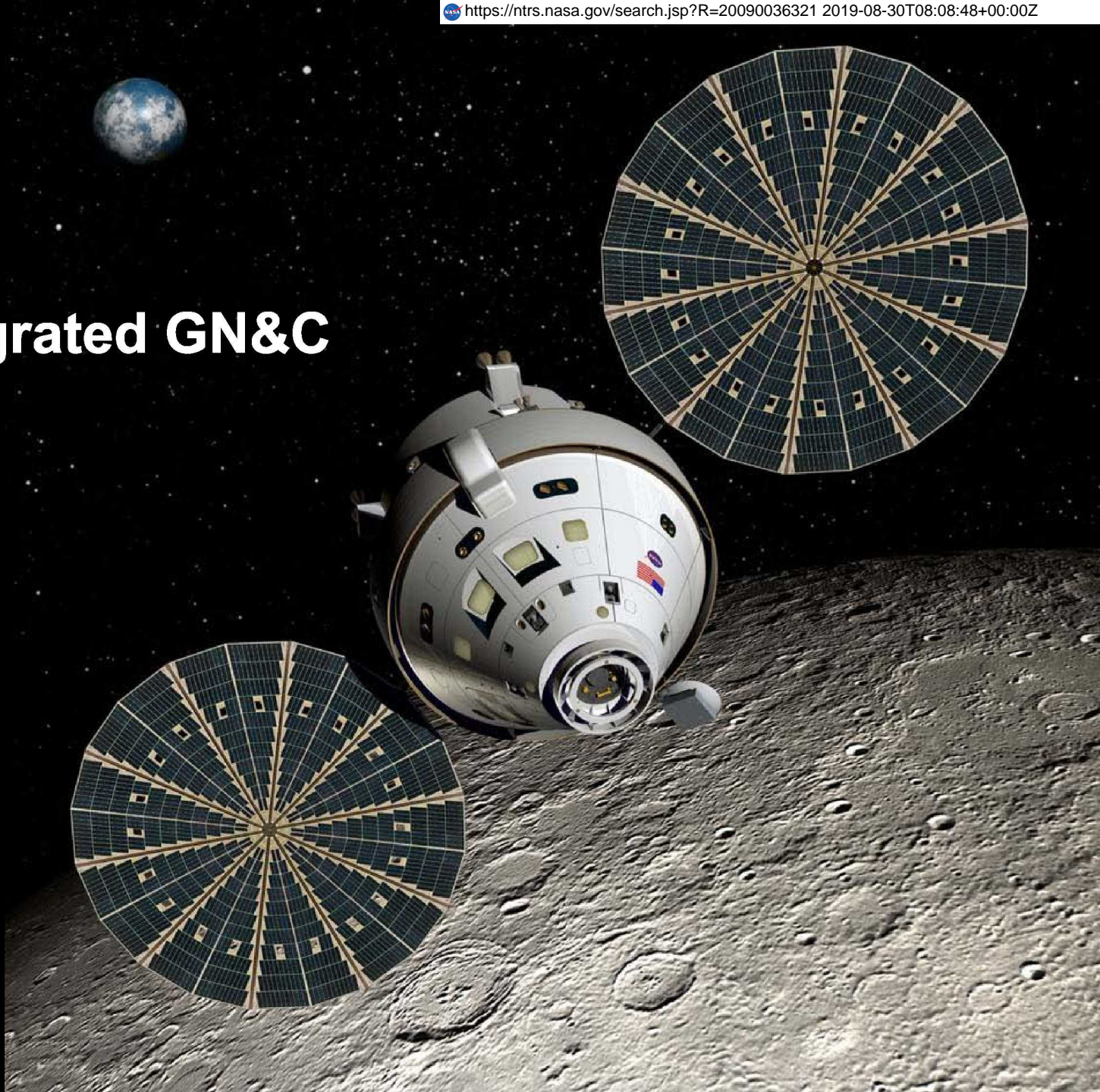




# Orion Integrated GN&C

**Kay Chevray**  
**NASA/JSC**

**October 2009**





## ◆ **As Background:**

- Project Orion Mission
- iGNC role in Orion Program

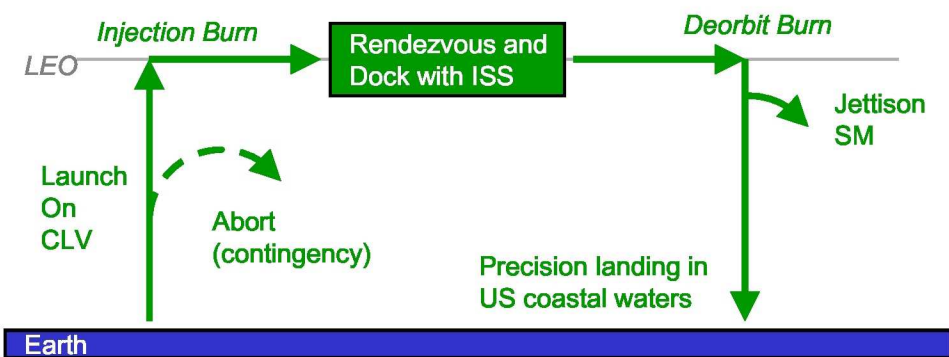
## ◆ **Design and Development Plans:**

- External Interfaces
- Functional Architecture
- GN&C Software Overview
- Development and Validation Process
- Key Challenges

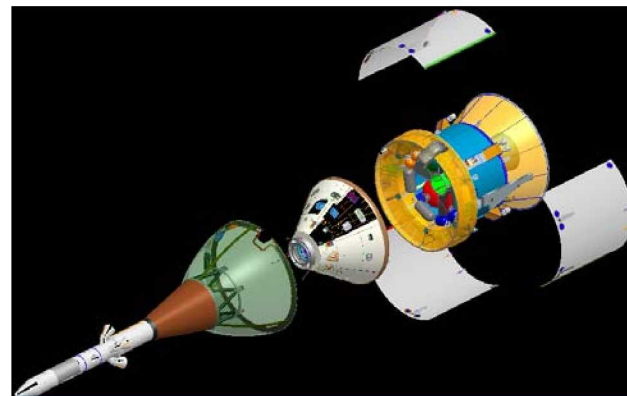


# Project Orion Mission At-A-Glance

Orion Project



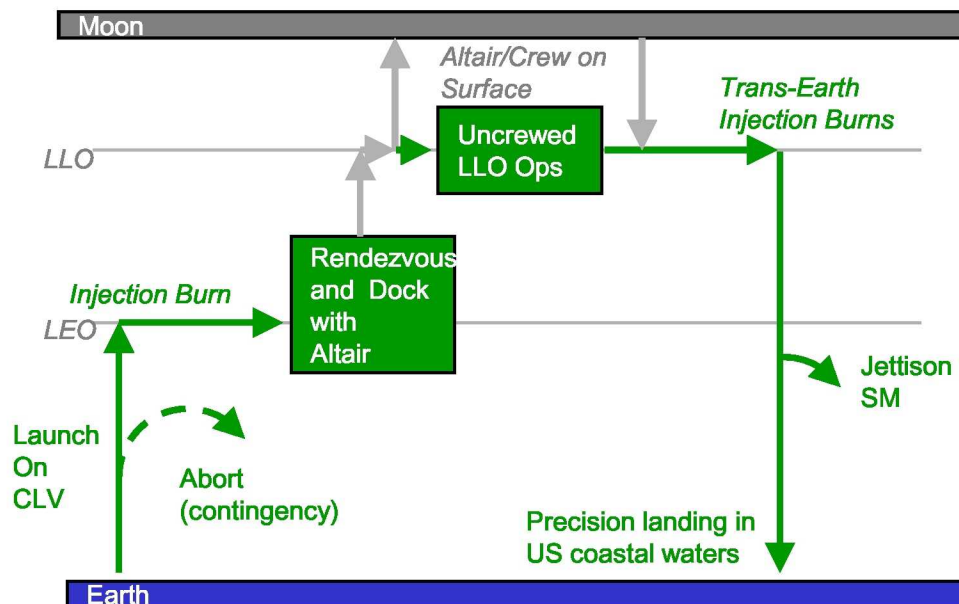
ISS Design Reference Mission



## Key Functions

- Safe
- Robust
- Reliable

Ref: Orion GN&C Subsystem Design Review  
February 2009



Lunar Design Reference Mission



# Integrated GN&C (iGNC) Role within Orion

Orion Project

- ◆ **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)

Orion Project

- ◆ **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

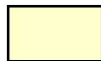
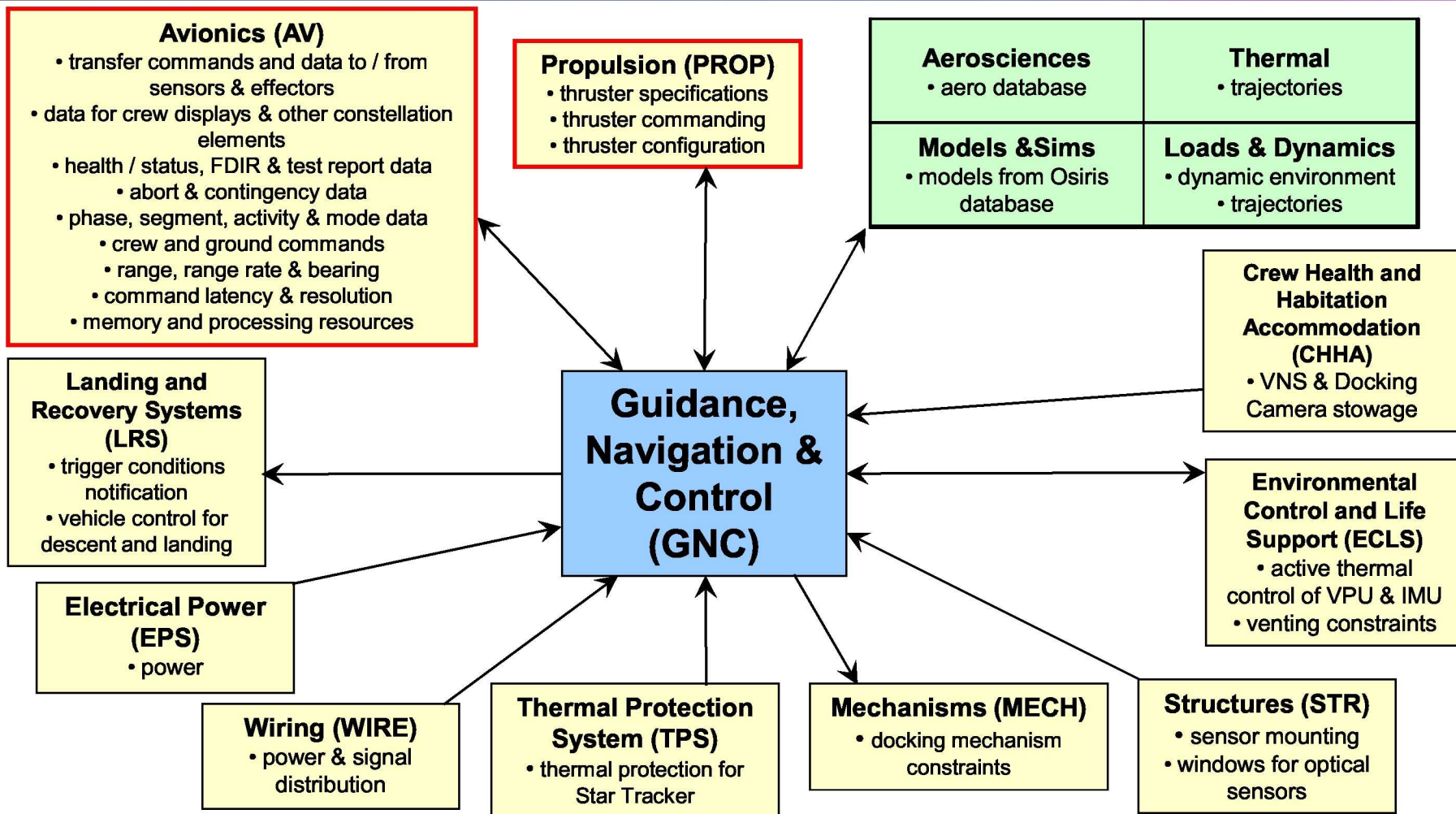
Orion Project

- ◆ **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



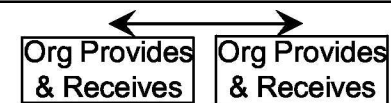
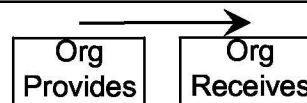
# External Interfaces

Orion Project



Driving Interface SEIT (Subsystem to Subsystem)

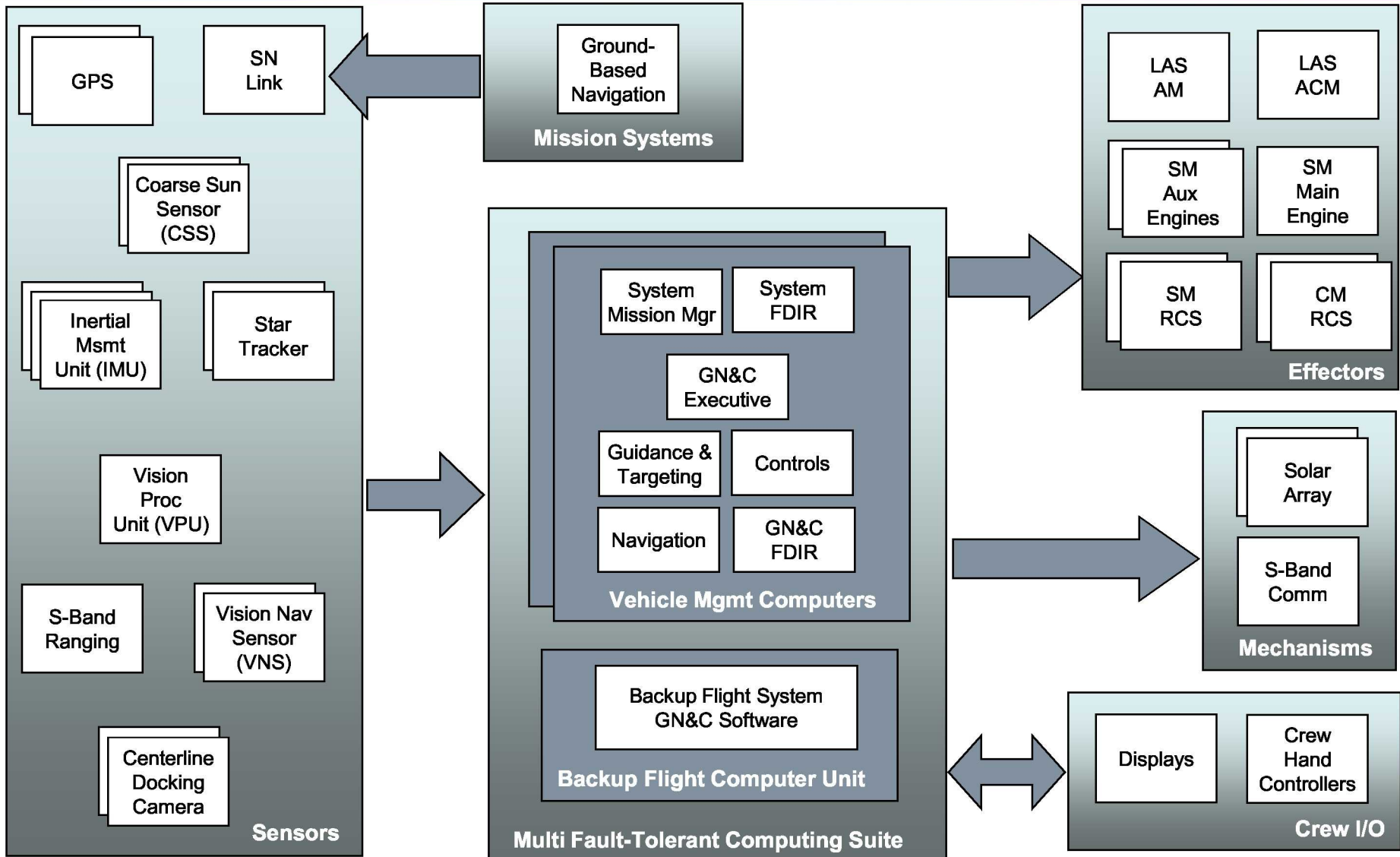
Other Organizations





# 606E GN&C Subsystem Boundary Diagram

Orion Project





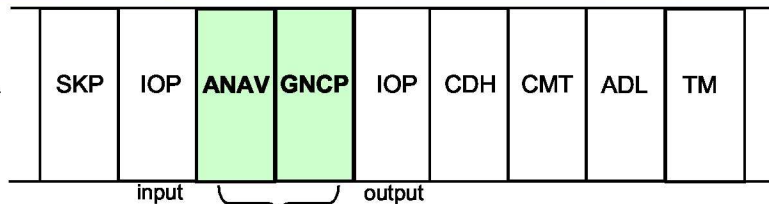
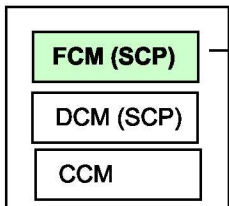


# Orion GN&C FSW Overview

## Time/Space ARINC 653 Partitions (notional)

Orion Project

### Flight Computer/VMC



### GNCP Partitions

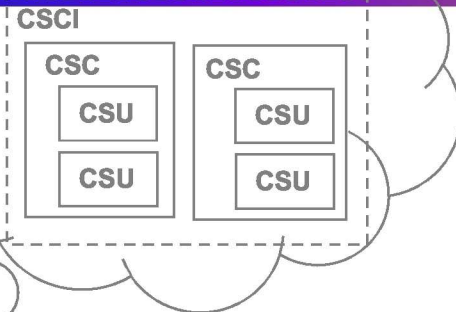
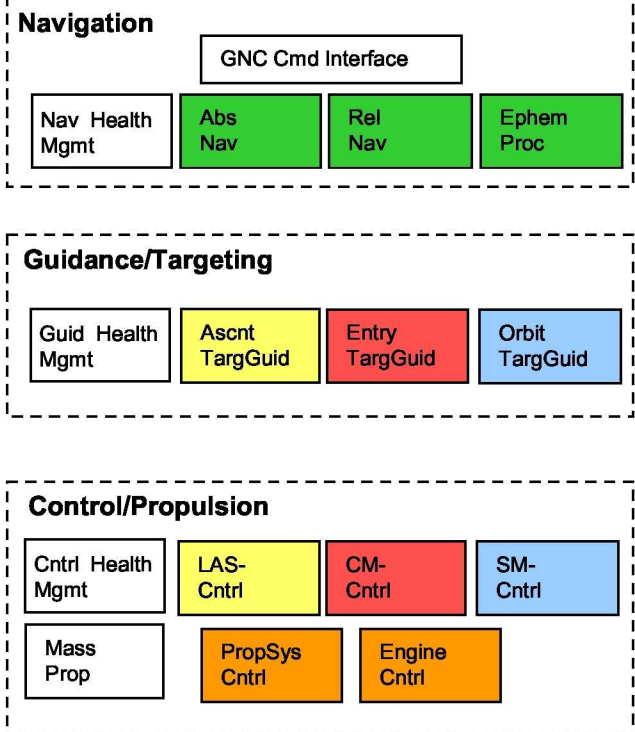
VMC = Vehicle Mgmt Computer  
 FCM = Flight Control Module  
 DCM = Display Control Module  
 CCM = Communications Control Module  
 SCP = Self Checking Pair (of processors)

"CSCIs"  
 (1 SRS per CSCI)

### 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

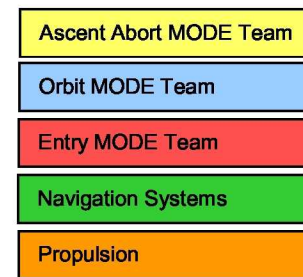
**Note:**  
 D&C HW/SW reuse requires data rates  
 in multiples of 20Hz (50 ms).



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

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

### Ownership



Multiple rate groups can reside within the partition.

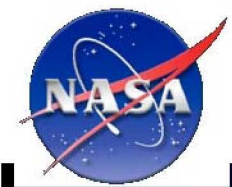
Ref: Orion GN&C FSW Overview  
 W. Tamblyn



# Development and validation process

Orion Project

- ◆ **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

Orion Project

## ◆ 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. iGN&C 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