BUILDING TRANSATLANTIC PARTNERSHIPS IN SPACE EXPLORATION THE MPCV-SM STUDY

Following the approval of the ESA ISS Exploitation Declaration for the ISS lifetime at the ESA Council Meeting in March 2011, ESA decided to partially offset the European obligations deriving from the extension of the ISS Programme until end 2020 with different means than ATVs, following the ATV-5 mission foreseen in mid 2014. The envisioned approach is based on a barter element(s) that would generate cost avoidance on the NASA side. NASA and ESA considered a number of Barter options, and concluded that the provision by ESA of the Service Module for the NASA Multi-Purpose Crew Vehicle (MPCV) was the barter with the most interest. A joint ESA - NASA working group was established to assess the feasibility of Europe developing this Module based on ATV heritage. The working group was supported by European and US industry namely Astrium, TAS-I and Lockheed-Martin.

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BUILDING TRANSATLANTIC PARTNERSHIPS IN SPACE EXPLORATION THE MPCV-SM STUDY

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This paper gives an overview of the results of the on-going study as well as its perspective utilisation for the global space exploration endeavour.

I. INTRODUCTION

The Multi-Purpose Crew Vehicle, (MPCV) is the spacecraft that NASA intends to use to send humans and cargo into space beyond low earth orbit and to 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 crewed lunar circular orbit mission at the end of 2021.

The MPCV configuration includes:

- A habitable Crew Module (CM)
- A Service Module (SM)
- A Crew Module Adaptor (CMA)
- A Spacecraft Adaptor (SA)
- Spacecraft Adaptor Jettisoned Fairings (SAJ)
- A Launch Abort System (LAS) for crew safety

An ESA provided Service Module would make use of Europe human space flight development heritage using European system know-how and subsystems. Major functionalities of the SM in support of the Crew Module are propulsive support and fuel storage, power generation and distribution, thermal control and consumable storage. For selected subsystems NASA provided subsystems (GFE) are under consideration to avoid parallel development and limit cost / risk. To facilitate a potential utilisation in future European missions the SM will have a modular configuration, adaptable avionics software architecture and will be compatible with an Ariane 5 launch. Following successful completion of the initial feasibility working group in September 2011, on 4 October 2011, NASA Associate Administrator for Human Exploration and Operations and ESA Director General signed a "Framework between NASA and ESA Concerning Follow-on Activities required for decisions to be taken in 2012 for the 2016 through 2020 ISS Common Operation Costs (CSOC) Barter". Both Agencies agreed to extend the assessment phase of the potential MPCV cooperation in order to achieve technical and programmatic maturity as would be necessary for the decision to be taken to the ESA Council at Ministerial level to be held in November 2012. Should ESA and NASA decide to pursue the

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collaboration past Phase A/B-1, a dedicated arrangement, pursuant to the IGA and NASA-ESA MOU, would be concluded after approval by the United States Government (through the C175 process and, as necessary, other mechanisms) and by the November 2012 ESA Ministerial Council meeting.

In November 2011, ESA and NASA commenced with the MPCV-SM phase A / B1 activities including conducting the System Requirements Review SRR and System Definition Review SDR milestones in 2012. The results of this effort are described in the following paragraphs.

II. MPCV CONCEPT AND MISSIONS

The Multi-Purpose Crew Vehicle (MPCV) is a spacecraft that is being built by Lockheed Martin for NASA, the national space agency of the United States, based on designs and tests already completed for the Orion spacecraft. The MPCV was announced by NASA on 24 May 2011.

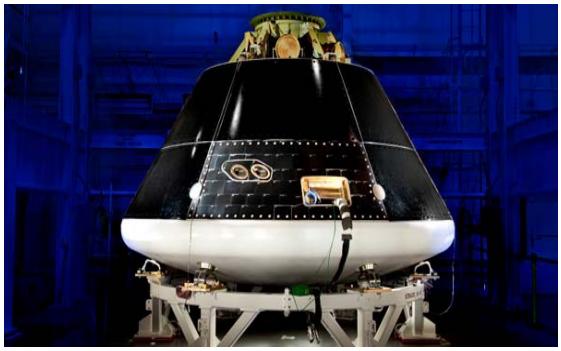


Figure 1 : MPCV Crew Module

The MPCV is being developed for crewed missions to the Moon's orbit, asteroids, and then to Mars. The capsule is also planned as a backup vehicle for missions to the International Space Station,ISS. It will be launched by the Space Launch System SLS.

The MPCV resembles its Apollo-era predecessors, but its technology and capability are more advanced. It is designed to support long-duration deep space missions of up to 216 days. The spacecraft's life support, propulsion, thermal protection and avionics systems are designed to be upgradeable as new technologies become available.

The MPCV spacecraft includes both Crew and Service Modules, Spacecraft Adaptor, and Launch Abort System.

The MPCV's Crew Module is larger than Apollo's and can support more crew members for short or long-duration spaceflight missions. The Service Module fuels and propels the spacecraft as well as storing oxygen and water for astronauts. The Service Module's structure is also being designed to provide locations to mount scientific experiments and cargo.

The first MPCV missions are:

- The first test flight is planned for 2014 with a Delta 4 launch vehicle that will launch MPCV CM into a high elliptical orbit to verify atmospheric Earth re-entry at a speed of about 9 km/s.
- EM-1 in 2017 is planned to be an un-crewed lunar flyby mission on a free return trajectory, lasting approximately one week in duration.
- EM-2 is planned to be a crewed lunar orbital mission, spending approximately four days in lunar orbit, for an overall mission duration of approximately fourteen days.

Figure 2 shows an artist impression of the MPCV with an ESA built SM on the way to the Moon.

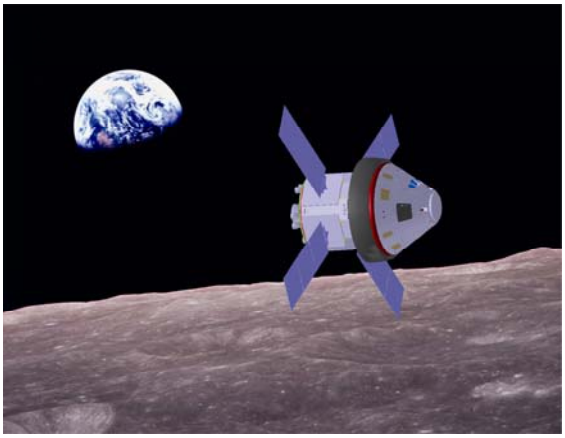
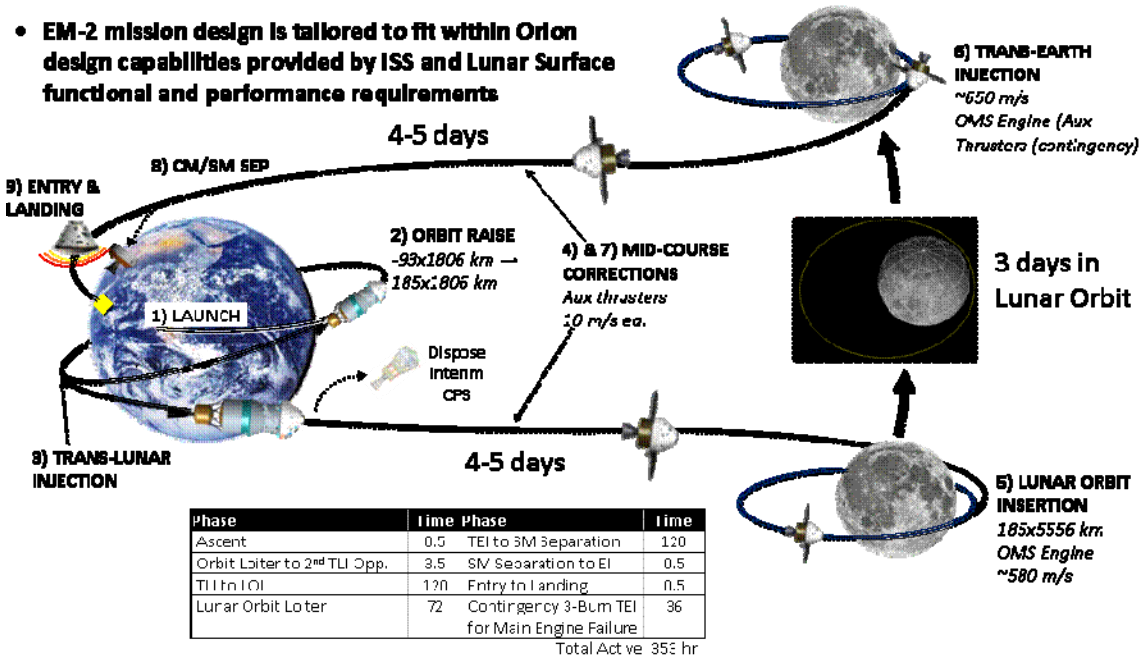


Figure 2: MPCV artist impression

Figure 3 illustrates the EM-2 mission as the first crewed MPCV flight.



Phase	Time	Phase	Time
Ascent	0.5	TEI to SM Separation	120
Orbit Loiter to 2nd TLI Opp.	3.5	SM Separation to EI	0.5
TLI to LOI	120	Entry to Landing	0.5
Lunar Orbit Loiter	72	Contingency 3-Burn TEI for Main Engine Failure	36

Figure 3 : MPCV Exploration Mission EM-2

III. MPCV-SM ESA CONCEPT

The Crew Module and Service Module will physically interface via an interface ring called the Crew Module Adapter (CMA). The Service Module is attached to the CMA from launch until just prior to the entry interface. At that time, the CMA separates from the CM for CMA/SM disposal and the CM performs final re-entry and landing operations.

NASA will be responsible for the CMA. This includes ensuring CMA separation from the CM. NASA will also be responsible for the LAS to SM interface, i.e. tangential connection and blade seal. The CMA will contain the phased array antennas, phase change material, sublimator water, fill and drain ports, T-0 umbilical, power and data unit (PDU), internal and external heat exchanger loops and micro-meteoroid and orbital debris (MMOD) ring. NASA will also be responsible for the fairing jettison panels (SAJ) that protect the CMA/SM during launch and ascent.

ESA will be responsible for the Service Module and Spacecraft Adapter. SM functions include propulsion for ascent orbit circularization, orbital and reaction control maneuvering, trans-Earth injection, and mid-course correction maneuvers.

The SM provides life support consumables, power generation and storage, heat rejection, and volume reserved for unpressurized cargo. The SM also provides abort to orbit capability during portions of the launch profile. For the ISS backup mission, the SM provides the capability for approach maneuvers, rendezvous, ISS departure, and return trajectory insertion.

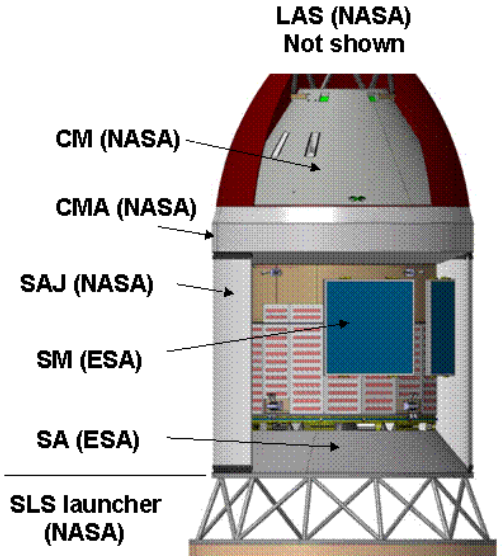


Figure 4 : MPCV NASA and ESA elements

For the lunar mission, the SM provides propulsive rendezvous capabilities for docking to other potential lunar mission elements. Once the MPCV

Spacecraft is in lunar orbit, the SM provides lunar orbital maneuvering propulsion for the MPCV Spacecraft. The SM provides the maneuvering propulsion for return to Earth trajectory insertion. During the return trip, the SM provides course correction propulsion maneuvers as necessary.

The Spacecraft Adapter (SA) provides the interface to the launch vehicle during launch. During launch and ascent, the SM and SA will be enclosed by three panels (collectively called the SAJ, Spacecraft Adapter Jettison panels) that encapsulate the SM and SA in a fairing for protection from the launch and ascent environments. These panels are jettisoned during ascent. The SA attaches to the aft end of the SM to the Launch Vehicle and includes the structural interface, separation mechanisms, and umbilical connectors for communication between the launch vehicle and the MPCV Spacecraft. At launch vehicle burnout, the MPCV Spacecraft separates from the SA at the SM/SA separation plane.

Figure 5 illustrates the MPCV-SM in launch and in-orbit configuration.

Figure 6 depicts the MPCV functional block diagram.

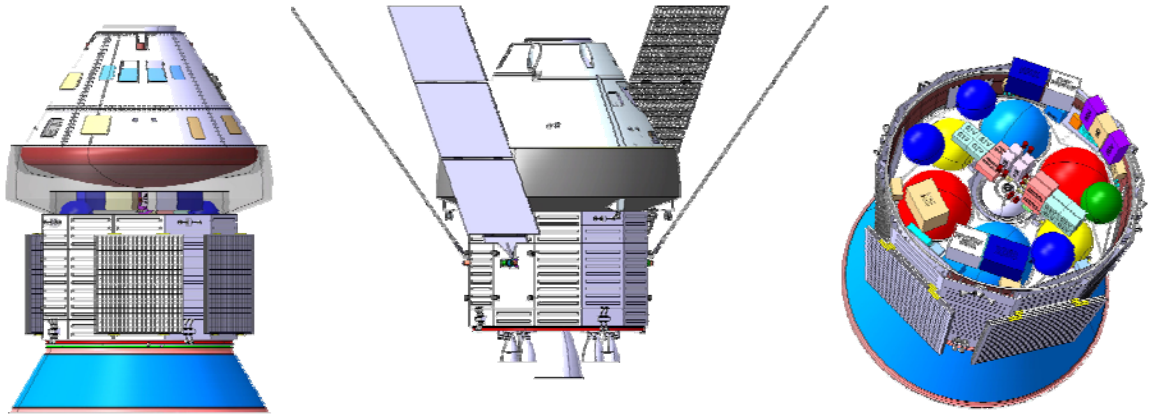


Figure 5 : MPCV-SM launch / in-orbit configuration

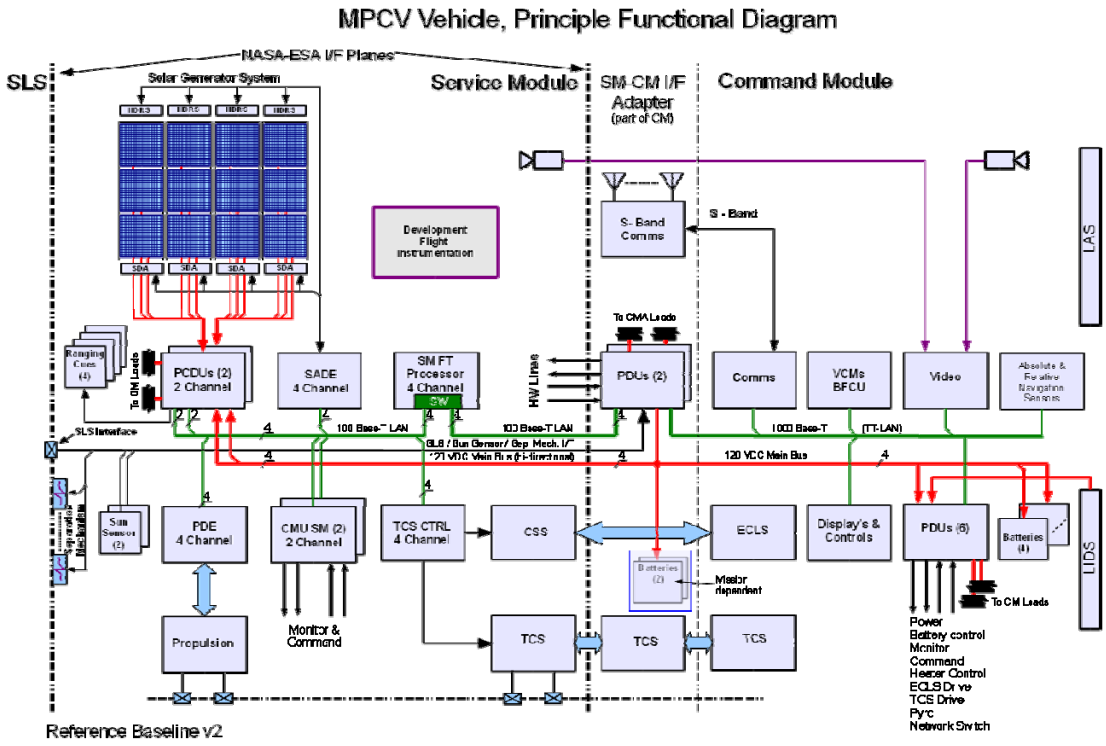


Figure 6 : MPCV functional blockdiagram

The major SM parameters for a lunar mission are:

- Dimensions : ca. 4 x 4 m
- Dry mass : ca. 3800 kg
- Fuel : ca. 9200 kg
- Solar array power : ca. 11 KW
- Heat dissipation : up to ca. 5 KW
- Propulsion :
  - 1 main engine, ca. 30 KN
  - 8 auxiliary thruster each 490 N
  - 16 or 24 RCS thruster each 220 N

Ariane 5 compatibility: Beside the primary MPCV-SM functionality a key aspect for ESA is the compatibility of the MPCV-SM with potential European applications resp. the use of Ariane 5 as launch system or the reutilization of the MPCV SM concept/design for future European applications.

IV. PROGRAMMATICS

The major program planning assumptions utilized for the Phase A/B1 study are as follows:

- Design approach :
  - ESA will design the SM in accordance with NASA provided requirements (functional, performance, safety, environment, …)
  - NASA will provide selected subsystems as GFE: e.g. Main Engine (STS OMS-E) & TVC
- Schedule :
  - EM-1 mission at the end of 2017
  - EM-2 mission in 2021, however NASA is aggressively pursuing options which pull forward the second flight
- Reproducibility :
  - NASA and ESA will work closely together throughout the design and development to ensure independent reproducibility of the ESA designed SM at the conclusion of the Implementing Arrangement. ESA and its contractors may procure some of the SM hardware from US sources.

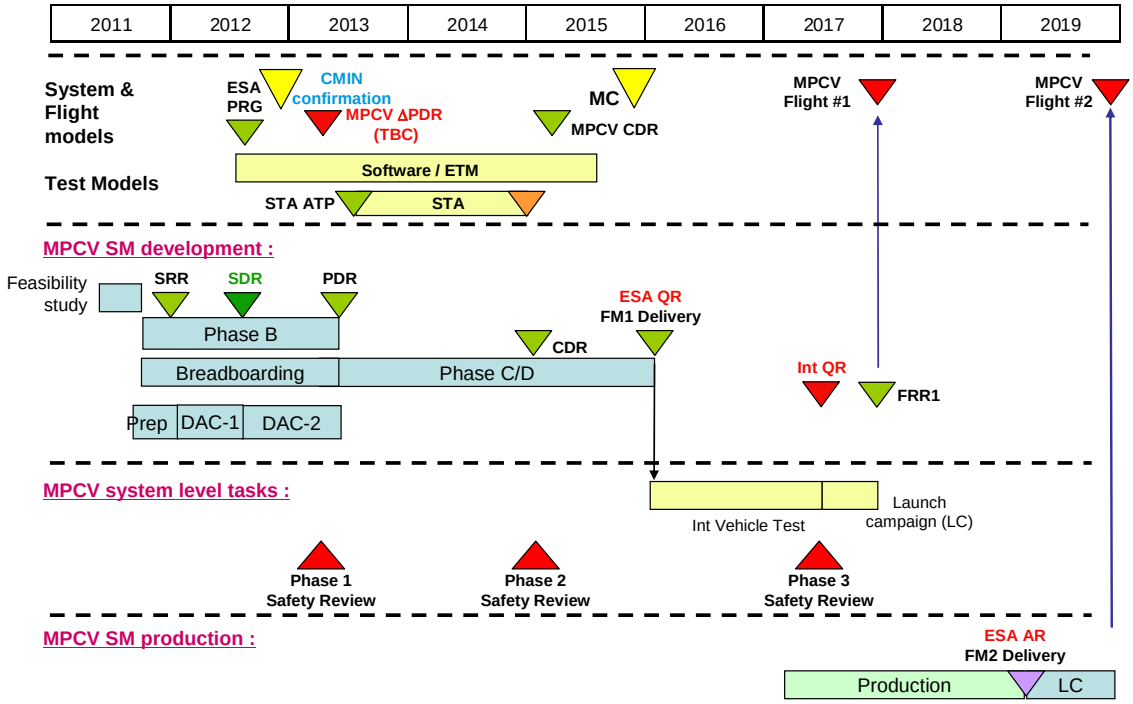


Figure 7 : MPCV SM Planning

- Development philosophy :
  - System Requirements Review (SRR) was performed in Phase A
  - SDR (System Definition Review) at end of phase B1
  - Phase B2 to be completed with PDR

- Bread-boarding of critical subsystems in phase B1 (goal TRL 5)
- Safety reviews :
  - Phase 0 prior to MPCV-SM SDR
  - Phase 1 at MPCV-SM PDR
  - Phase 2 at MPCV-SM CDR
  - Phase 3 at MPCV-SM PFM QR

For planning purposes, NASA and ESA have agreed to the following planning assumptions for the MPCV-SM development:

- MPCV SM :
  - SRR January 2012
  - SDR September 2012
  - PDR Mid 2013
  - CDR Dec 2014
  - QR Dec 2015
- MPCV Vehicle CDR: February 2015
- SM STA delivery (TBC): Dec 2014
- Flight 1 SM delivery: February 2016
- Flight 2 SM delivery (TBC): Dec 2018

Figure 7 illustrates the MPCV program planning.

V. PROJECT STATUS

Project phases 0/A have been performed between May 2011 and January 2012 concluding with a System Requirements Review. Phase B1 has been kicked-off early February running until November 2012 in order to prepare the technical and programmatic baseline for ESA - NASA decision about the implementation of MPCV-SM as a post ATV-5 barter.

Phase B1 will include an integrated NASA - ESA (supported by industry) Design Analysis Cycle - 1 (DAC-1) and a joint System Definition Review SDR in September 2012.

NASA is industrially supported by Lockheed-Martin and its team on the US side. In Europe Astrium ST in Bremen (as prime) and Les Mureaux with TAS-I Turin as main partner plus other European suppliers from Germany, Italy, France, Belgium, Switzerland, the Netherlands, Spain and Austria are supporting ESA in phase B1.

VI. PERSPECTIVE USE IN GLOBAL EXPLORATION ROADMAP

The Global Exploration Strategy: the Framework for Coordination, released in May 2007 by 14 space agencies, presents a vision for globally coordinated human and robotic space exploration focused on solar system destinations where humans may someday live and work. It calls for sustainable human exploration of the Moon, near-Earth asteroids, and Mars. Although Mars is unquestionably the most intriguing destination for human missions currently within our grasp, and a human mission to Mars has been the driving long-term goal for the development of the Global Exploration Roadmap, there is much work to be done before the risks associated with such missions can be reduced to an acceptable level and the required technologies are matured to enable a sustainable approach.

VII. ACKNOWLEDGEMENTS

The work performed by the Barter Element Working Group was initiated and guided by the NASA - ESA ISS / MPCV program management, namely Mike Suffredini and Mark Geyer from NASA and Bernardo Patti from ESA. The authors like to thank them for their inspiration and continued support to this joint ESA-NASA endeavor to prepare the next giant leap!

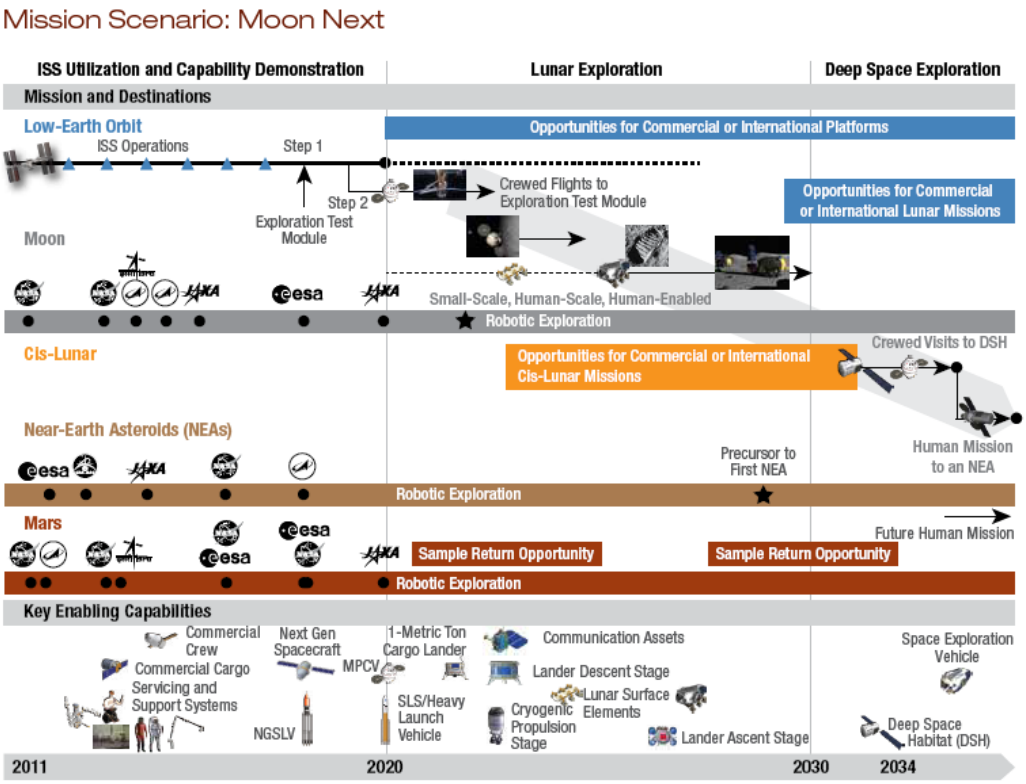


Figure 8 : GES Moon Next Scenario

VIII. CONLUSIONS

The inclusion of an International Partner in the development of the MPCV can be of benefit to both NASA and ESA and provides an opportunity for a significant International contribution towards NASA's exploration program. An ESA provided SM could accelerate the first crewed Orion MPCV flight by freeing the US contractors to concentrate on the Crew Module and Launch Abort System. An international partnership is consistent with the US National Space Policy to promote appropriate cost and risk sharing among participating nations through International partnerships. If the Implementing Arrangement is approved by both Agencies, it does not entail a long term commitment yet is an opportunity to build on existing strong cooperative relationships between NASA and ESA.

In addition, the MPCV SM provides ESA an opportunity for cooperation that builds on existing ATV Service Module technology, leveraging skills and knowledge created for ATV. An MPCV SM would 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 SM.

IX. REFERENCES

[1] Agreement among the Government of Canada, Governments of Member States of the European Space Agency, the Government of Japan, the Government of the Russian Federation and the Government of the United States of America Concerning Cooperation on the Civil International Space Station (referred to as the ISS IGA), signed on January 29, 1998

[2] Memorandum of Understanding between the National Aeronautics and Space Administration of the United States of America (NASA) *and the European Space Agency* (ESA) *Concerning Cooperation on the Civil International Space Station* (referred to as the ISS the MOU), signed on January 29, 1998

National Aeronautics and Space Administration

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BUILDING TRANSATLANTIC PARTNERSHIPS IN SPACE EXPLORATION

THE MPCV-SM STUDY

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Larry Price, Lockheed-Martin, USA
Franco Fenoglio, TAS-I, Italy
Siegfrid Chavy, Astrium France

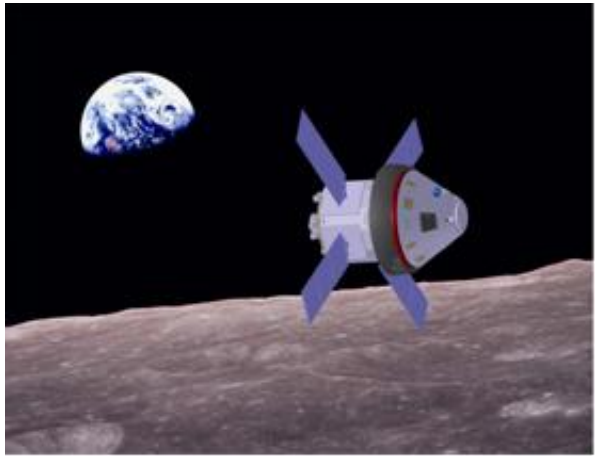
Introduction

- ESA decided in its Council Meeting in March 2011 to partially offset the European ISS obligations after 2015 with different means than ATVs
- The envisioned approach is based on a barter element(s) that would generate cost avoidance on the NASA side
- NASA and ESA considered a number of Barter options, NASA concluded that the provision by ESA of the Service Module for the NASA Multi-Purpose Crew Vehicle (MPCV) was the barter with the most interest.
- 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 working group was supported by European and US industry namely Astrium, TAS-I and Lockheed-Martin.
- The project is currently in phase B1 with the objective to prepare a technical and programmatic proposal for an ESA MPCV-SM development. This proposal will be one element of the package that ESA plans submit to go forward for approval by European Ministers in November 2012 !

MPCV Concept & Missions (1)

- The Multi-Purpose Crew Vehicle (MPCV), is the spacecraft that NASA intends to use to send humans and cargo into space beyond low earth orbit and to 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 at the end of 2021
- The MPCV configuration includes
  - Habitable Crew Module (CM)
  - Service Module (SM)
  - Crew Module Adaptor (CMA)
  - Spacecraft Adaptor (SA)
  - Spacecraft Adaptor Jettisoned Fairings (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 SM fuels and propels the spacecraft as well as storing oxygen and water for astronauts

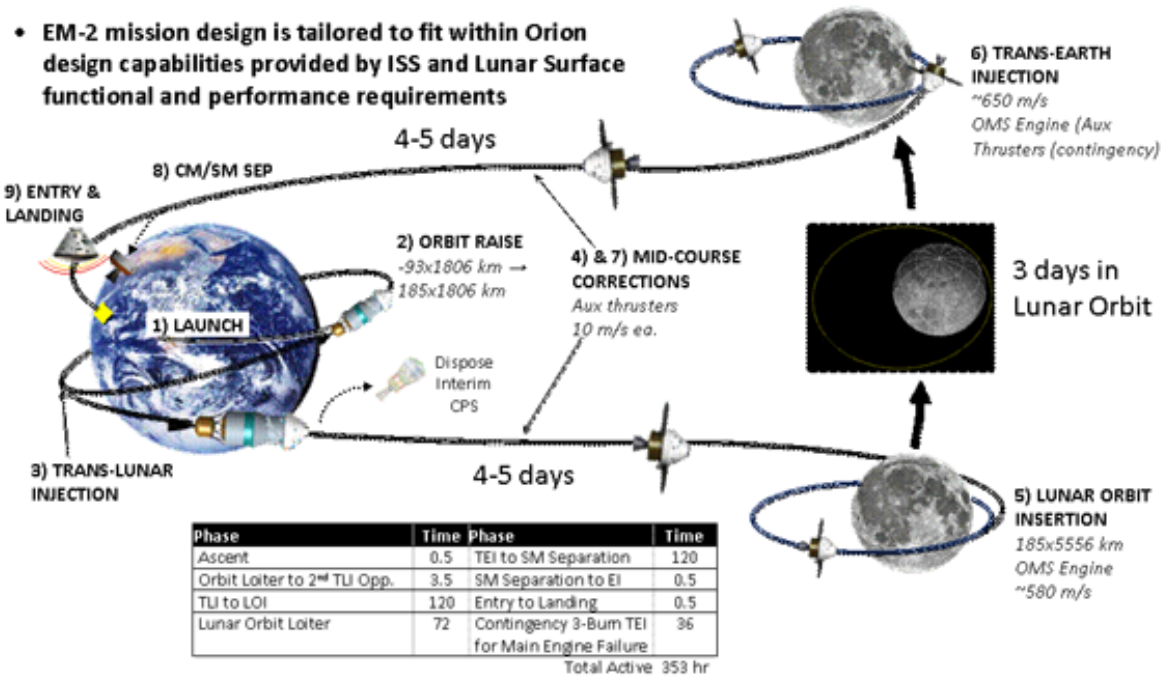
MPCV-CM (Orion)



MPCV with ESA SM

MPCV 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.
- EM-1 in 2017 is planned as an un-crewed lunar flyby mission on a free return trajectory, ca. 7 days
- EM-2 is planned as a crewed lunar orbital mission, spending ca. four days in lunar orbit, overall duration of ca. 14 days.



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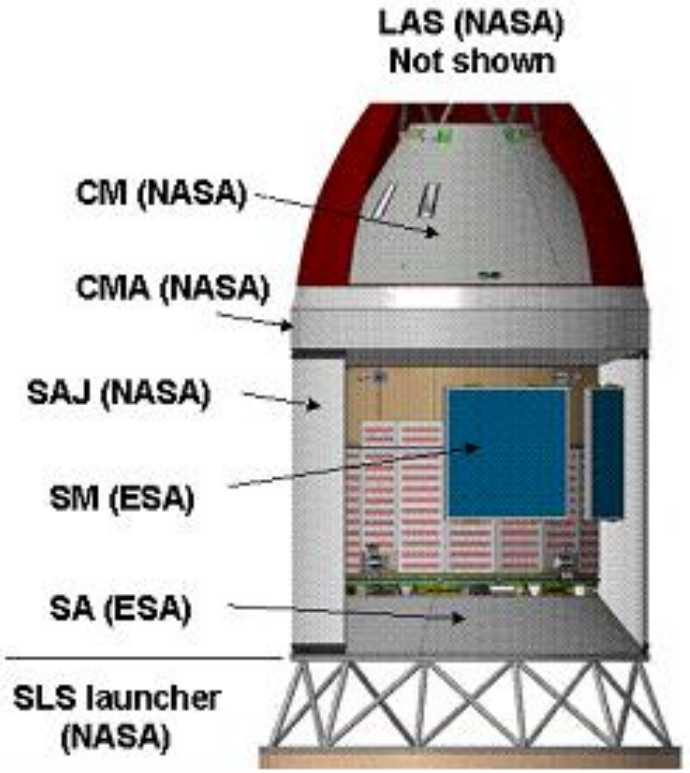
TLI to LOI	120	Entry to Landing	0.5
Lunar Orbit Loiter	72	Contingency 3-Burn TEI for Main Engine Failure	36

Total Active 353 hr

MPCV EM-2 mission

MPCV-SM ESA Concept (1)

- The Crew Module and Service Module will physically interface via an interface ring called the Crew Module Adapter (CMA).
- The SM and CMA is attached to the CM from launch until just prior to the entry interface.
- NASA will be responsible for the CM, CMA, SAJ, and the LAS.
- ESA will be responsible for the Service Module and Spacecraft Adapter. The SM 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



MPCV roles

MPCV-SM ESA Concept (2)

- **Major SM parameters for a lunar mission are:**
  - **Dimensions :** **ca. 4 x 4 m**
  - **Dry mass :** **ca. 3800 kg**
  - **Fuel :** **ca. 9200 kg**
  - **Solar array power :** **ca. 11 KW**
  - **Heat dissipation :** **up to ca. 5 KW**
  - **Propulsion :**
    - **1 main engine, ca. 30 KN**
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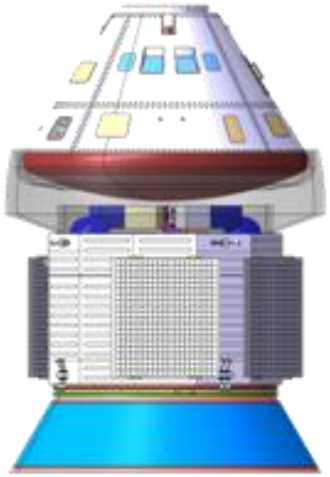
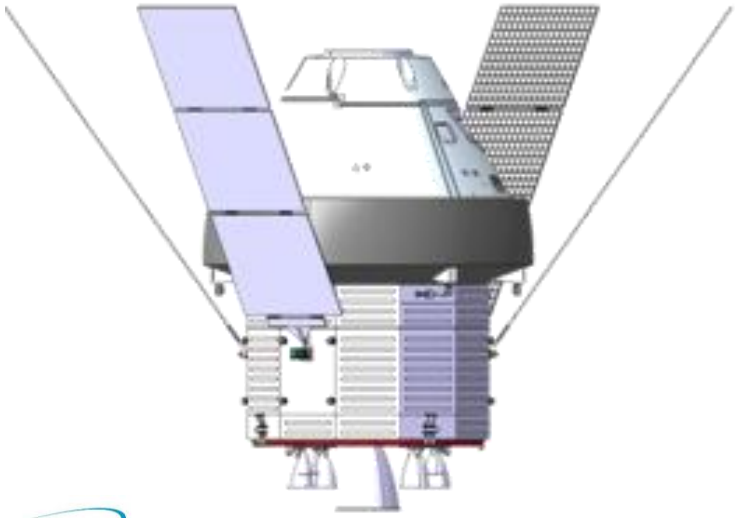
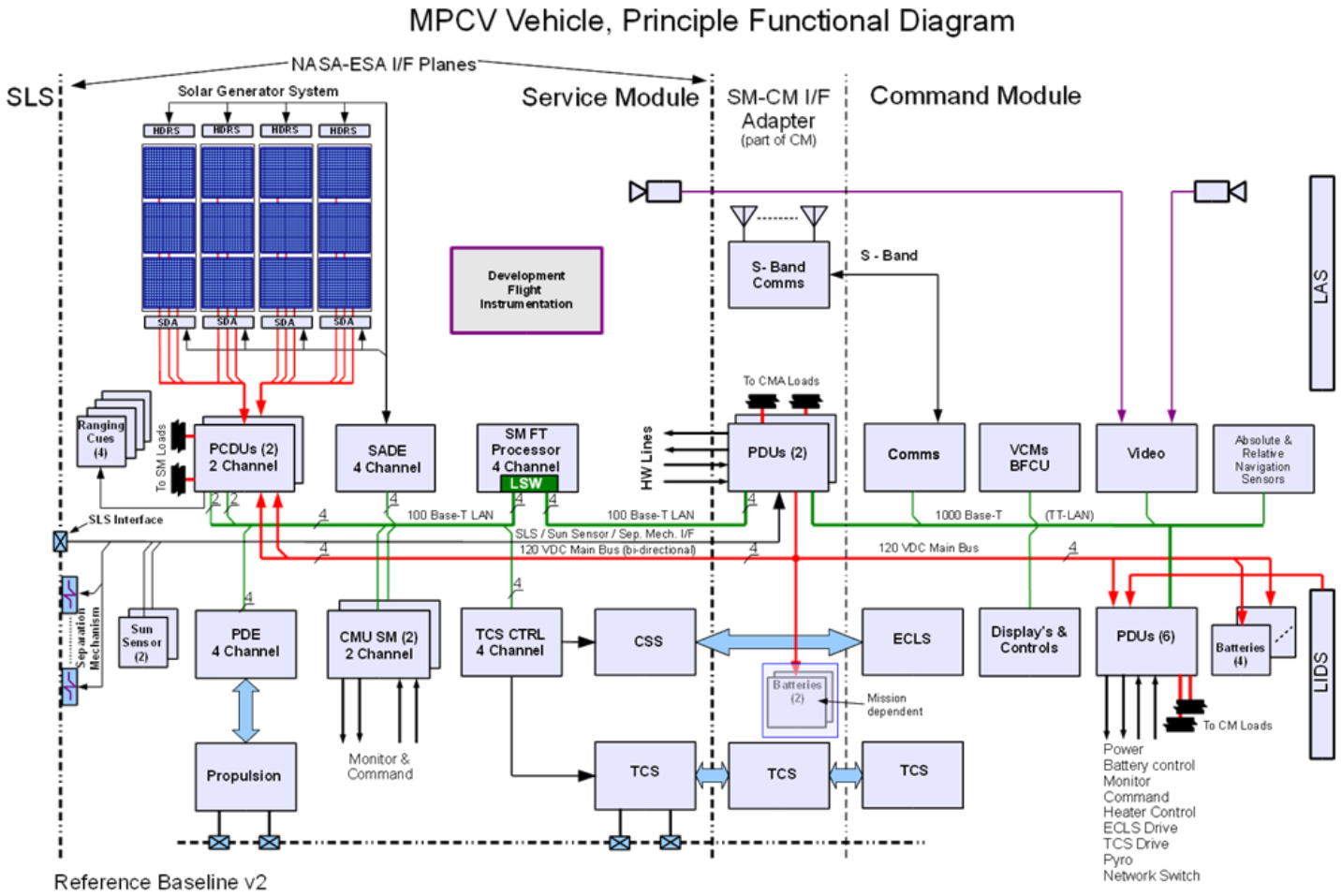




- **Ariane 5 compatibility to allow for European application of MPCV SM e.g. as space tug**

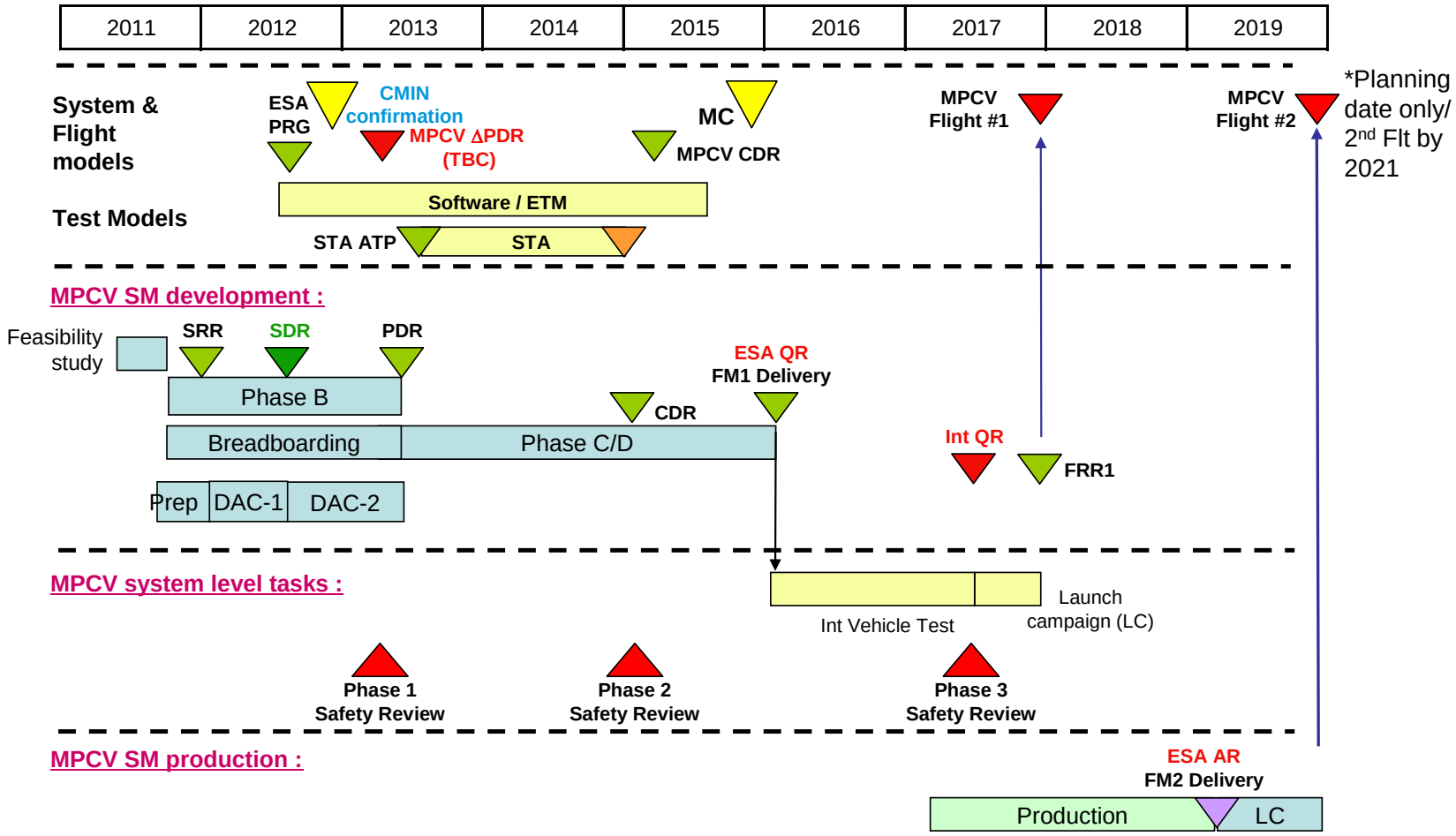
MPCV-SM ESA Concept (3)

- **ESA MPCV-SM Phase B1 functional block diagram**



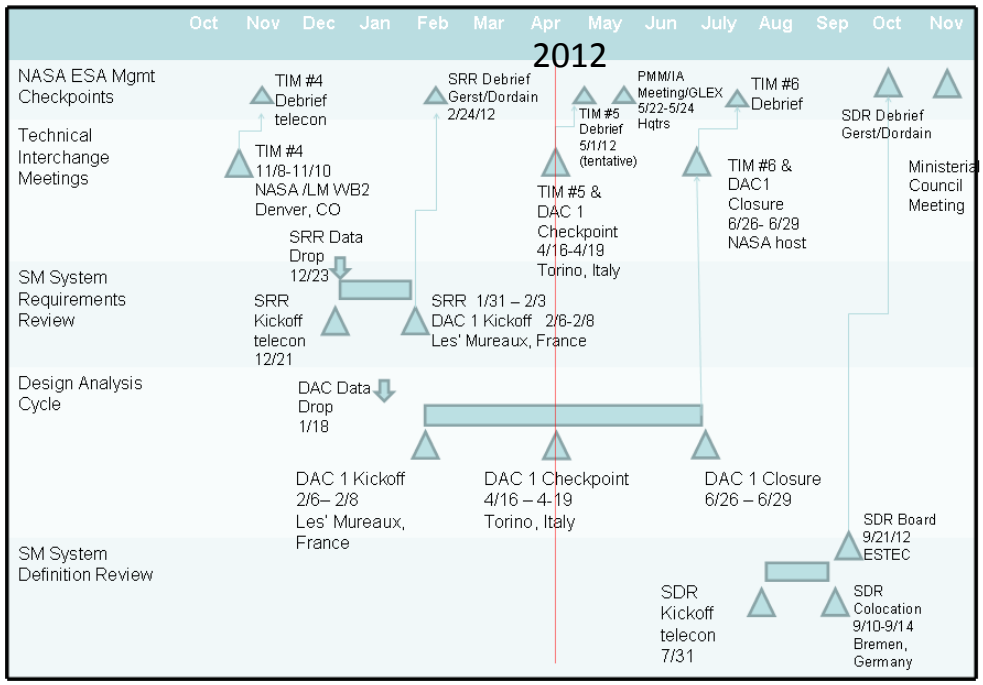
Programmatics (1)

- **MPCV-SM Program Planning**



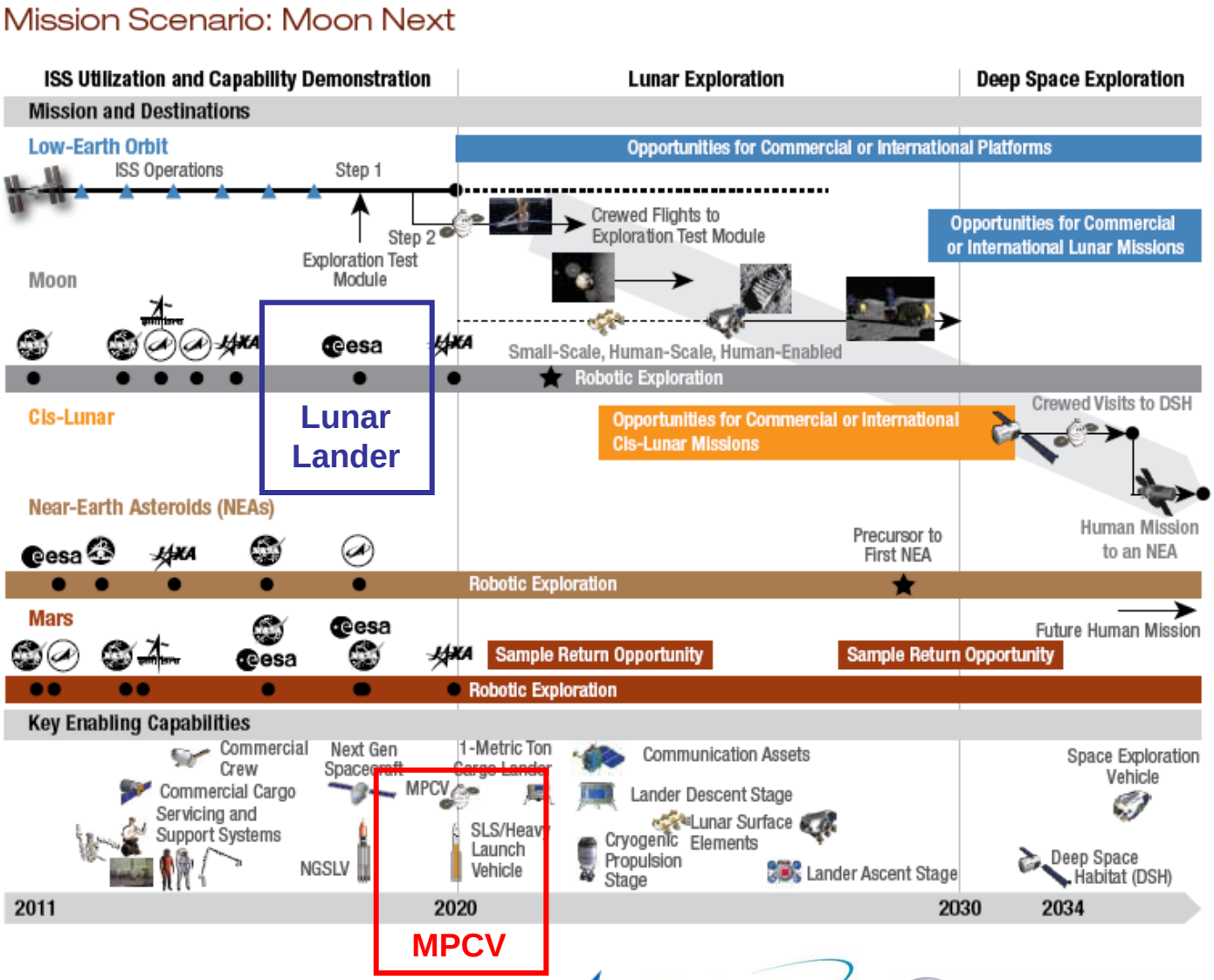
Project status

- Project phases 0/A have been performed between May 2011 and January 2012 concluding with a System Requirements Review early 2012.
- Phase B1 runs from February until November 2012 in order to prepare the technical and programmatic baseline for ESA - NASA decision about the implementation of MPCV-SM as a post ATV-5 barter.
- Phase B1 includes
  - integrated NASA - ESA (supported by industry) Design Analysis Cycle - 1 (DAC-1)
  - a joint System Definition Review SDR in September 2012.
- Industry teams :
  - NASA is industrially supported by Lockheed-Martin and its team
  - In Europe Astrium in Bremen (prime) and Les Mureaux with TAS-I Turin plus other European suppliers from Germany, Italy, France, Belgium, Switzerland, the Netherlands, Spain and Austria



MPCV-SM Phase A/B1

Use in Global Exploration Roadmap



Conclusions

- **The inclusion of an International Partner in the development of the MPCV can be of benefit to both NASA and ESA.**
- **Provides an opportunity for a significant International contribution towards NASA's exploration program.**
- **An ESA provided SM could accelerate the first crewed Orion MPCV flight by freeing the US contractors to concentrate on the Crew Module and Launch Abort System.**
- **An international partnership is consistent with the US National Space Policy .**
- **In addition, the MPCV SM provides ESA an opportunity for cooperation that builds on existing European knowledge and technology.**
- **An MPCV SM would 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 SM.**

Let's make it happen !!!