National Aeronautics and Space Administration

NASA AMMOS

Advanced Multi-Mission Operations System

Managed by the Multi-mission Ground System and Services (MGSS) Program Office for NASA

AMMOS Catalog
Version 5.5

AMMOS Products and Services support these mission types:

Deep Space CubeSats and SmallSats

Heliophysics

Astrophysics

Earth Sciences

Planetary Sciences

Catalog Custodian: Zsarina Benecken

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Section 1
Introduction

1.1 Identification

This document is the Advanced Multi-Mission Operations System (AMMOS) Catalog, Version 5.5 released in October 2022.

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 Mission Support Definitions and Commitments Office 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]

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

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 the distinctions between Products and Services capabilities are as follows:

1. **Products** – Products are multimission capabilities that include AMMOS core software, data, and models that are licensed for use by mission customers. AMMOS products include open source software that are available in GITHUB. Location of these open source products can be downloaded in https://github.com/NASA-AMMOS/. 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.

Section 2
AMMOS Overview

2.1 What is the AMMOS?

The 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.

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 from phases A through F along with critical events.

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.

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

[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.

AMMOS capabilities during a Periodic "Call for Ideas" via the AMMOS website (see https://ammos.nasa.gov/contributing/callforideas/).

2.3 System Context

2.3.1 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]

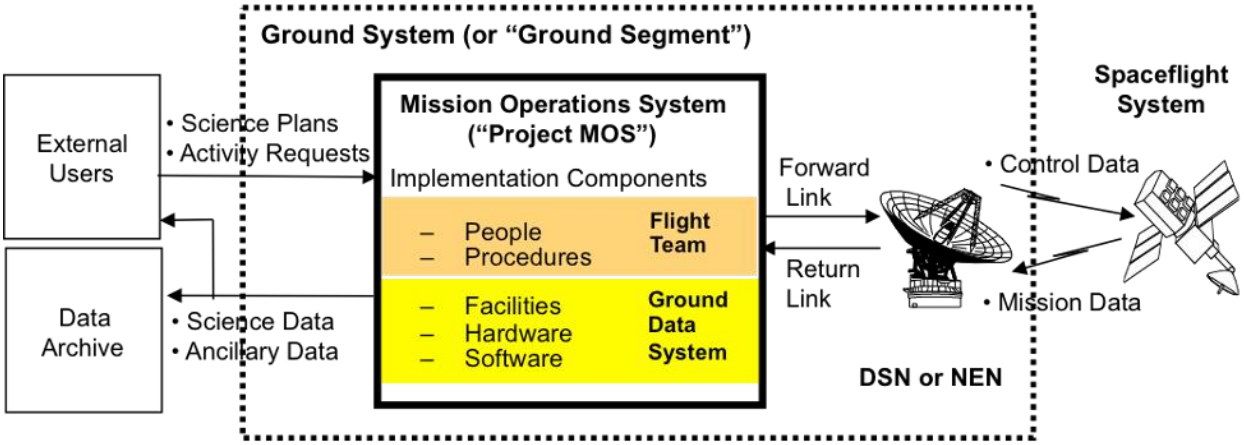

Figure 2.3-1. NASA space science Mission Operations System within the context of an end-to-end Ground System.

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.

2.4 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-Space Network (NSN)).

[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.

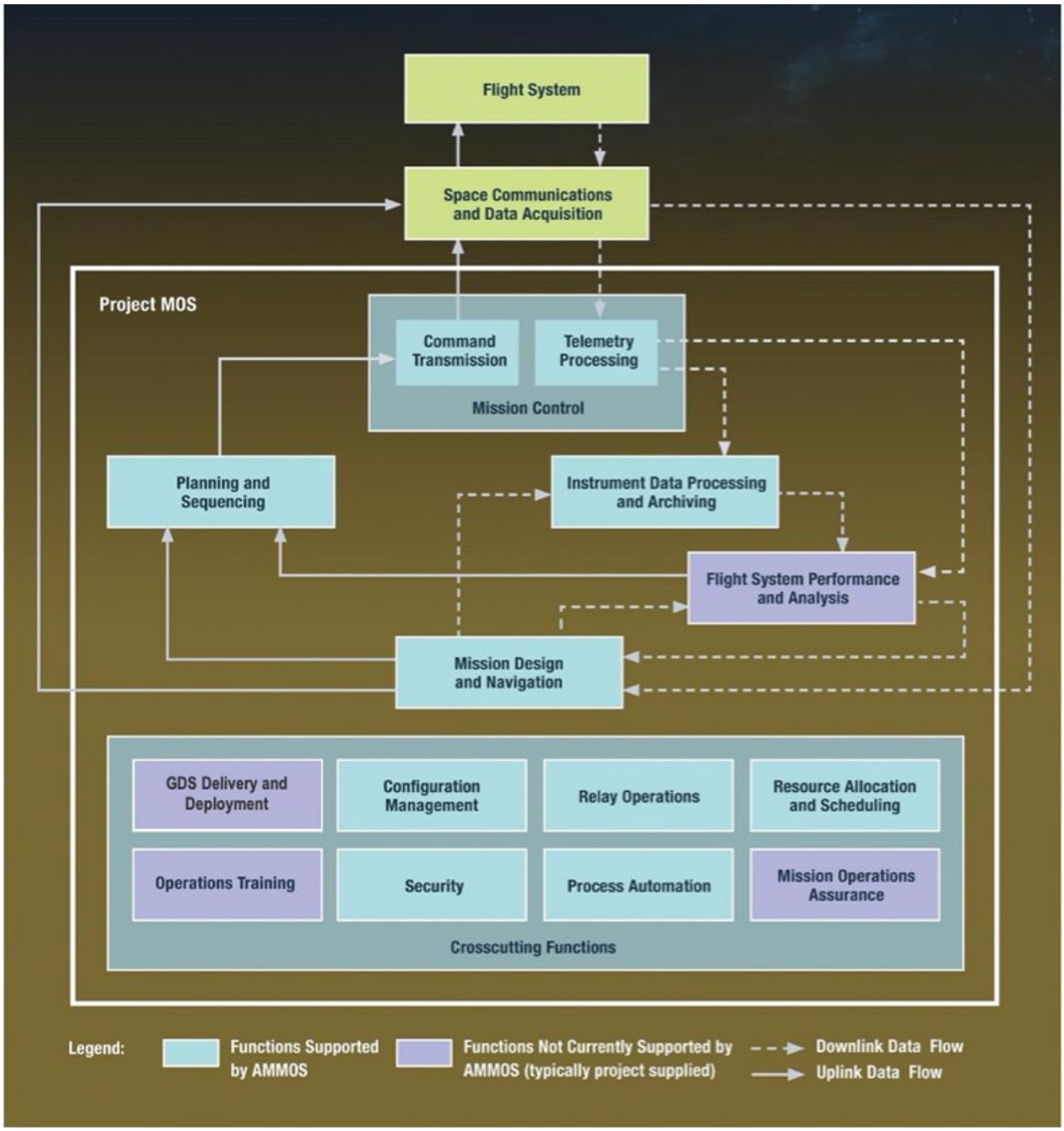

Figure 2.3-2. High-level Project MOS functions in a Mission Operations environment (or 'venue').

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.

- **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 NSN).
- **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.[4]
- **Mission Design and Navigation** – Planning/optimizing the flight system trajectory for future mission activities and maintaining knowledge of its position/velocity during flight.
- **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.
- **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

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

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.
- **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.

Section 3
AMMOS Products and Services: Functional Discipline Capabilities

3.1 Mission Planning, Sequencing and Analysis

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 Mission Planning, Sequencing and Analysis Products

Table 3.1.1. AMMOS Planning and Sequencing and Analysis Products.

Catalog ID /Title	Description
3.1.1-1 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.
3.1.1-2 Mission Planning andSequencing (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 ofSEQGEN. 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); 3.1.1-2Sequence Generation (SEQGEN); 3.1.1-5 Spacecraft Language Interpreter and Collector II (SLINC II)Spacecraft Language Interpreter and Collector II (SLINC II); 3.1.1-6 Mission Planning andSequencing Server (MPSServer); 0 Common Access Manager (CAM) (optional for authentication; used at mission's discretion)
3.1.1-3 Sequence Review (SEQ_ REVIEW)	Sequence Review (SEQ_REVIEW) is file viewer software that letsthe 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 allowsthe 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

Table 3.1.1. AMMOS Planning and Sequencing and Analysis Products.

Catalog ID /Title	Description
3.1.1-4 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)
3.1.1-5 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, displayedin a timeline format via web browser. NTR/NPO No. 50376 Dependencies: 3.1.1-6 Mission Planning and Sequencing Server (MPSServer)
3.1.1-6 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)
3.1.1-7 Multi Mission Time Correlation (MMTC)	A tailorable, stand-alone, mission-independent product that receivestime as measured onboard the spacecraft and associate it with defined Earth-time. The product records this association in a SPICE SCLK Kernel.
3.1.1-8 SequenceTracker	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 NSN).[5]

[5] 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 interfacewith a project's Ground Support Equipment (GSE) that is used to communicate with the flight system inthese environments (or so-called 'venues').

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 **Automation Support** • Script access to telemetry via Python • Alarm notification via email • Automated antenna station connections/disconnections and telemetry processing according to schedule **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.

Table 3.2.1. AMMOS Mission Control Products.

Catalog ID /Title	Description
3.2.1-2 Mission Control Web(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 Open MissionControl (MCT)for Mission Control Web Service (MCWS) (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-createddisplay layouts. NTR/NPO No. 50312 Dependencies: 3.2.1-1 AMMOS Mission Data Processing andControl System (AMPCS) and Common Access Manager CAM) **Note: Elasticsearch is a trademark of Elasticsearch BV, registeredin the U.S. and in other countries.**
3.2.1-3 Open Mission Control (MCT)for Mission Control Web Service (MCWS)	The Open MCT for MCWS 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. Open MissionControl (MCT)for Mission Control Web Service (MCWS) provides composable displays specialized for telemetry information including historical and realtime data for Channels, Event Records, Data Products, and Dictionaries. It allowsusers 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: Open MissionControl (MCT)for Mission Control Web Service (MCWS) is an application built on top of Open MCT, whichis 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.

Table 3.2.1. AMMOS Mission Control Products.

Catalog ID /Title	Description
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 aspacecraft 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 performone or more of the following functions, including but not limited to: • Demodulation • De-randomization • Decoding (Turbo & Reed Solomon) • 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 telemetrydata 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 themat 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 Space Network (NSN) 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 theDistributed Object Manager (DOM); or from a file system accessibleto 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 NSN 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 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, whereground 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.

Table 3.2.1. AMMOS Mission Control Products.

Catalog ID /Title	Description
	SCC Workstation is an environment intendedfor the users to directly access and run tools that interact with the SCC Server.
3.2.1-6 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 applicationand set of software libraries, respectively that translate sequencecommands from command mnemonics to binary. (Note: CCSDS File Delivery Protocol (CFDP) binary file can also be produced.) NTR/NPO No. 48066

3.3 Mission Design and Navigation

Software for 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. Using SPICE, engineers, scientists, and analysts can, for example: evaluate planned spacecraft trajectories; perform mission engineering analyses; plan instrument pointing profiles; analyze and/or visualize observation geometry; and perform science data analysis and archiving. NTR/NPO No: 19984, 42432, 47017 Comments: There is no charge for the SPICE Toolkit. It may be freely downloaded from http://naif.jpl.nasa.gov/naif/. The NAIF Group at JPL may be contracted to perform mission-specific SPICE kernel production/validation, mission-specific consultation on the use of SPICE, and SPICE archive preparation with delivery to the Planetary Data System. Contracting for an intermediate set of services, such as mission-specific SPICE training, or consultation on SPICE production, is also possible.
3.3.1-2 SPICE Generic Kernels	These data products consist of generic reference data sets containing ancillary navigation data that may be accessed or manipulated via the SPICE Toolkit. Three separate sets of ephemerides in SPICE-ready format are available: 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).

Table 3.3.1. AMMOS Mission Design and Navigation Products.

Catalog ID /Title	Description
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 through flight navigation services to end of mission. NTR/NPO No: NPO-48184, NPO-50395 Using Monte, mission design and/or navigation teams can provide the following services to flight projects (note that the actual services required by a mission are more properly defined by analysis in a Task Plan, Mission Plan, and/or Navigation Plan): Preliminary Mission Design: 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. Mission Design and Trajectory Optimization: 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. Launch Trajectory and Vehicle Performance Analysis: Optimization of launch vehicle targets to increase the range of launch opportunities or improve margins. Navigation Analysis and Design: 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. Entry, Descent, and Landing Analysis/Design: Analysis and design of atmospheric entry, descent and landing (EDL). Evaluation of landing accuracy, landing hazards, and success probability. Launch, Acquisition and Early Mission Orbit Determination: 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. Orbit Determination: 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). Trajectory Analysis and Maneuver Design: Analysis and re-optimization of trajectories and maneuvers that fulfill applicable mission requirements for different mission scenarios. Optical Navigation: 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

Table 3.3.1. AMMOS Mission Design and Navigation Products.

Catalog ID /Title	Description
	positions of landmarks on a body surface in the navigation process (i.e., landmark tracking).
3.3.1-4 Natural Body Ephemerides	These data products consist 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. Categories of ephemeris include (a) solar system planets, (b) planetary satellites, and (c) small bodies (e.g., comets, asteroids). Comment: Generic versions of ephemerides are available at no charge. Costs associated with the natural body ephemeris products may accrue if the mission has a special need (usually only if a dedicated observation campaign is required to gather the requisite data).
3.3.1-5 Natural Body Gravity Models	These data products consist 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 products 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.

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 Mission Design & Navigation Services	Mission Design & Navigation Services consist of mission designers and navigators using AMMOS products to provide the technical tasks as described in the product offerings above, as applicable to the mission needs. Specific details of the services to be provided to a mission should be described in a Task Plan and/or a Work Agreement.
3.3.2-2 Extraterrestrial Mission Conjunction Assessment Service	The conjunction assessment service is automatically provided for orbital environments where more than one planetary orbiter is in operation (e.g., Mars, Earth's Moon, Sun/Earth L1/L2). The overlapping spans of spacecraft ephemerides are screened to identify close approach events that meet flight project thresholds reflecting the uncertainty in orbit radial and down track position and timing. Reports are emailed to designated project personnel. A service representative works with projects to determine an appropriate response in cases where a close approach is determined to be "too close" based on thresholds.

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 preservingmeta-data content. NTR/NPO No. 30470, 47184 Comment: Transcoder tool.
3.4.1-2 Image Processing Toolkit	Image Processing Toolkit provides an integrated image processingsoftware 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 blemishremoval, image orientation, geometric transformations, map projections, and radiometric calibration. The Image Processing Toolkit is comprised of the following softwareproducts: 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 tie points using smart Fast Fourier Transforms between two similar-viewing orbital satellite reconnaissance Mars imageryto product a co-registered image product with sub pixel accuracy. c) AFIDS/Nest Map – uses Navigation, SPICE, and availableterrain 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.
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 aJava-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, andanalysis 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, allimage products associated with that image can be retrieved and viewed separately, and in some cases, graphically overlaid on the primary image.

Table 3.4.1. AMMOS Instrument Data Processing and Archiving Products.

Catalog ID /Title	Description
	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 GenerationToolkit	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.
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 PipelineService (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.
3.4.1-7 Terrain VisualizationToolkit	Terrain Visualization Toolkit is a software set that processes the reference (usually left camera eye) stereo image and its associatedXYZ 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 topof the polygonal surface. NTR/NPO No: 46659, 30154 Comment: Also known as 3D terrain mesh generation toolkit("CRUMBS"), Mesh Geometry Streaming Service, Mesh Quality Assessment.

Table 3.4.1. AMMOS Instrument Data Processing and Archiving Products.

Catalog ID /Title	Description
3.4.1-8 LocalizationToolkit	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 ofdetermining 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" (insertionand 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 asthe Position Location and Attitude Correction Estimate Storage (PLACES) database.
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 Comments: MMGIS has been open-sourced and released at https://github.com/NASA-AMMOS/MMGIS.
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
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.

Table 3.4.1. AMMOS Instrument Data Processing and Archiving Products.

Catalog ID /Title	Description
	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 Planetary Data System (PDS) Ongoing Delivery Service (PODS)	PODS is a service that provides an efficient method to prepare science data products with associated PDS metadata, validate all label data, bundle the data and deliver it to the appropriate PDS node(s) to support PDS delivery requirements.
3.4.1-13 AMMOS Instrument Toolkit (AIT)	AMMOS Instrument Toolkit (AIT) is an open source, easy-to-install, and easy-to-use toolkit of common instrument, CubeSat and SmallSat capabilities. It is python-based and provides discrete capabilities and interfaces to meet the most common requirements for uplink, downlink, basic sequencing and telemetry processing. Deploying AIT as part of a complete instrument control system requires integrating the toolkit components to align with instrument/CubeSat specific flight software as well as the development of packet handling capabilities and integration with your ground station provider. 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).

Table 3.4.2. AMMOS Instrument Data Processing and Archiving Services.

Catalog ID / Title	Description
	NTR/NPO No. 47089, 40075 Comment: Also known as the File Exchange Interface (FEI) or DataDrive 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.

Section 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.

4.1.1 Crosscutting Products

Table 4.1.1. AMMOS Crosscutting Products.

Catalog ID / Title	Description
4.1.1-1 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 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.
4.1.1-2 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: Common Access Manager (CAM) or LDAP (latter not provided by the AMMOS)
4.1.1-3 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

Table 4.1.1. AMMOS Crosscutting Products.

Catalog ID / Title	Description
4.1.1-4 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
4.1.1-5 Key Management and Cryptography(KMC)	The AMMOS Key Management and Cryptography (KMC) software provides data level cryptography capabilities, including file/data encryption, decryption, and cryptographically strong integrity check value (ICV) creation and verification. The KMC software provides a Web service interface, a Java library, and a command line interface (CLI) that software applications (and people, in the case of the CLI) can use to perform cryptography on files/data. The Uplink Summary Generator (ULSGEN) software has already been integrated with KMC, and additional applications will be integrated with KMC in future AMMOS releases. In the AMMOS A31.0 release, KMC adds a capability to apply the CCSDS Space Data Link Security (SDLS) protocol to telecommand transfer frames. KMC cryptography capabilities can use any off-the-shelf Key Management Service (KMS) product (not part of the AMMOS) that complies with the Key Management Interoperability Protocol (KMIP) with TLS mutual authentication, or a Java keystore. • NTR/NPO No.: 50015 • Dependencies: The KMC Cryptography Service (i.e., Web Interface) uses the Common Access Manager (CAM).

4.1.2 Crosscutting Services

Table 4.1.2. AMMOS Crosscutting Services

Catalog ID / Title	Description
4.1.2-1 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.

Table 4.1.2. AMMOS Crosscutting Services

Catalog ID / Title	Description
4.1.2-2 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.
4.1.2-3 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.
4.1.2-4 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.

Section 5
AMMOS Future Product Offerings

The AMMOS's continues to evolve its functionality by modernizing its product offerings. Publicizing upcoming products in the catalog allows customers to plan for utilizing these products for their missions. Future AMMOS products are described in this section.

5.1 Future AMMOS Planning and Sequencing Products

Table 5.1 AMMOS Mission Planning, Sequencing and Analysis Products

Product	Description	Planned Release Date
Aerie	Aerie is an extensible software system that provides mission planning, activity planning, and sequence capabilities. It provides simulation, constraint checking, and timeline visualization for both planning and sequencing operations processes. For planning, it also provides rules-based activity scheduling. Missions are responsible for defining activities, commands, and models that represent their flight and ground systems.	TBD

5.2 Future AMMOS Mission Control Products/Capabilities

Table 5.1 AMMOS Mission Control Capabilities

Product/Capabilities	Description	Planned Release Date
ATD (Automated Telemetry Downlink)		Late 2022
Mission Data Management Services (MDMS)	A general-purpose file management and cataloging system supporting mission ground data systems.	Mid 2023
Asynchronous Network Management System (ANMS)	Software framework for network monitoring and control of spacecraft and other assets that communicate using Delay/Disruption Tolerant Networking (DTN) protocols, including Asynchronous Management Protocol (AMP).	Late 2023
Mission-Independent Memory Examiner (MIME)	Software allows users to accurately examine and make assertions about spacecraft onboard memory content, by processing commands, telemetry and other information obtained via AMPCS.	Late 2022
Mission-Independent Test Environment (MITE)	End-to-end AMMOS mission control software (including AMPCS) test and test automation	Mid 2023

	framework. Assists verification and validation of a mission's ground data system deployment.	

Section 6
Obtaining AMMOS Products, Services, and Support

6.1 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.[6]

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.[7]

6.2 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

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

[7] 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.

(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.

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.[8] The SRA then produces the appropriate software license depending on dissemination type (as summarized above). If approved, the MIO notifies the customer.

For AMMOS Software that are open-sourced, obtaining the software can be downloaded from https://github.com/NASA-AMMOS/.

6.3 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.

6.4 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 MIO.

6.5 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.

[8] An AMMOS Catalog Checklist is provided in Appendix B and can be printed and completed by prospective 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).

6.6 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.

Appendix A
Acronyms and Abbreviations

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
ANMS	Asynchronous Network Management System
AOS	Advanced Orbiting System
APGEN	Activity Plan Generator
APPS	AMMOS-PDS Pipeline Service
ASTTRO	AMMOS Science Targeting for Robotic Operations
ATD	Automated Telemetry Downlink
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

Acronyms and Abbreviations

IND	Interplanetary Network Directorate
JADE	Java Advanced Display Environment
JEDI	Java Experimental Data Record Display Interface
KMC	Key Management and Cryptography
JPL	Jet Propulsion Laboratory
LDAP	Lightweight Directory Access Protocol
MCT	Open Mission Control
MCWS	Mission Control Web Service
MDMS	Mission Data Management Services
MGSS	Multimission Ground System and Services
MIPL	Multimission Image-Processing Laboratory
MMCM	Multimission Configuration Management
MMGIS	Multimission Geographical Information System
MIM	Mission Interface Manager
MIME	Mission-Independent Memory Examiner
MIO	Mission Interface Office
MITE	Mission-Independent Test Environment
MOS	Mission Operations System
MPS	Mission Planning and Sequencing
NAIF	Navigation Ancillary Information Facility
NASA	National Aeronautics and Space Administration
NPO	NASA Pasadena Office
NSN	Near Space Network
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

Acronyms and Abbreviations

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
WRP	Web Resource Platform
w10n	Webification

Appendix B
AMMOS Catalog Checklist: Version 5.5

Catalog ID	AMMOS Products and Services	Yes	No	Maybe
Functional Discipline Capabilities				
3.1.1	**Planning and Sequencing (Products)**			
3.1.1-1	Sequence Generation (SEQGEN)	☐	☐	☐
3.1.1-2	Mission Planning and Sequencing (MPS) Editor	☐	☐	☐
3.1.1-3	Sequence Review (SEQ_REVIEW)	☐	☐	☐
3.1.1-4	Mission Planning and Sequencing Server (MPSServer)	☐	☐	☐
3.1.1-5	Resource and Activity Visualization Engine (RAVEN)	☐	☐	☐
3.1.1-6	Uplink Summary Generator (ULSGEN)	☐	☐	☐
3.1.1-7	Multi Mission Time Correlation	☐	☐	☐
3.1.1-8	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	Open MissionControl (MCT)for Mission Control Web Service (MCWS)	☐	☐	☐
3.2.1-4	Test Data Acquisition and Command (TDAC)	☐	☐	☐
3.2.1-5	SLE Command Client (SCC)	☐	☐	☐
3.1.1-6	Spacecraft Language Interpreter and Collector II (SLINC II) / Command Translation Subsystem (CTS)	☐	☐	☐

Catalog ID	AMMOS Products and Services	Yes	No	Maybe
3.3.1	**Mission Design and Navigation (Products)**			
3.3.1-1	SPICE Toolkit	☐	☐	☐
3.3.1-2	SPICE Data/Kernels	☐	☐	☐
3.3.1-3	Monte	☐	☐	☐
3.3.1-4	Natural Body Ephemerides	☐	☐	☐
3.3.1-5	Natural Body Gravity Models	☐	☐	☐
3.3.2	**Mission Design and Navigation (Services)**			
3.3.2-1	Mission Design and Navigation Service	☐	☐	☐
3.3.2-2	Extraterrestrial Mission Conjunction Assessment 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	☐	☐	☐
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)	☐	☐	☐

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

Catalog ID	AMMOS Products and Services	Yes	No	Maybe
4.2-4	Duty Roster Service	☐	☐	☐

Notes: Catalog product item not needed in an SLA; freely available in the public domain.
For Mars Relay Operations Service (MaROS), catalog product item not needed in an SLA; paid for by Mars Program Office.

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