

The Multi-purpose Crew Vehicle European Service Module: a European Contribution to Human Exploration AIAA-2013-5477

September 12, 2013

SPACE 2013

Kathleen Schubert, NASA Glenn Research Center

Co-Authors:

[Philippe Berthe, ESA](#)

[Julie Grantier, NASA](#)

[Klaus Pietsch, Astrium GmbH](#)

[Philippe Angelillo, Astrium SAS](#)

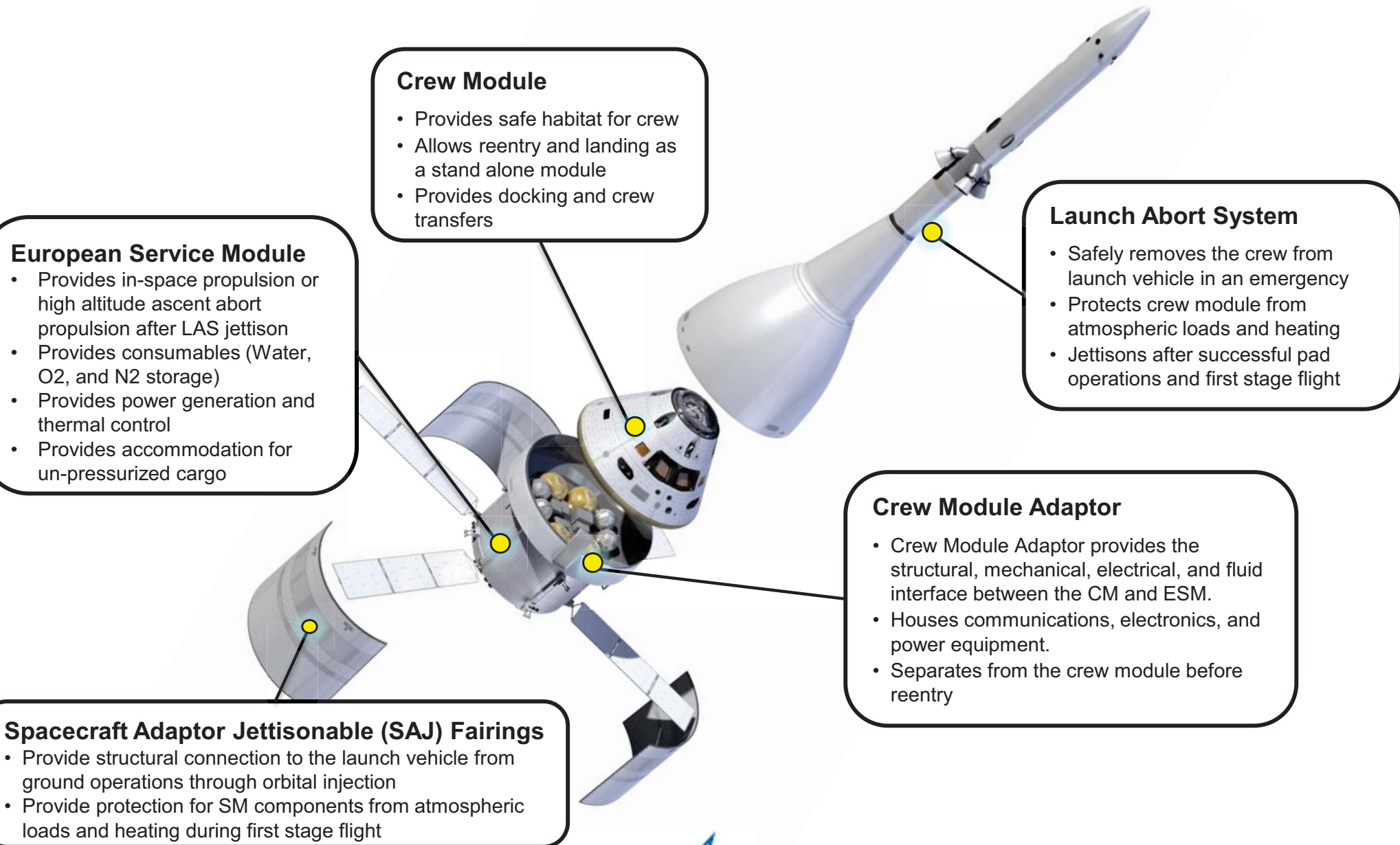
[Laurence Price, Lockheed Martin](#)





- ESA decided in its Council Meeting in March 2011 to partially offset the European International Space Station obligations after 2015 with different means than ATVs.
- NASA and ESA considered a number of barter options, NASA concluded that the provision by ESA of the Service Module for the NASA Orion Multi-Purpose Crew Vehicle (MPCV) was the barter with the most interest and benefit.
- A joint ESA - NASA working group was established in May 2011 to assess the feasibility of Europe developing this Module based on ATV heritage.
- The team continued the activity through Phase A/B1 that included the successful completion of two reviews, the System Requirements Review (SRR) and the System Definition Review (SDR), carried out in 2012.
- The agreement between NASA and ESA was ratified in December 2012 and formally announced in January 2013.
- The project design effort has continued with the Preliminary Design Review currently in progress that will complete in November 2013.
- ESA will supply the European Service Module for the first Exploration Mission (EM-1) of Orion towards the Moon in 2017.

Orion Overview



Crew Module

- Provides safe habitat for crew
- Allows reentry and landing as a stand alone module
- Provides docking and crew transfers

European Service Module

- Provides in-space propulsion or high altitude ascent abort propulsion after LAS jettison
- Provides consumables (Water, O₂, and N₂ storage)
- Provides power generation and thermal control
- Provides accommodation for un-pressurized cargo

Launch Abort System

- Safely removes the crew from launch vehicle in an emergency
- Protects crew module from atmospheric loads and heating
- Jettisons after successful pad operations and first stage flight

Crew Module Adaptor

- Crew Module Adaptor provides the structural, mechanical, electrical, and fluid interface between the CM and ESM.
- Houses communications, electronics, and power equipment.
- Separates from the crew module before reentry

Spacecraft Adaptor Jettisonable (SAJ) Fairings

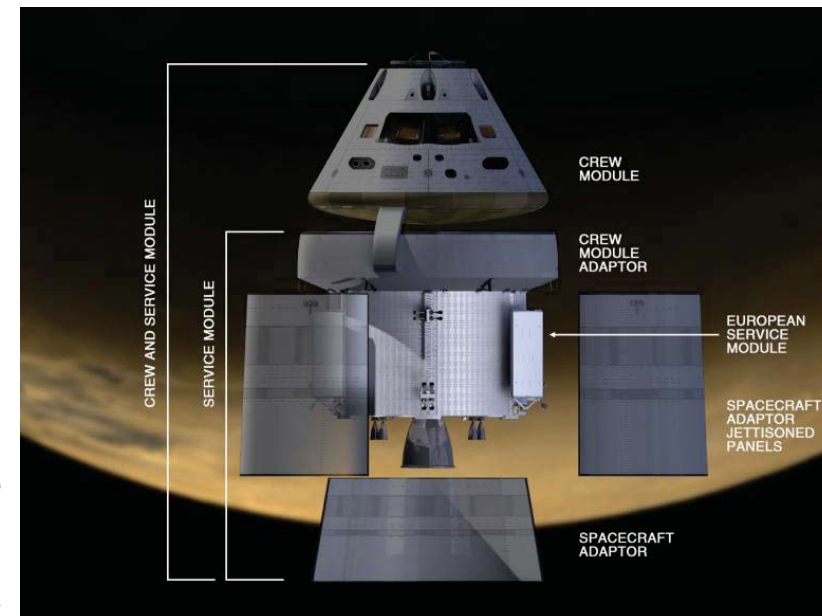
- Provide structural connection to the launch vehicle from ground operations through orbital injection
- Provide protection for SM components from atmospheric loads and heating during first stage flight



Orion Concept & Missions



- The Orion is a Multi-Purpose Crew Vehicle (MPCV) spacecraft that will send humans and cargo into space beyond low earth orbit and return them safely to earth.
- The first two exploration missions consider an uncrewed lunar fly-around mission for system qualification at the end of 2017 as well as a crewed lunar circular orbit mission no later than 2021.
- The MPCV configuration includes
 - Habitable Crew Module (CM)
 - European Service Module (ESM)
 - Crew Module Adaptor (CMA)
 - Spacecraft Adaptor (SA)
 - Spacecraft Adaptor Jettisoned Panels (SAJ)
 - Launch Abort System (LAS) for crew safety
- The CM is larger than Apollo's and can support more crew members for short or long-duration missions
- The ESM fuels and propels the spacecraft as well as stores oxygen and water for astronauts



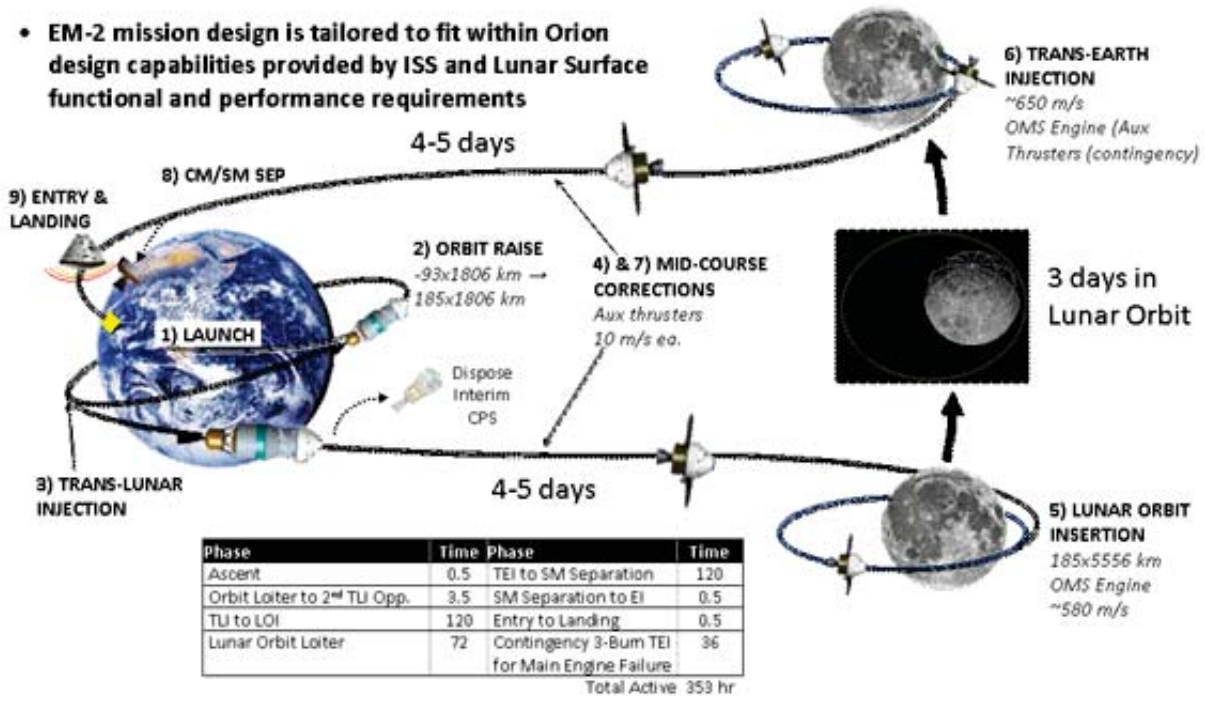
MPCV with ESA SM



Orion Concept & Missions (2)



- The first test flight is planned for 2014 with a Delta 4 -> MPCV CM into a high elliptical orbit to verify atmospheric Earth re-entry speeds of about 9 km/s, mission duration of approximately 5 hours.
- EM-1 in 2017 is planned as an un-crewed lunar flyby mission on a free return trajectory, mission duration of approximately 7 days
- EM-2 is planned as a crewed lunar orbital mission, spending ca. four days in lunar orbit, overall mission duration of approximately 14 days.



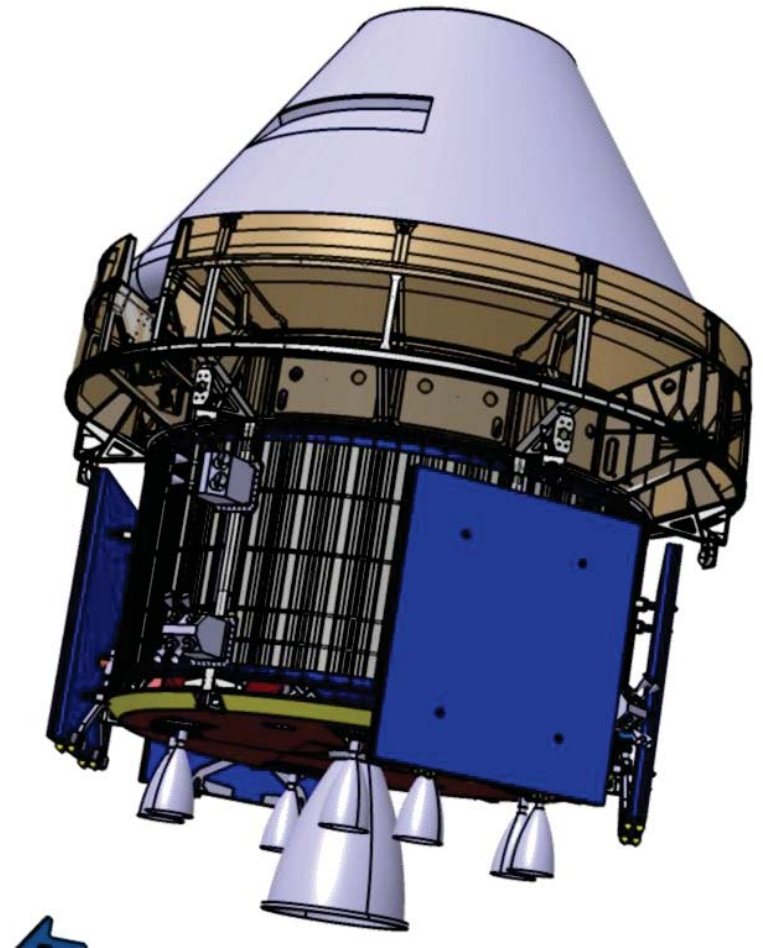
MPCV EM-2 mission



Orion-ESM Overall Concept (1/2)



- The Crew Module and European Service Module will physically interface via an interface ring called the Crew Module Adapter (CMA).
- The ESM and CMA are attached to the CM from launch until just prior to the entry interface.
- NASA is responsible for the CM, CMA, SAJ, SA and the LAS.
- ESA will be responsible for the European Service Module. The ESM provides :
 - propulsion for ascent orbit circularization, orbital and reaction control maneuvering, trans-Earth injection, and mid-course correction maneuvers
 - life support consumables, power generation and storage, heat rejection, and volume reserved for unpressurized cargo
 - abort to orbit capability during portions of the launch profile
 - ISS backup capability for approach maneuvers, rendezvous, departure, and return trajectory

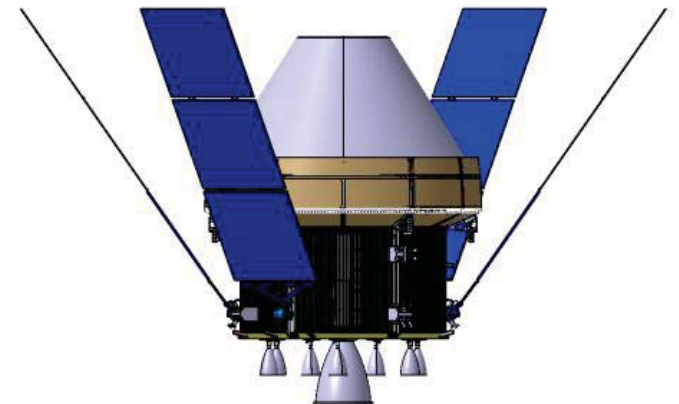
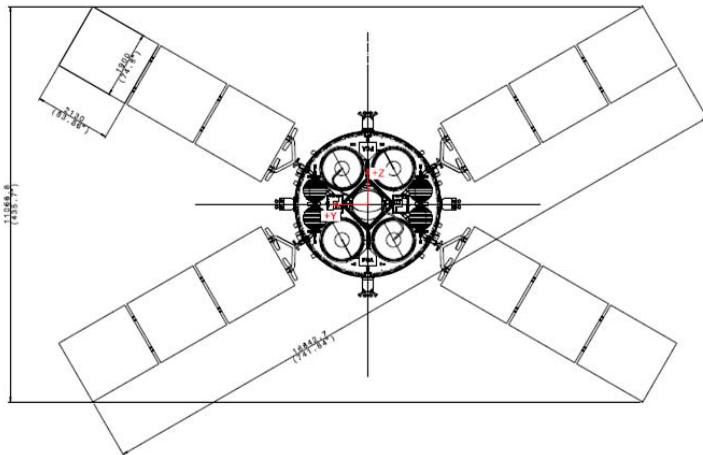
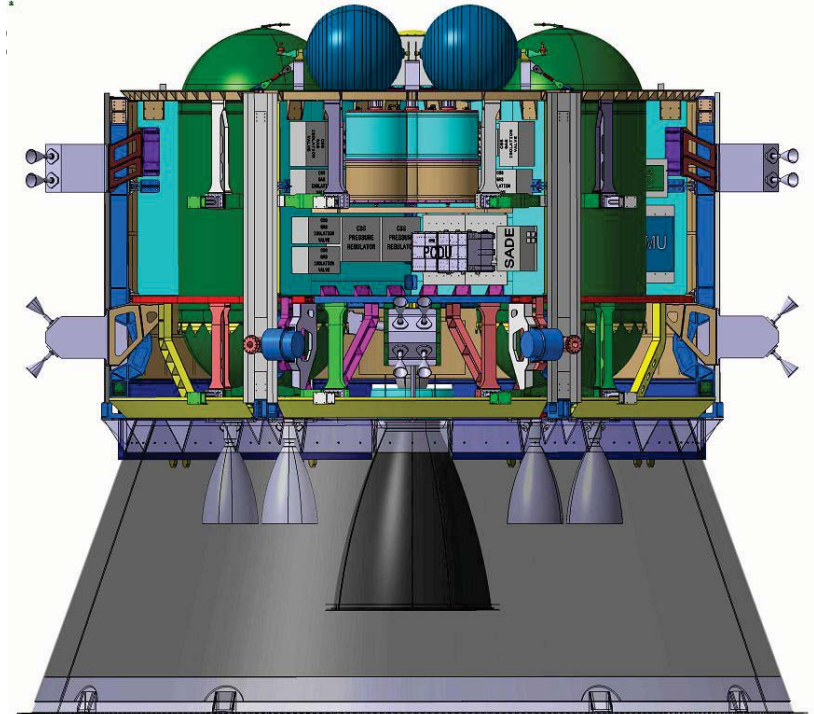


Orion-ESM Overall Concept (2/2)



- Major SM parameters for a lunar mission are

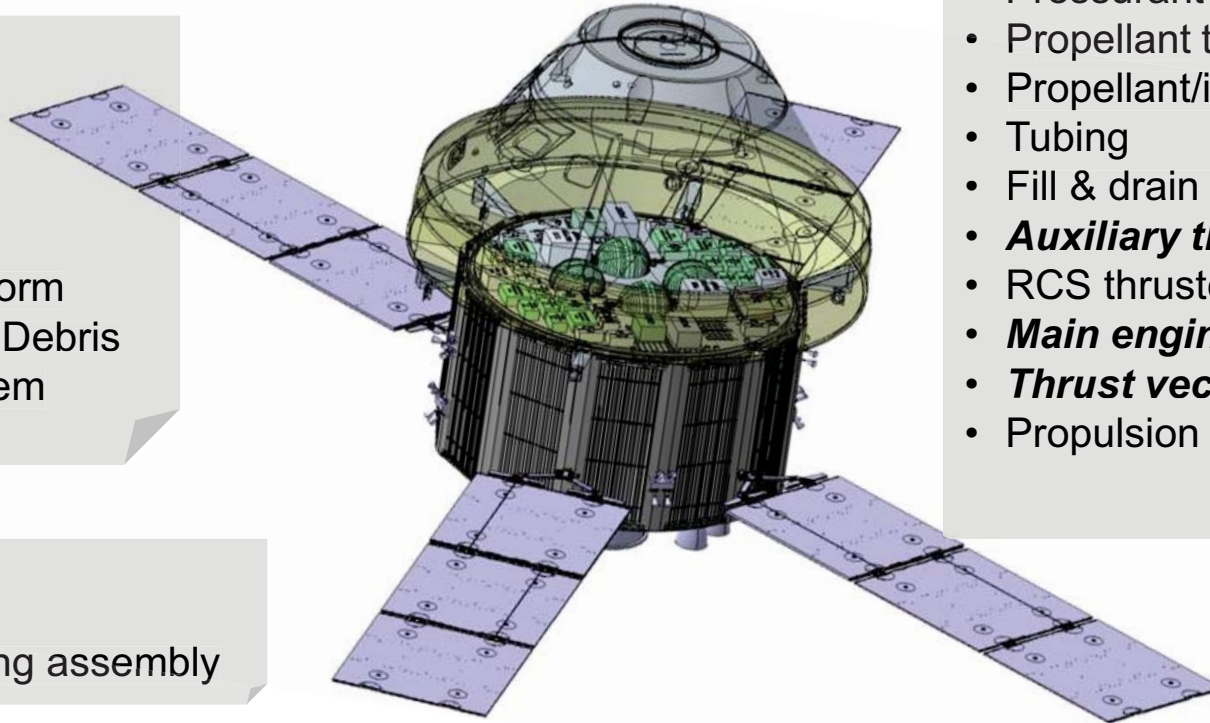
- Dimensions : ca. 4 x 4 m
- Dry mass : ca. 3800 kg
- Fuel : ca. 8600 kg
- Solar array power : ca. 11 kW
- Heat dissipation : up to ca. 5 kW
- Propulsion :
 - 1 main engine, ca. 30 KN
 - 8 auxiliary thrusters each 490 N
 - 24 RCS thrusters each 220 N



ESM Reference Configuration

Structure

- Upper cylinder
- Tank platform
- main cylinder
- Lower platform
- Equipment platform
- Micrometeoroid Debris Protection System



Solar Generator

- **Solar cells**
- Solar array wing assembly

Solar array drive assembly

- Solar array drive mechanism
- Solar array drive electronics

Electrical Power

- Power control & distribution unit

Sun Sensor

Consumable Storage

- Water delivery system
- Gas delivery system

Propulsion

- Pressure control assembly
- Pressurant tanks
- Propellant tanks
- Propellant/isolation system
- Tubing
- Fill & drain valves
- **Auxiliary thrusters**
- RCS thrusters
- **Main engine**
- **Thrust vector control**
- Propulsion drive electronics

Data Management

- Command & management unit
- **Network Interface Cards**

Thermal Control

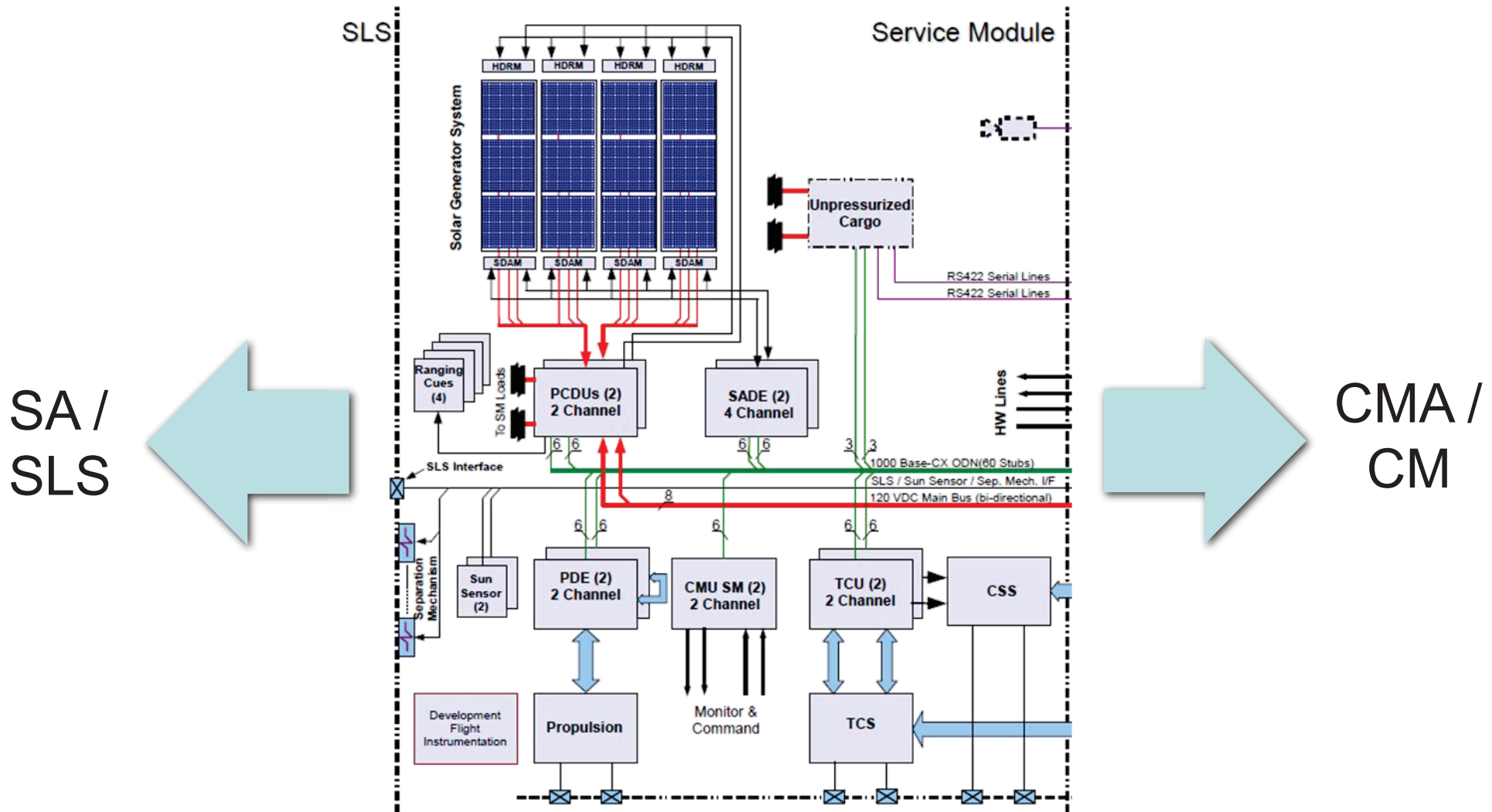
- Passive thermal control
- Active thermal control
- Thermal control unit

*Note: Items in **bold italic** are the agreed to NASA contributions to the ESA SM*

Orion- ESM Functional architecture



- Overall functional architecture and associated interfaces



Reference Baseline v5



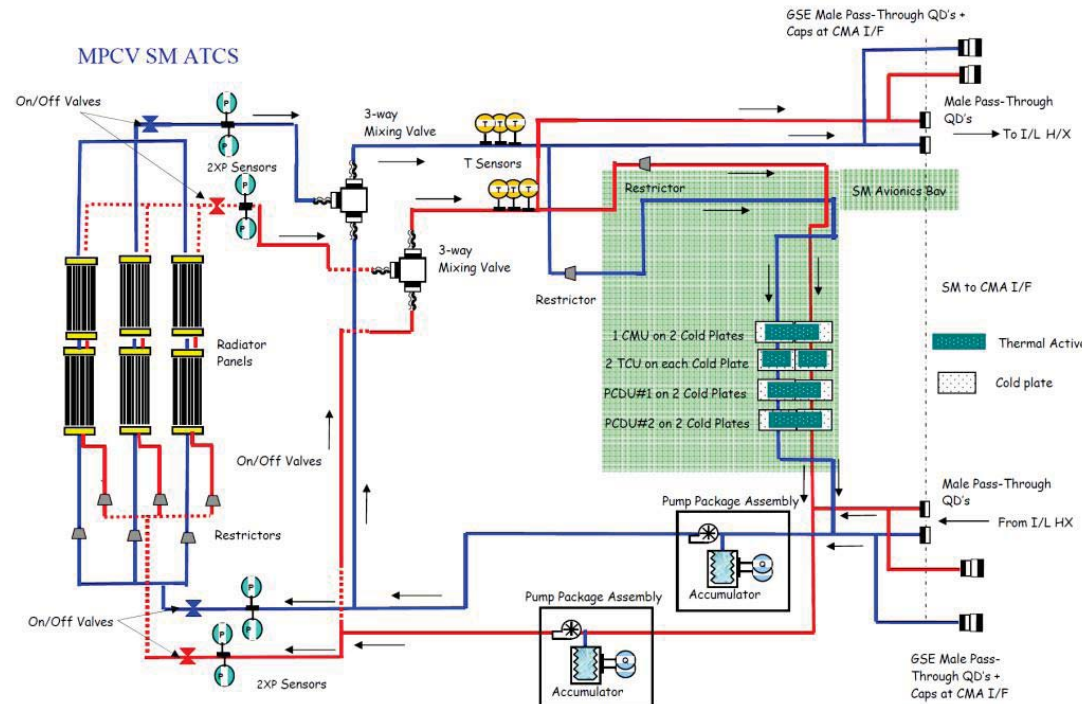
- **The primary structure is composed of:**
 - Six longerons linked to the CMA frame, directly supporting external equipment such as propulsion pods and solar array wings
 - Tank bulkhead supporting the four propellant tanks as well as Consumable Storage tanks
 - Radial shear webs and internal “square” webs assembly, housing most of the ESM equipment including propulsion, attached to the six longerons, to the tank bulkhead and to the lower platform at the bottom
 - The central square provides attachment to the OMS-E via a specific platform
 - Water delivery system is implemented on two intermediate platforms linked to the shear webs
 - Lower platform on which the main propulsion equipment is connected: OMS-E, auxiliary thrusters, ACS, and Propulsion Isolation Equipment
 - MDPS aft closure panels
- **The secondary structure supports the following equipment**
 - Solar Array Wings
 - RCS clusters
 - Water Delivery and Gas Delivery system
 - The other equipment is directly attached to the primary structure

Orion- ESM Thermal Control System



Thermal Control System includes:

- Active Thermal Control System
 - Collects and rejects thermal loads from the CM and ESM powered equipment
 - Two fully independent loops in hot redundancy
 - Each loop includes
 - Six body mounted radiators
 - One 3-way modulating valve
 - Four Cold Plates
 - One Fluid Pump Package
 - Associated valves, sensors and hoses, tees, couplings and restrictors
- Passive Thermal Control System
 - Heaters
 - Insulation (MLI thermal blankets)
- Thermal Control Unit (TCU)
 - Manages the TCS and the CSS

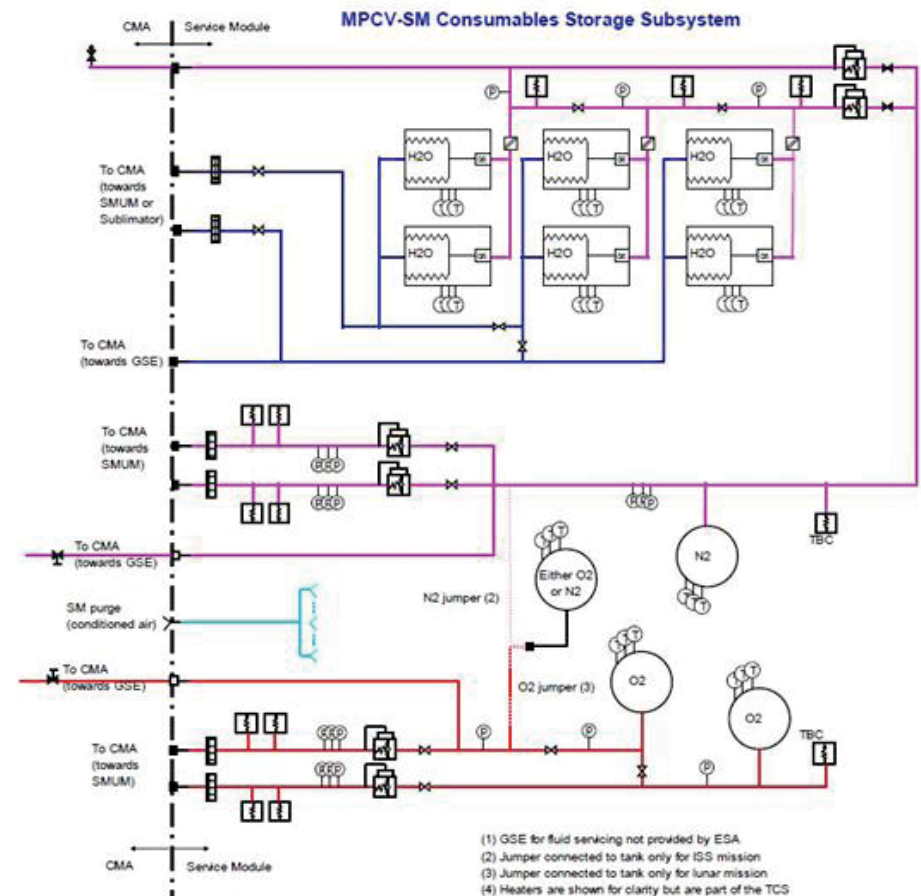


Orion- ESM Consumable Storage System



Consumable Storage System includes:

- Water Delivery System
 - Six potable water metallic bellow tanks (280 kg of water total)
 - Water is supplied to the CM and to the Water Sublimation Assembly (WSA) in the CMA via a double distribution line
 - Each branch can be isolated
 - Connected to the Gas Delivery System for pressurisation
- Gas Delivery System
 - Four gas tanks (33 kg of gas at 275 bar).
 - Two tanks for O₂
 - One tank for N₂
 - One tank for either O₂ or N₂
 - Two independent distribution lines for each gas



Orion- ESM Propulsion



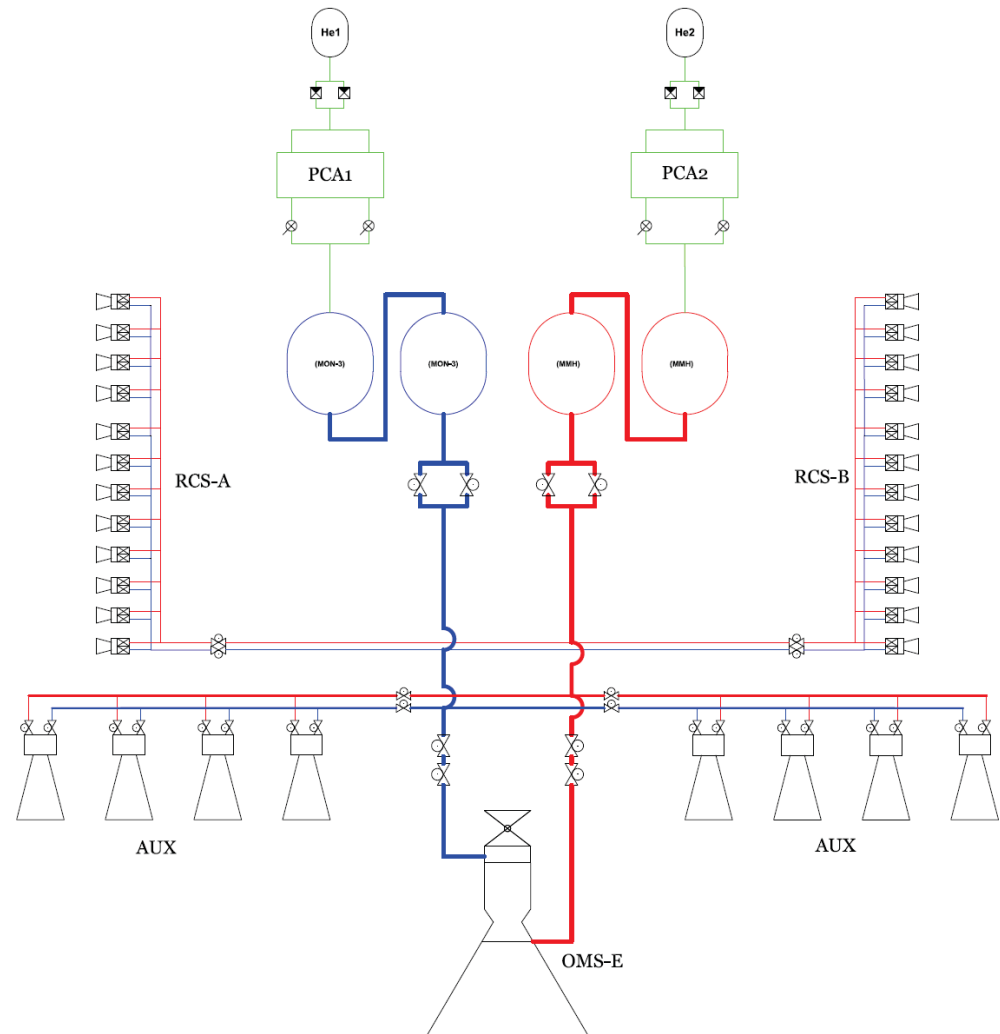
Propulsion includes three types of engines/thrusters:

- Single Main Engine (Shuttle OMS-E) – 27.7 kN, gimballed by the Thrust Vector Control
- 8 auxiliary thrusters – 490 N
- 24 RCS thrusters – 220 N accommodated in eight pods (4 x 2 + 4 x 4)

Propellant is MMH with MON-3 as oxidiser

Each propellant type is stored in two propellant tanks, arranged in series, with their own pressurisation system.

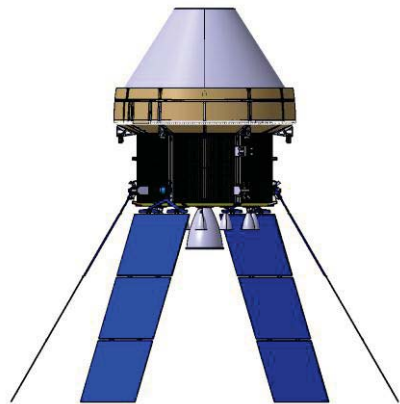
Propulsion is controlled by the Propulsion Drive Electronics (PDE) which handles the commands issued by the CM.



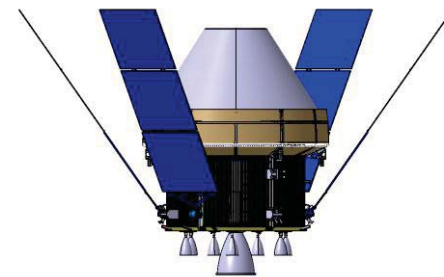
Orion- ESM Power



- Four Solar Array Wings (SAW)
 - Deployable CFRP rigid panels covered by triple junction AsGa solar cells
 - Total output of 11.1 kW.
 - Each SAW linked to the ESM structure by a 2 Degrees of Freedom mechanism
 - This mechanism allows
 - Sun tracking
 - Repositioning of the SAW to reduce the loads during Orion orbital manoeuvres (TLI, LOI, TEI).
 - Controlled by Solar Array Drive Electronics (SADE)
- Power Control and Distribution Units (PCDUs)
 - Distribute power to ESM users and transfer power to the CMA
 - Power transfer through four independent 120 V busses



TLI configuration (iCPS acceleration)



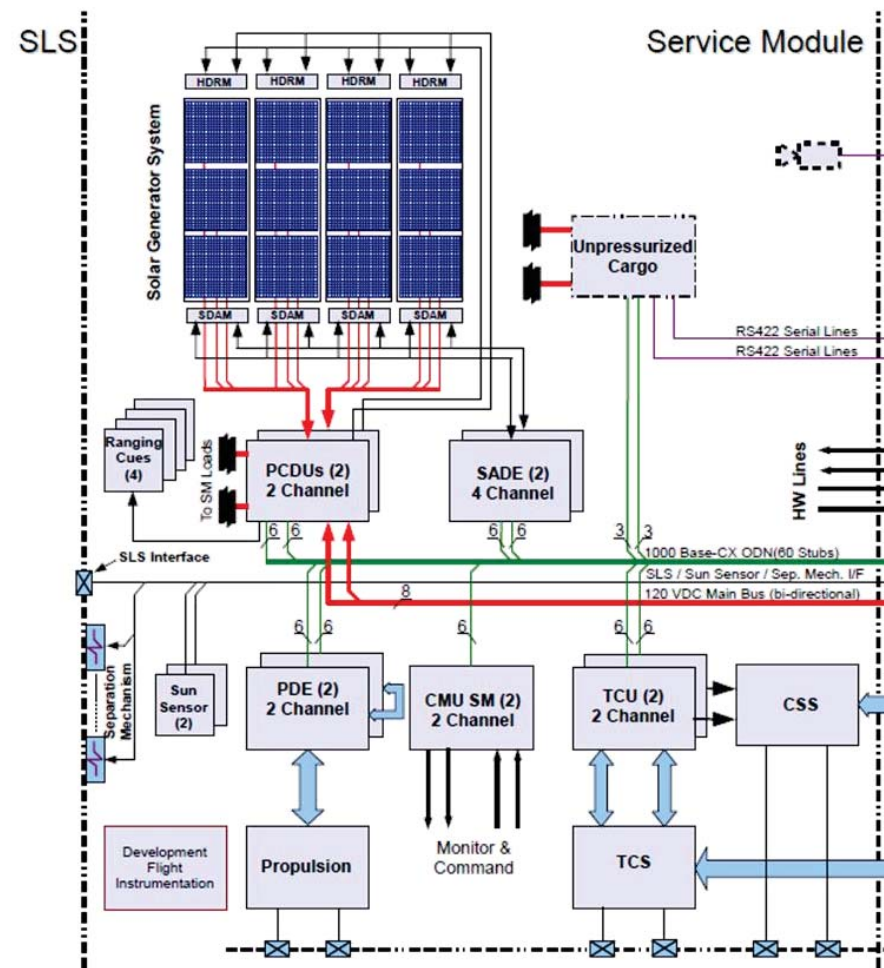
LOI/TEI configuration (OMS-E deceleration)

Orion- ESM Avionics



- High level management of the spacecraft is performed at the Orion Vehicle Management Computer (VMC) level
- ESM is controlled and monitored by specific controller units, dedicated to the various subsystems/subassemblies:
 - PCDU - Power Control and Distribution Unit
 - SADE - Solar Array Drive Electronics
 - PDE - Propulsion Drive Electronics
 - TCU - Thermal Control Unit
 - CMU - Command and Monitoring Unit

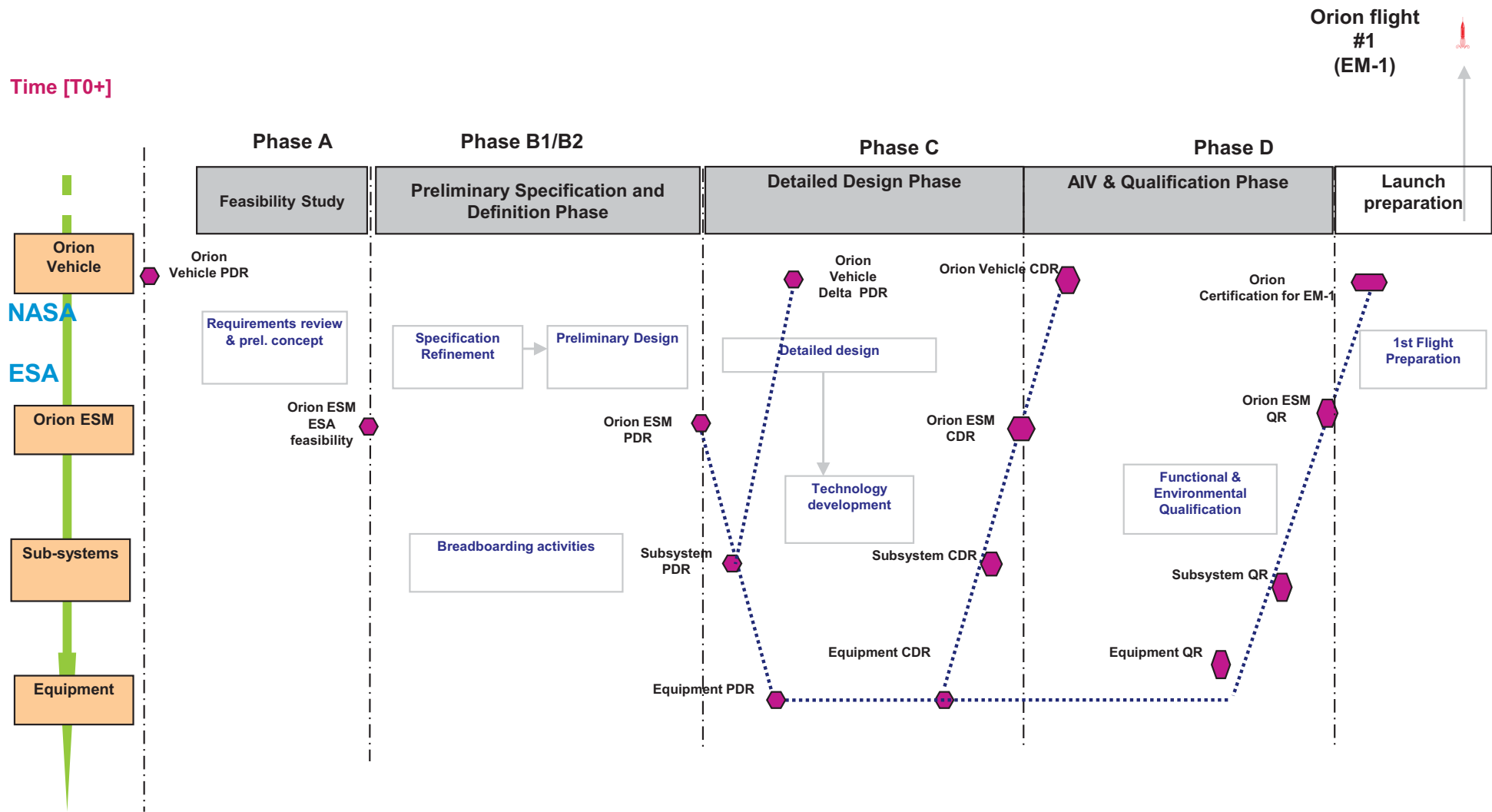
All units are connected by the Onboard Data Network (ODN) to the VMC and the Backup Flight Control Unit (BFCU) of the Orion.



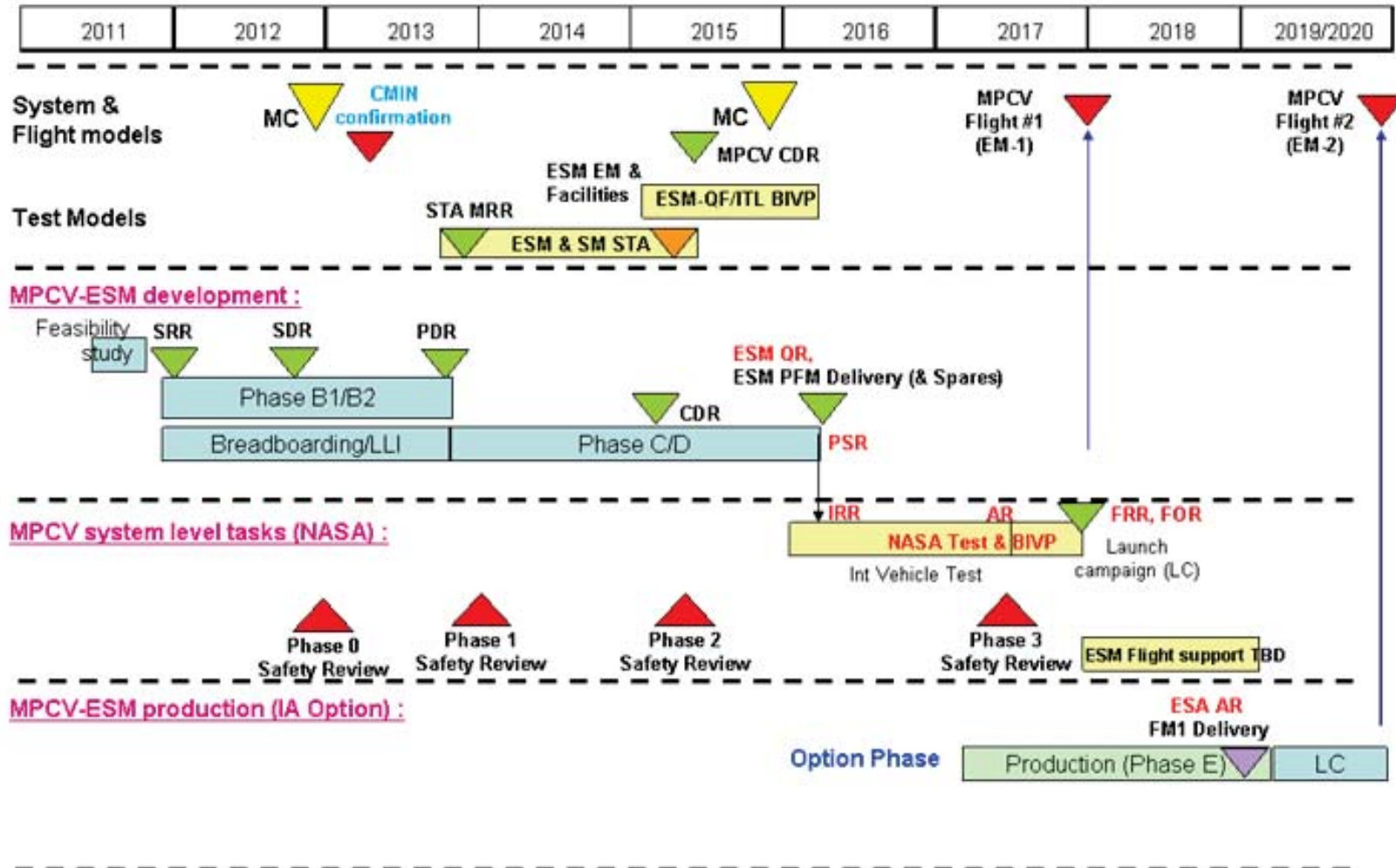
Reference Baseline v5



ESM Testing and Integration Process



MPCV-ESM Program Planning objective



*Planning date only/
2nd Flt by
2021

- Project phases 0/A have been performed between May 2011 and January 2012 concluding with a System Requirements Review (SRR) early 2012.
- Phase B1 continued from February until November 2012 in preparation for establishing the technical and programmatic baseline for ESA - NASA decision regarding the implementation of Orion-ESM as a post ATV-5 barter and concluded with the System Definition Review (SDR)
- Phase B2 includes
 - integrated NASA - ESA (supported by industry) Design Analysis Cycle - 2 (DAC-2)
 - ESM Preliminary Design review in September-November 2013.
- Industry teams :
 - NASA is industrially supported by Lockheed-Martin and its team
 - In Europe, Astrium in Bremen (prime contractor) and Les Mureaux with Thales Alenia Space Turin plus other European suppliers from Germany, Italy, France, Belgium, Switzerland, the Netherlands, Spain and Austria

Astrium GmbH Bremen:

- B2 prime contractor, system lead, avionics, propulsion, programmatic

Astrium SAS Les Mureaux and Élanecourt:

- System engineering, software, pressurant tanks, simulation facility, command and monitoring unit (CMU)

TAS-I Torino:

- Thermal/mechanical subsystems, consumable storage system (CSS)

Dutch Space:

- Solar Generator System (SGS)

RUAG Zurich:

- Solar Array Drive Assembly (SADA)

MT Aerospace Augsburg:

- CSS tanks

CRISA Madrid:

- Thermal Control Unit

Selex Galileo Milano:

- Power Control and Distribution Unit

Antwerp Space Belgium:

- Ground Support Equipment



Conclusions



- The inclusion of an International Partner in the development of Orion is of benefit to both NASA and ESA.
- Provides an opportunity for a significant International contribution towards NASA's exploration program.
- An ESA provided ESM may accelerate the first crewed Orion flight by freeing the US contractors to concentrate on the Crew Module and Launch Abort System.
- This international partnership is consistent with the US National Space Policy.
- The Orion ESM provides ESA an opportunity for cooperation that builds on existing European knowledge and technology.
- The Orion ESM will also benefit ESA in the development of additional capability for use toward future ESA missions, creation of long term cooperation on future programs, and strengthen the strategic partnership with NASA.
- The NASA and ESA teams including their respective contractors have worked very well together and have made swift progress towards the advancement of both a technical and programmatic baseline for an ESA provided ESM.
- The Preliminary Design Review (PDR) of the ESM is under way and will conclude next November.



