Orion Multipurpose Crew Vehicle (MPCV) Overview – Embedded Flight Software

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Background Information

The Orion Spacecraft

Launch Abort System

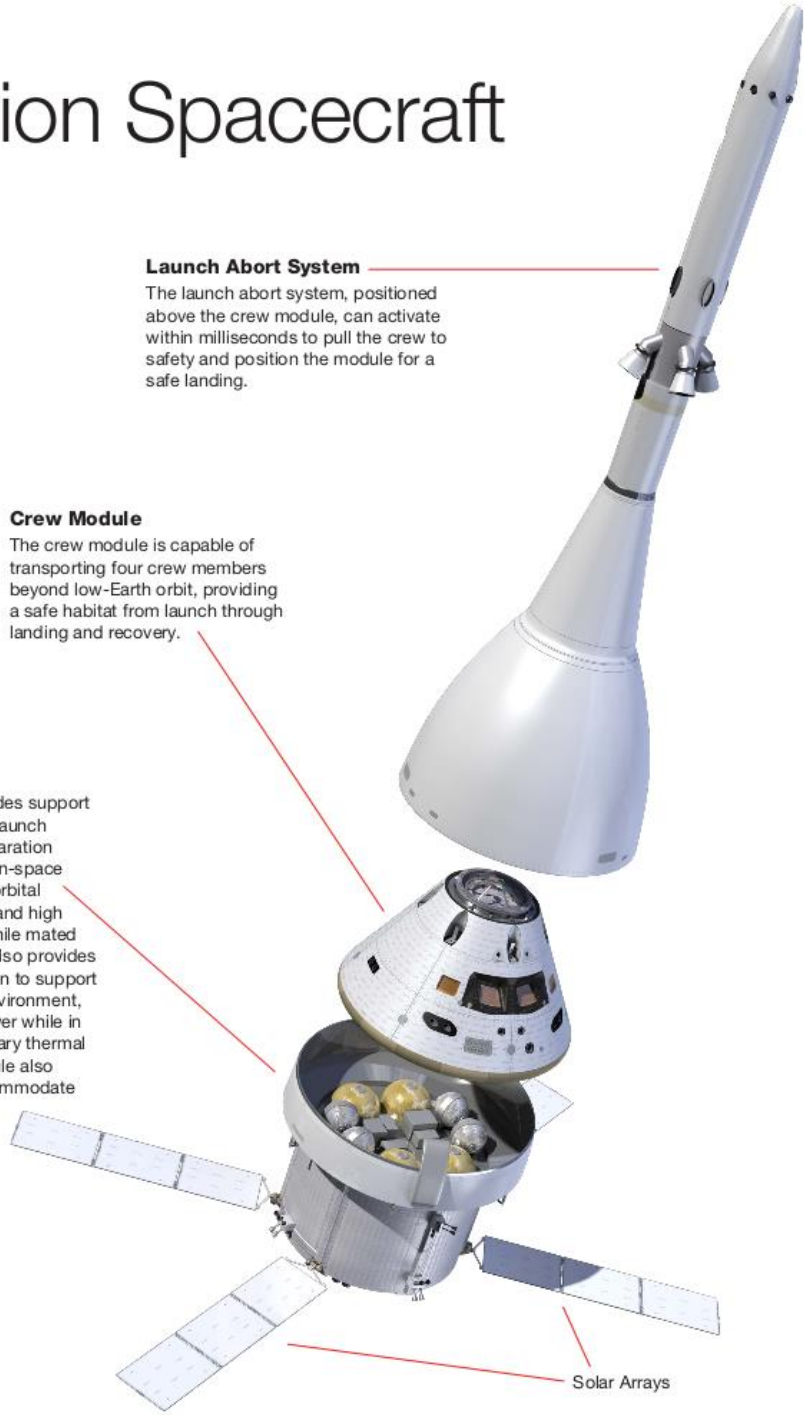
The launch abort system, positioned above the crew module, can activate within milliseconds to pull the crew to safety and position the module for a safe landing.

Crew Module

The crew module is capable of transporting four crew members beyond low-Earth orbit, providing a safe habitat from launch through landing and recovery.

Service Module

The service module provides support to the crew module from launch through crew module separation prior to entry. It provides in-space propulsion capability for orbital transfer, attitude control, and high altitude ascent aborts. While mated with the crew module, it also provides water, oxygen and nitrogen to support the crew module living environment, generates and stores power while in space, and provides primary thermal control. The service module also has the capability to accommodate unpressurized cargo.



The Bird

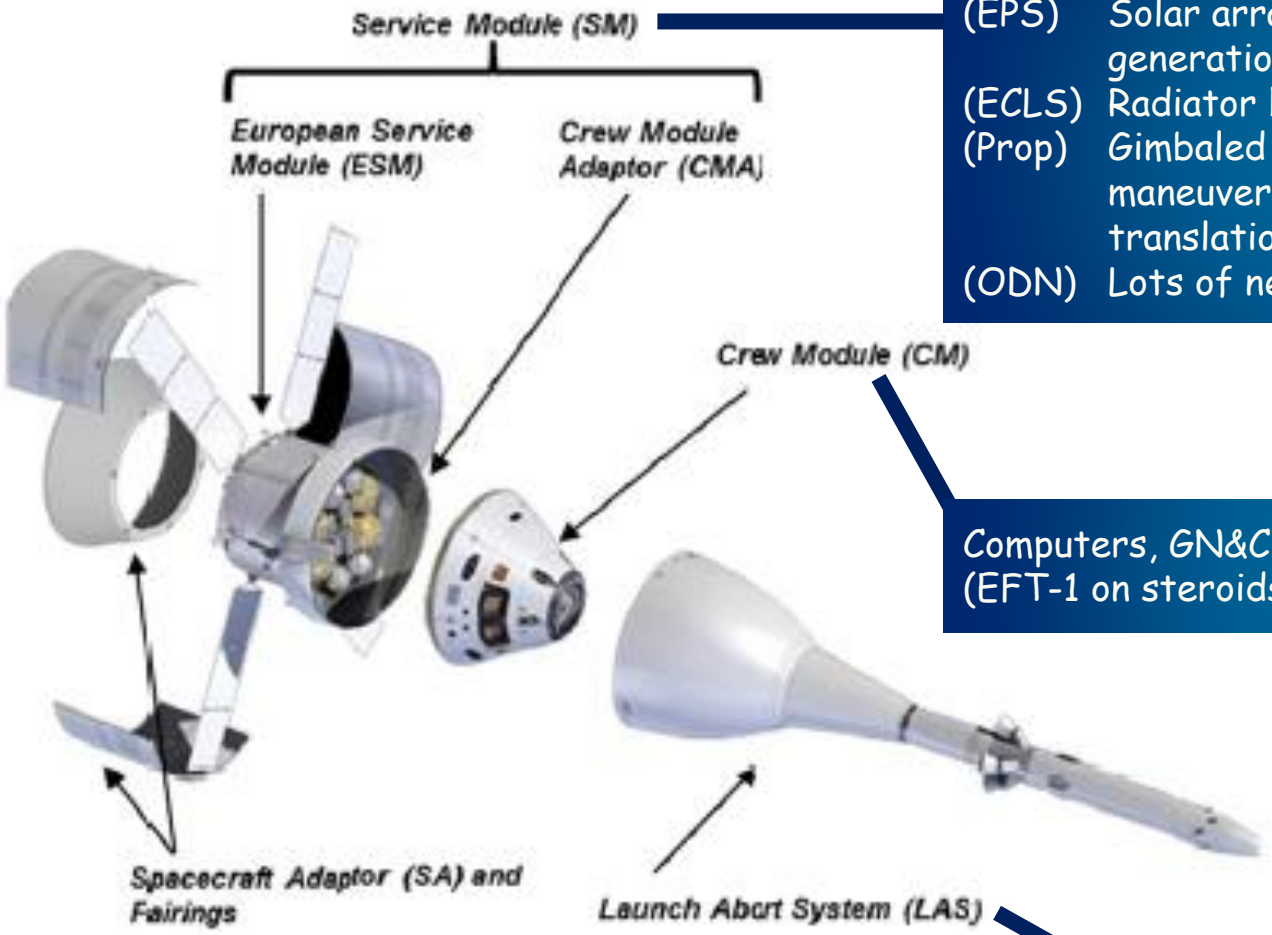


FIGURE 3.1-2 THE ORION SYSTEM

(EPS) Solar arrays and electrical generation, sun sensors
(ECLS) Radiator heat dump
(Prop) Gimbaled main engine, attitude maneuvering RCS, auxiliary translation jets
(ODN) Lots of new end items!

Computers, GN&C sensors, entry systems (EFT-1 on steroids)

Abort motor, attitude control motor, jettison system – remember PA-1?

What is the Orion Multipurpose Crew Vehicle

- **The MPCV will be the next NASA spacecraft capable of carrying a human crew to destinations beyond low Earth orbit (LEO)**
  - Up to four crew
  - Capable of long duration missions
- **Will launch on a variety of vehicles, but will eventually ride the Space Launch System, also being developed by NASA**
- **The MPCV is being developed under contract by Lockheed Martin**
- **The Flight Software is being developed by Lockheed Martin with significant contributions by their contract partners, including Honeywell**

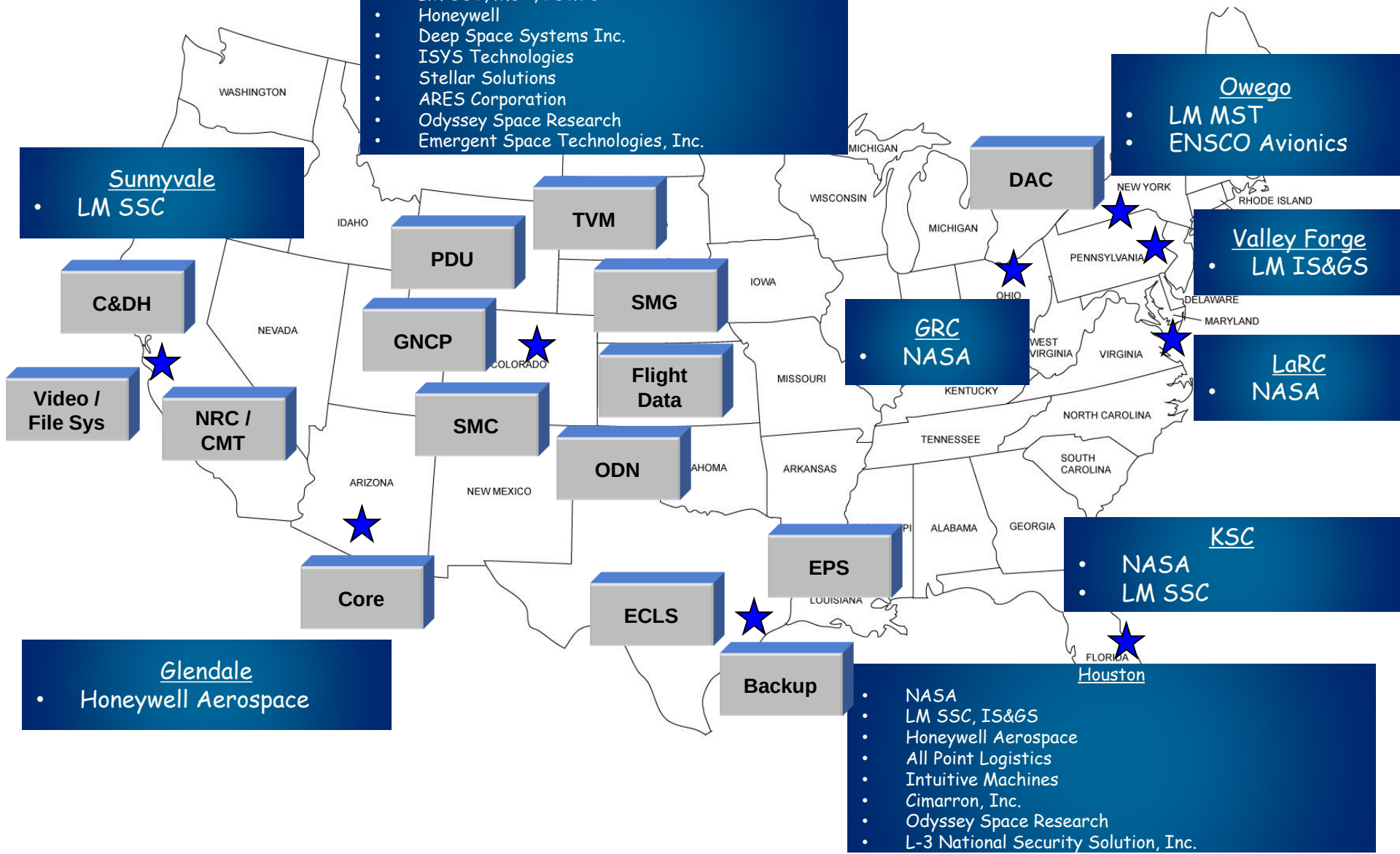
Schedule

Important Dates Past and Future

- **December 2014 – Orion makes the first earth orbit flight**
  - The flight lasted just over 4 hours
  - The flight tested many of the on-board systems
- **Ascent Abort Test 2**
  - Will test a high velocity abort maneuver during critical ascent using the Launch Abort System
  - Scheduled for 2018
- **Exploration Mission 1**
  - An unmanned flight that will cover all of the mission objectives for the first manned flight
  - Schedule is currently under review
- **Exploration Mission 2**
  - First flight of Orion with humans aboard
  - Schedule is currently under review

Who's Working on Orion Flight Software?

FSPT Geographic Distribution



Exploration Flight Test 1 (EFT-1)

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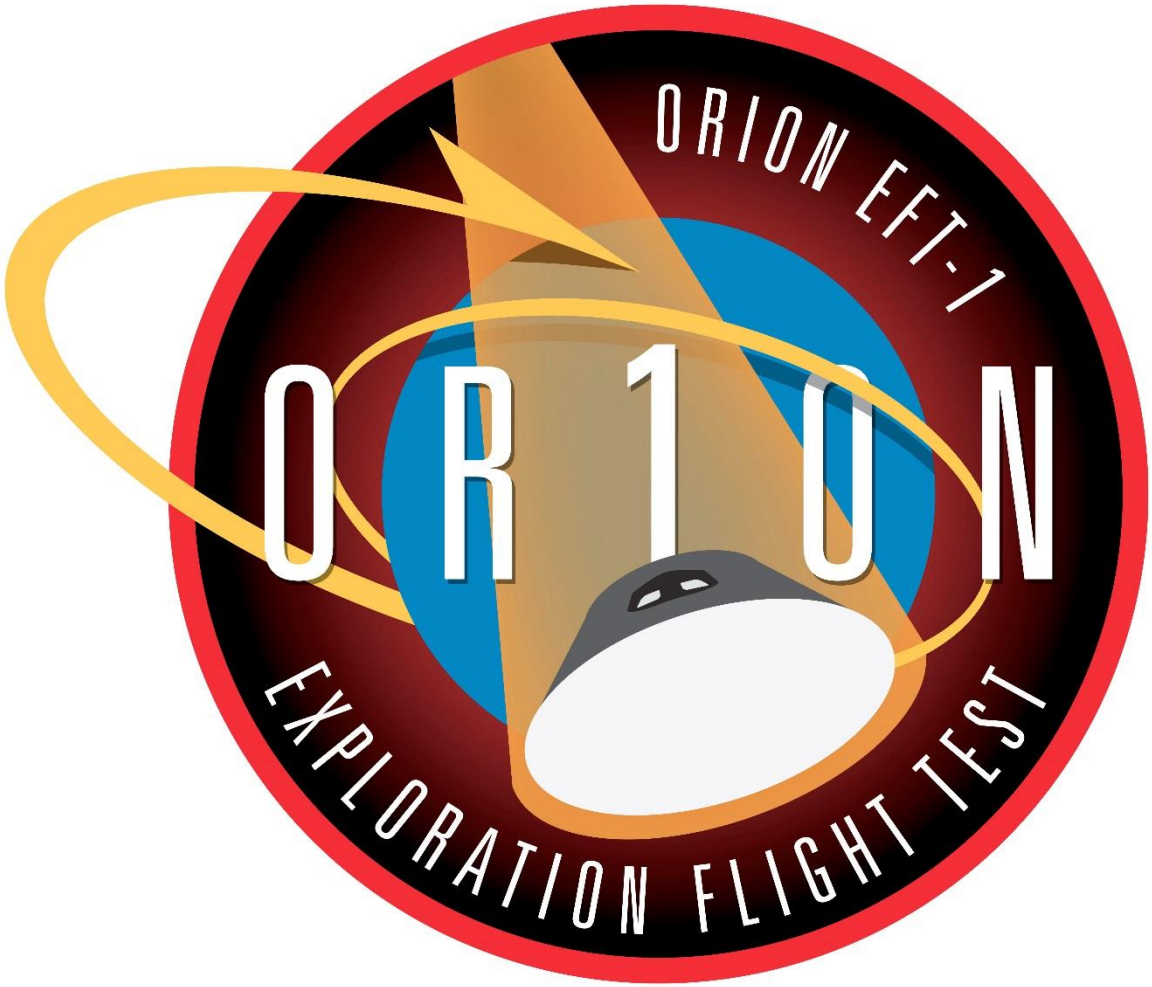


EFT-1 Mission

“Trial by Fire” Video

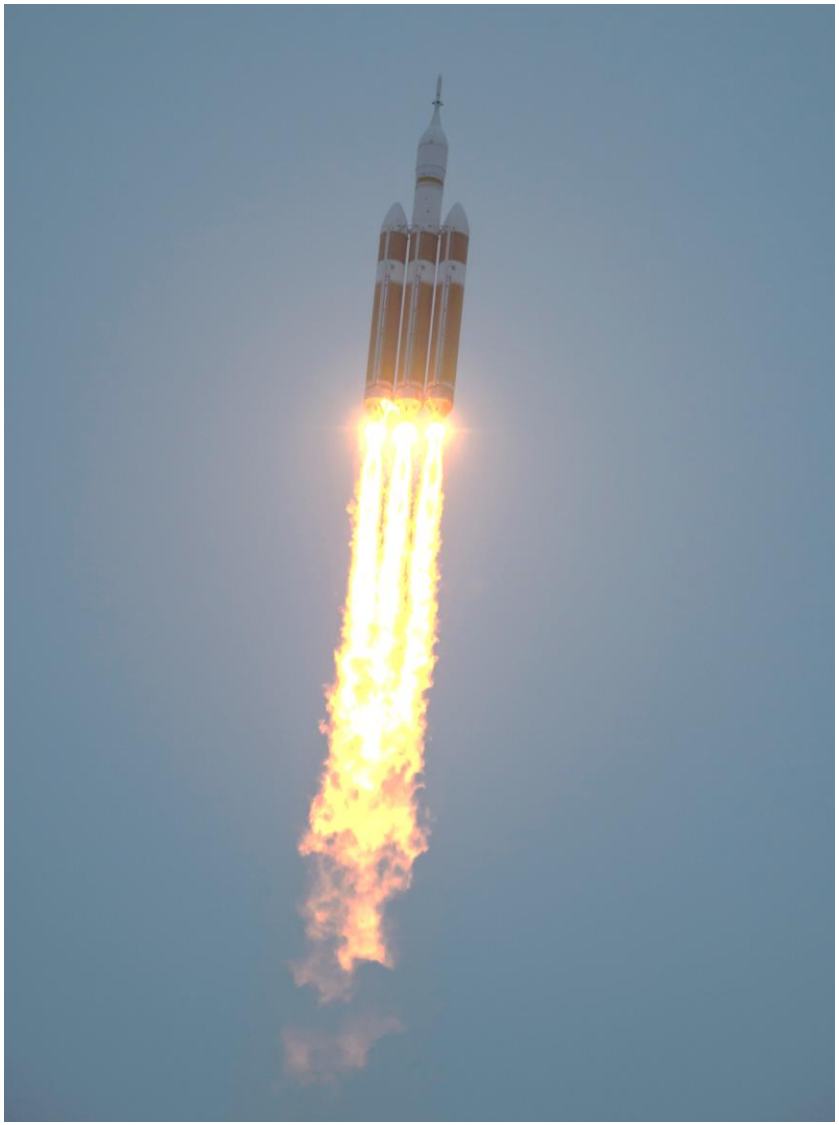
- This video does a excellent job of explaining the objectives of EFT-1
- Video is available online here: http://bit.ly/1pMQUkx

Ready to Stack Orion for EFT-1

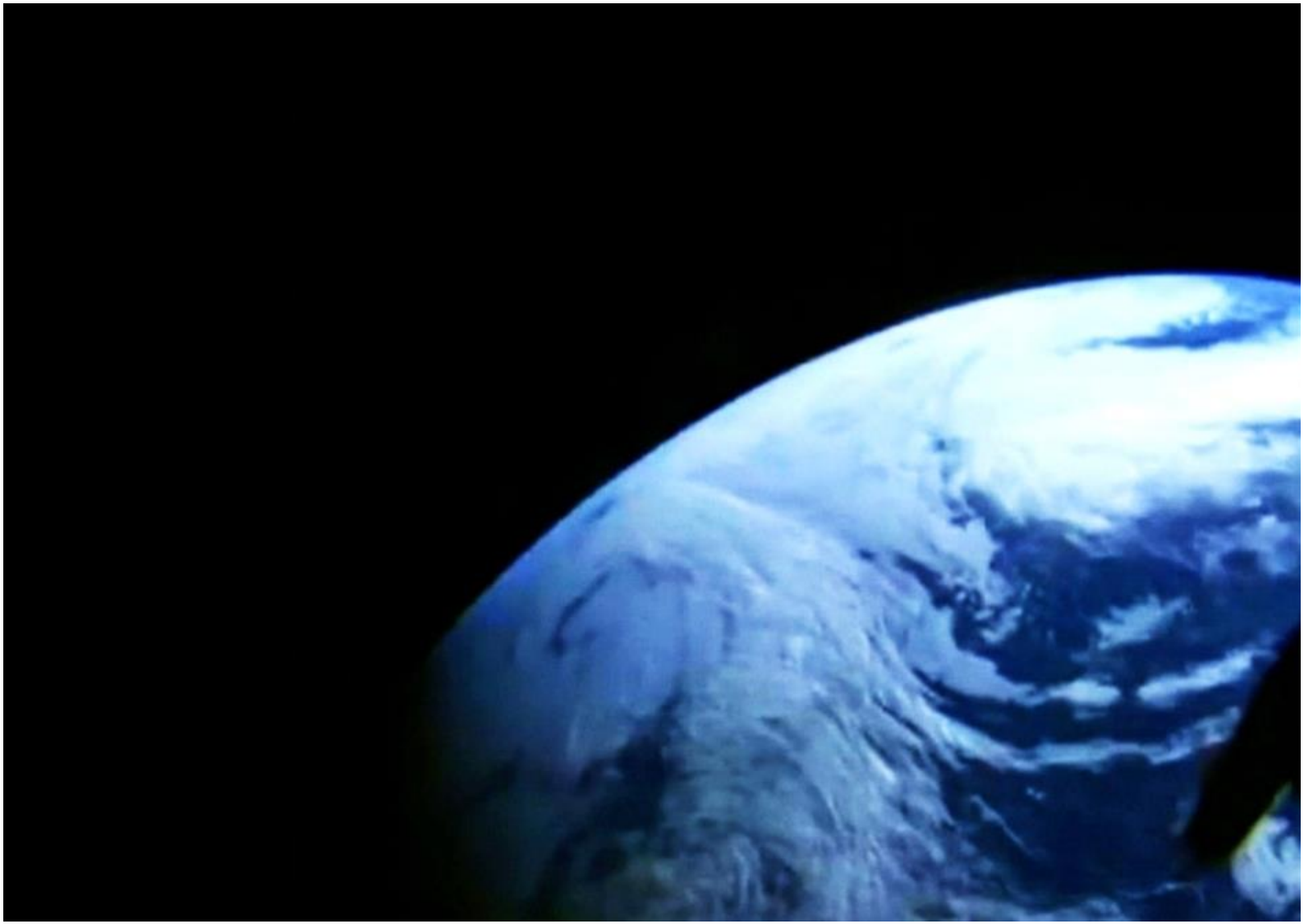
EFT-1 Actual Flight

December 5, 2014

We Exhaled at This Point



Out the Window of Orion



Drogue Chute Deployment

Back to Earth – Ready for Post-flight Analysis

Quick Analysis of Flight Software

- **There were no known issues with the flight software during the entire mission**
- **The Flight Control Modules (FCMs) did not reset within the high radiation regions**
  - We expected that there could be several such resets
- **The software worked so well that we did not get any flight data on the off-nominal processing capabilities**

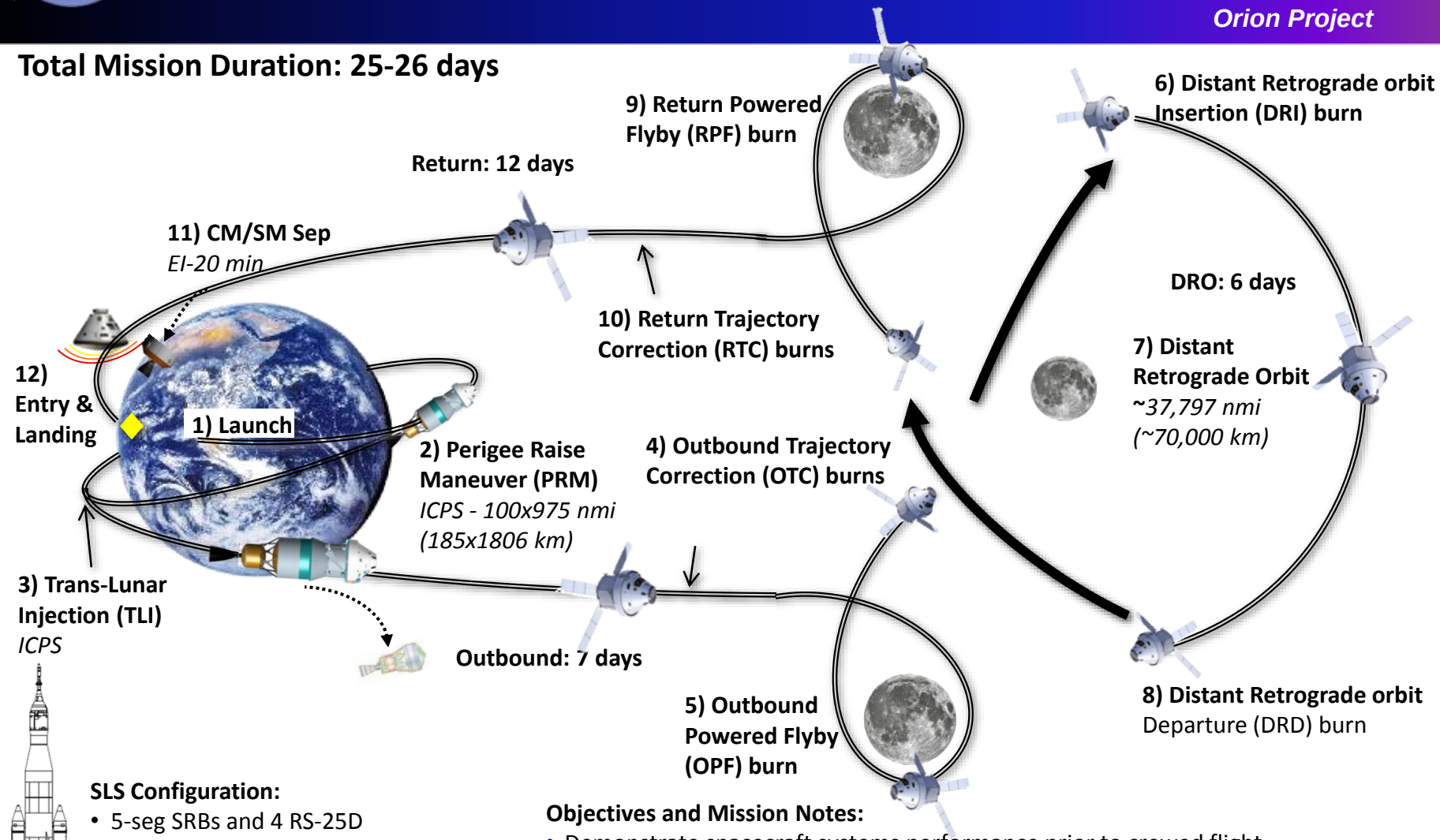
Two Critical Issues Were Found Late in Testing

- **Dual FCM reset**
  - A latent problem with timing (round-off error) between high level software and low level software would cause both flight control computers to reset at virtually the same time
  - More than one problem contributed to the final result
  - Longer test runs and better analysis of the initial problem discovery (a year earlier) may have allowed this problem to be dealt with earlier
- **Process Overrun of Allocated Partition Time**
  - A couple of partitions were overrunning their allotted time
  - Again, multiple problems contributed to the issue
  - Processor usage analysis was discontinued for a period of time
    - Allowed the problem to creep up on the team
  - Continual assessment of processor usage would have caught this much earlier

The EM Missions

EM-1: Uncrewed Distant Retrograde Orbit

Total Mission Duration: 25-26 days



SLS Configuration:

- 5-seg SRBs and 4 RS-25D
- Interim Cryogenic Propulsion Stage
- 22x975 nmi (40.7x1806 km) insertion orbit
- 28.5 – 35 deg inclination parking orbit

Objectives and Mission Notes:

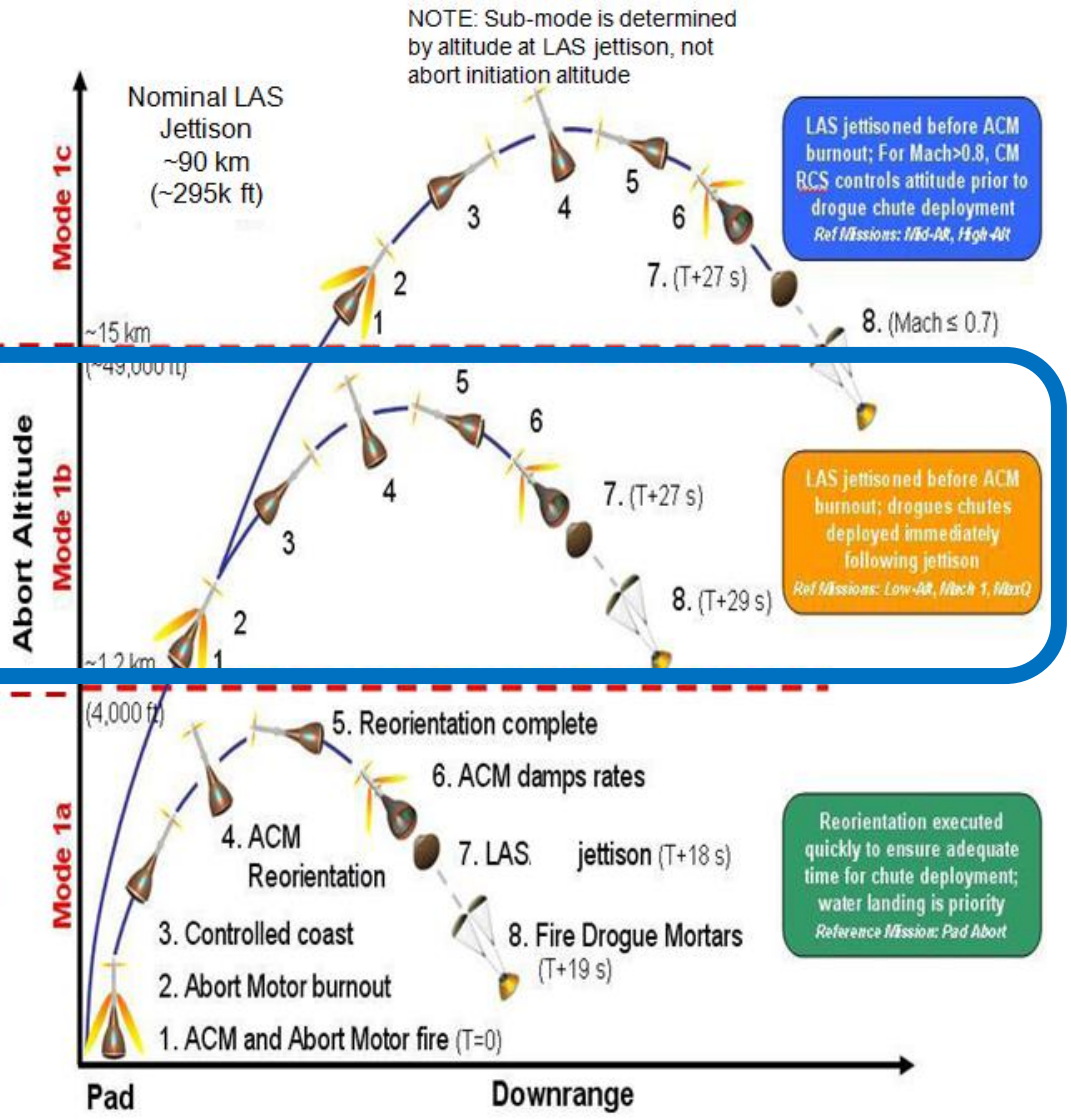
- Demonstrate spacecraft systems performance prior to crewed flight
- Demonstrate high speed entry (~11 km/s) and TPS performance prior to crewed flight
- Landing off the coast of California

EM-1 DRO Mission Description

- **EM-1 will be an uncrewed mission to a Distant Retrograde Orbit (DRO)**
  - The total mission duration is around 25 days with 6 days in the DRO. This corresponds to a minimum DV type mission for Orion.
  - The DRO has a radius (with respect to the Moon) of 70,000 km
  - Orion is not on a free return trajectory at any point of the mission
- **SLS/ICPS**
  - The SLS core stage inserts ICPS/Orion into an 22 x 975 nmi (40.7 x 1806 km) MECO state; ICPS performs a Perigee Raise Maneuver (PRM) at the first apogee to raise the orbit to 100 x 975 nmi (185 x 1806 km)
  - Near the 2nd perigee passage ICPS performs TLI, which targets Orion's Outbound Flyby Maneuver (OFM) initial state
- **Orion**
  - Orion performs the OFM, which is a Lunar Gravity Assist (LGA) powered flyby that targets the DRO Arrival Maneuver
  - After about 6 days in DRO Orion performs the DRO Departure Maneuver, which targets the Inbound Flyby Maneuver (IFM)
  - Orion performs the IFM, which is a Lunar Gravity Assist (LGA) powered flyby that targets Entry Interface (EI) for a splashdown landing off the coast of San Diego

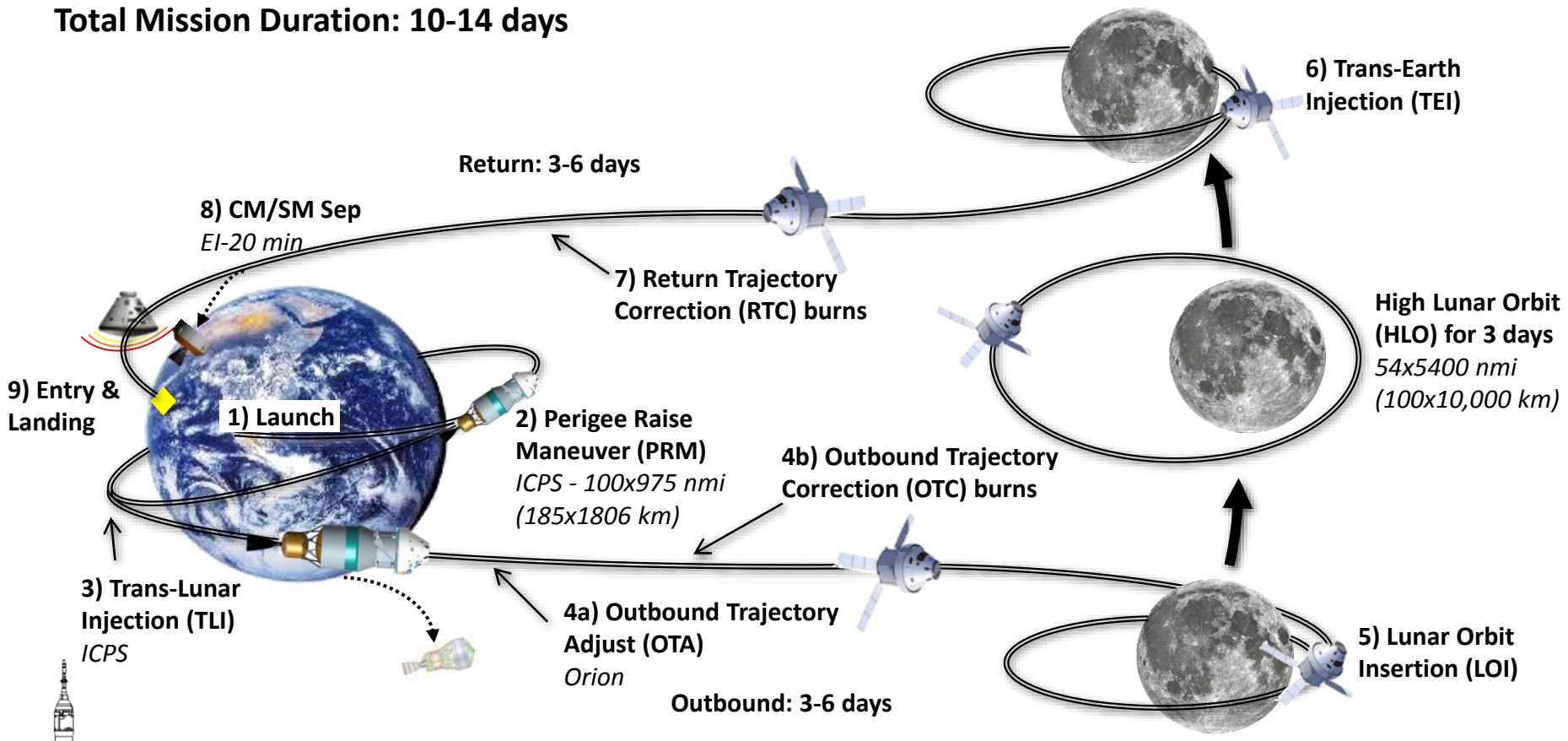
AA-2

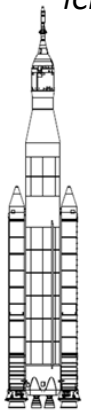
- **High Altitude**
  - Relatively benign LAS abort region
  - Highest abort motor acceleration levels
  - CM attitude control required post-LAS jettison
  - Nominal entry chute sequence and environments
- **Mid Altitude**
  - Includes max drag & dynamic pressure regimes
  - Peak LAV tumbling region
  - LAS jettisoned near ACM burnout
  - Transition from compressed to nominal chute sequence
- **Low Altitude**
  - Includes Pad Aborts
  - Land landing is primary constraint
  - Compressed chute sequence (straight to mains for pad abort)
  - LAS jettisoned immediately after re-orientation



EM-2: Crewed (High) Lunar Orbit

Total Mission Duration: 10-14 days





SLS Configuration:

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Objective and Mission Notes:

- Demonstrate crewed (up to 4) flight beyond LEO
- Demonstrate baseline Orion vehicle
- TLI places Orion on a lunar flyby free-return trajectory

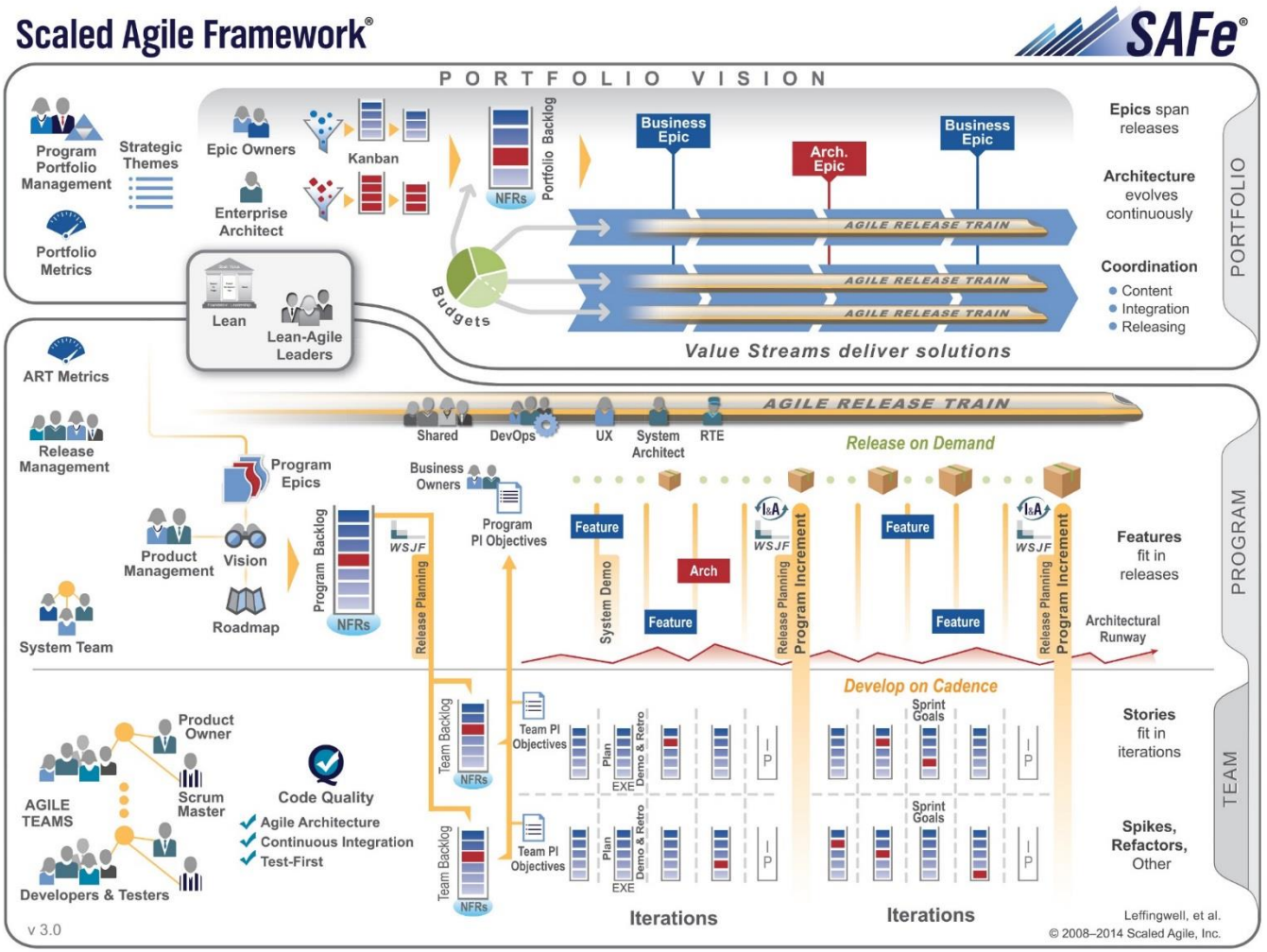
What is New (FSW) for EM-1

- **Electrical Power System**
  - Solar arrays and electrical generation, sun sensors
- **Environmental Control and Life Support**
  - Radiator heat dump
- **Propulsion**
  - Gimbaled main engine, attitude maneuvering RCS, auxiliary translation jets
- **Guidance Navigation and Control**
  - Control of the new propulsion items (above)
  - Guidance and navigation for the new mission objectives
- **Onboard Data Network and computers**
  - Changes to the number and purpose of onboard computers
  - Major modifications to the data network and traffic routing
- **Crew Displays**
  - Addition of infrastructure that will allow the crew displays to be added for EM-2
  - Add network traffic to feed the crew displays

Software Challenges for EM-1

- **New Processes**
  - SAFe (see next chart) – Scaled Agile Framework
  - The largest project to ever have attempted Agile
- **Automated testing**
- **Integration much sooner than on EFT-1**
- **Further distribution of the software onto disperse computing elements**

EM-1 New Processes



Questions?