New Developments in ISHM for NASA Ground, Launch, and Flight Systems

Fernando Figueroa
NASA Stennis Space Center

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Paradigm for Autonomy and ISHM

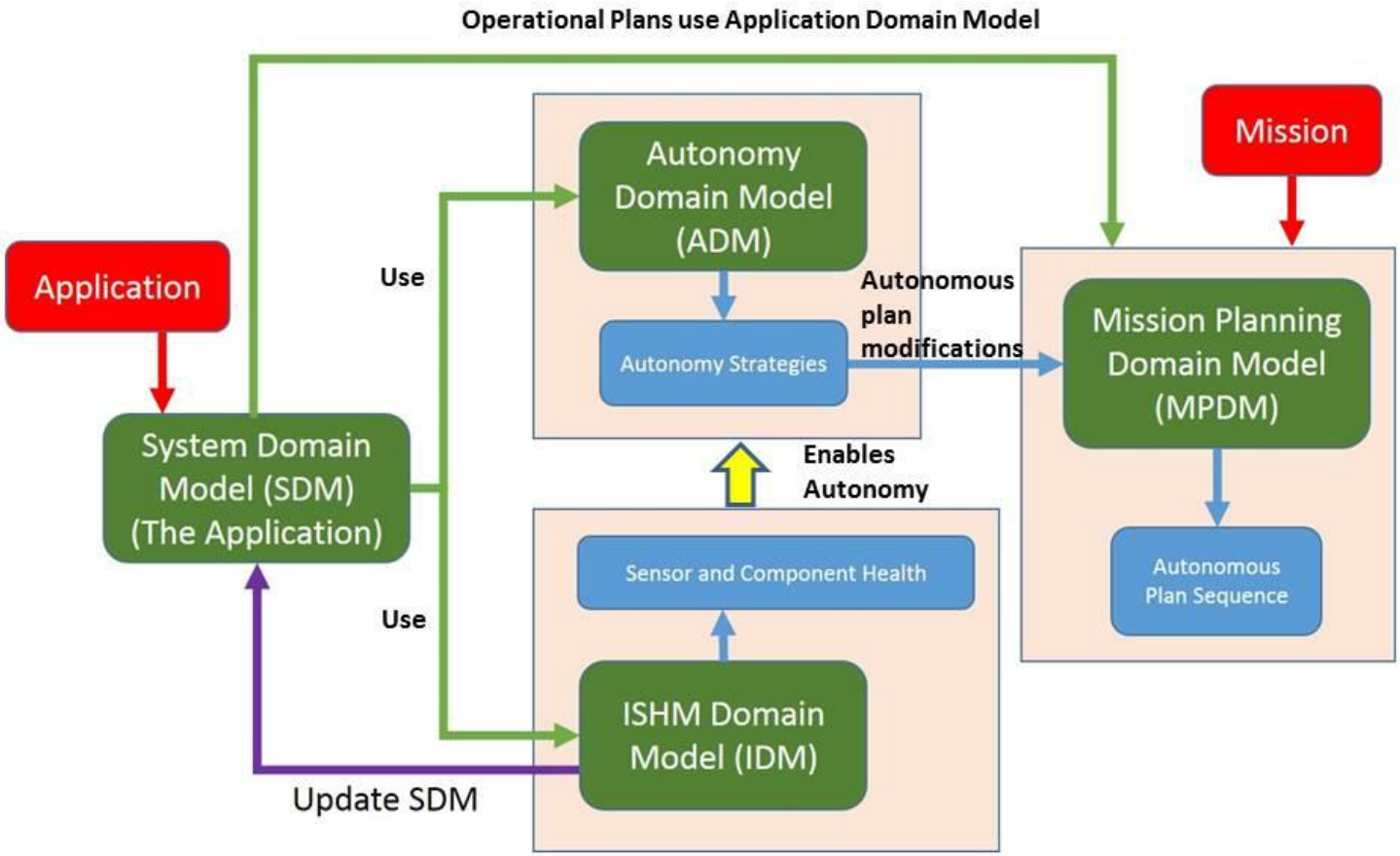
- **Autonomy is a capability that is not absolute. There are degrees of autonomy, ranging from low levels to high levels, but there is no maximum level (how many autonomy strategies are implemented?).**
- **It is an evolutionary capability that can handle increasing degrees of complexity for reasoning and decision making.**
- **It must know the condition of the system elements and their ability to carry out specific tasks. Integrated System Health Management (ISHM) then becomes an enabler for autonomy.**

NASA has developed the software platform **Autonomous Operations Flexible Software Suite (AO-FlexSS)** that is used to make systems operate with any desirable degree of autonomy and provides comprehensive system awareness to developers and users.

Personal Experience: ISHM/Autonomous Systems

- **Development of a software platform to implement autonomous systems enabled by ISHM and encompasses creation and execution of mission plans.**
  - Evolved from **NASA ISHM Toolkit** to **AO-MDS** (Autonomous Operations Mission Development Suite) to **AO-FlexSS** (Autonomous Operations Flexible Software Suite).
  - Validated initially at the KSC Cryogenic Testbed Laboratory, continues development using a portable launch system (autonomous propellant loading – APL), and infused at the High Pressure Gas Facility (HPGF) at NASA SSC, and the ORION Power System integrated health management.
  - NASA SSC plans to use AO-FlexSS to implement autonomous operations at the HPGF and potentially test stands.
  - Pilot space habitat implementations are being formulated.

Autonomy Software Functional Architecture with Knowledge Domain Models



Implementation of Autonomy: NASA's AO-FLexSS

1. **Comprehensive Knowledge Modeling System**
   a) Object libraries to create domain-knowledge from schematics (i.e. electrical, fluid, mechanical) including specification/behavior (i.e. sensors, pumps, RPCs)
   b) Supports modeling paradigms including ***physics, empirical, statistical, FMEA, system engineering processes***
2. **Integrated System Health Management (ISHM)**
   a) Provides integrated and comprehensive system awareness
   b) Detects anomalies, diagnosis causes; predicts future anomalies
3. **Autonomy Strategies**
   a) Strategies based on using redundancy, alternate paths to an objective, alternate and intermediate goals, temporary solutions, and the like; can adjust operations- when unexpected anomalies occur
4. **Autonomous Operations**
   a) Incorporates autonomy strategies as part of operational plans
   b) Dynamically executes multiple plans simultaneously incorporating ISHM, autonomy strategies, concepts of operations and system state

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NASA Stennis Space Center HPGF Implementation

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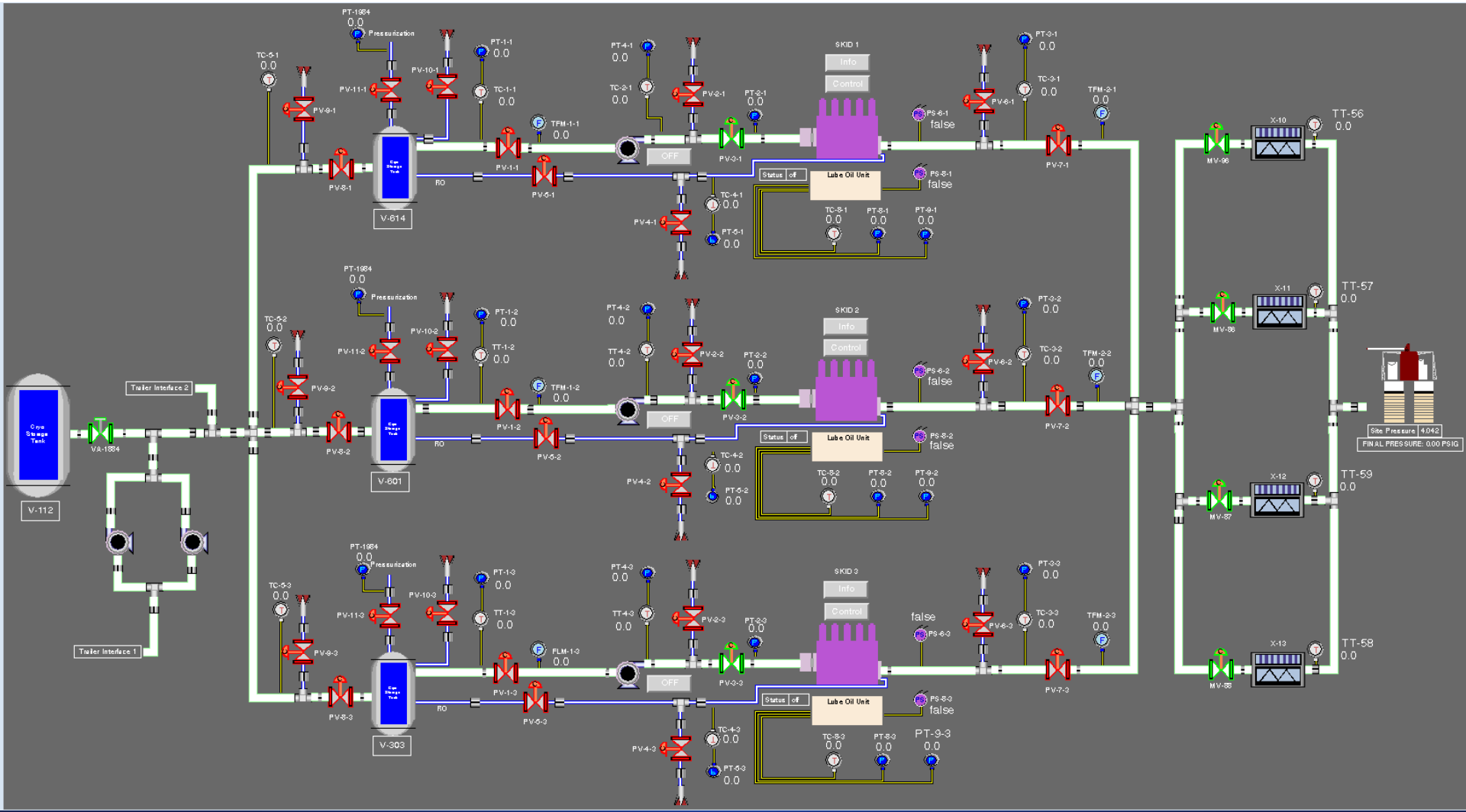
SSC High Pressure Gas Facility Implementation

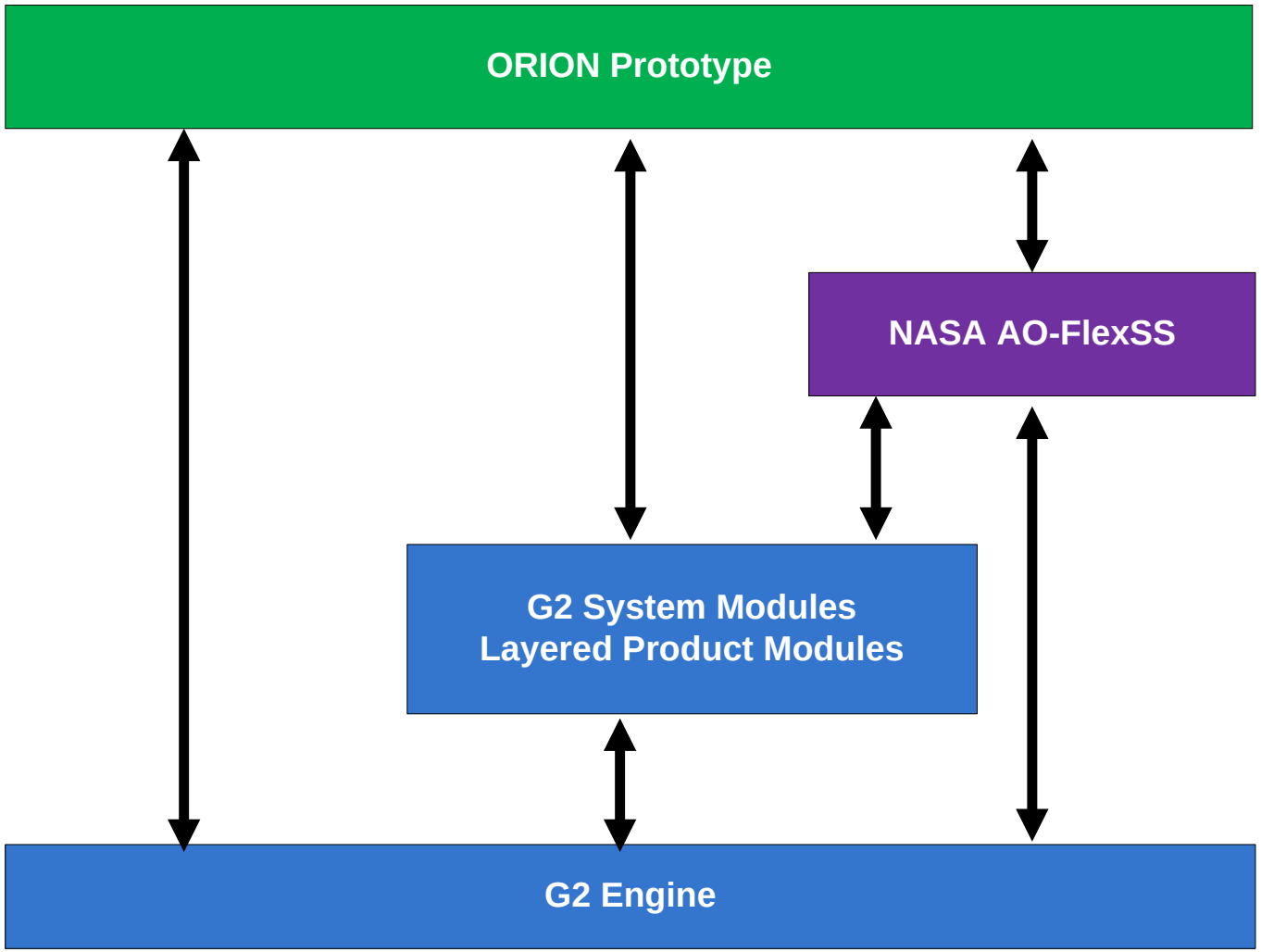
NASA SSC High Pressure Gas Facility
Nitrogen System Control Screen

Not Schematic



ORION EFT-1 Capsule

ORION EFT-1 Power System Integrated Health Management Overall Software Architecture



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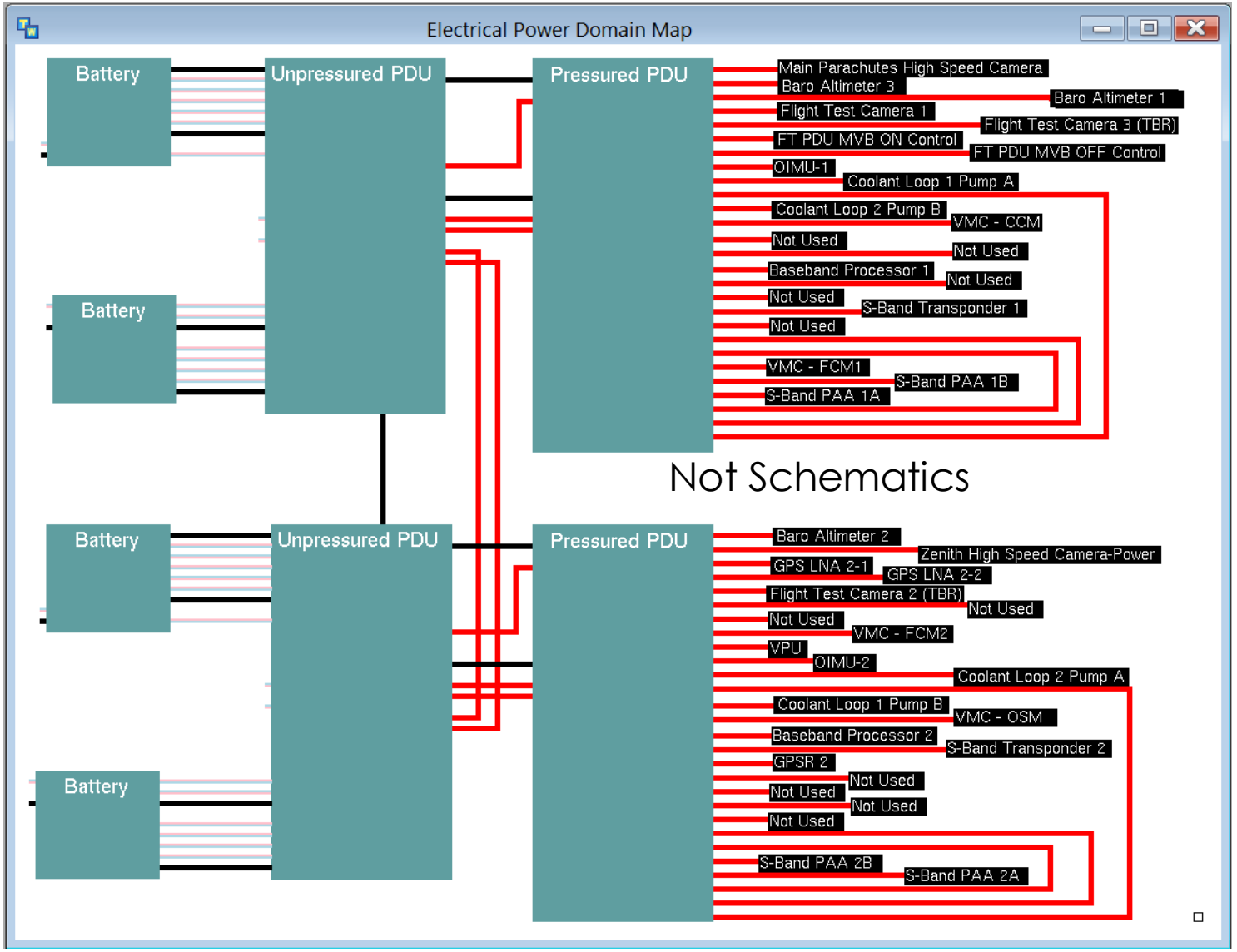
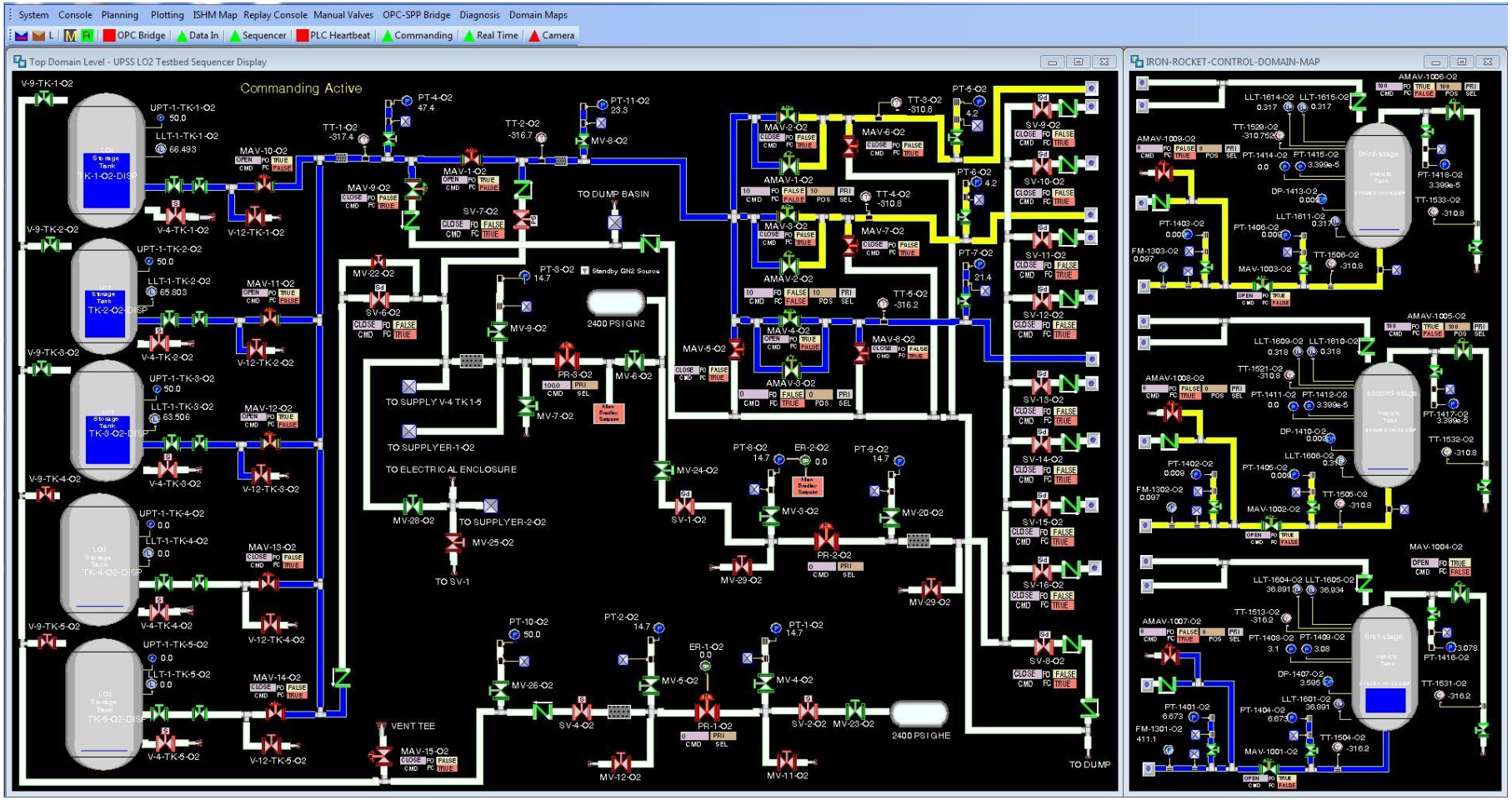
ORION Power System Domain



KSC Autonomous Propellant Loading Implementation

Not Schematics



Steps Toward Advancing ISHM

- Move beyond brute-force approaches. Enable the system to work the solutions based on concepts and models instead working out all the solutions off-line and creating a lookup table for use by the system.
- Paradigm: capability must leverage a knowledge domain and generic models. This is consistent with model-based systems engineering processes.
- Develop capable software platforms that enable creation of application knowledge models, and be able to leverage of these models for mission planning, reasoning, and decision making based on a broad range of process models that describe nominal and anomalous behaviors.