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SPACE LAUNCH SYSTEM

SLS Model Based Design: A Navigation Perspective

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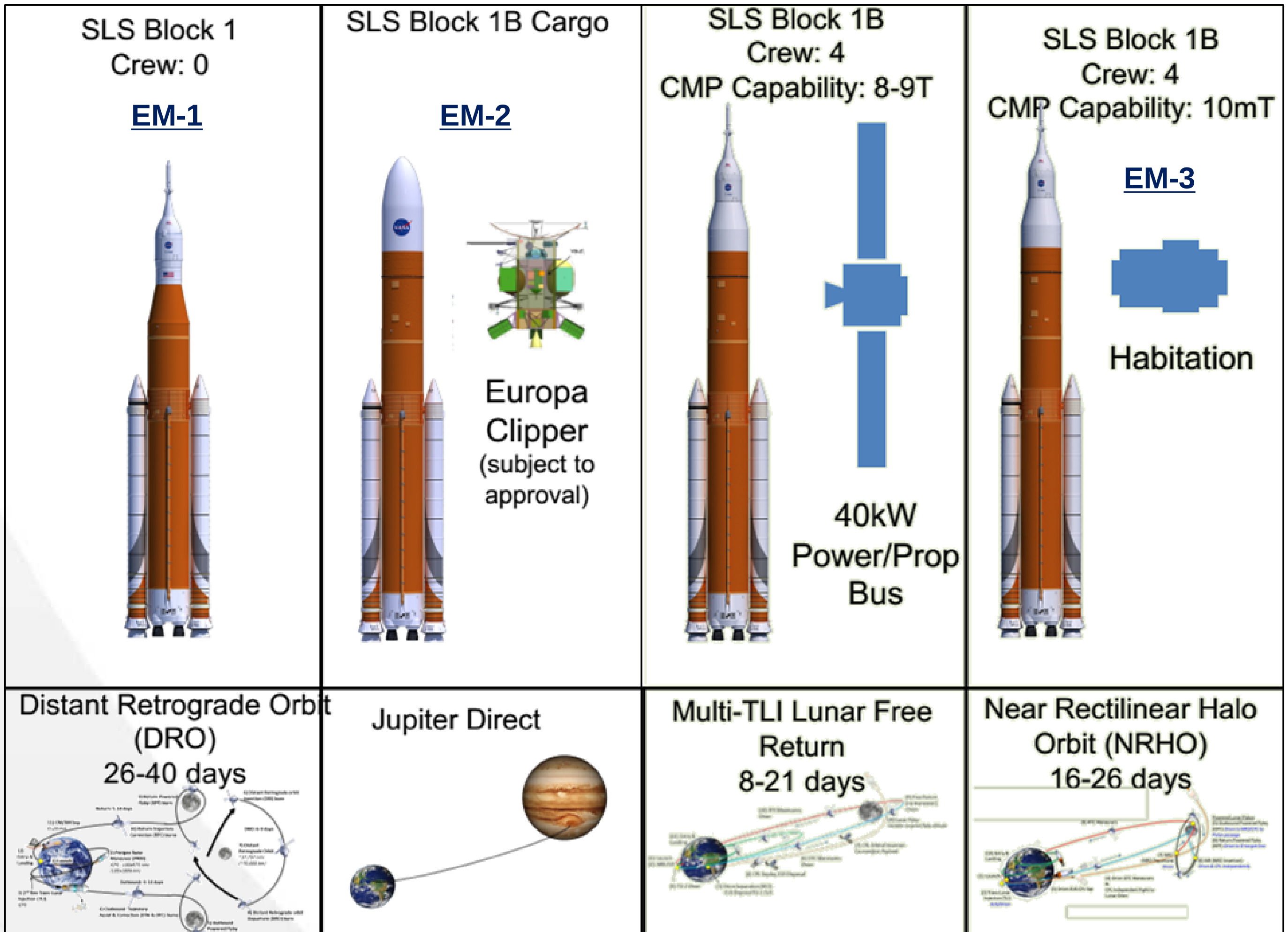
Overview

- Introduction to Space Launch Systems (SLS)
- SLS Requirements and Design Math Models (DMMS)
- The SLS GN&C Model
- The SLS Inertial Navigation System (INS) Performance Model
- Marshall Advanced GPS Model for Analysis (MAGMA)
- Conclusions and Lessons Learned

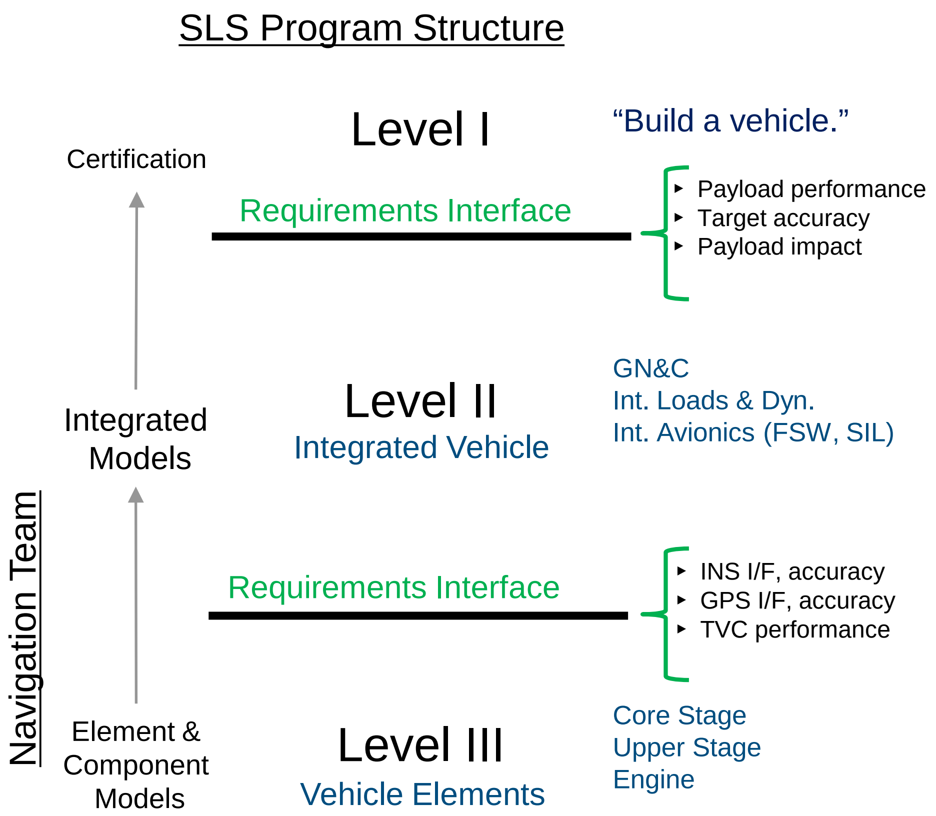
Introduction to Space Launch System (SLS)

- **NASA is developing a phased plan to deep space exploration enabled by SLS, an evolution of Launch vehicles.**
  - Currently completing the design and building the Block 1 vehicle
  - In the process of Block 1B design



SLS SE&I Model Based Design

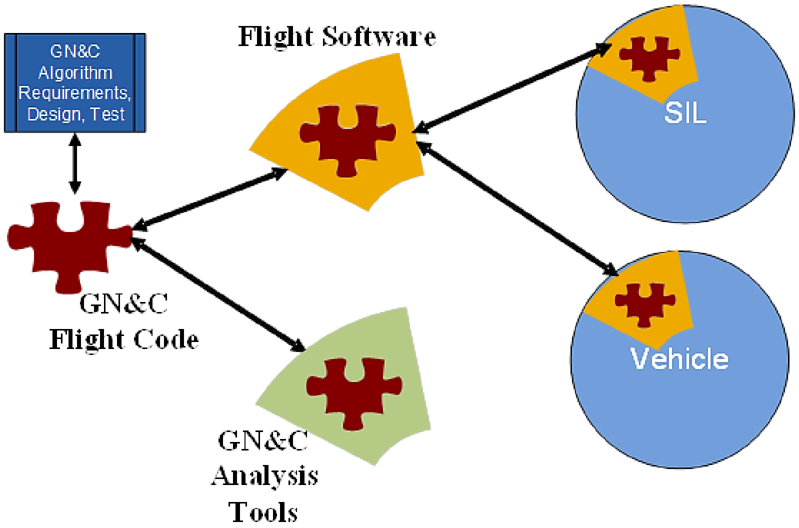
- **Reduced Program structure**
- **Emphasis on heritage hardware**
- **Relatively sparse requirements set over previous design projects**
- **DMMs convey the design**
  - Controlled at program level
  - Maturity/limitations/use tightly tracked
  - Component models are verified against vendor design and validated against flight hardware (or equiv.)
  - Physics models (e.g. 6DOF sim) verified against other simulations and validated with test data.
  - Model parameters of high sensitivity can be elevated to requirements
- **SLS Navigation Supports Level II and Level III**
- **Example**
  - Level II DMMs: GN&C Model, MAVERIC (6DOF Sim)
  - Level III DMMs: INS Performance, GPS

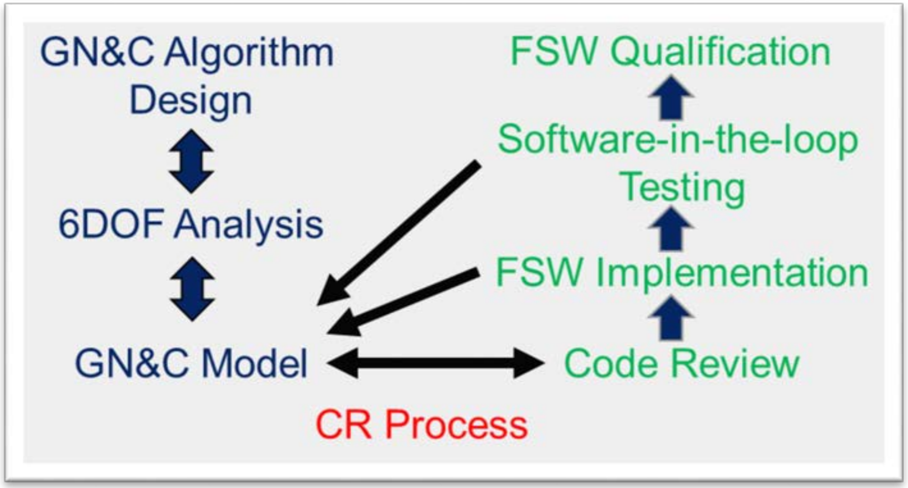


GN&C Model

- **Began as pilot program 2010**
- **Common GN&C code across SLS Disciplines & Functions**
- **Efficient GNC/FSW Process**
- **DMM Contents**
  - Executable Algorithms
  - Parameter Definition
  - Technical Memorandum
  - Interface assumptions
  - Unit test cases
- **GN&C/Navigation Model**
  - Inertial Measurement Processing
  - State derived quantities
  - RINU Initialization
  - RINU FDIR Parameters
  - GCA Convergence check
  - RINU Frame check
  - GPS Measurement Processing
  - SDINS algorithms
  - Navigation EKF

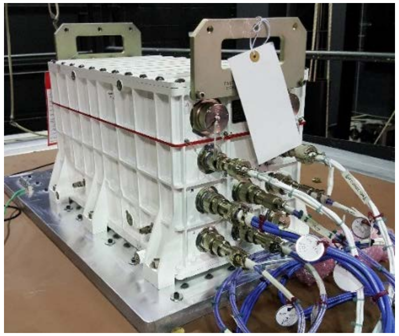
(Block 1B only)

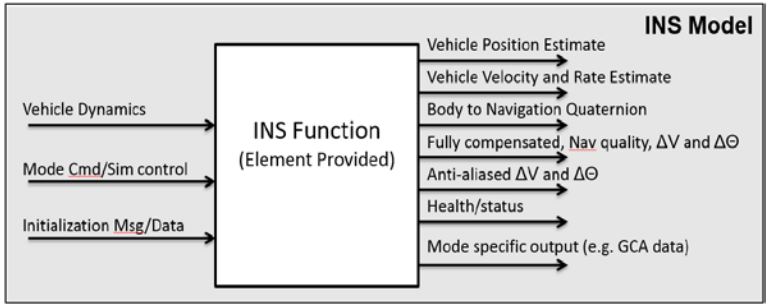


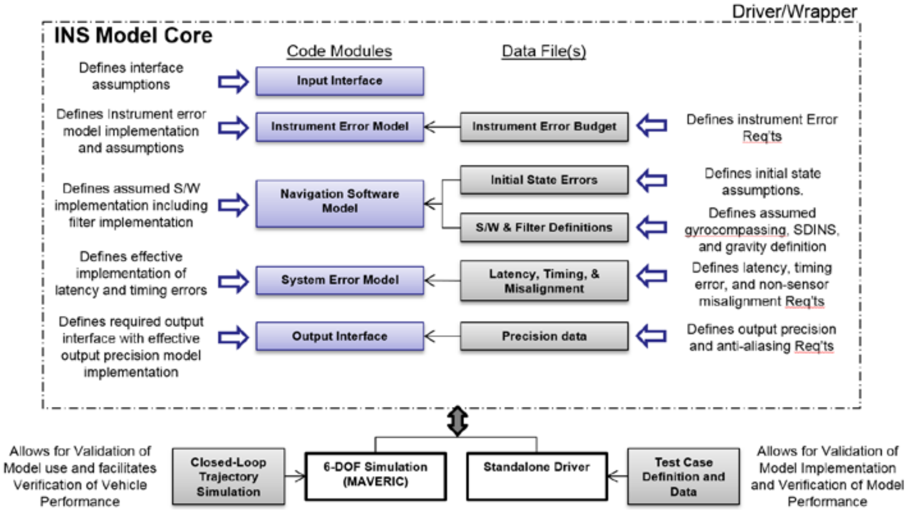


INS Performance Model

- **RINU: Redundant Inertial Navigation Unit**
- **Level II Requirements Definition**
  - Interface and frequency response
  - Performance constrained with reference trajectory
  - Reduction in requirements with explicit modeling
- **Level III Model Description**
  - Detailed instrument error modeling
  - Algorithms which affect performance
  - Detailed interface model
- **Verified against vendor documentation, FQT data, and analysis**
- **Validated against test data**
  - GCA 6DOF Test
  - Frequency response test
  - Vendor ATP/QTP data
- **Analyses Performed**
  - Navigation performance
  - Gyrocompassing alignment
  - Coning/Sculling
  - Integration into vehicle 6DOF

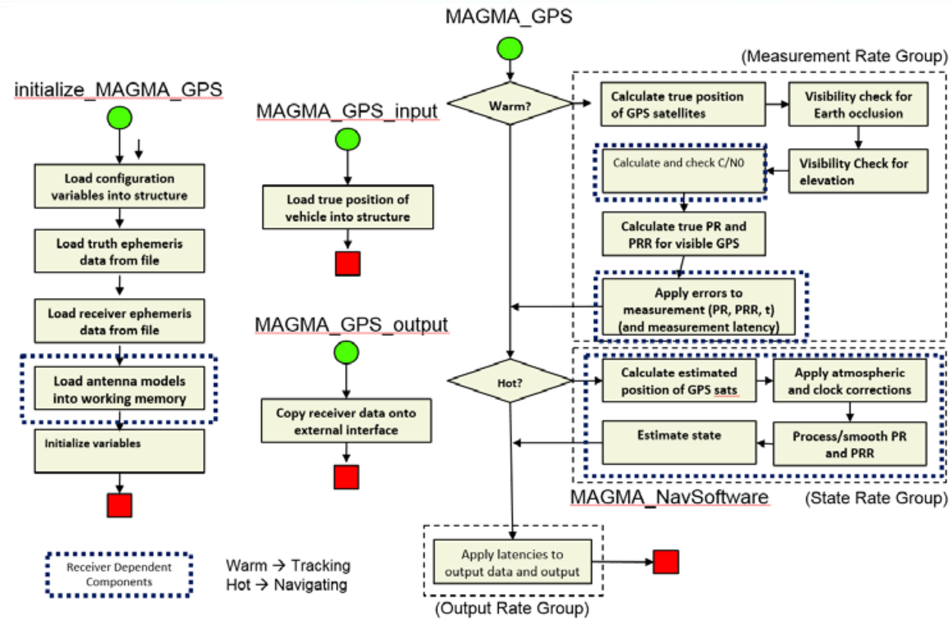


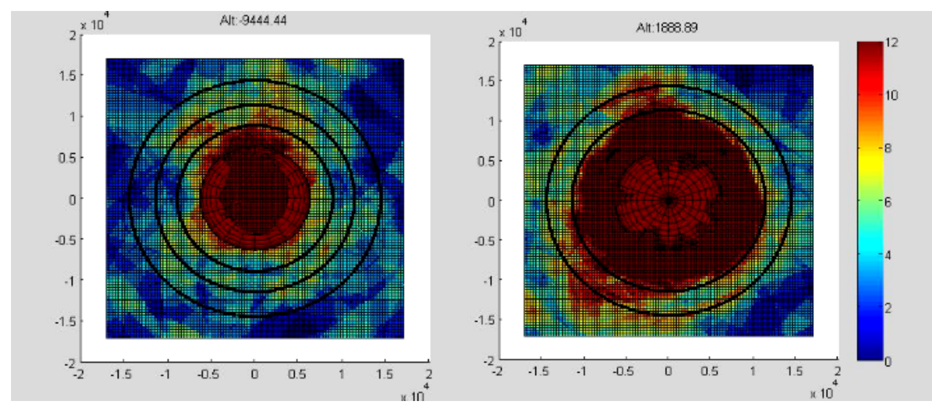




MAGMA GPS Model

- **Marshall Advanced GPS Model for Analysis**
- **Framework developed to support**
  - Requirements development,
  - Early Navigation System design
  - Seed Level III DMM development
- **Level II Requirements**
  - Interface definition
  - Measurement accuracy
- **Functional Components**
  - Detailed truth model
  - SV and Receiver Antenna modeling
  - Receiver hardware modeling
  - Receiver software modeling
- **Models measurement availability, accuracy, and latency**





Simulation of GPS availability within 2D plane

Conclusion

- **Implementation of MBD on SLS has significantly increased efficiency**
  - Reduced requirements burden
  - Provide explicit communication of component and integrated system design
- **Provides a mechanism for**
  - Detailed modeling and design insight
  - Identification of key vehicle sensitivities
  - Gaining additional insight through testing and validation process
  - Enforcing rigor in modeling through validation
- **DMM V&V process forces high fidelity emulation of hardware**

- **Lessons Learned:**
  - Model form and function should consider user and developer
  - GN&C Model
    - Software requirements drive the software test program
    - Approach conflicted with established FSW processes and culture
  - Component models,
    - Good data requirements and supplier integration are key to enabling process
    - V&V plans should be defined early to support data requirements definition and to identify gaps which require additional testing.
    - Sensitivity analyses should be used to identify key performance drivers
    - Commonality between HWIL models and Performance/Analysis models reduces cross-validation effort in verification

Thank you!

Any questions?