DLR / Airbus Defence & Space – Study
Free Flyer for Exploration in Cis-lunar Space

Intro to FISO Presentation

Dr. Juergen Hill, DLR Space Administration

June 17, 2015

Preface

- Human Spaceflight & Exploration in Europe
  - ISS-Utilization planned until at least 2020
  - Decision on the development of the European Service Module for MPCV
    ➔ Increased cis-lunar activities from 2021 (?)
  - Robotic exploration in partnership (ExoMars, Russian Lunar Programme?)

- German National Space Strategy defines:
  - Utilization/Exploitation (including scientific discovery) is the core of German space activities
  - Focus of human spaceflight on ISS
  - Exploration driven by clear scientific goals and enabled through robotics/automation

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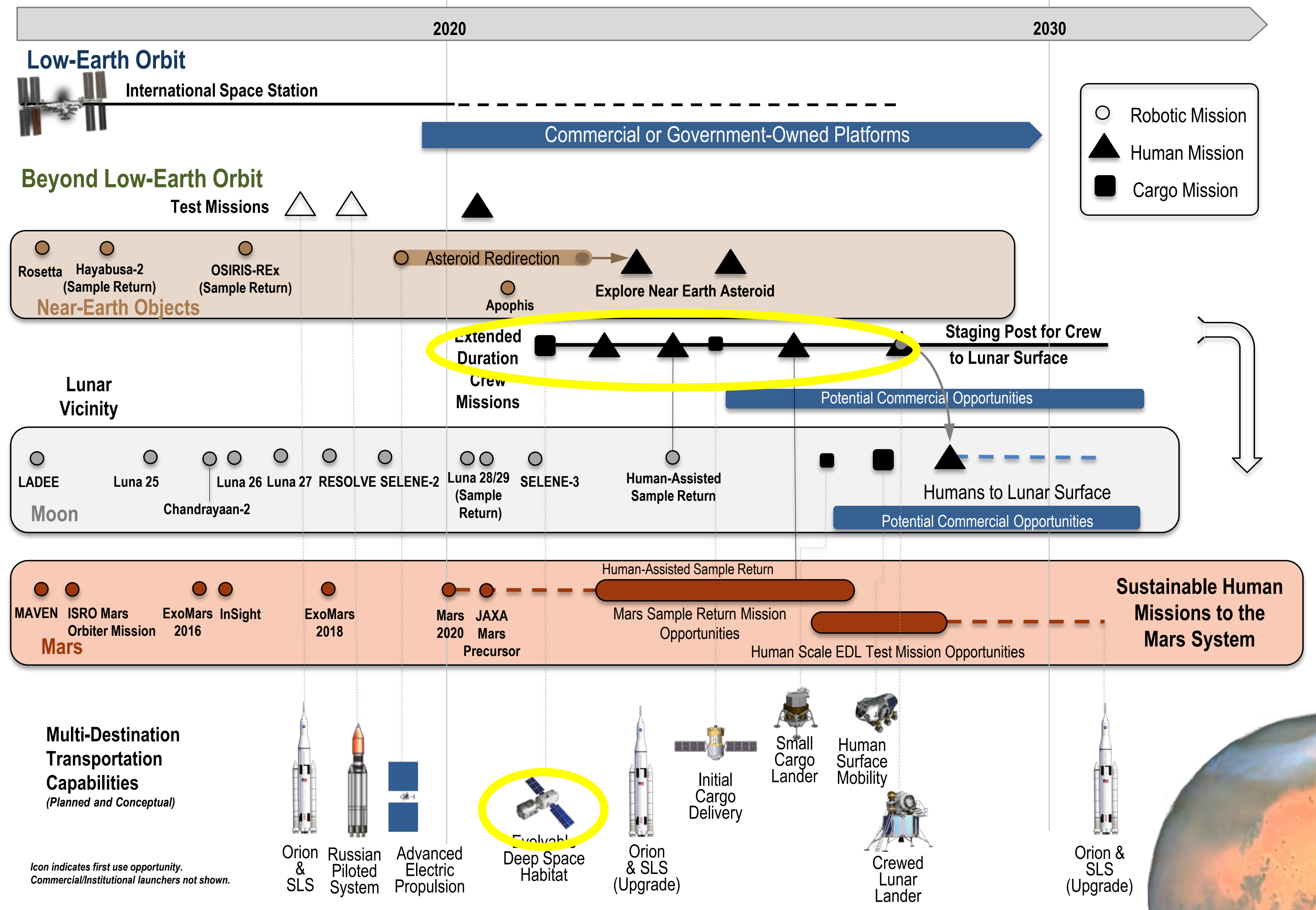
ISECG Mission Scenario



Freeflyer for Exploration (eDSH)

- Underlying questions:
  - microgravity research will not be driver for post-ISS human infrastructure in LEO
    ➔ how do we address life sciences research?
  - Institutional activities of human spaceflight post-ISS target beyond LEO destinations
    ➔ what role does Germany/Europe want to take?
    ➔ which research themes are possible that cannot be addressed in LEO?

- Objectives of the study:
  - Utilization aspects of German priority for freeflyer in Earth-Moon-Space
    ➔ which research themes are enabled?
  - Understanding of the technical concept of the freeflyer
    ➔ technologies? German/European competences? utilization aspects?
  - Identification of relevant contributions for Germany/Europe
    ➔ hardware for utilization? barter opportunities?

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The German Free Flyer Study: A European Perspective on an International Infrastructure in the Earth Moon Libration Point 2

Future In-Space Operations (FISO) Working Group

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17th June 2015

Study Objectives

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  - Utilization aspects of German priority for free flyer in Earth-Moon-Space
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Requirements for German Utilization of a Free Flyer Beyond LEO

Gravitational and radiation biology research:
- ➔ requires possibility for artificial gravity
- ➔ requires options for radiation protection
- ➔ requires orbit beyond LEO
- ➔ requires at least a 3 person crew (not permanent)
- ➔ requires a system life time of at least 5 years

Health and human performance, life sciences
- ➔ requires diagnostics and training equipment
- ➔ crewed missions: 30-270d

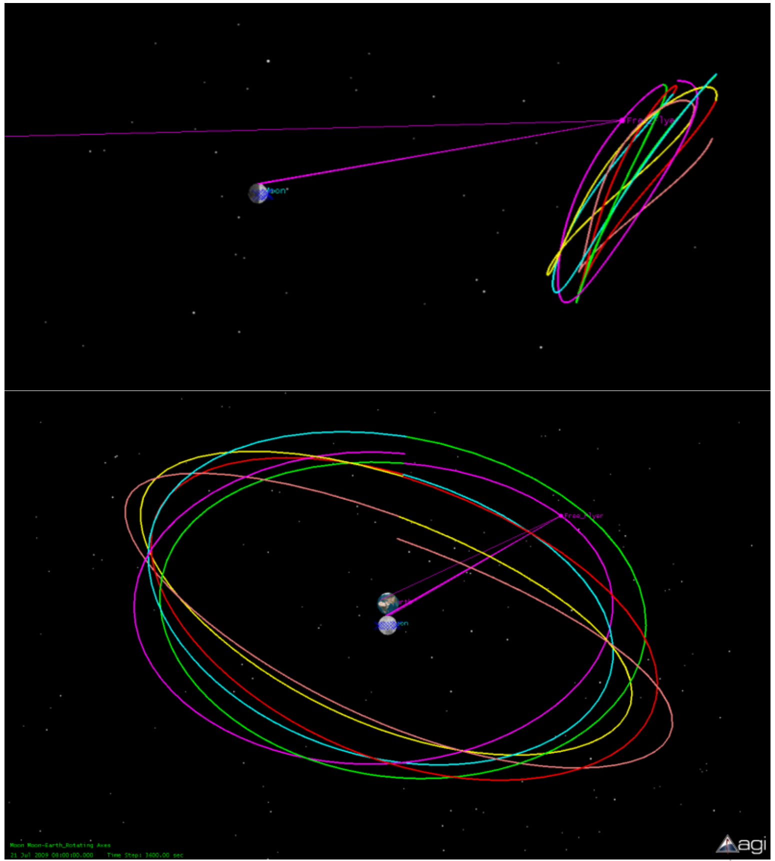
Advanced closed loop life support systems
- ➔ High water and oxygen loop closure to reduce logistic needs
- ➔ Biological systems for life cycle closure/food production as technology demonstration

Technology demonstration (exploration / terrestrial potential)
- ➔ requires opportunities for advanced systems testing

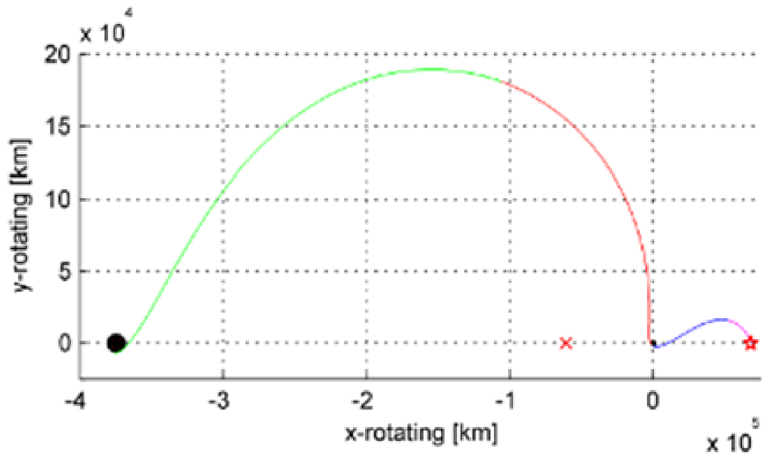
Automation and robotics
- ➔ requires opportunities for ops in non-manned phases and for interaction with robotic assets in cis-lunar space

Orbit Selection

- Considered orbital destinations for free flyer GEO, LLO, EML1/2, EML4/5
- EML2 defined as baseline:
  - Provides similar environmental (radiation) conditions as in interplanetary space
  - Enables the remote control as well as data relay to assets on the lunar far side
  - Can be reached with moderate ΔV using either lunar gravity assist for crewed missions or weak stability boundary transfers for cargo missions
  - However, the ΔV will be higher in any case as for LEO missions

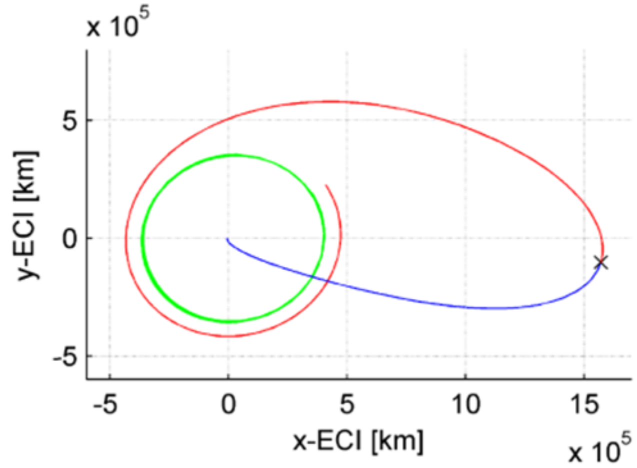


Lunar Gravity Assist Transfer



F. Renk, ESA ESOC

Weak Stabilty Boundary Transfer



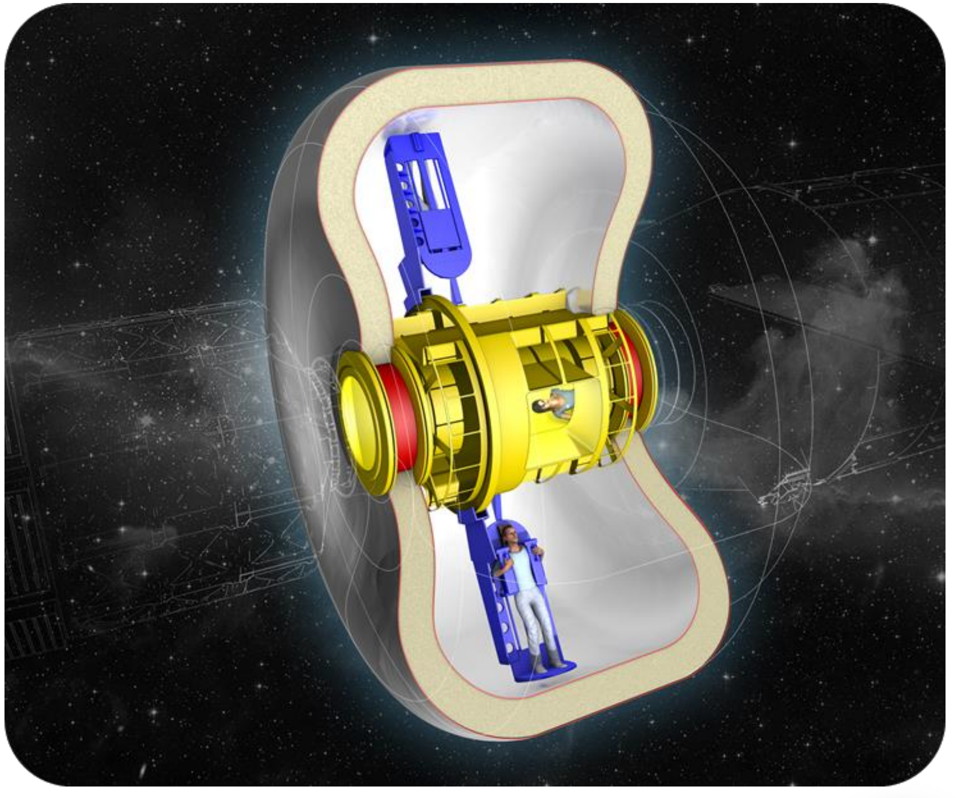
F. Renk, ESA ESOC

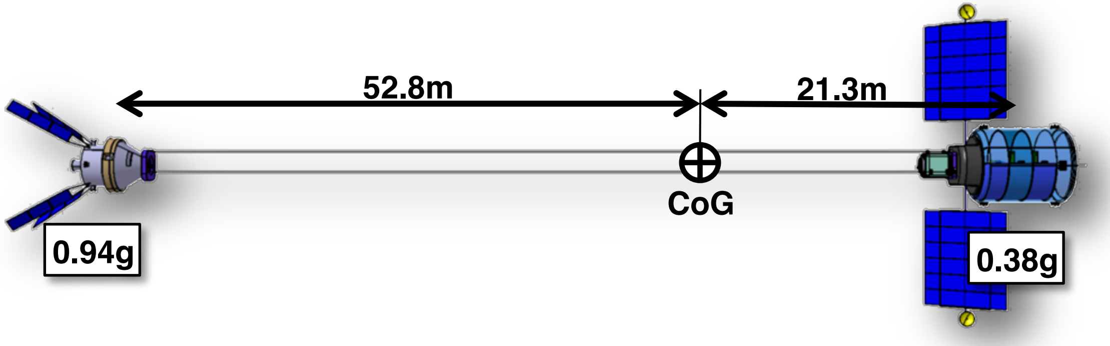
Artificial Gravity – A Main Design Driver

Artificial gravity can be created by means of centrifugal force

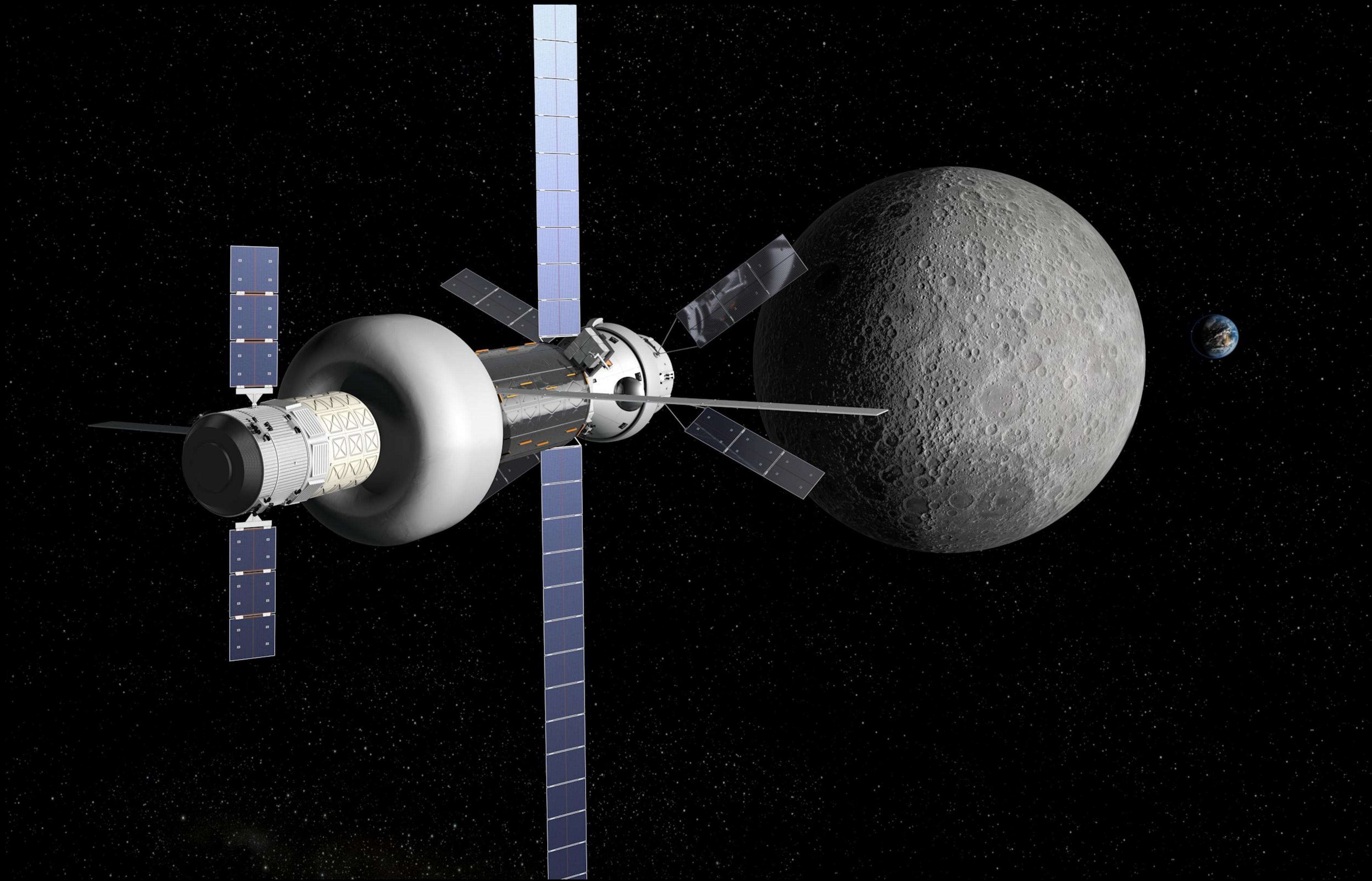
Two options exist:

- Short arm human centrifuge (SAHC):
  - Can be implemented in conventional, ISS like modules, but a larger diameter would be beneficial
  - Gravity level can be varied easily between 0-1.2 g
  - Crew members can be exposed only for limited periods
- Rotation of the entire habitat:
  - Crew is exposed continuously to artificial gravity
  - => crew can adapt to gravity level
  - => working in artificial gravity may reduce training need
  - But changing the gravity level requires additional propellant
  - Maximal gravity level has been constrained to 0.38 g (Mars gravity) for mass reasons



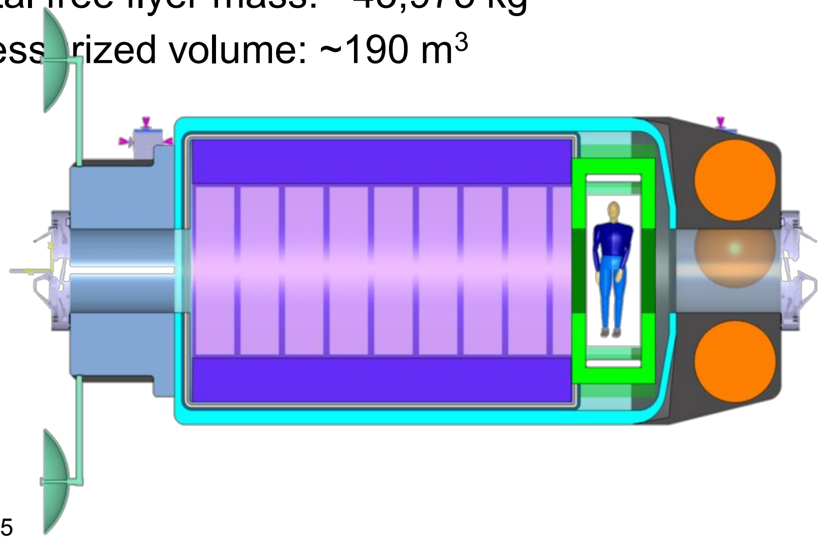


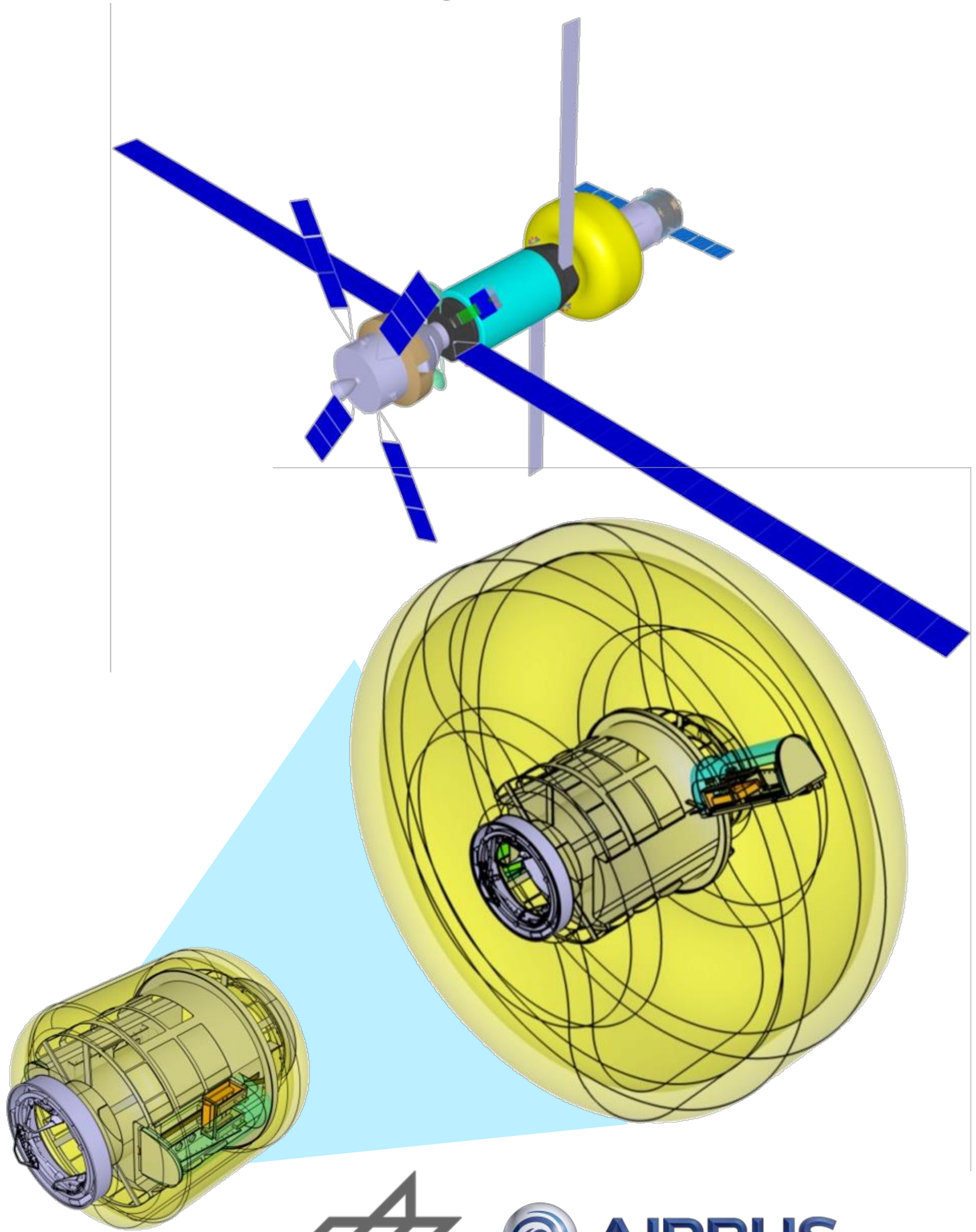
Concept 1: Free Flyer with Short Arm Human Centrifuge 1/2



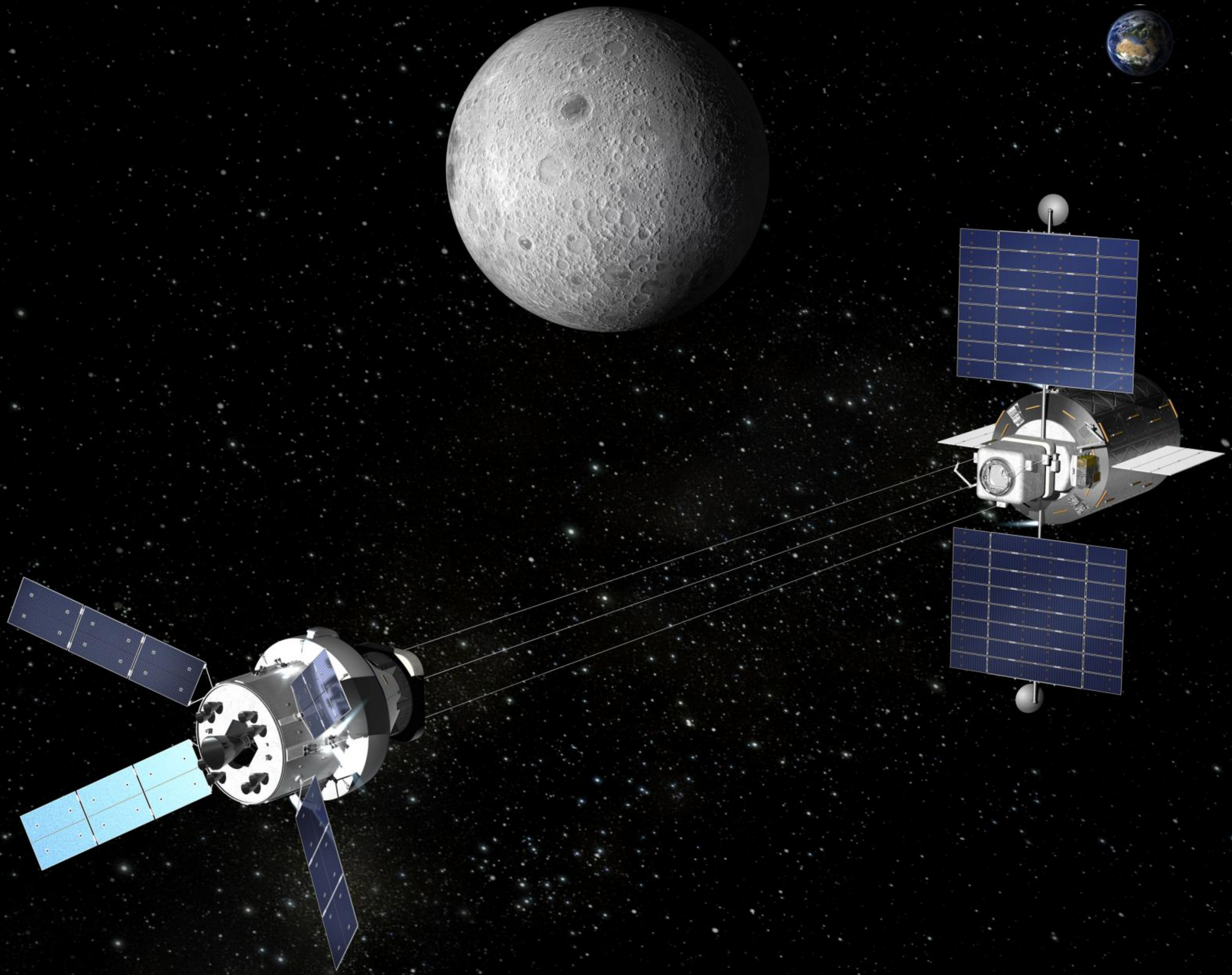
Concept 1: Free Flyer with Short Arm Human Centrifuge 2/2

- Conventional, rigid module (ø4.5 m, cyan), providing basic spacecraft functions and hosting experiments
- Inflatable module (ø8 m, yellow) hosts the centrifuge
  - Inflatable structure with flexible, multi-layer shell, filled with foam after inflation and hardened against UV radiation
  - Rigid core structure supports the inflatable part during launch, accommodates short arm centrifuge, and allows transit during centrifuge operation
- Key characteristics
  - Central module mass at launch: ~26,100 kg
  - Inflatable module mass at launch: ~5,200 kg
  - Total free flyer mass: ~43,975 kg
  - Pressurized volume: ~190 m^3



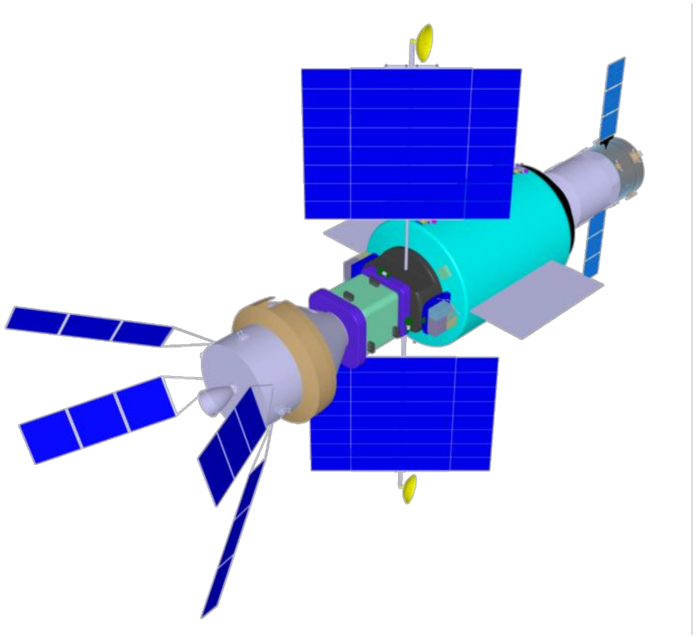


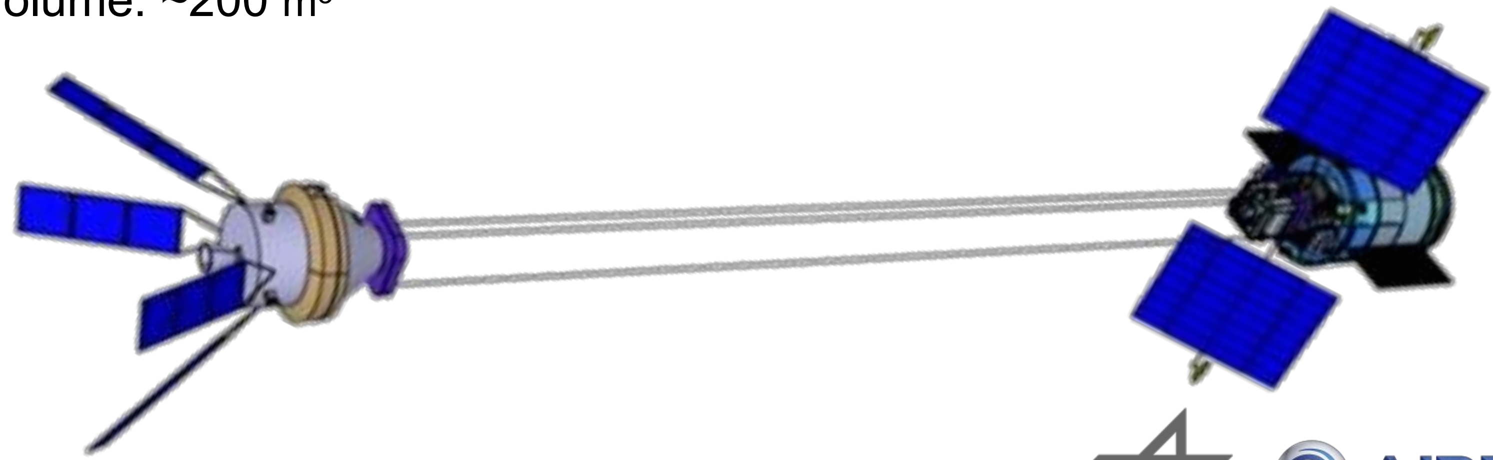
Concept 2: Rotation of the Entire Habitat 1/2



Concept 2: Rotation of the Entire Habitat 2/2

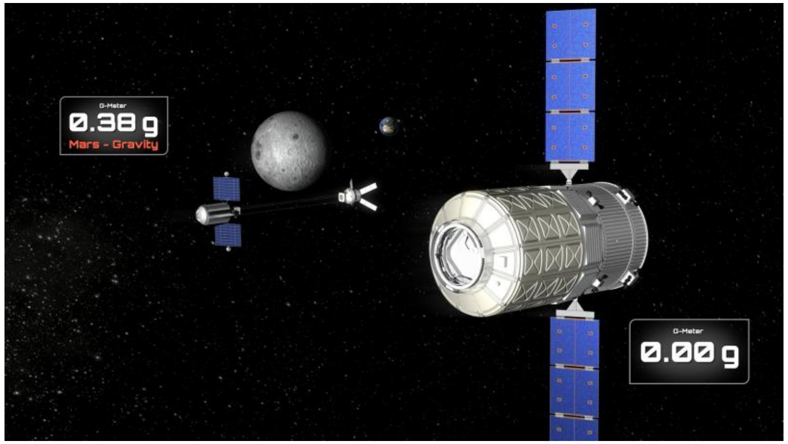
- Consists of habitat, MPCV, and a transfer module, rotating around common CoG
  → ~0.38g in habitat, ~1g in MPCV
- All spacecraft functions are integrated in the rigid habitat module (ø6.4 m, cyan), designed for µg and for 0.38 g
- A transfer module enables to deploy the tether connection and allows free flyer – MPCV crew transfer
- Key Characteristics
  - Central module mass at launch: ~31,800 kg
  - Total free flyer mass: ~55,000 kg
  - Pressurized volume: ~200 m^3

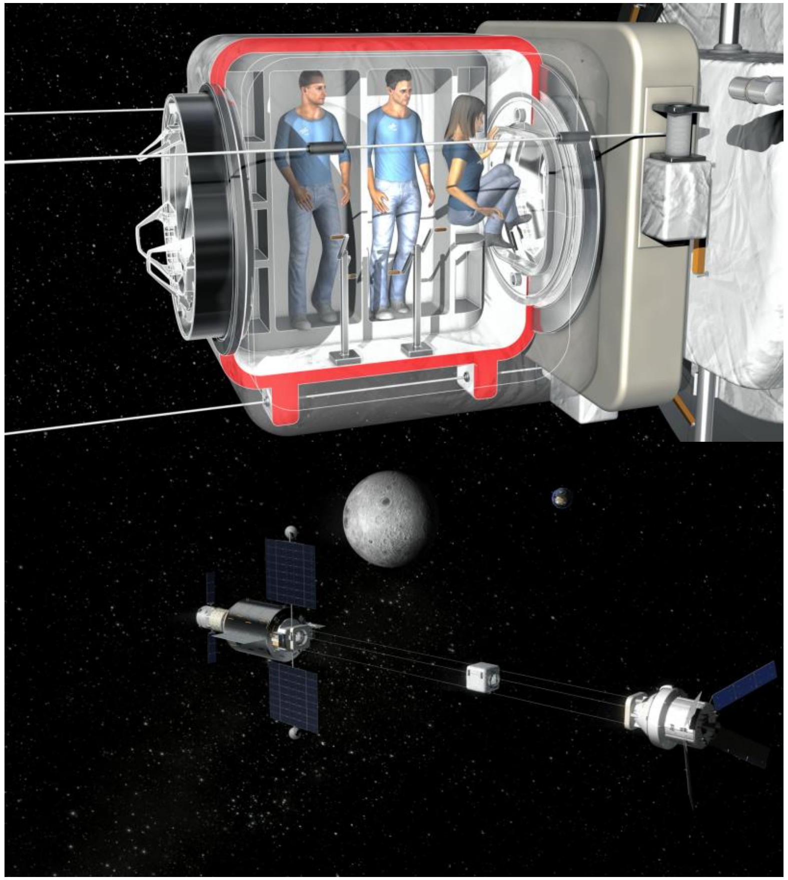




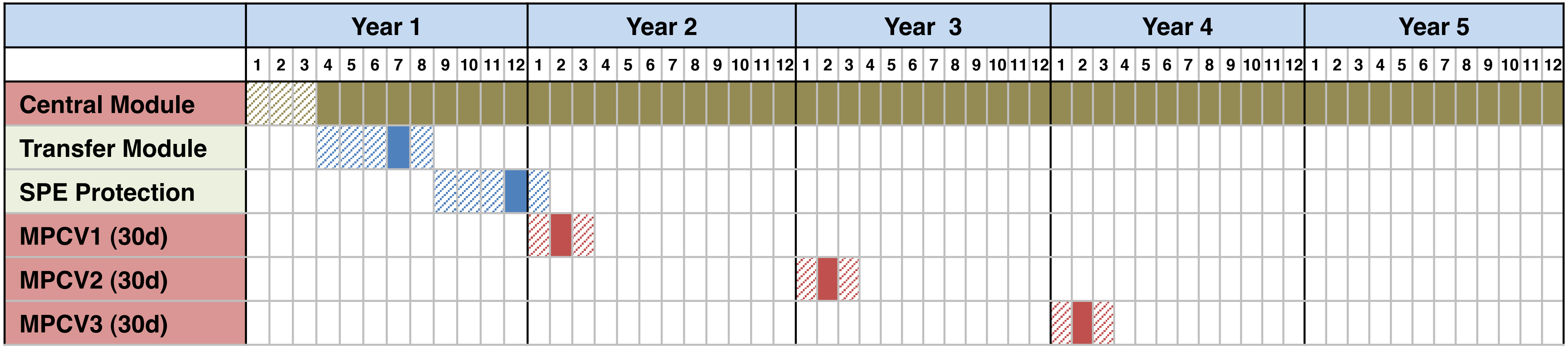
Concept 2: Operational Implications of Artificial Gravity

- Logistic vehicle has to undock before station spin up
- MPCV is used as counterweight to the free flyer
- Free flyer can be operated up to 4 rpm, providing Mars gravity inside habitat
- Logistic vehicle offer ~0 g environment and may be used for reference experiments
- After spin down, logistic vehicle may be re-docked and experiment samples extracted
- Payloads, placed inside MPCV, would be exposed to ~1 g
- During free flyer rotation, a pressurized cabin (transfer module) offers access to MPCV (contingency scenario), transfer module can move along the tether connection and dock to MPCV and habitat module





Concept 2: Logistics for Short Duration Missions



- Scenario foresees only 3 crewed missions
- Missions limited to 30 d to avoid need for protection against galactic cosmic rays (GCR)
- Protection against solar particle events (SPE) required in any case
- No artificial gravity during first crewed mission

Number of heavy lift launchers (~100t to LEO): 5

Number of heavy lift launchers (~50t to LEO): 2

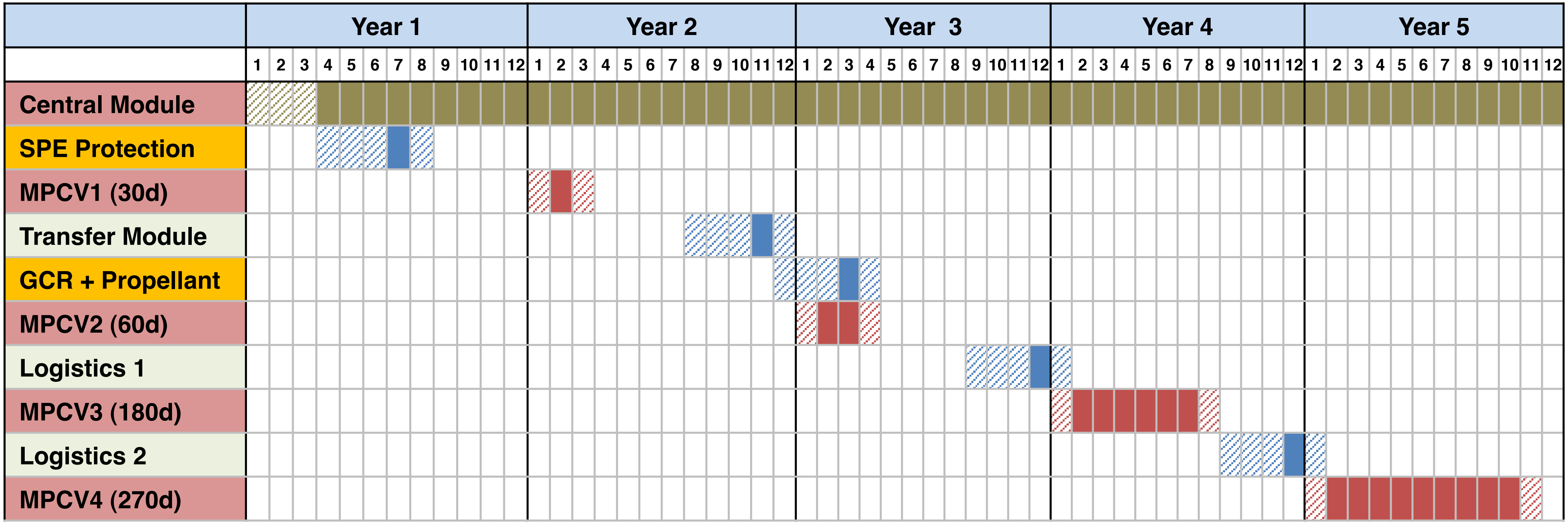
Number of medium lift launchers (~20t to LEO): 3

Robotic missions

Crewed missions

(Dashed: in transfer)

Concept 2: Logistics for Short Duration Missions



- Scenario foresees only 4 crewed missions
- Missions duration shall be increased gradually up to 270 d to simulate Earth - Mars transfer
- Spacecraft has to provide protection against SPE and GCR
- Later missions consists of 1 logistic flight + 1 crew flight

Number of heavy lift launchers (~100t to LEO): 5

Number of heavy lift launchers (~50t to LEO): 2

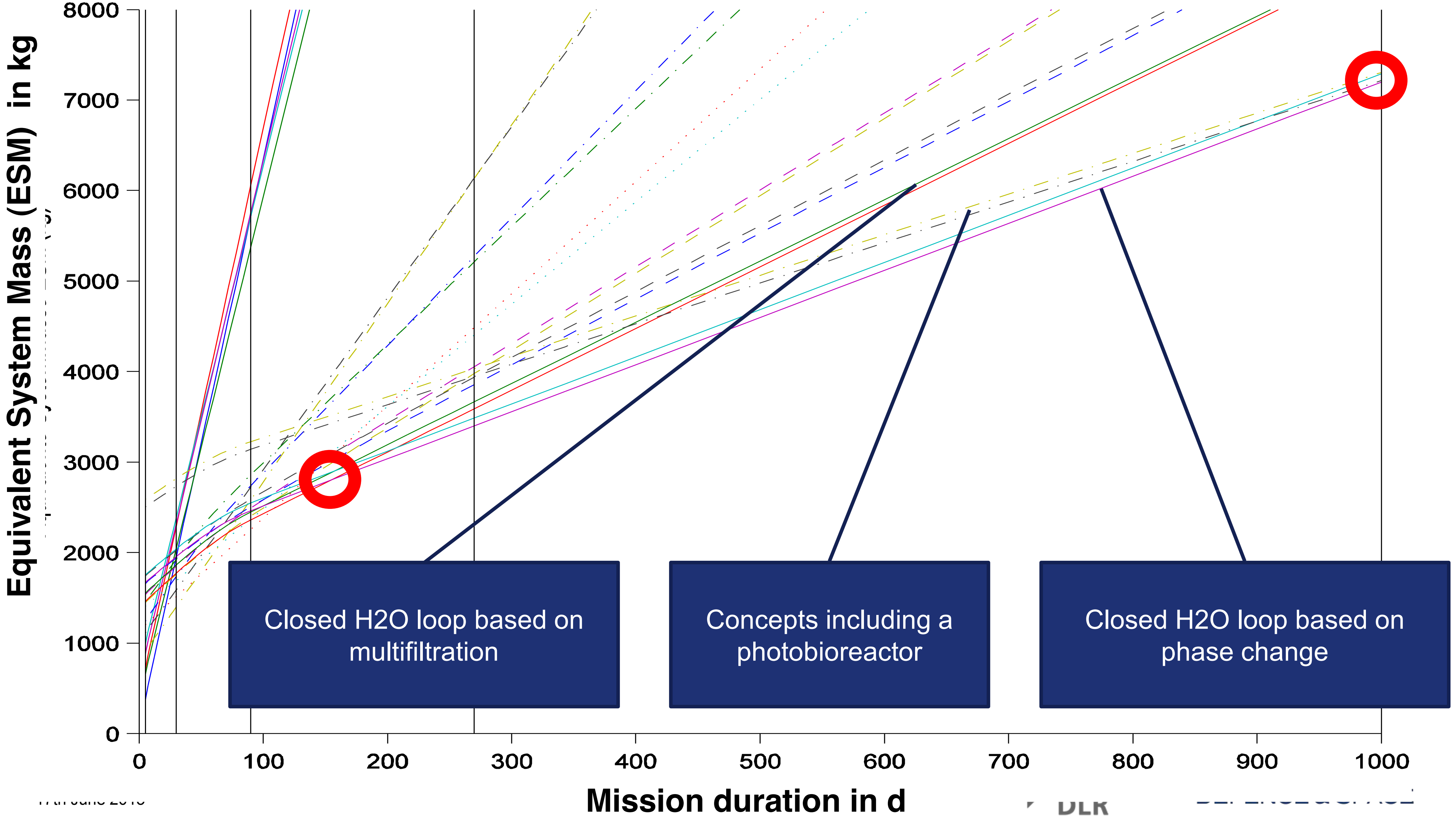
Number of medium lift launchers (~20t to LEO): 3

Robotic missions

Crewed missions

(Dashed: in transfer)

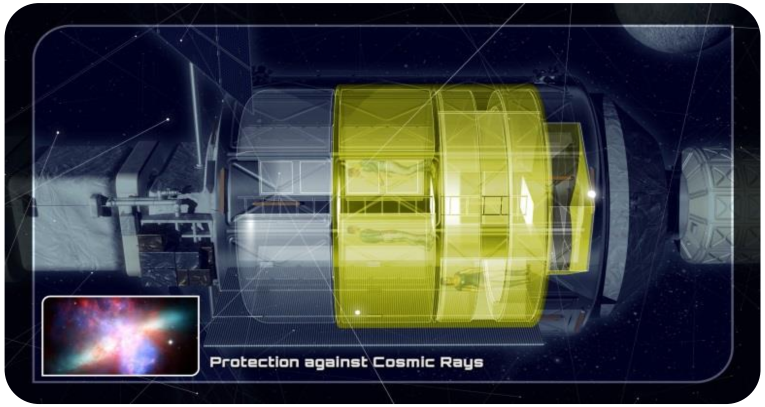
ECLSS Trade Off

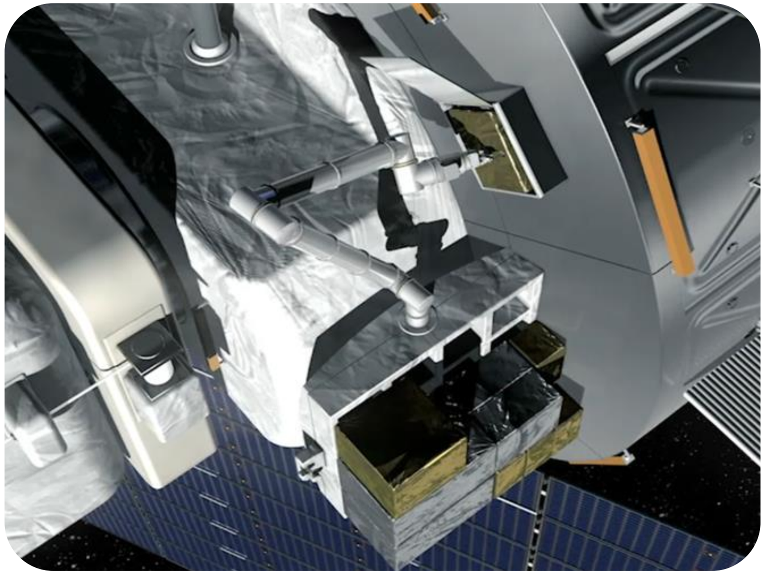


Radiation Shielding Aspects

Habitat internal layout

- Crew quarters, living room and kitchen shielded against galactic cosmic rays (GCR)
- ➔ Volume of ~115 m^3 protected by 8 g/cm^2 water (marked yellow)
- Radiation shelter protects crew during solar particle events (typical duration of 1d)
- ➔ Volume of 4.7 m^3 protected by 20 g/cm^2 water (marked green)
- Laboratory deck has no dedicated radiation protection, in particular used for radiation biology experiments
- External platform allows research in undisturbed interplanetary radiation conditions

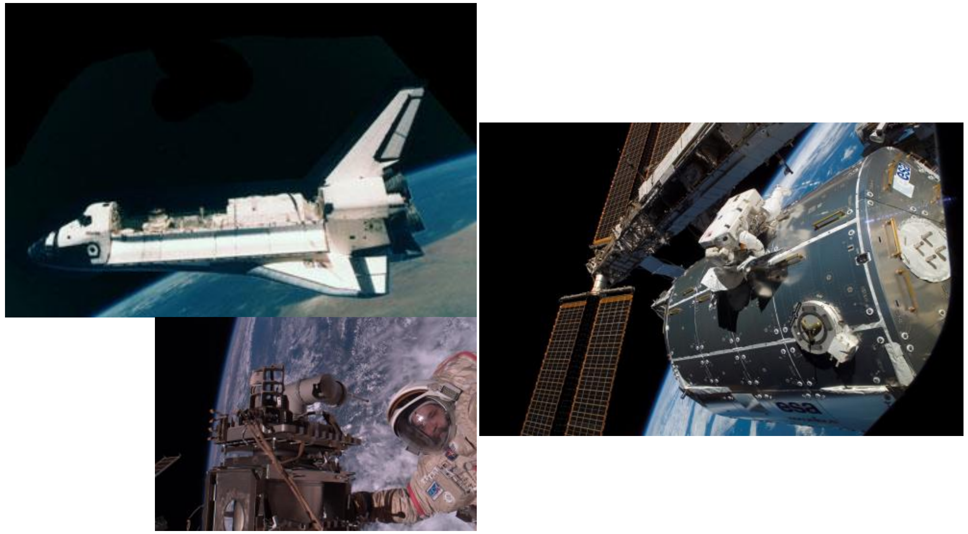




Areas of German / European Interest – Utilization Aspects

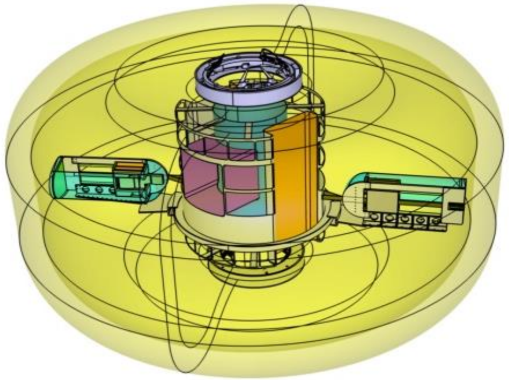
European Heritage:

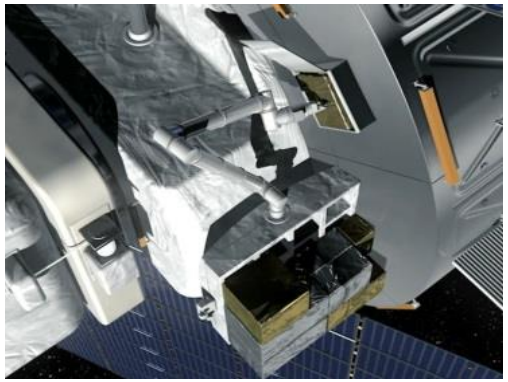
- Spacelab on Shuttle
- Robotic Experiments in Spacelab and ISS (ROTEX ROKVISS)
- Columbus incl. research facilities e.g. BIOLAB, Fluid Science Lab etc.

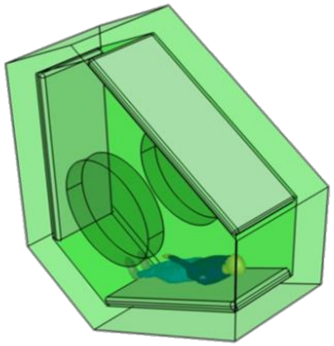


Utilization aspects

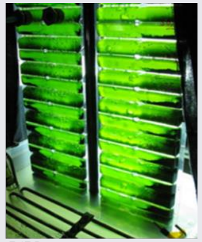
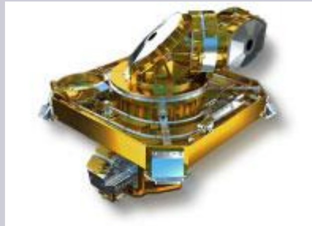
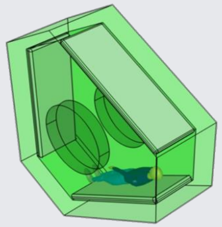
- Ability to generate artificial gravity
- Ability for experiments under various radiation levels
- Research under deep space radiation environment
- Experiments on external platforms with robotics
- Interaction with robotic assets (tele-operations) e.g. or lunar surface







Areas of German / European Interest – Operations & Technologies

Potential European Contributions	European Heritage	
Transportation and logistics	• ATV • Orion - ESM	 
Closed loop life support	• Advanced Closed Life Support System ACLS, (CO_2 recycling) • Photobioreactor	 © IRS  © DLR
Laser Communication	• European Data Relay Satellite System/Copernicus constellation	
Radiation protection for crew survival		

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Back up

Concept 1 – Mass and Size Aspects

		Mass (kg)	Size
Central Module	Dry mass incl. 20% sys. margin	19,025	**Span over solar array: 68.5 m** **Span over radiators: 32.5 m** **Overall length: 10.2 m** **Length of pressure shell: 7.2 m** **Diameter: 4.4 m** **Pressurized volume: ~90 m^3**
	Payload	2,280	
	Consumables	660	
	Propellant	4,025	
	Mass at launch	**26,085**	
	Water for SPE shelter	4,925	
	Water for GCR protection	7,760	
	Free Flyer incl. radiation protection	**38,770**	
Inflatable Module	Dry mass incl. 20% sys. margin	4,430	**Overall length: 3.3 m** **Diameter: 8 m** **Pressurized volume: ~100 m^3**
	Centrifuge	650	
	Consumables	130	
	Mass at launch	**5,210**	
Total Free Flyer Mass:		**43,980**	

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Concept 2 – Mass and Size Aspects

		Mass (kg)	Size
Central Module	Dry mass incl. 20% sys. margin	25675	**Span over solar array: 24 m** **Span over radiators: 12.5 m** **Overall length: 12.3 m** **Length of pressure shell: 9 m** **Diameter: 6.4 m** **Pressurized volume: ~200 m^3**
	Payload	2660	
	Consumables	660	
	Propellant	2790	
	Mass at launch	**31785**	
	Water for SPE shelter	5385	
	Water for GCR protection	9835	
	Additional propellant (for 5 yr mission)	4300	
	Free Flyer incl. radiation protection	**51305**	
Transfer Module	Dry mass incl. 20% sys. margin	3690	**Overall dimension:** **3.5 x 3.1 x 3.1 m** **Pressure shell dimensions:** **2.5 x 2.5 x 2.5 m**
	Mass at launch	**3690**	
Total Free Flyer Mass:		**54955**	

Rotating Space Station

- Rotating space station, consisting off
  - Resource + node module offering 2 docking ports along rotational axis
  - Science module
  - Crew habitat module
  - Inflatable, pressurized connection tunnels
  - Non-rotating platform for antennas and solar arrays
  - Station offers low g and 1/3 g conditions
- Option has not been investigated further, because
  - Very complex configuration and mechanisms => considered as not applicable to future human Mars missions
  - Objectives call for an outpost, limited in scope and life time => options is oversized