PROCESSES AND METHODS USED FOR NASA COMMUNICATIONS SERVICES PROJECT CONCEPTUALIZATION AND FORMULATION

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Abstract

The U.S. National Aeronautics and Space Administration (NASA) is partnering with the commercial SATCOM industry to demonstrate the industry's capabilities to provide services to NASA's near-Earth missions. Leveraging commercial capabilities will become increasingly necessary for NASA, as its incumbent Government-owned-and-operated near-Earth satellite network, the Tracking and Data Relay Satellite System (TDRSS), will approach retirement towards the end of the current decade.

NASA is actively taking the first steps to making the vision of using commercial SATCOM a reality. For more than two years, NASA's Communication Services Project (CSP) has been evaluating the feasibility of employing commercial satellite communication (SATCOM) networks for near-Earth operations. This past April, CSP awarded US$278.5 million in Funded Space Act Agreements to select commercial SATCOM providers, so they may begin developing and demonstrating their specific near-Earth space communication services that may support future agency missions.

Each company will match or exceed agency contributions during the five-year development and demonstration period, totaling more than $1.5 billion of cost-share investment. The companies will complete technology development and in-space demonstrations by 2025, after which NASA intends to seek multiple long-term contracts to acquire these kinds of services.

The six companies (Inmarsat Government Inc., Kuiper Government Solutions (KGS), SES Government Solutions, Space Exploration Technologies (SpaceX), Telesat U.S. Services and Viasat Inc.) will shortly begin developing and demonstrating their capabilities to provide services, ranging from launch to standard on-orbit operations. The demonstrations will be across multiple spectrum regimes from L-Band to optical, and will utilize Geostationary Orbit (GEO), Medium-Earth Orbit (MEO) and Low-Earth Orbit (LEO) constellations.

This paper discusses methodologies and processes used over the past two years to reach the point of entering into these partnerships. It also includes CSP's goals and objectives going forward, following the award of six Funded Space Act Agreements to commercial SATCOM providers to develop and demonstrate these capabilities.

Introduction

The Communications Services Project (CSP) represents a potential sea change in the way future NASA missions will utilize satellite communication to send commands and receive scientific data to, from and within near-Earth space. This undertaking is necessary because the existing Government-owned and operated TDRSS, a reliable NASA resource for the past three decades, will reach end of viability in the early 2030s, and will not be replaced. The large amount of commercial SATCOM services now offered, simply not available when TDRSS was developed, provide an alternative to Government-owned and operated systems, with improved performance and at lower costs.

To that end, CSP has established multiple partnerships between NASA and commercial SATCOM companies to develop and demonstrate capabilities that can allow future NASA missions to

acquire and deploy flight-qualified capabilities. A capability demonstration is required because NASA cannot currently procure commercial SATCOM services for its missions. Many U.S. companies have the capability to develop reliable, qualified space communication systems. However, adjustments are needed to adapt terrestrial services to space-based customers. No technology breakthroughs are required, and demonstrations do not push the state-of-the-art. The chosen demonstrations are needed to prove end-to-end operational capabilities.

Indeed, CSP's goal is to spur new commercial SATCOM service markets where NASA is one of many customers. Government and commercial demand for SATCOM services exists currently and represents a market with substantial growth potential. The NASA funding is an incentive to bridge the gap and to attract the private capital needed to offer these services commercially. CSP will bolster American industry; reduce costs to NASA; and maximize interoperability between Government and commercial SATCOM providers while promoting a diverse and growing market.

The NASA Glenn Research Center (GRC) in Cleveland, Ohio was strategically chosen to lead and formulate CSP. GRC has a long history of success working with the commercial sector on SATCOM dating back to the 1960's, to advance and demonstrate commercial space communications technology. GRC's public-private partnerships (PPPs) paved the way for current SATCOM markets in broadcasting, broadband, Direct TV and software-defined radios. Many of these initiatives led the way for CSP's formulation, most notably:

- Management and development of the Advanced Communications Technology Satellite (ACTS); the first high-speed, all-digital communications satellite – demonstrated transformational capability that was subsequently adopted by the commercial satellite communications industry (1993-2000)
- The SCaN Testbed on the International Space Station (ISS) (2012-2019)
- SATCOM architecture studies (2013 – present)
- Microwave and optical communications technology and standards development
- Radio Frequency Spectrum Management

CSP 3 Phase strategy

NASA's move to commercial SATCOM services is a major undertaking that took years of investigation and scoping. The ongoing journey involves multiple methodologies and inputs that are explained in this paper. These steps may offer some guidance to others within NASA and other Government agencies who are tasked with similar initiatives that involve considerable change. CSP formulation was based on U.S. National Space Policy; guided by lessons learned from Commercial Orbital Transportation System (COTS) and Commercial Crew Programs; and informed by extensive market research and industry engagement since 2013.

CSP is being executed under a 3-phase strategy:

- **Phase 1** (complete). CSP identified, characterized, and quantified NASA's future SATCOM needs. CSP identified future missions needing commercial communication services separated into suitable mission classes. Goals and requirements were developed for end-to-end service demonstrations that will prove the viability of the services. CSP also had extensive engagements with industry to understand their interests and capabilities.

- **Phase 2** (active). CSP is conducting Commercial Capability Development and Demonstrations (CDDs) through established partnerships with six commercial SATCOM companies. CSP will validate the performance of the demonstrations for suitability as useful services. Concurrently, CSP will work with NASA missions to build confidence in commercial capabilities and identify the future services required. CSP will conduct an analysis of alternatives (AoA) to determine the most effective approach to transition NASA missions to commercial services by FY 2030 or sooner. Data from the CDDs and AoA will be provided to mission stakeholders and inform development of an acquisition strategy and transition plan.

- **Phase 3** (future). NASA plans to acquire commercial SATCOM services from multiple providers. Procurement of services will be through long-term contracts and traditional procurements. Phase 3

includes supporting an integrated approach for mission communication systems and enterprise management (scheduling and data delivery).

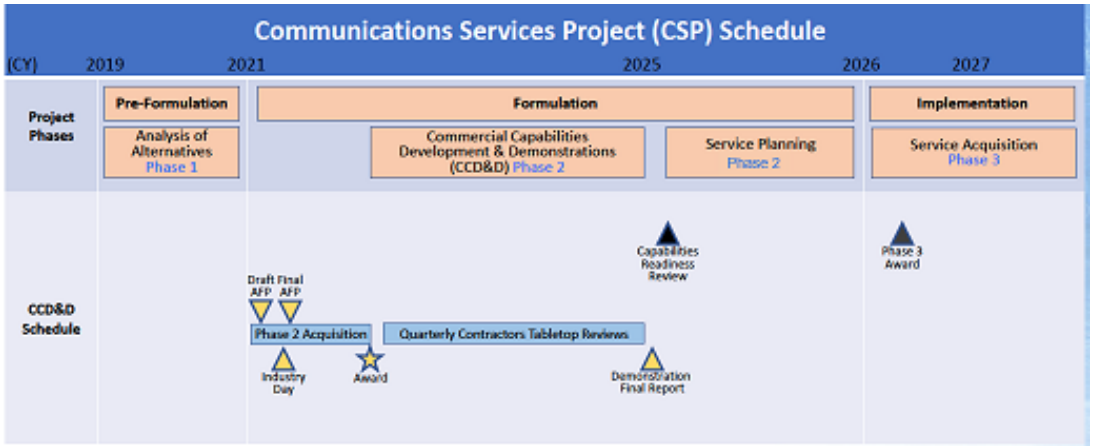

Figure 1. Communications Services Project Schedule

CSP Formulation/Phase 1 Studies

CSP synthesized data obtained from extensive Architecture Studies (spanning a seven-year period), industry engagement and mission engagement. The Space Communication and Navigation (SCaN) program's Architecture Studies have investigated numerous alternatives to replace TDRSS – including commercial services, hosted payloads, and more. SCaN conducted market research to gain better understanding of both capability and industry viewpoints on responding to NASA requirements near- and long-term. Based on this extensive research, CSP determined that capability demonstrations extensible for a class of missions were a necessary step to create options for acquiring future services.

- The Next Generation Space-Based Relay Communication and Navigation Architecture RFI. (2013). Responses to a Request for Information were required to include current/future communications and navigation approaches, innovative business models/partnerships, potential cost savings, innovative spacecraft communications, navigation technologies and systems, space internetworking, and more.

- The Space Based Relay Study (SBRS) (2014). The purpose of this study was to identify future space-based relay communication and navigation architectures that will support NASA missions in the 2022 and beyond timeframe. The study included both technological and acquisition scenarios, including use of commercial services, hosted payloads, services distributed among swarms of smaller satellites, etc. Other areas of interest included interoperability with other US civil Government, commercial, and international relay assets.

- The Earth Regimes Network Evolution Study (ERNESt) (2015-16). The purpose of this study was to create a next generation near-Earth space communications and navigation architecture for 2025+ which focused on the Space Network (SN) and Near-Earth Network (NEN) services to near-Earth Regime Users.

- The Next Generation Relay Architecture Study (2016). The purpose of this study was to 1) obtain industry input for NASA future architecture, 2) define the role of space relay capabilities for Earth and Mars networks, 3) provide rationale for architecture, and 4) identify long-lead, high-cost procurements necessary for the next generation architecture.

- A Commercial Relay Services Assessment (2017). This study was undertaken to evaluate the near-term and long-term feasibility of commercial service providers to meet the space data link requirements for SCaN NASA user missions. NASA GRC provided representative current and future use cases to be used for the evaluation, which included 1) Telemetry, Tracking and Command (TT&C) Return Data, 2) Science/ Human Space Flight (HSF) Return Data, 3) TT&C Forward Data, 4) Science/HSF Forward Data, and 5) Launch Vehicle Return Data.

- The Optical Relay for Future NASA Geosynchronous Orbiting Satellite for High Data Rate Links to NASA Use Missions study (2018). This study describes the needs, drivers, and the associated challenges for the Next Generation Optical Relay Pathfinder to be capable of connecting multiple LEO and GEO satellites at high data rates. It details the Concept of Operations (ConOps) and system architecture, including satellite configurations considered, their attributes and limitations, and the size of the satellite needed for each configuration. It provides a summary of the Next Generation Optical Relay Pathfinder satellite design trades and key elements. Finally, it presents the path needed for implementation and operations.

- The How Public-Private Partnerships Enable NASA Future Space Communication Needs study (2018). This study describes the NASA Next Generation Architecture, ConOps, and characteristics; discusses the rationale of PPPs to achieve that architecture; and summarizes the preliminary analysis performed to date and describes the path forward.

- The Broad Agency Announcement (BAA) (2018-2019) engaged industry in understanding viability of commercial services – both RF and optical – and sought industry input on partnership, investment and demonstration concepts. The NextSTEP BAA Space Relay Partnership and Services Study (2019) established PPPs with U.S. commercial entities to support the evolution of its existing network infrastructure into an interoperable, extensible space communications and navigation network. This study synthesized, analyzed, and evaluated BAA industry participant reports for their ability and approach to provide services to NASA utilizing RF and optical relay satellites. The BAA study concluded that significant industry capability exists, but commercial services are not yet ready to meet the full breadth of NASA use cases.

- Focused CSP studies (2020) involved Commercial Networks, USAF SMC AoA, User Projections and CSP Architecture/Concept. CSP operational and capability DoDAF diagrams were developed. OV-1: high-level operational concept graphic and OV-2: operational resource flow description. Capability viewpoint including CV-1: vision, CV-2: capability taxonomy, and CV-4: capability dependencies. CSP created a Future Missions Data Set and Commercial Network Data Set. CSP also collected and summarized industry spectrum and bandwidth data for uplink from LEO platforms to commercial relay networks. CSP further developed a DoD Commercial Services Report.

Since the 2016 industry studies, GRC had a consistent industry engagement strategy with multiple touch points for commercial SATCOM services. CSP's direct engagement in FY 2020 was highlighted at a number of events: formal external introduction of CSP was presented by Phil McAlister at the Ka-Band/ICSSC conference in October 2019; Mr. McAlister introduced CSP in an address to the Washington Space Business Roundtable (WSBR) in December 2019, at which Eli Naffah was introduced as a principle point of industry contact. CSP conducted virtual industry meetings due to COVID-19 restrictions during the Satellite 2020 (March 2020) conference regarding the upcoming Capability Development and Demonstration procurement.

Throughout this period, industry clearly stated the need to retain the benefits of their investment to justify offering competitive commercial SATCOM services, therefore requiring maximum confidentiality. Accordingly, the NASA approach should assure that commercial partners retain the benefit of their investment to encourage the development of commercial space industry capabilities.

CSP also established a Commercial Services User Group (CSUG) to enlist participation from the NASA mission user community. The CSUG discussed identification of future mission needs and suitable mission classes, and informed development of reference service level requirements for end-to-end demonstrations.

Key Features and Guiding Principles for Phase 2

Key Features of the CDD approach reflected lessons learned from NASA's Commercial Orbital Transportation Services (COTS) and Commercial Crew programs, including:

- Addresses a high priority public purpose. CSP Phase 2 addresses development of new SATCOM service market for customers operating in near-Earth orbit. Potential customers include NASA other government agencies & commercial space companies.
- Matures emerging commercial capabilities prior to a contract for purchase. PPP is envisioned for the Phase 2 Capability Development and Demonstration. CSP Phase 2 extends and matures the current SATCOM systems for terrestrial users and adds the links to the orbiting spacecraft in an end-to-end service for users operating in near earth orbit.
- Fosters collaborative environment and supportive leadership. CSP envisions PPPs involving significant private investment, knowledge and risk-sharing based on the capabilities and interests of NASA's partners to create new markets that NASA can leverage.
- Mitigates risk with backup options and alternatives. CSP's intent during Phase 2 is to develop a portfolio of capabilities through multiple awards that allow different approaches to be leveraged.
- Indicates multiple viable service providers. During Phase 2, CSP intends to invest in the development of capability through multiple service providers to ensure a candidate pool of viable service providers that can be considered to propose for Phase 3 Service Acquisition.
- Secures sufficient financial and technical resources. CSP intends to leverage both appropriated and private funding to develop and demonstrate capabilities during Phase 2.
- Incorporates existing or high readiness technologies. Phase 2 CDDs are end-to-end service demonstrations involving operational constructs, acquisition models and performance validations needed to define the future communications architecture and acquisition strategy for the Phase 3 transition of near-Earth NASA users to suitable commercially-provided services. The CSP focus is not technology development. Significant commercial capability and infrastructure exists with the intention of leveraging private investment to extend it for space-based users. Development of technologies will be limited to high Technology Readiness Level (TRL) systems as required to close technical gaps for creation of the new service capabilities.
- Identifies reliable and predictable markets for Government and commercial uses. NASA desires to be one of many customers of commercial SATCOM services. CSP plans to partner with industry during Phase 2 to create a new market for commercial SATCOM services for space based users.

Additional CSP guiding principles include:

- The Phase 2 objective is to stimulate innovation by the commercial SATCOM industry in leveraging their existing capabilities toward solutions for near-Earth NASA spacecraft. Commercial SATCOM Service Provider waveforms, acquisition models and operational constructs are currently proprietary and closely guarded. Specific results from each demonstration are expected to be proprietary and cannot be released to other Government entities or the private sector. Release would undermine the business case for the services developed and demonstrated by the commercial partner and would discourage private investment needed to form the PPP.

- CSP is not acquiring goods and services and is not advancing scientific and technical knowledge; NASA will NOT obtain hardware or systems designs. Data deliverables will minimize Government rights in and retention of data, and will be only those necessary to verify that the contractor has satisfied its required performance milestones for purposes of payment for those milestones.

- NASA is a catalyst, not a technical monitor or contributor to the work. There is no requirement for Technical Oversight of specified NASA requirements. A goals vs. requirements approach will drive innovation and flexibility. However, limited NASA participation may be required to assure integration of service capability at mission interfaces (e.g., if a NASA mission is proposed to be part of the demonstration).

- Title to property acquired through the CDDs will inure to the industry partner. CSP will allow partners to retain maximum intellectual property rights, and limit the Government's right to use or distribute it. If, however, the agreement is terminated for failure to perform, NASA may exercise all rights to data, to ensure its investment benefits are not lost.

Phase 2 Approach

CSP proposed using Funded Space Act Agreements (FSAAs) which were successfully used in the COTS demonstrations program. The primary purpose of CSP's FSAAs is to stimulate and accelerate the commercial SATCOM industry's development of its own capabilities. FSAAs were approved as the appropriate legal instrument to establish multiple PPPs featuring shared resources, cost, and risk for the CDD phase. FSAAs permit NASA to transfer appropriated funds to domestic Partners to fulfill one or more of the Agency's authorized statutory objectives under the U.S. Space Act. Those statutory objectives include "seek[ing] and encourag[ing], to the maximum extent possible, the fullest commercial use of space." Agency resources provided under FSAA's can include personnel, funding, services, information, or facilities to accomplish the joint objectives of the partners. NASA has the authority to waive rights in inventions under Section 305(f) of the U.S. Space Act if determined to be in the Government's interest.

The demonstrations focus on two key interfaces: Service-Spacecraft, and Service-Mission Operation Center (MOC). The commercial services are composed of Ground, Space, and Mission planning capabilities.

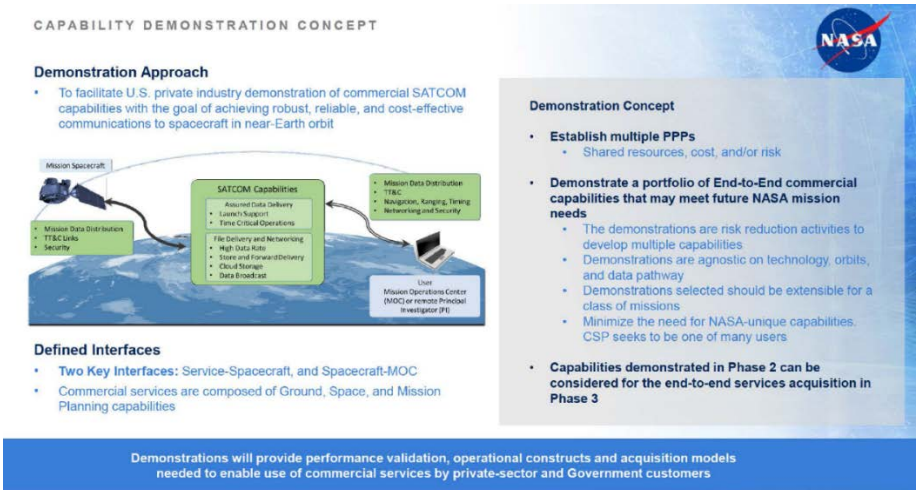

Figure 2. CSP Capability Demonstration Concept

Capability was defined as communication function that is delivered by a commercial provider which meets a NASA mission need. Relay data transport from NASA spacecraft to commercial ground station is considered a Capability. Products developed and demonstrated will include acquisition models, operational constructs and performance validations that can be used to transition the capability into an end-to-end service.

End-to-End Service consists of a portfolio of capabilities that, when coupled together, address the need of a NASA mission for seamless Commercial SATCOM services that are provided from the Spacecraft to the MOC or direct to the user.

CSP developed six mission use cases. Mission reference documents were compiled by NASA summarizing past and present service usage data, as well as future projected mission needs:

- Appendix 4 - Future Mission Space Communications Navigation Needs.pdf
- Appendix 5 - User Data Volume .xlsx
- Appendix 6 - User Technical Data.xlsx

Figure 3. CSP Demonstration Reference Mission Use Cases

The use cases and mission reference data were included in an Announcement for Proposals released on July 21, 2022. For each capability, several user goals were identified and intended for demonstrating comparable performance to NASA's existing systems. Participants were asked to select goals based on their business thrusts and interests, and plans for offering future commercial SATCOM services. Participants were asked to use their customary industry practices, processes and standards. Proposed demonstrations need to result in the offering of a service that provides a balance among reliable, robust, and cost-effective services for any space user. Operational requirements were defined to ensure that the demonstration validates an end-to-end operational service capability.

NASA's intention was that the demonstration should be as close to the operational service as possible; any differences should be noted. The duration of the demonstration as proposed by the service provider will need to be sufficient to verify key performance parameters of the capability. Evidence of meeting the end-to-end operational requirements will be provided in the appropriate milestone(s) defined by the participant. NASA asked the demonstration partners to develop Business Models, Acquisition Models; Technical Feasibility; Performance Validation; a Spacecraft and MOC Integration Approach; Operational Constructs; Near Earth Mission Compatibility, Risks and Costs.

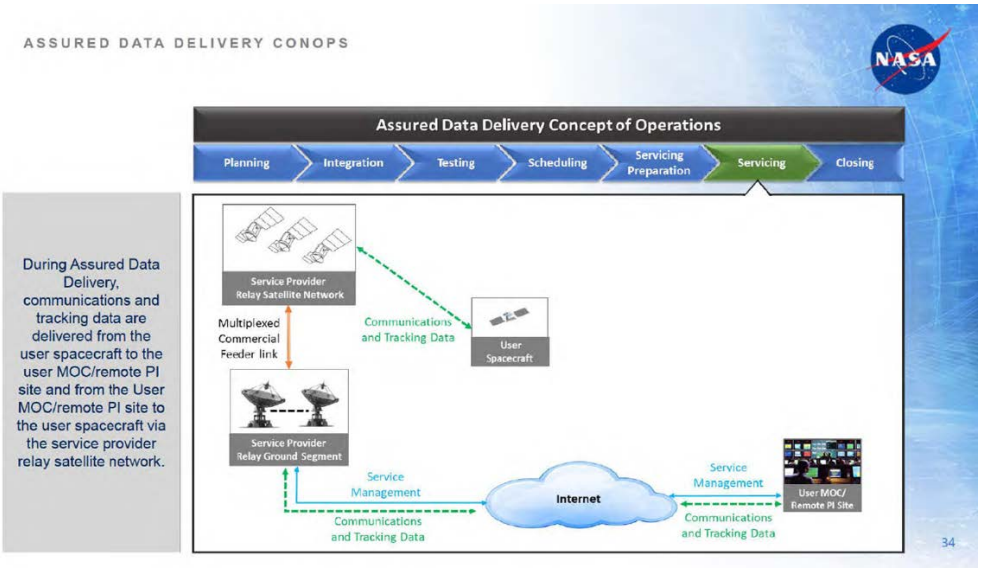

Figure 4. Assured Data Delivery Concept of Operations

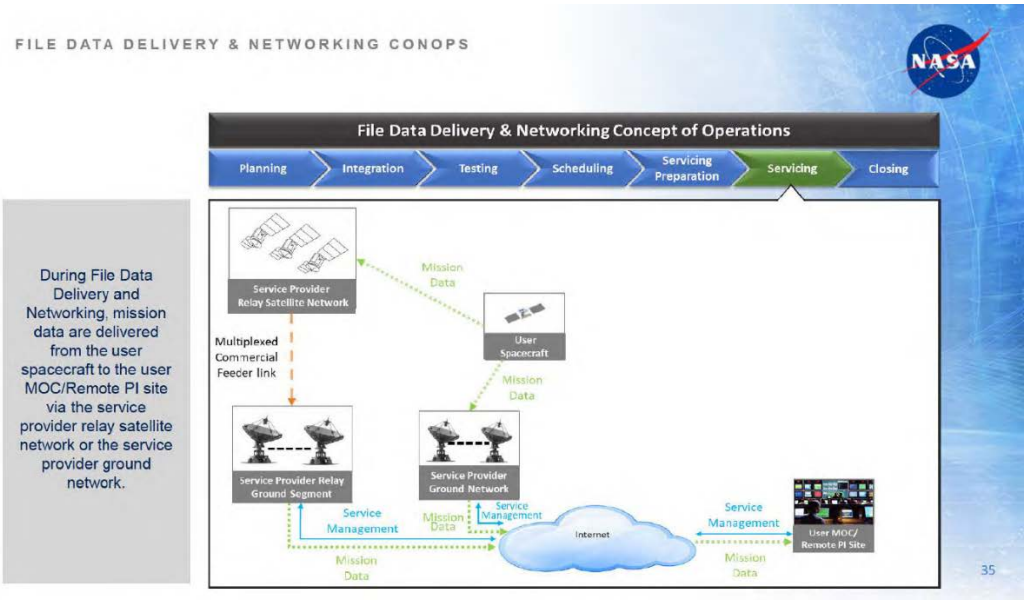

Figure 5. File Data Delivery and Networking Concept of Operations

4. References

[1] National Space Policy of the United States of America, 09 December 2020 (accessed 06.09.2022)

[2] Communications Services Project (CSP) Announcement for Proposals, 21 July 2021 (accessed 25.07.2022)

[3] Northern Sky Research Study, NASA Goddard Space Flight Center, 2020

[4] NSSAG: NASA Space Act Agreements Guide

[5] NPD 1050.1I – Authority to Enter into Space Act Agreements

[6] Future Mission Space Communication and Navigation Needs, NASA Space Communication and Navigation Program, 2020

[7] Funded Space Act Agreement Best Practices Guide (NASA proprietary)

5. Glossary

AoA – Analysis of Alternatives

BAA – Broad Agency Announcement

CDD – Capability Development and Demonstration

ConOps – Concept of Operations

COTS – Commercial Orbital Transportation System

CSP – Communications Services Project

FSAA – Funded Space Act Agreement

GRC – Glenn Research Center

MOC – Mission Operations Center

NASA – National Aeronautics and Space Administration

PPP – Public-Private Partnership

SATCOM – Satellite Communications

SCaN – Space Communications and Navigation

TDRSS – Tracking and Data Relay Satellite System