Program update
February, 2017

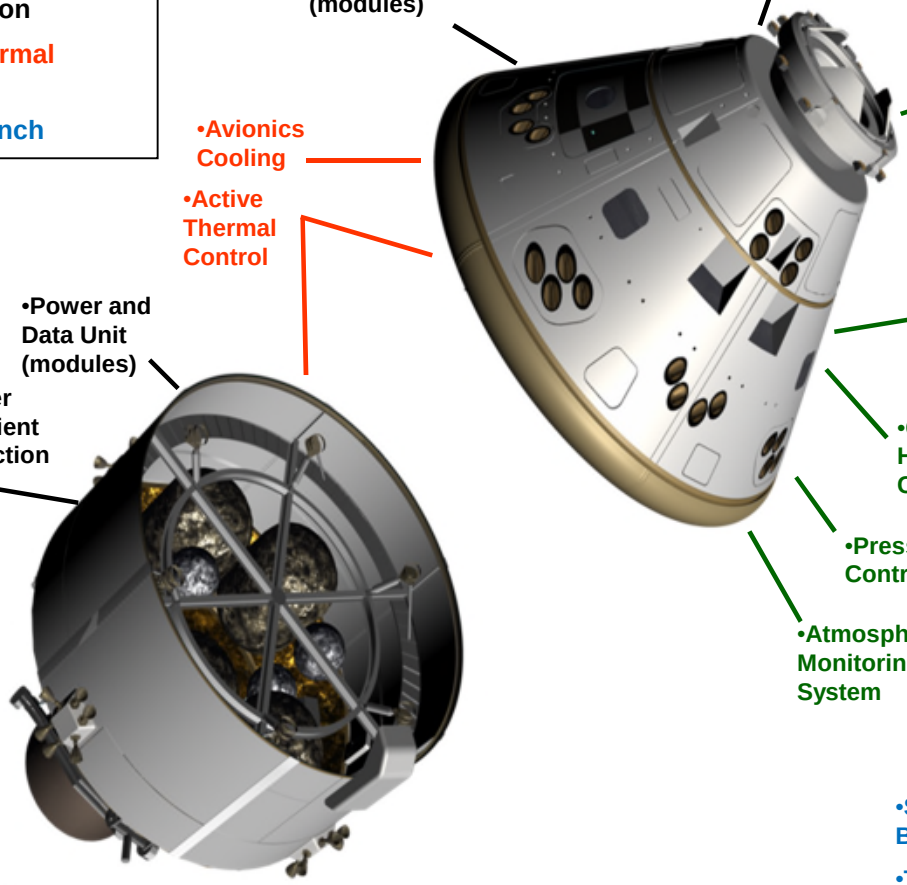
UTC Aerospace Systems

585 Days

To LAUNCH

NASA SPACE LAUNCH VEHICLE

- Environmental Control & Life Support – SE&I
- Power Management & Distribution
- Active Thermal Control
- Space Launch System



•Orion

•Space Launch System

Export Controlled Information: EAR99

UTC Aerospace Systems

Orion MPCV

The Orion Multi-Purpose Crew Vehicle (MPCV) is NASA's first spacecraft designed for long-duration, human-rated deep space exploration

Consists of two main modules:

- Crew Module (CM) - Lockheed Martin
- Service Module (SM) – European Space Agency
  - SM supports the crew module from launch through separation prior to reentry

SM propelled by eight R-4D Auxiliary Engine thrusters

- 110-pound-thrust bipropellant thrusters

CM propelled by 12 MR-104G catalytic thrusters

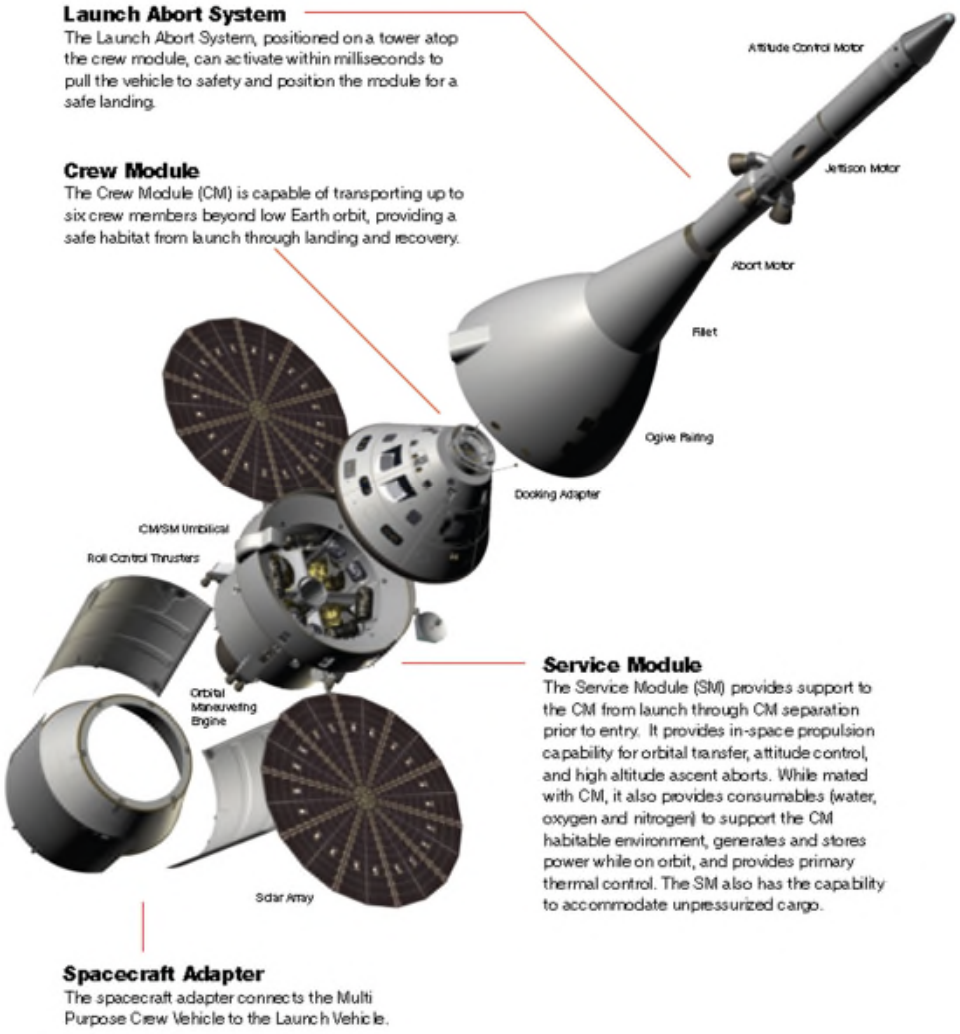
- **Thrust generated by catalytic decomposition of hydrazine over a heated metallic catalyst bed**

First test flight - Exploration Flight Test 1 (EFT-1)

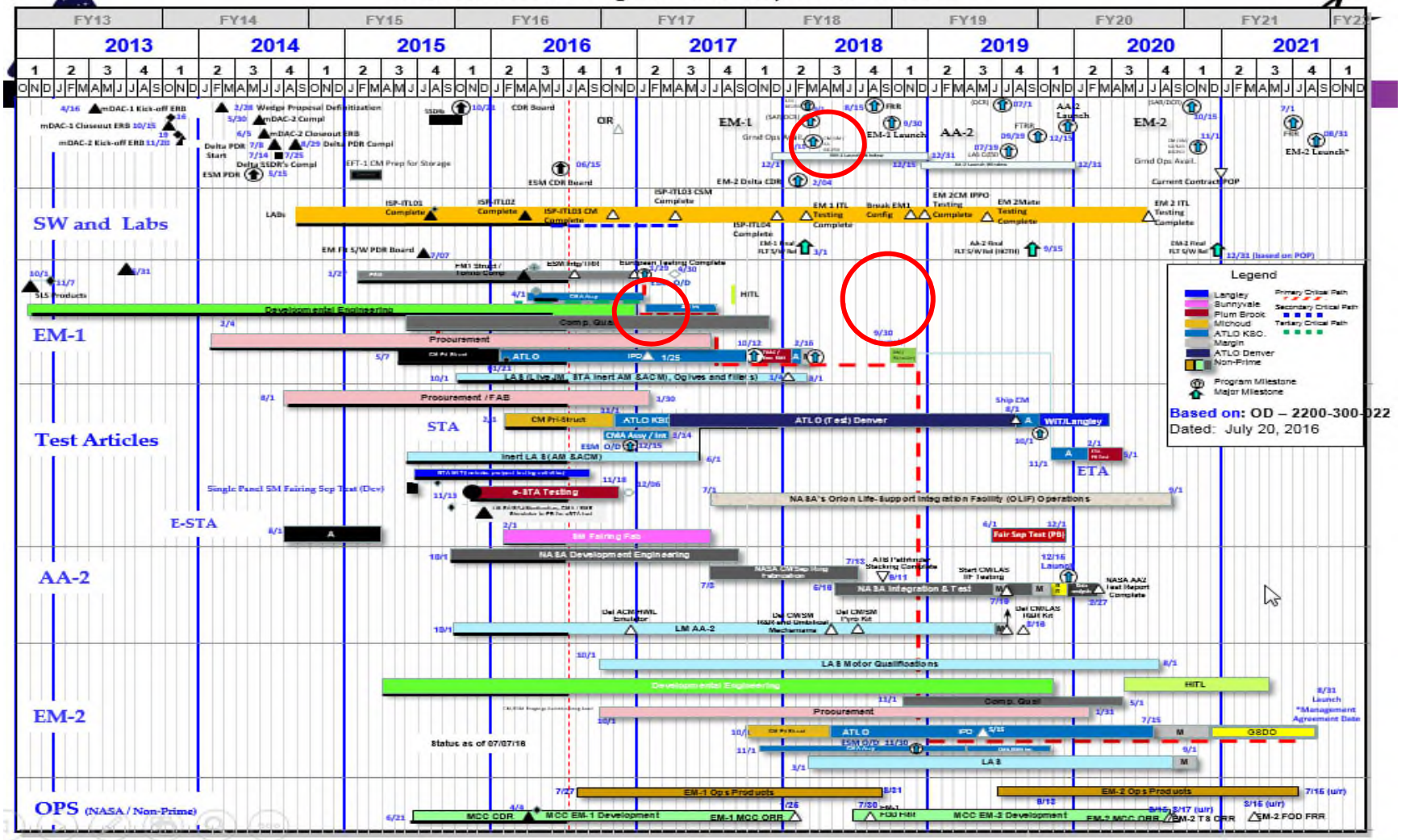
- Launched on December 5, 2014 by a Delta IV Heavy rocket

Future missions:

- Exploration Mission – 1 (EM-1) Uncrewed, launched by Space Launch System
- EM-2 Crewed mission, launched by Space Launch System



Orion MPCV EM Program Summary Master Schedule



UTC Aerospace Systems

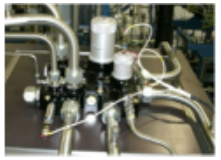
•UTC Aerospace Systems

•*Space Launch System (SLS) and Orion*

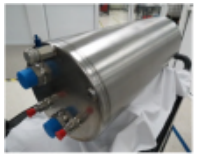
•CAPU

•CAPU Controller

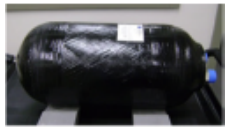
•Filter Manifold



•Hyd Reservoir



•Hyd. Supply Accumulator



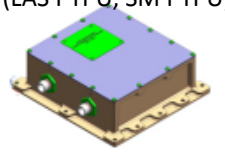
•Booster APU

•Auxiliary Bus Control Unit (ABCU)

•Portable Utility Panel (PUP)

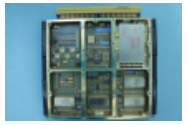
•Power Transient Protection Unit for Launch Abort System and Service Module

•(LAS PTPU, SM PTPU)

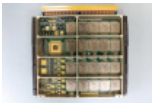


•Umbilical Switch Card (USC)

•ECLSS Drive Electronics Card (EDE)



•Load Switch Card (LSC)



•28V Converter Card (28VCC)

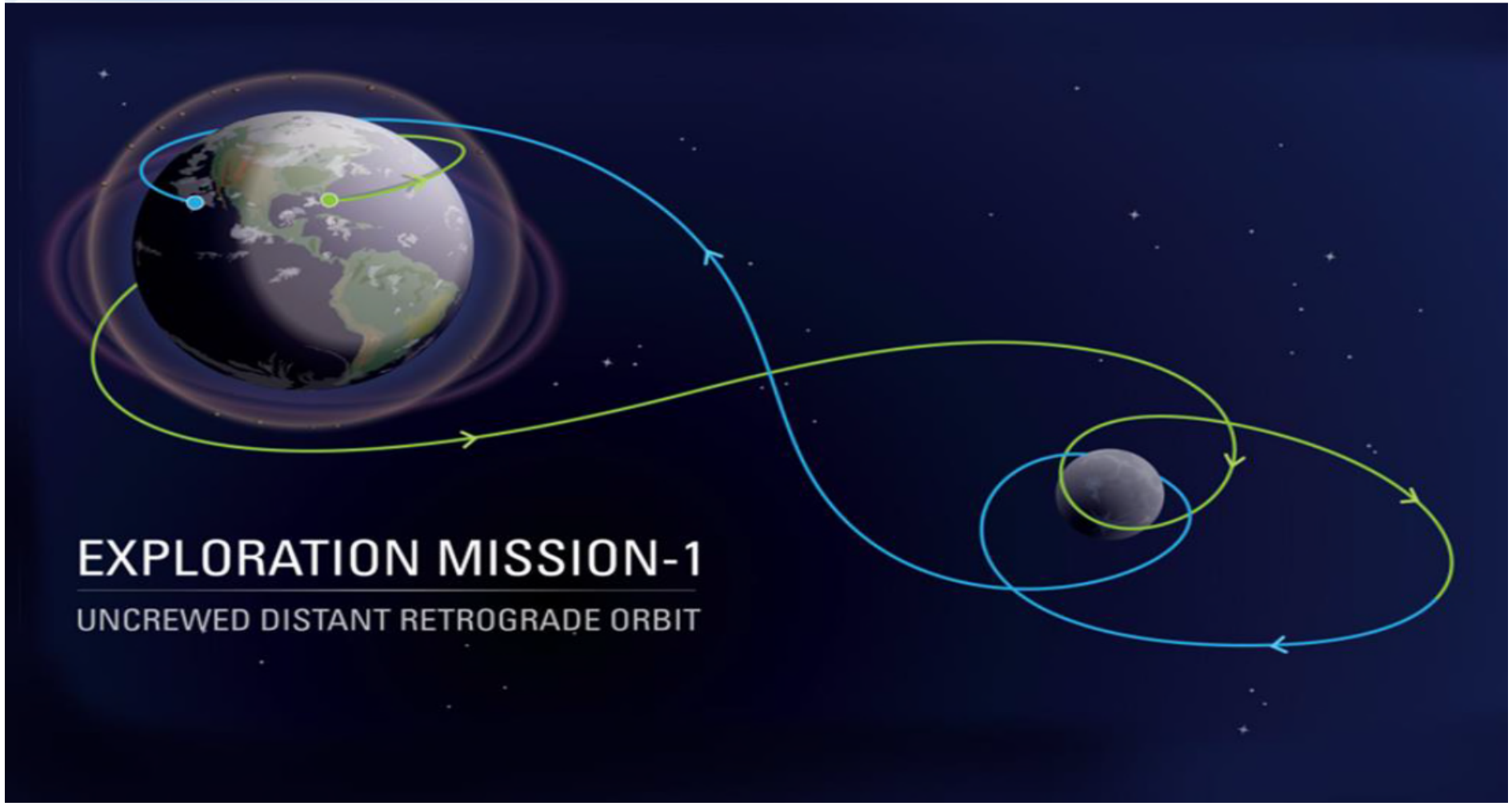
•Ready to support new Exploration Upper Stage with cryogenic fluid handling, power generation & mgmt, and actuation solutions.

•SLS Rockford Content
• 45 IL Employees

•Orion Rockford Content
• 44 IL Employees

•New Technologies backed by 40 years of Proven Human Space and Rocketry Performance

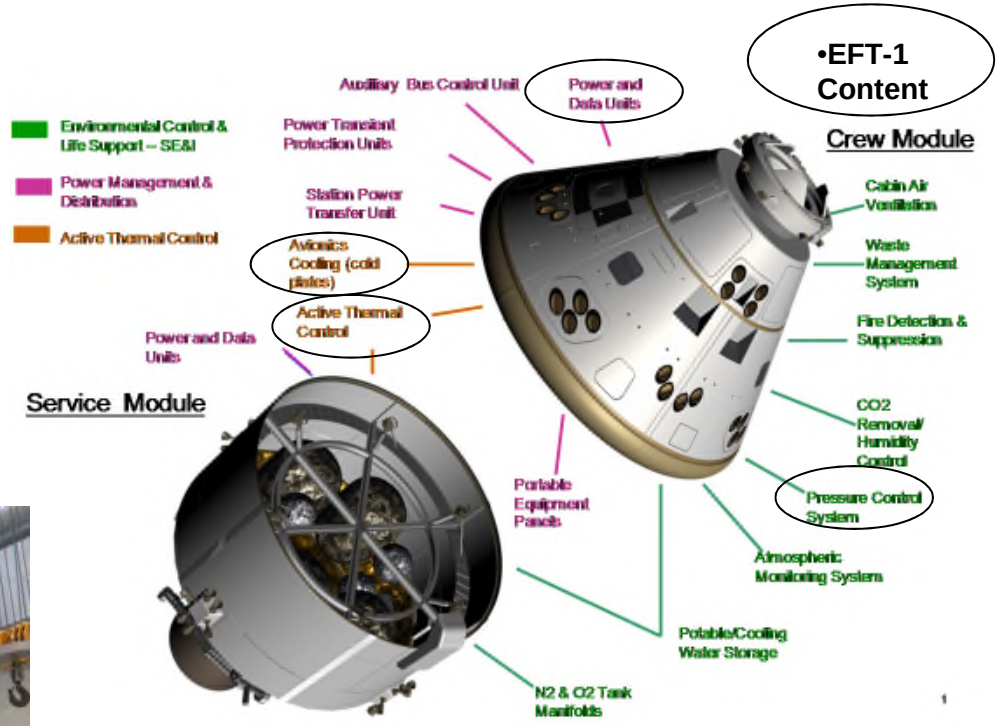
The First SLS/Orion Mission - 2018

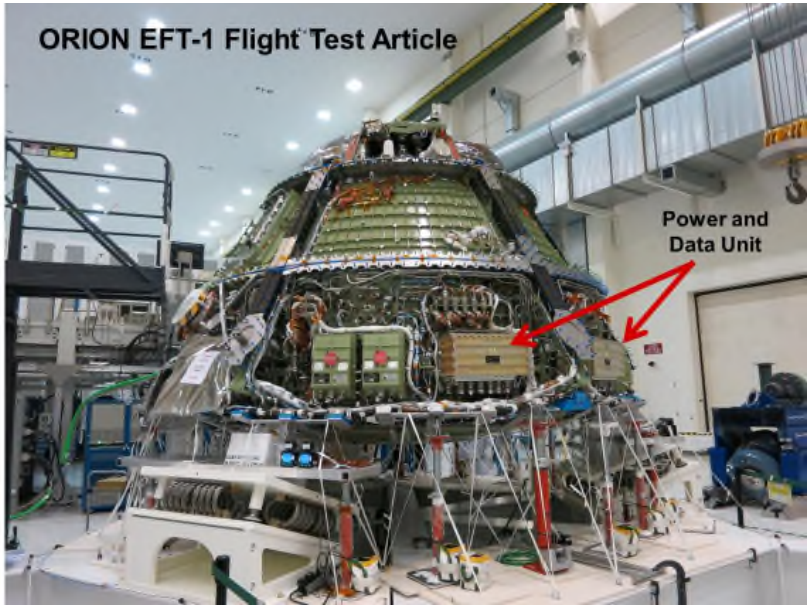


Orion Program

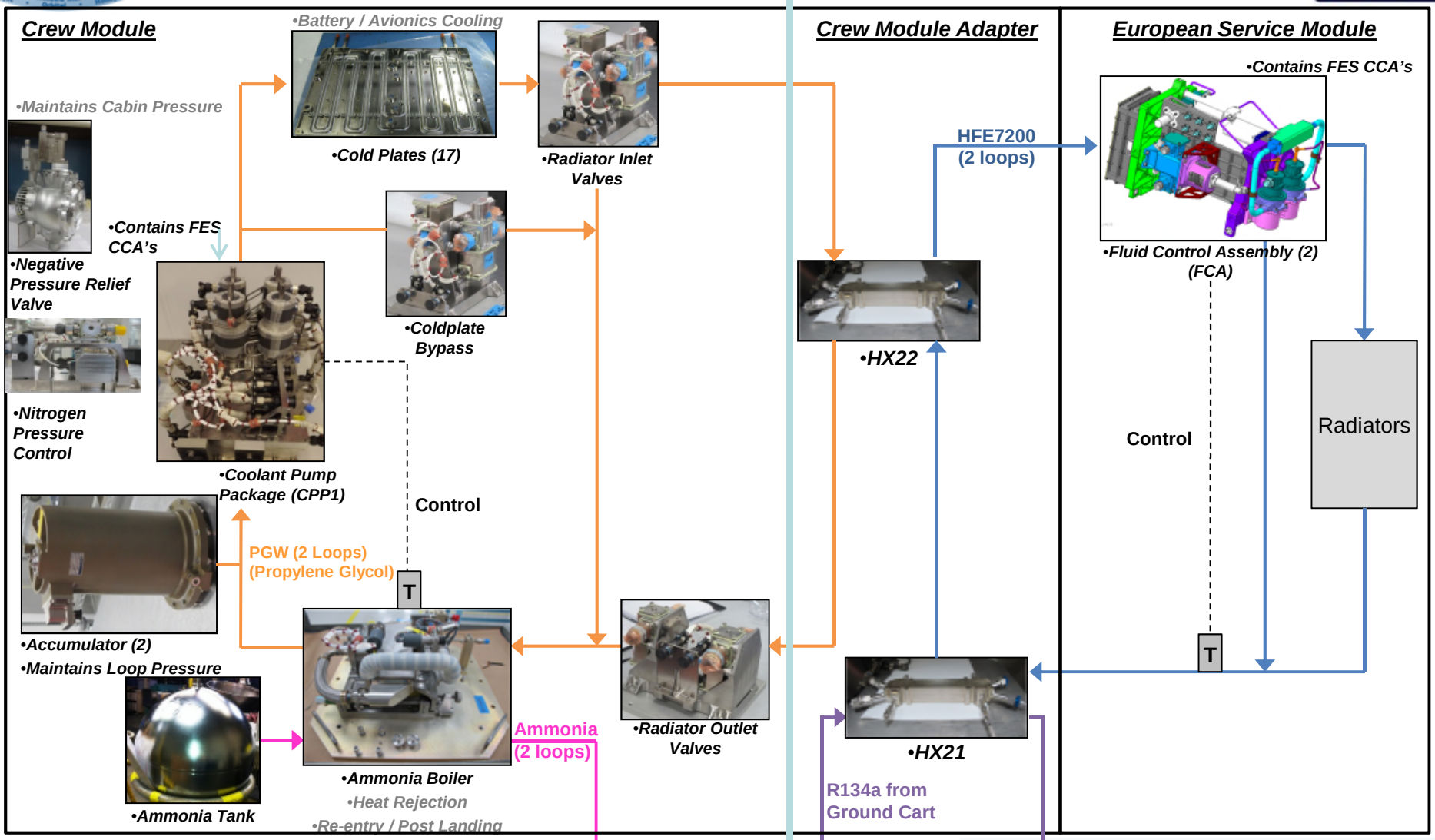
- Orion Multi-Purpose Crew Vehicle (MPCV) is a cross site systems level program, with responsibilities spread across several UTAS Space Systems sites
- Rockford plant site is responsible for Power Management and Distribution (PMAD) system

•UTAS Content for Orion Capsule





ECLSS SYSTEM OVERVIEW – EM-1



•CPP1

•Heart of the PGW loop, circulates PGW fluid throughout system and controls pulsing valves in ABHX to regulate PGW temperature (4 Pumps / 2 Coolant Loops)

•Vent Overboard

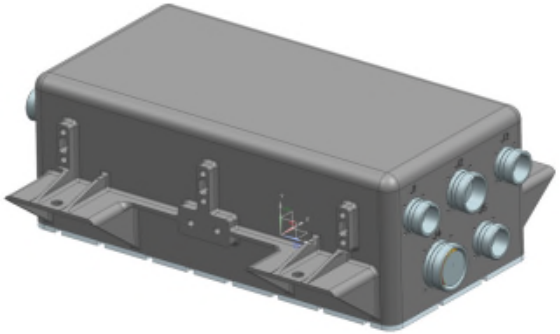
•Jettisoned During Re-Entry

•FCA

•Heart of SM ATCS system; Circulates HFE7200 throughout loop (to be cooled by radiators and to cool PGW within HX22) (2 Pumps / 2 Coolant Loops)

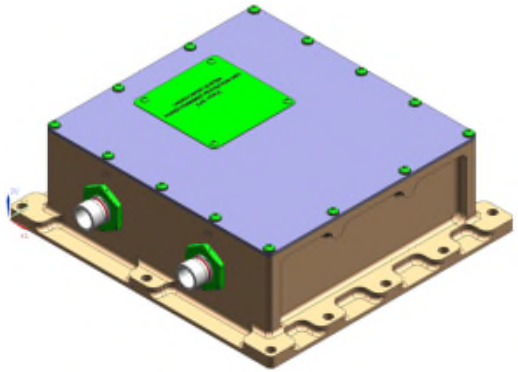
Export Controlled Information: EAR99

Orion Power Management And Distribution (PMAD)



•Auxiliary Bus Control Unit (ABCU)

•Portable Utility Panel (PUP)



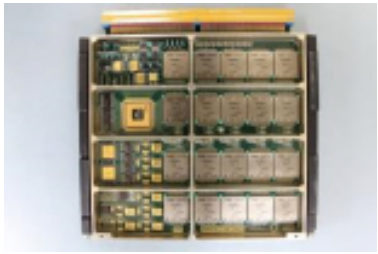
•Power Transient Protection Unit for LAS and Service Module

•(LAS PTPU, SM PTPU)

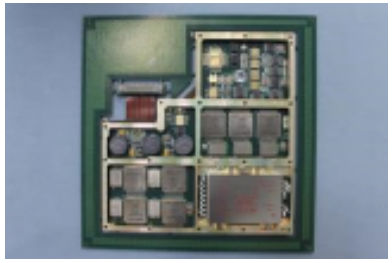
•Power and Data Unit (PDU) Assemblies

•Umbilical Switch Card (USC)

•ECLSS Drive Electronics Card (EDE)

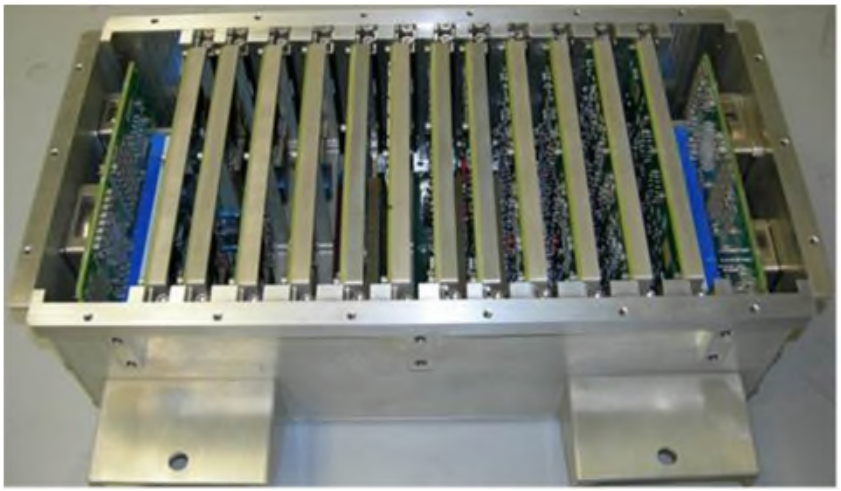


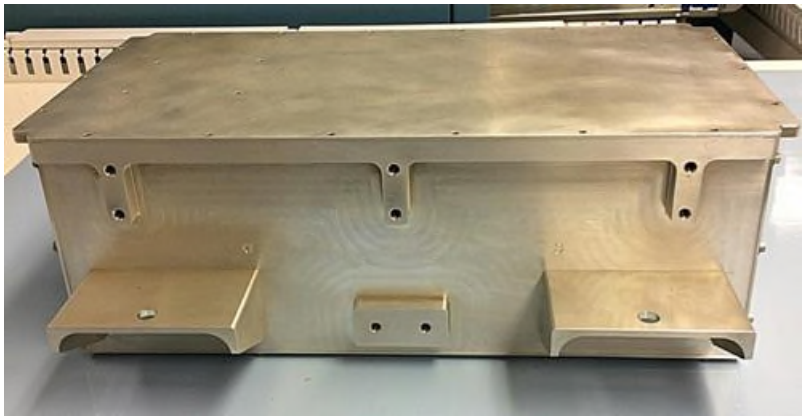
•Load Switch Card (LSC)



•28V Converter Card (28VCC)

ITL ABCU





4Amp (4 per)

15Amp

7.5Amp (2 per)

10Amp (2 per)

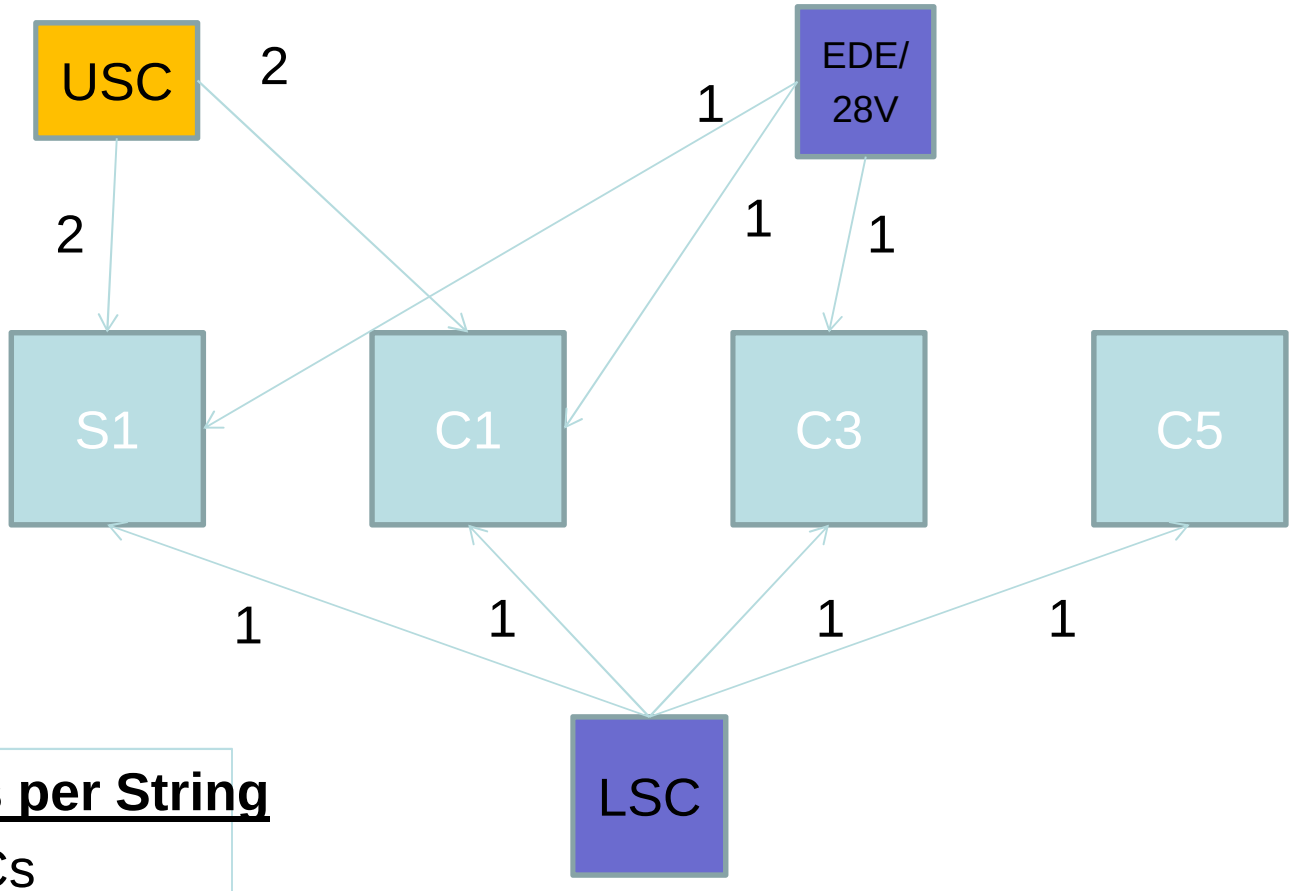
Backplane

30W Converter (3 per)

Aux1

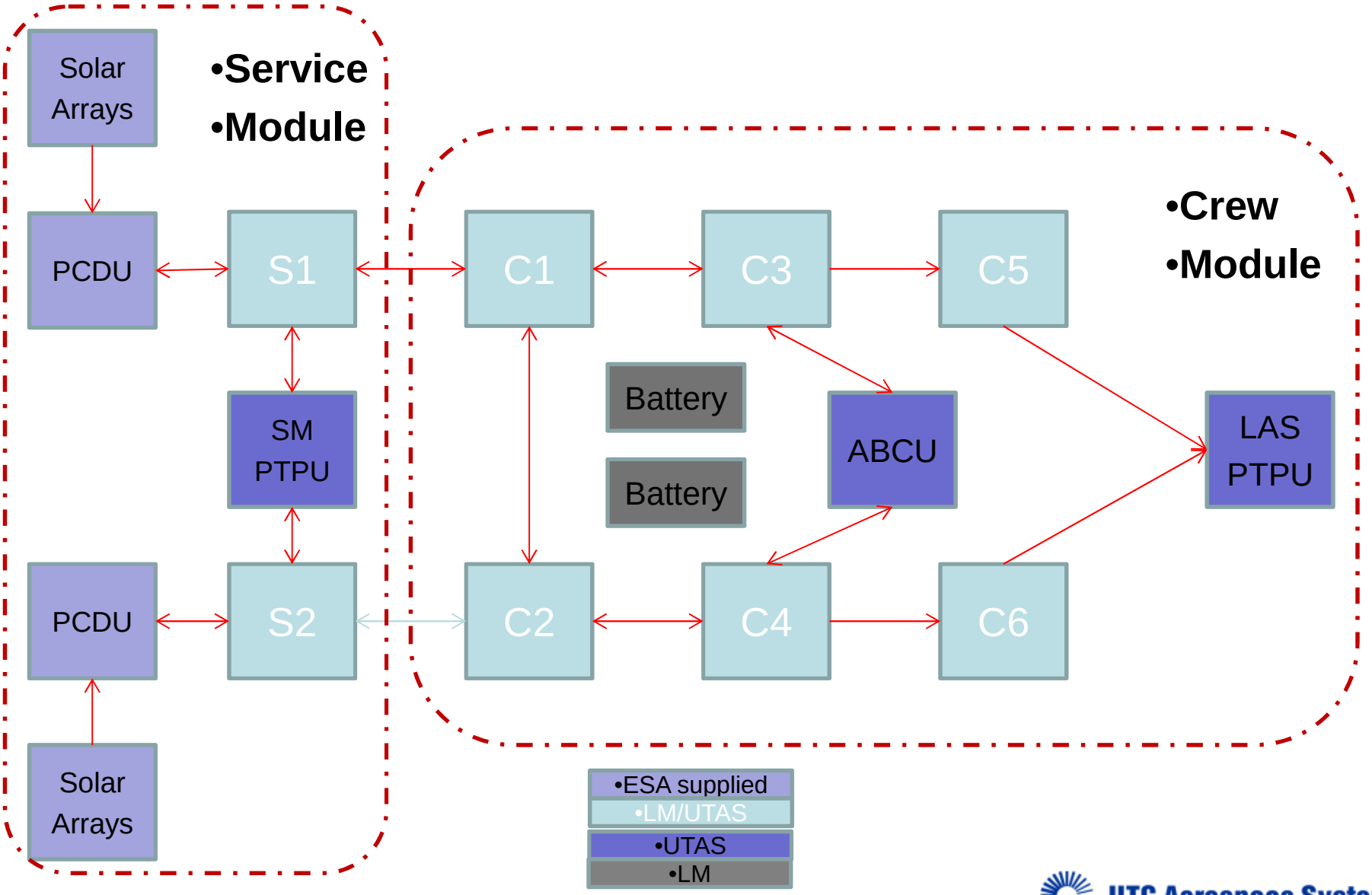
Aux2

UTAS PDU Card Content



- **<u>Cards per String</u>**
- 4 USCs
- 4 LSCs
- 6 EDE/28V

Orion Electric Power System



Export Controlled Information: EAR99

UTC Aerospace Systems

EPS and PMAD

- **Aircraft EPS traditional**
  - Typical 2 Channel, AC generator sources, 28VDC derived from TRUs and batteries
  - Centralized Switches, Relay/Contactor Drives, contact breaker panels in cockpit (accessible by pilot/flight engineer)
- **Aircraft PMAD evolution**
  - Distributed SPDAs – remote contact breakers with electronic solid state breakers/switches
  - Remote control from flight deck over digital communications (Arinc 429, Ethernet based etc….)

Space Craft (Human)EPS/PMAD

- **Apollo**
  - 28VDC Fuel Cells(3) SM and Batteries CM (~3-5kW fuel limited)
  - Contact Breaker panels crew accessible
- **Space Shuttle Orbiter**
  - 28Vdc Fuel cells(3) and Batteries (~10 – 12 kW fuel limited)
  - Remote solid state comms bus (1553?), and pilot accessible contact breakers
- **International Space Station**
  - 120Vdc, Solar Array and Batteries (~85kW+ Array/Battery limit)
  - Well regulated power to EPCE/Users
  - Remote electronic power contactors, computer controlled via Mil Std 1553

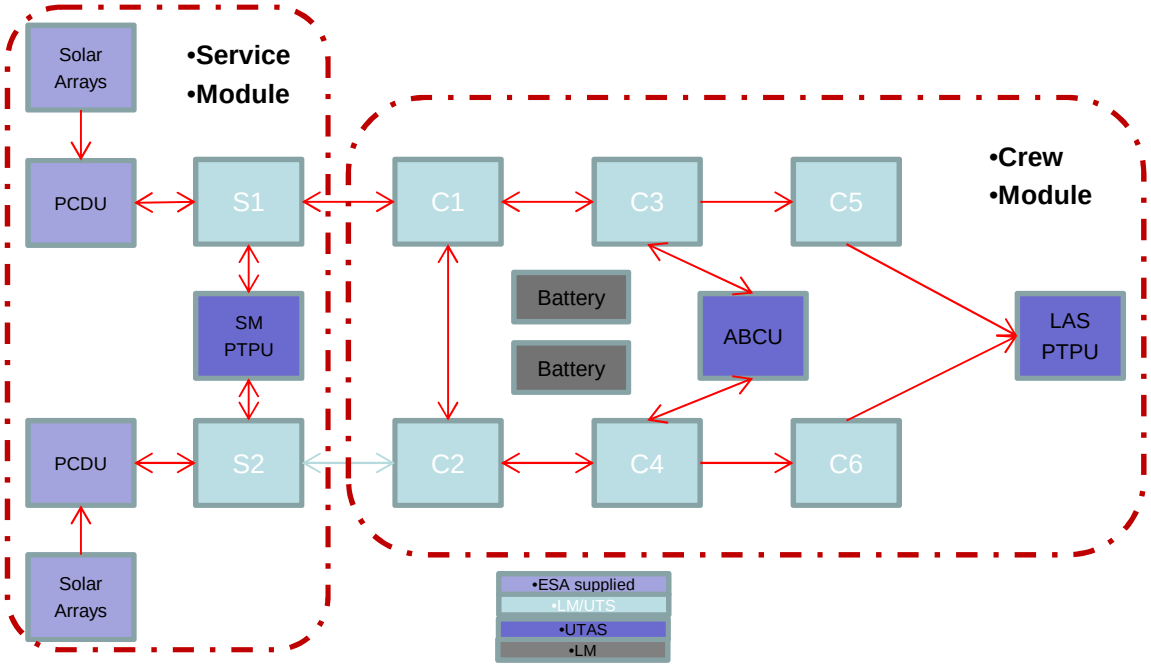
Operation/Profile

- **Mission energy Profile.**
  - Important to be able to guarantee that the system has capacity to meet the full mission needs from launch to recovery
  - Detailed planning needed to size the “array and batteries” to meet needs for all orbital cases, deterioration of components, and faults.
  - Or carry enough Fuel in the case of Fuel Cell technology.
  - Enough battery power for reentry and recovery
- **Power Quality**
  - Voltage drop, trip characteristics, losses, EPCE (Electrical Power Consumer Equipment) details…

Orion EPS and PMAD

- **Space vehicle similar to the Apollo**
- **120Vdc Dual Bus, Solar Array and Batteries (Li-ion)**
  - Arrays located in Service Module, Batteries in the Crew Module
  - Battery Regulated! (low losses but large voltage range)
  - Remote electronic power control, computer controlled via "Ethernet" (T-Tech 1G similar to 787 EPS internal)
- **Power Distribution achieved by PDU (Power Data Units)**
  - PDUs accommodate some utilities, network switching and power control/conversion
  - UTAS provides highly integrated "switching elements" as RPCs
  - RPCs are able to "current limit" prior to trip during fault conditions. This helps maintain the integrity of the rest of the power system upstream from the fault.

Orion – how it's arranged

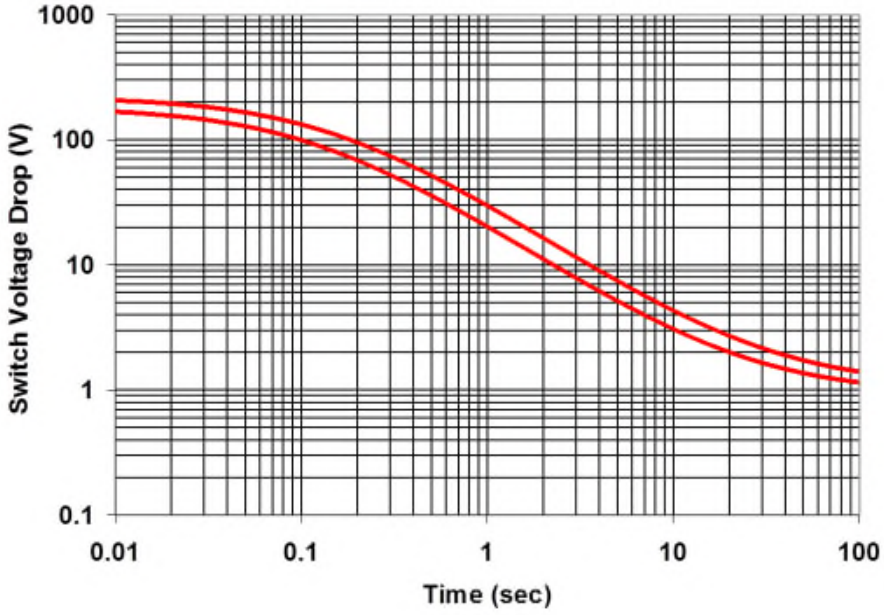


- **PDU Power Data Units**
  - 2 in SM, 2 external CM, 2 internal CM
- **Batteries (2) feed C1 and C2 and ABCU**
- **120Vdc distributed, some 28Vdc**

- **LAS PTPU**
  - Power feed to Launch Abort System (basically a big wocket)
  - Located in SM to protect incoming external power
- **Transient protection lightning during launch and ascent**
- **PCDU**
  - Interface between European SM EPS to Orion EPS

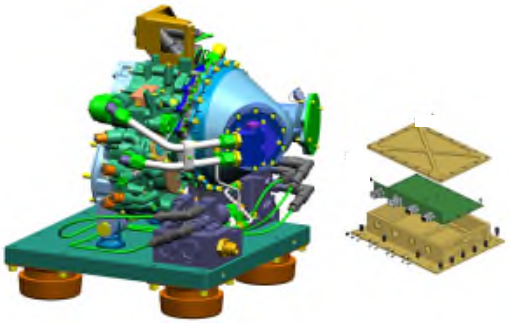
Why Remote Power Contactors

- **Current Limiting**
  - Mitigates/limits upstream disturbances
  - Voltage across device proportional to fault current
  - Mimics i2t inverse characteristic
  - More complex, stressful for limiting device (SOA)

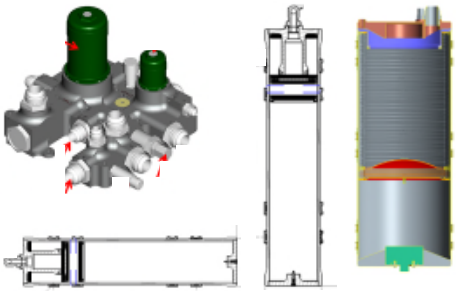


SLS CORE STAGE

•TVC Components



•APU and Controller



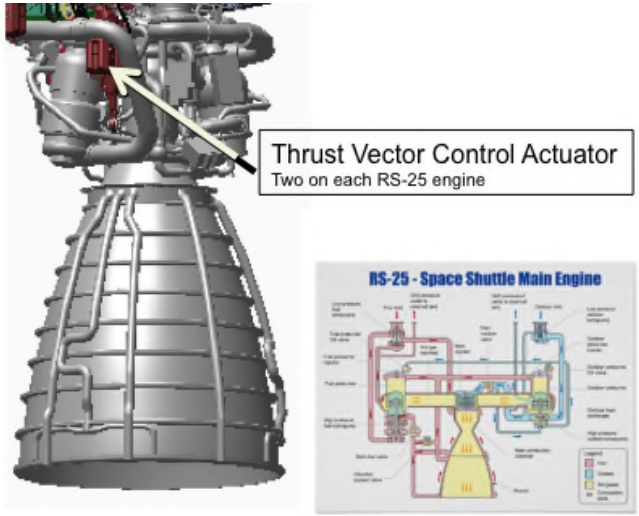
•Hydraulic Circuit Components

•UTAS is developing six components for each of the four thrust vector control systems (RS-25 Main Engines gimbaling) on Boeing's Space Launch System Core Stage.

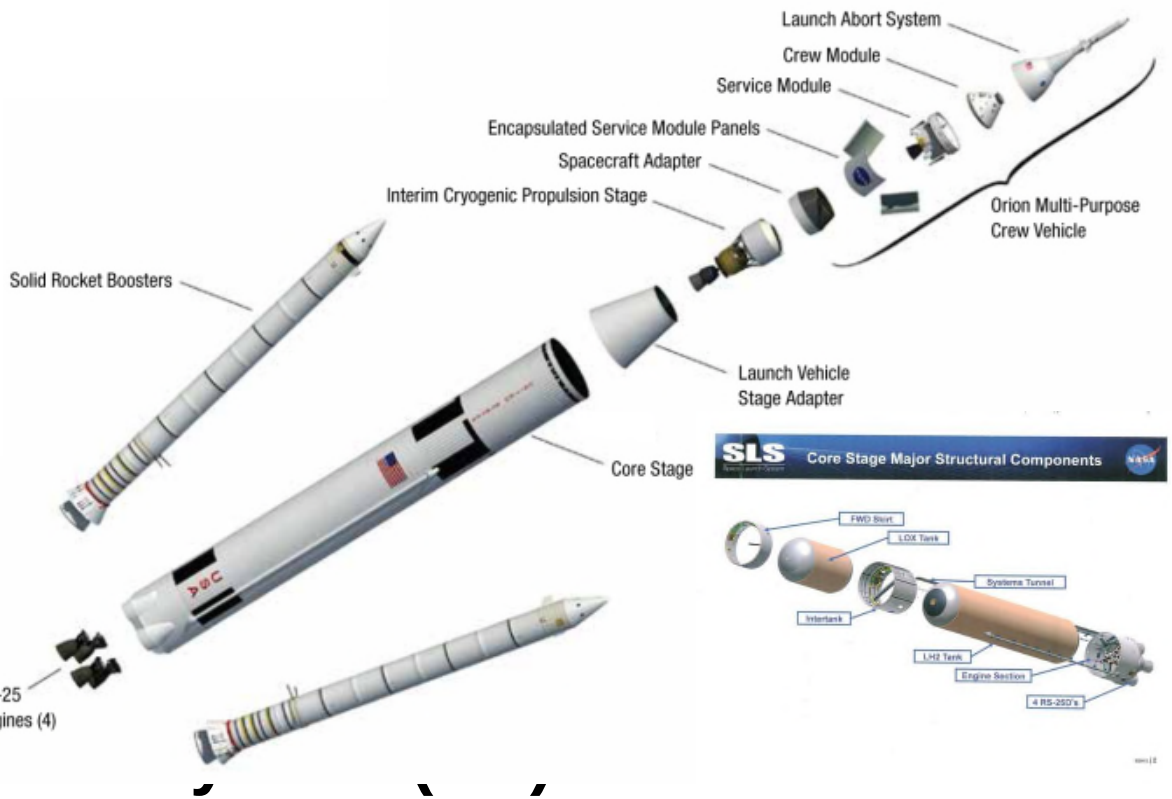
•Shuttle Orbiter hydrazine APUs are being converted to cold-gas blow-down units (CAPU) with new technology controllers.

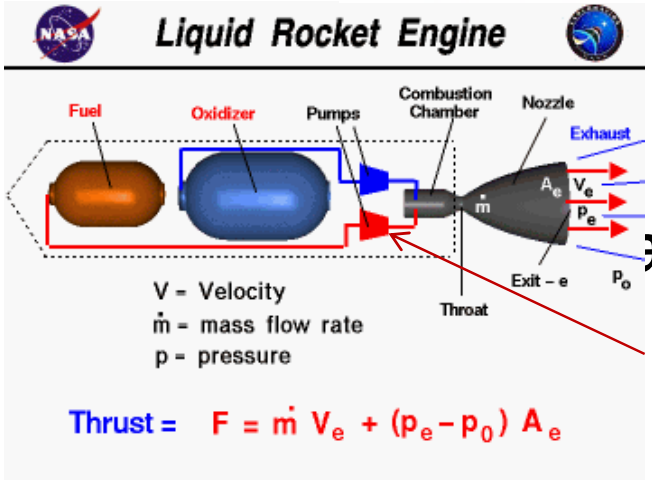
•Customer: Boeing
•Status: Starting Design, Development, Test & Evaluation

RS-25 Engine



•SLS 70-metric-ton Initial Configuration

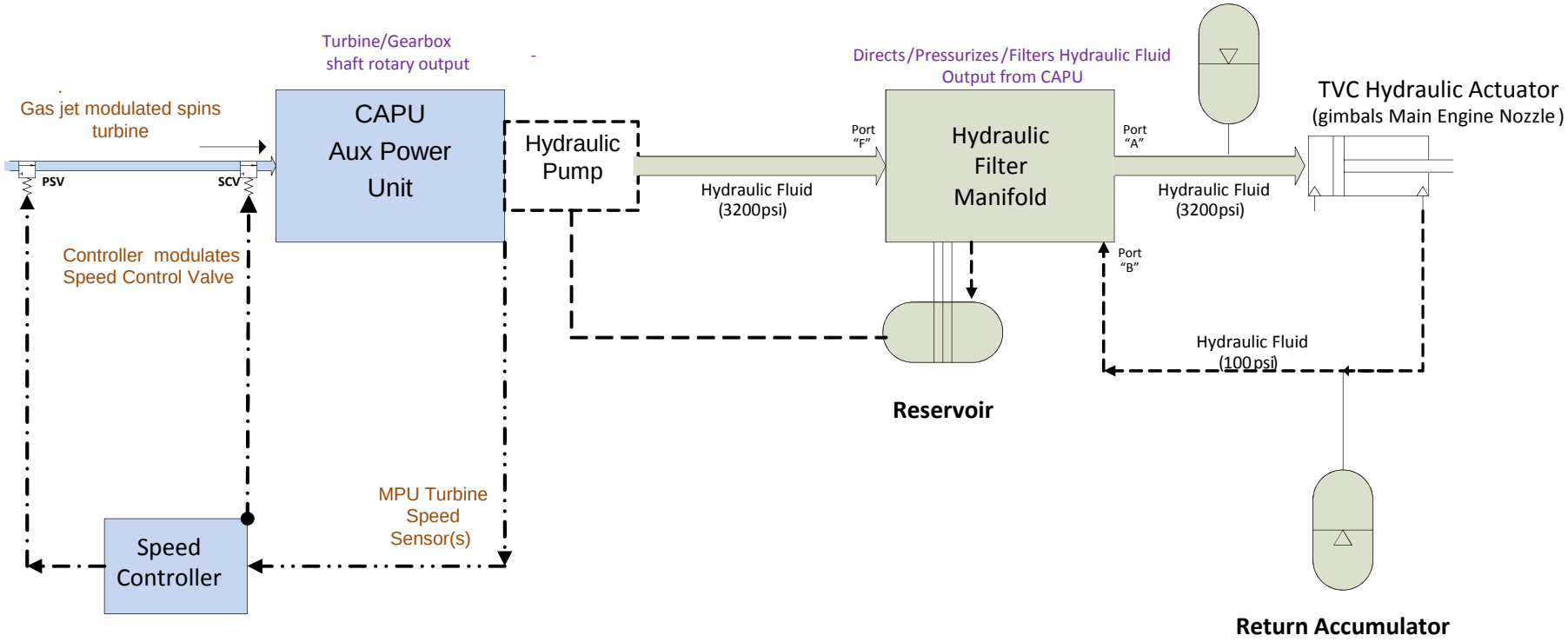




•~3500 psia gaseous hydrogen that powers the CAPU is tapped from the LH2 turbo pump

Space launch system (SLS)

UTAS supplied (Heritage Shuttle basis)



76 Days

To Power On

What it Takes to Go Beyond Low Earth Orbit

Why an Incremental Approach Makes Sense

Phase 0
Demonstrate technologies and conduct research to support exploration

- Deep Space Technologies
- Human Health

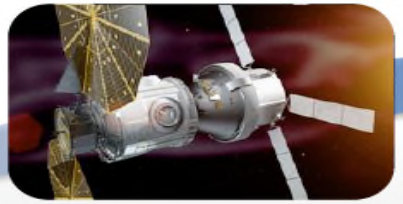
Phase 1
Demonstrate Critical Systems near the Moon
[Early 2020's]

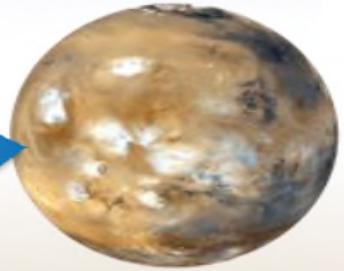
- Orion
- Space Launch System
- Exploration Habitat
- Solar Electric Propulsion

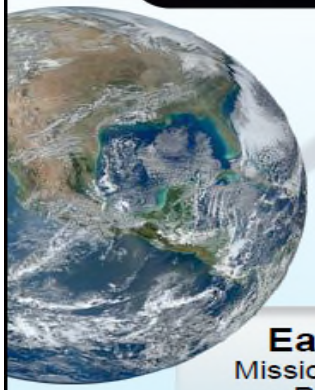
Phase 2
Validate Mars-Class Systems and Operational Readiness
[Late 2020's]

- Lunar Science
- Lunar Landing – International
- Simulated Mars mission

Phase 3+
Journey to the Mars System
[2030+]





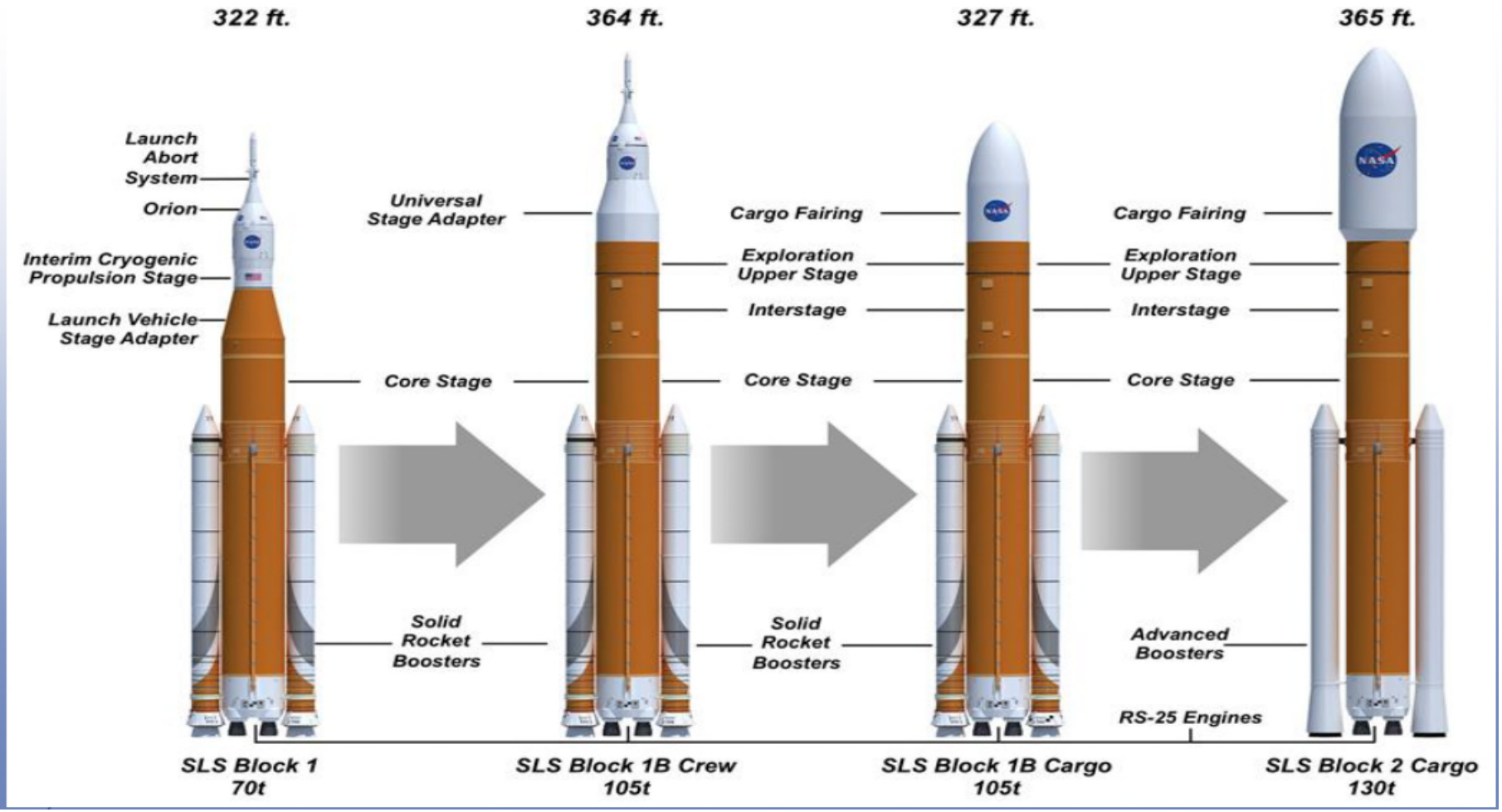


Earth Reliant
Missions: 6-12 months
Return: Hours
~250 miles

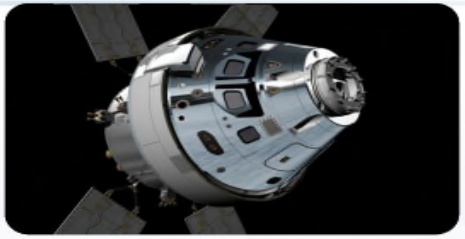
Proving Ground
Missions: 1-12 months
Return: Days
~240,000 miles

Earth Independent
Missions: 2-3 years
Return: Months
~140 million miles

Evolvable Rocket



6 Essential Capabilities for the Journey to Mars



Orion
- ✓ Full scale development underway
- ✓ Successful uncrewed flight test Dec 2014
- Second flight in 2018 - 1st human-rated spacecraft flight to moon since 1972
- Human lunar flight in 2021

Habitat
- ✓ ECLSS systems testing underway on ISS
- ✓ Habitat & subsystem studies underway
- Advanced hab testing during in late 2020s

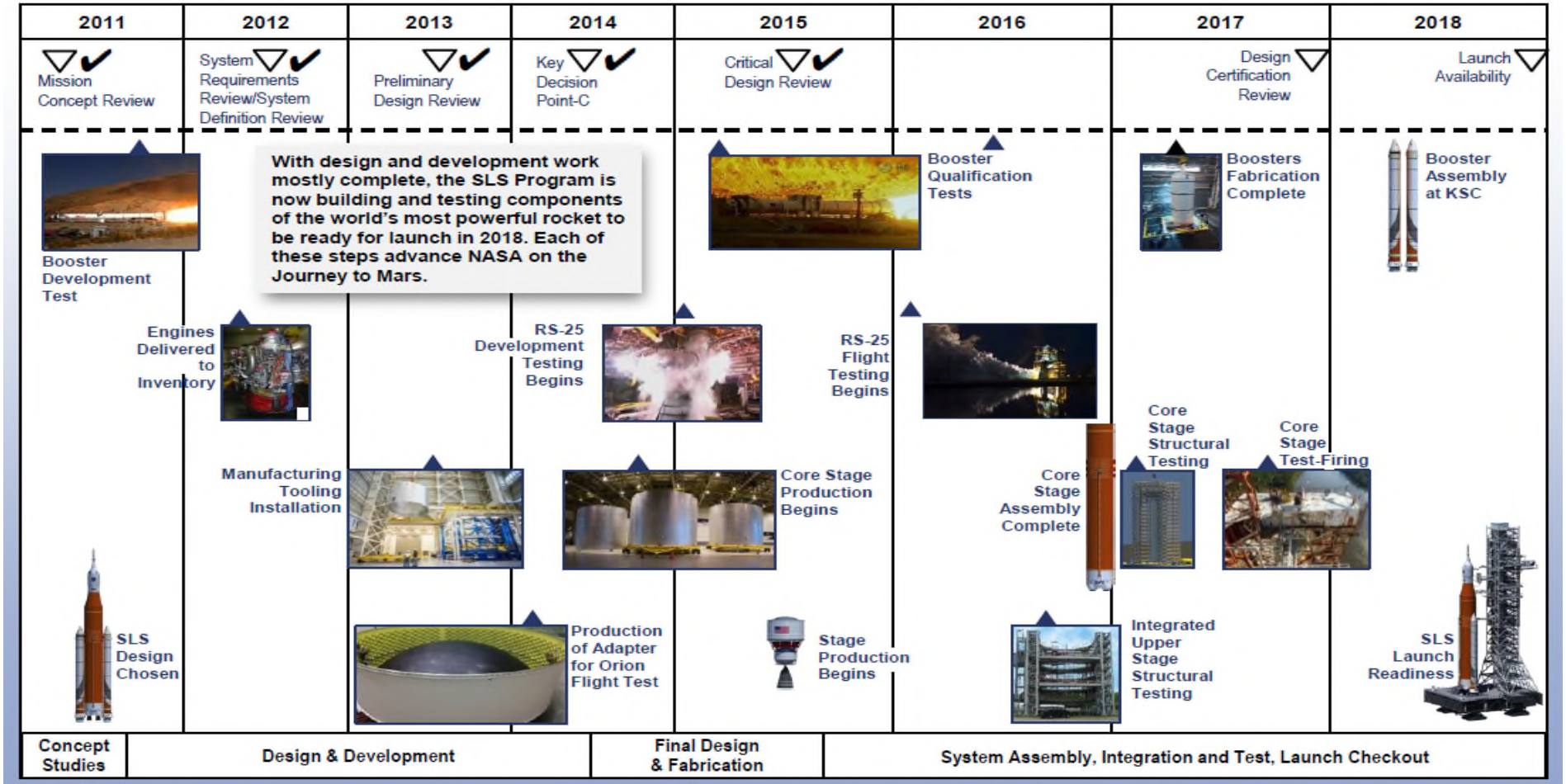
Mars Ascent Vehicle (MAV)
- ✓ Component level testing with LOX /Methane
- Lunar Lander in mid 2020's
- Mars precursor mission in late 2020's
- Mars MAV ready in early 2030s

Space Launch System
- ✓ Full Scale Development Underway
- ✓ Critical Design Review completed
- 2018 first flight hardware in production
- Exploration Upper Stage in 2021 increasing SLS capability

Power
- Next generation array testing underway at ISS
- Initial 50 kW demonstration - Asteroid Redirect Mission
- 150 kW - Translunar SEP tug

Mars Lander & Surface Systems
- Capability testing with lunar landers and habs
- Precursor EDL testing with robotic missions

The Space Launch System's Path To The Pad



Summary

- Rockford has Legacy with NASA Space programs
- Power Distribution in Space has challenges
- Rockford has a significant role in the future of NASA space programs

We ARE building America's Next Space Ship

585 Days

To LAUNCH