



SPACE  2015



Autonomous  
Mission  
Operations

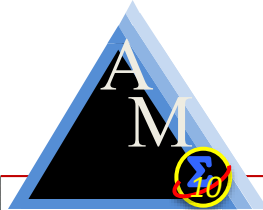
# AMO EXPRESS

**A Command and Control Experiment for Crew  
Autonomy Onboard the International Space Station**



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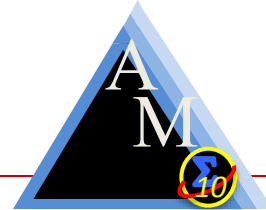
# Welcome and Thank You



SPACE  2015

Co-Author Introductions

# AMO Investigation Overview



The Autonomous Mission Operations project is investigating crew autonomy capabilities and tools for deep space missions.

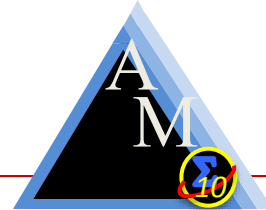
Team members at Ames Research Center, Johnson Space Center and Marshall Space Flight Center are using their experience with ISS Payload operations and TIMELINER to:

- Move earth based command and control assets to on-board for crew access.
- Safely merge core and payload command procedures
- Give the crew single action intelligent operations.
- Investigate crew interface requirements

Operations Scenario Driver:

How would the crew power-up and initialize a medical facility during a crew medical emergency on a deep space mission with large communication delays without assistance from Earth?

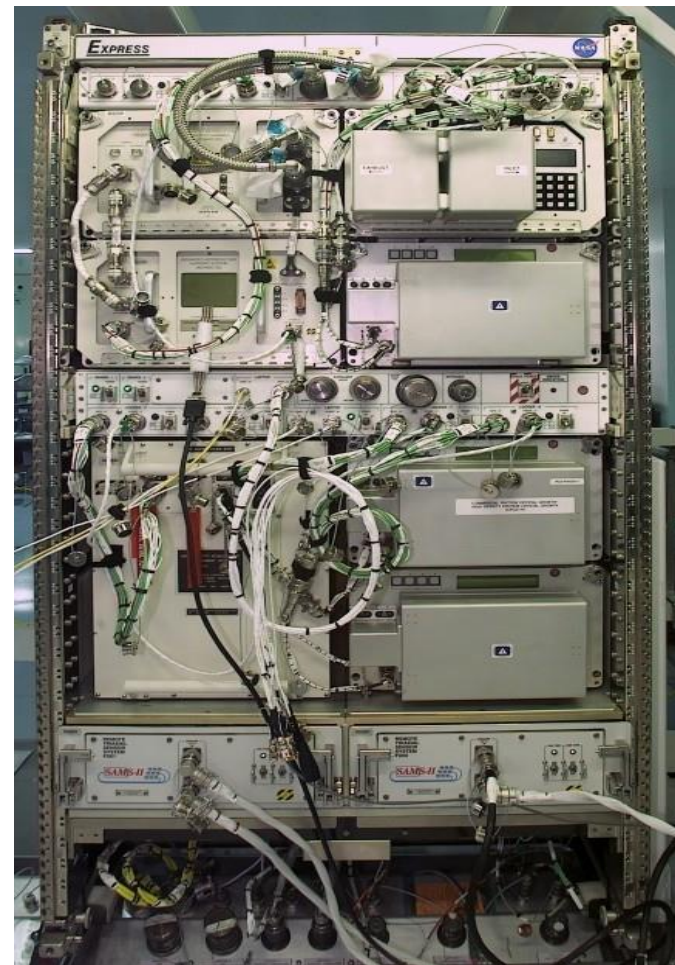
# Target: ISS EXPRESS Rack 7



EXPRESS is a good example of a facility class payload rack

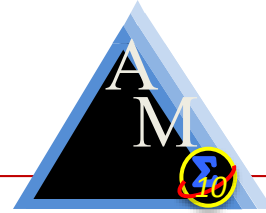
Requires:

- Thermal fluid flow control
- Power control
- Fire Detection System control
- Payload Configuration
- Lap Top Power and Operations
- Verification of Nominal Ops
- Downlink of Status Telemetry



EXPRESS 7

# Required ISS Interfaces



## **Thermal:**

- Rack Flow Control Assembly Modes, Flow Set Point commands
- Rack Flow Control Assembly telemetry status

## **Power:**

- Main and Aux Power commands
- Main and Aux telemetry status

## **Fire Detection System:**

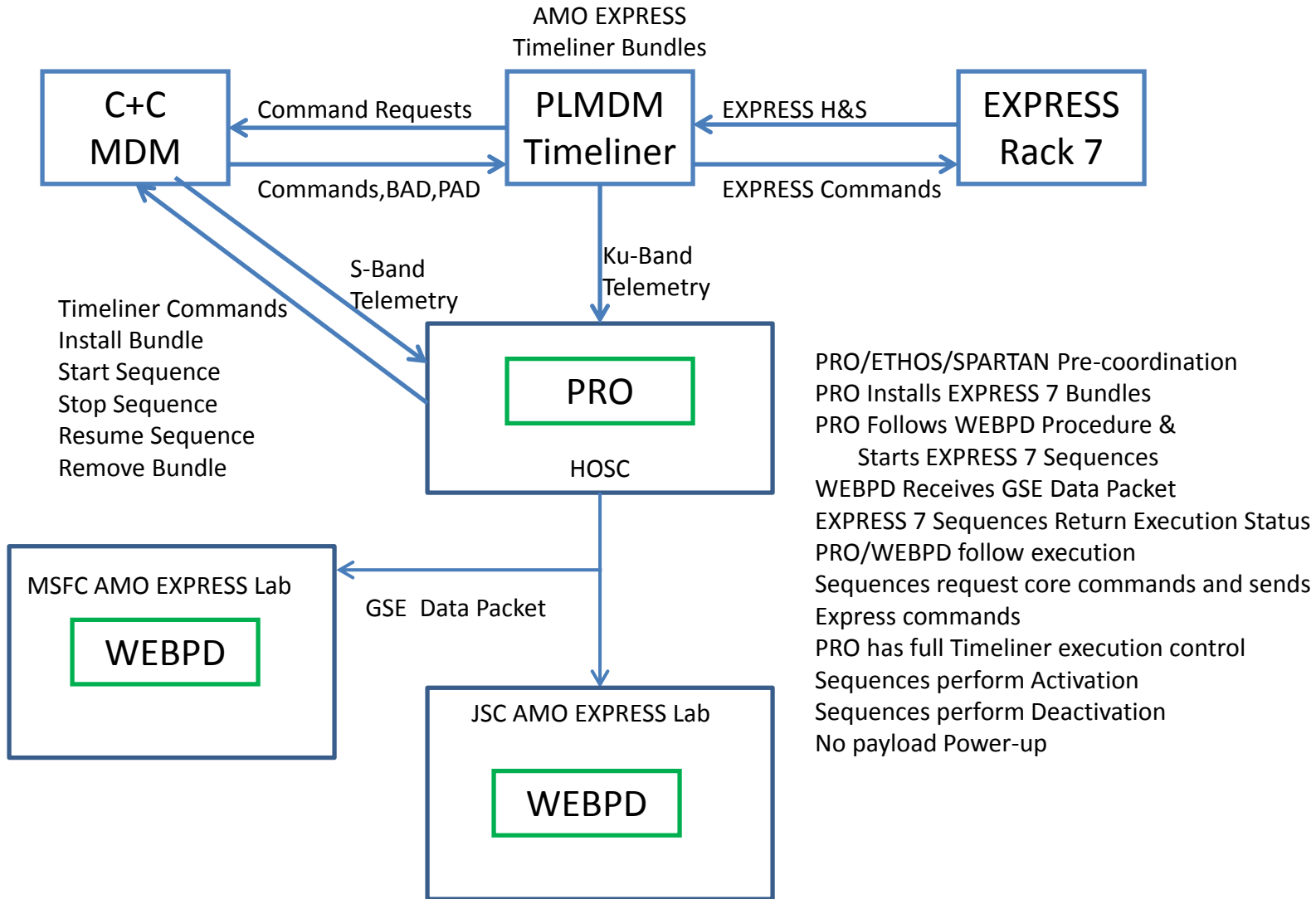
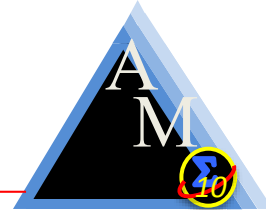
- Smoke Detector Enablement and Disablement commands
- Smoke Detector telemetry status

## **Rack:**

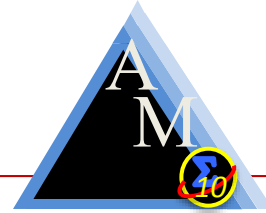
- Rack Operations and Configuration commands and telemetry

Almost none of the required core interface capabilities (Thermal, Power, FDS) were available at the PLMDM where the auto-procedures would execute. Obtaining these for PLMDM Timeliner access would be the first hurdle to clear.

# AMO EXPRESS Context Diagram



# WebPD User Interface



- Developed jointly by AMES Research Center and Johnson Space Center
- Utilized with the TOCA SSC Experiment

Auto Procedure Steps

Execution Status

Messages

AMO EXPRESS 2.0 will encompass WebPD Executing on the Payload PCS for crew access to EXPRESS 7 activation and Deactivation auto-procedures

The screenshot displays a web browser window titled "[seqmaster1]seq\_master" at the URL "127.0.0.1/webpd/". The interface is divided into three main sections: "Active", "Completed", and "TOC". The "Active" section shows a sequence of steps with their execution status and associated messages. The "Completed" section shows a list of steps that have finished. The "TOC" section shows a list of steps that are currently active.

**Active Section:**

- Start (blue play button) Stop (red stop button) Close (red X button)
- 2.1 verify [RIU1] POWER\_SEQUENCESTATE **INACTIVE**
- 2.2 verify [RIU1] POWER\_STATUSCODE **RACK POWER UP SUCCESS OK TO CONTINUE**
- 3 Smoke Sequence
- NOTE: The Smoke Sequence is started onboard
- 3.1 verify [RIU1] SMOKE\_SEQUENCESTATE **INACTIVE**
- 3.2 verify [RIU1] SMOKE\_STATUSCODE **SMOKE DETECTION NOMINAL**
- 4 Initialize Drives Sequence
- NOTE: The Initialize Drives Sequence is started onboard
- 4.1 verify [RIU1] INITDRIVES\_SEQUENCESTATE **INACTIVE**
- 4.2 verify [RIU1] INITDRIVES\_STATUSCODE **OFF-NOMINAL AUTO LOAD**
- 4.3 If Boot Loader Nominal
- 4.3.1 Activation Closeout Sequence
- 4.3.1.1 verify [RIU1] ACTCLOSEOUT\_SEQUENCESTATE **INACTIVE**
- 4.3.1.2 verify [RIU1] ACTCLOSEOUT\_STATUSCODE **THERMAL VALUES LIMIT ERROR**
- 4.4 Else
- 4.4.1 Manual Configuration Sequence
- NOTE: The Manual Configuration Sequence is started onboard
- 4.4.1.1 verify [RIU1] MANUALCONFIG\_SEQUENCESTATE **INACTIVE**
- 4.4.1.2 verify [RIU1] MANUALCONFIG\_STATUSCODE **NOMINAL CONFIGURATION OK TO CONTINUE**
- 5 Deactivation Sequence
- 5.1 verify [RIU1] DEACTIVATION\_SEQUENCESTATE **INACTIVE**
- 5.2 verify [RIU1] DEACTIVATION\_STATUSCODE **NO ERROR**

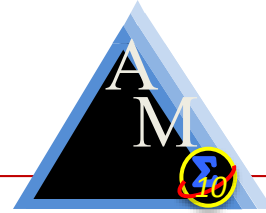
**Completed Section:**

- 1.0 seq\_master

**TOC Section:**

- 1.0 seq\_master

# AMO EXPRESS Auto-Procedure Design



Each Timeliner Sequence provides a specific intelligent function

Each Function (sequence) must complete successfully before the next sequence is activated

Core commanding and payload commanding are separated and reside in different bundles and sequences (except single action Deactivation)

Sequences model the SPARTAN, ETHOS, and Payload Rack Officer's console operations and ground command procedures for EXPRESS 7.

Each Sequence is started by the Payload Rack Officer via ground command

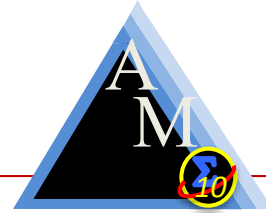
Option is provided for single action activation (AMOE\_Activate\_Express7 master sequence starts each sequence)

Each Sequence is monitored on the ground with full ground execution control of the sequence (can stop execution at any time).

Full Sequence Messaging during execution available in two streams, HAL Memory (APID 956) and PEP Events (APID 876, subset 0)



# AMO EXPRESS Timeliner Architecture



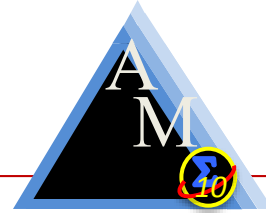
## AP\_AMOE\_PLSS (core command bundle)

	AMOE_Activate_Express7	- Single action rack activation sequence
Execution Order	1 AMOE_THERMAL	- RFCA command procedures sequence
	2 AMOE_MAIN_POWER	- Main RPC command procedures sequence
	3 AMOE_SDMON_ENABLE	- Smoke Detection command procedures sequence
	AMOE_DEACTIVATION	- Single Action rack deactivation sequence

## AP\_AMOE\_RACK (EXPRESS 7 Rack command bundle)

Execution Order	4 AMOE_INIT_DRIVES	- Monitors boot-up, powers up laptop, initiates payload configuration if needed
	AMOE_MANUAL_CONFIG	- Commands payload configuration when no retrieval drive is available or configuration files are missing.
	5 AMOE_ACT_CLOSEOUT	- performs rack activation close out procedures and commands transmit status's (medium rate end items)
	6 TELEMETRY_CHECK	- Performs a complete health and status verification

# AMO EXPRESS Sequence Breakdown



## AMOE\_Thermal

Verifies RFCA Software State

Verifies RFCA State

Commands RFCA Flow Mode (Command Request Command)

Commands RFCA Flow Set Point (Command Request Command)

Commands RFCA Close Loop Control (Command Request Command)

Monitors Flow Rate

Monitors Valve Speed

Commands RFCA Idle State (Command Request Command)

Provides up to 10 minute waits for ground coordination (RFCA SW not started as an example)

## AMOE\_MAIN\_POWER

Verifies and commands PLMDM H+S Polling before Power-up if needed

Verifies RPS Monitoring is active

Verifies RPS state

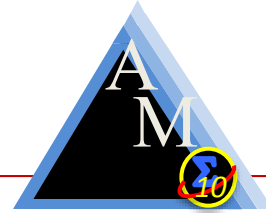
Verifies RPCM state

Verifies Main RPC State and close inhibit

Commands Main RPC Close (Command Request Command)

Provides up to 10 minute waits for ground coordination (Inhibit removal, RPS State as examples)

# AMO EXPRESS Sequence Breakdown Part 2



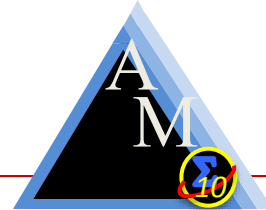
## AMOE\_SDMON\_Enable

- Tests Scatter within limits and messages
- Tests Obscuration within limits and messages
- Verifies Percent Trip (calculated from Scatter/Obscuration)
- Verifies smoke detection monitoring is enabled
- Commands Smoke Detector enable for EXPRESS 7 (Command Request Command)
- Verifies smoke detector BIT result

## AMOE\_DEACTIVATION

- Verifies all payloads are unpowered and Comm deactivated
- Verifies payload leg valves are closed
- Verifies retrieval drive for next bootup
- Commands Laptop Shutdown
- Inhibits Smoke Detection Monitoring (Command Request Command)
- Commands rack shutdown
- Commands RPC Open verifies Open inhibit (Command Request Command)
- Verifies RFCA S/W State and RFCA Mode
- Commands RFCA Idle Mode (Command Request Command)
- Commands RFCA Test Mode (Command Request Command)
- Verifies Flow Rate to Zero
- Verifies Valve Speed

# AMO EXPRESS Sequence Breakdown Part 3



## AMOE\_Activate\_Express7

Starts AMOE\_THERMAL Sequence and waits for the sequence to return status code

Starts AMOE\_MAIN\_POWER Sequence and waits for the sequence to return status code

Starts AMOE\_SDMON\_ENABLE Sequence and waits for the sequence to return status code

Starts AMOE\_INIT\_DRIVES Sequence and waits for the sequence to return status code

Starts AMOE\_ACT\_CLOSEOUT Sequence and waits for return status code

Sequences are started in order and only when the previous has finished with no anomalies

Sequences return only 1 good status code, all other codes are specific anomalies encountered

This Sequence stops itself if an anomaly status code is returned from any sequence and ground operations will take over.

## AMOE\_INIT\_DRIVES

Verifies Boot Loader is active

Verifies Health and Status data received at the PLMDM

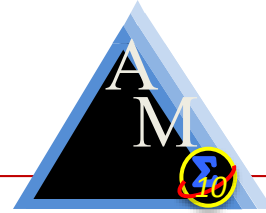
Verifies the retrieval drive (EMU or Laptop)

Validates an EMU Failure and sets retrieval drive to Laptop

Commands Laptop Power-up

Verifies Auto-Load execution and performs H+S telemetry verification

# AMO EXPRESS Sequence Breakdown Part 4



## AMOE\_Manual\_Config

Sequence is started when EMU/Laptop failure both occur and commands payload configuration

Verifies EMU and Laptop as retrieval drives and their states

Commands load of each configuration file if a valid retrieval drive can be found

Commands specific flight configuration for all payload locations if no configuration files can be loaded or if individual configuration files are missing (our 3<sup>rd</sup> retrieval drive)

## AMOE\_ACT\_CLOSEOUT

Verifies rack in operation

Commands ISS LAN Configuration

Downlink Transmit Status's (medium rate end items) for PRO to view

Commands downlink of Rack Telemetry Configuration

Commands downlink of Rack Thermal Configuration

Commands downlink of Payload Configuration

Commands downlink of Payload Telemetry Configuration

Commands downlink of Ancillary Data Configuration

Commands downlink of ISS LAN Configuration

Commands downlink of PEHB LAN CAM Configuration

Commands downlink of SSPCM Initial State Configuration

Verifies thermal configuration

Commands EXPRESS 7 Thermal Control

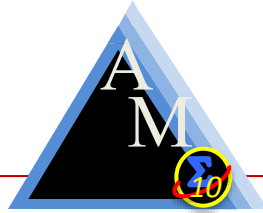
Re-Verifies the rack flow rate

Verifies LAN CAM and Sonic data

Verifies Heartbeats incrementing

# AMO EXPRESS Sequence Breakdown Part 5

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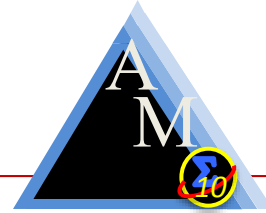


## Telemetry\_Check

This is the Health and Status Telemetry Check Sequence for AMO EXPRESS. It contains the necessary steps to verify the Auto-load Function of ER7 and Flag any checkpoint files that did not load. It also performs H&S checks for ER7 subsystems and compares them against expected boot-up conditions.

# Core Command Safety Mitigations

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Core commanding is divided by sub-system and reside in separate sequences.

No two sequences active simultaneously, allowing focus on one function at a time

Condition verification before sending a command (inhibit checks)

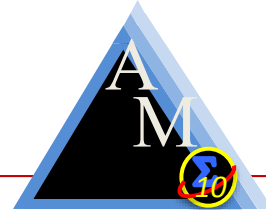
Command verification after each command

POIC has full execution control at all times during experiment execution

POIC has full command capabilities if anomalies occur

AMO EXPRESS experiment validates the sequence execution, AMO EXPRESS 2.0 experiment validates the crew can activate EXPRESS 7 with a change of locus of control.

# Verification and Validation



## Software Development and Integration Laboratory (SDIL) *A World Class ISS Development and Test Facility*

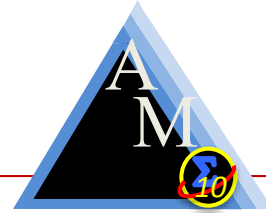
Verification and Validation testing was performed with the Software Integration and Development Laboratory, the Hardware/Software Integration Laboratory, and the Payload Software Integration and Verification Facility.



Operational Readiness Testing



# AMO EXPRESS On Orbit Operations



Uplink 4 files to the PLMDM SSMMU

AP\_AMOE\_PLSS.TLX (Timeliner executable)

AP\_AMOE\_PLSS.TLA ( Timeliner PUI memory address map file)

AP\_AMOE\_RACK.TLX (Timeliner executable)

AP\_AMOE\_RACK.TLA (Timeliner PUI memory address map file)

Install both executables into Payload MDM Timeliner Executor

As scheduled via OSTP, Payload Rack Officer issues payload Timeliner start sequence commands for each sequence during execution run number 1 for rack activation (GCP 3.9.1)

As scheduled via OSTP, Payload Rack Officer issues 1 payload Timeliner start sequence (GCP 3.9.2) command for rack deactivation for run number 1.

As scheduled via OSTP, Payload Rack Officer issues 1 payload Timeliner start sequence command for rack activation during execution run number 2 (AMOE\_Activate\_Express7 Sequence)

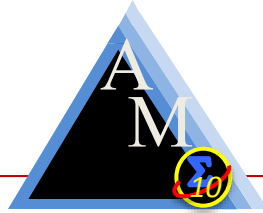
As scheduled via OSTP, Payload Rack Officer issues 1 payload Timeliner start sequence command for rack deactivation for run number 2.

## **Notes:**

Bundles may be removed after each run.

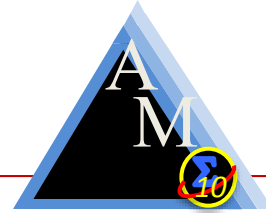
Time to keep EXPRESS 7 operational may vary depending upon the OSTP and any planned payload operations within EXPRESS 7 during the time period, none planned at this time.

# Operations Results



- Performed Single action EXPRESS Rack 7 Deactivation
- Performed single step function EXPRESS Rack 7 Activation (Thermal, Power, Smoke, Init\_Drives)
- Performed single action EXPRESS Rack 7 Deactivation
- Performed single action EXPRESS Rack 7 Activation
- All activities were successful
- Changes to make (Run #2):
  - Increase Lap-top boot-up time monitoring loop
  - Change range check for internal flow to simple < or >
  - Add additional verbose messaging in HAL downlink

# Forward Plan



- Test and checkout of WebPD on the Payload PCS for AMO EXPRESS 2.0 operations with the crew
- Re-uplink AMO EXPRESS Timeliner Auto-Procedures
- Tests tests tests
- Execute on-orbit with crew – late 2015 to mid 2016

