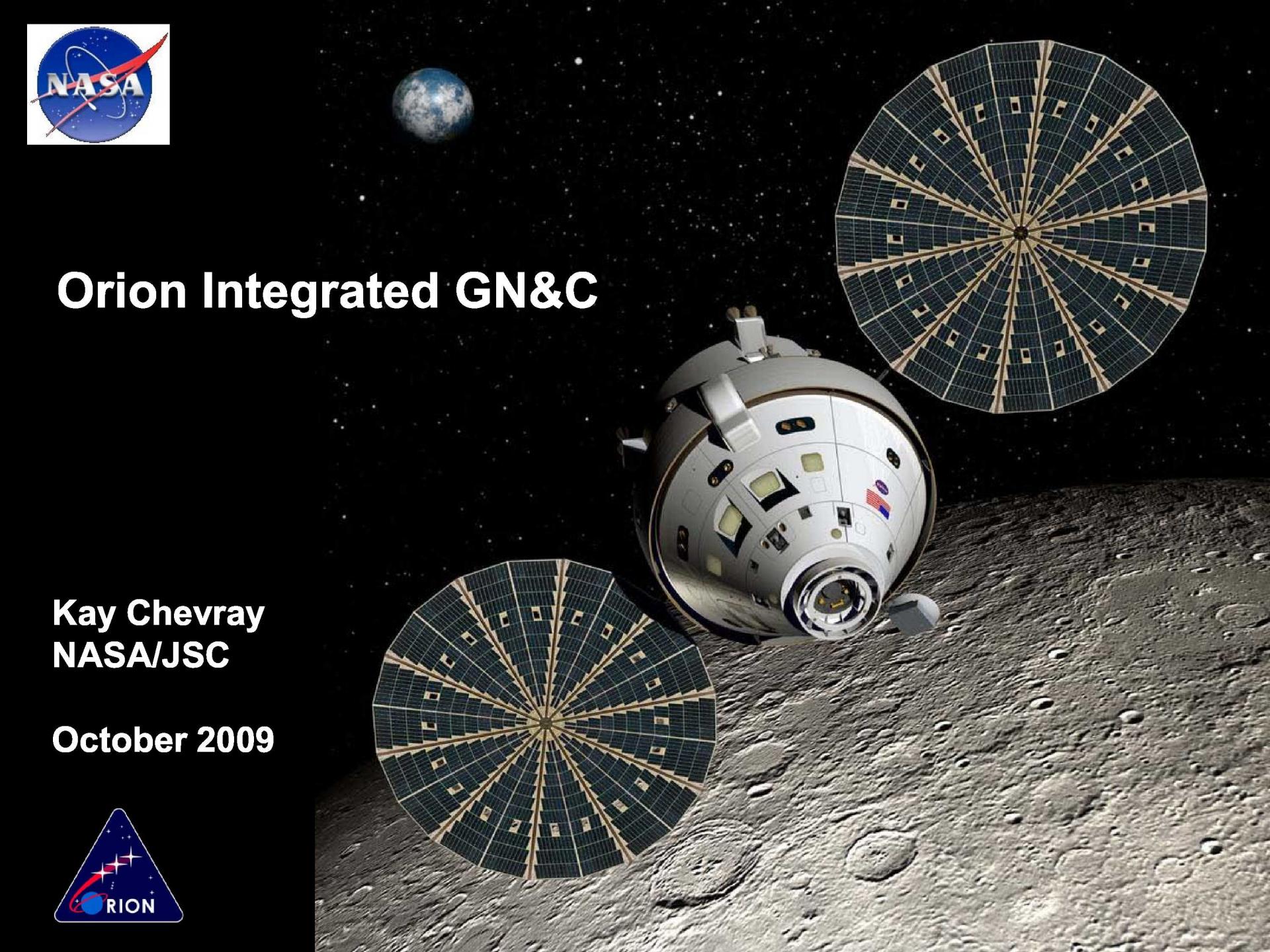


Orion Integrated GN&C

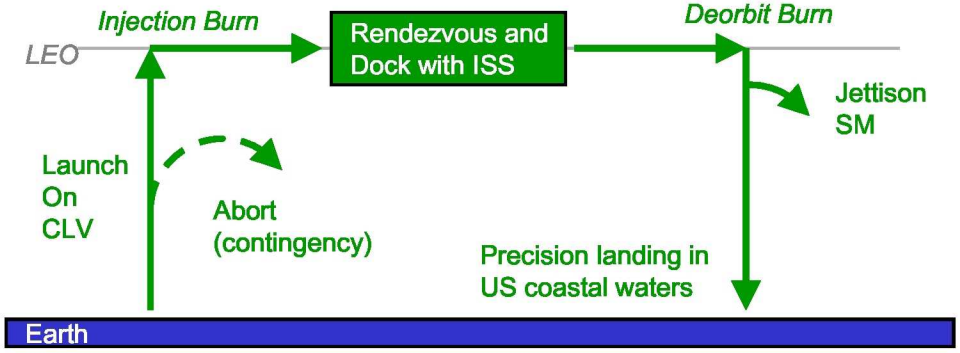
Kay Chevray
NASA/JSC

October 2009

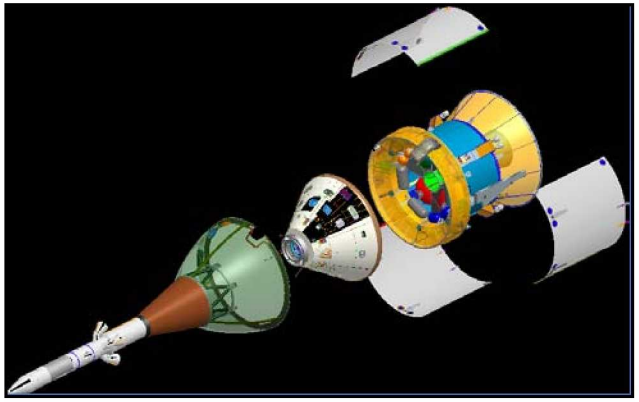
Outline

- **As Background:**
  - Project Orion Mission
  - iGNC role in Orion Program
- **Design and Development Plans:**
  - External Interfaces
  - Functional Architecture
  - GN&C Software Overview
  - Development and Validation Process
  - Key Challenges

Project Orion Mission At-A-Glance

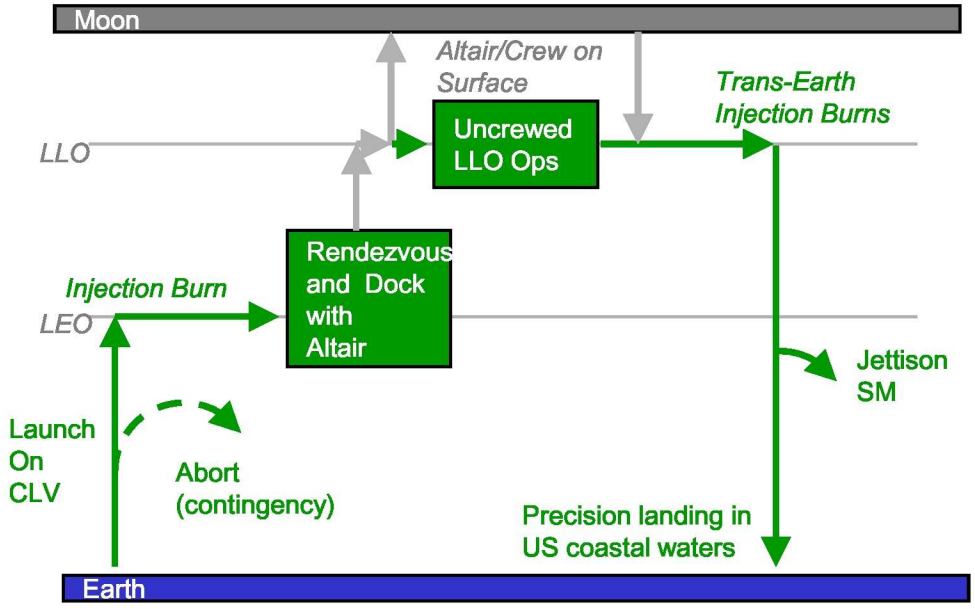


ISS Design Reference Mission



Key Functions

- Safe
- Robust
- Reliable



Lunar Design Reference Mission

Ref: Orion GN&C Subsystem Design Review February 2009

Integrated GN&C (iGNC) Role within Orion

- **Orion GN&C team operates under Multiple Organizational Design and Engineering (MODE) team agreement between NASA and prime contractor, Lockheed-Martin (LM)**
  - MODE team arrangement allows NASA engineers to collaborate with the prime contractor during design process
    - Allows to leverage off of NASA's experience with manned systems
  - Allows greater insight into prime contractor's design
  - Each MODE team within the GN&C Subsystem Products Team (GNC SPT) is co-led by a NASA lead and a LM lead
- **As a NASA side lead, I have responsibilities on both sides**
  - As a System Manager, monitor design activities and evaluate the design
    - 30 System Managers and 80 Subsystem Managers
  - The roles are expected to diverge after CDR, as LM personnel concentrates on test and verification while NASA personnel will focus on assessment of LM data for vehicle acceptance

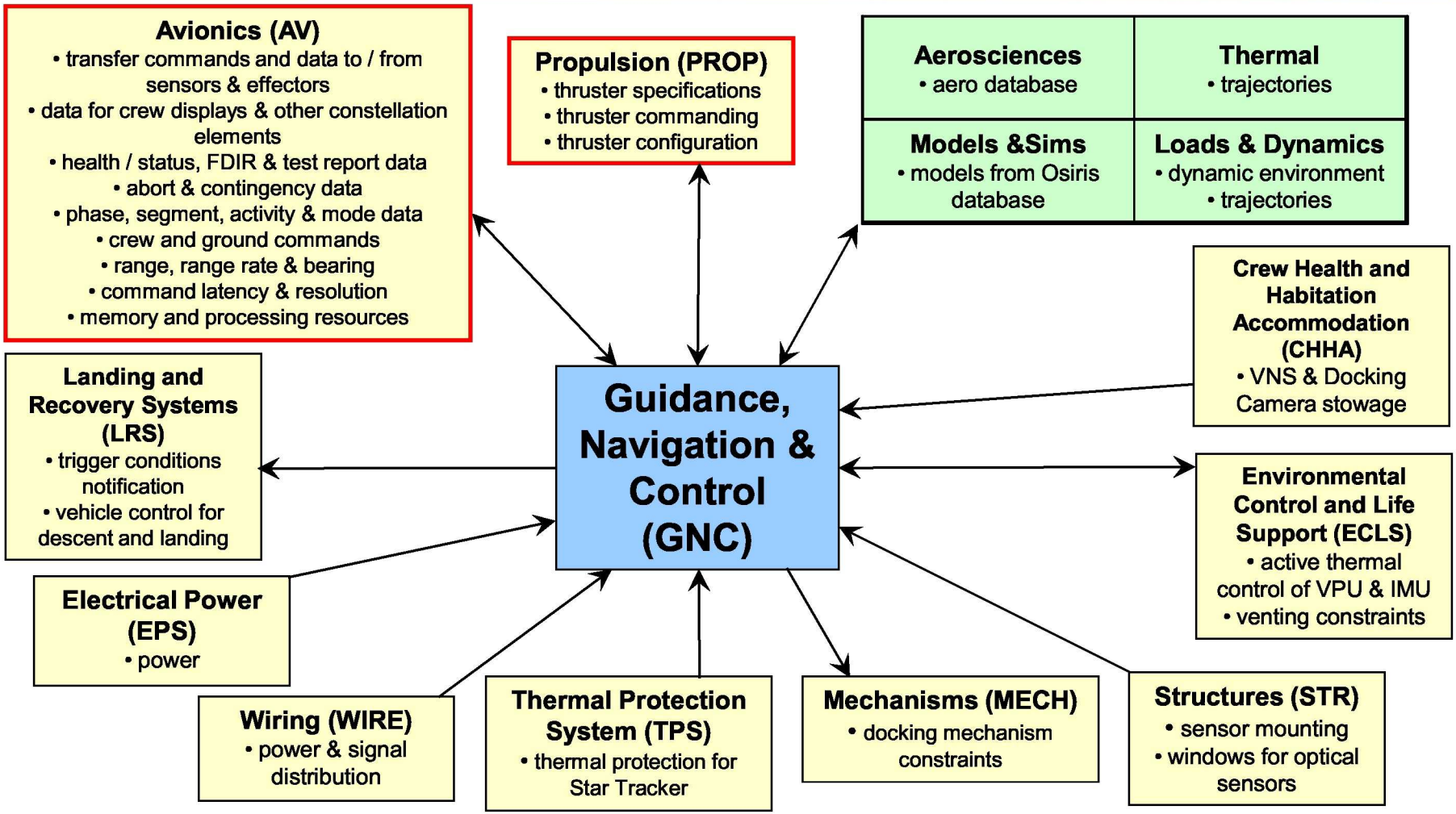
iGNC Role within Orion (cont'd)

- **iGNC is a MODE team that is responsible at the subsystem level for:**
  - Systems Engineering
  - Inter-MODE team integration and external interfaces
  - Requirements
  - Flight software architecture including Phases, Segments, and Modes
  - Fault Detection, Isolation, and Recovery (FDIR)
  - Test and Verification
  - Simulation development
- **In addition, iGNC personnel participates in the following activities with other organizations**
  - Constellation (level II) requirements coordination through Flight Performance System Integration Group (FPSIG) – CARD and IRD requirements
  - Coordination with the International Space Station (ISS) for Rendezvous, Proximity Operations, and Docking (RPOD) related topics – Orion/ISS IRD requirements, docking conditions

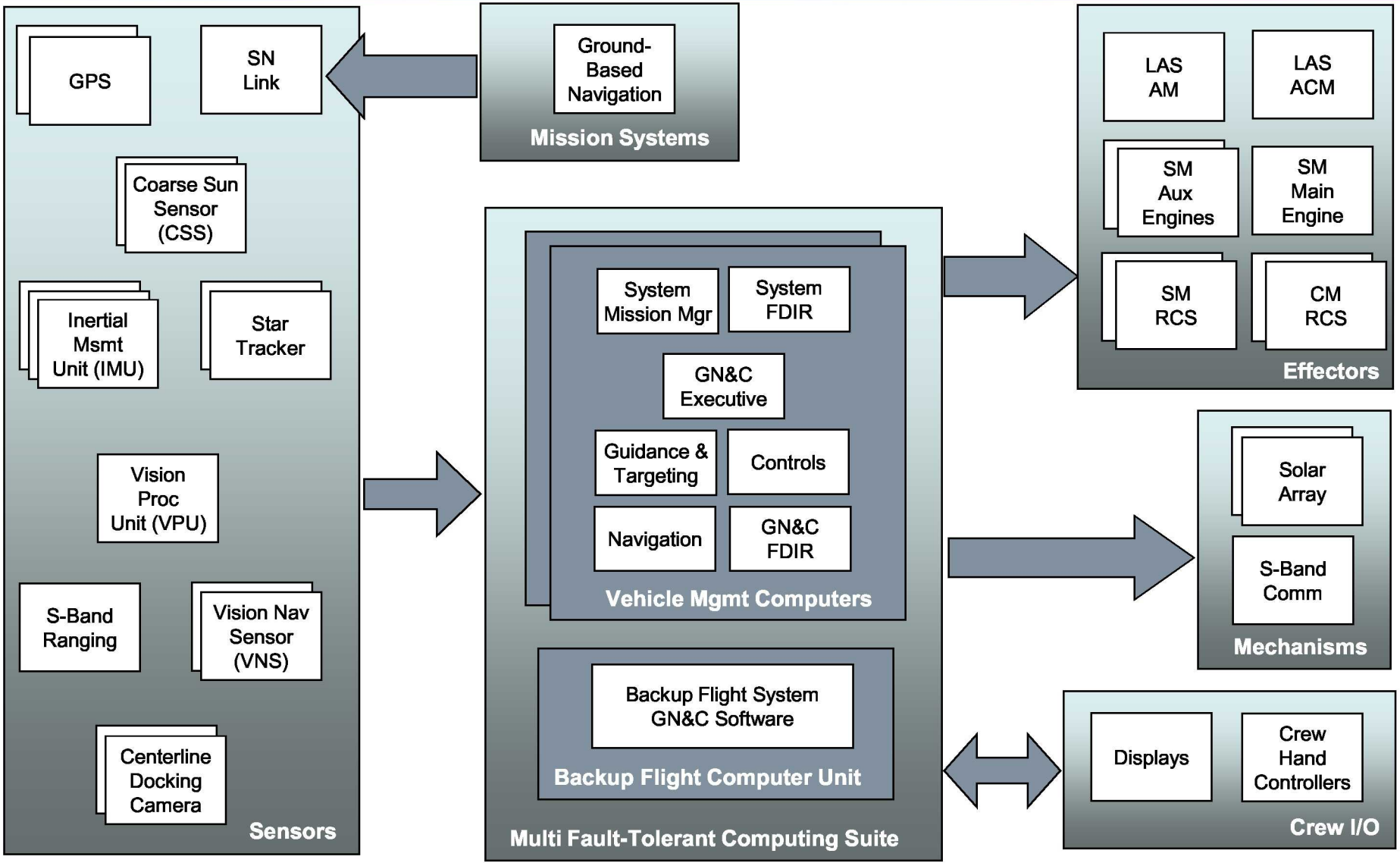
MODE Team Responsibilities

- **Integrated GN&C (iGNC):**
  - Requirements, verification, sim development, and technical integration
- **Ascent Abort (AAMT):**
  - Handles GN&C for all ascent aborts including LAS and SM aborts
- **Orbit (OMT):**
  - Handles navigation filter design and GN&C for on-orbit, transit, and RPOD
- **Entry (EMT):**
  - Handles entry GN&C including CM burns, guided entry, and roll under mains
- **Operability and Piloting (OPMT):**
  - Handles manual control, flight displays, and ops interfaces across mission
- **Contingency Return (CRMT):**
  - Handles GN&C for BEC/MRC vehicle capabilities
- **Navigation Systems (NavSys):**
  - Nav hardware design and system integration across all mission phases

External Interfaces



606E GN&C Subsystem Boundary Diagram



Ref: Orion GN&C Subsystem Design Review February 2009

Orion GN&C FSW Overview

Time/Space ARINC 653 Partitions
(notional)

Orion Project

Flight Computer/VMC

- FCM (SCP)
- DCM (SCP)
- CCM

VMC = Vehicle Mgmt Computer
FCM = Flight Control Module
DCM = Display Control Module
CCM = Communications Control Module
SCP = Self Checking Pair (of processors)

SKP	IOP	ANAV	GNCP	IOP	CDH	CMT	ADL	TM

input — output

GNCP Partitions

Navigation
- GNC Cmd Interface
- Nav Health Mgmt
- Abs Nav
- Rel Nav
- Ephem Proc

Guidance/Targeting
- Guid Health Mgmt
- Ascnt TargGuid
- Entry TargGuid
- Orbit TargGuid

Control/Propulsion
- Cntrl Health Mgmt
- LAS-Cntrl
- CM-Cntrl
- SM-Cntrl
- Mass Prop
- PropSys Cntrl
- Engine Cntrl

"CSCIs"
(1 SRS per CSCI)

"Domains"/CSCs
(CSU detail not shown here)

CSCI
- CSC
  - CSU
  - CSU
- CSC
  - CSU
  - CSU

CSCI = Computer SW Configuration Item
CSC = Computer SW Component
CSU = Computer SW Unit

Rate Groups, Hz (ms)
40 (25 ms) - High
20 (50 ms) - Med-High
10 (100 ms) - Med
5 (200 ms) - Med-Low
1 (1000 ms) - Low

Note:
D&C HW/SW reuse requires data rates in multiples of 20Hz (50 ms).

Ownership
- Ascent Abort MODE Team
- Orbit MODE Team
- Entry MODE Team
- Navigation Systems
- Propulsion

Multiple rate groups can reside within the partition.

Ref: Orion GN&C FSW Overview W. Tamblyn

Development and validation process

- **GN&C MODE teams responsible for the development of GN&C algorithms**
  - Guidance, navigation, control, executive, FDIR, parameters for display
- **Algorithms documented in modeled based design tool (Matlab/Simulink)**
  - FSW provides the executive architecture
    - Architecture developed by GN&C FSW architecture working group, co-led by GN&C and FSW
  - GNC provides the detailed algorithms within the architecture (CSCI's)
  - Simulation capability to close the loop directly with the FSW algorithms during the development phase
- **Auto-coded version of the Matlab/Simulink becomes the flight software at the CSCI level**
- **Flight software then will get tested and verified via various test facilities**

Key Challenges

- **Communication**
  - With the size of Orion Project and the GN&C team, maintaining an open communication channels is difficult
  - Need to find the right balance of enough participation to make correct decisions vs. too many people attending too many meetings to get the "real" work done
- **Horizontal vs. vertical integration**
  - GN&C team is organized by flight phase, which allows for easier integration inside a given phase. iGNC is responsible for horizontal integration across various flight phases, which requires matrixed support from flight phase teams.
- **Requirements management**
  - Flow down from Level II (Constellation Program) and Level III (Orion Project) through Crew Module and Service Module Specifications to GN&C Specifications
  - Performance allocations at the vehicle level
  - GN&C subsystem spec vs. flight software requirements
  - How many requirements is too many?
- **Test and verification**
  - Development vs. formal verification testing
  - Testing at subsystem vs. system level
  - Time required to complete the verification in test facilities