A Multifacted Approach to Modernizing NASA's Advanced Multi-Mission Operations System (AMMOS) System Architecture

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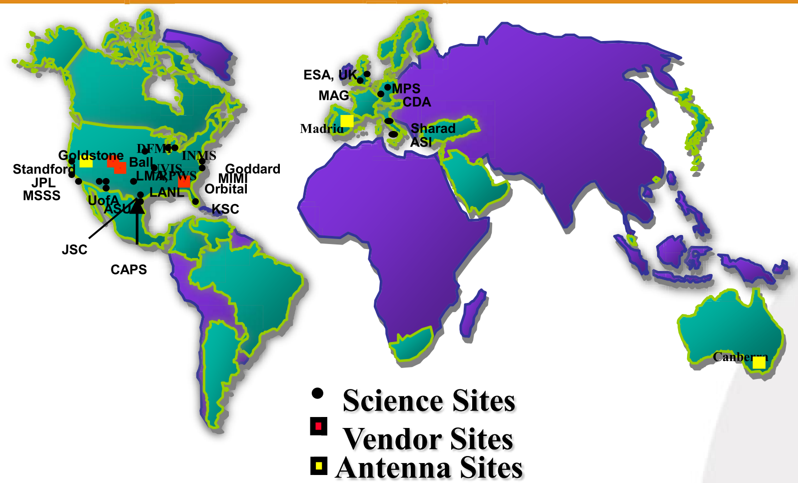
Agenda

- Today's AMMOS
- The Evolutionary AMMOS
- Current Challenges
- Improvement Opportunity
- Customer-Driven Architectural Goals
- Core Architectural Tenets
- Architecture Highlights
- Summary

Today's AMMOS
Overview



Facilities

- Hosted on workstation-class computing platforms connected via a secure flight network supporting data interchange and interaction among the functions
- Projects can choose to obtain elements (tools and services) of their MOS from the AMMOS
  - AMMOS systems must be customized (adapted) to project specifications

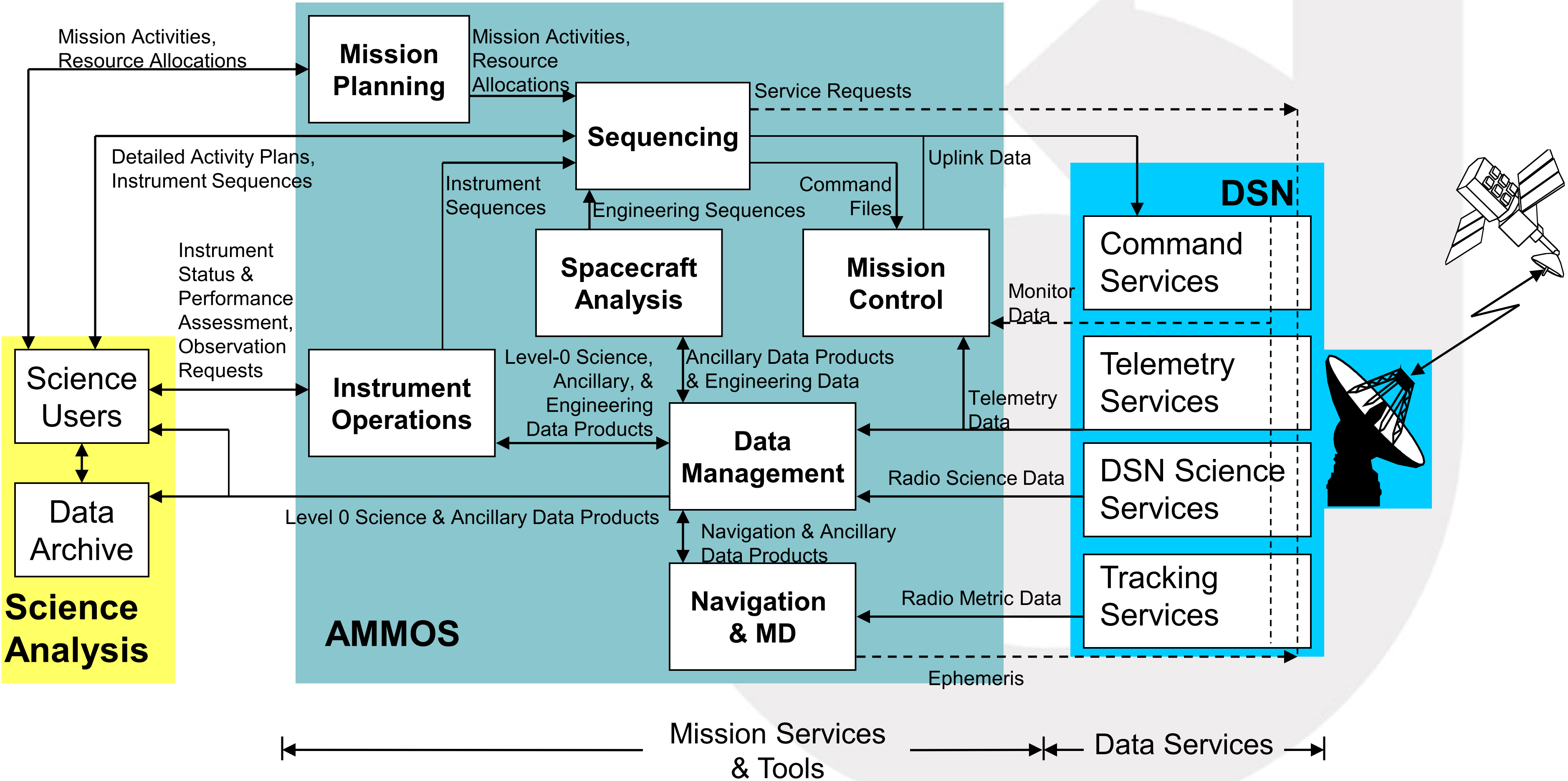
Capabilities

- NASA's AMMOS provides tools and services that are common to most deep space and astrophysics missions
  - Navigation & Mission Design
  - Mission Control
  - Data Management
  - Spacecraft Analysis
  - Instrument Operations
  - Mission Planning & Sequencing
  - Test Development & Operations support
  - Communications, Computers, Configuration

Business Value ….

- **Lowers mission cost and risk by providing mature base for project MOSs with significantly reduced development and deployment time**
- **Tailored support for a large number of diverse missions**
- **Efficient mission & science operations at globally distributed sites**
  - Collaborating communities of scientists

Today's AMMOS
Functional View (w/Major Interfaces)



The Evolutionary AMMOS

AMMOS Modernization [1]

- The AMMOS has evolved over the years and is currently a mixture of capabilities developed using older technologies and newer state-of-the-art technologies
- "Advanced" is in the name to reinforce NASA's intent to continually invest in the AMMOS to keep pace with state-of-the-art/practice
  - Continual, modest evolution of the system was determined to be more cost effective than periodic large incremental updates
- Nevertheless, the level of new investment dropped significantly in the late 1990s and early 2000s
  - The AMMOS began to lag the existing technology
  - Projects began to notice and voice concern
- This lead to the formation, in FY2005, of Multimission Ground Systems & Services (MGSS) Prgm Office with a mandate to "reinvigorate the AMMOS"
- In response, MGSS has been actively pursuing modernization and continues to evolve the AMMOS by incorporating enhanced capabilities and newer technologies into AMMOS
- Considerable progress has been made and is continuing to be made

The Evolutionary AMMOS
Approaches to Modernization [1]

- General approach has included the following categories of improvement:
  - Replacement of obsolete systems (some critical systems have a heritage from the 1960s)
    - Brings applications up to modern programming standards
    - Improves operability, testability, and maintainability
  - Remediation of dated hardware systems
    - Replaces aging and unreliable hardware (workstations, routers, switches, etc.)
  - Addition of fundamental new capabilities
  - Revitalization of multimission operations teams and processes
  - Upgrade to the technical infrastructure
  - Pro-actively extending the use and implementation of the AMMOS to a wider NASA community

Current Challenges
Flight Project Issues*

1. **Mission information is represented in multiple instances (generally in many flat files spread across the system) and tightly coupled with software applications**
   - Difficult and inefficient to manage same piece of information in multiple formats and locations across end-to-end spacecraft activity
     - From planning to execution to receipt of downlink data and across mission activities (system development, system test, ATLO, operations, etc.)
2. **Operating the system is more complex than desirable; should reduce need for personnel to perform manual, time-consuming work to reconcile plans with predictions and observations**
3. **Instantiating the system and making updates to it is disruptive and causes the need to retest more software than simply the software that has been modified (and its dependencies)**
   - Instantiating a system in development environment then test environment then ATLO environment then operations environment is time-consuming and requires a lot of personnel

List reflects synthesized set of the top issues/pain points for flight projects when standing-up their project MOSs, based on stakeholder interviews with multi-project mission operations personnel.

Improvement Opportunity
Architecture Modernization

- **An inflection point in AMMOS modernization has been reached**
  - **Limits to evolutionary modernization model** that focuses principally on functional areas without condieration of overall system architecture
    - Substantiated by list of top flight project issues
  - Current AMMOS architecture utilizes **lowest common denominator** approach to integrating GSW applications across functional areas
    - File Transfer w/pipe-and-filter connections (in use since AMMOS inception)
    - Approach necessary many years ago when standards, technologies, and best practices to application integration were limited – **Not the case today**
  - **No common runtime platform provisioning model**, prescriptive set of industry standards, or third-party software used across *all* AMMOS functional areas
  - **A better integrated, "Family of Systems" approach** is needed to help drive down cost of standing up a Project MOS
    - Lower the cost of tool and mission service integration
    - Leverage economies of scope in use of common standards, technologies, and platform computing capabilities for AMMOS core assets

Customer-Driven Architectural Goals*

Mapped to Flight Project Issues

Issue*	Goal
Multiple instances of mission data tightly coupled with software applications	**Lower the cost of integration across AMMOS functional areas**
Difficult to reconcile plans with observations	**Increase operations efficiency in multimission operations while reducing risk and enhancing mission return**
Instantiating, testing, and maintaining system is difficult	**Improve ability to test, deploy, and maintain the AMMOS in mission environments‡**

‡Parallel Goal: Lower the cost and effort <u>to the program</u> to test, deploy, and maintain the AMMOS

Oriented toward mission customer/flight project needs. There also exists a set of System Strategic Goals articulated in the NASA AMMOS Strategic Plan & Roadmap (summarized in the Backup slides). The new architecture needs to respond to both.

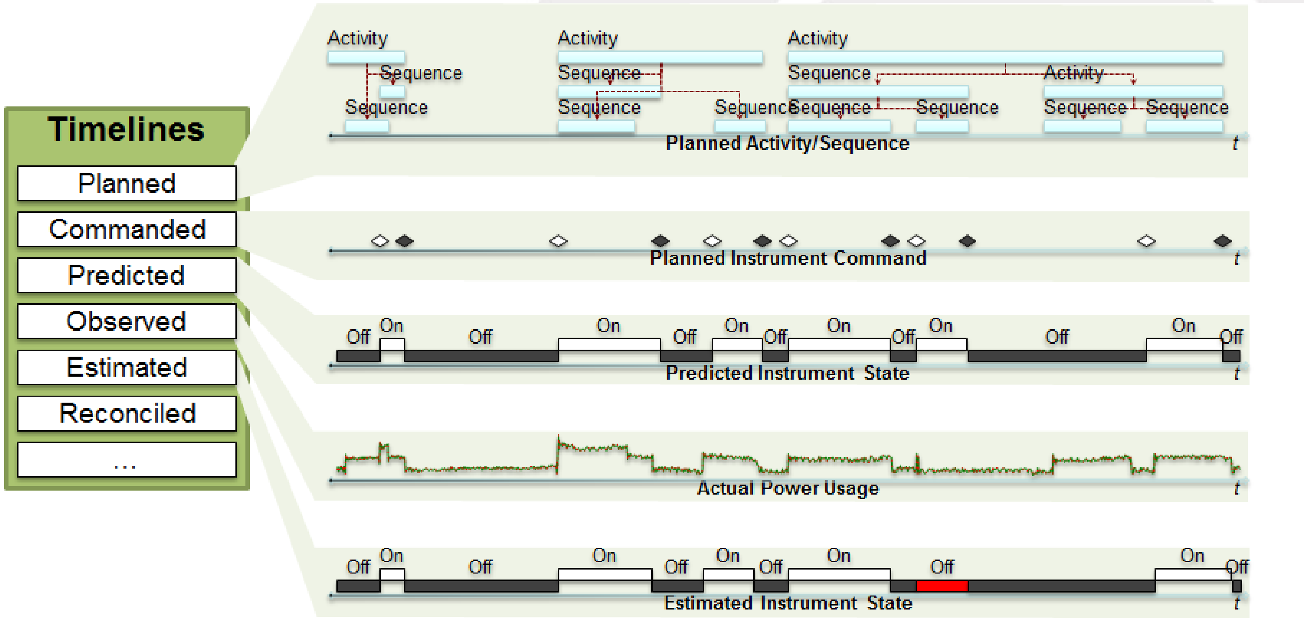
Core Architectural Tenets [2]
Foundational Concepts

1. ***Timeline as the Foundational Data Structure of our Domain***
   - "Timeline" proposed as basis of unifying 'canonical' (common/standardized) information model for storage and communication of MOS time-varying information (by functional software applications *and* in operations)
     - Help reduce adaptation cost by lowering cost of integration
     - Serve as basis for end-to-end data accountability
2. ***MOS as a Closed-Loop Control System***
   - Envision closed-loop control system tasked with achievement of mission and science goals, managing resources, an capable of closing the loop on goals and resource management "out-of-the-box"
     - Help increase operations efficiency (fewer gaps in operations processes that must be closed by costly and inefficient means)
3. ***Institutionalizing the Practice of Separation of Concerns (SoC)***
   - Apply architectural pattern of "layering" providing logical separation of functions with each layer having specified set of roles and responsibilities
     - Help make overall system easier to deploy and maintain

Core Architectural Tenets
Uniform Information Representation – "Timelines"

Tenet 1 – ***Timelines as the foundational data structure of our domain***

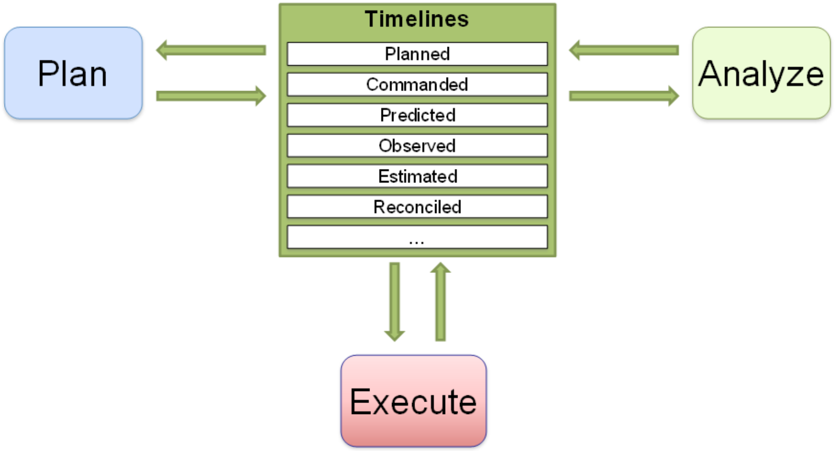
- A **timeline** is a representation of time-varying information; more specifically, a set of a set of values with associated times
- Example timelines for representing time-varying MOS information:

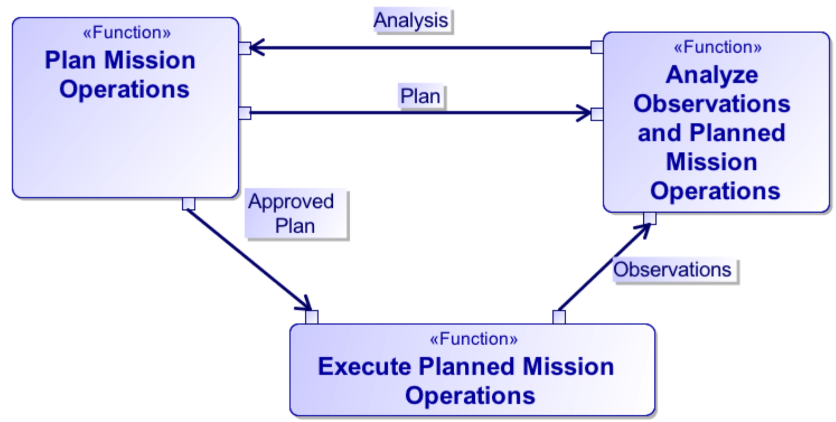


Core Architectural Tenets
[Timeline-Centric] Closed-Loop Control Pattern

Tenet 2 – ***MOS as a closed-loop control system***

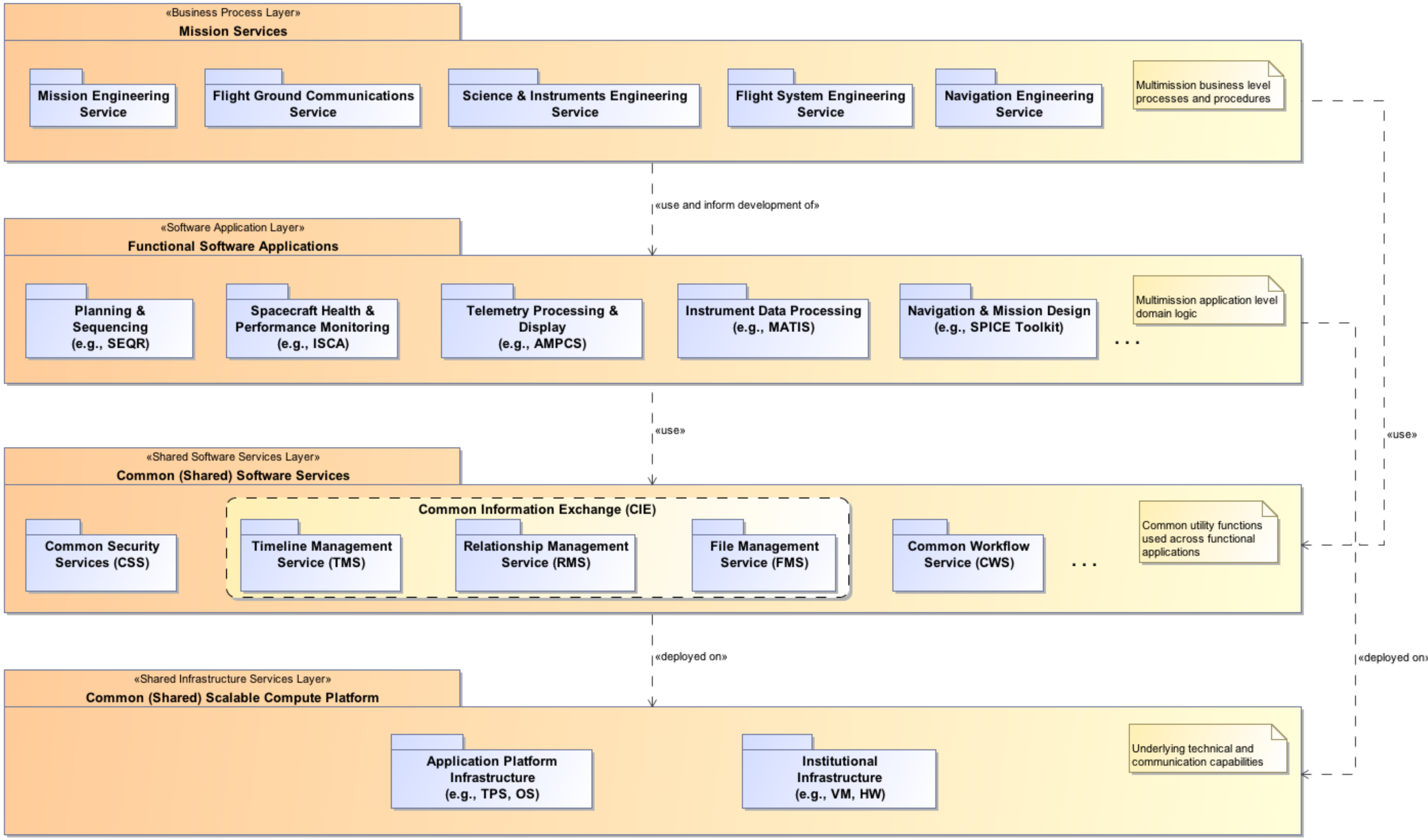
- Plan, Execute, Analyze ("PEA") closed-loop control pattern centered around Timelines
- Allows missions to standardize planning, execution, and reconciliation operational processes



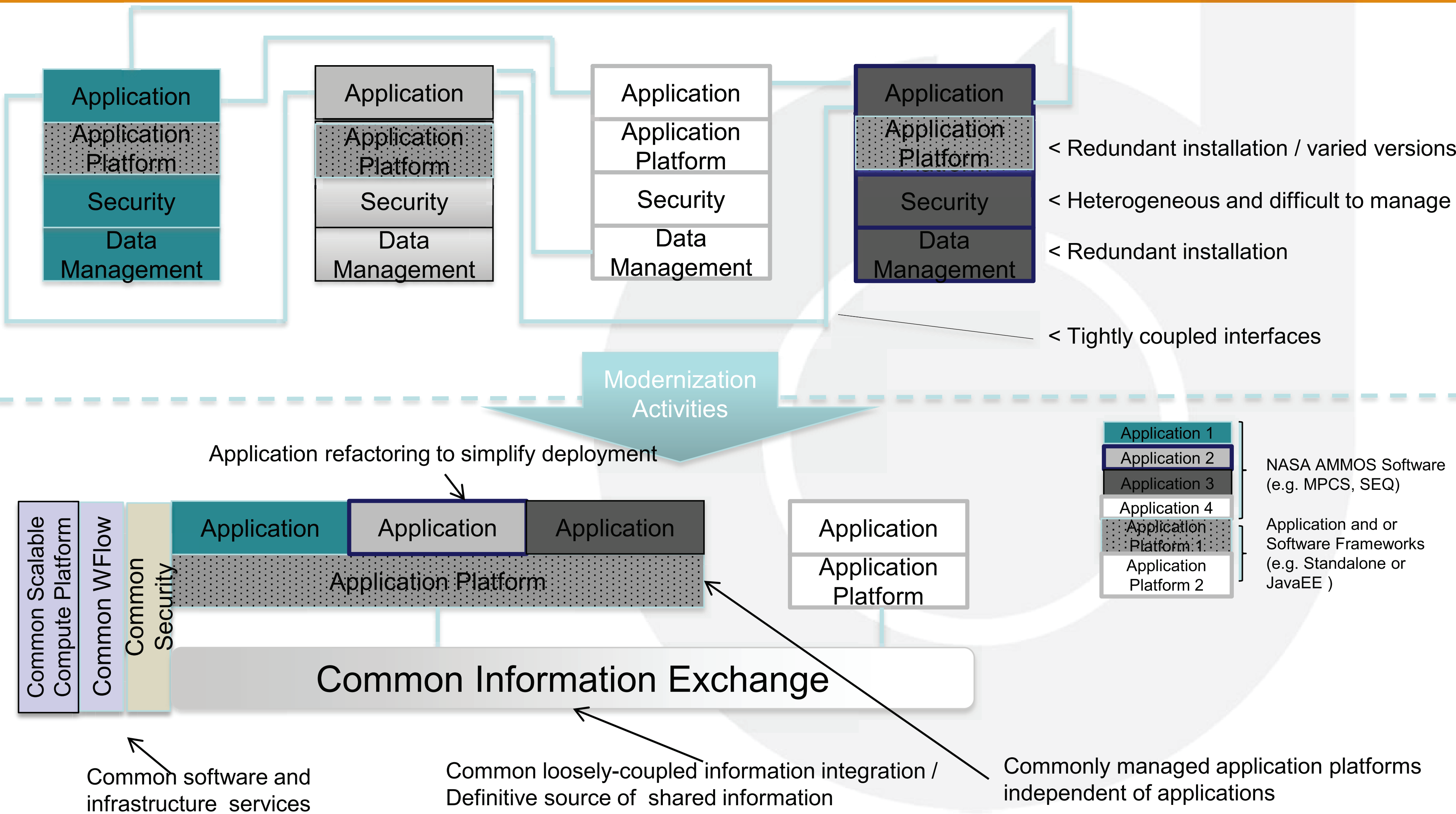


Core Architectural Tenets
Architectural Layering

Tenet 3 – ***Institutionalizing the practice of Separation of Concerns (SoC)***

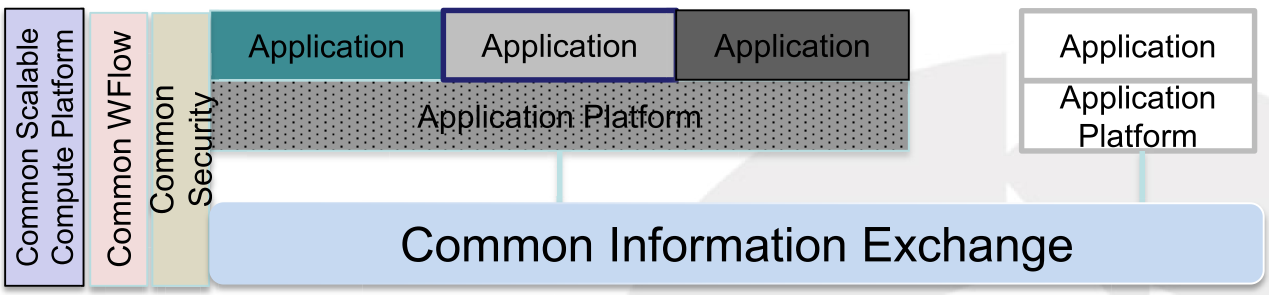


Architecture Highlights
Multimission GDS Modernization

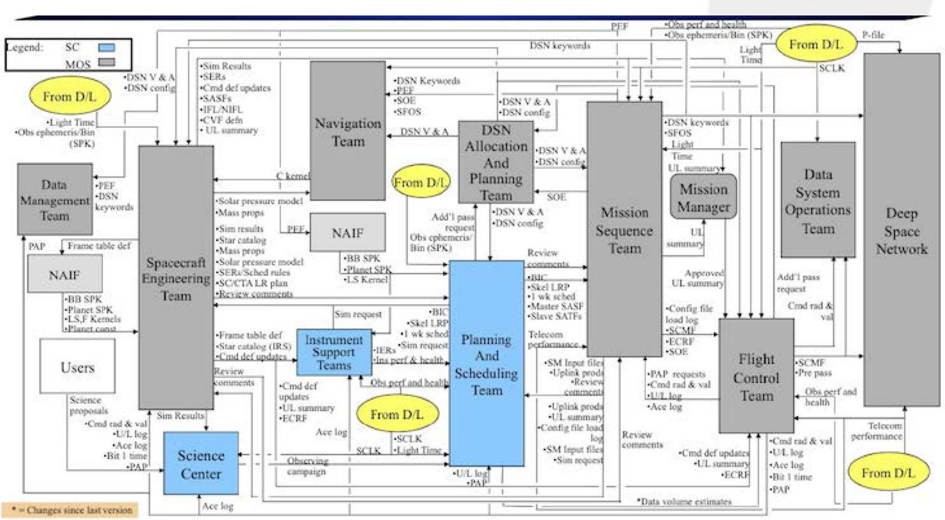


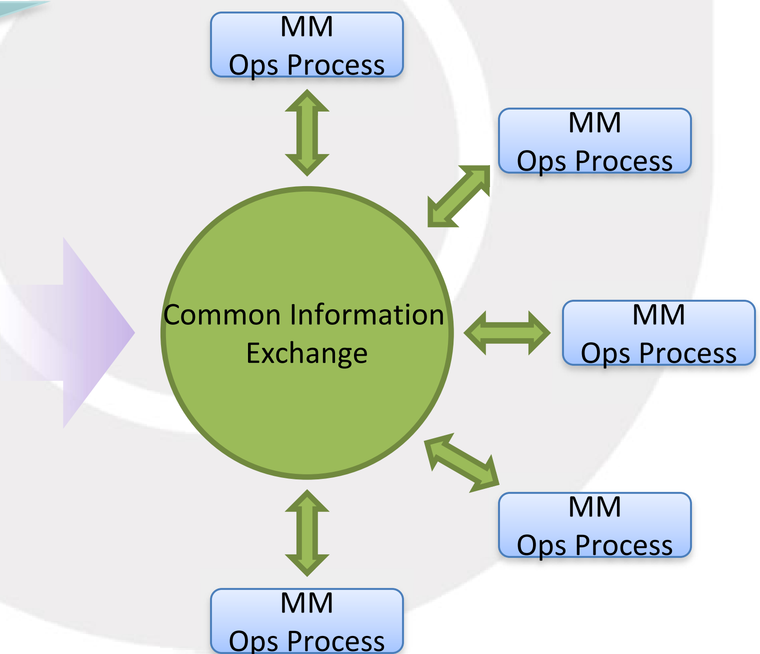
Architecture Highlights

Multimission Operations Modernization



Enables operations modernization





Summary

How the New Architecture Responds to Flight Project Issues

Issue	Response
Multiple instances of mission data tightly coupled with software applications	• Timelines and other definitive sources of MOS information managed by Common Information Exchange set of services
Difficult to reconcile plans with observations	• [See 1st bullet above] • Operations modernization allows missions to standardize planning, execution, & reconciliation operational processes
Instantiating, testing, and maintaining system is difficult	• Commonly managed, application-independent platforms

References Used in this Presentation Package*

1. Gunn, J. and E. Basilio, "Strategic Context," Presentation Slides (internal document), NASA AMMOS Working Group Meeting, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, Nov. 15, 2011.
2. Estefan, J. A. (and team), "AMMOS Architecture Vision," MGSS Doc No DOC-000780 (internal document), Multimission Ground Systems & Services (MGSS), Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, Nov. 15, 2011.
3. Giovannoni, B., "Strategic Plans: System & Elements AMMOS System," Presentation Slides (internal document), NASA AMMOS Working Group Meeting, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, Nov. 27, 2012.

A full set of references is provided in the companion paper.

Questions?

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Thank You!

Backup

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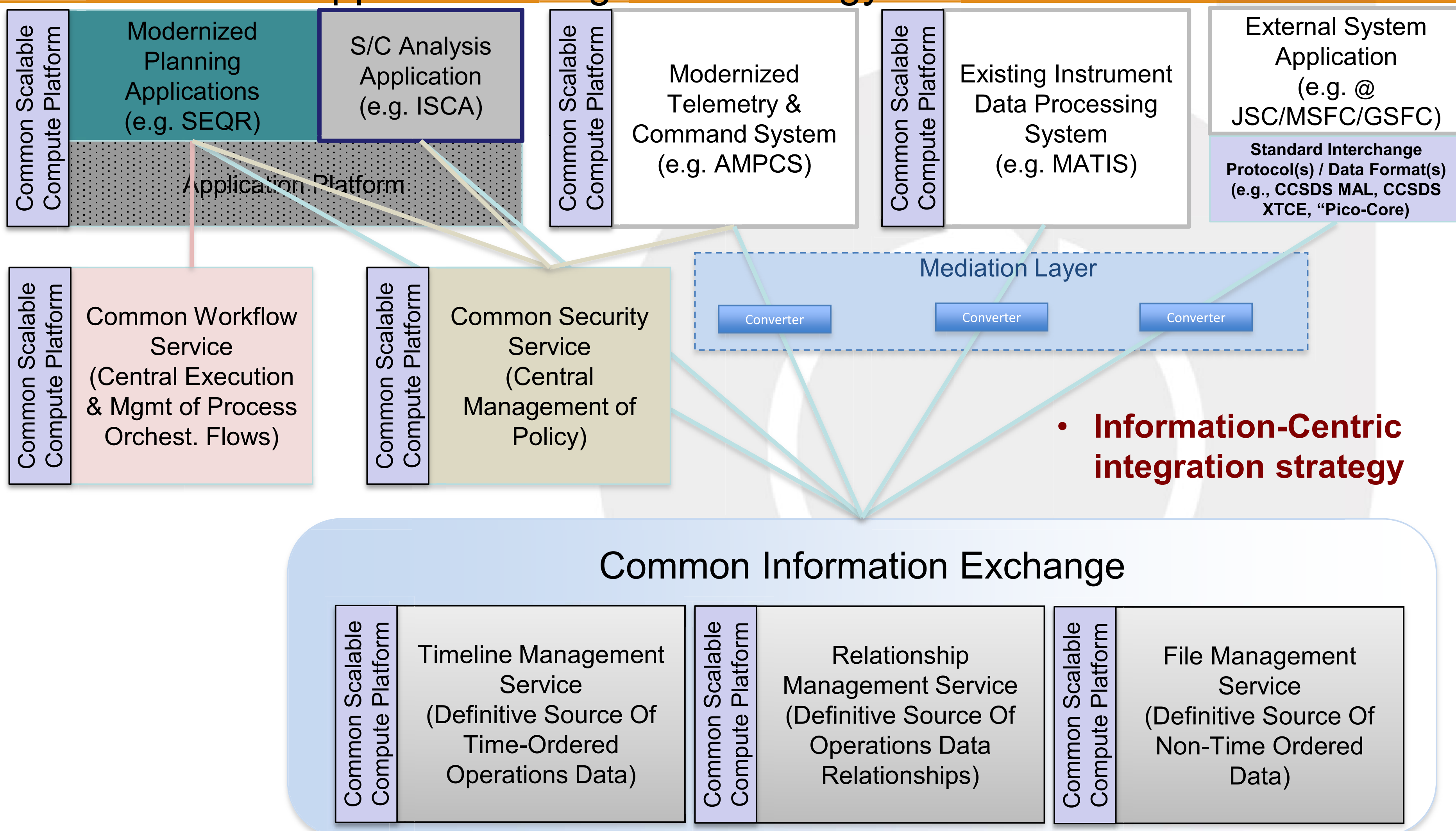
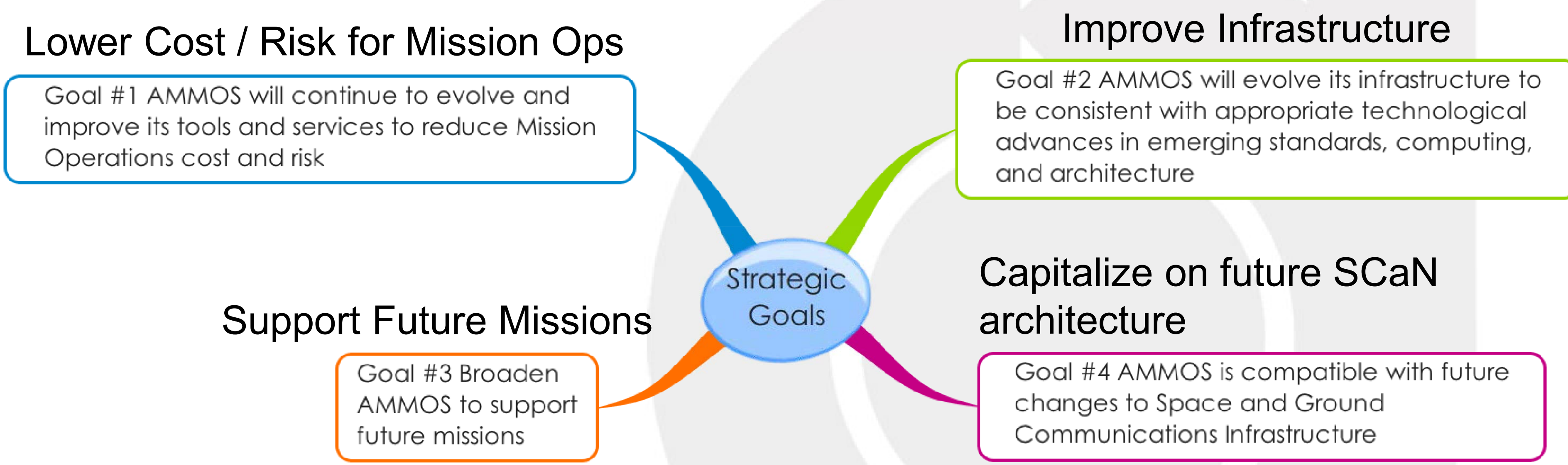
Architecture Highlights
Evolvable Application Integration Strategy



- **Information-Centric integration strategy**

AMMOS System Strategic Goals [3]



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