Human Spaceflight and Exploration

Robert P. Veldhuyzen (ESA ret.)

9th ESPI Autumn Conference
21 – 22 September 2015, Vienna

OUTLINE OF PRESENTATION

- **What are the likely scenarios for Human Spaceflight and Exploration in the timeframe 2015 – 2030**

- **How will these scenarios be influenced by developments in launchers and launch services**

  - **Which (new) launchers and launch services would be enablers for such scenarios**

  - **Which (new) launchers and launch services could be driven by such scenarios**

International Fora on Space Exploration

- **International Space Exploration Forum (ISEF)**: fosters political level dialogue; last meeting January 2014 (Washington), next meeting 2016/2017
- **International Space Exploration Coordination Group (ISECG)**: space agencies' forum for advancing common vision on next steps for space exploration; output: Global Exploration Roadmap (GER) as result joint work 14 space agencies
- **International Mars Exploration Working Group (IMEWG)**: space agencies definition of common international Design Reference Mission (DRM) for sample return from Mars
- **United Nations Office for Outer Space Affairs (UNOOSA)**: promotes emerging space fairing nations in future global space exploration endeavor

GLOBAL EXPLORATION ROADMAP (GER)

- Reflects common long-range robotic and human exploration strategy
- Developed by 12 space agencies participating in ISECG
- Starting point is ISS, expending human presence into solar system and leading to human missions on surface of Mars
- Driven by set of goals and supporting objectives that reflect commonality, while reflecting individual agency's priorities

Global Exploration Roadmap

2013 2020 2030

International Space Station

General Research and Exploration
Preparatory Activities

Note: ISS partner agencies have agreed to use the ISS until at least 2020.

Commercial or Government Low-Earth Orbit Platforms and Missions

Robotic Missions to Discover and Prepare

LADEE
Luna-25
Chandrayaan-2
Luna-26
Luna 27
RESOLVE
SELENE-2
Luna 28/29
SELENE-3
Rosetta
Hayabusa2
OSIRIS-REx
Apophis
MAVEN
ISRO Mars
ExoMars
InSight
ExoMars
Mars 2020
JAXA Mars Precursor

Mars Sample Return and Precursor Opportunities

Human Missions Beyond Low-Earth Orbit

Explore Near-Earth Asteroid

Multiple Locations In the Lunar Vicinity

Extended Duration Crew Missions

Humans to Lunar Surface

Missions to Deep Space and Mars System

Sustainable Human Missions to Mars Surface

ISECG Mission Scenario

2020 2030

Low-Earth Orbit

International Space Station

Commercial or Government-Owned Platforms

Beyond Low-Earth Orbit

Test Missions

Robotic Mission
Human Mission
Cargo Mission

Near-Earth Objects

Rosetta
Hayabusa2 (Sample Return)
OSIRIS-REx (Sample Return)
Asteroid Redirection
Apophis
Explore Near-Earth Asteroid

Lunar Vicinity

Extended Duration Crew Missions
Staging Post for Crew to Lunar Surface
Potential Commercial Opportunities

Moon

LADEE
Luna 25
Chandrayaan-2
Luna 26
Luna 27
RESOLVE
SELENE-2
Luna 28/29 (Sample Return)
SELENE-3
Human-Assisted Sample Return
Humans to Lunar Surface
Potential Commercial Opportunities

Mars

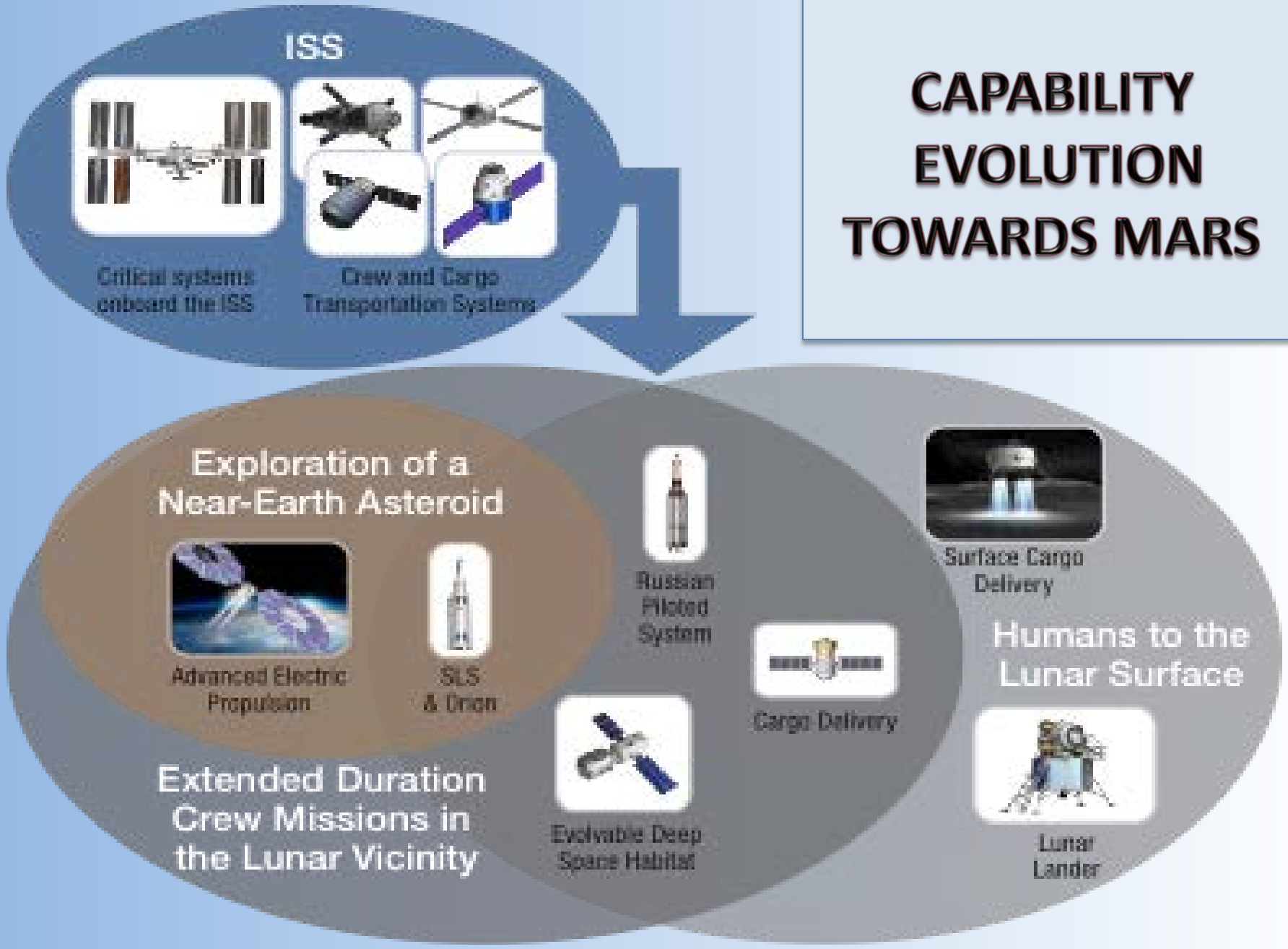
MAVEN
ISRO Mars Orbiter Mission
ExoMars 2016
InSight
ExoMars 2018
Mars 2020
JAXA Mars Precursor
Human-Assisted Sample Return
Mars Sample Return Mission Opportunities
Human Scale EDL Test Mission Opportunities
Sustainable Human Missions to the Mars System

Multi-Destination Transportation Capabilities
(Planned and Conceptual)

Orion & SLS
Russian Piloted System
Advanced Electric Propulsion
Evolvable Deep Space Habitat
Orion & SLS (Upgrade)
Initial Cargo Delivery
Small Cargo Lander
Human Surface Mobility
Crewed Lunar Lander
Orion & SLS (Upgrade)

Icon indicates first use opportunity.
Commercial/institutional launchers not shown.

CAPABILITY EVOLUTION TOWARDS MARS



Solar Electric Propulsion System

human-rated Moon Lander

evolvable Deep Space Habitat

ESA Council meeting at ministerial level, Luxemburg, December 2014

- **Resolution on Europe's space exploration strategy**
  - **ESA ambition to pursue a significant European contribution to the global exploration of space with a view to securing role on the critical path of international exploration programmes**
  - **Current three destinations that ESA includes in its exploration strategy are Low Earth Orbit (LEO), the Moon and Mars**
  - **Global cooperation through flexible partnerships: LEO exploration, including continuation of ISS cooperation (2024) and robust plan for the coordinated use of space transportation vehicles and systems for exploration purposes, participation in robotic missions for the exploration of the Moon, the robotic exploration of Mars, leading to a broad Mars Sample Return mission with Europe as a full partner, and human missions beyond LEO in the longer term**

ESA Mission Roadmap:

- ✧ Sustained exploitation of LEO (incl. ISS extension)
- ✧ Participation in sustained Moon exploration, incl. crew transportation to vicinity of moon (with NASA) and lunar surface access/sample return (with Russia)
- ✧ Participation in first mission to return samples from Mars

Note: ESA Roadmap fully coherent with ISECG developed Global Exploration Roadmap of August 2013 !

Implementing ESA‘s role

Inspiring a permanent International Moon Station

Exploration
Human & robotic
Moon Science
Cosmology / astronomy
Fundamental research
Transportation
Resource management
Mining
Communication
Technology
Pioneering
Stepping stone…
Tourism
Outreach /STEM

- **Free and open access, multiple uses and multiple users**

Initial Exploration Decisions in Europe

- To be taken at ESA Council meeting at Ministerial Level, scheduled for end-2016
- To be taken in conjunction with decision on ISS Exploitation extension to 2024
- To be coherent with the Global Exploration Roadmap (GER) and the ESA Space Exploration Strategy
- To use results from ISS Exploration Capability Study (IECS), mandated by ISS Partner's Heads of Agency (scenarios in Cislunar space for missions in 2022-2030 timeframe; critical technologies)
- To be complemented through cooperation with China
- To involve strategic partnerships with the private sector

Strategic Partnerships with Private Sector

- **ESA Call For Ideas (CFI): Space Exploration as a Driver for Growth and Competitiveness: Opportunities for the Private Sector (issued 01/03/2015)**
- **Strategic Partnerships as commitment between ESA and private sector, short/medium/long term, based on clear and mutually agreed objectives**
- **Potential areas and themes:**
  - ✧ **Low earth Orbit (LEO) infrastructures**
  - ✧ **Joint Research and Development**
  - ✧ **Exploiting the inspirational potential**
  - ✧ **Lunar and Mars Exploration (In-Situ Resources Utilization (ISRU))**

Sub-Orbital Spaceflight

- Ignored in Global Exploration Roadmap
- Several private industry initiatives with innovative designs
- Most promising projects:
  - X-15 (NASA; 1963 (!): > 100km)
  - Spaceship 2 (Virgin Galactic)
  - Lynx (XCOR)
  - New Shepard (Blue origin)
  - SOAR (Swiss Space Systems)
- Opens up edge of space for tourism, science and (?) launch platform for nano-/microsats
- Will 2016 be year of truth after years of promises and delays ?

Transportation and Operations in LEO

- Increasing role for "private industry" to develop and operate transportation services for cargo and crew to LEO and return to earth, both for ISS and post-ISS

- NASA pioneering approach with Commercial Resupply Services (COTS/CRS) contracts with Space X (Dragon/Falcon 9) and Orbital Sciences (Cygnus/ Taurus) for ISS cargo; possible new entrant: Sierra Nevada (Dream Chaser)

- Same approach in progress for crew transportation (Commercial Crew Transportation Capability (CCtCap): down select by NASA of Boeing (CST-100/Atlas 5) and SpaceX (Crew Dragon/Falcon 9 v1.1)

- Significant cost reductions expected: 58 M$ per seat versus 76 M$ (Soyouz)

- Also private industry initiative for modules in LEO: Bigelow Aerospace inflatable habitat; demonstrated in orbit and upcoming test on ISS

- No short/medium term initiatives by private industry in Europe, nor elsewhere (Russia, China, Japan, India,……..)

PROVIDERS

Boeing

Spacecraft:
CST-100

Launch Vehicle:
ULA Atlas V

Height:
171 Feet

Launch Pad:
Space Launch Complex 41

Destination:
International Space Station

Maximum potential value:
$4.2B

SpaceX

Spacecraft:
Crew Dragon

Launch Vehicle:
Falcon 9 v1.1

Height:
208 Feet

Launch Pad:
Launch Complex 39A

Destination:
International Space Station

Maximum potential value:
$2.6B

Transportation to Cislunar Space and beyond (1)

DRM	Approximate IMLEO (metric tons)
ARM	100
Earth-Moon L2	200
Asteroid in native orbit	200
Lunar sortie	400
Lunar outpost	900
Mars moons	400-800
Mars surface	900-1,300

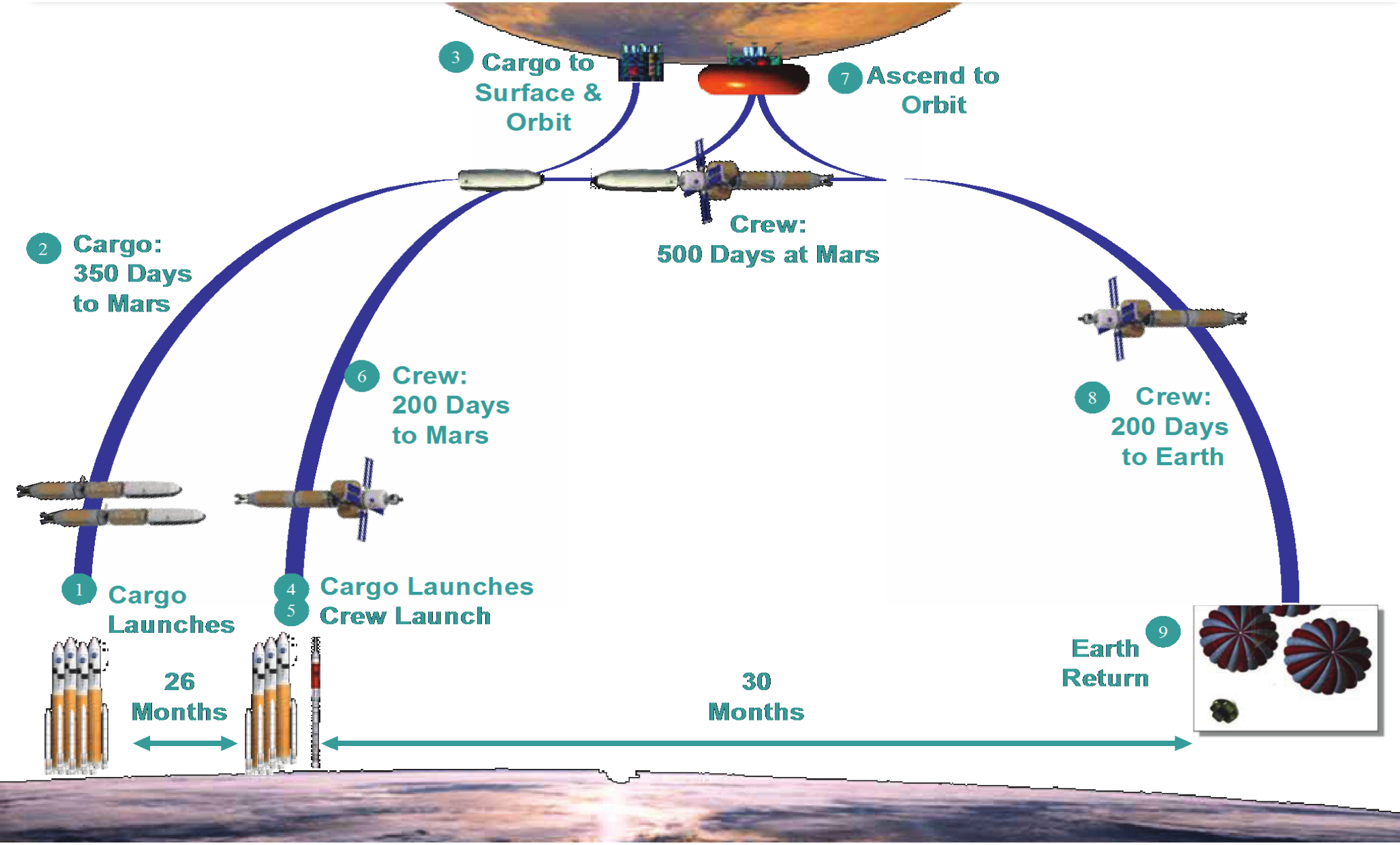
DRM: Design Reference Missions, as used by NASA

IMLEO: Initial Mass in LEO, including all launch mass needed up to and including first human launch

Lunar missions: includes habitat in lunar orbit as waypoint and docking station for reusable moon lander

Mars missions: actual value within range would depend on propulsion system chosen

Note: in-orbit mass ISS in LEO is 420 metric tons



Design Reference Mission for Human Landing on Mars (Source: NASA)

Transportation to Cislunar Space and beyond (2)

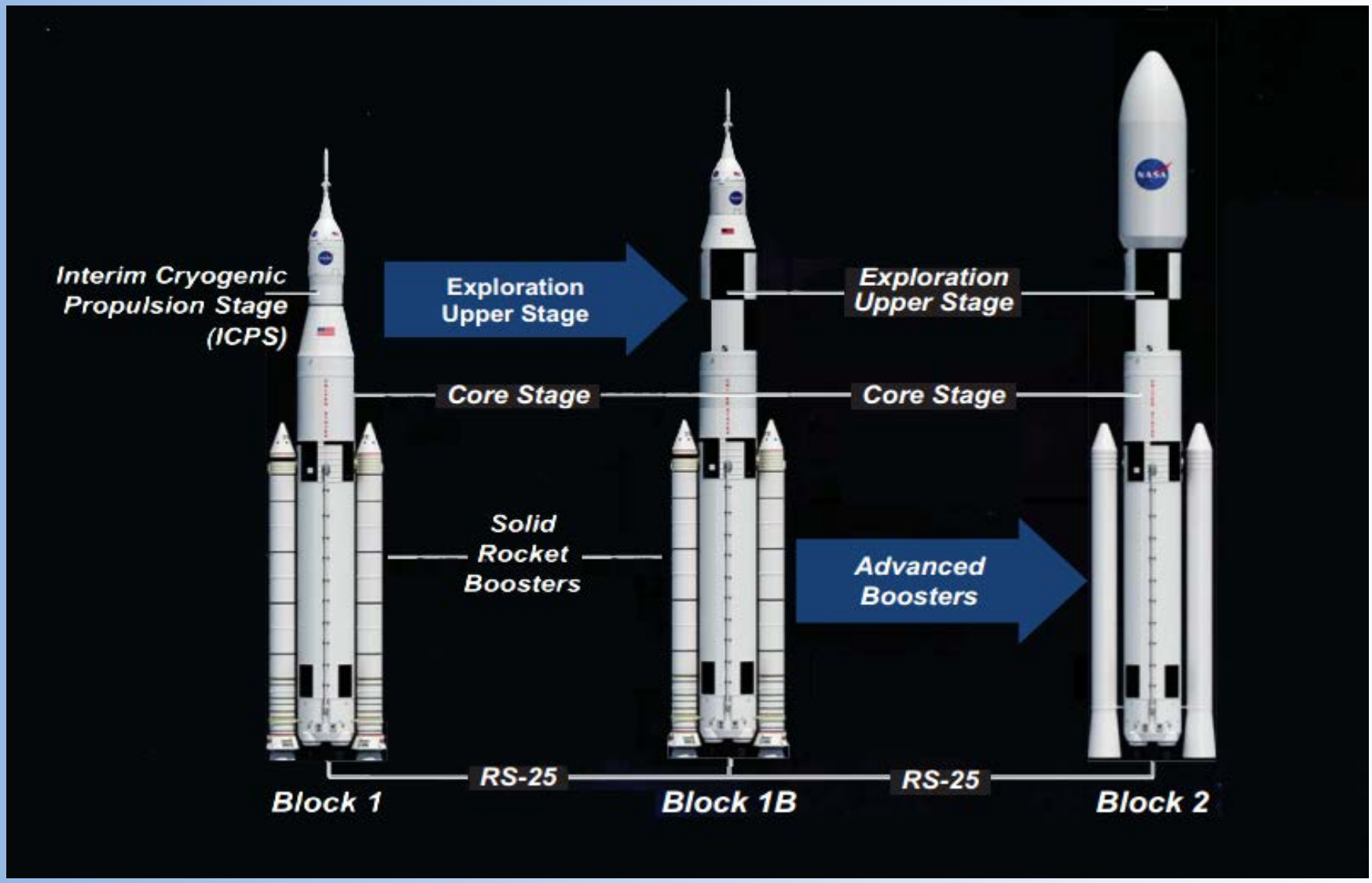
- Saturn V: launched 13 times between 1966 and 1973; 140 T to LEO or 48,6 T to TLI; project cost: 41.3 B$ (3.2 B$ per launch, at e.c. 2014)
- Need for heavy-lift launch vehicle reconfirmed in many blue ribbon studies
- Planned NASA SLS has LEO payload capacity of 70 – 130 T, depending on version
- Falcon Heavy (SpaceX) will have payload capacity of up to 53 T (cf. Ariane 5 ES with appr. 20 T)
- Alternatives to SLS: trade-off with more launches, more time in LEO, more docking events (with reduced mission reliability), more complex interface architecture with mass penalties, BUT commonality with existing launch systems reducing development and operations costs

Transportation to Cislunar Space and beyond (3)

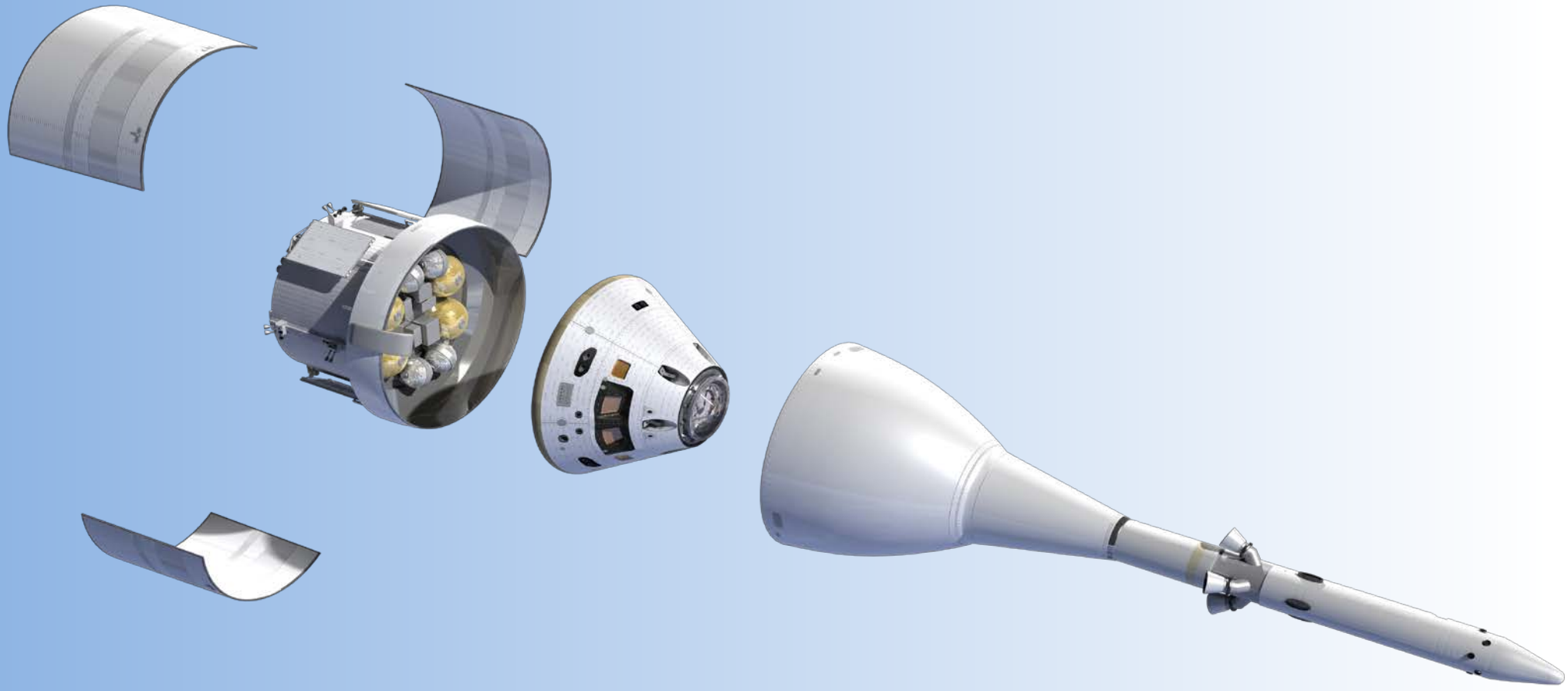
- **SLS business model and schedule: driven by projected costs and flat budget profile established for STS program instead of "normal" development funding profile; 2011 projected development cost (including ground-based infrastructure) of 12 B$ through 1st flight in late 2017**

- **Orion Multi-Purpose Crew Vehicle (MPCV): crew capsule for SLS to support human space exploration beyond LEO; projected 6 B$ development cost**

- **European Service Module (MPCV-ESM): developed by ESA for NASA's Orion MPCV, as barter element in context of ISS cooperation and based on demonstrated ATV development experience**



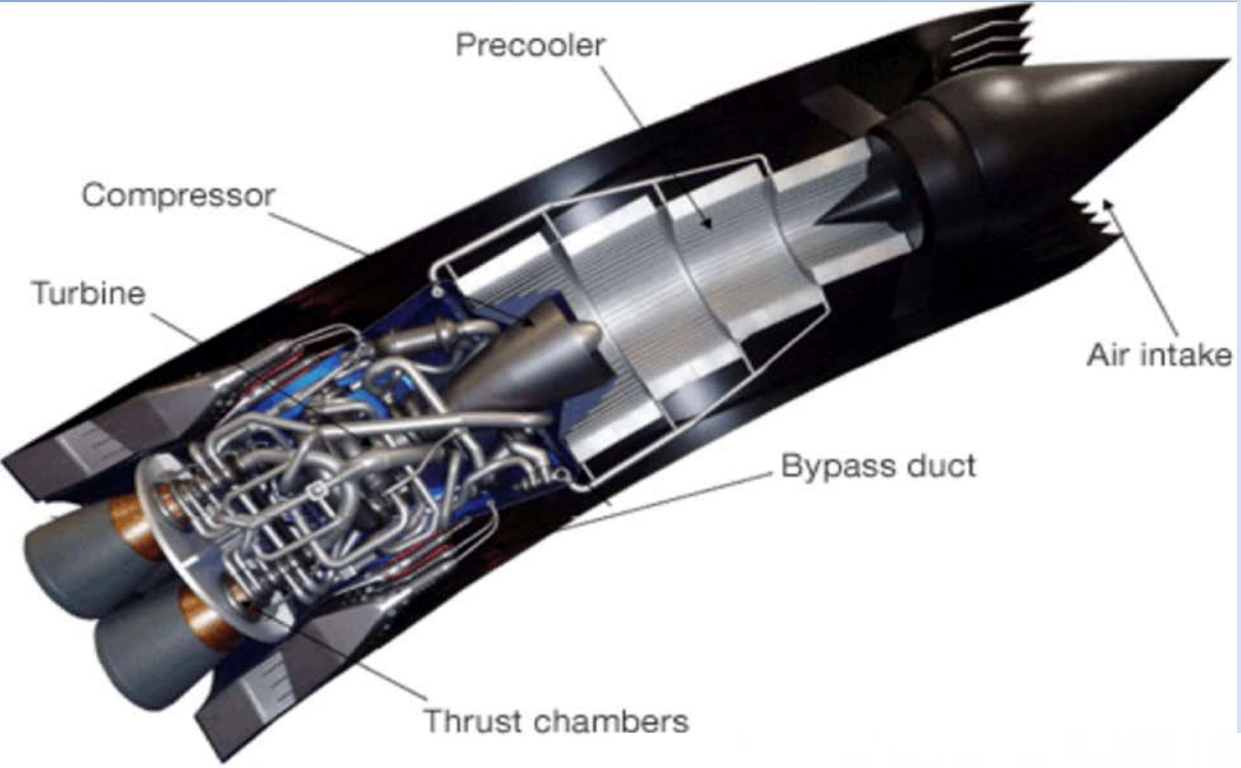
NASA Space Launch System (SLS) family



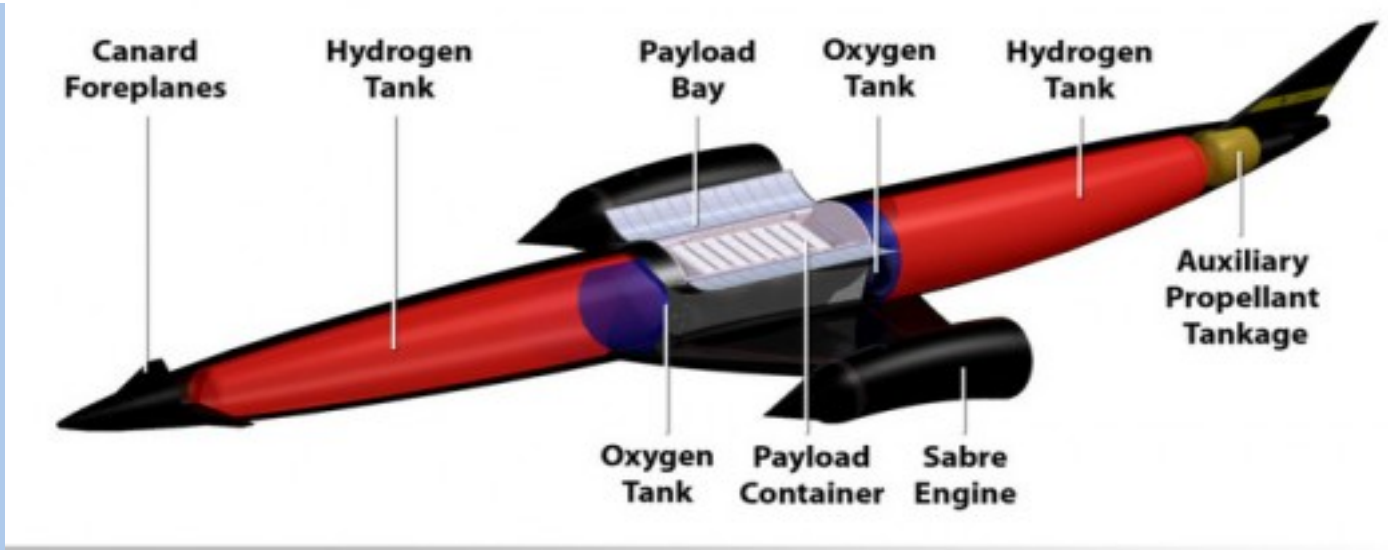
Orion Multi-Purpose Crew Vehicle (MPCV) with European Service Module (ESM)

Game changing concepts for Exploration

- **For LEO:**
  - **US Space Transportation System (Space Shuttle): 1981 – 2011, 5 vehicles, 135 missions, >350 astronauts; but, 2 fatal disasters and very high operating costs**
  - **Single Stage to Orbit (SSTO) Skylon with Synergetic Air Breathing Rocket Engines (SABRE)**
- **For Cislunar:**
  - **Solar Electric Propulsion (SEP)**
  - **Cryogenic propellant storage for long periods at minimal loss**
- **For deep space (including Mars):**
  - **Nuclear Thermal Propulsion (NTP)**
  - **Nuclear Electric Propulsion (NEP)**



Source: Reaction Engines



QUESTIONS ?

Source: courtesy NASA, Apollo 8