdf](#)

Lt. Col. Jehle drew parallels to terrestrial logistics and sustainment operations, emphasizing the importance of establishing a logistics enterprise in space to support sustained maneuver and operational flexibility. Key metrics important to value modeling include capability (number of combat satellites and number of sorties or missions each satellite can perform in their designed lifespan, when including refueling), capacity (the generation of each satellite), and readiness (how often operators practice performing their mission with the satellite). There is an understanding amongst USSF that the framework



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for logistics in space is still evolving, and that industry needs to perform services for other commercial and government satellites.

In-Space Servicing for Science Missions

How does NASA approach satellite lifecycles and how does the agency view the potential of on-orbit servicing?

- Speaker: Carolyn Mercer, NASA Science Mission Directorate (SMD)
- Presentation Slides: [COSMIC OOS Mercer Sept 2025 v2.pptx](#)

NASA’s goals for satellite lifecycles are much different than commercial or military satellites, as NASA often seeks to improve the state of the art with each new mission. As a result, it is rare for NASA to simply extend the life of a satellite through servicing, as new missions typically require different capabilities. They are in the business of technological advancements with a planned end of life for each mission. There is an opportunity for unplanned servicing, such as the current situation with the Swift Observatory, which is losing altitude faster than expected due to increased solar activity. NASA is building refueling capability into the Nancy Grace Roman Space Telescope and is planning for serviceability for the future Habitable Worlds Observatory, but overall NASA does not see a high volume of need for on-orbit servicing in the near term and therefore would not be a strong anchor tenant for the industry. Current studies hope to answer if any servicing or reboosting can be done at a cost that is significantly less than the cost and schedule of a new mission, and if there is any benefit to NASA in that type of life extension.

Perspectives on Commercial Client Value of OOS

How do commercial operators think about on-orbit servicing?

- Speaker: Joe Anderson, SpaceLogistics
- Presentation Slides: [Approved 25-1637 COSMIC Cost and Value Workshop.pdf](#)

This presentation identified different business models that commercial satellite operators have discussed regarding the value of on-orbit servicing, particularly for life extension. These include: deferring capital expenditures for like-for-like or growth replacements, strategic smoothing of capital expenditure profiles, capacity bridging for delayed replacements, repurposing satellites for new business roles, and capitalizing on end-of-life assets through sales or repurposing. There are many considerations that impact a commercial user’s decision to purchase repair services including the importance of timing, satellite age, revenue impact, and insurance. To be valuable, many servicing requirements should be met within days to months, not years. Commercial clients can also enhance capabilities through payload upgrades, but the business case depends on the associated costs for servicing. SpaceLogistics’ perspective is that while there is significant demand for life extension services at the right price point, the current challenge is a lack of supply in the market.



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1.3 The Research: Theoretical Frameworks

Quantifying the Value of Satellite Refueling and Reposition Using a Technology Maturation-Based Tradespace Approach

- Speaker: Dan Hastings, Massachusetts Institute of Technology (MIT),
- Presentation Slides: [CVMMW_Theoretical Framework_Dan Hastings.pptx](#)

The Technology Progression-Informed Tradespace Analysis (TPITA) method is a structured and quantitative approach to valuing client-servicer systems, accounting for the time-dependent nature of technology performance. By applying TPITA, this work determines the value of on-orbit refueling and repositioning for Earth imaging satellite owners and operators. TPITA utilizes the Advanced Technology Roadmap Architecture (ATRA) to develop a mathematical state-of-technology progression for space refueling and repositioning systems. A combination of Epoch Era Analysis (EEA), Multi-Attribute Tradespace Exploration (MATE), and a novel Benefit Metric are used to capture the relative cost-benefit of using refueling or repositioning throughout lifetime scenarios. This work culminates in the creation of stakeholder Look-up Charts (LuCs), which provide an aggregate community-wide view of the circumstances where on-orbit refueling and repositioning can provide value to client spacecraft. This is particularly useful for long-lifecycle systems where advancements can significantly impact system performance and value delivery. While it is comprehensive and highly informative, the TPITA technique is computationally intensive, technically demanding, and requires significant data collection, analysis, and stakeholder engagement.

Systems Design in the 3rd Space Age

- Speaker: Jon Arenberg, Northrop Grumman
- Presentation Slides: [COSMIC Design for Neo-Space Age A 091325.pptx](#)

The Neo-Space Age Design and Value Analysis Methodology is a heuristic framework designed around the philosophy that each Space Age is characterized by a distinct culture and design paradigm, and that each subsequent Space Age has been defined by the ability to directly solve the challenges faced in the previous Space Age. Space 3.0 (Neo-Space Age) is specifically aimed at directly solving the challenges faced in Space 2.0 of flexibility, cost, and risk through the integration of new technologies and design philosophies. This heuristic framework provides 12 distinct Space 2.0 challenges and six Space 3.0 toolboxes that can be systematically mapped to identify potential value creation pathways. The methodology emphasizes the importance of understanding how these technologies can create value through scope avoidance, operational efficiency gains, and programmatic risk mitigation. By using these toolboxes to directly address the challenges faced in Space 2.0, the methodology provides an approach for analyzing technology trends over time and determining whether capability enhancements of specific missions can be leveraged to create quantifiable value.



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1.4 Modeling Servicing: Modeling the Client-Focused Value of On-orbit Servicing

United States Space Command Perspectives on On-Orbit Servicing

- Speaker: Mr. Tom Lockhart, United States Space Command J8 (USSPACECOM/J8)
- Presentation Slides: [\(U\)COSMIC Brief \(SPACECOM J8\).pptx](#)

One of the priorities in the FY27 USSPACECOM Integrated Priorities List is Sustained Space Operations and Maneuver, which is generally viewed as being enabled by commercially provided upgrade, repair, and refueling services with the USSF as the end user. Open standards and modularity are viewed as being key enablers of these capabilities. Current trades show that these servicing capabilities are more valuable when applied to exquisite expensive assets in geosynchronous Earth orbit (GEO) rather than proliferated low Earth orbit (LEO) constellations, as LEO satellites tend to have quicker technology turnaround time, which favors a replacement architecture. The Department of War (DOW) is looking to continue to fund some development of servicing capabilities, but they intend to heavily leverage the commercial sector’s private investment to achieve their objectives. Creating accurate cost estimates for those potential servicing capabilities is critical to understanding if servicing is achievable within budget constraints.

Serviceability for NASA’s Habitable Worlds Observatory (HWO) - A Look at Cost Impacts and Value/Benefits

- Speaker: Julie Van Campen, NASA HWO Project Office, Servicing Lead
- Presentation Slides: [COSMIC HWO Servicing Value Decisions Sept 2025 update.pptx](#)

Servicing an in-space observatory has the potential to increase scientific return; for HWO, this scientific return could result from an increased number of observations of potential Earth-like planets to look for signatures of possible life, or it could result from an increase in the data quality or type of data collected over the mission. Planned servicing for a flagship mission may allow for a shorter timeline to launch via pushing the riskiest and longest-lead time instrument technology developments into a planned servicing mission. However, the technical-risk-cost parameters that impact a new vision of designing serviceable missions is not yet part of a NASA standard mission architecture or programmatic design. It is important to understand how NASA conceives, funds and implements a mission to determine the “value proposition” of the serviceability of that mission, because “more” is not always “more valuable.” At this time, the serving vehicle and robotic systems needed to service the conceptual designs for HWO, even though technically feasible, do not currently exist for the Sun-Earth L2 orbit or for instruments of the size planned for HWO. NASA is designing HWO for serviceability and is anticipating that synergistic efforts in the space ecosystem will help to determine the optimal servicing approach with a future commercial provider. NASA is currently exploring how trades will be done for what is serviceable and how servicing will fit into the programmatic mission confines.

Introduction to REVIVE – ISAM Lifecycle Value Modeling

- Speaker: Alex Ulin, The Aerospace Corporation



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- Presentation Slides: [REVIVE Brief - COSMIC 2025.pptx](#)

The Responsive Evolvable ISAM Value Estimator (REVIVE) tool assesses the value added to a client architecture for implementing servicing and informs users when it makes sense to implement servicing based on the value and cost added. REVIVE uses parametric inputs including trigger-based thresholds that determine when a refuel or upgrade service is performed, along with tunable knobs that allow for different mission cases such as servicing lead times, servicing blackout periods, and on-orbit degradation. The REVIVE team completed a Design for Serviceability Survey to better determine the costs to implement a servicing architecture. The relative cost of a prepared versus an unprepared client is one of the inputs into the cost breakdown analysis used to determine whether or not to integrate a service into an architecture. In general, when applying the REVIVE tool to real-world cases for clients, the team has found that a single spacecraft-single refueler architecture is expensive to implement and is only economically viable in special cases. The business case is much more likely to close when there are multiple spacecraft being serviced because it reduces the recurring cost for any given service. Ultimately the REVIVE tool can be used to show a client the value that can be achieved via on-orbit servicing and the price at which servicing buys its way into an architecture. This information could help inform a potential service provider the service price to work towards.

1.5 Modeling Spacecraft: Modeling the Cost to Client Spacecraft

NASA ISAM Cost Estimation Framework (NICEF) - Advancing ISAM Readiness at NASA

- Speaker: Tammy Brown, NASA
- Presentation Slides: [NICEF Presentation to COSMIC Cost and Value Workshop Sept 2025 FINAL Sept 18.pptx](#)

NICEF's goal is to decompose ISAM into elements that can be incorporated into NASA's cost models and frameworks. However, due to the nascent nature of ISAM, the community of cost modelers are not familiar enough with the set of capabilities to create consistent analyses and results. Investment-Benefit Maps have been developed by NICEF's core team to capture architecture-level assumptions for mission formulation, build consensus at the agency on ISAM benefits, and enable the expansion of ISAM providers. The process of creating the Investment-Benefit Maps will identify gaps in ISAM Investments that cannot currently being estimated by an existing cost model. New investments that enable a novel ISAM use case may provide overlapping benefits to the entire ISAM enterprise while enhancing the understanding of ISAM at NASA. This information helps identify which cost elements can be estimated and creates community consensus around methodologies for each nascent cost element, which in turn helps drive mission decisions in a growing ISAM ecosystem.

Cost & Value Modelling of On-Orbit Servicing - The Cost of Unprepared Client Spacecraft

- Speaker: Joe Chan, SES
- Presentation Slides: [Cost & Value Modelling of On-Orbit Servicing Final.pptx](#)



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Life extension services provide commercial GEO communication satellite operators the opportunity to save capital expenditures (CapEx) and avoid the costs associated with replacing a satellite in an uncertain business environment. This allows for a less risky business model and consistent revenue stream for the business; however, risk is assumed when deciding to move forward with a service due to the cost of collecting sufficiently detailed data about the client satellite. Moreover, when planning a service, a client must work with the satellite bus manufacturer to provide design materials and support verification and validation, which can prove difficult if the client spacecraft was launched years or decade earlier. Joint operation preparations are necessary between the client and the servicer which accrues mission cost and must be included in a cost estimate, along with the insurance cost that is rolled up in the cost of the service. Ultimately the client, the manufacturer of the client bus, and the service provider need to have clear lines of communication to solve real-time problems, and the client must update their organizational procedures as lessons are learned.

2. Common Themes Across Presentations

2.1 Two Tradespaces: Life Extension Services and Upgrade Services

Amongst the presentations, there was a focus on two types of services: extending a satellite’s lifespan via life-extension servicing capabilities and improving or maintaining satellite capability via upgrade and replacement of system or component services. The life-extension service was generally described with more concrete metrics, while the upgrade case contained much more modeling uncertainty. A common methodology for determining whether or not a life-extension servicing architecture should be adopted is to perform a trade space analysis that compares an architecture with and without life extension services. Given the primary metrics of revenue generation of the satellite, the satellite lifetime, and the cost of replacing the satellite, cost models help to determine whether or not a satellite should have its life extended via servicing capabilities or be replaced with a new vehicle. The upgrade case analysis was shrouded with more uncertainty and contained less metrics for evaluation, most likely due to the complexity of the tradespace analysis. Of the briefings that detailed both types of services, the focus was primarily on services in GEO due to the higher projections of customer demand.

2.2 Servicing as a Risk Reduction

On-orbit satellite services range from simple and straightforward to highly complex. While the capability is still in the early stages of developing into an on-orbit ecosystem, satellite servicing can be recognized as a risk-reduction mechanism. To start, satellite servicing capabilities are not new and have been performed and demonstrated on-orbit multiple times in the past, including the Hubble Space Telescope Servicing Missions, the construction of the International Space Station, and the present-day Mission Extension Vehicles. While new technologies still need to be developed to the appropriate level of technology maturity to mitigate mission risk, satellite servicing opens up risk-reduction activities due to its nature of reducing single points of failure, providing backup options for mission continuation, and



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allowing for quicker anomaly correction than replacement options. Examples from the presentations include choosing to service a malfunctioning satellite rather than replacing it via a launch and deployment, refueling to make up for unexpected propellant burns, de-coupling an instrument’s development from the project schedule to later install via servicing, and developing less-redundant and higher-risk systems that are repairable. Each of these risk-reduction activities impacts mission cost and can be incorporated into a satellite servicing cost and value model.

2.3 Reliance on Infrastructure and a High Client: Servicer Ratio

Presenters consistently identified the need for space-based logistics infrastructure comprising multiple ISAM elements to close business and value models. These elements may involve depots stationed in varying orbits or a transportation network that serves multiple clients and space vehicles. This infrastructure does not currently exist, so mission planners must project future operational capability in the ecosystem and build that uncertainty into their cost models. This makes cost modeling for missions that require servicing incredibly difficult, with wider ranges of cost uncertainty than mission planners would like to have. Additionally, presenters pointed out that for many use cases to close, the client-spacecraft-to-servicer-spacecraft ratio needs to be higher than one, so clients pay for the recurring costs of their servicing operation and not the entire cost of the logistics infrastructure. For some servicing customers, this dependency requires fundamental changes to their architectures and systems that is not feasible in the near term. For long-term viability, these cases would require enterprise-level collaboration and coordination to leverage an ISAM services network that works for single clients, but such an architecture has multiple elements which all come with their own uncertainty in modeling cost, complexity, and risk.

2.4 The Demand Signal Will Come: Leveraging Industry’s Developments

Multiple speakers from the government side expressed the need for commercial servicing providers to continue the progress they have made in developing their systems and concepts, as these capabilities may benefit future government customers. The industry’s investments and collaborations independent of government funding – including inter-industry partnerships and missions – will help establish a robust ISAM capability that the government can then buy and leverage to achieve their objectives. This is an important step which industry can take toward the development of an ISAM ecosystem while the government refines its future goals and identifies how ISAM can help achieve them. In doing so, industry stakeholders should increase the fidelity and accuracy of their cost models and pricing structures as they develop their technology and as the government creates more ISAM funding opportunities, which further strengthens the demand signal.



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3. Gaps Identified and Actionable Next Steps

3.1 What Do Satellite Operators Value?

Gap: A common phrase used amongst the COSMIC community is, “Value is in the eye of the beholder.” What this means is that the various members of the space community from industry, government, and academia value certain attributes of a mission architecture over others depending upon their goals, mission needs, and constraints. Value can come in many different forms – some of which are easier to quantify than others. Given the presentations at the workshop, USSF and USSPACECOM value on-orbit mobility and mission utility, NASA values scientific return, and both commercial satellite operators and commercial service providers value revenue generation. However, these values are inferred and not exhaustive. Additionally, there are many other satellite operators outside of these mentioned stakeholders. Without understanding exactly what various customer organizations value, servicing providers can not accurately pitch their ideas and services using cost and value models that align to their potential customer desires.

Next Step: To better understand what satellite operators value, a systematic survey of the satellite operator community could be conducted. The information obtained from this survey would help inform COSMIC members that identify as service providers to further improve their cost and value models and corresponding methodologies. This improved understanding of end-user goals and values could also help inform future COSMIC products intended to promote and enable the creation of a future servicing ecosystem. To create a successful survey, a team from COSMIC would need to precisely identify the specific information to be collected by the survey and then construct questions that obtain that desired information.

3.2 Servicing Effect Definitions Beyond Life Extension

Gap: The cost and value modeling methodologies presented at the workshop revolved around a common metric of dollars. Commercial satellite revenue generation as a function of orbital lifetime, the dollar cost to refuel, and the dollar cost to replace a spacecraft are extremely helpful when examining the tradeoff between life extension and satellite replacement. However, servicing use cases enable other on-orbit effects, such as capability upgrade or maintenance via instrument and component swap out, enhanced maneuverability via refueling, risk reduction via orbital debris removal services, investigative analysis via inspection for failure assessment, and many others. This servicing end-user variety necessitates the development of tailored cost-benefit analyses that accurately reflect the specific value propositions for this diverse set of stakeholders. A clear gap exists in the definition of these effects hindering the applicability of cost and value models to many end users with goals other than life extension.

Next Step: Further defining relationships like technological obsolescence as a function of time, on-orbit flexibility, mission utility, and other on-orbit performance characteristics is critical to developing cost and value modeling methodologies that are applicable to users of OOS beyond life extension. System characteristics such as upgradability and serviceability could also be better defined, potentially in relation



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to modularity, to help determine the complexity of a service and improve accuracy of cost and value models. Discrete metrics that form the foundation of these relationships and on-orbit effects should be further identified and studied. This effort should involve input from all stakeholder groups to ensure that the definitions and metrics are inclusive and representative of the diverse perspectives within the community. These definitions should then be integrated into cost-benefit analysis frameworks and decision-making processes to ensure consistent evaluation of servicing architectures.

Next Step: The continued integration and expansion of modeling tools to include additional ISAM use cases such as component swap out may increase the applicability to additional end users. Socializing these tools within the broader space community, aiming for eventually broader access beyond proprietary confines, may stimulate common best practices in ISAM analysis. Efforts could be made to validate and enhance these tools through pilot projects, case studies, and real-world demonstrations to ensure their accuracy and relevance to the broader community.

3.3 Servicer Client Mismatch

Gap: A key challenge for both service providers and potential clients is the mismatch between the demand timeframes for services and the development and deployment timelines of service providers. Providers cannot commit to positioning assets until they have a clear demand signal from clients, and clients are not willing to commit until they see the assets in place that are capable of servicing them within a specific timeframe. Service providers bear all risk with clients not committing to services until they are needed, which creates uncertainty in the service provider’s business model. This is not typical in domains where services are procured well in advance of need, allowing providers to plan and allocate resources effectively.

Next Step: Address the lack of education on the servicer-client mismatch by creating workshops and other materials explaining how different industries (e.g., construction, aircraft leasing, telecommunications infrastructure, cloud Software as a Service) reduce uncertainty and risk in their cost models by securing long-term commitments from clients.

- Create case studies highlighting how different industries manage lead time and secure long-term commitments from clients to reduce risk and uncertainty. These case studies can serve as examples for both service providers and potential clients in the on-orbit servicing market.
- Highlight innovative contracting strategies used in other industries to secure long-term commitments from clients. This can include advance purchase agreements, milestone payments, and blended public-private finance models that help mitigate risk for service providers.

3.4 The Lack of Historical Data

Gap: One of the problems with building cost and value models for on-orbit servicing is the lack of historical data from previous missions that makes the risk modeling and cost estimation difficult. While there have been several on-orbit servicing missions in the past, such as DARPA’s Orbital Express and



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NASA's Hubble Space Telescope Servicing Missions, there is a lack of publicly available and centralized location for cost data from these missions. This makes it difficult to build accurate cost models for future servicing missions, as there is no baseline data to reference. Additionally, the lack of historical data makes it difficult to validate the assumptions and methodologies used in cost and value modeling.

Next Step: COSMIC should consider collecting and disseminating cost data from previous on-orbit servicing missions for members who want to build a database of historical costs. This database can be used to inform future cost and value models, as well as validate the assumptions and methodologies used in these models.

3.5 OOS is not a Common Mission Consideration

Gap: Since on-orbit servicing is not routine in the space enterprise, it is not a frequent consideration of space mission architects. Past servicing missions, the current attention to servicing by the media, the few modern servicing missions, and planned servicing demos have helped garner enough attention to give the servicing ecosystem some new momentum. However, the knowledge based on OOS is still small compared to other aspects of space mission design and space business. This knowledge gap slows full-scale industry growth and limits the future workforce from tapping into this new domain.

Next Step: Developing college and professional training on OOS will enable the current and future workforce to consider servicing options for future space missions. Options could include:

- Update existing systems engineering references to address OOS, including how to decide on cost/value of incorporating OOS into a program or not. Currently, professionals lack standard resources to help them address the costs and benefits of ISAM suitable to use in trade studies. Updates with OOS considerations should be made to the following:
 - AIAA G-042, Guide to Design for On-Orbit Satellite Servicing (current draft 1992)
 - Space Mission Engineering: The New SMAD
 - NASA SE Handbook, NASA SP-2016-6105 Rev2
 - INCOSE Systems Engineering Handbook: A Guide for System Life Cycle Processes and Activities, 5th Edition
- Perform a targeted distribution and promotion of the existing tools and resources on OOS, including:
 - MSFC-HDBK-3074, Selection Methodology for Orbital Replaceable Units (2002)
 - On-Orbit Satellite Servicing Study Project Report (October 2010)
 - ISO 24330, Space Systems — Rendezvous and Proximity Operations (RPO) and On Orbit Servicing (OOS) — Programmatic principles and practices



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- Develop additional training and education materials leveraging the COSMIC community, including:
 - COSMIC seminars on how to make satellites serviceable and how to provide servicing
 - COSMIC education documents to better develop an OOS knowledge base amongst the space community
- Develop a series of studies that draw analogies between terrestrial logistics and in-space logistics, such as the development of the transcontinental railroad. Additional studies could detail analogies between enterprise-level changes that have occurred in other industries and the current space industry and servicing ecosystem.
- Develop standardized text(s) for Statements of Work and WBS dictionaries for activities associated with RPO and OOS.

