National Aeronautics and Space Administration

NASA AMMOS

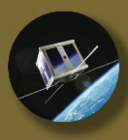
Advanced Multi-Mission Operations System

Managed by the Multimission Ground System and Services (MGSS) Program Office for NASA

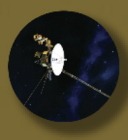
AMMOS Catalog

Version 5.3

AMMOS Products and Services support these mission types:

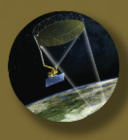


Deep Space CubeSats and SmallSats



Heliophysics

Astrophysics



Earth Sciences

Planetary Sciences

Catalog Custodian: Zsarina Benecken

Document Change Log

Revision	Issue Date	Affected Sections or Pages	Change Summary
Initial (Version 5.0)	19-Jan-2017	All	Initial issue of document. **Note:** This is the first major update to what was formerly Version 4.0 of the AMMOS Catalog published on the AMMOS website and now being managed as a separate document-based deliverable.
Rev. A (Version 5.1)	04-Apr-2017	1. Pg. 6 2. Pg. 18 3. Pg. 30 4. Pg. 36-38	1. Updated Figure 2.3-2 as standard AMMOS context diagram. 2. Added Monte as new MDNav product item 3.3.1-3 in Table 3.3.1. 3. Added CAM as abbreviation to product item 4.1-2 in Table 4.1. 4. Updated Catalog ID numbers in checklist using fixed vs. auto-generated numbers.
Rev. B (Version 5.2)	17-Aug-2018	1. Pg. 6 2. Pg. 13 3. Pg. 14 4. Pg. 25 5. Pg. 29 6. Pg. 31 7. Pg. 32	1. Updated Figure 2.3-2 as standard AMMOS context diagram. 2. DSN Keyword File (DKF) service no longer offered as an AMMOS service; therefore dropped Table 3.1.2 and from Catalog checklist in Appendix B. 3. Added AMMOS to 3.2.1-1 name for AMPCS. 4. New entries added for Automatic Fusion of Image Data System (AFIDS)/Nest and AFIDS/Nest_Map under 3.4.1-2 Image Processing Toolkit. 5. Updated entry for 3.4.1-10 to now reflect Web Resource Platform (WRP) 6. New entry for 3.4.1-13 AMMOS Instrument Toolkit (AIT) 7. New entry for 3.4.2-3 PDS Archive Transformation Service (PATS)

		8. Pg. 34 9. Pg. 35 10. Pp. 39-41 11. Pp. 42-44	8. New entries for 4.1-4 System Security Monitor (SSM) and 4.1.-5 Compute Environment Configuration Modules (CECM). 9. Removed Operational Interface Agreement (OIA) capability support from 4.2-1 MMCM Services. 10. Updated Acronyms & Abbreviations List 11. Updated Catalog checklist to reflect new additions.
Rev. C (Version 5.3)	27-Apr-2020	1a. Pg. 18 1b. Pg. 33 1c. Pg 14 2. Pg. 42 3. Pg 45-46 4. Pg. 35 5. Pg. 29 6. Pg. 14, 19	1. New entry for: a) SLE Command Client b) ASTTRO c) MMTC d) Sequence Tracker 2. Updates to Abbreviation List 3. Updated Catalog checklist to reflect new additions. 4. Deleted AMMOS Automated Deployment System per ECR-122706. 5. Added DataDrive under 3.4.1-5 6. Removal of 3.1.2 and 3.2.2

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1 Introduction

1.1 Identification

This document is the *AMMOS Catalog, Version 5.3 Rev C* for the Multimission Ground System and Services (MGSS) Program, Interplanetary Network Directorate (IND) Office.

1.2 Purpose

The AMMOS Catalog provides a comprehensive overview of capabilities in the form of products and services available to support flight projects and experiment investigations. AMMOS products today are predominantly software applications and tool sets, but can extend beyond software to include data products, and models. AMMOS services on the other hand are mission operations capabilities offered in the form of human capital (expertise) according to agreements negotiated between the mission's flight project management team and MGSS program management the latter of which contracts with an implementing organization to provide such expertise.

The descriptions given in this Catalog are intended to aid those preparing mission and experiment proposals, as well as those in early stages of project planning:

1. Provides a standard taxonomy of products and services and other supporting aspects. This serves as a basis for service-level agreements and other instruments of commitment between flight project and experiment investigation customers and the service providers.
2. Provides high-level descriptions of the capabilities. This assists proposers and planners in scoping their efforts and in developing credible conceptual designs for their mission operations systems.
3. Provides basic information regarding how to obtain products, services, and support. This aids pre-project customers in their planning processes.

1.3 Applicability

The capabilities described in this AMMOS Catalog are intended to serve as guidance and as the 'gold source' capability descriptions when developing Service Level Agreements (SLAs) with mission customers. The MGSS Mission Interface Office (MIO) handles SLA management. In accordance with established policy, this Catalog only includes capabilities that are either available or have funded deployment plans and approved commitment dates at the time of its release.

Software capabilities listed in this AMMOS Catalog include a New Technology Report (NTR) / NASA Pasadena Office (NPO) number necessary for a mission customer to request copies of the software and depending on the requesting entity such as a U.S. Government Agency (including NASA) and 3rd Party for Research Use, a royalty free license granted for use. In some cases, a partner U.S. Government Contractor may also be granted a royalty free license for use. The Software Release Authority (SRA) at JPL's Office of Technology Transfer is the software licensor for all JPL-developed software described herein in accordance with Caltech copyright policy for such software.[1]

[1] See http://ott.jpl.nasa.gov/index.php?page=software.

1.4 Revision Control

This document (and any revisions) is released in accordance with DOC-000016, MGSS Documentation Structure, Standards and Definitions, Rev. D and supporting procedure DOC-000014 Document Submission and Release Procedure, Rev. A. Requests for changes or clarification to this document should be addressed in writing to the document author or custodian.

1.5 MGSS Governing Documents and Processes

MGSS Document Number	Document Name	Document Description	Document Status
DOC-000014, Rev. A	MGSS Document/Record Submission & Release Procedures	Defines steps to submit, release, and control MGSS Controlled Documents. Includes steps to setup and capture records within MGSS's DocuShare collections.	Released
DOC-000016, Rev. D	MGSS Documentation Structure, Standards and Definitions	Identifies MGSS documentation requirements so that document related actions can be audited, documents are retained or disposed of properly, and their content protected.	Released
DOC-000001, Rev. C	AMMOS L3 Requirements Document	Specifies AMMOS System Level (Level 3) requirements and allocates them to one or more AMMOS Subsystems.	Released
DOC-000861, Rev. A	AMMOS Strategic Plan & Roadmap	Defines overall direction and goals of the MGSS organization and communicates the AMMOS System Level strategic goals and objectives and multiyear roadmap to the organization's stakeholders.	Released

1.6 MGSS Applicable Documents and Processes

MGSS Document Number	Document Name	Document Description	Document Status
DOC-001012	Multimission Ground Systems and Services (MGSS) Commitments Process (Pre-phase A)	Describes process to establish, monitor and manage agreements between the MGSS program office and customers during Pre-Phase A (Concept Studies) of the NASA project lifecycle.	Released
DOC-001013	Multimission Ground Systems and Services (MGSS) Commitments Process (Phase A)	Describes process to establish, monitor and manage agreements between the MGSS program office and customers during Phase A (Concept and Technology Development) of the NASA project lifecycle.	Released

1.7 MGSS Subordinate Documents and Processes

None identified for this revision.

1.8 Notation and Terminology

In this AMMOS Catalog document the distinction between Products and Services capabilities is important:

1 **Products** – Products are multimission capabilities that include AMMOS core software, data, and models that are licensed for use by mission customers. Adaptation of these products to meet mission specific requirements is not considered multimission core and thus paid for and maintained by the project.

2 **Services** – Services are mission operations functionality performed by human capital (expertise) according to agreements negotiated between the project customer and MGSS. MGSS works with an implementing organization to staff and cost the expertise. This is in contrast to obtaining and using products directly.

Note: Though infrequent, there are cases where certain capabilities listed in this AMMOS Catalog contain the word ‘Service’ in their name, but do not adhere to the Service definition provided above. Notable examples include the Common Workflow Service (CWS) and AMMOS-PDS Pipeline Service (APPS). In cases such as this, it is

important to read the description of the capability to distinguish it as a product offering versus a true services (expertise) offering.

2 AMMOS Overview

2.1 What is the AMMOS?

The Advanced Multi-Mission Operations System (AMMOS) is NASA's recommended provider of multimission products and services for NASA space science missions, particularly missions exploring our solar system and beyond.[2] This recommendation is based on the high quality, low risk, and cost effectiveness of AMMOS products and services.

The AMMOS is an Agency-wide products and services offering comprising implementers and customers from multiple NASA centers, Federally Funded Research and Development Centers (FFRDCs), University Affiliated Research Centers (UARCs), academia, and industry.

The Multimission Ground System and Services (MGSS) Program Office within the Interplanetary Network Directorate (IND) at the NASA's Jet Propulsion Laboratory (JPL) manages the AMMOS.

2.2 Value Proposition

The AMMOS is based on a simple idea: For those elements of a mission operations system that are common to multiple projects, build them once rather than duplicate that development and maintenance effort for each project. The AMMOS provides a core set of products and services that can be readily customized to accommodate the specific needs of individual missions. The net result is:

- Lower costs (for projects and NASA) – Projects do not have to pay for the development or the maintenance of AMMOS core (multimission) capability.
- Shortened development cycles – Project-specific adaptation takes less time than full life-cycle capability development (weeks or months compared with years).
- Reduced risk – AMMOS is a mature system that has been successfully used by numerous projects in a variety of mission-specific situations. As such, projects enjoy greater reliability of a mature well-tested and exercised set of capabilities.

The AMMOS supports the *full lifecycle* of a NASA flight project or experimental investigation specializing in support for critical events such as entry, descent, and landing, deep space trajectory correction maneuvers, and orbit insertion. AMMOS networks provide Principal Investigators, regardless of geographical location, with the capability to interact with their instruments and their data.

Additionally, the AMMOS through its MGSS Program Office maintains a strong governance model comprised of a program executive committee, a working group consisting of members from multiple NASA centers and partner facilities, and a project users group that provides tactical as well as strategic input for future AMMOS capability needs of projects.

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[2] Green, J., "Governance of the Advanced Multi-Mission Operations System (AMMOS)," Internal Memorandum (un-numbered), NASA's Planetary Science Division (PSD), NASA Science Mission Directorate (SMD), National Aeronautics and Space Administration, Washington, DC, Jan. 19, 2008.

Finally, per NASA sponsor directive, contribution to the AMMOS core by multiple NASA centers, partner FFRDCs and UARCs, universities, etc. is highly encouraged. Partners can propose new AMMOS capabilities during a Biennial "Call for Ideas" via the AMMOS website (see https://ammos.nasa.gov/contributing/callforideas/).

2.3 System Context

Ground System and Mission Operations System ("Project MOS")

Before articulating the underlying capabilities offered by the AMMOS, it is important to first understand a flight project's Mission Operations System within the context of an overall Ground System (see Figure 2.3-1).[3]

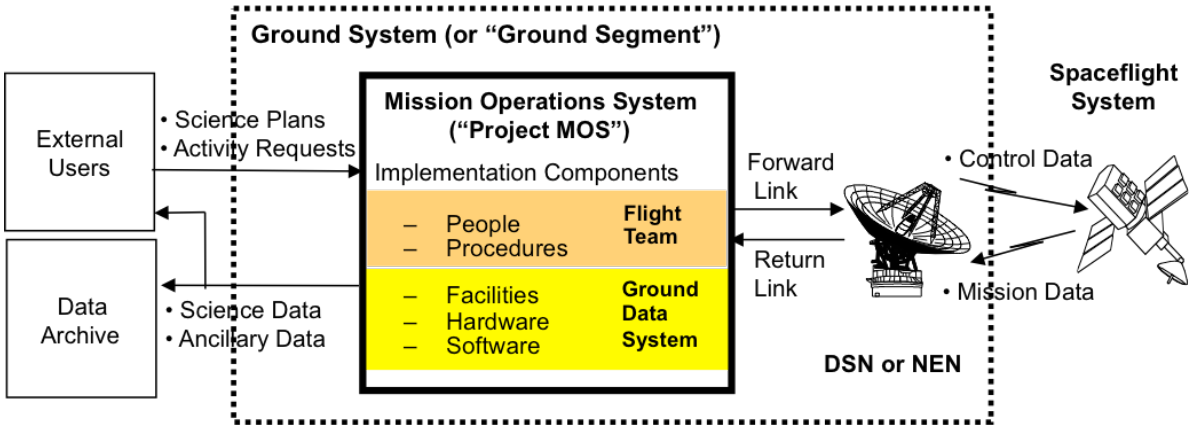

Figure 2.3-1. NASA space science Mission Operations System within the context of an end-to-end Ground System.

A flight project's Mission Operations System, or "Project MOS" for short, is comprised of a set of implementation components that include a skilled workforce (Flight Team) as well as Ground Data System (GDS) components and support services.

The skilled workforce is used to staff the project Flight Team, who are trained in a set of standard processes and procedures organized around mission operations discipline areas such as Planning and Sequencing and Mission Control to name a few.

Typical elements of a GDS include software, hardware (including networks) and facilities as well as support services such as system administration support.

Project MOS and the AMMOS

Figure 2.3-2 depicts the primary discipline-specific functional areas as well as a (non-exhaustive) set of major crosscutting functions typical of a Project MOS. Also shown are the high-level downlink and uplink data flows between the discipline-specific functions and the forward and return links between the Project MOS and space communications and data acquisition provider (e.g., NASA's Deep Space Network (DSN) or Near-Earth Network (NEN)).

[3] In some circles, the term "Ground Segment" is used over Ground System and in others the terms are used interchangeably. For purposes of this AMMOS Catalog, the two terms are considered synonymous.

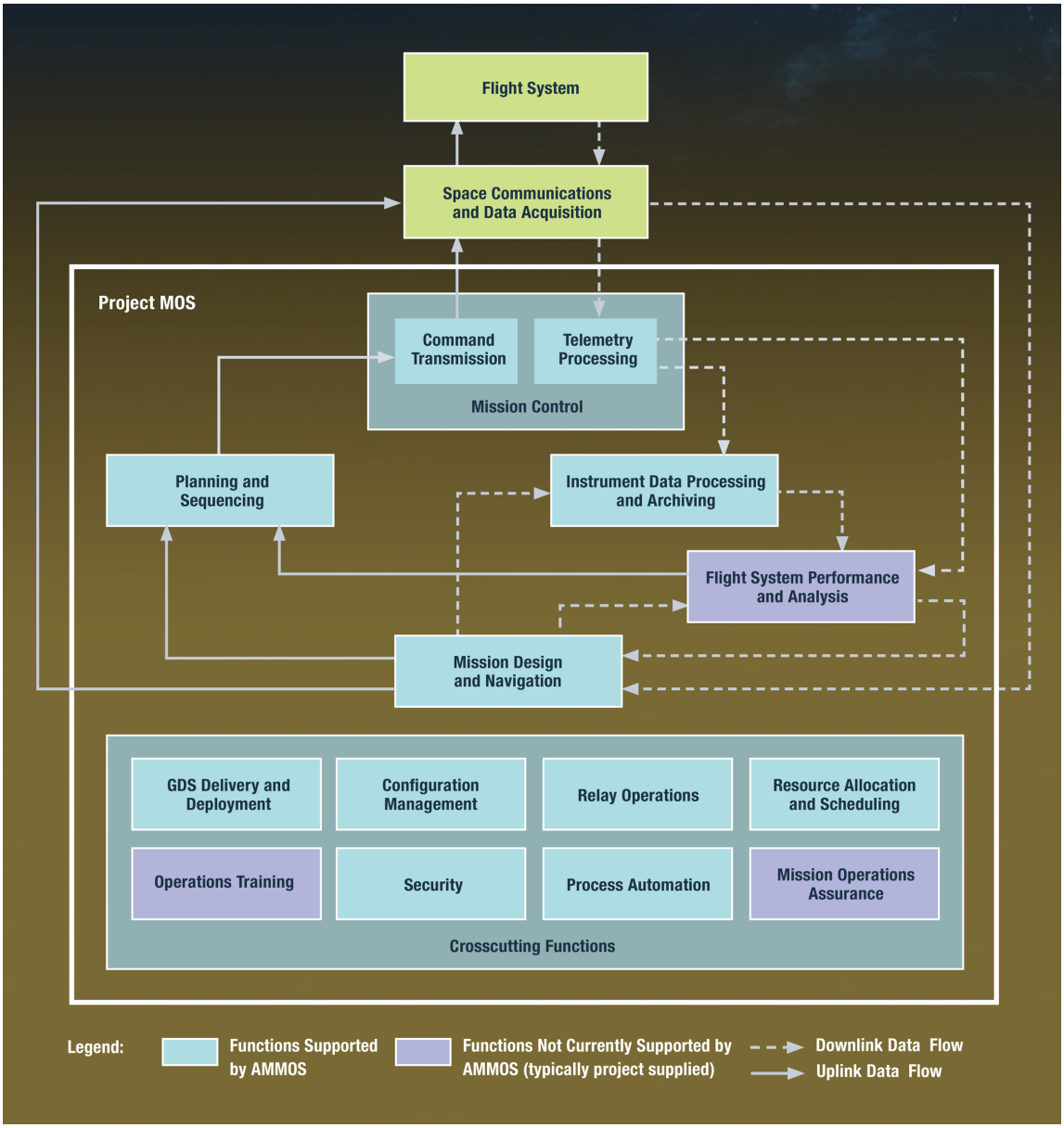

Figure 2.3-2. High-level Project MOS functions in a Mission Operations environment (or 'venue').

The functional areas at the top Figure 2.3-2 represent major discipline functions of a typical Project MOS. These include, for example:

- **Planning and Sequencing** – Generation of activity plans, science observation plans, and sequence and command generation. Spacecraft operability constraints, mission rules, and flight rules are enforced, and spacecraft activities, science activities, and instrument activities are merged during the planning and sequencing process to produce integrated, conflict-free command products to control the spacecraft.

> ***Sequencing Defined***
> *Sequencing is the process of wrapping several spacecraft commands into high-level activities, which allows the spacecraft to be commanded at a higher level. The process of expanding activities into sequences is accomplished by adapting sequencing software for a specific project. This includes defining the spacecraft commands, defining activities and how they expand into commands, defining spacecraft subsystem models and how the commands affect the models, and defining mission rules.*

- **Mission Control** – Real-time monitoring and control of a spacecraft (both pre-launch and post-launch) including downlink telemetry processing and display as well as preparation and initiation of the transmission of spacecraft commands through the ground-space telecommunications network (e.g., DSN and NEN).[4]
- **Mission Design and Navigation** – Planning/optimizing the flight system trajectory for future mission activities and maintaining knowledge of its position/velocity during flight.
- **Flight System Performance and Analysis** – Assessing the health and performance of the flight system through monitoring, performance trending and analysis of its subsystem telemetry (e.g., telecommunications, power, thermal) as well as support of planning activities throughout the mission life cycle. [5]
- **Instrument Data Processing and Archiving** – Science instrument data product generation, includes processing: display and delivery of science and related engineering data for use by instrument engineers, activity and science planners, in-situ drivers and operators; and public information releases. A product archive

[4] For purposes of this AMMOS Catalog, the Mission Control functional area for pre-launch test and development environments (thus not shown in Figure 2.3-2) includes front-end processing which serves to provide an external interface with a project's Ground Support Equipment (GSE) that is used to communicate with the flight system in these environments (or so-called 'venues').

[5] At present, AMMOS does not provide capability offerings of any significant depth or breadth in the area of Flight System Performance and Analysis. These capabilities have historically been provided by the flight system provider and often developed by and in support of the flight system engineering team. It is anticipated that in the future, a greater need by the flight community will ultimately drive a greater level of multimission investment in this area.

pipeline is also provided for metadata/label design, data format transformation, validation and bundling of the mission archive product deliveries to NASA's Planetary Data System (PDS) while ensuring compliance to PDS4 standards.

The AMMOS capability offerings in terms of products and services are further described in Sections 3.1 through 3.4 of this Catalog.

In addition to the aforementioned primary discipline functions, the following (non-exhaustive) set of crosscutting functions are in support of a Project MOS:

- **GDS Delivery and Deployment** – Provision of a standard, cost effective, GDS configuration based on a multimission solution that facilitates deployment and operations procedures with minimal tailoring to project specific needs.
- **Configuration Management** – A process-oriented function that establishes and maintains consistency of a product's attributes with the requirements and product configuration information throughout the product's lifecycle.[6] From a mission operations perspective, its scope includes configuration management of GDS software products from development through sustaining and maintenance. Its scope also includes configuration control of mission operations products and systems comprised of flight project/mission adaptations, mission development, test, and operations environments.
- **Relay Operations** – Operational infrastructure and support given to an in-situ telecommunications network established for purposes of providing space communications and data acquisition between landed assets (e.g., landers, rovers) and orbiting assets around specific target bodies of exploration. Such a network is often referred to as a 'relay network.'
- **Resource Allocation and Scheduling** – A key function needed by all project mission operations for generating opportunities and conflict-free schedules for usage of space communications and data acquisition resources. It is important to note that flight system tracking hours are limited by practical limits of total user demand and internal engineering and maintenance.
- **Operations Training** – The training and certification of mission support personnel with the critical skills required to conduct mission operations safely and successfully. Ops training approaches typically include the following elements: training needs assessment, position training, flight school/training presentations, walkthroughs/table top sessions, thread tests/rehearsals, operational readiness tests (ORTs), and position certification.
- **Security** – Ensures the confidentiality, integrity, and availability of mission operations resources. This includes restricting access to critical GDS software products as well as operations data/information products to authorized users while also protecting critical mission data/information both at rest and in transit.

[6] Source: "NASA Configuration Management (CM) Standard," NASA Technical Standard (NASA-STD-005), National Aeronautics and Space Administration, Washington, DC, Sept. 29, 2008.

- **Process Automation** – Mission operations processes are comprised of a set of operations-related activities each forming a logical step within a process to carry out a unit of work. Historically, operations-related activities have largely been performed manually by human intervention (i.e., *manual activities*); however, efficiency gains can be achieved by identifying potential *automated activities* in which machine resources could support automated execution.
- **Mission Operations Assurance** – Typically a collaborative function between a center's mission assurance and systems engineering line organizations that work to improve the operational reliability of projects during mission operations. It involves the engagement of the operations team in assurance related functions such as anomaly reporting and resolution, risk management, software and hardware quality assurance, formal reviews, contingency planning, and verification and validation of operational processes and procedures.

The AMMOS capability offerings in terms of products and services that support these crosscutting functions of a Project MOS are described in Section 4 of this Catalog.

3 AMMOS Products and Services: Functional Discipline Capabilities

3.1 Planning and Sequencing

Generation of activity plans, science observation plans, and sequence and command generation. Spacecraft operability constraints, mission rules, and flight rules are enforced, and spacecraft activities, science activities, and instrument activities are merged during the planning and sequencing process to produce integrated, conflict-free command products to control the spacecraft.

3.1.1 Planning and Sequencing Products

Table 3.1.1. AMMOS Planning and Sequencing Products.

Catalog ID / Title	Description
3.1.1-1 Activity Plan Generator (APGEN)	Activity Plan Generator (APGEN) is a software application that is a long-range and short-range activity planner, to be used by flight project personnel such as mission planners, science planners, and other flight team members. Its primary purpose is assisting the user in establishing an integrated mission plan containing activities (e.g., maneuvers or science observations) that does not oversubscribe (or undersubscribe) available spacecraft and/or ground resources. NTR/NPO No. 40520 Dependencies: 3.1.1-4 Sequence Review (SEQ_REVIEW)
3.1.1-2 Sequence Generation (SEQGEN)	Sequence Generation (SEQGEN) is a software application that expands a series of science and engineering activities into their resultant spacecraft commands, model changes in spacecraft state based on commands in order to produce event predictions, model sequences expanded onboard the spacecraft and those expanded on the ground, and indicate conflicts in the modeling of commands and violations of flight rules. NTR/NPO No. 40650, 49069 Comment: The cost of adaptation varies depending on the complexity and fidelity of sequence modeling. The sequence modeling involves the number of commands, number of flight rules, number of subsystems, degree of interaction, fidelity of resource modeling, stability of requirements during development, stability of command dictionary during development, and the degree of inheritance from prior adaptations.

Table 3.1.1. AMMOS Planning and Sequencing Products.	
Catalog ID / Title	Description
3.1.1-3 Mission Planning and Sequencing (MPS) Editor	Mission Planning and Sequencing (MPS) Editor is a software application that enables the creation and editing of spacecraft sequences and the capability to ingest, merge, and output sequences in a variety of formats (e.g., Spacecraft Activity Type File (SATF), Spacecraft Activity Sequence File (SASF)). Enables modeling of blocks, sequences and commands via the invocation of SEQGEN. Includes a drag-n-drop Graphical User Interface (GUI) to assemble blocks and sequences. NTR/NPO No. 47237 Dependencies: 3.1.1-4 Sequence Review (SEQ_REVIEW); 3.1.1-2 Sequence Generation (SEQGEN); 3.1.1-5 Spacecraft Language Interpreter and Collector II (SLINC II); 3.1.1-6 Mission Planning and Sequencing Server (MPSServer); 0 Common Access Manager (CAM) (optional for authentication; used at mission's discretion)
3.1.1-4 Sequence Review (SEQ_ REVIEW)	Sequence Review (SEQ_REVIEW) is file viewer software that lets the user open any arbitrary text file for display with the use of adaptable File Descriptors that tell SEQ_REVIEW what the file looks like and what the user wants to see from the file. This allows the user to modify the appearance of the file (e.g., remove unwanted information, re-format data into columns, add derived quantities computed from data in the file) to simply file analysis. NTR/NPO No. 21209
3.1.1-5 Spacecraft Language Interpreter and Collector II (SLINC II)/ Command Translation Subsystem (CTS)	Spacecraft Language Interpreter and Collector II (SLINC II)/ Command Translation Subsystem (CTS) is a software application and set of software libraries, respectively that translate sequence commands from command mnemonics to binary. (**Note:** CCSDS File Delivery Protocol (CFDP) binary file can also be produced.) NTR/NPO No. 48066

Table 3.1.1. AMMOS Planning and Sequencing Products.	
Catalog ID / Title	Description
3.1.1-6 Mission Planning and Sequencing Server (MPSServer)	Mission Planning and Sequencing Server (MPSServer) is a client/server application that provides RESTful Application Programming Interface (APIs) in order for all MPS applications, including MPS's web applications (3.1.1-8 ULSGEN and 3.1.1-7 RAVEN) to be able to import to and query from various project data repositories, run external tools and allow users to communicate with MPS applications from remote sites. NTR/NPO No. 50382 Dependencies: 0 Common Access Manager (CAM) (optional for authentication; used at mission's discretion)
3.1.1-7 Resource and Activity Visualization ENgine (RAVEN)	Resource and Activity Visualization ENgine (RAVEN) is a web-based application that allows users to view science planning, spacecraft activities, resource usage and predicted data, displayed in a timeline format via web browser. NTR/NPO No. 50376 Dependencies: 3.1.1-6 Mission Planning and Sequencing Server (MPSServer)
3.1.1-8 Uplink Summary Generator (ULSGEN)	Uplink Summary Generator (ULSGEN) is a software application that generates Uplink Summaries of uplink file products and manages their signature cycle and approval process before the products are radiated to the spacecraft. NTR/NPO No. 48423 Dependencies: 3.1.1-6 Mission Planning and Sequencing Server (MPSServer); 0 Common Access Manager (CAM) (optional for authentication; used at mission's discretion)
3.1.1-9 Telecom Prediction and Trending Analysis	Telecom Prediction and Trending Analysis provides a suite of tools to support telecom prediction and analysis. The TFP toolkit includes support for various environments and deployments, as well as a web-based service. NTR/NPO No. 20875

Table 3.1.1. AMMOS Planning and Sequencing Products.	
Catalog ID / Title	Description
3.1.1-10 Multi Mission Time Correlation (MMTC)	A tailorable, stand-alone, mission-independent product that receives time as measured onboard the spacecraft and associate it with defined Earth-time. The product records this association in a SPICE SCLK Kernel.
3.1.1-11 Sequence Tracker	Sequence Tracker is a tool that automates the tracking and review of deliverables into a mission's sequencing process. It allows a mission to create templates representing the schedules of their various sequence development processes and then apply a template to create a schedule for development of a single sequence. This schedule details the process milestones and due dates for deliverables into the process. It tracks which of these products have actually been delivered and which have been reviewed. It displays this status so that sequence integration engineers and managers can determine delivery status of all products at a glance. NTR/NPO No: 51491

3.2 Mission Control

Real-time monitoring and control of a spacecraft (both pre-launch and post-launch) including downlink telemetry processing and display as well as preparation and initiation of the transmission of spacecraft commands through the ground-space telecommunications network (e.g., DSN and NEN).[7]

3.2.1 Mission Control Products

Table 3.2.1. AMMOS Mission Control Products.

Catalog ID / Title	Description
3.2.1-1 AMMOS Mission Data Processing and Control System (AMPCS)	AMMOS Mission Data Processing and Control System (AMPCS) is a software application that performs the following functions: **Telemetry Processing** • Processing of CCSDS formatted Advanced Orbiting System (AOS) transfer frames or TM transfer frames containing Space Packets or file Protocol Data Units (PDUs) • Extracting telemetry channels from packets using decommutation maps • Constructing ground-derived channels • Calculating Engineering Units for channels using a table, polynomial, or custom algorithm • Alarm computations (high value, low value, inclusive range, exclusive range, mask, state, change, delta, digital, and combination alarm types) • Extracting Event Records (EVRs) from packets • File reconstruction from PDUs • Processing of received files of recorded telemetry **Information Monitoring, Storage, and Query** • Real-time displays with lists, plots, alarms, and messages • All received and processed information is stored and can be queried, for both testbed and operations scenarios • Historical lists and plots; standardized data reports and summary reports

[7] For purposes of this AMMOS Catalog, the Mission Control functional area for pre-launch test and development environments includes front-end processing which serves to provide an external interface with a project's Ground Support Equipment (GSE) that is used to communicate with the flight system in these environments (or so-called 'venues').

Table 3.2.1. AMMOS Mission Control Products.	
Catalog ID / Title	Description
	Automation Support • Script access to telemetry via Python • Alarm notification via email **Commanding Support** • User interface for building spacecraft commands, controlling the uplink of commands and command files, and archiving command logs primarily in the spacecraft test environment NTR/NPO No. 44256 Dependencies (Third-Party): The AMMOS Mission Data Processing and Control System (AMPCS) utilizes third-party Commercial-off-the-Shelf (COTS) software from an external provider to support the CCSDS Space Link Extension (SLE) standardized set of services that allow ground antenna sites and control centers to send spacecraft data back and forth. This spacecraft data includes the data channels in the return link (spacecraft to ground) and the forward link (ground to spacecraft). The current COTS provider of this SLE capability is LSE Space GmbH and the specific software used to support this capability is referred to as the "SLE User Framework." Mission customers that wish to make use of this capability must arrange to procure a third-party software license for use in operations through their local acquisition office.
3.2.1-2 Mission Control Web Service (MCWS)	The Mission Control Web Service (MCWS) application is server software that provides Web-based access to mission engineering data from a wide-variety of information sources. It provides a well-documented and flexible Web interface for multiple clients. The AMMOS provided client to support local and remote mission users is called Visualization for Telemetry Analysis (VISTA) (3.2.1-3). MCWS is designed to support multiple mission venues with a flexible deployment and configuration strategy. It can support Elasticsearch, MySQL, and real-time information sources for telemetry data as well as associated data such as user-created display layouts. NTR/NPO No. 50312 Dependencies: 3.2.1-1 AMMOS Mission Data Processing and Control System (AMPCS)

Table 3.2.1. AMMOS Mission Control Products.	
Catalog ID / Title	Description
	Note: Elasticsearch is a trademark of Elasticsearch BV, registered in the U.S. and in other countries.
3.2.1-3 Visualization for Telemetry Analysis (VISTA)	The Visualization for Telemetry Analysis (VISTA) application is client software that is designed to work with the Mission Control Web Service (MCWS) to enable flexible interactive display and analysis of telemetry information. VISTA provides composable displays specialized for telemetry information including historical and realtime data for Channels, Event Records, Data Products, and Dictionaries. It allows users to create and save layouts developed during analysis as well as shared subsystem displays pre-configured for operations. NTR/NPO No. ARC-15256-1D (Open MCT – See Comment) Dependencies: 3.2.1-1 AMMOS Mission Data Processing and Control System (AMPCS), 3.2.1-2 Mission Control Web Service (MCWS), Open MCT (see Comment) Comment: VISTA is an application built on top of Open MCT, which is a mission control framework for visualization of data on desktop and mobile devices. It is developed at NASA's Ames Research Center in Silicon Valley, in collaboration with the JPL. As a generalizable and open source framework, Open MCT could be used as the basis for building applications for planning, operation, and analysis of any systems producing telemetry data. Open MCT is available on NASA's GitHub repository at https://github.com/nasa/openmct.
3.2.1-4 Test Data Acquisition and Command (TDAC)	The Test Data Acquisition and Command (TDAC) is a subsystem comprised of hardware and software that connects the AMMOS to a spacecraft serial interface via the Ground Support Equipment (GSE), converting analog signals to binary data (downlink) and vice versa (uplink) for use with a spacecraft testbed. For downlink, TDAC processes a CCSDS data stream to perform one or more of the following functions, including but not limited to: • Demodulation • De-randomization • Decoding (Turbo & Reed Solomon)

Table 3.2.1. AMMOS Mission Control Products.	
Catalog ID / Title	Description
	• Cyclic Redundancy Check (CRC) checking • Frame Synchronization • Recording, playback, and recording archive The binary output bit stream is CCSDS formatted transfer frames that can be processed by the 3.2.1-1 AMMOS Mission Data Processing and Control System (AMPCS) or other ground telemetry data processing system that is compatible with the input CCSDS formatted transfer frames. For uplink, TDAC receives, from the AMPCS or another command uplink tool, CCSDS formatted Command Link Translation Units (CLTUs) and converts them into an analog bit stream metering them at a set rate to the spacecraft serial interface via the GSE. Comment: The patch panel between the TDAC and a specific mission's GSE varies from mission to mission and adaptation is required. The number of serial downlink and uplink streams required by a mission may also vary and should be determined at the time of the TDAC hardware purchase.
3.2.1-5 SLE Command Client (SCC)	The SLE Command Client (SCC) is the primary product in the AMMOS Catalog for commanding spacecraft. SCC provides the ability to send spacecraft commands via any ground station that offers CCSDS-compliant Space Link Extension (SLE) provider services, such as JPL's Deep Space Network (DSN). SCC can also send commands via Near Earth Network (NEN) and Space Network (SN) stations. SCC consumes Spacecraft Command Message Files (SCMFs) or Command Link Transmission Unit Files (CLTUFs) as input. SCC can receive the input files via Representational State Transfer (REST) over Hypertext Transfer Protocol Secure (HTTPS); from the Distributed Object Manager (DOM); or from a file system accessible to the user. SCC extracts the Command Link Transmission Units (CLTUs) from the SCMF or CLTUF files, and forwards the CLTUs to SLE providers via the standard Forward Communications Link Transmission Unit (FCLTU) protocol, or to NEN/SN via the 0232-Telecomm-CMD specification. SCC uses the AMMOS Common Access Manager (CAM) for securing its HTTPS endpoints. AMMOS Mission Data Processing and Control System (AMPCS) uses SCC as a command service

Table 3.2.1. AMMOS Mission Control Products.	
Catalog ID / Title	Description
	when commanding through ground stations or their emulators. Also, as previously mentioned, SCC can use DOM as its file store service. SCC is intended to be used in project testbed, Assembly, Test and Launch Operations (ATLO), and in Operations (Ops) venues, where ground stations or their emulators are used for commanding. SCC is divided into two sub-products: SCC Server and SCC Workstation. Both run as Docker containers. SCC Server is the main sub-product that runs the commanding system described in previous paragraphs. SCC Workstation is an environment intended for the users to directly access and run tools that interact with the SCC Server.

3.3 Mission Design and Navigation

Planning/optimizing the flight system trajectory for future mission activities and maintaining knowledge of its position/velocity during flight.

3.3.1 Mission Design and Navigation Products

Table 3.3.1. AMMOS Mission Design and Navigation Products.

Catalog ID / Title	Description
3.3.1-1 SPICE Toolkit	The SPICE Toolkit (Spacecraft, Planet, Instrument, C-Matrix, Events) provides application programs and a subroutine library that read and write SPICE kernel files and calculate observation geometry quantities. NTR/NPO No: 19984, 42432, 47017 Comment: There is no charge for the SPICE Toolkit. It may be freely downloaded from http://naif.jpl.nasa.gov/naif/.
3.3.1-2 SPICE Data/Kernels	Provision of generic reference data sets containing ancillary navigation data that may be accessed or manipulated via the SPICE Toolkit. Three separate sets of ephemerides are provided: planetary bodies, natural satellites, and small bodies (e.g., comets and asteroids). Data sets containing planetary constants and leap seconds are similarly provided. Comment: There is no charge for SPICE generic kernels. They may be freely downloaded from the NAIF server (see http://naif.jpl.nasa.gov/naif/data.html for details).
3.3.1-3 Monte	Monte is the AMMOS' signature astrodynamics computing platform. It supports all phases of space mission development from early stage design and analysis (e.g., trajectory discovery; trajectory design and optimization; launch and arrival date planning; launch vehicle performance analysis; delta-V analysis; navigation planning) through flight navigation services (e.g., orbit determination; orbit propagation; orbit reconstruction; maneuver design and analysis; entry, descent, and landing; optical navigation). Monte is the principal tool set utilized in performing the services described in the next section, "Mission Design and Navigation Services." NTR/NPO No: NPO-48184, NPO-50395

3.3.2 Mission Design and Navigation Services

Table 3.3.2. AMMOS Mission Design and Navigation Services.	
Catalog ID / Title	Description
3.3.2-1 Natural Body Ephemeris Service	Generation of up-to-date natural body ephemerides and their associated uncertainties, either generic solar system ephemerides or specific ephemeris improvements required by a particular mission. Comment: Generic versions of ephemerides are available at no charge. Costs associated with the natural body ephemeris service may accrue if the mission has a special need (usually only if a dedicated observation campaign is required to gather the requisite data).
3.3.2-2 Gravity Modeling Service	Generation and provision of multimission gravity models for solar system bodies. Comment: Generic versions of gravity models are available at no charge. Costs associated with the gravity modeling service may accrue if the mission has a special need. Updated gravity models are often required by (a) planetary orbiters, or (b) comet/small body missions. This service is not necessary for Earth orbiters, observatory missions, or planetary landers/rovers.
3.3.2-3 Preliminary Mission Design Service	Discovery of trajectories that fulfill the mission needs, including any combination of maneuvers, gravity assists, low-thrust segments, aero-assist segments, and low-energy transfers in support of pre-Phase-A and Phase-A studies. Determination of launch and arrival date ranges. Preliminary design of operational orbits. Comment: Missions at the low end might include earth orbiters, trajectories to inner planets or the Moon. Missions at the high end might include missions to outer planets or small bodies. This service is not needed if the AMMOS customer already has a mission design, and only desires navigation services.

Table 3.3.2. AMMOS Mission Design and Navigation Services.	
Catalog ID / Title	Description
3.3.2-4 Mission Design and Trajectory Optimization Service	Refinement and optimization of trajectories that fulfill the mission requirements, including any combination of maneuvers, gravity assists, low-thrust segments, aero-assist segments, and low energy transfers. Refinement of launch and arrival date ranges. Detailed design of operational orbits. Analysis of delta-V budgets. Analysis and re-optimization of trajectories after a mission event that requires a replanning of the mission. Comment: Missions at the low end might include earth orbiters, trajectories to inner planets or the Moon. Missions at the high end might include missions to outer planets or small bodies. Mission "re-design" costs would be in the category of contingency planning, or extended mission. Mission re-design services are potentially more expensive than preliminary mission design because there may be new and more challenging constraints due to the conditions that necessitated the re-design. This service is not needed if the AMMOS customer already has a mission design, and only desires navigation services. Potentially an annual cost.
3.3.2-5 Launch Trajectory and Vehicle Performance Analysis Service	Optimization of launch vehicle targets to increase the range of launch opportunities or to improve margins. Comment: This service is not necessary if the mission has already launched. It is mandatory if the mission has not yet launched. Missions at the low end might have only a single instantaneous launch opportunity per day during relatively short launch period. Missions at the high end might have a launch opportunity at each minute during each launch window through the entire launch period(s).
3.3.2-6 Vehicle Break-up Analysis Service	Ground impact for spacecraft components. Comment: This service is recommended for any mission to cover anomalous launch contingencies. This service is highly recommended for any lander/rover. This service is mandatory for any mission that involves a designed Earth return. Mission features that increase the cost include use of nuclear materials (launch approval issues), Earth return, missions that jettison parts of the spacecraft (re-contact avoidance).

Table 3.3.2. AMMOS Mission Design and Navigation Services.	
Catalog ID / Title	Description
3.3.2-7 Navigation Analysis and Design Service	Analysis and design of the navigation plan, including optimization of tracking data types and tracking schedules, orbit determination strategy, prediction, delivery and reconstruction accuracy analysis and planetary protection analysis. Comment: This service is mandatory if the navigation service is selected. Missions at the low end might include very low cost missions, earth orbiters, observatory missions, ballistic trajectories to the Moon, or missions for which the operations phase is either short or very routine. Missions at the high end might include missions to outer planets or small bodies, and/or missions for which the operations phase lasts several years. Potentially an annual cost.
3.3.2-8 Entry, Descent, and Landing Analysis and Design Service	Analysis and design of atmospheric entry, descent and landing (EDL). Analysis and optimization of entry parameters and descent profiles. Evaluation of landing accuracy, landing hazards, and success probability. Monte Carlo analysis of EDL trajectories. Also applies to analysis of scenarios where there is no atmosphere (i.e., descent and landing). Comment: This service is not needed for flyby or planetary orbiter missions. This service is mandatory for lander/rover missions. Factors affecting cost include size of the body, whether or not there is an atmosphere, mass of the vehicle, whether or not the landing is guided and/or powered, etc.
3.3.2-9 Launch, Acquisition and Early Mission Orbit Determination Service	Generation of trajectory predicts in support of all possible launch dates and times, launch accuracy assessment, orbit determination and prediction in support of second station acquisition. Comment: This service is not necessary if the mission has already launched when the navigation service is selected. This service is mandatory if the navigation service is selected for a mission that has not yet launched.

Table 3.3.2. AMMOS Mission Design and Navigation Services.	
Catalog ID / Title	Description
3.3.2-10 Orbit Determination Service	Generation of accurate predicted and reconstructed trajectories using a combination of tracking data types. Generation of simulated trajectories and measurements for Operational Readiness Tests and other analysis. Real-time monitoring of tracking data residuals during mission critical events (e.g., maneuvers, orbit insertions, proximity operations). Comment: This is the core service of the Navigation service. Mandatory if the navigation service is selected. Missions at the low end might include Earth orbiters, lunar missions, observatory missions, missions in a very stable orbit, or other missions of short duration. Missions at the high end include orbiters to outer planets or certain phases of missions to small bodies. Cost drivers for include the number of significant events in the mission (e.g. launch, orbit insertions, EDL, critical maneuvers). Annual cost in operations phase may vary widely depending on the mission design.
3.3.2-11 Trajectory Analysis and Maneuver Design Service	Analysis and re-optimization of trajectories and maneuvers that fulfill applicable mission requirements for different mission scenarios. Comment: Mandatory if the navigation service is selected. Missions at the low end might include earth orbiters, observatory missions, libration point missions, etc. Missions at the high end include outer planet orbiters. Potentially an annual cost.
3.3.2-12 Optical Navigation Service	Analysis of optical navigation requirements and camera design. Determination of image parameters, pointing, and imaging schedules. Conversion of images into navigation observables. Determination of small-body surface models and dynamic characteristics based on optical images. May include utilization of the positions of landmarks on a body surface in the navigation process (i.e., landmark tracking). Comment: This service is not necessary for missions to inner planets. Highly recommended for missions to outer planets. Mandatory for missions to outer planet moons and/or small bodies (asteroids, comets). Missions at the low end might have a single target of interest. Missions at the high end might include outer planet orbiters. Cost drivers include the number of opnav pictures taken, number of surface features of interest, number of views of same landmark.

Table 3.3.2. AMMOS Mission Design and Navigation Services.	
Catalog ID / Title	Description
3.3.2-13 Navigation and Ancillary Information Facility (NAIF) Data Processing Service	Production of mission specific SPICE kernels. Provision of reduced and interpreted ancillary datasets to space scientists pertaining to their experiments. (See http://naif.jpl.nasa.gov/naif/index.html.) Comment: Cost drivers include need for unique processing (software development and/or manual intervention).

3.4 Instrument Data Processing and Archiving

Science instrument data product generation, includes processing: display and delivery of science and related engineering data for use by instrument engineers, activity and science planners, in-situ drivers and operators; and public information releases. A product archive pipeline is also provided for metadata/label design, data format transformation, validation and bundling of the mission archive product deliveries to NASA's Planetary Data System (PDS) while ensuring compliance to PDS4 standards.

3.4.1 Instrument Data Processing and Archiving Products

Table 3.4.1. AMMOS Instrument Data Processing and Archiving Products.

Catalog ID / Title	Description
3.4.1-1 Image Format Translation Tool	Image Format Translation Tool is a software application to transform from one image data format to another, while preserving meta-data content. NTR/NPO No. 30470, 47184 Comment: Transcoder tool.

Table 3.4.1. AMMOS Instrument Data Processing and Archiving Products.	
Catalog ID / Title	Description
3.4.1-2 Image Processing Toolkit	Image Processing Toolkit provides an integrated image processing software set, libraries, and a standardized interface. This tool set includes programs for image registration, image display, data conversion routines, pixel plots or listings, label processing and/or display, contrast enhancement, text and graphic overlays, color reconstruction, digital filters, fast Fourier transforms, image blemish removal, image orientation, geometric transformations, map projections, and radiometric calibration. The Image Processing Toolkit is comprised of the following software products: a) Core Video Image Communication And Retrieval (VICAR) Image Processing Software b) Automatic Fusion of Image Data System (AFIDS)/Nest – VICAR-based software scripts that automatically finds tiepoints using smart Fast Fourier Transforms between two similar-viewing orbital satellite reconnaissance Mars imagery to product a co-registered image product with sub pixel accuracy. c) AFIDS/Nest Map – uses Navigation, SPICE, and available terrain data to georeference unmapped Mars images NTR/NPO No. a) VICAR: 49845, b) AFIDS/Nest: 50774, c) AFIDS/Nest_Map: 50779 Comment: Core VICAR does not include the tactical planning enabling software package. Adaptation to be paid by the project. VICAR is NASA open source software and available on NASA's GitHub repository at https://github.com/nasa/vicar.

Table 3.4.1. AMMOS Instrument Data Processing and Archiving Products.	
Catalog ID / Title	Description
3.4.1-3 Image/ Experiment Data Record Display Toolkit	Image/Experiment Data Record Display Toolkit is a software set that provides for display of image files in a variety of image formats: • Java Experimental Data Record Display Interface (JEDI) is a Java-based near real-time image display capability, • xvd is an X-windows, motif based Image Viewer that displays large images, • Java Advanced Display Environment (JADE) provides a high performance image viewer with rapid display of large images (gigabytes), including overlays, stereo display (anaglyph, color glyph, and Java 3D), pan, and zoom features, • Marsviewer is a multi-platform image product display application designed to aid in quality control browsing, and analysis of first-order (Experiment Data Record, or EDR) image data products and "derived" higher order (Reduced Data Record, or RDR) image data products returned by in-situ missions. After selecting one image designated as the primary lookup key, all image products associated with that image can be retrieved and viewed separately and in some cases, graphically overlaid on the primary image. NTR/NPO No. (a) JEDI: 48386, 48387, (b) xfd: 46412, 46922, (c) JADE: 30471, (d) Marsviewer: 40852, 46698, 48691 Comment: Image/EDR/RDR Display collective toolkit.
3.4.1-4 Tactical Product Generation Toolkit	Tactical Product Generation Toolkit is a software set that enables production of tactical instrument data products (e.g., primarily for lander or rover projects, but can be used for orbiters). NTR/NPO No. 47724, 47728, 47731, 47726, 47083, 46696, 30472 Comment: Tactical planning capability enabling single-frame and image mosaicking software.

Table 3.4.1. AMMOS Instrument Data Processing and Archiving Products.	
Catalog ID / Title	Description
3.4.1-5 Instrument Product Access/ Delivery Tool	Instrument Product Access/ Delivery Tool is a software application that provides automated, secure data delivery and integrity validation by subscription (e.g., type, mission, time, filename) within seconds of generation. NTR/NPO No. 47089, 40075 Comment: Also known as File Exchange Interface (FEI) Server and Client. A cloud-based option, Data Distribution Remote Interface for Verified Exchange (DataDRIVE) is a cloud-native instantiation of a data product registration, hosting, and distribution service that offers secure cloud storage, file synchronization, data organization, and client software. Mission data products are tactically generated and stored in Amazon Web Service's Simple Storage Service (S3) and made accessible through both a robust web client and command line tools to remote scientists and engineers. It includes a very powerful search and indexing capability that allows users to quickly find, view and share datasets to support mission and science operation needs.
3.4.1-6 AMMOS-PDS Pipeline Service (APPS)	AMMOS-PDS Pipeline Service (APPS) APPS is a software set that enables creation and validation of PDS4 labels and archive bundles by science data producers. It includes a distributed processing system that can attach to the operational data pipeline and produce archive ready products on the fly. NTR/NPO No. 49793, 49546 Comment: APPS data product archive labeler and pipeline.

Table 3.4.1. AMMOS Instrument Data Processing and Archiving Products.	
Catalog ID / Title	Description
3.4.1-7 Terrain Visualization Toolkit	Terrain Visualization Toolkit is a software set that processes the reference (usually left camera eye) stereo image and its associated XYZ image into a 3-D terrain mesh product. Integration of multiple per-XYZ terrain meshes constitutes the nominal “unified” terrain mesh serviceable that can support rover traverse planning. The XYZ files contain point clouds: sets of vertices in a specific coordinate system. The corresponding image files are used to obtain intensity or color information for each vertex in the point cloud. The terrain meshes are generated by triangulating point clouds using volume based surface extraction. The original image is used as a texture map to add detail and color to the polygonal surface representation, serving as the “skin” (scene) draped on top of the polygonal surface. NTR/NPO No: 46659, 30154 Comment: Also known as 3D terrain mesh generation toolkit (“CRUMBS”).
3.4.1-8 Localization Toolkit	Localization Toolkit is a software set in which one element provides a web-based user interface for display and simple analysis of cartographic (mapping) and science instrument information describing the rover location (“localization”). Another element is a database that stores solutions for rover “localization,” the process of determining the position (location) and orientation (attitude) of the rover at any point in time. The database is a simple query-based mechanism that provides web-based “one-stop shopping” (insertion and extraction) of all Localization solutions Project-wide for use in tactical planning. NTR/NPO No. 49087 Comment: The second element described above is also known as the Position Location and Attitude Correction Estimate Storage (PLACES) database.

Table 3.4.1. AMMOS Instrument Data Processing and Archiving Products.	
Catalog ID / Title	Description
3.4.1-9 Multi-mission Geographical Information System (MMGIS)	Multi-mission Geographical Information System (MMGIS) is software that provides automated daily production of instrument data product localization for orbiters, rovers and instrument placement. NTR/NPO No. 50389
3.4.1-10 Web Resource Platform (WRP)	WRP is an extensible and flexible resource platform that simplifies the use of data products and applications via the web. Powering WRP, is the Webification (w10n) specification that allows resources (data and application) to be exposed through the web via meaningful URLs in a RESTful way. WRP consists of three service components: a) Product Repository The *Product Repository* component provides a capability for uniform access of data products. For a planetary product file on a remote repository, its inner parts, such as labels and imagery data point arrays can be directly retrieved through meaningful URLs in a piece-wise fashion. b) Resource Discovery The *Resource Discovery* component provides a capability for efficient and accurate search of planetary data products. Its instances are built from product metadata information exposed by Product Repository instances. c) Tool Service The *Tool Service* component provides a capability of remote and distributed processing of data products. Its instances are established through auto web service creation of existing off-line tools and libraries. NTR/NPO No. w10n: 48378; a) Product Repository: 50834, b) Resource Discovery: 50835, c) Tool Service: 50836

Table 3.4.1. AMMOS Instrument Data Processing and Archiving Products.	
Catalog ID / Title	Description
3.4.1-11 Autonomous Exploration for Gathering Increased Science (AEGIS)	Autonomous Exploration for Gathering Increased Science (AEGIS) is software that detects science targets in images and enables automated follow-up measurements to be performed on those targets. AEGIS processes grayscale images and using computer vision techniques, identifies a set of cloud boundary contours that correspond to surface targets, such as rocks, veins or nodules. Once targets are identified, AEGIS calculates a set of target features (or properties) that include measures such as size, intensity, shape, orientation, and location. Targets can then be ranked or prioritized based on certain properties, which enables AEGIS to identify certain classes of terrain targets, such as dark float rocks, lighter colored bedrock, or bright veins. Once targets are prioritized, follow-up measurements can be automatically taken of top ranked targets using different remote sensing instruments. NTR/NPO No. 46876
3.4.1-12 Hyperspectral Image Interpretation and Holistic Analysis Tools (HiiHAT)	Hyperspectral Image Interpretation and Holistic Analysis Tools (HiiHAT) is an intelligent assistant to help analysts efficiently browse, summarize, and search hyperspectral images. The software is available as a plugin to the IDL environment. The HiiHAT algorithms are designed for the special challenges of planetary science datasets: 1 **High noise levels** – Many of the most interesting planetary science questions involve spectral features at the limits of detectability. We emphasize robust strategies capable of detecting subtle spectral features with high levels of noise. 2 **Uncertain constituents** – Unlike terrestrial remote sensing, we have very few if any samples from the surface. We address this with “unsupervised” analysis that looks for patterns in the observed data itself. 3 **Fast turnaround time** – Tactical observation planning may require fast decisions, favoring automation where appropriate. NTR/NPO No. 47358

Table 3.4.1. AMMOS Instrument Data Processing and Archiving Products.	
Catalog ID / Title	Description
3.4.1-13 AMMOS Instrument Toolkit (AIT)	AMMOS Instrument Toolkit (AIT) is an easy-to-install, easy-to-operate suite of tools for operating instruments and small satellites. AIT provides commanding and simple sequencing, telemetry processing including limits, unit conversions, plots, archive, and query capabilities, powerful scripting with Python, and modern web-based user interfaces supporting desktop, tablets, and smartphones. Instrument teams, missions with simple spacecraft, missions with small budgets, missions with inexperienced operators, missions operating at Earth, the Moon, at Lagrange points, or in Deep Space would all benefit from the AIT solution. NTR/NPO No. 50696 Comments: 1) AIT supports uplink and downlink to NASA's Deep Space Network (DSN) using the CCSDS Space Link Extension (SLE) protocol; 2) AIT has been open-sourced and released at https://github.com/NASA-AMMOS.
3.4.1-14 AMMOS Science Targeting Toolkit for Robotic Operations (ASTTRO)	AMMOS Science Targeting Toolkit for Robotic Operations (ASTTRO) provides a multi-mission interface to display the surface environment and represent in-situ robotic asset(s) contextually in order to make it easy to view, select and validate achievable science targets. It provides an interactive 3D terrain visualization that acts like a 'Google Street View' for planetary surface missions, displaying a 3D representation of the spacecraft (e.g. a rover) along with instrument data products such as 3D terrain meshes and multiple image product types co-registered together. In addition to creating and viewing targets, ASTTRO can visualize mission activities that are to be performed on targets of interest and provide feedback to users whether an observation is spatially and/or kinematically feasible based on mission-specific constraints.

3.4.2 Instrument Data Processing and Archiving Services

Table 3.4.2. AMMOS Instrument Data Processing and Archiving Services.	
Catalog ID / Title	Description
3.4.2-1 Instrument Product Delivery Service	The Instrument Product Delivery Service provides delivery of instrument products to remote sites. Tracks, delivers, and provides accountability information about delivered products and provides access to Level-0 products (Experiment Data Records-EDRs) and Level-1 or higher products (Reduced Data Records-RDRs). NTR/NPO No. 47089, 40075 Comment: Also known as the File Exchange Interface (FEI) offering As A Service. The project pays for the hardware and the people for deployment and maintenance during the life of the mission/project.
3.4.2-2 Science Data Infrastructure Service	The Science Data Infrastructure Service provides the following services: a) Monitors system processes and performance, b) Provides a long-term (life-of-mission) repository for system / project programs and files, c) Provides hosting capability for project applications servers, d) Provides data facility support, including system administration, monitoring of system processes and performance and notification, e) Performs system maintenance activities, such as routine backups, user accounts, installation of Third Party Software, f) Performs analysis of requirements and provides design of hardware system to meet user requirements. Comment: This is the infrastructure Service known as the Multimission Image-Processing Laboratory (MIPL).
3.4.2-3 Planetary Data System (PDS) Archive Transformation Service (PATS)	Planetary Data System (PDS) Archive Transformation Service (PATS) is a service that provides an efficient method to transform archived data from PDS3 to PDS4 standards, process labels (and reprocess data if necessary) and deliver back to the PDS as PDS4-compliant bundles.

4 AMMOS Products and Services: Crosscutting Capabilities

In addition to capabilities offered in support of the major mission operations discipline-specific functions described in Sections 3.1 through 3.4, MGSS offers AMMOS crosscutting capabilities needed to standup a GDS and to operate and sustain a Project MOS.

4.1 Crosscutting Products

Table 4.1.1. AMMOS Crosscutting Products.

Catalog ID / Title	Description
4.1-2 Common Access Manager (CAM)	Common Access Manager (CAM) is software that provides application layer access control capabilities, including single sign-on (SSO), federation, authorization management, authorization checking & enforcement, identity data retrieval, and associated logging. CAM can use Lightweight Directory Access Protocol (LDAP), Active Directory, Kerberos, NASA Personal Identity Verification (PIV) smart card and RSA SecurID® for identification and authentication. NTR/NPO No: 49943 Dependencies (Third-Party): The CAM Server software includes an Enterprise Release of OpenAM Server 13.5.x from ForgeRock (http://www.forgerock.com). It is free to distribute and free to use for development and testing, but an OpenAM product support license from ForgeRock is required for operational use. A support license is not needed for operational use of the CAM Client software (i.e., the part integrated into software applications). Mission customers that wish to make use of this capability must arrange to procure a third-party software license for use in operations through their local acquisition office.

Table 4.1.1. AMMOS Crosscutting Products.	
Catalog ID / Title	Description
4.1-3 Common Workflow Service (CWS)	Common Workflow Service (CWS) is a standards-based Business Process Management (BPM) software solution for executing and managing mission operations processes. Supports the Business Process Model & Notation™, Version 2.0 (BPMN™ 2.0) standard developed by the Object Management Group® (OMG®). Can use 0 Common Access Manager (CAM) and/or local Lightweight Directory Access Protocol (LDAP) provider for authentication. Authorization is internally managed within CWS. NTR/NPO No: 49929 Dependencies: 0 Common Access Manager (CAM) or LDAP (latter not provided by the AMMOS)
4.1-4 System Security Monitor (SSM)	System Security Monitor (SSM) is software used to alert designated recipients (e.g., System Administrators) when important system files have been altered unexpectedly. Such mechanisms can be applied to monitor the integrity of operating system files, software application files, configuration files, and other files that are not expected to change when the system is operated. The monitored files list is customizable. SSM logs detected changes, and can send an e-mail to a customizable list of recipients. NTR/NPO No: 50932
4.1-5 Compute Environment Configuration Modules (CECM)	Compute Environment Configuration Modules (CECM) is a set of Puppet (http://puppet.com) modules used by System Administrators (SAs) and Deployment Engineers to configure instances of the Red Hat Enterprise Linux (RHEL) 7 operating system (OS) and its bundled software during system deployment and when upgrading systems. The CECM configures operating system security (e.g., disabling unnecessary services such as telnet) and desktop settings to provide a secure platform that is properly set up to run the AMMOS software. NTR/NPO No: 50933

4.2 Crosscutting Services

Table 4.2.1. AMMOS Crosscutting Services	
Catalog ID / Title	Description
4.2-1 Multimission Configuration Management (MMCM) Services	The Multimission Configuration Management (MMCM) Services establishes controls and compliance allowing for traceability, repeatability and accountability throughout a project's entire lifecycle. It consists of six functional areas: 1) Source code management, 2) Build engineering, 3) Environment control, 4) Change control, 5) Release engineering, 6) Deployments, and 7) Operations Management (of blocks, commands, sequences, and any other form of command to the flight system). These functional areas are configurable to fit any size Project/Mission. Also provided are certified and trained CM engineers that are equipped to effectively implementing CM for Projects/Missions. An archive repository is provided for mission-released software that is maintained locally as well as providing scheduled off-site backups.
4.2-2 Relay Operations Service	The Relay Operations Service enables an asset orbiting a target body (e.g., Moon, Mars, asteroid) to return data to Earth on behalf of a landed asset and enables data from Earth to be forwarded to a landed asset via an orbiting asset. Relay Planning involves coordinating and scheduling these relay activities. Missions that use this service integrate the earth-orbiter-lander communication sessions into their mission plans.
4.2-3 Multimission Resource Scheduling Service (MRSS)	The Multimission Resource Scheduling Service provides support to customers in the Resource Allocation and Planning (RAP) process, helping to communicate and coordinate Project needs for DSN tracking. The service includes (but is not limited to) assisting projects with resource selection and planning, submitting project requests to the RAP Services Team and overseeing their accuracy, negotiating DSN resources to support Project activities, participation in relay coordination between landed and orbiting assets, delivering files to support the sequencing process, and reporting status of requests to projects.

Table 4.2.1. AMMOS Crosscutting Services	
Catalog ID / Title	Description
4.2-4 Duty Roster Service	The Duty Roster Service is a web based notification system that allows a customer (mission/service provider) to tailor functional roles that map to their organization structure, and enable teams and individual members to be responsible for their status. By mapping to an organization structure, distinct groups can be defined. Groups can be a collection of roles, resources or other groups. The entire duty roster is laid out so that a user can quickly view role and contact information they need. Additionally, it provides search capability to expedite finding individuals assigned to specific roles. Notifications can be sent to a customizable list of active roles and individuals. The system incorporates a calendar capability that provides a history of status changes and allows for scheduling future role availability. The Roster is available across a broad range of mobile devices.

5 Obtaining AMMOS Products, Services, and Support

5.1 MGSS Contacts

The primary MGSS Mission Interface Office (MIO) contact persons as well as MGSS Program Management contacts are provided on the AMMOS website and will thus not be repeated here.[9]

Managing customer commitments is the primary responsibility of the MGSS MIO and as such the MIO should be the customer's primary contact point when soliciting additional information regarding AMMOS Products and Services capabilities described in this Catalog. The MIO supports customers from ongoing missions, assigned missions, competed missions, and Universities and other Research entities requiring AMMOS capabilities.

Although the internal workings and process architectures used by the MIO team to execute their work is detailed in the cited reference MGSS Applicable Documents and Processes (Section 0), the primary components of the MIO commitments process include: a) Contributions to proposal development both internal and external, b) development and update of Service Level Agreements (SLAs), c) updating cost estimates and d) monitoring of customer commitments over the course of the project lifecycle.[10]

5.2 Obtaining AMMOS Software

All software capabilities listed in this AMMOS Catalog include a New Technology Report (NTR) / NASA Pasadena Office (NPO) number in the description field. This number is required for all JPL-developed AMMOS software when requesting a software license for use whether it be dissemination to a U.S. government agency (including NASA), a U.S. government contractor, a 3rd party for research use, or a 3rd party for commercial use. The website for requesting software licenses can be found at the following URL: https://download.jpl.nasa.gov.

The basic process for obtaining AMMOS software involves the MIO's vetting customer requests to ensure valid requests are being made and not from unauthorized sources such as Internet bots or unlawful foreign or domestic entities. For internal (JPL-managed project) customers, the request is approved and passed to the cognizant AMMOS Element Manager (AEM) to negotiate with the customer any needed support, including software adaptation. The AEM then works in collaboration with the implementing line organization and with key members of the MGSS Systems Engineering Organization (SEO) including the MGSS Configuration Management (CM) Lead; Multimission Integration, Test, and Deployment Engineers; and the MGSS System Security Engineer to ensure the software is the correct version, documentation is in place, that it is secure, and that it works in its targeted environment.

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[9] See https://ammos.nasa.gov/contact/.

[10] An AMMOS Catalog Checklist is provided in Appendix B and can be printed and completed by prospective mission customers to assist in the initial SLA development process. Alternatively a softcopy of a native MS Word file with active checkboxes can be provided to the customer upon request.

For external customers, following the customer request vetting process by the MIO, the request is passed to the JPL/Caltech Software Release Authority (SRA) as a request for license.[11] The SRA then produces the appropriate software license depending on dissemination type (as summarized above). If approved, the MIO notifies the customer.

5.3 Cost Estimates

As stated in the AMMOS Value Proposition section of this Catalog document (Section 2.2), adaptation of multimission core AMMOS components is faster and less costly than developing a new mission operations system from the bottom up for every individual project, and these projects enjoy greater reliability by using proven tools. Missions can choose AMMOS multimission components and/or mission-specific adaptations in unique combinations that meet their specific needs. They pay only for the components they need.

Cost Estimation Policy

NASA has established policies that govern how the cost for AMMOS products and services are allocated between multimission base funding and individual project (i.e., mission) funding.

The cost of *adapting* AMMOS products and services for specific mission operations is charged to the benefiting mission. If the new capability will benefit several missions, MGSS may provide some or all of the development cost.

A "grass-roots," design-based, costing exercise is highly recommended for estimation of costs for services, products, and support. This is typically conducted for missions in the formulation phase by an engineering team organized through the Mission Interface Office (MIO).

Cost Estimates for Standard Missions

In general, engineering, development, routine maintenance and delivery of multimission core tools are considered to be multimission costs. Adaptation costs (engineering, development, maintenance, and deployment) and operations costs are considered to be project-specific costs.

Engineering and Shared Operations Support Costs

Except as otherwise noted, the customer will incur the costs of the Engineering Support Activities and Shared Operations Support to which they subscribe, as negotiated through the MIO.

[11] The SRA within JPL's Office of Technology Transfer (OTT) is the software licensor for all JPL-developed software described in this Catalog in accordance with Caltech copyright policy for such software (see https://ott.jpl.nasa.gov/index.php?page=software).

Appendix A
Acronyms and Abbreviations

AEGIS	Autonomous Exploration for Gathering Increased Science
AEM	AMMOS Element Manager
AFIDS	Automatic Fusion of Image Data System
AIT	AMMOS Instrument Toolkit
AMMOS	Advanced Multi-Mission Operations System
AMPCS	AMMOS Mission Data Processing and Control System
AOS	Advanced Orbiting System
APGEN	Activity Plan Generator
APPS	AMMOS-PDS Pipeline Service
ASTTRO	AMMOS Science Targeting for Robotic Operations
CAM	Common Access Manager
CCSDS	Consultative Committee for Space Data Systems
CECM	Compute Environment Configuration Modules
CM	Configuration Management
COTS	Commercial Off-The-Shelf
CRC	Cyclic Redundancy Check
CTS	Command Translation Subsystem
CWS	Common Workflow Service
DSN	Deep Space Network
EDL	Entry Decent and Landing
EDR	Experimental Data Record
EVR	Event Record
FEI	File Exchange Interface
FFRDC	Federally Funded Research and Development Center
GDS	Ground Data System
GSE	Ground Support Equipment
HiiHAT	Hyperspectral Image Interpretation and Holistic Analysis Tools
IND	Interplanetary Network Directorate
JADE	Java Advanced Display Environment
JEDI	Java Experimental Data Record Display Interface
JPL	Jet Propulsion Laboratory
LDAP	Lightweight Directory Access Protocol

MCWS	Mission Control Web Service
MGSS	Multimission Ground System and Services
MIPL	Multimission Image-Processing Laboratory
MMCM	Multimission Configuration Management
MMGIS	Multimission Geographical Information System
MIO	Mission Interface Office
MOS	Mission Operations System
MPS	Mission Planning and Sequencing
NAIF	Navigation Ancillary Information Facility
NASA	National Aeronautics and Space Administration
NEN	Near-Earth Network
NPO	NASA Pasadena Office
NTR	New Technology Report
OTT	Office of Technology Transfer
OS	Operating System
PATS	Planetary Data System Archive Transformation Service
PDS	Planetary Data System
PDU	Protocol Data Unit
RAP	Resource Allocation and Planning
RAVEN	Resource and Activity Visualization ENgine
RDR	Reduced Data Record
SA	System Administrator
SCC	SLE Command Client
SEO	Systems Engineering Office
SEQGEN	Sequence Generation
SEQ_REVIEW	Sequence Review
SLA	Service Level Agreement
SLE	Space Link Extension
SLINC	Spacecraft Language Interpreter and Collector
SRA	Software Release Authority
SSM	System Security Monitor
SSO	Single Sign-On
TDAC	Test Data Acquisition and Command
TM	Telemetry
UARC	University Affiliated Research Center

ULSGEN	Uplink Summary Generator
VICAR	Video Image Compression and Retrieval
VISTA	Visualization for Telemetry Analysis
WRP	Web Resource Platform
w10n	Webification

Appendix B
AMMOS Catalog Checklist
Version 5.3 Rev C

Catalog ID	AMMOS Products and Services	Yes	No	Maybe
Functional Discipline Capabilities				
3.1.1	**Planning and Sequencing (Products)**			
3.1.1-1	Activity Plan Generator (APGEN)	☐	☐	☐
3.1.1-2	Sequence Generation (SEQGEN)	☐	☐	☐
3.1.1-3	Mission Planning and Sequencing (MPS) Editor	☐	☐	☐
3.1.1-4	Sequence Review (SEQ_REVIEW)	☐	☐	☐
3.1.1-5	Spacecraft Language Interpreter and Collector II (SLINC II) / Command Translation Subsystem (CTS)	☐	☐	☐
3.1.1-6	Mission Planning and Sequencing Server (MPSServer)	☐	☐	☐
3.1.1-7	Resource and Activity Visualization Engine (RAVEN)	☐	☐	☐
3.1.1-8	Uplink Summary Generator (ULSGEN)	☐	☐	☐
3.1.1-9	Telecom Prediction and Trending Analysis	☐	☐	☐
3.1.1-10	Multi Mission Time Correlation	☐	☐	☐
3.1.1-11	Sequence Tracker	☐	☐	☐
3.2.1	**Mission Control (Products)**			
3.2.1-1	AMMOS Mission Data Processing and Control System (AMPCS)	☐	☐	☐
3.2.1-2	Mission Control Web Service (MCWS)	☐	☐	☐
3.2.1-3	Visualization for Telemetry Analysis (VISTA)	☐	☐	☐
3.2.1-4	Test Data Acquisition and Command (TDAC)	☐	☐	☐
3.2.1-5	SLE Command Client (SCC)	☐	☐	☐
3.3.1	**Mission Design and Navigation (Products)**			
3.3.1-1	SPICE Toolkit[a]	☐	☐	☐
3.3.1-2	SPICE Data/Kernels[a]	☐	☐	☐
3.3.1-3	Monte	☐	☐	☐
3.3.2	**Mission Design and Navigation (Services)**			
3.3.2-1	Natural Body Ephemeris Service	☐	☐	☐
3.3.2-2	Gravity Modeling Service	☐	☐	☐
3.3.2-3	Preliminary Mission Design Service	☐	☐	☐
3.3.2-4	Mission Design and Trajectory Optimization Service	☐	☐	☐

Catalog ID	AMMOS Products and Services	Yes	No	Maybe
3.3.2-5	Launch Trajectory and Vehicle Performance Analysis Service	☐	☐	☐
3.3.2-6	Vehicle Break-up Analysis Service	☐	☐	☐
3.3.2-7	Navigation Analysis and Design Service	☐	☐	☐
3.3.2-8	Entry, Descent, and Landing Analysis and Design Service	☐	☐	☐
3.3.2-9	Launch, Acquisition and Early Mission Orbit Determination Service	☐	☐	☐
3.3.2-10	Orbit Determination Service	☐	☐	☐
3.3.2-11	Trajectory Analysis and Maneuver Design Service	☐	☐	☐
3.3.2-12	Optical Navigation Service	☐	☐	☐
3.3.2-13	Navigation and Ancillary Information Facility (NAIF) Data Processing Service	☐	☐	☐
3.4.1	**Instrument Data Processing and Archiving (Products)**			
3.4.1-1	Image Format Translation Tool	☐	☐	☐
3.4.1-2	Image Processing Toolkit[a]	☐	☐	☐
3.4.1-3	Image/Experiment Data Record Display Toolkit	☐	☐	☐
3.4.1-4	Tactical Product Generation Toolkit	☐	☐	☐
3.4.1-5	Instrument Product Access/Delivery Tool	☐	☐	☐
3.4.1-6	AMMOS-PDS Pipeline Service (APPS)	☐	☐	☐
3.4.1-7	Terrain Visualization Toolkit	☐	☐	☐
3.4.1-8	Localization Toolkit	☐	☐	☐
3.4.1-9	Multi-Mission Geographical Information System (MMGIS)	☐	☐	☐
3.4.1-10	Web Resource Platform (WRP)	☐	☐	☐
3.4.1-11	Autonomous Exploration for Gathering Increased Science (AEGIS)	☐	☐	☐
3.4.1-12	Hyperspectral Image Interpretation and Holistic Analysis Tools (HiiHAT)	☐	☐	☐
3.4.1-13	AMMOS Instrument Toolkit (AIT)[a]	☐	☐	☐
3.4.1-14	AMMOS Science Targeting Toolkit for Robotic Operations (ASTTRO)	☐	☐	☐
3.4.2	**Instrument Data Processing and Archiving (Services)**			
3.4.2-1	Instrument Product Delivery Service	☐	☐	☐
3.4.2-2	Science Data Infrastructure Service	☐	☐	☐
3.4.2-3	Planetary Data System (PDS) Archive Transformation Service (PATS)	☐	☐	☐

Catalog ID	AMMOS Products and Services	Yes	No	Maybe
Crosscutting Capabilities				
4.1	**Crosscutting Capabilities (Products)**			
4.1-2	Common Access Manager (CAM)	☐	☐	☐
4.1-3	Common Workflow Service (CWS)	☐	☐	☐
4.1-4	System Security Monitor (SSM)	☐	☐	☐
4.1-5	Compute Environment Configuration Modules (CECM)	☐	☐	☐
4.2	**Crosscutting Capabilities (Services)**			
4.2-1	Multimission Configuration Management (MMCM) Services	☐	☐	☐
4.2-2	Relay Operations Service[b]	☐	☐	☐
4.2-3	Multimission Resource Scheduling Service	☐	☐	☐
4.2-4	Duty Roster Service	☐	☐	☐

Notes:

a. Catalog product item not needed in an SLA; freely available in the public domain.

b. For Mars Relay Operations Service (MaROS), catalog product item not needed in an SLA; paid for by Mars Program Office.

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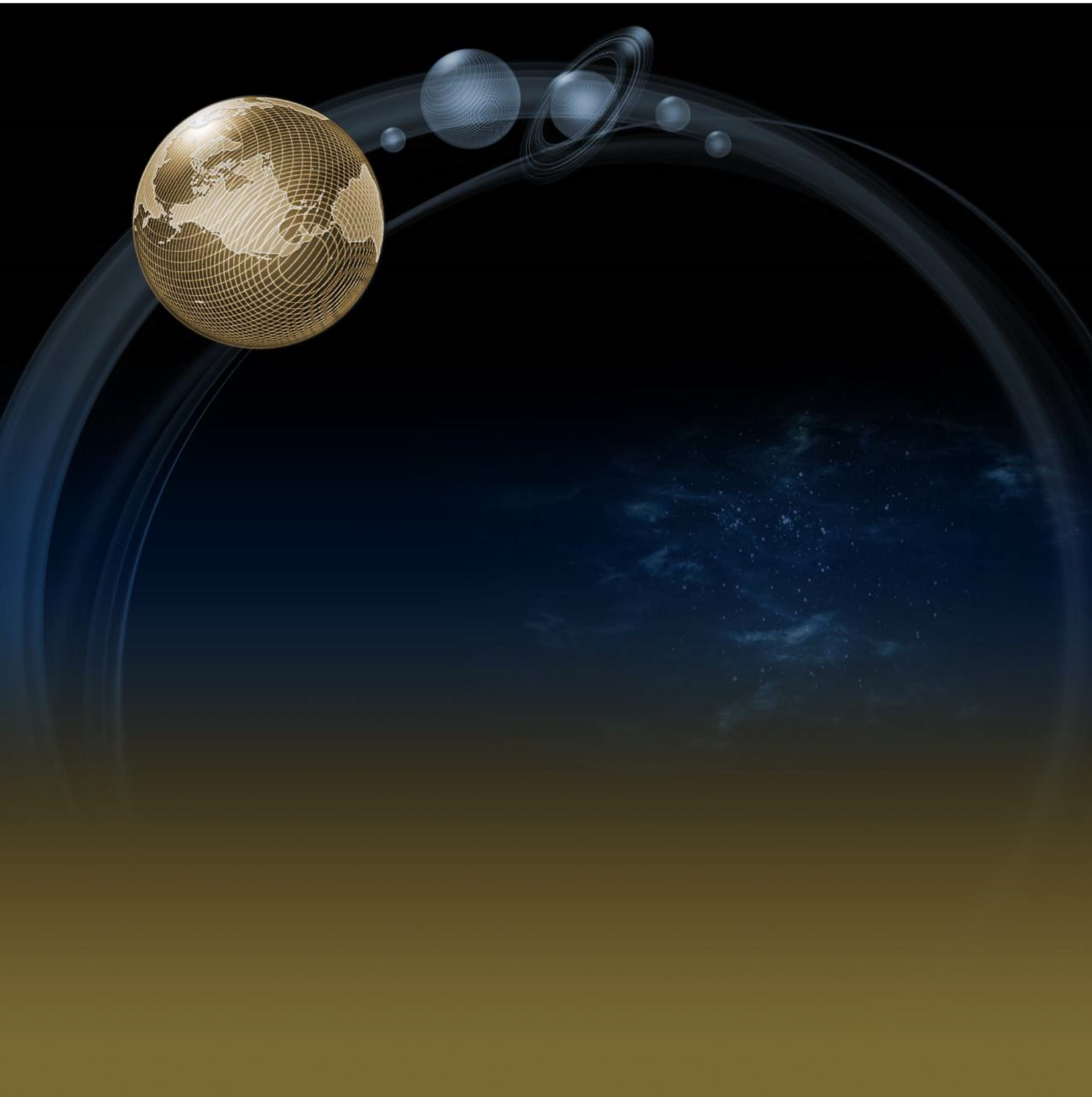

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