Multimission Ground Systems and Services

NASA AMMOS Strategic Plan and Roadmap

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1.0 Introduction

1.1 Purpose

The NASA Advanced Multimission Operations System (AMMOS) Strategic Plan defines the overall direction and goals of Multimission Ground Systems and Services (MGSS) organization and serves the following purpose in the organization:

- Clearly defines the purpose of the MGSS organization and establishes realistic goals and associated roadmaps to meet those goals
- Communicates AMMOS goals and objectives to the organization's stakeholders
- Ensures the most effective use is made of organizational resources by establishing priorities.
- Provides a baseline from which progress can be measured.
- Provides a baseline for informed change when the need arises.

The AMMOS Strategic Plan will consequently influence numerous aspects of the organization, including:

- Program priorities.
- Products and services that will be provided by the AMMOS
- How products and services provided by the AMMOS will be developed or procured and used operationally.
- Funding decisions. All investments in the AMMOS must trace to the Strategic Plan.
- Organizational design required to effectively meet the strategic goals.
- Program performance measures to determine progress against the strategic goals

1.2 AMMOS Overview

The AMMOS is NASA's recommended provider of multi-mission tools and services for missions exploring our solar system and beyond. This recommendation is based on the high quality, low risk, and cost effectiveness of AMMOS products and services. The AMMOS is an Agency-wide program comprising implementers and customers from multiple NASA centers, Federally Funded Research and Development Centers, academia, and industry. The AMMOS is managed by the MGSS Program Office at JPL. The AMMOS provides a core set of products that can be readily customized to accommodate the specific needs of individual missions. Using AMMOS lowers mission cost and risk by providing a mature base for mission operations systems with significantly reduced development and deployment time.

The AMMOS provides most of the functions needed to support the design, implementation, and operation of an MOS, consisting of multi-mission tools and services for the following activities:

- **Planning & Sequencing** – Planning and commanding science observations and engineering activities of a Mission and the engineering needed to sustain that capability.
- **Downlink** – Capturing and distributing Flight System (spacecraft and instruments) data, maintaining knowledge of Flight System performance and ensuring its continued health and safety, and instrument and science data processing..

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- **Navigation & Mission Design** – Maintaining knowledge of Flight System position/velocity and planning its trajectory for future Mission activities.
- **Ground Data System (GDS) Integration, Test, Deployment & Support** – Integrating, installing, and maintaining Ground Data System (GDS) hardware and software in operational and test environments.
- **Operations Engineering** – Cross-cutting and support functions necessary to operate and sustain a Mission Operations System.

A functional view of the AMMOS is shown in Figure 1-1 following

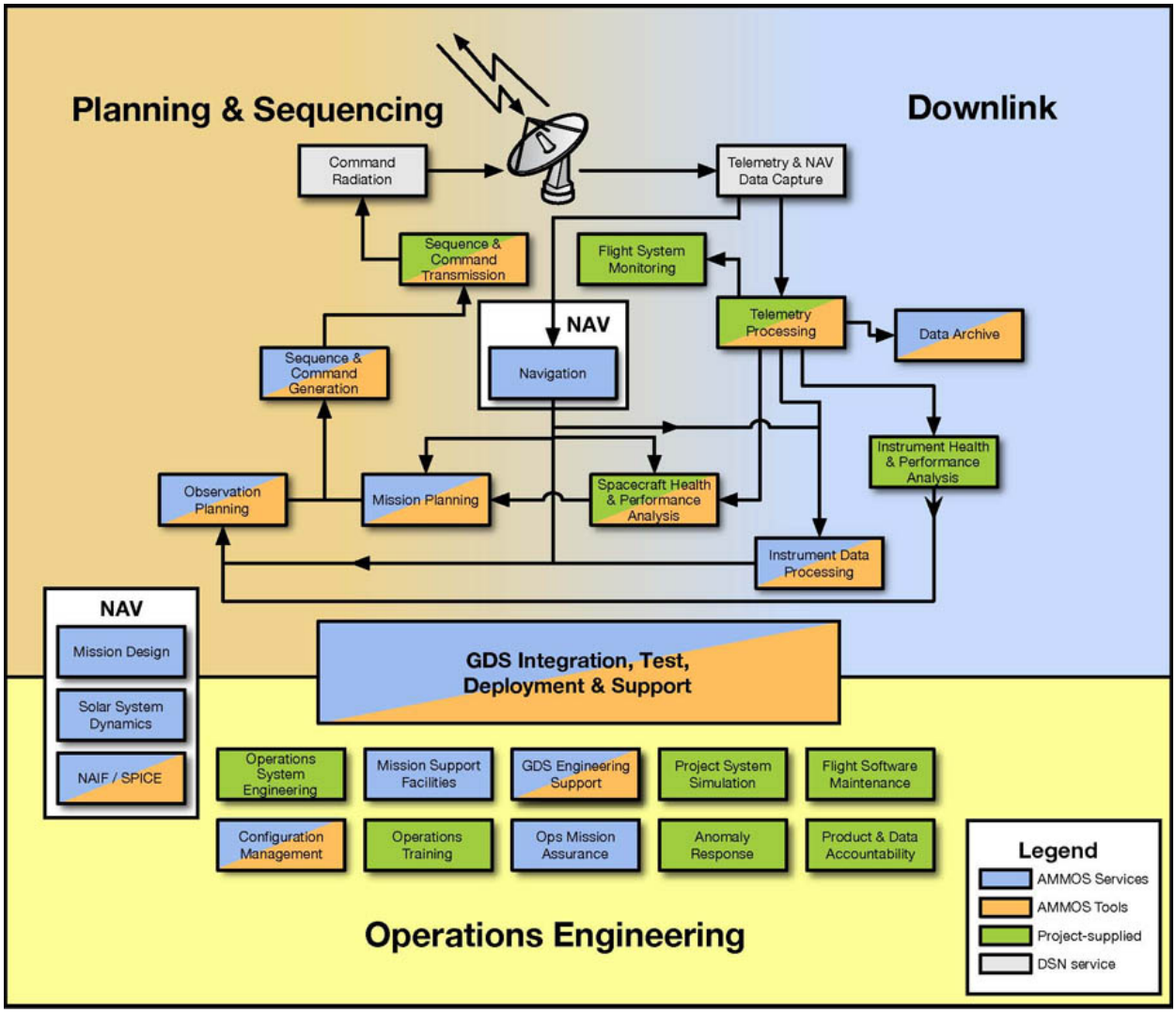

Figure 1-1. AMMOS Functional Support for NASA Missions

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1.3 Definition of Terms

- ***Vision***: The vision is the over-arching principle that guides the organization and determines future direction. The intention of the vision is to guide, control, and encourage the organization as a whole to reach the desired state of the organization as described in the System Goals and Roadmap.

- ***Future Drivers***: Time dependent drivers on the AMMOS System Goals and Roadmap and, by extension, the Element Subsystem Goals and Roadmaps. These drivers are derived from an analysis of the needs of current and future missions, emerging standards, and anticipated future capabilities of space communication systems.

- ***Architecture Principles:*** Architecture principles are qualitative statements of intent that should be met by the system architecture. The principles provide a basis for decision-making—guiding MGSS across all phases of AMMOS and operations engineering, from the strategic planning phase to the operations and maintenance phase.

- ***Goals***: Goals are end results that the AMMOS plans to achieve within the associated planning epochs. The AMMOS Roadmaps are associated with these goals such that MGSS can, where applicable. measure the progress of the AMMOS Roadmaps toward meeting the goals. System goals and associated subgoals drive element-level goals.

- ***Subgoals:*** Elaboration of goals that are needed to achieve the overall Strategic Goals of the AMMOS. Subgoals are considered part of the goals.

- ***Strategic Roadmap***: Guides the technology and development of the AMMOS in the direction needed in order to achieve the Vision and fulfill the AMMOS Mission. The Roadmap includes key milestones and their priorities for each strategic goal and subgoal through 2025.

- ***Technical Roadmap:*** A dynamic plan for realizing the AMMOS strategic goals and vision. The Technical Roadmap indicates the specific activities necessary to meet organizational objectives, interdependencies among the activities, and harmonizes legacy systems and new implementations with mission needs.

- ***Implementation Plan:*** Six-year plan approved by NASA for future funding of implementation tasks.

- ***Technology Plan:*** Three-year plan approved by NASA for future funding of AMMOS technology tasks, generally TRL level 6-9. All technologies are required to have clearly identified infusion paths.

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1.4 MGSS Mission Statement

NASA defines the MGSS Mission as follows:

> MGSS shall exploit the benefits of commonality to provide multimission tools and services that enable mission customers to operate at a lower total cost to NASA, with comparable or higher reliability and performance, than would be the case if these customers acquired their own unique tools and services.
>
> The multi-mission tools and services provided as part of the AMMOS shall include the following functional areas: mission design & navigation, mission planning & sequencing, telemetry & command, spacecraft and instrument control and analysis, instrument data processing, data management, and product delivery.

1.5 AMMOS Vision

The AMMOS envisions itself as the premier provider of multimission operations capabilities to the NASA community for all missions within its charter. We will be a highly valued world-class organization that meets science and mission needs with full customer satisfaction. We will partner effectively across the Agency to provide the most efficient solutions for NASA missions and will drive and seamlessly infuse operations-focused technology to meet our objectives.

Accordingly, the AMMOS Vision is defined as follows:

- AMMOS provides missions with a Mission Operations System that dramatically reduces mission development effort and cost, significantly improves operations efficiency, and reduces risk for flight and ground systems.

- The AMMOS enables Principal Investigators to directly, immediately, flexibly, and seamlessly interact with their instruments and their data from wherever they are located without requiring expertise in mission operations or the AMMOS.

1.6 AMMOS Architecture Principles

The future state AMMOS is based on a set of nine key architecture principles that are intended to guide multimission Operations Engineering as well as GDS solution engineering: 1) Primacy of Principles, 2) Use of Common Services, 3) Customer Focus, 4) Learn from Experience, 5) Close the Loop, 6) Data/Information Visibility, Accessibility, and Understandability, 7) Technology/Platform Independence, 8) Interoperability, and 9) Universality of Data/Information Security [1].

A summary description of each of these principles is provided described in the list below:

1. *Primacy of Principles* means these core principles apply to all organizational entities that are responsible for the management and delivery of the AMMOS.
2. *Use of Common Services* means AMMOS provides operations capabilities via adaptable, loosely-coupled common services. These expose adaptable portions to customers while maintaining key common aspects as part of the multimission system.

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3. *Customer Focus* means AMMOS exists in order to provide operations capabilities that enable Missions to operate at lower total cost to NASA, while satisfying needs for reliability and performance.
4. *Learn from Experience* means for the AMMOS to improve and/or maintain capabilities in the face of imperfection and a changing world, it must be maintained and improved over time. This requires intentional effort to acquire and apply the lessons that experience offers.
5. *Close the Loop* means AMMOS enables closed-loop control of flight assets, including reconciling the reported state of a flight system with science and engineering plans. To enable missions to efficiently and effectively perform planned-to-actual reconciliation, it is necessary to identify, architect, design, build, maintain, and operate elements of the System that respond to this principle.
6. *Data/Information Visibility, Accessibility, and Understandability* means data/information is defined externally to any given user (including software systems or services) and is readily visible, accessible, and understandable to all authorized AMMOS and external partner users, software systems, and services.
7. *Technology/Platform Independence* means AMMOS software systems and its interfaces are architected independent of specific technology choices and therefore can operate on a variety of technology platforms.
8. *Interoperability* means software and hardware conform to defined industry standards (preferably open standards) that promote interoperability for data/information, applications, and technology..
9. *Universality of Data/Information Security* means the confidentiality, integrity, and availability of data/information in all components of the AMMOS is a first class concern and not designed into AMMOS software systems and services as an afterthought.

These AMMOS architecture principles provide a basis of decision-making, guiding MGSS from the strategic planning phase to AMMOS operation and maintenance phase. These principles are key elements in AMMOS modernization initiatives that affect the entire AMMOS. Consequently, they are intended to provide context for MGSS Level 3 (L3) requirements as well as used in formal and informal MGSS Systems Engineering-led architecture and design reviews.

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1.7 MGSS Strategic Plan Framework

The Strategic Plan consists of the AMMOS Vision, Future Drivers, Architectural Principles, System Strategic Goals, System Strategic Roadmap, System Technical Roadmap, and Element Strategic Goals and Roadmaps. The framework for the AMMOS Strategic Plan is shown in Figure 1-2. Definitions of the components of the framework can be found in Section 1.3.

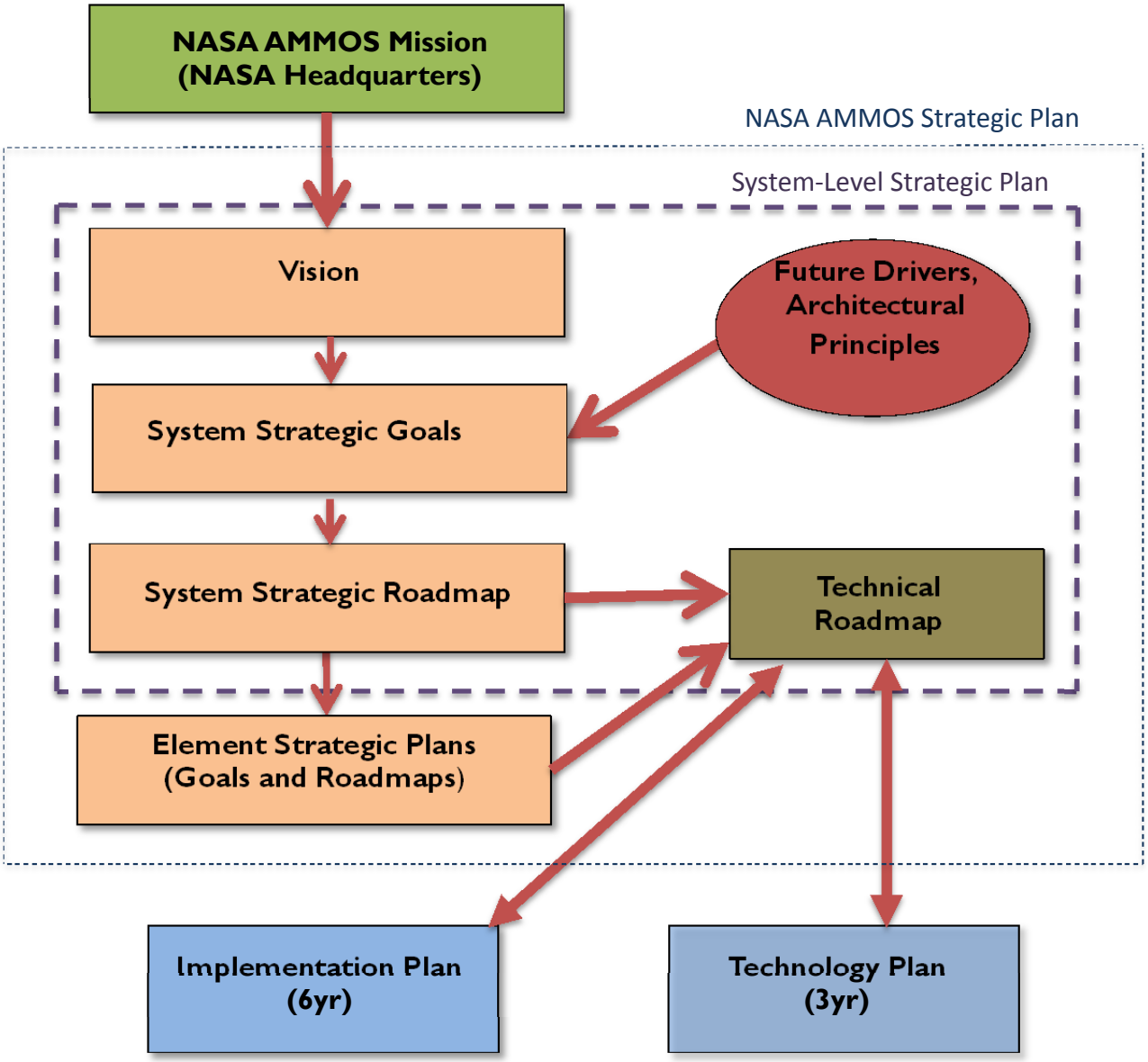

Figure 1-2. NASA AMMOS Strategic Planning Framework

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1.8 Measurement of Progress Against Strategic Plan

The AMMOS Strategic Plan and Roadmap set the priorities for the tactical planning process resulting in the Six-year Implementation Plan. The System Level Strategic Roadmap, where applicable, has quantitative goals that will be measured each year to assess our progress. The tactical planning process will utilize these measures to prioritize and adjust the implementations approved for the updated Six-year Implementation Plan and Three-year Technology Plan.

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2.0 AMMOS Future Drivers

(listed in order of anticipated magnitude of impact)

2.1 Declining Planetary Science Budget

NASA's planetary science program is facing significant budgetary reductions that are forecast to continue for at least the next five years. These reductions are expected to have significant long-term impact to the planetary program including flagship missions and the Mars exploration program. AMMOS will need to respond with increasing, demonstrable cost effectiveness for customers across NASA.

2.2 Dominance of Competitively Chosen Missions

The mission set to which AMMOS responds is increasingly less predictable as the number of long-lead assigned missions decreases and the number of competitively selected missions increases. As competition between proposed missions intensifies, the pressure to reduce their planned costs increases commensurately. Rather than narrowly targeting specific mission types, AMMOS will need to focus on having a nimble, easily deployed system that efficiently and effectively supports a range of mission types.

2.3 Increasing Security Threat

NASA, including the AMMOS, faces an increasing number of sophisticated attacks that target its critical infrastructure. Attackers employ a variety of methods to obtain unauthorized access to systems, data, and intellectual property. This heightened threat environment will lead to additional requirements placed on the AMMOS to ensure system security. The AMMOS will need to proactively manage security risks, while ensuring mission success. AMMOS will need to implement and maintain systems that enable the integration of processes and information across the full breadth of partner organizations while achieving a risk-based balance between security, system functionality and operability, and funding resources.

2.4 Increasing Number of Missions Employing Small Body Navigation

Future NASA missions include small body targets and small body sample return missions. Small body targets and small body sample return missions are envisioned to drive a need to develop a multimission autonomous onboard navigation system and develop tools that provide rapid and highly accurate orbital thrust profiles. In addition, there is a need to decrease, from several months to a few hours or less, the time required to compute small body landing trajectories for complex gravity fields and topographies.

2.5 In Situ Robotic Explorers with High Tempo Ops

In situ missions are a major focus of NASA's solar system exploration program. Future missions are expected to have the capability to explore the universe with more autonomy – i.e., with more onboard decisions based on local information and less dependence on frequent human intervention, particularly when two-way light times are long.

This greater autonomy may drive migrating more of the mission planning and sequencing to the in situ exploration element and ensuring that the associated software is sophisticated enough to handle unexpected situations that are likely to occur. Other key capabilities for in situ missions include precision landing, real-time autonomous navigation, and, for sample return missions, ascent and rendezvous navigation.

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2.6 Dissimilar, Multi-Spacecraft Missions to Single Target

Over the long term there will likely be an increasing need for dissimilar, multi-spacecraft operations, particularly across successive inter-related missions to the same target. Because these successive mission assets depend upon one another, cross-mission planning, sequencing, and navigation become increasingly complex. Additionally, multiple spacecraft with dissimilar orbits (particularly heliophysics-related constellations) present similar challenges.

2.7 Increase in Data Volume and High-Rate Data Throughput

AMMOS will need to respond to a continuing increase in data volume and data rate. Potential drivers for increasing data volume and high-rate data throughput include telescope and human exploration missions.

2.8 Increase in External Partnerships

Ability to further and take advantage of external partnerships for jointly developed data systems and mission operations enables the AMMOS to increase its infusion across the Agency and supports the potential for increasing international partnership on missions to minimize expenditures. NASA is increasingly looking at international partnerships as a way to leverage its limited budget in a manner that enables a greater science return than would otherwise be the case. To the extent that AMMOS can further reduce NASA's mission ops and GDS expenditures in such ventures, the science return per NASA dollar will be even greater.

2.9 Maturation and Infusion of Operations-Focused Technology

A well-integrated technology-to-implementation pipeline for operations-focused technology will enable the AMMOS to reach its vision and goals more quickly and cost effectively through infusion of emerging technologies.

2.10 Space Communications and Navigation Architecture

NASA's Space Communications and Navigation (SCaN) Office envisions a future network architecture that integrates the Deep Space Network (DSN), Space Network (SN), and Near Earth Network (NEN) in a manner that renders operational differences between the networks transparent to the mission customer and provides a single interface point for service subscription. The SCaN network elements (DSN, NEN, SN) are moving toward adoption of common, CCSDS based, services. Through a phased incremental approach SCaN will integrate all three network elements into a new Integrated Network Architecture.

The SCaN architecture implies that AMMOS will need to operate at higher data rates and data volumes and continue to evolve its ground communications interface in accord with SCaN's integrated network architecture. Functionality potentially impacting the AMMOS include forward data delivery, return data delivery, radio-metrics, position and timing, standard interface for service planning, and a common portal for secure service access and management.

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3.0 AMMOS System Goals and Roadmap

This section defines the four primary system goals needed to achieve the AMMOS vision and the motivation for establishing these goals. These four goals are divided into subgoals in the strategic roadmap that are the key capabilities needed to achieve each goal. The strategic roadmap following each goal allows the user to see the key milestones and their priorities through 2025.

3.1 System Goals and Rationale

3.1.1 Goal #1: AMMOS will continue to evolve and improve its tools and services to reduce Mission Operations cost and risk.

Drivers: 2.1 Declining Planetary Science Budget, 2.2 Dominance of Competitively Chosen Missions, and 2.3 Increasing Security Threat

Rationale: To provide the most effective and efficient solution for missions, MGSS will strive to maintain the AMMOS with a modern and secure architecture in both hardware and software. Also important is to strive towards more automation where possible in the Mission Operations System. This includes ground processes as well as moving some processes to the flight system where it makes sense.

3.1.2 Goal #2: AMMOS will evolve its infrastructure to be consistent with appropriate technological advances in emerging standards, computing, and architecture.

Drivers: 2.1 Declining Planetary Science Budget, 2.3 Increasing Security Threat, and 2.9 Maturation and Infusion of Operations-Focused Technology

Rationale: MGSS has three key motivations in evolving its infrastructure: 1) Eliminate duplicate functionality across the system, 2) Move toward increased virtualization and platform independence in order to improve and expand availability of AMMOS services and to increase efficiency in the use of computer resources, 3) Build, develop, and deploy AMMOS services that are agile, adapted to project MOS configurations, and responsive to broadly supported, open standards.

3.1.3 Goal #3: Broaden AMMOS to support future missions.

Drivers: 2.2 Dominance of Competitively Chosen Missions, 2.4 More Small Body Navigation, 2.5 In Situ Robotic Explorers with High Tempo Ops, 2.6 Dissimilar, Multi-Spacecraft Missions to Single Target

Rationale: Section 2 identifies the following types of missions as drivers on the AMMOS: (1) more small body navigation, (2) in situ robotic explorers with high tempo operations, and (3) dissimilar, multi-spacecraft missions to a single target. Within these classes, specific mission types not fully addressable with current AMMOS capabilities include: in situ balloons, sample return missions (with the exception of navigation), lander networks, surface ascent and on-orbit rendezvous operations, next generation rovers, and active formation flyers. These challenges imply a need for AMMOS that is less human interactive, has more on-board autonomy, and has the ability to command and/or collaborate across multiple spacecraft.

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3.1.4 Goal #4: AMMOS is compatible with future changes to Space and Ground Communications Infrastructure.

Drivers: 2.7 Increase in Data Volume and High-Rate Data Throughput, 2.8 Increase in External Partnerships, and 2.10 Space Communications and Navigation Architecture

Rationale: The NASA vision for the future of integrated network architecture is defined within the Space Communications and Navigation Integrated Network (SCaN). The SCaN architecture implies that AMMOS will need to operate at high data rates and data volumes, work with optical communications, and continue to evolve our ground communications interface through the implementation of an integrated service portal.

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3.2 System Strategic Roadmap

3.2.1 Roadmap for Goal #1: AMMOS will continue to evolve and improve its tools and services to reduce Mission Operations cost and risk.

Table 3-1. Goal #1 Roadmap: AMMOS Improvements

Subgoals	2014	2017	2020	2025
1-1 Automate manual processes	1-A baselined AMMOS architectural model exists that enables interrogation of system effects of and on process (includes an Information Model). 2-A baselined model of AMMOS processes for flight operations and adaptation exists in key areas. 3-Methods and software are in place to facilitate process development and execution and that are ready for adoption by Phase A/B Projects.	1-High-leverage process areas for automation (cost/benefit) have been identified based on metrics and AMMOS system models. 2-AMMOS services "simple" (repetitive, straightforward) processes can be automated and used in "lights-out" fashion for flight operations. 3-Automation software development is facilitated by available AMMOS system and services models requirements and specifications. 4-Automation of instrument data processing workflow capability has been demonstrated (includes but not limited to systematic code orchestration pipelines, zero installation vs. licensing of software, remote deployment, interface with Planetary Data System-PDS).	1-High-benefit AMMOS processes have been automated and used for lowering the cost of flight operations. 2-Evidence exists of high utilization of AMMOS service/process methods and tools for GDS deployments and system testing (stretch goal: ATLO, FSW dev). 3-Continuous improvement of automation capabilities are in place.	1- "Lights-out" operations capabilities are in use by projects for cruise or routine operations (e.g., orbital mapping).
Rationale	• Areas where automation has highest potential for reduced cost and risk			

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Table 3-2. Goal #1 Roadmap: AMMOS Improvements (cont'd)

Subgoals	2014	2017	2020	2025
1-2 Modernize tools that have become expensive to maintain	1-Modernized AMMOS functional software applications exhibit the following set of architectural patterns and properties: a) Distributed multi-tier architectures b) Component-based frameworks c) Greater use of industry standards d) Use common (shared) cross-cutting software utility services (e.g., security) as opposed to "rolling their own"	1-50% of the 2014 legacy tools have been modernized incorporating architectural patterns and properties cited for 2014 target. 2-Instrument data processing subsystem has been modernized (including but not limited to information model-driven applications to automatically generate code to ease adaptation, flexible selection/deployment of software tool-suites, etc.).	1-75% of the 2014 legacy tools have been modernized incorporating architectural patterns and properties cited for 2014 target.	1-100% of the 2014 legacy tools have been modernized incorporating architectural patterns and properties cited for 2014 target.
Rationale	• Improves maintainability of aging systems and enhances performance • Reduces number of monolithic tools, which are expensive to update and maintain • Increases modularity to help minimize duplication and overlap of design and implementations • Facilitates greater interoperability between tools			

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Table 3-3. Goal #1 Roadmap: AMMOS Improvements (cont'd)

Subgoals	2014	2017	2020	2025
1-3 Reduce effort to deploy AMMOS into the mission environment	1-All AMMOS software systems are auto-deployable: a) Non-Functional operational "ilities" have been defined for MPCS, Security Service, Timeline Management Service, Information Management Service b) Dependency checking for all AMMOS software is automatically handled via auto-deploy 2-VM instances have been version controlled and made available for all AMMOS releases. 3-Mission can use AMMOS services in project formulation and implementation phases to guide and facilitate adaptation (mission engineering, flt-ground communications, science & instruments, and flight system engineering services provide significant reuse of development artifacts including Requirements (Level 4), Interfaces & Agreements, Information structures (timelines), Processes, Training, and V&V materials.)	1-AMMOS common services can be shared: a) Missions can elect to share services, e.g., a single instance of the Security Service, Information Management Service (IMS) or Timeline Management Service (TMS).		
Rationale	• Reduces errors and turnaround time for deployments • Lowers the cost of AMMOS deployments • Improves system utilization - reduce cost to smaller mission			

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Table 3-4. Goal #1 Roadmap: AMMOS Improvements (cont'd)

Subgoals	2014	2017	2020	2025
1-4 Reduce security risks	1-Security improvements identified, prioritized, & implemented based on an informed security risk mgmt process. 2-Common Security Services (CSS) provided by the AMMOS: a) Application layer Single Sign-On integrated with desktop login b) Application layer authorization policy mgmt and enforcement c) Security audit data collection, analysis, and reporting 3-Modernized AMMOS applications utilize the CSS: a) e.g., MPCS, IOS, DM&A 4-Increased security processes: a) System sec engineer involved in reqts & design reviews b) Improved sec-related testing; vulnerability testing included in subsystem and system verification c) Security-related ops procedures are efficient, effective, and well-documented	1-Strong authentication supported: a) PIV-II smart card 2-Federated id and authN is supported: a) Enable systems to use JPL and NASA credentials 3-Key Management Infrastructure and encryption/signing enable data security in-transit and at-rest a) Secure cmds and telem 4-Security situational awareness is increased through tech, mgmt, and ops improvements: a) Audit data analysis & reporting capabilities & processes provide insight into sec issues & effectiveness of sec controls b) Enhanced training increases sec-related knowledge and understanding within MGSS orgs & its customers 5-Ability to selectively grant access to data based on credentials (at the application layer).	1-Enhanced perimeter, network, and desktop security controls further harden the AMMOS for remote operations and greater connectivity. 2-Advanced intrusion detection mechanisms are utilized. 3-AMMOS security controls support a wide range of end user devices - including PDAs and smart phones.	1-Security controls keep pace with AMMOS capabilities and customer needs: a) Enabling lights out operations b) Supporting complete range of mission types
Rationale	• Reduces risk of unauthorized access • Lowers the cost of security-related mission adaptation • Facilitates compliance with NASA & JPL IT Security Requirements			

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3.2.2 Roadmap for Goal #2: AMMOS will evolve its infrastructure to be consistent with appropriate technological advances in

Table 3-5. Goal #2 Roadmap: AMMOS Infrastructure

Subgoals	2014	2017	2020	2025
2-1 Exploit emerging standards	1-Stable and mature industry standards at this timeframe are adopted for the following logical areas of the AMMOS:* a) Mission operations process modeling & execution b) Functional software applications c) Common (shared) software "utility" services (e.g., security) d) Common (shared) runtime platform infrastructure 2-A technology forecast identifying emerging standards for the next roadmap timeframe (i.e., 2017) has been produced for all four logical areas noted. *Based on earlier technology assessment and forecast.	1-Stable and mature industry standards identified in the former timeframe technology forecast are adopted for use by all AMMOS modernization tasks. 2-A technology forecast identifying emerging standards for the next roadmap timeframe (i.e., 2020) has been produced for all four logical areas noted	1- Stable and mature industry standards identified in the former timeframe technology forecast are adopted for use by all AMMOS modernization tasks. 2-A technology forecast identifying emerging standards for the next roadmap timeframe (i.e., 2025) has been produced for all four logical areas noted	1- Stable and mature industry standards identified in the former timeframe technology forecast are adopted for use by all AMMOS modernization tasks. 2-A technology forecast identifying emerging standards for the next roadmap timeframe (i.e., 20xx-TBD) has been produced for all four logical areas noted
Rationale	• Standards help ensure consistency thereby improving the ability to manage systems and improve user satisfaction. • Standards for interoperability additionally help ensure support from multiple vendors for their products, and facilitate external partner integration.			

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Table 3-6. Goal #2 Roadmap: AMMOS Infrastructure (cont'd)

Subgoals	2014	2017	2020	2025
2-2 Leverage common (shared) software services	1-The following common (shared) software services are available for use by all AMMOS functional applications that need such capability: a) Security Service b) Timeline Management Service c) Information Management Service d) Business Process Mgmt Service 2-Security Service utilized by all AMMOS modernization applications. 3-Timeline type registry and common domain (**ammos.nasa.gov**) exists for all Uniform Resource Identifier (URI)-dereferenceable data.	1-The following common (shared) software services are available for use by all AMMOS functional applications (in addition to 2014 list) that need such capability: a) Visualization Service b) Systems Management Service c) File Management Service d) Accountability Reporting Service 2-Security, Timeline Management, Information Management, and Accountability Reporting utilized by all AMMOS modernization applications. 3-File Management, and Business Process Mgmt Services utilized by all AMMOS modernization applications that need such capability. 4-A common (shared) infrastructure that supports multimission models has been deployed.	1-All 2014 and 2017 listed common services utilized by all funded AMMOS modernization applications that need such capability. 2-Candidate legacy applications for modernization to utilize common services identified and initially funded with specific emphasis on use of Security Service.	1-Legacy applications from 2020 target identified for modernization utilize all common services that need such capability.
Rationale	• Eliminates duplicate functionality across AMMOS functional applications.			

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Table 3-7. Goal #2 Roadmap: AMMOS Infrastructure (cont'd)

Subgoals	2014	2017	2020	2025
2-3 Exploit evolving networking and computing technologies	1-All AMMOS s/w is running on the Linux Platform 2-Key services can operate in a Data Center Model for example: a) Security b) Timeline Management Service c) Information Management Service d) Timeline type registry and common domain (ammos.nasa.gov) 3- Virtual Machine (VM) Provisioning cost variants and business model exists for: a) Physical server consolidation to virtualized platforms b) Migration strategies c) Failover	1-The Solaris Platform is no Longer supported (Linux Only is supported). 2-AMMOS offers (but does not mandate) a Data Center Business Model to missions: a) Missions can elect to share services and servers b) missions can have standalone software and hardware provisioned	1-AMMOS provides seamless transition between private data center services and Cloud Computing services; specifically, the Infrastructure-as-a-Service (IaaS) model is provided as a common compute platform offering. 2-AMMOS begins to exploit Cloud-based distributed processing technologies (e.g., Platform-as-a-Service (Paas). 3-AMMOS supports an interface to SCaN Delay Tolerant Networking (DTN) for space networking.	
Rationale	• Lowers platform cost of AMMOS deployments • Improves backup, CM, and disaster recovery of GDS • Improves system utilization - reduce cost to smaller mission • Improves development / test / deployment environment commonality and migration - reduce cost			

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3.2.3 Roadmap for Goal #3: Broaden AMMOS to support future missions.

Table 3-8. Goal #3 Roadmap: AMMOS New Capabilities

Subgoals	2014	2017	2020	2025
3-1 Provide end-to-end data accountability	1-An End-to-End (E2E) data accountability solution has been defined. a) Flight software gaps that prevent a full end-to-end accountability solution have been identified with an understanding of the ground system workarounds. b) A data accountability infrastructure (partial components) is in place, e.g., Information Management Service (IMS), Timeline Management Service (TMS), Accountability Reporting Service (ARS). c) A fully-defined ops process in support of data accountability has been described, which is needed to influence a 2017 E2E accountability solution.	1-E2E data accountability solution for planning and production of science products is available (MPCS, IOS, MPS). 2- CCSDS SM, SCaN standard services & reports integrated into accountability solution.	1-E2E data accountability solution is available for NMD and Housekeeping.	
Rationale	• Project need is not currently provided by the AMMOS. Individual missions implement this capability in piecemeal and inefficient ways.			

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Table 3-9. Goal #3 Roadmap: AMMOS New Capabilities (cont'd)

Subgoals	2014	2017	2020	2025
3-2 Provide end-to-end [AMMOS] system monitoring and control	1-A common (shared) Enterprise Systems Management (ESM) service (system-wide admin of distributed systems) has been system engineered and is available for infusion, including the selection of a supporting third-party product offering that supports a common programming model and runtime environment. 2-Autonomic Computing has been explored for application to the AMMOS with a prioritized set of operations and GDS subsystems identified with highest potential payoff in terms of cost and risk reduction for candidate infusion of such capability. *Autonomic Computing* refers to the self-managing characteristics of distributed computing resources, adapting to unpredictable changes while hiding intrinsic complexity from operators and users.	1-The common ESM service is utilized across half of the AMMOS operations and software subsystems providing a centralized, end-to-end monitoring and control of any multimission or project-adapted AMMOS runtime environment. 2-Autonomic Computing has begun to be infused at a low maturity level with application to the AMMOS runtime architecture for a small set of operations process and supporting GDS subsystems from one or two functional areas and provided as engineering releases.	1-The common ESM service is utilized across all AMMOS operations and software subsystems providing a centralized, end-to-end monitoring and control capability of any multimission or project-adapted AMMOS runtime environment. 2-Autonomic Computing is being applied to the AMMOS runtime architecture supporting up to half of the operations and GDS subsystems across all functional areas to a medium level of maturity.	1-The entire AMMOS runtime architecture of its operations and GDS subsystems across all functional areas exhibits a fully self-managing, autonomic system at a high maturity level. 2-The full autonomic capability is fully integrated with the ESM providing complete end-to-end AMMOS monitoring and control capability.
Rationale	• Project need is not currently provided by the AMMOS. • Reduces project risk.			

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Table 3-10. Goal #3 Roadmap: AMMOS New Capabilities (cont'd)

Subgoals	2014	2017	2020	2025
3-3 Expand multimission operations services	1-The following mission services have been validated and delivered: mission engineering, flight system engineering, and flight-ground communications. 2-Current IOS and NMD processes can be integrated with mission services processes. Multimission operations services deliverable products include Timelines, Services Capabilities, Interfaces, Agreements, and Processes.	1-The following mission services have been validated and delivered: science and instrument engineering, navigation engineering (actually exists today). 2-The following mission services have been adopted by at least one flight project customer: mission engineering, flight system engineering, flight-ground communications.	1-The following mission services have been adopted by at least one flight project customer: science and instrument engineering, navigation engineering. 2-Evidence exists for "lights out operations" of flight-ground communications.	1-Evidence of "lights out operations" exists from planning through sequencing and command generation.
Rationale	• Multimission services reduces cost and risk. • Services consolidate capability which means less development effort (i.e., cost) for common functions of a mission. • Consolidation of common function reduces risk of errors and bugs getting re-introduced into process. • Because the services are organized by engineering discipline, mission needs for software are much clearer for discipline-specific needs as well as software needs across all services.			

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Table 3-11. Goal #3 Roadmap: AMMOS New Capabilities (cont'd)

Subgoals	2014	2017	2020	2025
3-4 Provide highly flexible tools to support a variety of mission types	1-An initial set of **easily adaptable**, fully tested, pre-configured/pre-packaged telemetry processing, telemetry display, and command capabilities is available for mission customers. 2-AMMOS provides a suite of telemetry processing & display capabilities for mission customers that includes low-cost, pre-packaged Off-The-Shelf (OTS) solutions in addition to its flagship telemetry processing & display offering (e.g., MPCS).	1-An initial set of easily adaptable, fully tested, pre-configured/pre-packaged mission planning & sequencing capabilities is available for mission customers. 2-AMMOS has expanded its tool catalog to include a set of non, pre-integrated OTS tool offerings in support of low-cost missions.	1-An initial set of easily adaptable, fully tested, pre-configured/pre-packaged instrument data processing capabilities is available for mission customers. 2-AMMOS provides a complete end-to-end, easily adaptable, fully tested, pre-configured/pre-packaged suite of multimission tools for mission customers based on a set of low-cost, OTS products to support low-cost missions.	1-AMMOS provides a complete end-to-end, easily adaptable, fully tested, pre-configured/pre-packaged suite of multimission tools for mission customers based on its flagship set of products to support mid-range to higher-cost missions.
Rationale	• Competitively-bid mission environment may force focus toward more generically applicable endeavors. • Ability to readily scale up or down in terms of offering MOS capability will better position the AMMOS for a competitive environment.			

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Table 3-12. Goal #3 Roadmap: AMMOS New Capabilities (cont'd)

Subgoals	2014	2017	2020	2025
3-5 Support increased autonomy for flight systems	1-AMMOS provides autonomous mission planning & sequencing capability to make real-time, onboard re-plan decisions based on local information (e.g., hazard avoidance, unforecasted science events (also known as "opportunistic science").	1-AMMOS provides multimission onboard targeting & hazard avoidance capability for small body and planetary encounter missions. 2-AMMOS provides autonomous instrument data processing capability to reduce data return volumes of astrophysics missions (specifically, data that does not meet science criteria, with the determination made onboard).	1-AMMOS multimission Autonomous Guidance, Navigation, & Control (AutoGN&C) capability has been "productized" so that it can be readily adopted and adapted for use by in situ investigation planetary science missions. 2-AMMOS provides multimission ascent Autonomous Rendezvous & Docking (AutoR&D) capability for planetary science sample return missions.	1-AMMOS supports autonomous networked ("fractionated") spacecraft systems that require real-time ops.
Rationale	• An enabler for "high-tempo" ops, meaning periods of operations where there is little time for Earth-based deliberation. • Reduces cost and increases mission capability.			

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3.2.4 Roadmap for Goal #4: AMMOS is compatible with future changes to Space and Ground Communications Infrastructure (SCaN).

Table 3-13. Goal #4 Roadmap: AMMOS Support for SCaN

Subgoals	2014	2017	2020	2025
4-1 Support future downlink data rates for Deep Space missions (Mbps)	6 Mbps	28 Mbps	50 Mbps	150 Mbps
Rationale	• Based on 2011 Future Mission Trends & Implications for the DSN - D. Abraham and Architecture, Strategic Planning, and System Engineering Office - Aug. 25, 2011 (Corresponds to maximum individual mission data rate that MOS and GDS will need to support in this timeframe.)			
4-2 Support future downlink data volumes for Deep Space Missions (maximum daily) (Tb)	0.03 Terabytes per day (per mission) 127 Terabytes per year (for 10 simultaneous missions stored in a Data Center)	0.15 Terabytes per day (per mission) 592 Terabytes per year (for 10 simultaneous missions stored in a Data Center)	0.27 Terabytes per day (per mission) 1,056 Terabytes per year (for 10 simultaneous missions stored in a Data Center)	0.83 Terabytes per day (per mission) 3,170 Terabytes per year (for 10 simultaneous missions stored in a Data Center)
Rationale	• Worst case data volume analysis (used for potential sizing of data center) • 3 streams at X(Mbps) - 67% duty cycle per mission - Data Center concept should consider 10 simultaneous missions, one at max data rate.			

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Table 3-14. Goal #4 Roadmap: AMMOS Support for SCaN (cont'd)

Subgoals	2014	2017	2020	2025
4-3 Be compatible with the SCaN Integrated Service Architecture (Integrated Service Portal)	1-SCaN standard services based on applicable CCSDS standards have been identified with supporting Ops Concepts. 2-An interface between the AMMOS and the Deep Space Network (DSN) Service Portal exists for the following capabilities: a) Link analysis tool b) Service Agreement & mission configuration specs c) Service catalog d) Users Guides 3-AMMOS supports CCSDS Space Link Extension (SLE) forward and return services.	1-AMMOS supports the CCSDS Service Mgmt standard as a means of requesting services from SCaN. 2-AMMOS supports CCSDS Cross Support Transfer Services (CSTS). 3-AMMOS supports CCSDS Radiometric Transfer Services. 4-AMMOS supports the Position and Timing Service. **Note:** Above list based on roll out of Space Network Ground System Sustainment (SGSS) project into the Deep Space Element (DSE) in the SCAN Integrated Architecture (See SCaN Architecture Description Document (ADD) Vols 1 & 2).	1-AMMOS supports an interface to SCaN CCSDS Delay Tolerant Networking (DTN).	
Rationale	• AMMOS is compatible with SCaN / DSE network modernization - DSE evolves as part of SCAN Integrated Architecture, assumed to be based on adapted version of the SGSS project capabilities.			

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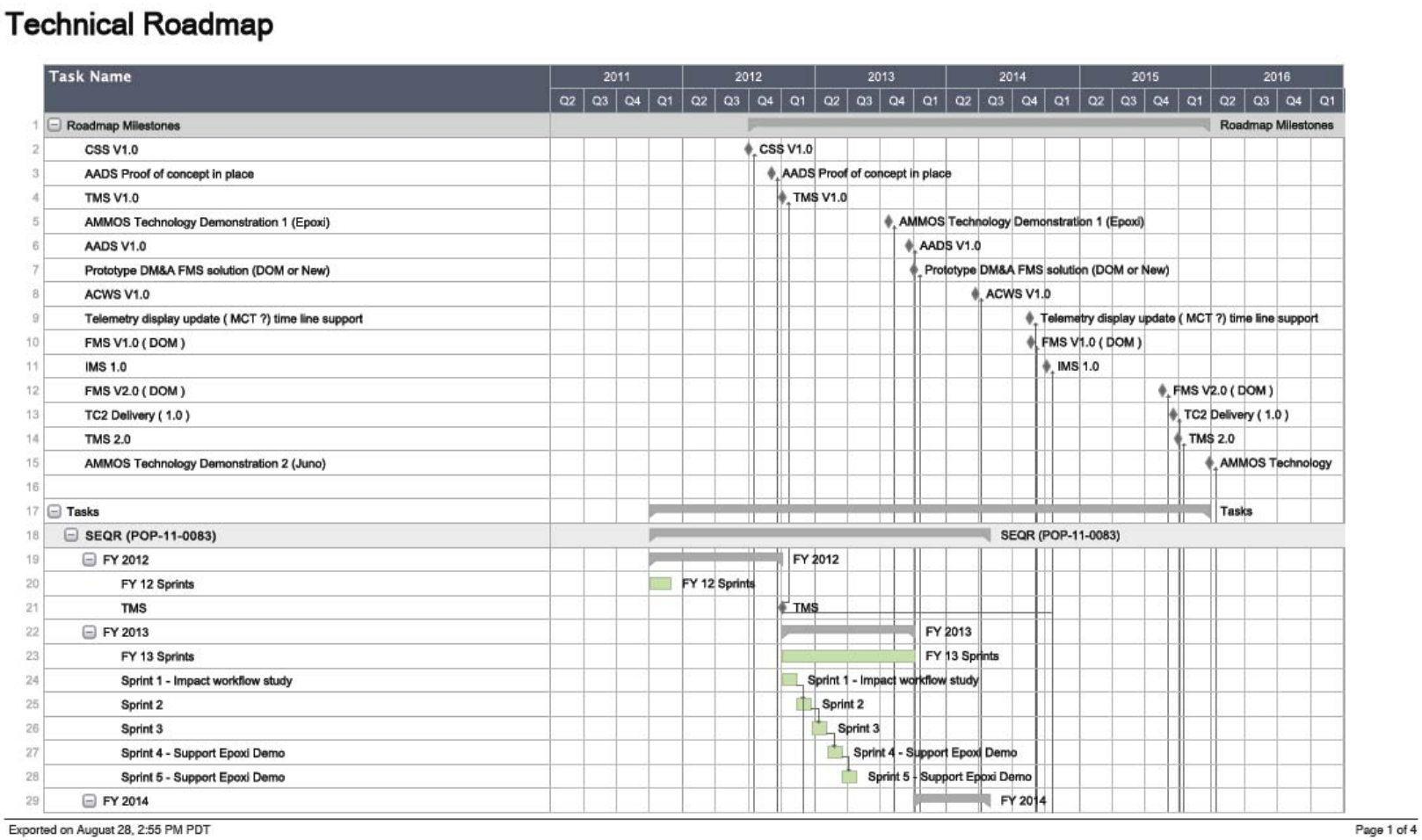
A. APPENDICES

A-1. Technical Roadmap (dated 28 August, 2010)

Note that the Technical Roadmap is a dynamic, living document. The version following is included for information and is current as of the date of publication.



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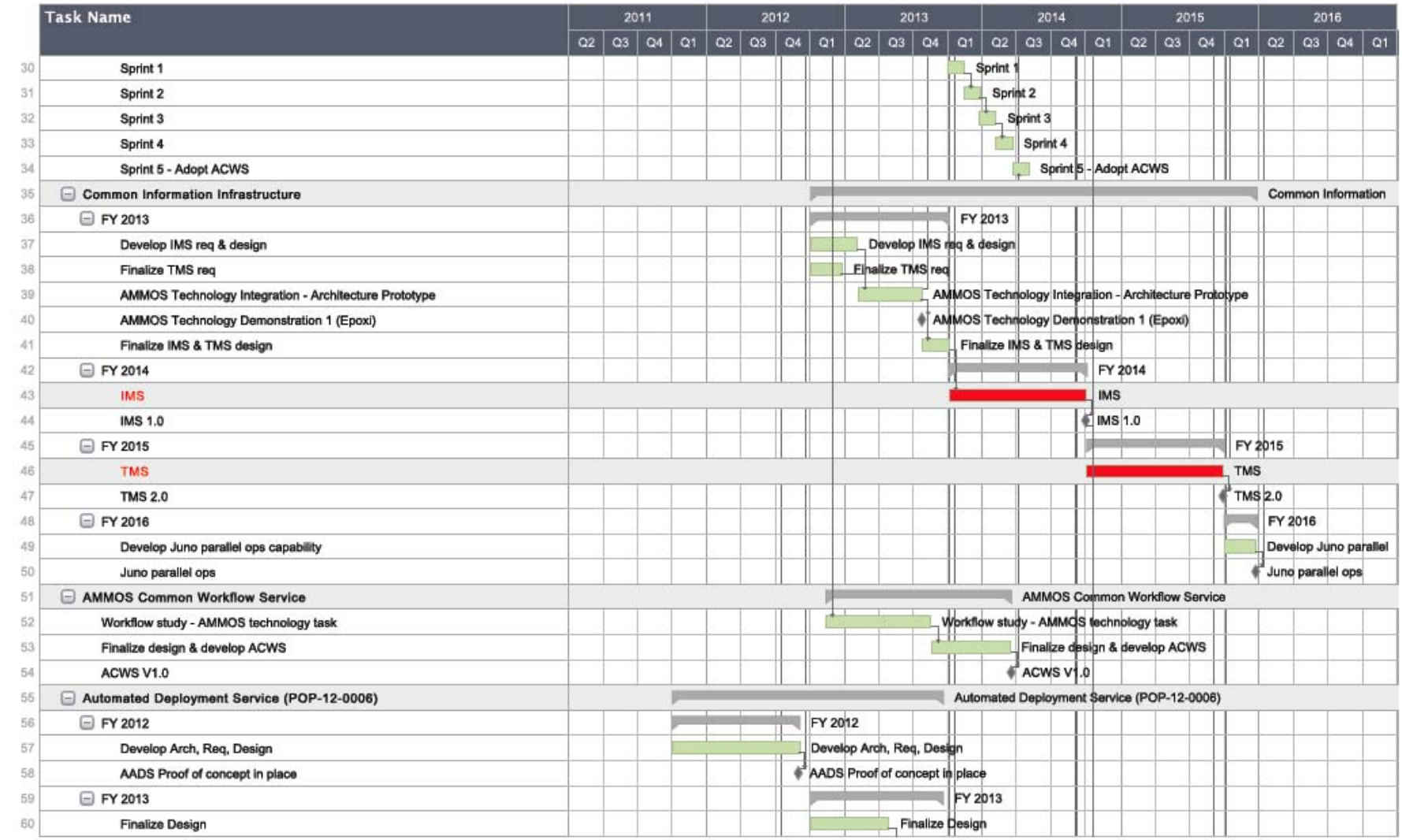

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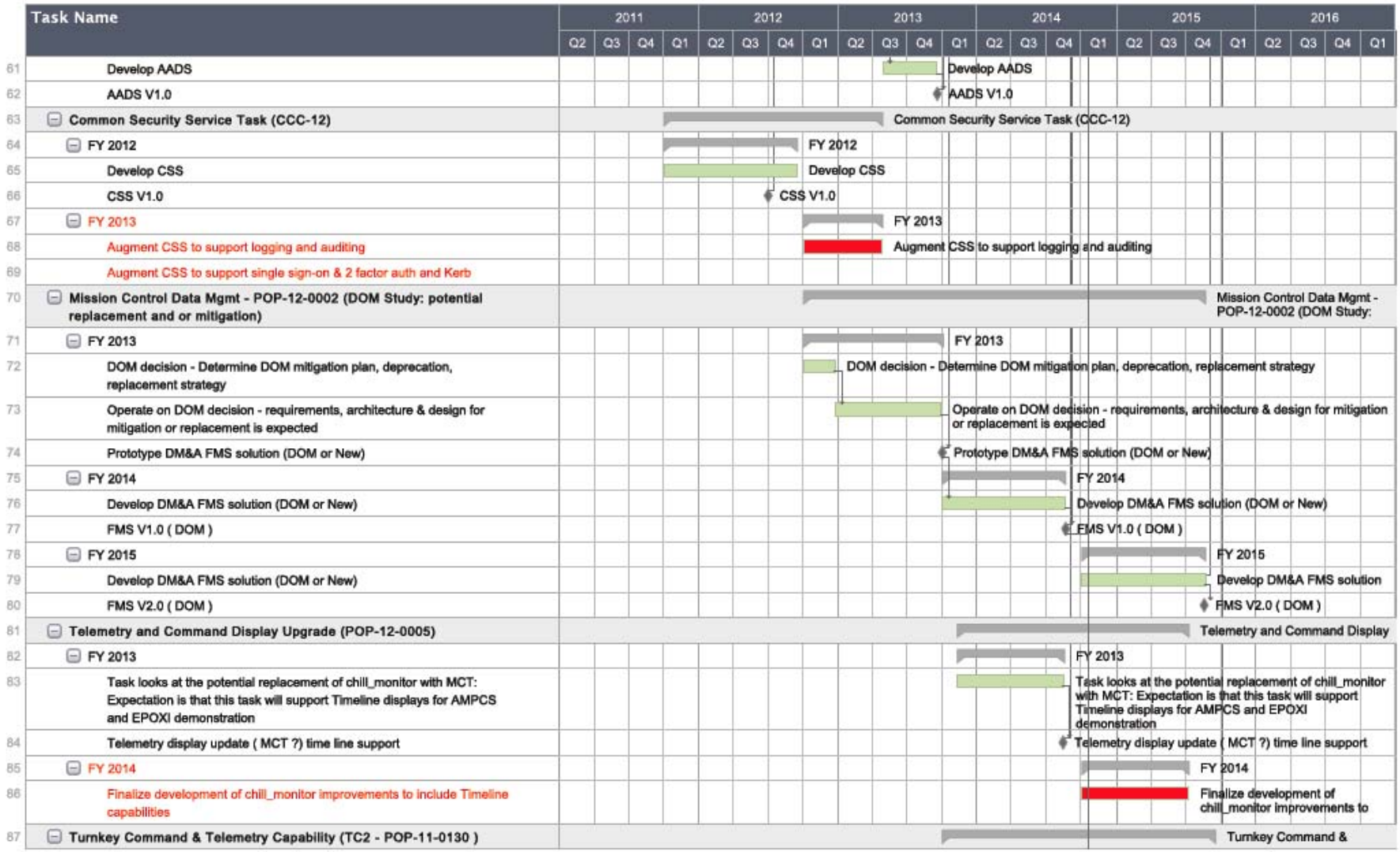

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	Task Name	2011				2012				2013				2014				2015				2016			
		Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1
88	FY 2013																								
89	Develop requirements and design for integrated AMPCS, CMD, DSNE to meet reference mission requirements for Dev, Test and Ops configurations that can be inherited and reused by projects																								
90	FY 2014																								
91	Integrate with IMS Dictionary Registry/Repository for multi-mission command and telemetry dictionaries																								
92	TC2 Delivery (1.0)																								
93	FY 2015																								
94																									
95																									
96	Footer																								

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A-2. Source Documents

1. Abraham, D.. Jet Propulsion Laboratory (JPL) IND Architecture and Strategic Planning Office, 2011 Future Mission Trends & Implications for AMMOS, (June 16, 2011)
2. National Research Council Decadal Surveys: Vision and Voyages for Planetary Science in the Decade 2013-2022, New Worlds, New Horizons in Astronomy and Astrophysics, (2010) Solar and Space Physics: A Science for a Technological Society (2012)
3. NASA Strategic Plan 2011

A-3. Works Cited

1. Bindschadler, D., Delp, C., Estefan, J., Giovannoni, B. and A. Ko, (Aug. 13, 2010), "AMMOS Architecture Principles," MGSS Doc No: DOC-000485.Fccsts

A-4. Acronyms & Abbreviations

ADD Architectural Description Document
AEM AMMOS Element Manager
AMMOS Advanced Multi-Mission Operations System
APL Applied Physics Laboratory
ARC Ames Research Center
ARS Accountability Reporting Service
ATLO Assembly, Test and Launch Operations
AutoGN&C Automated Guidance, Navigation and Control
AutoR&D Autonomous Rendezvous & Docking
CCC Communications, Computing, & Configuration
CCSDS Consultative Committee for Space Data Systems
CSTS Cross Support Transfer Services
CM Configuration Management
CSS Common Security Services
DM&A Data Management and Accountability
DSE Deep Space Element (of SCaN)
DSN Deep Space Network
DTN Delay Tolerant Networking
E2E End to End
ESM Enterprise Systems Management
FFRDC Federally Funded Research and Development Center
FSW Flight Software
GDS Ground Data System
GSFC Goddard Space Flight Center
IMS Information Management Service
IND Interplanetary Network Directorate
IOS Instrument Operations Service
JSC Johnson Spaceflight Center
MDAS Mission Control, Data Management & Accountability, and Spacecraft Analysis

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MGSS Multimission Ground System and Services Program
MITD Multimission Integration, Test and Deployment
MOS Mission Operations System
MPCS Mission Data Processing and Command System
MPS Mission Planning and Sequencing
NASA National Aeronautics and Space Administration
NEN Near Earth Network
NMD Navigation and Mission Design
OTS Off The Shelf
SCaN Space Communications and Navigation
SGSS Space Network Ground System Sustainment

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