

# Integrated System for Health Management and Autonomous Control (ISHM-AC): Development and Application

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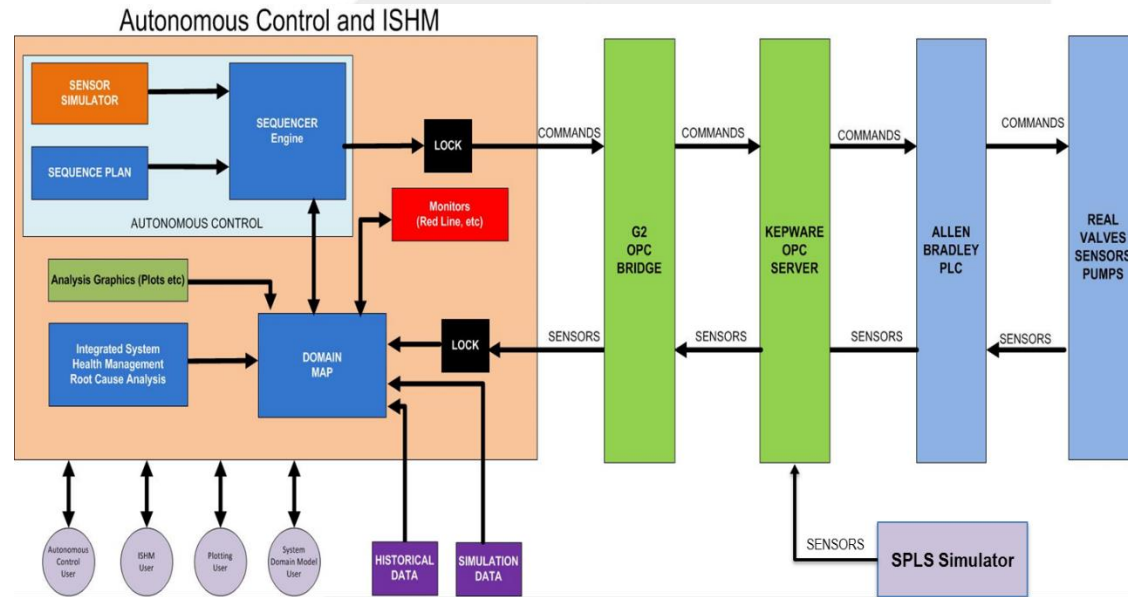
Salt City Lake, UT

## Introduction

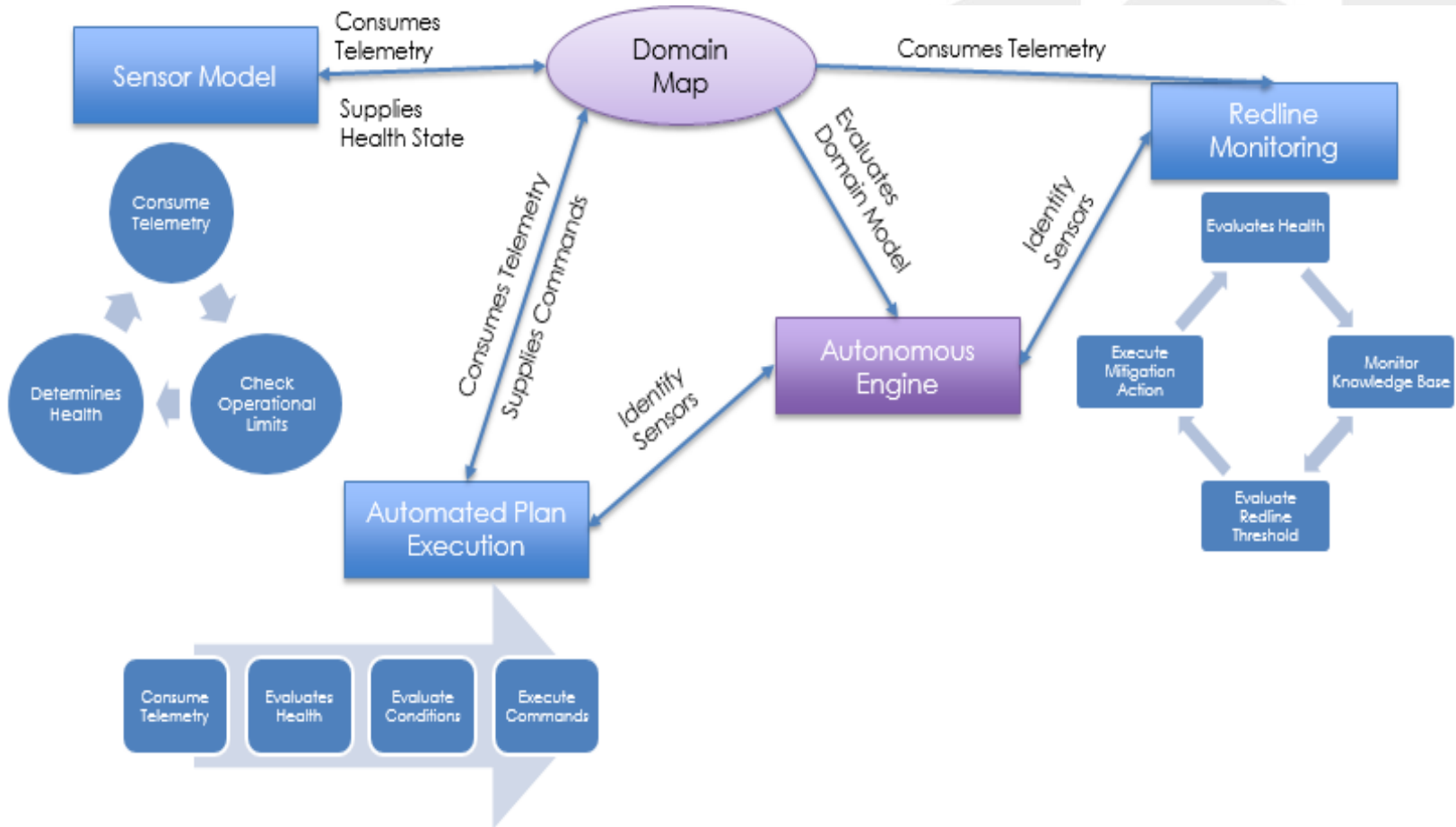
- Project Overview
- Software Design Description
- Autonomous Operations
  - Nominal
  - Off-nominal
- Health Monitoring Operations
- Application
- Test Results

# Project Overview

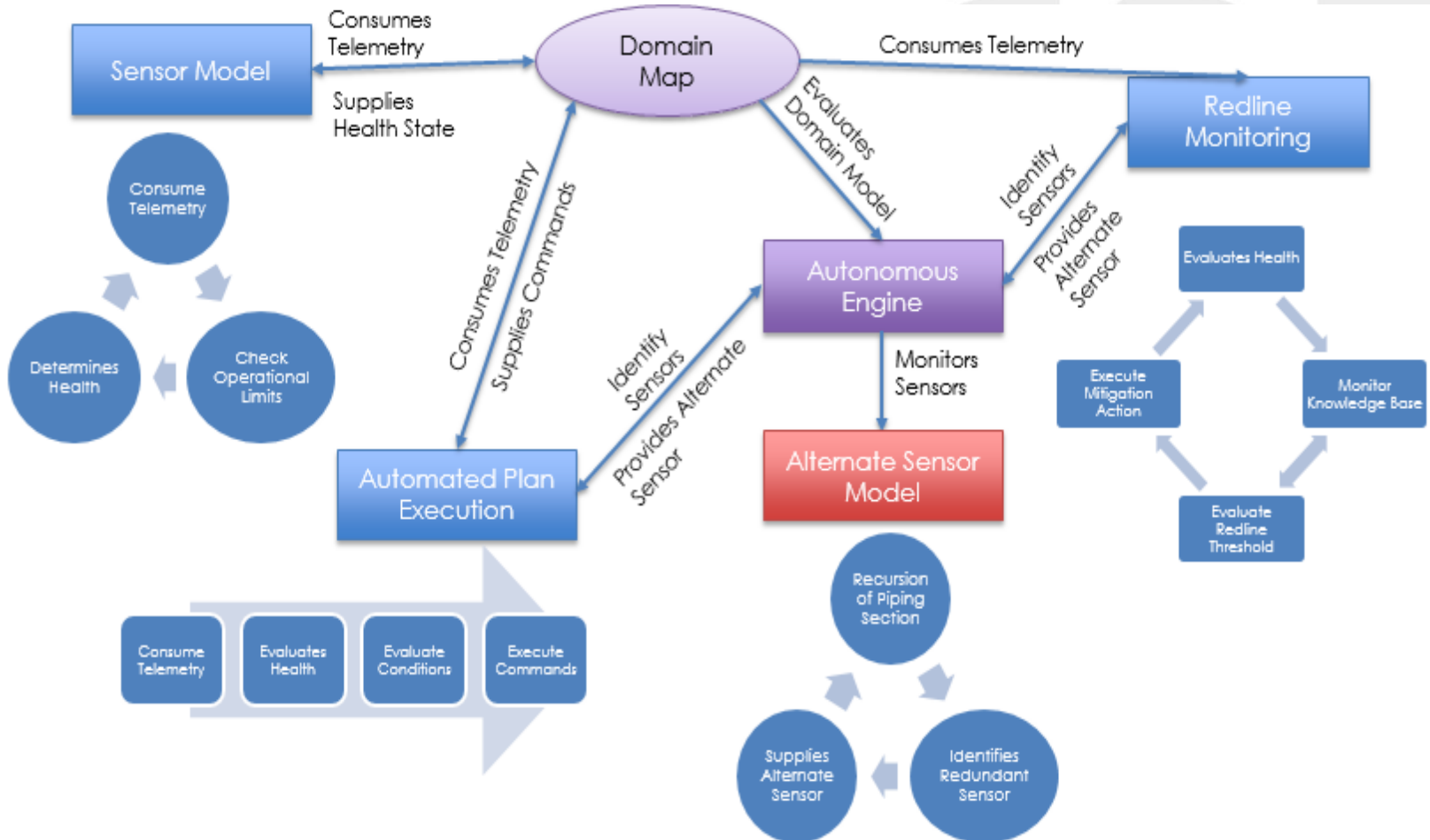
- Knowledge Base
- Modeling
- Automated Control
- Monitoring
- User Interface
- External I/O
- Autonomous Control



# Autonomous Operations - Nominal



# Autonomous – Off-Nominal



## Health Monitoring

- Nominal
  - Phase Detection
  - Flow Subsystem
- Off-Nominal
  - Leak Detection
  - Valve Consistency

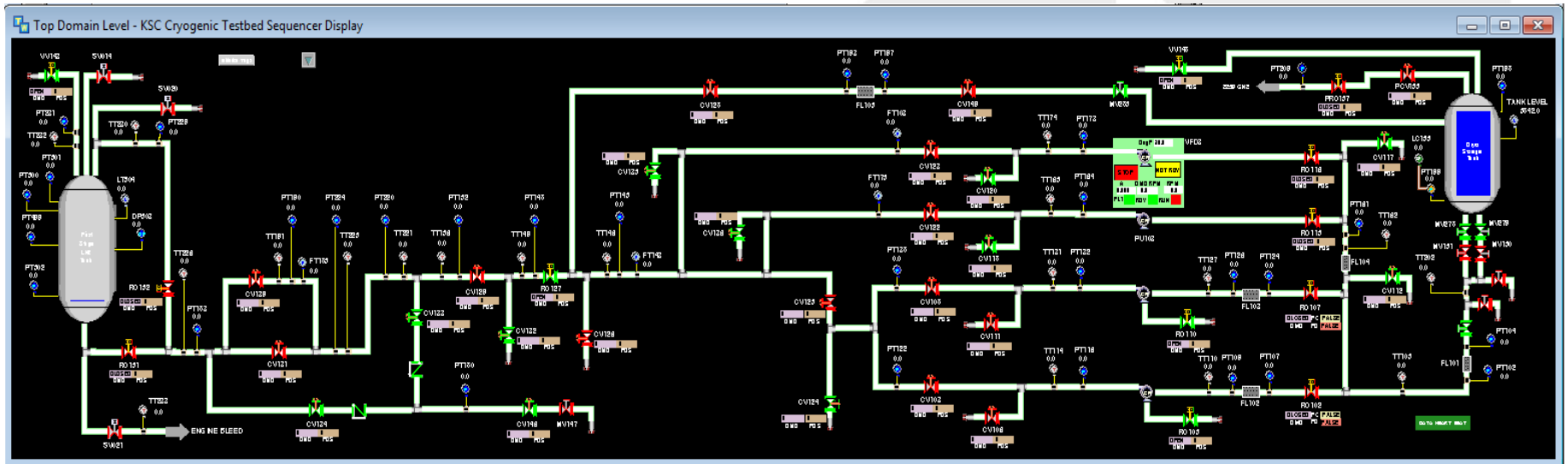


## Application – Simulated Propellant Loading System (SPLS)

- Propellant Transfer Lines
- Storage Tank
- Simulated Vehicle
- Instrumentation
- Data Acquisition
- Command and Control System



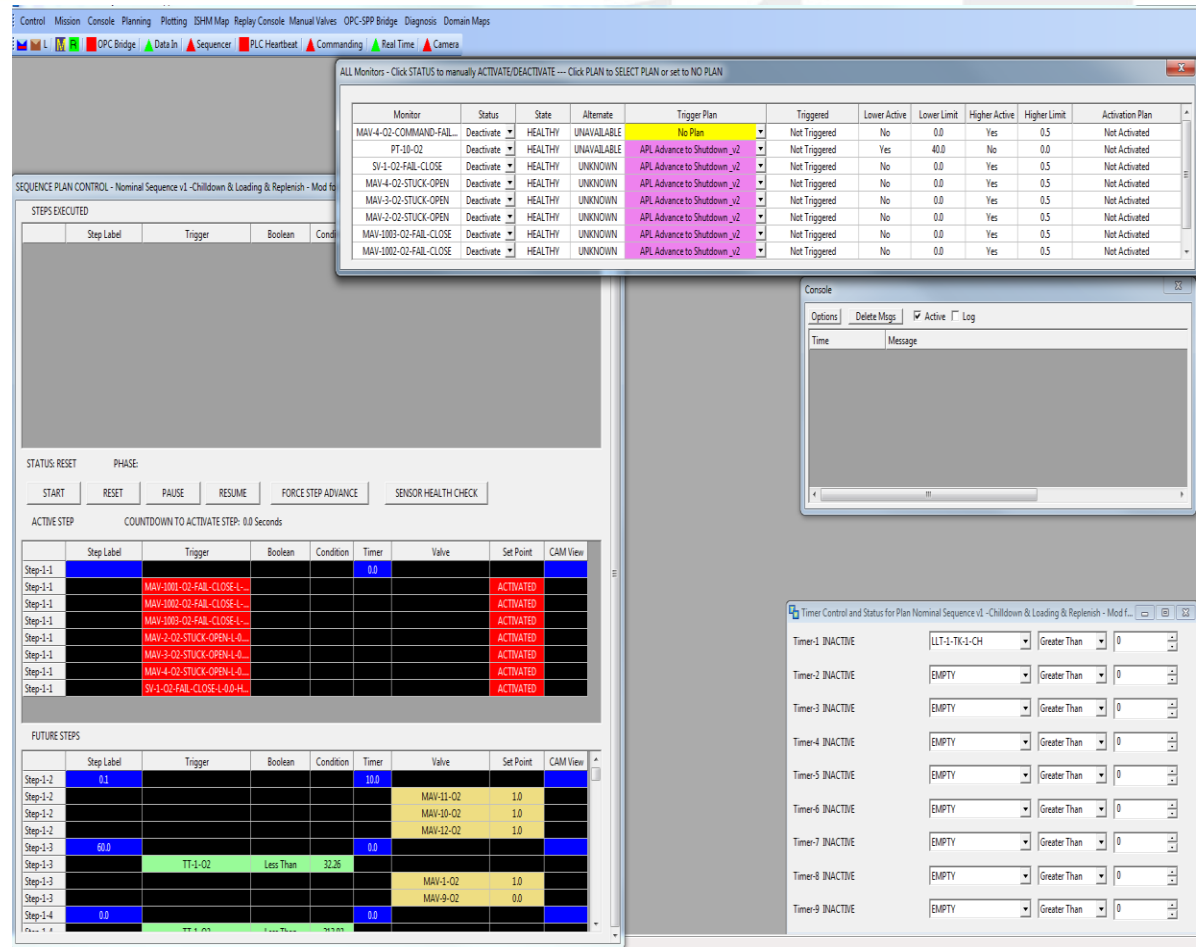
# Application Development System – Control Map





# Application Development System – Operator User Interface

- Plan Execution
- Redline Monitoring
- Console Message
- Timers



The screenshot displays the Operator User Interface for the Application Development System. It features several key components:

- SEQUENCE PLAN CONTROL:** A panel for managing the sequence plan, including buttons for START, RESET, PAUSE, RESUME, FORCE STEP ADVANCE, and SENSOR HEALTH CHECK. It shows the current phase and countdown to activate the next step (0.0 seconds).
- Monitor Status Table:** A table listing various monitors and their current status.
 

Monitor	Status	State	Alternate	Trigger Plan	Triggered	Lower Active	Lower Limit	Higher Active	Higher Limit	Activation Plan
MAV-4-02-COMMAND-FAIL	Deactivate	HEALTHY	UNAVAILABLE	No Plan	Not Triggered	No	0.0	Yes	0.5	Not Activated
PT-10-02	Deactivate	HEALTHY	UNAVAILABLE	API_Advance to Shutdown_v2	Not Triggered	Yes	40.0	No	0.0	Not Activated
SV-1-02-FAIL-CLOSE	Deactivate	HEALTHY	UNKNOWN	API_Advance to Shutdown_v2	Not Triggered	No	0.0	Yes	0.5	Not Activated
MAV-4-02-STUCK-OPEN	Deactivate	HEALTHY	UNKNOWN	API_Advance to Shutdown_v2	Not Triggered	No	0.0	Yes	0.5	Not Activated
MAV-3-02-STUCK-OPEN	Deactivate	HEALTHY	UNKNOWN	API_Advance to Shutdown_v2	Not Triggered	No	0.0	Yes	0.5	Not Activated
MAV-1003-02-FAIL-CLOSE	Deactivate	HEALTHY	UNKNOWN	API_Advance to Shutdown_v2	Not Triggered	No	0.0	Yes	0.5	Not Activated
MAV-1002-02-FAIL-CLOSE	Deactivate	HEALTHY	UNKNOWN	API_Advance to Shutdown_v2	Not Triggered	No	0.0	Yes	0.5	Not Activated
- ACTIVE STEP Table:** A table showing the current step's details.
 

Step Label	Trigger	Boolean	Condition	Timer	Valve	Set Point	CAM View
Step-1-1	MAV-1001-02-FAIL-CLOSE-L...			0.0		ACTIVATED	
Step-1-1	MAV-1002-02-FAIL-CLOSE-L...					ACTIVATED	
Step-1-1	MAV-1003-02-FAIL-CLOSE-L...					ACTIVATED	
Step-1-1	MAV-2-02-STUCK-OPEN-L-0...					ACTIVATED	
Step-1-1	MAV-3-02-STUCK-OPEN-L-0...					ACTIVATED	
Step-1-1	MAV-4-02-STUCK-OPEN-L-0...					ACTIVATED	
Step-1-1	SV-1-02-FAIL-CLOSE-L-0-0H...					ACTIVATED	
- FUTURE STEPS Table:** A table showing upcoming steps.
 

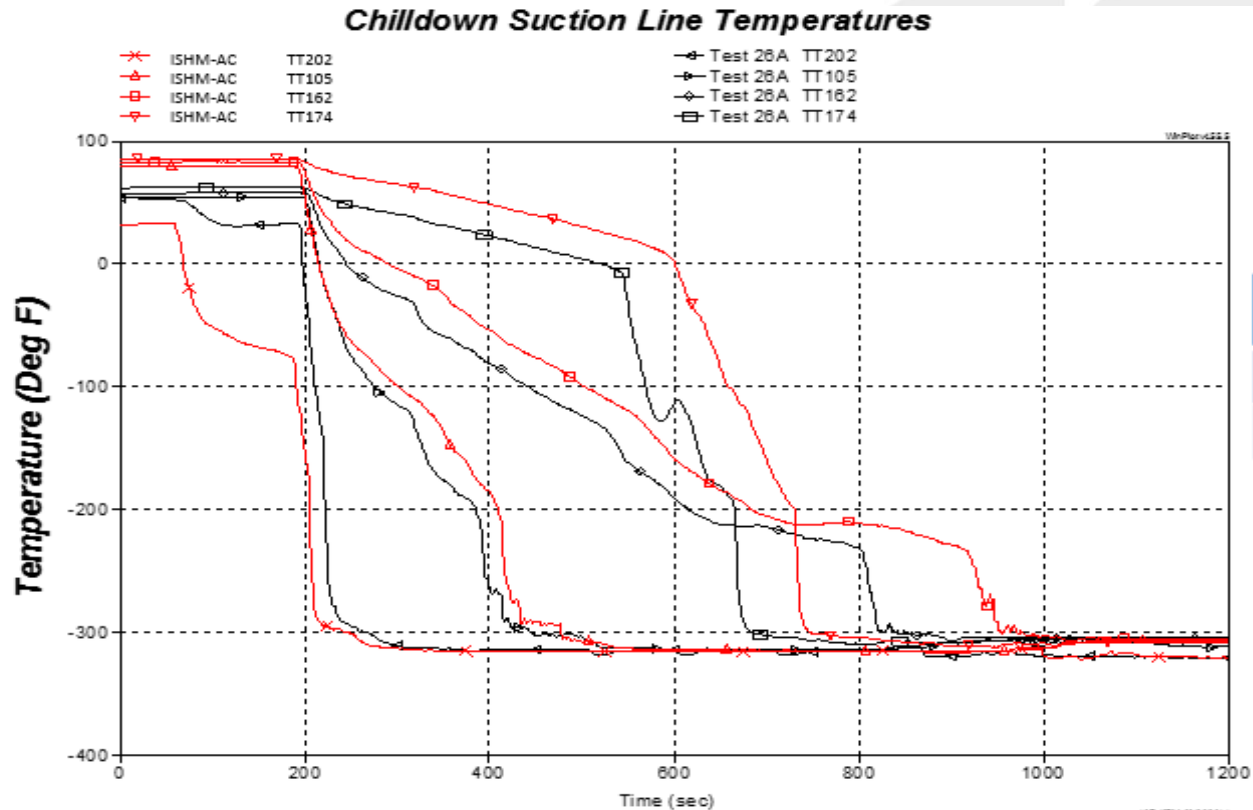
Step Label	Trigger	Boolean	Condition	Timer	Valve	Set Point	CAM View
Step-1-2	0.1			10.0			
Step-1-2					MAV-11-02	1.0	
Step-1-2					MAV-10-02	1.0	
Step-1-2					MAV-12-02	1.0	
Step-1-3	60.0			0.0			
Step-1-3	TT-1-02	Less Than	32.26		MAV-1-02	1.0	
Step-1-3					MAV-9-02	0.0	
Step-1-4	0.0			0.0			
- Console:** A panel for displaying system messages, with options to delete messages, activate logging, and view the message log.
- Timer Control and Status:** A panel for managing individual timers, showing their status (e.g., INACTIVE) and configuration (e.g., LLT-1-TK-1-CH, Greater Than, 0).

ISHM – AC vs. SPLS Baseline

# TEST RESULTS



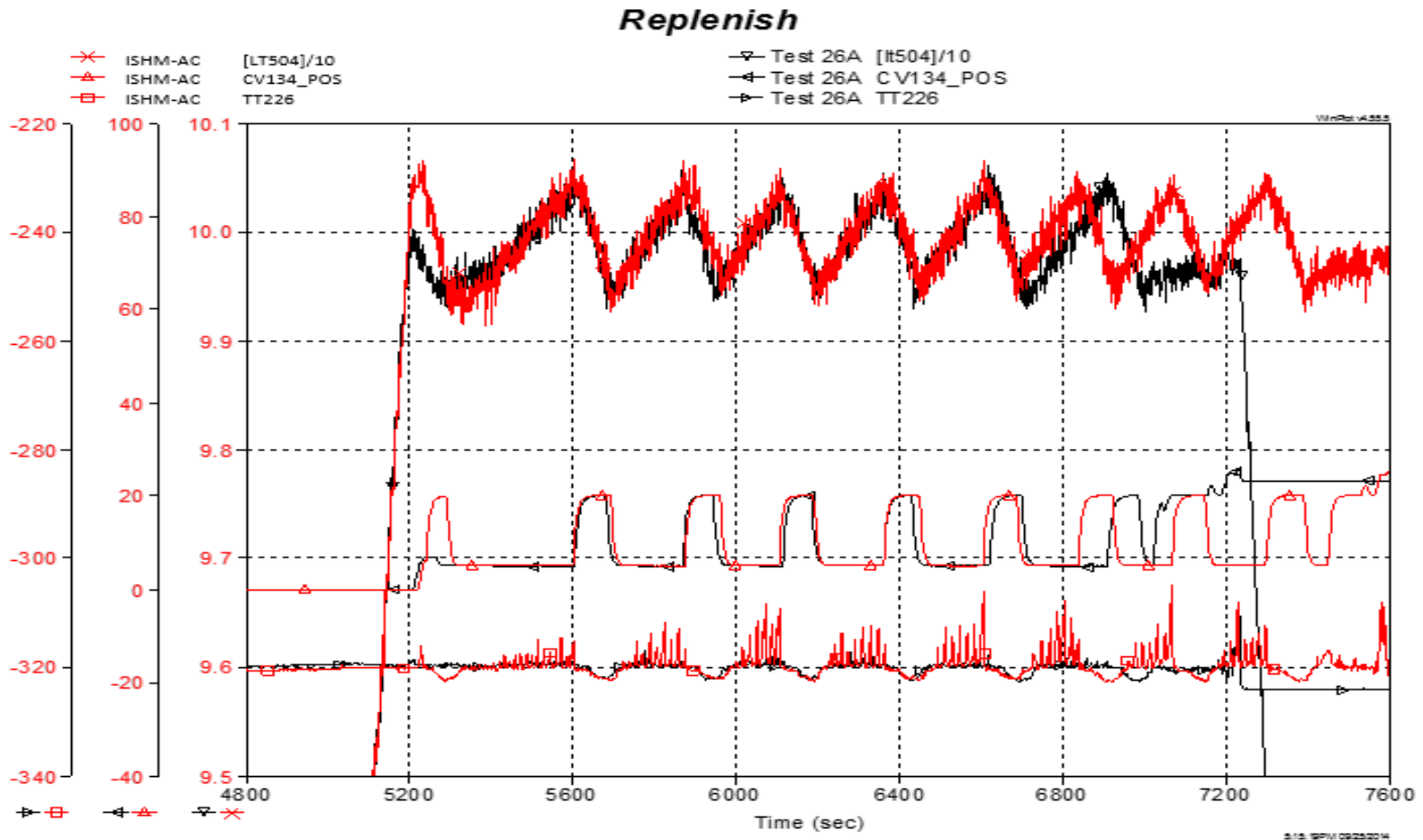
# Nominal: Chardown Phase – Simulated GSE



Time Alignment Reference	
Test 26A	1337
ISHM-AC	0

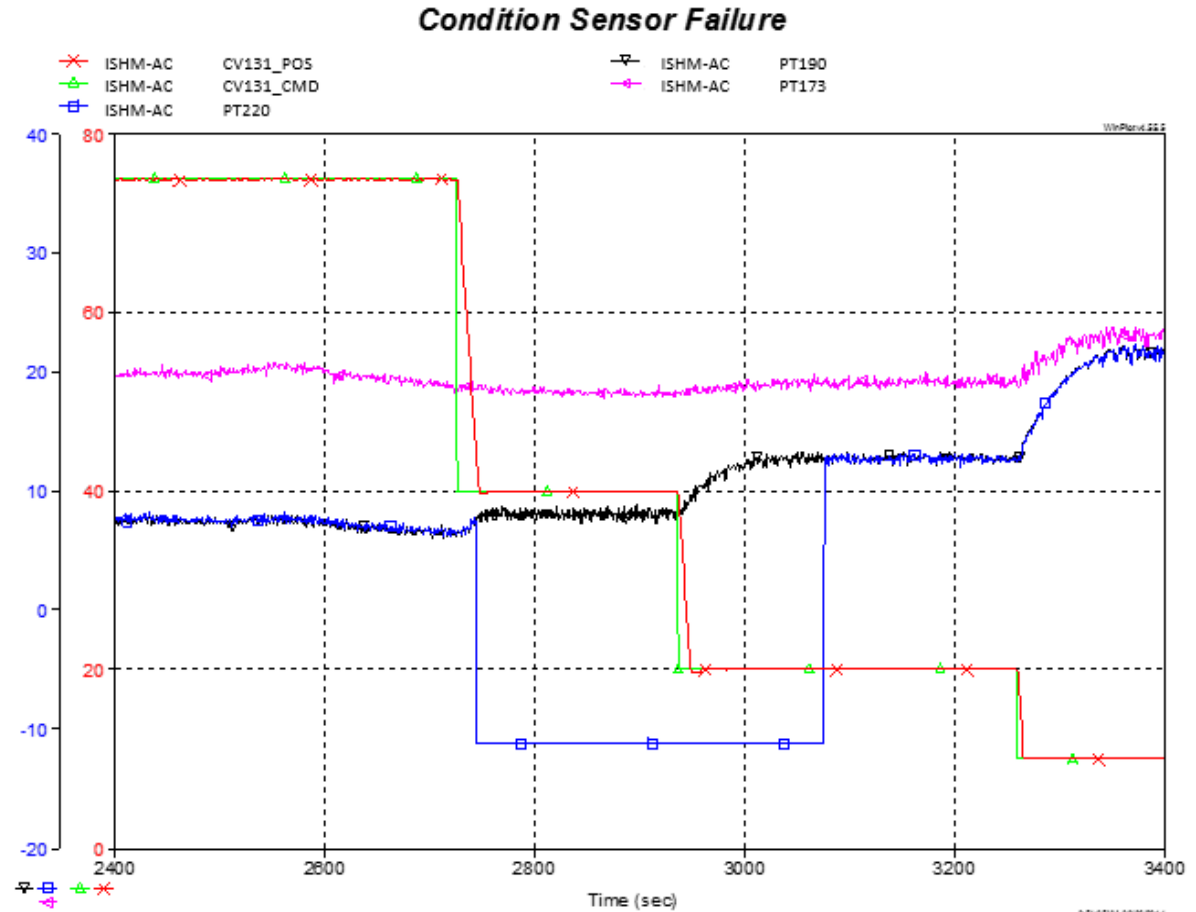
TT105: Tank-Pump Suction	TT202: Tank Discharge	TT162: Pump Suction	TT174: Pump Discharge
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# Nominal: Replenish Phase – Simulated Flight Vehicle



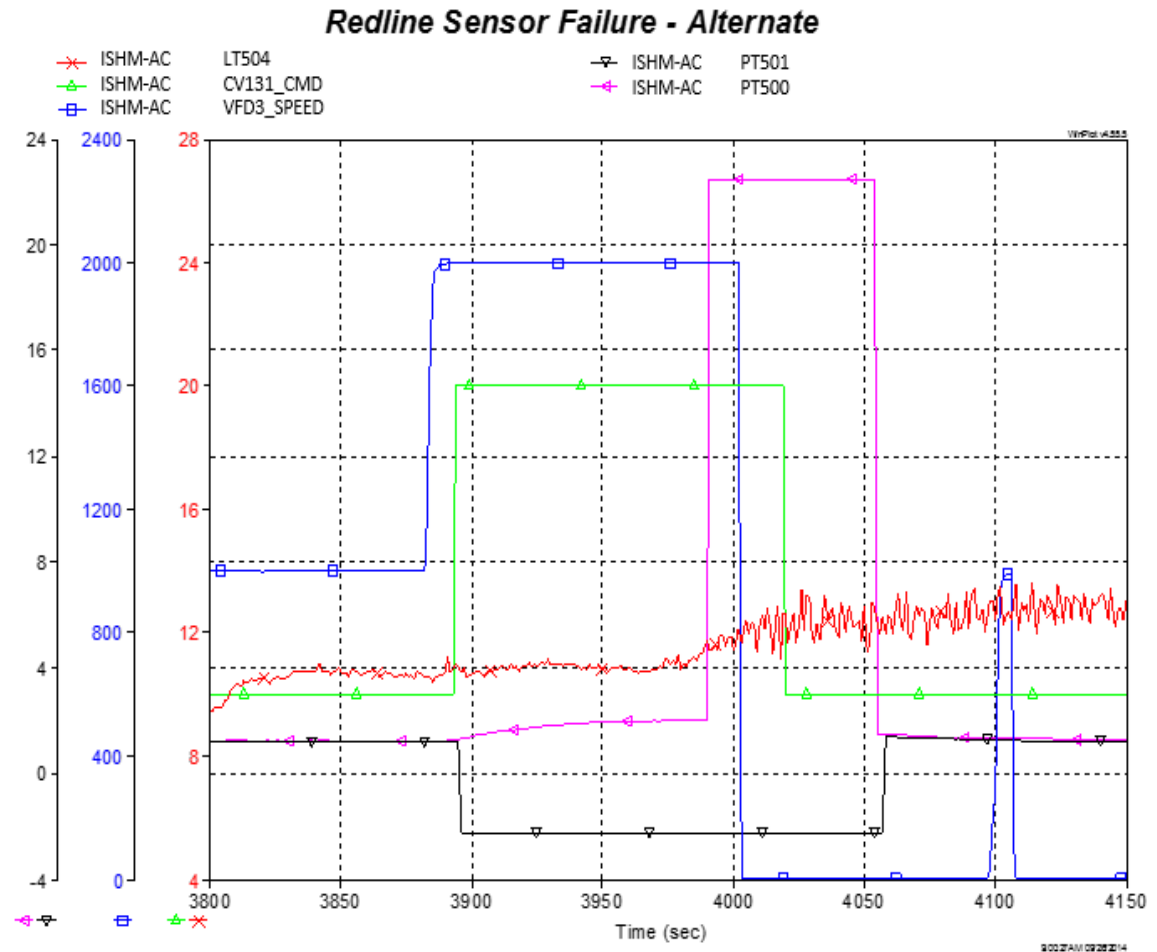
# Off-Nominal: Autonomous Engine

- Plan Execution
- Failure Insertion
- Alternate Sensor Model
- Mitigation Telemetry
- Plan Execution Continuation



# Off-Nominal: Autonomous Engine

- Redline Monitoring
- Failure Insertion
- Alternate Sensor Model
- Mitigation Telemetry
- Redline Monitoring Continues



## Conclusion

- ISHM-AC: Verification and Validation on Autonomous Operations
- Application supports real-time laboratory operations with cryogenic commodity
- Support mitigation procedures that allow safe continuation of operations
- NASA Technology Readiness Level (TRL) from an analytical and experimental proof-of-concept (Level 3) to validation in laboratory environments (Level 4)



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