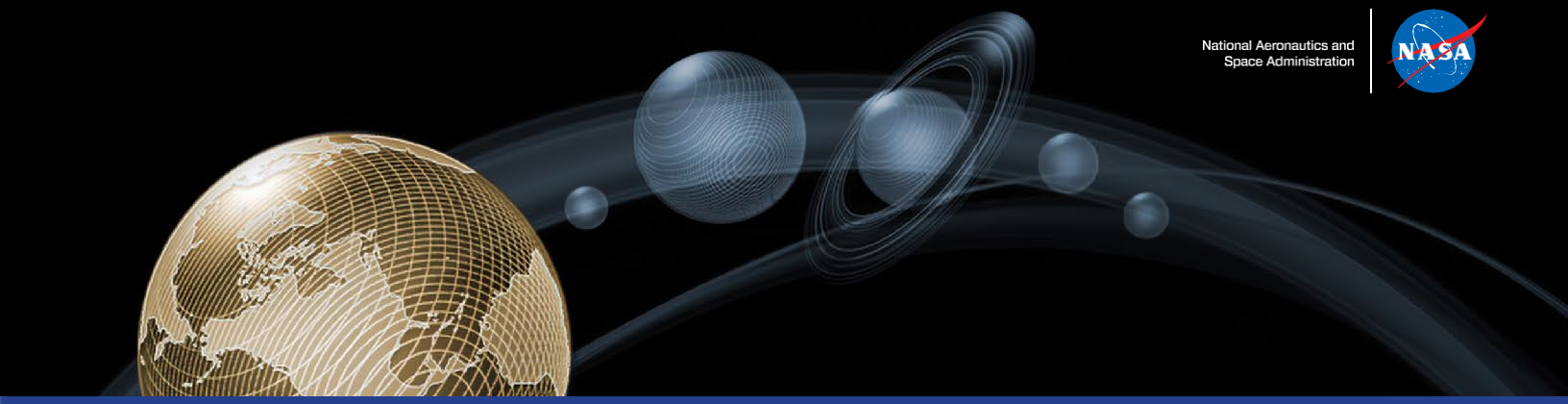

National Aeronautics and Space Administration

NASA AMMOS

Advanced Multi-Mission Operations System

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

AMMOS Catalog
Version 5.8

AMMOS Products and Services support these mission types:

Deep Space CubeSats and SmallSats

Heliophysics

Astrophysics

Earth Sciences

Planetary Sciences

AMMOS Catalog V5_8

Other

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California Institute of Technology

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Document Change Log

Revision	Issue Date	Affected Sections or Pages	Change Summary
Initial (Version 5.0)	19-Jan-2017	All	1. Initial issue of document. 2. 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; removed from Table 3.1.2 and 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. New entries for 4.1-4 System Security Monitor (SSM) and 4.1.-5 Compute Environment Configuration Modules (CECM).
Rev. C (Version 5.3)	27-Apr-2020	1. Pg. 18 2. Pg. 33 3. Pg 14 4. Pg. 42 5. Pg 45-46 6. Pg. 35 7. Pg. 29 8. 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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Revision	Issue Date	Affected Sections or Pages	Change Summary
Rev. D (Version 5.4)	30-Aug-2021	1. Pg. 13 2. Pg. 15 3. Pg. 38 4. Pg. 25 5. Pg. 19 6. Pg. 39 7. Pg. 32	1. Remove 3.1.1-9 TFP. 2. Added description under AMPCS. 3. Added 4.2-5 Key Management and Cryptography (KMC) under Crosscutting. 4. Added 3.3.2-14 Extraterrestrial Mission Conjunction Assessment Service 5. Moved SLINCII/CTS from MPSA to MMCS Element. SLINCII/CTS Catalog ID has been reassigned to 3.1.1-6 6. Added Section 5: Future AMMOS Products 7. HiiiHAT was removed from the AMMOS IDS Product List.
Rev. E (Version 5.5)	21-October-2022	1. Sec 3.1.1 2. Sec 3.3 3. Sec 3.4.1 4. Appendix B 5. Sec 5.2	1. Remove APGen from the Catalog section under MPSA. 2. Removed Gravity Modeling Service, Preliminary Mission Design Service, Mission Design and Trajectory Optimization Service, MDNAV Products and Services. 3. AMMOS Instrument Toolkit (AIT) Description Update 4. Updated table to match the current products and services offered. 5. Updated ATD and MCMS Release dates
Rev. F (Version 5.6)	18-September-2024	1. Sec 1.8 2. Sec 2.2 3. Sec 2.3.1 4. Table 3.1.1 5. Table 3.3.1 6. Table 3.3.2 7. Table 3.4.1 8. Table 3.4.2 9. Table 4.1.1 10. Table 5.1 11. Table 5.2 12. Appendix A	1. 1st Paragraph reworded, clear instruction for GitHub download. 2. 3rd paragraph, Removed “program executive committee”. 4th paragraph section, contribution to the AMMOS core by multiple partners, “call for ideas” removed. 3. Replace NEN with NSN in figure 2.3-1 4. Removed MPS Editor, ULSGEN, and update to MMTC description. ID# 3.1.1-4: removed MPS’s web apps ULSGEN and RAVEN, dependencies updated to reflect CAM only. Replace Aerie with AMMOS Activity Planner, reference Aerie as code name. 5. Removed SPICE Toolkit and SPICE Generic Kernels. Added Monte full list of NTR/NPO Numbers 6. Replaced “should” with “must” for Mission Design & Navigation Services: 7. Updated descriptions for Cat IDs 3.4.1-2, -3, -5, and -9. Removed Cat ID 3.4.1-10 WRP 8. Removed 3.4.2-2 Science Data Infrastructure Services 9. Removed 4.1.1-2 CWS and 4.1.1-4,CECM. Updated description 4.1.1-5 KMC to removed reference to ULSGEN integration 10. Added MIME 11. Updated MDMS, ANMS, and BPSec Library. 12. Updated to reflect current set of acronyms

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Revision	Issue Date	Affected Sections or Pages	Change Summary
Rev. G (Version 5.7)	Feb 2025	1. Table 3.1.1 2. Table 3.2.1 3. Table 3.3.2 4. Table 3.4.1 5. Sec 3.4.2 6. Sec 3 & 4 7. Sec 5 8. Appendix A 9. Appendix B	1. Replaced acronym “SEQGEN” with “SeqGen”. Removed catalog item 3.1.1-4, Mission Planning and Sequencing Server. Removed dependencies from 3.1.1-5 RAVEN. Removed code name “Aerie”, replaced with AMMOS Activity Planner. Added catalog item 3.1.1-10 AMMOS Sequence Development Environment. Product listing reordered for enhanced user identification. 2. Updated acronym definitions for CLTU and CLTUF. Added acronym definition for CCSDS. Updated description for catalog item 3.2.1-2, Mission Control Web Service. Added catalog item 3.2.1-7, Asynchronous Network Management System. 3. Removed catalog item 3.3.2-2, Extraterrestrial Mission Conjunction Assessment Service. Description update for 3.3.2-1 Mission Design & Navigation Services. 4. Removed catalog item 3.4.1-1, Image Format Translation Tool, added to 3.4.1-2, Image Processing Toolkit. Removed Catalog item 3.4.1-6, APPS and 3.4.1-12 PDS & PODS. Description updates for 3.4.1-13, AIT. 5. Removed section 3.4.2, Instrument Data Processing and Archiving Services. 6. Removed acronyms from Cat ID/Title column in all tables. 7. Removing sec 5.2. All future AMMOS products listed in section 5.1 in Table 5.1. 8. Updated to reflect current set of acronyms. 9. Updated to reflect current set of products and services.
Rev. H (Version 5.8)	April 2025	1. Sec 3.3.2 & Table 3.3.2 2. Sec 6.3 3. Table 3.4.1 4. Table 5.1 5. Appendix B	1. Removed AMMOS Mission Design and Navigation Services 2. Specified cost is for adaptation 3. 3.4.1-13 AMMOS Instrument Toolkit description updated 4. MIME 1.2 release date updated to September 2025 5. Updated to reflect current set of products and services.

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Table of Contents

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Section 1
Introduction

1.1 Identification

This document is the Advanced Multi-Mission Operations System (AMMOS) Catalog, Version 5.8 released in April 2025.

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

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Software Release Authority (SRA) at Jet Propulsion Laboratory's (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

1.6 MGSS Applicable Documents and Processes

MGSS Document Number	Document Name	Document Description	Document Status
DOC-001012	Multimission Ground Systems and Services	Describes process to establish, monitor and manage agreements between the MGSS	Released

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

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	(MGSS) Commitments Process (Pre-phase A)	program office and customers during Pre-Phase A (Concept Studies) of the NASA project lifecycle.	
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 some that are proprietary (closed source) and a growing number that are open source software available in GITHUB, downloaded from 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 contrasts with 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 example is the Common Workflow Service (CWS). 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 service (expertise) offering.

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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 governance model, 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.

[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.

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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]

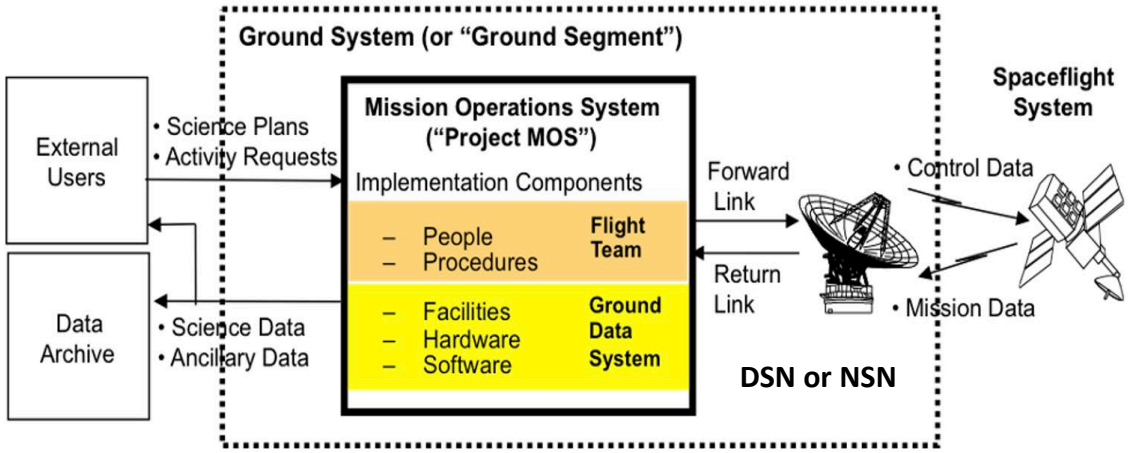

Figure 2.3-1. NASA space science Mission Operations System within the context of an end-to-end Ground System.

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, Mission Control, and Navigation 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 2.4-1 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

[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.

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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)).

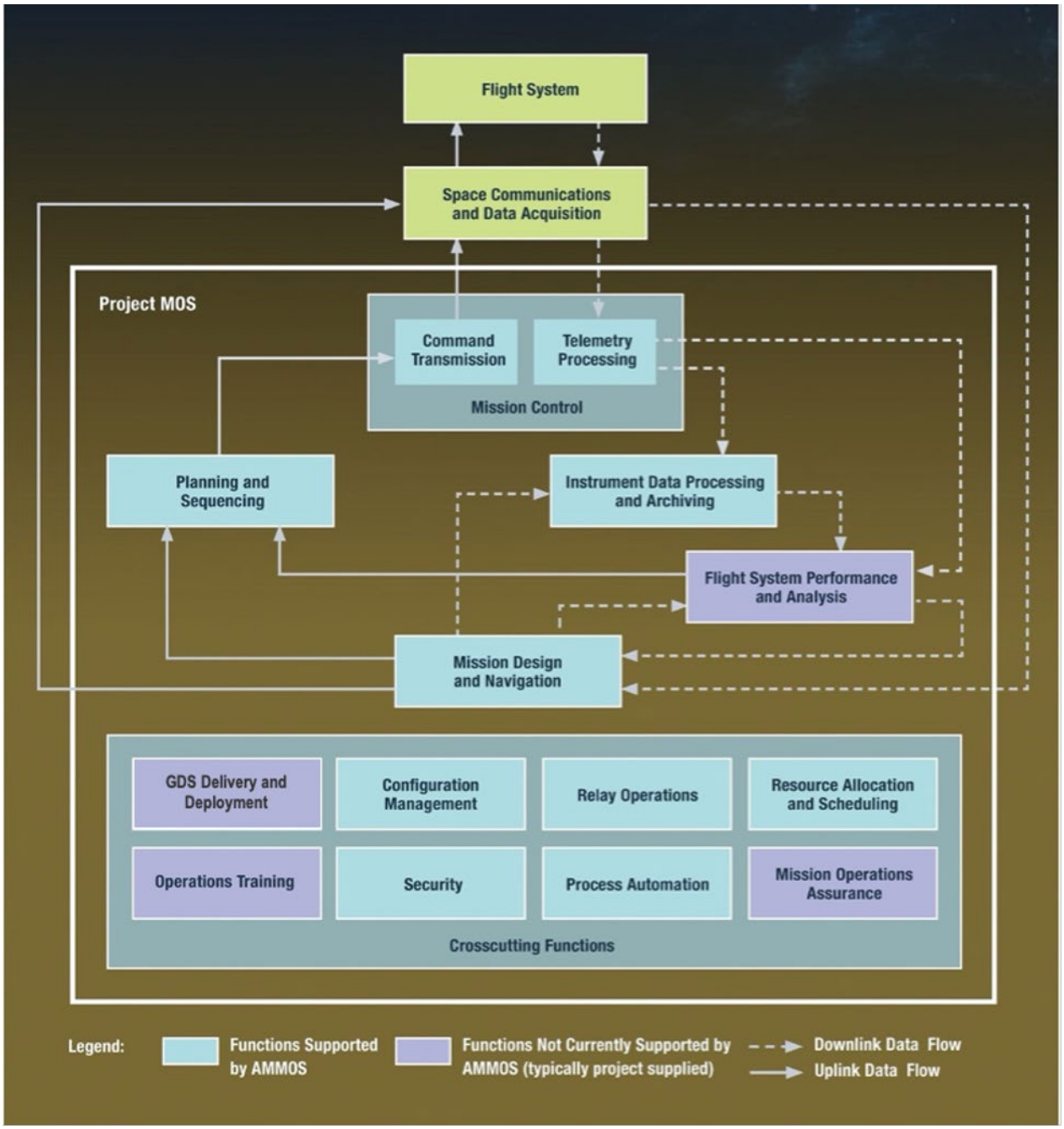

Figure 2.4-1. High-level Project MOS functions in a Mission Operations environment (or 'venue').

The functional areas at the top Figure 2.4-1 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

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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. 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.'

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

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- **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/tabletop 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.

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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
3.1.1-9 AMMOS Activity Planner	AMMOS Activity Planner is an open source, extensible software system for planning, scheduling, and commanding space missions. It provides modeling and simulation capabilities that can be used for mission planning and analysis during project formulation all the way through operations, where it can be used to manage and validate spacecraft activity plans. Included with AMMOS Activity Planner is a powerful web-based user interface geared to facilitate operators with the creation and analysis of plans. AMMOS Activity Planner provides low-code solutions for authoring scheduling rules to autogenerate plans, authoring and evaluating constraints to assist with plan validation, and authoring logic to expand activities into sequences of commands for execution. Sequences can also be authored and edited independently following an open source sequencing specification, seq-json, that includes a variety of commanding styles (e.g. absolute, relative, command completion). As a multi-tenant system, AMMOS Activity Planner allows multiple distributed users to collaborate in real-time on a single plan or concurrently work on multiple plans for multiple missions. Additionally, AMMOS Activity Planner's service-based architecture allows for efficient system deployment and scalability on the cloud. Visit github.com/NASA-AMMOS/aerie to test out AMMOS Activity Planner by getting the system set up, deployed, and running in your environment in just a few minutes. NTR/NPO No. 51389
3.1.1-10 AMMOS Sequence Development Environment	AMMOS Sequence Development Environment (SDE), also known as Phoenix, is an open source product for authoring the sequences of commands that control the execution of spacecraft. Much like an integrated development environment (IDE) for programming, AMMOS SDE helps spacecraft operators develop sequences of commands efficiently by providing syntax highlighting and content assist while operators write their sequences. As with programming, many different languages exist for writing sequences. AMMOS SDE provides a simple, but powerful sequencing language called "SeqN" out of the box that follows the open source sequencing specification, seq-json. SeqN can be translated and exported into other sequencing languages via an adaptation interface or missions can use a completely different primary sequencing language via the SDE's language binding interface.

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Table 3.1.1. AMMOS Planning and Sequencing and Analysis Products.

Catalog ID/Title	Description
	Syntax highlighting and content assist is driven primarily from a mission's command dictionary but can be modified and extended via an adaptation interface. AMMOS SDE also supports custom command dictionary formats via its dictionary parser plug-in interface. AMMOS SDE can be deployed separately or together with the AMMOS Activity Planner. When deployed together, activities expanded into sequences within AMMOS Activity Planner will automatically be sent and received by AMMOS SDE. Visit github.com/NASA-AMMOS/aerie to try out AMMOS SDE and learn more about its capabilities.
3.1.1-1 Sequence Generation	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.
3.1.1-5 Resource and Activity Visualization Engine	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
3.1.1-7 Multi MissionTime Correlation	Multi MissionTime Correlation (MMTC) is a tailorable, stand-alone, mission-independent spacecraft time to ground time correlation system. All space missions need to maintain an accurate, and in many cases, an extremely accurate knowledge of time as measured onboard the spacecraft. MMTC provides an automated way of maintaining knowledge of [the relationship between spacecraft and ground] time and produces standard and widely used time correlation products (e.g. SPICE SCLK Kernel). MMTC provides a plug-in architecture to interface to a space mission's telemetry archive to gather data on time as measured onboard the spacecraft and then associates those times with a defined Earth-time system. * A plug-in for AMPCS is already built and available. *
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

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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]

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	AMMOS Mission Data Processing and Control System (AMPCS) is a software application that performs the following functions: Telemetry Processing • Processing of Consultative Committee for Space Data Systems (CCSDS) formatted Advanced Orbiting System (AOS) transfer frames or Telemetry (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

[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').

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Table 3.2.1. AMMOS Mission Control Products.

Catalog ID/Title	Description
	• 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.
3.2.1-2 Mission Control Web Service	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 called Open Mission Control (MCT) for Mission Control Web Service (MCWS) (OMM) (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) and Common Access Manager CAM) Note: Elasticsearch is a trademark of Elasticsearch BV, registered in the U.S. and in other countries.

This document has been reviewed and determined not to contain export controlled technical data.

Table 3.2.1. AMMOS Mission Control Products.

Catalog ID/Title	Description
3.2.1-3 Open Mission Control for Mission Control Web Service	The Open Mission Control (MCT) for Mission Control Web Service (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 Mission Control (MCT) for Mission Control Web Service (MCWS) provides composable displays specialized for telemetry information including historical and real-time 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: Open Mission Control (MCT) for Mission Control Web Service (MCWS) 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 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	The Test Data Acquisition and Command (TDAC) is a subsystem comprised of hardware and software that connects 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) • 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 Communications Link Transmission Units (CLTUs) and converts them into an analog bit stream metering them at a set rate to the spacecraft serial interface via the GSE.

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Table 3.2.1. AMMOS Mission Control Products.

Catalog ID/Title	Description
	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	The Space Link Extension (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 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 Communications 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 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, 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.
3.2.1-6 Spacecraft Language Interpreter and Collector II/Command Translation Subsystem	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

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Table 3.2.1. AMMOS Mission Control Products.

Catalog ID/Title	Description
3.2.1-7 Asynchronous Network Management System	Asynchronous Network Management System (ANMS) is a 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).

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
3.3.1-3 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. Full list of NTR/NPO Numbers: • 52423 04-AUG-2022 • 52063 26-JUL-2021 • 50395 01-NOV-2016 • 48184. 16-MAY-2011 • 47639. 03-MAY-2010 • 46083 25-APR-2008 • 41826. 05-APR-2005 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.

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Table 3.3.1. AMMOS Mission Design and Navigation Products.

Catalog ID/Title	Description
	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 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.

3.4 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

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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
3.4.1-2 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 blemish removal, image orientation, geometric transformations, map projections, and radiometric calibration. The Image Processing Toolkit is comprised of the following software products: A. Video Image Communication And Retrieval (VICAR) Image Processing Software – general purpose image processing software system with specialized capabilities for surface multi-dimensional imaging data. B. Automatic Fusion of Image Data System (AFIDS/Nest) – software to automatically finds tie points between two similar-viewing orbital satellite imagery to a co-registered image product with sub pixel accuracy. C. Automatic Fusion of Image Data System (AFIDS/Nest Map) – software that uses navigation, SPICE, and available terrain data to georeferenced unmapped imagery. D. Spectral Open File Format Visualizer and Library – describes and visualizes a hyperspectral observation acquired with multiple instruments including, but not limited to, mapping point spectrometers (e.g. Mars 2020 SHERLOC, PIXL, and MSL ChemCam), multi-spectral imagers (e.g. Mars 2020 Mastcam Z), and hyperspectral remote sensors (e.g. Cassini VIMS). E. Image Format Translation Tool is a software to transform from one image data format to another while preserving metadata content (i.e. Transcoder tool) NTR/NPO No. a) VICAR: 49845, b) AFIDS/Nest: 50774, c) AFIDS/Nest Map: 50779 d) SOFF: 52793 & 52063; e) No. 30470, 47184 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: Astria is an image data studio product designed to display, aid in quality control browsing, and analysis of raw or first-order (e.g. Experiment Data Record) image data products and derived or higher-order (e.g. Reduced Data Record) image data products. Astria was built with surface (i.e. in-situ) missions in mind. In depth analysis can be done on individual basis or collectively when a primary image is designated. Once a primary image is selected, a set of related images can be retrieved, analyzed, and overlaid (where possible). Note: Astria was previously known as Marsviewer. Its heritage is tied to Mars surface operations however, the application is transferrable to other domains.

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Table 3.4.1. AMMOS Instrument Data Processing and Archiving Products.

Catalog ID/Title	Description
	NTR/NPO No. Astria (previously Marsviewer): 40852, 46698, 48691
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. The instrument product access and delivery tool comes in the following versions: A. File Exchange Interface (FEI) – client/server-based software built to support instrument product access and delivery. B. Data Distribution Remote Interface for Verified Exchange (DataDRIVE) – cloud-native instantiation of a data product registration, hosting, and distribution service that offers secure cloud storage, file synchronization, data organization, and client software. Generated mission data products are stored in Amazon Web Service's Simple Storage Service (S3) and made accessible through a robust web client and command line tools to remote scientists, engineers, and external systems. It includes a powerful search and indexing capability enabling users to quickly find, view, and share datasets to support mission and science operation's needs. NTR/NPO No. 47089, 40075
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 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.
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 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.

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Table 3.4.1. AMMOS Instrument Data Processing and Archiving Products.

Catalog ID/Title	Description
	NTR/NPO No. 49087 Comment: The second element described above is also known as the Position Location and Attitude Correction Estimate Storage (PLACES) database.
3.4.1-9 Multi-Mission Geographical Information System	Multi-Mission Geographical Information System (MMGIS) is software that provides automated daily visualization and analysis of instrument data product localized from orbiters, rovers, airborne, and in-situ instruments. It has been used to support Planetary and Earth missions from initial field campaigns to full-fledged operations. MMGIS provides a collaborative online map-based analysis platform that brings teams together around mission data allowing them to analyze past and plan for future science campaigns. The platform is built on pervasive open-source geospatial software and standards allowing adaptability to support a variety of data formats, coordinate reference systems, geospatial services, and much more. NTR/NPO No. 50389 Comment: MMGIS has been open-sourced and released at https://github.com/NASA-AMMOS/MMGIS.
3.4.1-11 Autonomous Exploration for Gathering Increased Science	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
3.4.1-13 AMMOS Instrument Toolkit	Developing instrument systems requires flexible and reliable control solutions. The AMMOS Instrument Toolkit (AIT) is an open-source, Python-based toolkit engineered to provide exactly that. AIT offers instrument teams a set of modular capabilities and well-defined interfaces for essential functions for instrument operations: command uplink, data downlink, sequencing, and telemetry processing. AIT's architecture is designed for seamless integration with instrument and CubeSat flight software, allowing you to build complete control systems tailored to your specific instrument requirements and ground station setups. Leverage AIT's established support for the CCSDS Space Link Extension (SLE) protocol for compatibility with NASA's Deep Space Network (DSN) and other SLE-compliant systems. **Key Capabilities:** • **Instrument Commanding:** AIT empowers your team to reliably **generate, validate, and uplink commands** to your instrument. Its flexible design supports various command types and interfaces, ensuring precise control over instrument operations.

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Table 3.4.1. AMMOS Instrument Data Processing and Archiving Products.

Catalog ID/Title	Description
	• **Instrument Telemetry Handling: Receive, process, and analyze instrument telemetry data** in real-time. AIT provides tools for parsing, displaying, and archiving telemetry streams, giving your team immediate insights into instrument health and performance. • **Automated Instrument Sequencing: Define and execute complex sequences of instrument operations** with ease. AIT's sequencing capabilities enable pre-programmed activities, freeing up operator time and ensuring consistent execution of procedures. • **Data Downlink & Management:** Facilitate efficient data downlink and management workflows. AIT supports data handling, ensuring transfer and archiving of valuable instrument data for analysis and scientific return. • **Integration-Ready Architecture:** AIT's modular design and well-defined interfaces simplify **integration with existing ground station infrastructure, instrument-specific flight software, and data processing pipelines.** This reduces development effort and promotes interoperability within your overall mission system. • **DSN/SLE Compatibility for Deep Space Missions:** Benefit from **built-in support for the CCSDS Space Link Extension (SLE) protocol**, enabling seamless uplink and downlink communication with NASA's Deep Space Network and other SLE-compliant facilities – crucial for deep space and interoperable missions. **Python-Based Flexibility & Extensibility:** Leverage the power and versatility of Python. AIT's open-source nature allows for **easy customization, extension, and adaptation** to meet the evolving needs of your instrument operations throughout the mission lifecycle. AIT-CORE: https://github.com/NASA-AMMOS/AIT-CORE AIT-DSN: https://github.com/NASA-AMMOS/AIT-DSN Note: Currently has CFDP Type 1 implemented and tested while CFDP Type 2 implementation exists it is merely a starting point implementation with minimal testing and deployments. AIT-DSN has a contributed community plugin to receive DSN monitor data. At this time this capability should be treated as a community supported feature and implementation for people to examine. Docs: AIT-CORE: https://ait-core.readthedocs.io/ AIT-DSN: https://ait-dsn.readthedocs.io/ NTR/NPO No. 50696
3.4.1-14 AMMOS Science Targeting Toolkit for Robotic Operations	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)

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Table 3.4.1. AMMOS Instrument Data Processing and Archiving Products.

Catalog ID/Title	Description
	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.

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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	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.
4.1.1-3 System Security Monitor	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 email to a customizable list of recipients. NTR/NPO No: 50932
4.1.1-5 Key Management and Cryptography	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. 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

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Table 4.1.1. AMMOS Crosscutting Products.

Catalog ID/Title	Description
	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 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 implement 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.
4.1.2-2 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	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.

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Section 5
AMMOS Future Product Offerings

The AMMOS 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 Products

Table 5.1 Future AMMOS Products and Services

Product/Service	Functional Area	Description	Planned Release Date
Mission-Independent Memory Examiner (MIME) Version: MIME 1.2	Mission Planning, Sequencing and Analysis	Software allows users to accurately examine and make assertions about spacecraft onboard memory content, by processing commands, telemetry and other information obtained via AMPCS.	September 2025
BPSec Library Version: BPSec 1.0	Mission Control Products/ Capabilities	A multi-mission embedded, open-source library for Bundle Protocol Security support (BPSec <RFC9172>). Bundle Protocol supports end-to-end communications in environments in which more commonly known communications protocols (e.g., TCP/IP) tend to break down and stop functioning.	June 2025

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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

[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.

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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.

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 is 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 adaptations 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 “grassroots,” 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.

[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).

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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.

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.

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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
ASTTRO	AMMOS Science Targeting Toolkit for Robotic Operations
CAM	Common Access Manager
CCSDS	Consultative Committee for Space Data Systems
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
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
KMC	Key Management and Cryptography
JPL	Jet Propulsion Laboratory
LDAP	Lightweight Directory Access Protocol
MCT	Mission Control Technology
MCWS	Mission Control Web Service
MGSS	Multimission Ground System and Services

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Acronyms and Abbreviations

MMCM	MultiMission Configuration Management
MIM	Mission Interface Manager
MIME	Mission-Independent Memory Examiner
MIO	Mission Interface Office
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
PDU	Protocol Data Unit
RAP	Resource Allocation and Planning
RAVEN	Resource and Activity Visualization ENgine
REST	REpresentational State Transfer
SA	System Administrator
SCC	SLE Command Client
SEO	Systems Engineering Office
SeqGen	Sequence Generation
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

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Appendix B
AMMOS Catalog Checklist: Version 5.8

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)	☐	☐	☐
3.1.1-5	Resource and Activity Visualization ENgine (RAVEN)	☐	☐	☐
3.1.1-7	Multi Mission Time Correlation (MMTC)	☐	☐	☐
3.1.1-8	Sequence Tracker	☐	☐	☐
3.1.1-9	AMMOS Activity Planner	☐	☐	☐
3.1.1-10	AMMOS Sequence Development Environment (SDE)	☐	☐	☐
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 Mission Control (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)	☐	☐	☐
3.2.1-6	Spacecraft Language Interpreter and Collector II (SLINC II)/Command Translation Subsystem (CTS)	☐	☐	☐
3.2.1-7	Asynchronous Network Management System (ANMS)	☐	☐	☐

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Catalog ID	AMMOS Products and Services	Yes	No	Maybe
3.3.1	**Mission Design and Navigation (Products)**			
3.3.1-3	Monte	☐	☐	☐
3.3.1-4	Natural Body Ephemerides	☐	☐	☐
3.3.1-5	Natural Body Gravity Models	☐	☐	☐
3.4.1	**Instrument Data Processing and Archiving (Products)**			
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	☐	☐	☐
3.4.1-7	Terrain Visualization Toolkit	☐	☐	☐
3.4.1-8	Localization Toolkit	☐	☐	☐
3.4.1-9	Multi-Mission Geographical Information System (MMGIS)	☐	☐	☐
3.4.1-11	Autonomous Exploration for Gathering Increased Science (AEGIS)	☐	☐	☐
3.4.1-13	AMMOS Instrument Toolkit (AIT)	☐	☐	☐
3.4.1-14	AMMOS Science Targeting Toolkit for Robotic Operations (ASTTRO)	☐	☐	☐
	Crosscutting Capabilities			
4.1.1	**Crosscutting Capabilities (Products)**			
4.1.1-1	Common Access Manager (CAM)	☐	☐	☐
4.1.1-3	System Security Monitor (SSM)	☐	☐	☐

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Catalog ID	AMMOS Products and Services	Yes	No	Maybe
4.1.1-5	Key Management and Cryptography (KMC)	☐	☐	☐
4.1.2	**Crosscutting Capabilities (Services)**			
4.1.2-1	Multimission Configuration Management (MMCM) Services	☐	☐	☐
4.1.2-2	Relay Operations Service	☐	☐	☐
4.1.2-3	Multimission Resource Scheduling Service (MRSS)	☐	☐	☐
4.1.2-4	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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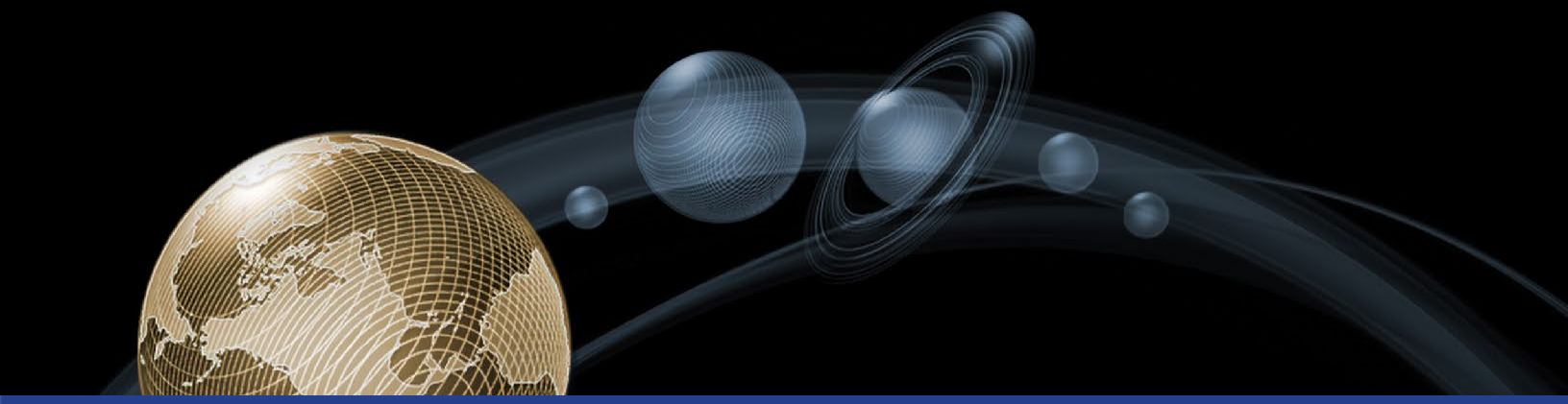

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