PRINCIPLES TO PRODUCTS: TOWARD REALIZING MOS 2.0

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Context

• AMMOS
  - Advanced Multi-Mission Operations System
  - Product line: Adaptable tools and services for operating NASA’s robotic missions
  - Key advantage: Cost and Risk
    ▪ “Why re-invent the wheel?”

• Ops Revitalization Initiative
  - Enhance, extend multi-mission Ops

• MOS 2.0
  - The Next-Generation Mission Operations System
An Architectural Approach

- Principled
- Stakeholder-focused
- Components, connections, constraints
- Separation of concerns
- Identification of fundamental patterns
- Model-Based Methodology
  - Didn’t start with MBSE
Architectural Principles

- Intended to be pervasive invariants
  - Inform design and implementation
  - Not requirements (not strictly verifiable)

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Stakeholder Engagement

- Directly engaged with domain experts via meetings, 1-1 interactions, talks, etc.
- Major Concerns include:
  - Control and estimate of State
    - Of spacecraft and instruments
  - Lifecycle support by MOS for Mission
    - Availability during FSW development
  - Adaptation (or Development) of the MOS
    - Ease in formulating/implementing (maximizing reuse)
MBSE Methodology

- Rigorous language for system engineering
  - SysML 1.2 and BPMN 2.0
- Explicit
- Standards-based
- Authoritative source
- Leverages architectural patterns
- Substantial gains in managing complexity
- Engineers spend more time engineering
Concerns, Viewpoints, Views

• **View**
  - Description of a system that addresses a particular point of view or *Viewpoint*

• **Viewpoint**
  - Template for information needed to construct a *View*
  - Aligned with/responds to *Concerns*

• **Stakeholder have *Concerns***
  - Statement expressing interest in a quality or characteristic of the system of interest
MOS 2.0 Concepts & Patterns

- Timelines
- Control System
- Process
- Services
  - Capabilities offered According to Agreements
- Queueing & Process simulation
- Standardized Design Specs

**Key Point**
- Each has a value proposition that supports the overall business case
Timelines

• Fundamental to mission planning
• More powerful when applied to all aspects of MOS
• For more, see:
  - Reinholtz, Thurs., 1100-1130 (CSIS)
  - Chien et al., Thurs., 1130-1200 (ME)
  - Seung & Bindschadler, Fri., 0930-1000 (ME)
Control System: To-Be
Control System: As-Is

Uplink

- Command Radiation
  - Sequence & Command Transmission
    - Observation Planning
    - Mission Planning

Downlink

- Telemetry & NAV Data Capture
  - Flight System Monitoring
  - Telemetry Processing
    - Data Archive
    - Instrument Health & Performance Analysis
    - Instrument Data Processing
    - Spacecraft Health & Performance Analysis
AMMOS Lifecycles

Project and Mission Deployment Lifecycle

- Project Start - Pre-launch Development
  - Mission Adaptation Operations Concept
  - Mission Adaptation
  - Process Concept
  - Mission Operations
    - Deployed Multi Mission Operations

Life of Multi-Mission Product

- Multi Mission Continuous Product Development Operations
- Multi Mission Continuous Product Development
Adaptation Concept
Ops Revitalization Results
Documentation & Reports

- Conceptual Operations Document
- Mission Operations System Architecture Document
- System Interface Control Document
- System Requirements Document
- Service Requirements Document
- Service Operational Description Document
- Service Implementation Document
- Process Description Document
- Timeline and Information Dictionary Document
- Multi Mission Process Catalog
- Multi Mission Timeline Catalog
- Software Application Configuration Document
- Adaptation Guide
- Training and Certification Guide
- Adaptation and Impact Report
- Training and Certification Report
Control Interactions

MOS 2.0 has several key interfaces with other systems. For a given deployment, MOS 2.0 receives requests for work and products from the Project and Project Science. MOS 2.0 is composed of Services. These services perform the work necessary to command and control mission resources in pursuit of Mission and Science Objectives.

These arrows denote who controls whom.
Controlling Interface

MOS

MOS-Ground Communications Network Interface

MOS-Ground Station Controller Interface

Monitor Data -0158
Actual Measurement DSS System Timeline

Ground Station Controlled Interface

Ground-MOS Interface

DKF
Actual Command DSS System Timeline

CONTROLS
Directing Interface

This is the Director port

This is the Directed port
Control System using Timelines

Flight System Engineering

Power

ABSL Li-Ion Battery

INTENTION  PREDICTION  ACTUAL  TREND

PLANNING

Battery SOC Intended State Timeline

Battery SOC Predicted State Timeline

Battery SOC Predicted Measurement Timeline

Battery SOC Intended Command Timeline

Battery SOC Intended Activity Timeline

ANALYSIS

Battery SOC Trend State Timeline

Battery SOC Trend Activity Timeline

Battery SOC Trend Activity Timeline

EXECUTION

Battery SOC Actual Command Timeline

Battery SOC Actual Measurement Timeline
Conclusions

• Architecture and MBSE enable a new kind of Mission Operations System

• A Control System
  - Composed of Services
    • Common components and interaction patterns
  - Using Timelines
    • *Lingua franca* for the MOS
  - With Authoritative Sources for Information
    • *Within* the MOS
    • *About* the MOS
Backup
Directing Interface

Mission Engineering Service

DIRECTS

Science Instruments Engineering Service

This is the Director port

This is the Directed port
Timeline-Based Control

Plan

Timelines
- Planned
- Commanded
- Predicted
- Observed
- Estimated
- Reconciled
- ...

Execute

Analyze