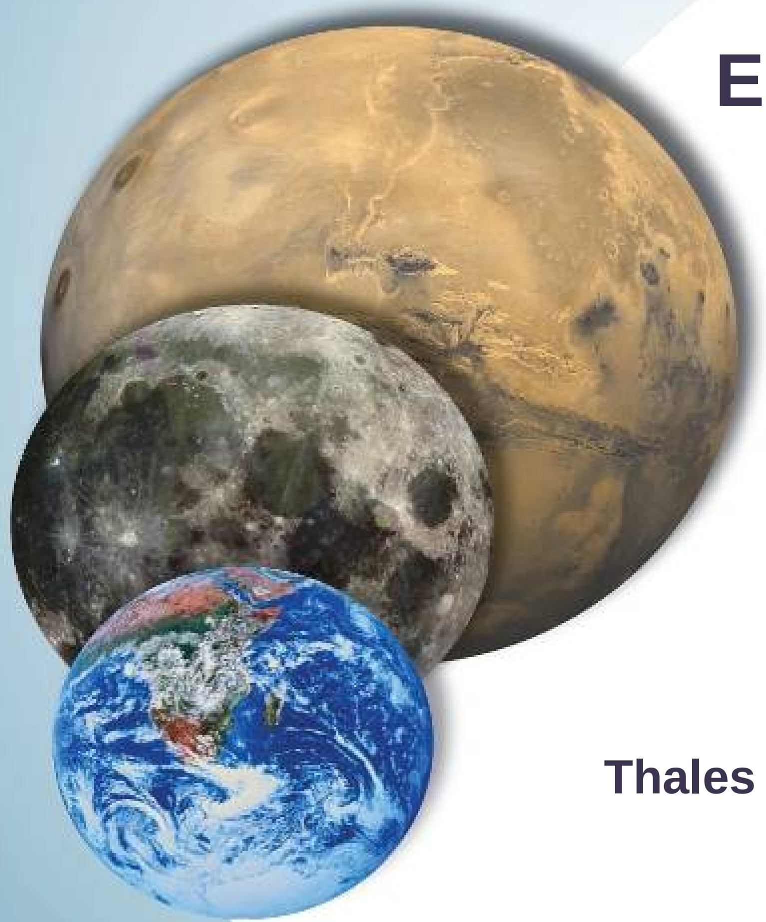
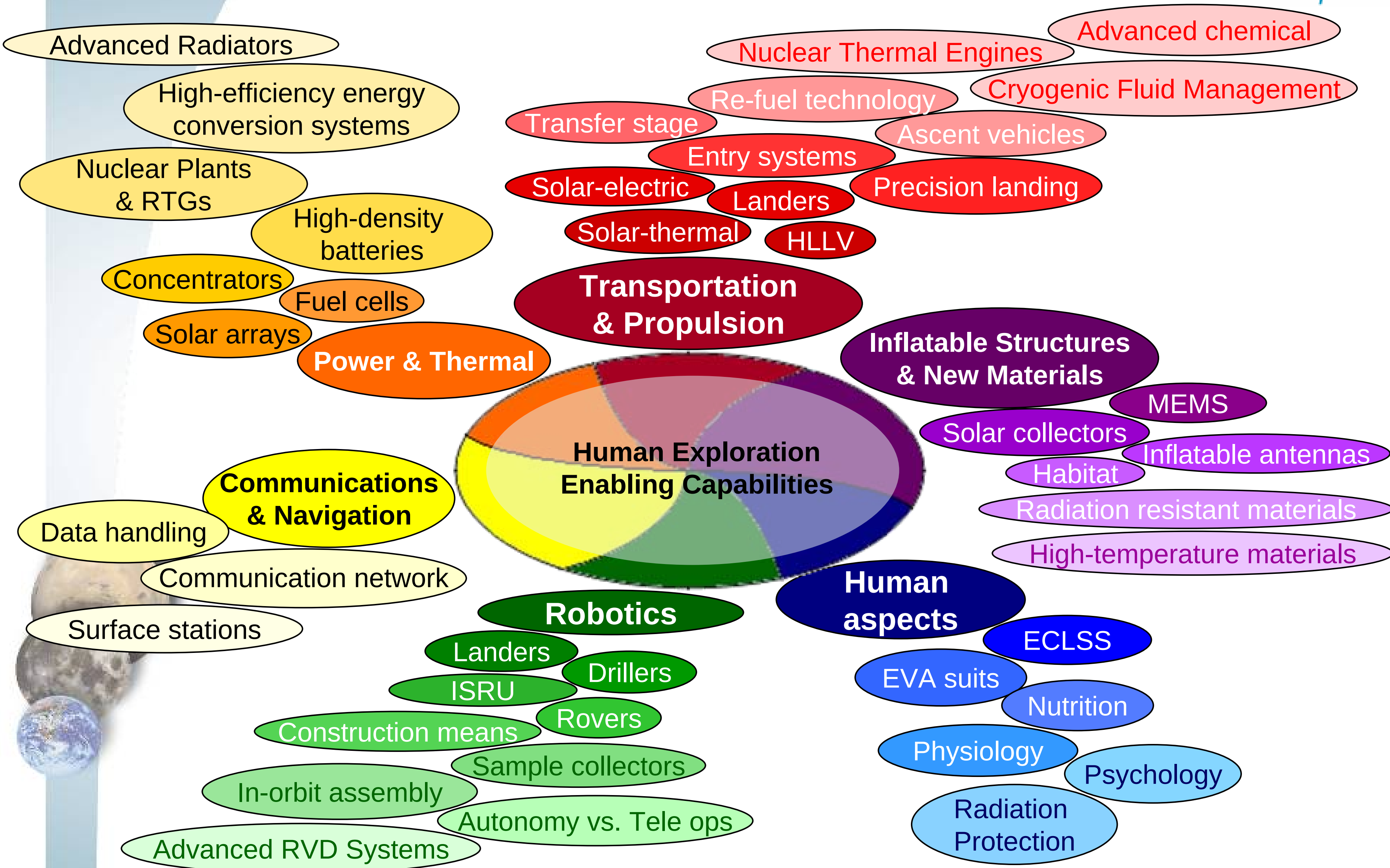
Enabling Capabilities



Thales Alenia Space, Mrs. M.A. Perino

ESA-ESRIN, 16 January 2009

Enabling Technologies



Objective:

- To develop a system allowing **automated rendezvous and docking** maneuvers in Moon/Mars orbit
- To reduce risk associated with relative navigation during **proximity operations** and docking

Tasks:

- Develop a Terminal Approach and Capture Strategy (MSR)
- Perform an In-Orbit Rendezvous (MSR)
- Rendezvous in elliptical orbits
- Approach to and Rendezvous with Minor Bodies (Rosetta)
- Gain knowledge on relative navigation for autonomous rendezvous beyond Earth orbit (MSR)

Objective:

- To develop an **autonomous landing GN&C** system for Moon/Mars crewed and cargo descent vehicles
- To develop an autonomous landing GN&C system capable of identifying and avoiding surface hazards to enable a **safe precision landing** (within tens of meters) at designated landing sites

Tasks:

- Improve available sensor technology
- Integrate achievable sensor capabilities with appropriate trajectory development
- Improve inadequate atmospheric knowledge and entry system aerodynamic uncertainties
- Perform analysis, simulations and sensor testing to define the required capabilities of an integrated manned system

Ablative Thermal Protection System

Objective:

- To develop a heat-shield design that meets **Mars Direct Return** re-entry requirements
- To develop new thermal protection systems to allow **Mars aerocapture** and atmospheric entry

The effort includes

- Develop new TPS materials
- Carefully investigate the interface between structures and attachments
- Gain knowledge on inflatable heat shield (materials, deployment mechanisms etc)
- Qualify thermal protection system materials in arc-jet tests and develop different heat shield prototypes

Cryogenics System Development

Objective:

- To develop a **cryogenic fuel management system** allowing the fuel containment and distribution during the long period associated to Moon/Mars missions (dewar tanks, active cryo-coolers, etc)
- To develop a **cryogenic throttable propulsion system** for Moon/Mars Ascent/Descent
- To develop a **cryogenic RCS system** for Moon/Mars Spacecrafts

Tasks:

- Improve the cryogenic fuel storage (for Ascent/Descent Modules)
- Improve the cryogenic fuel distribution (for all transportation building blocks)
- Design a cryogenic throttable propulsion system (for Ascent/Descent Modules)
- Design a cryogenic RCS system for Moon/Mars Spacecrafts (for all transportation building blocks)

Nuclear Propulsion

Objective:

- To develop powerful **nuclear thermal propulsion systems** to enable human and cargo missions to Mars
- To develop powerful **nuclear electric propulsion systems** to enable human and cargo missions to Mars

Tasks:

- Resurrect the experience gained during the NERVA project and advance the technology augmenting the performances and reducing the engine mass
- Identify new lightweight materials able to shield the crew from the reactor radiations
- Investigate the possibility to reutilize the nuclear reactor
- Improve the knowledge in ion and MPD engines augmenting the performances and increasing the operational life
- Reassure public opinion about the limited hazards related to nuclear in space

Power Systems

Objective:

- To develop an **advanced power conversion system** from nuclear to electric (i.e. based on a Brayton cycle) to produce the needed energy for the different Mars Architecture building blocks
- To intensify the development of **advanced solar arrays, fuel cells and batteries** having increased performances w.r.t. actual ones

Tasks:

- Identify new materials able to increase the power conversion and storage efficiency
- Identify critical subsystems and components to be further developed
- Improve materials resistance or identify new materials able to withstand the high temperatures and stresses associated to this technology
- Plan tests to validate this technology for space applications

Energy Storage

Objective:

- To advance battery and fuel cell technology to meet critical energy storage needs
- To develop and demonstrate **advanced lithium-ion battery technology** for human-rated systems
- To develop and demonstrate **advanced Fuel Cell technology** for human-rated systems

Tasks:

- Advance lithium-ion battery technology increasing safety, specific energy, energy density, and temperature tolerance
- Advance FlowThru Proton Exchange Membrane Fuel Cell (PEMFC) systems by replacing active balance-of-plant components with passive components
- Advance Non-FlowThru PEMFC systems by eliminating most balance-of-plant components altogether
- Investigate potential reduction in weight and complexity, and increased reliability and life for both primary fuel cell systems and Regenerative Fuel Cell (RFC) energy storage systems
- Develop different classes of fuel cells for Exploration missions:
    - Low (1-kW class) for advanced EVA portable life support systems
    - Medium (8-kW class) for un-pressurized rovers
    - High energy (25-kW class) for power plants and pressurized rovers

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Objective:

- To develop **advanced thermal control systems** designed for use on Moon/Mars surface missions

Tasks:

- Gain knowledge on long duration thermal control fluid stability for Moon/Mars outpost
- Re-design systems to reduce heat exchangers and pumps mass (i.e. using new materials)
- Advance the expertise on Evaporative Heat Sinks for future vehicles and space suit
- Design radiators for surface applications taking into account the effects of dust and the surface radiation environment.

Electronics Systems

Objective:

- To advance the electronics systems increasing the performances and **augmenting the radiation-hardness** to enable long missions and reliable vehicle operations in the extreme radiation and temperature environment of planetary exploration missions.

Tasks:

- Develop critical electronic components to operate reliably in space or planetary environment (i.e. SiGe Integrated Electronics)
- Improve high-performance radiation hardened processors' capabilities
- Develop model to diagnose the causes of Single Event Effects and tools to support real-time prediction of component reliability
- Provide reconfigurable computing capability (this will reduce the flight spares and provision for circuit life limitation)

Objective:

- To develop **lightweight primary structures** for both the pressurized and un-pressurized elements
- To develop **low-temperature mechanisms** to allow operations in low temperatures environments

Tasks:

- Advance manufacture capability of Al-Li alloys for lightweight primary structures (i.e. spun form domes)
- Gain knowledge and expertise on inflatable structures
- Advance the expertise on composite structures
- Gain knowledge on flexible radiation shielding structures
- Develop low temperature mechanisms
- Gain knowledge on human mission scaled braking parachutes

Planetary Environment: Dust

Objective:

- To better characterize Moon/Mars environment (regolith, temperatures, storms, etc)
- To develop valid **countermeasures to Moon/Mars dust** (i.e. seals, more resistant materials etc)

Tasks:

- Complete the Moon/Mars regolith and environment characterization
- Develop mechanical components and seals having augmented resistance to the dust aggressiveness
- Develop innovative concepts for dust mitigation for Habitat/Airlocks and for surface system applications
- Advance the characterization of the Moon/Mars regolith simulant

In-Situ Resource Utilization (ISRU)

Objective:

- To develop and mature pilot and production systems for **local resources extraction**
- To develop the technologies to permit the **indigenous water/fuel production**, storage and distribution
- To **validate the physical and chemical processes** using Moon/Mars simulants and in Moon/Martian simulated environments

Tasks:

- Develop Moon/Mars Regolith Excavation & Material Handling
- Advance methodologies for Oxygen Production from Moon/Mars Regolith
- Advance volatile/Water Extraction & Production and Resource Prospecting
- Design a pilot plant to validate ISRU operations
- Design a production, storage and distribution architecture applicable on Moon/Mars surface

Objective:

To develop **robotics to aid humans** operating on the Moon/Mars surface (Mobility, Sample handling, Human Systems interaction)

Tasks:

- Reutilize the experience gained during the Apollo mission to design an Un-pressurized rover supporting human operations
- Design a pressurized rover to sustain human exploration on the Moon and Mars surface
- Design a large scale offloading/handling element to manage the habitats required for a manned mission
- Improve the Man-Machine interfaces in both the surface and in-space environments

Environment Control & Life Support System

Objective:

- To identify, develop and mature a suite of environmental control and life support system technologies
- To develop the technologies to **ensure fire safety** on exploration vehicles and habitats
- To **use ISS** to demonstrate and validate **monitoring technology**

Tasks:

- Advance the expertise on regenerative systems for food and oxygen production
- Develop more efficient biological waste management systems
- Develop new systems capable of detecting and removing possible microbial contamination in the pressurized cabin
- Provide material flammability tests relevant to the different exploration conditions (microgravity and on surface)
- Provide reliable fire detection and suppression systems in all exploration environments

EVA Suit

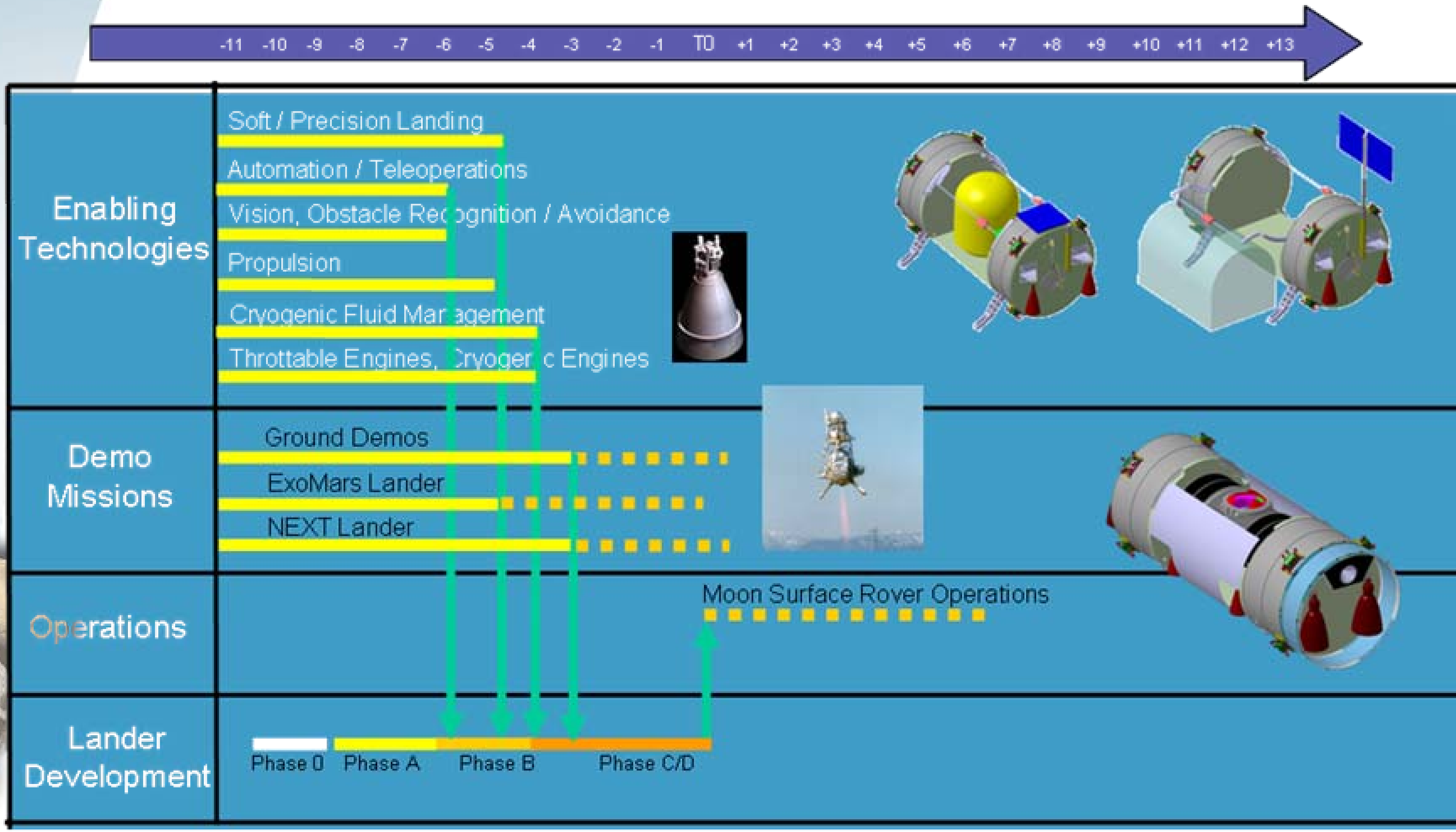
Objective:

- To develop a **new concept of EVA suit** to facilitate crew operations on the Moon/Mars surface
- To **increase the autonomy** of the EVA suit
- To **minimize** the **pre- and post-EVA operations** duration

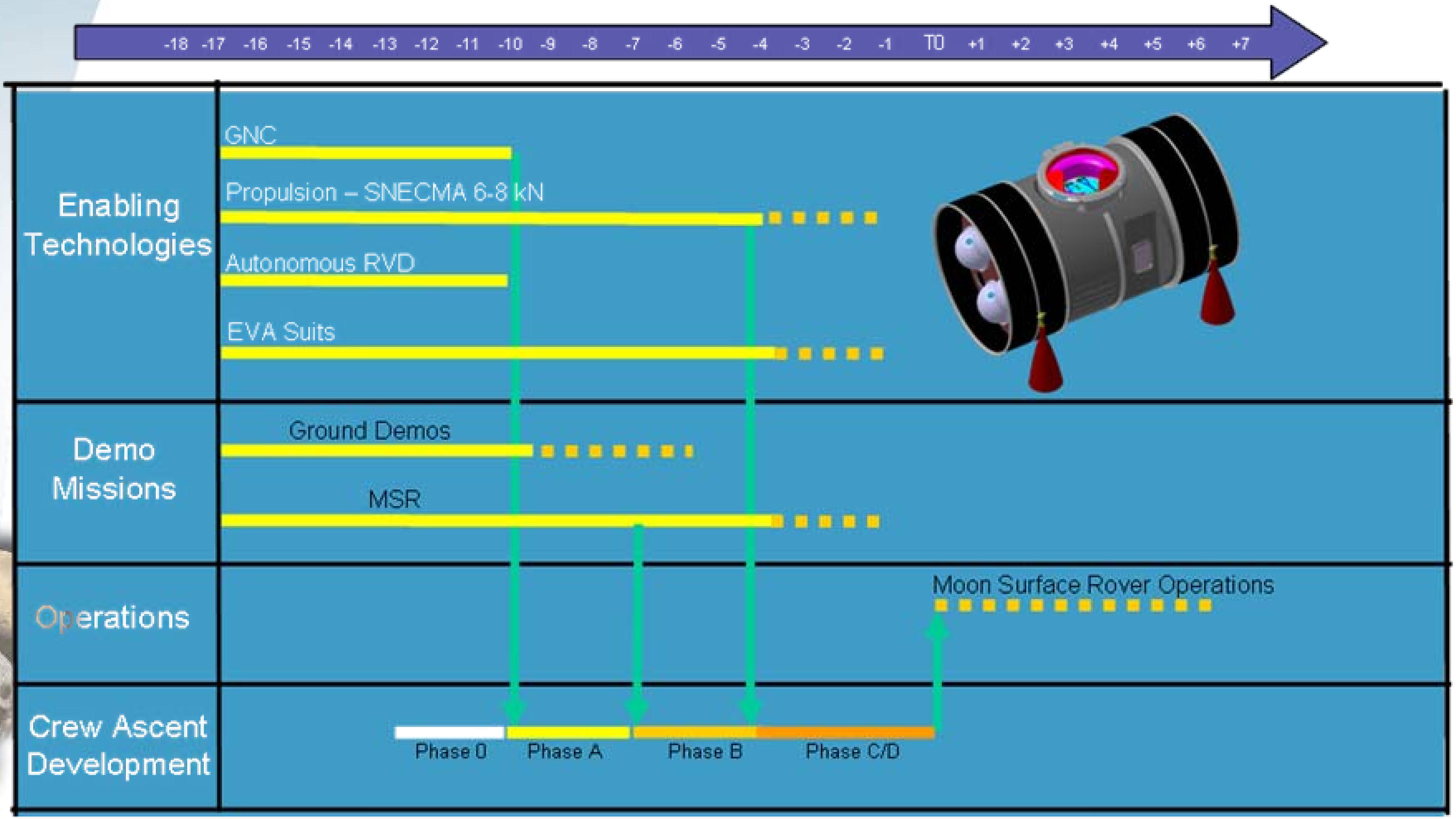
Tasks:

- Design a new type of planetary EVA suit
- Re-design the life support subsystems (i.e. thermal, oxygen supply, ventilation systems)
- Advance the battery development to increase the autonomy and decreasing the weight and the recharging time
- Further investigate the necessity to adopt a rear entry suit/airlock interface instead of the classical airlock solution

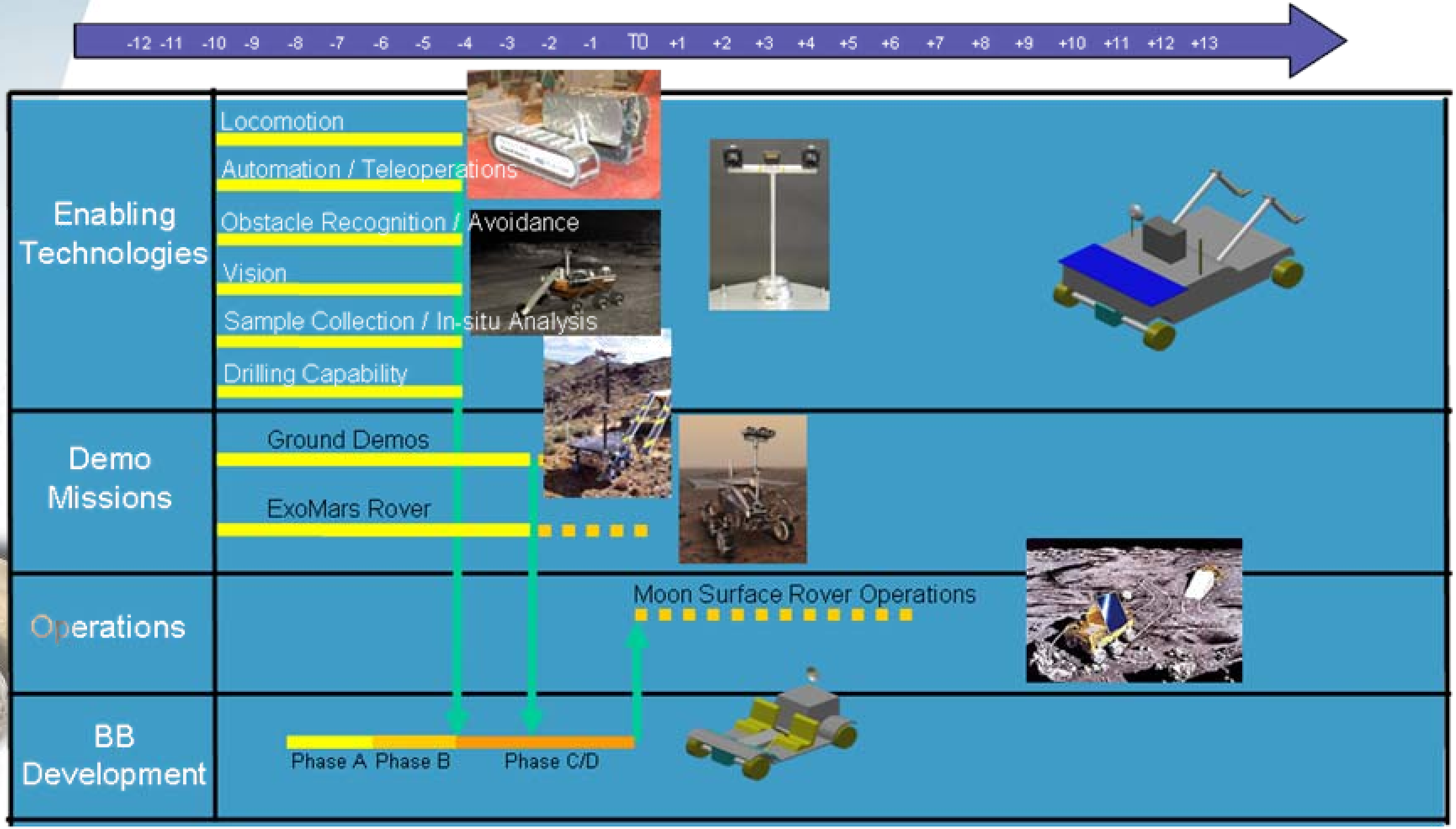
Landing Technology Roadmap



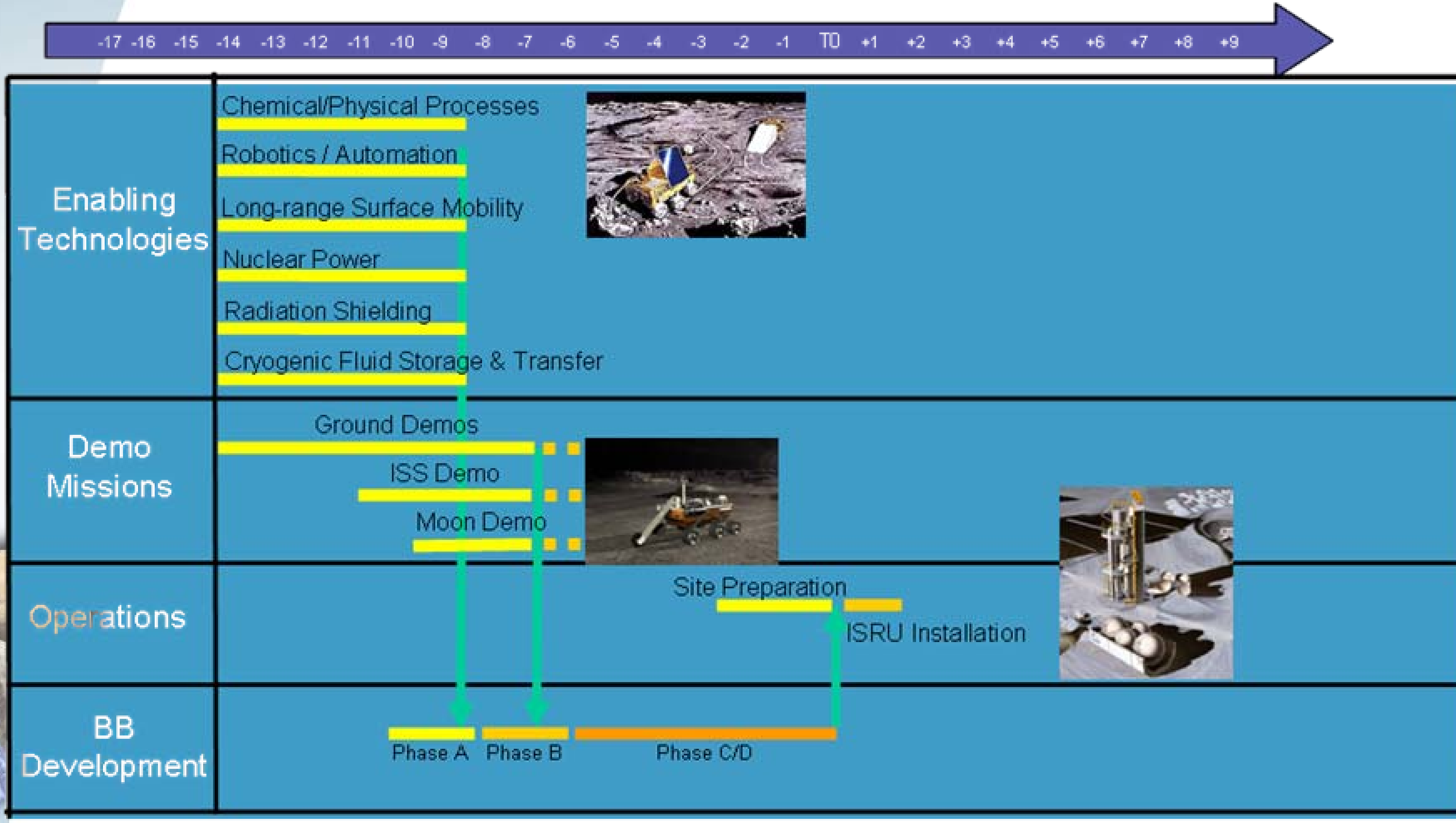
Crew Ascent Vehicle Roadmap



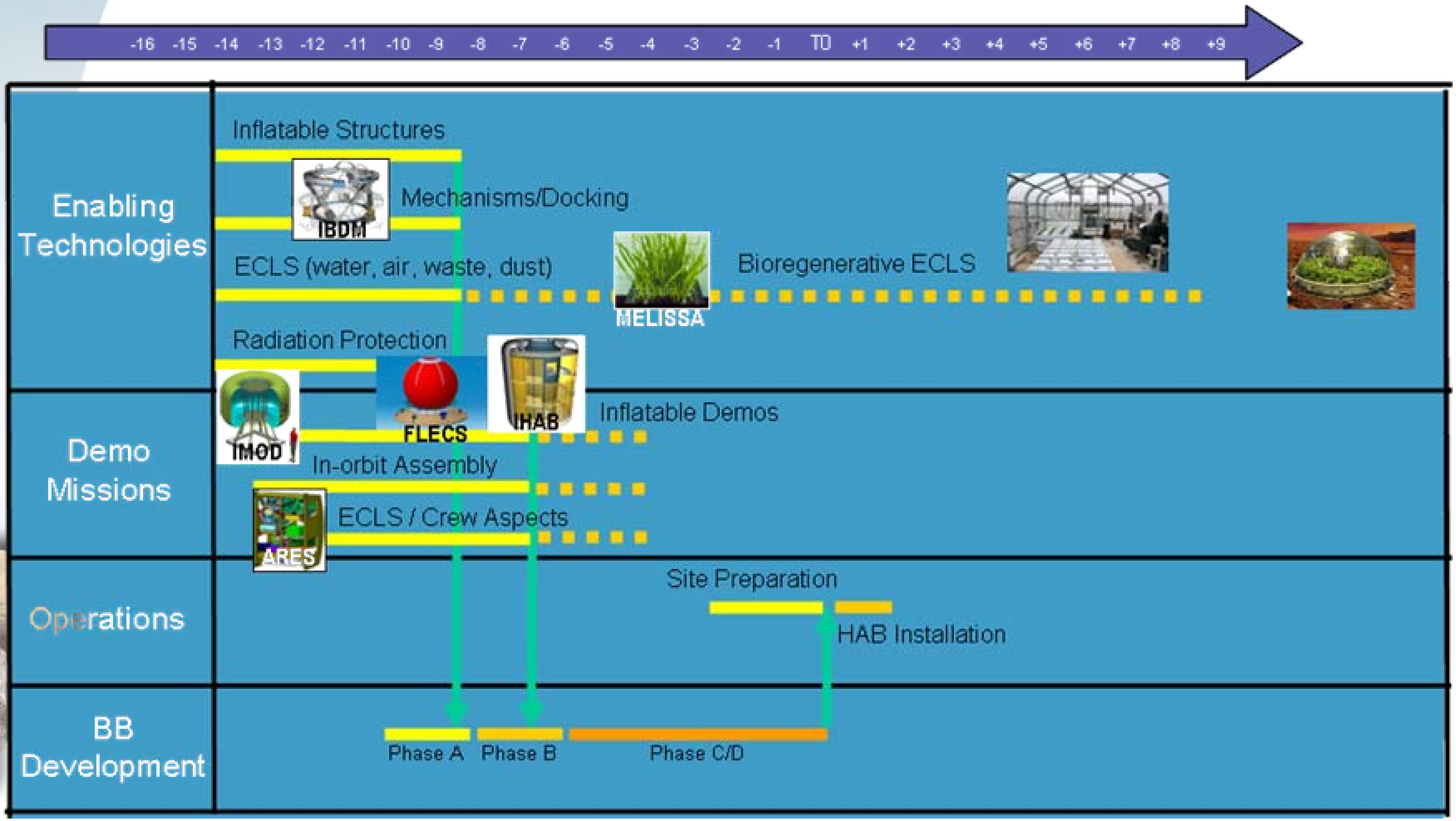
Deep Drilling Roadmap



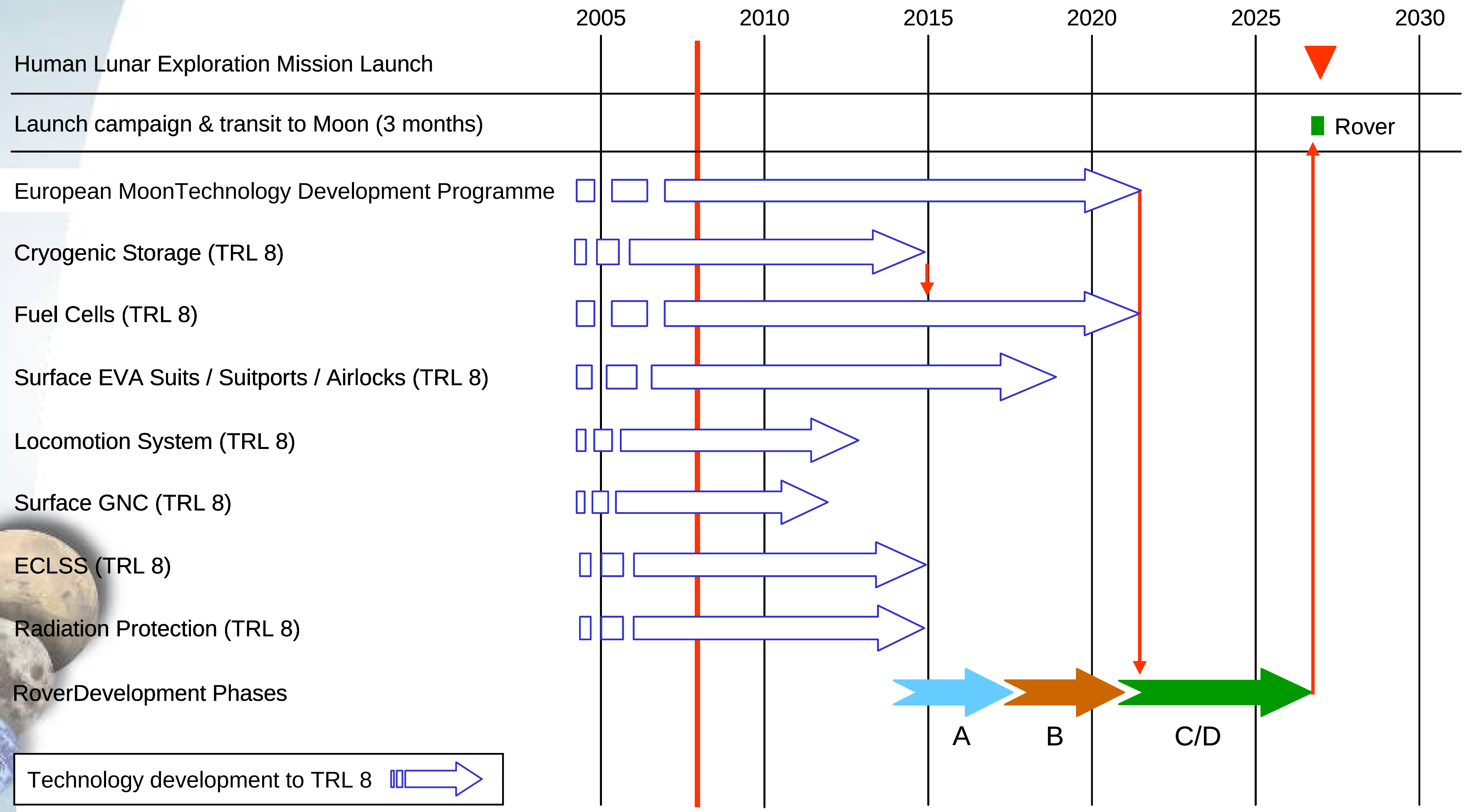
ISRU Roadmap



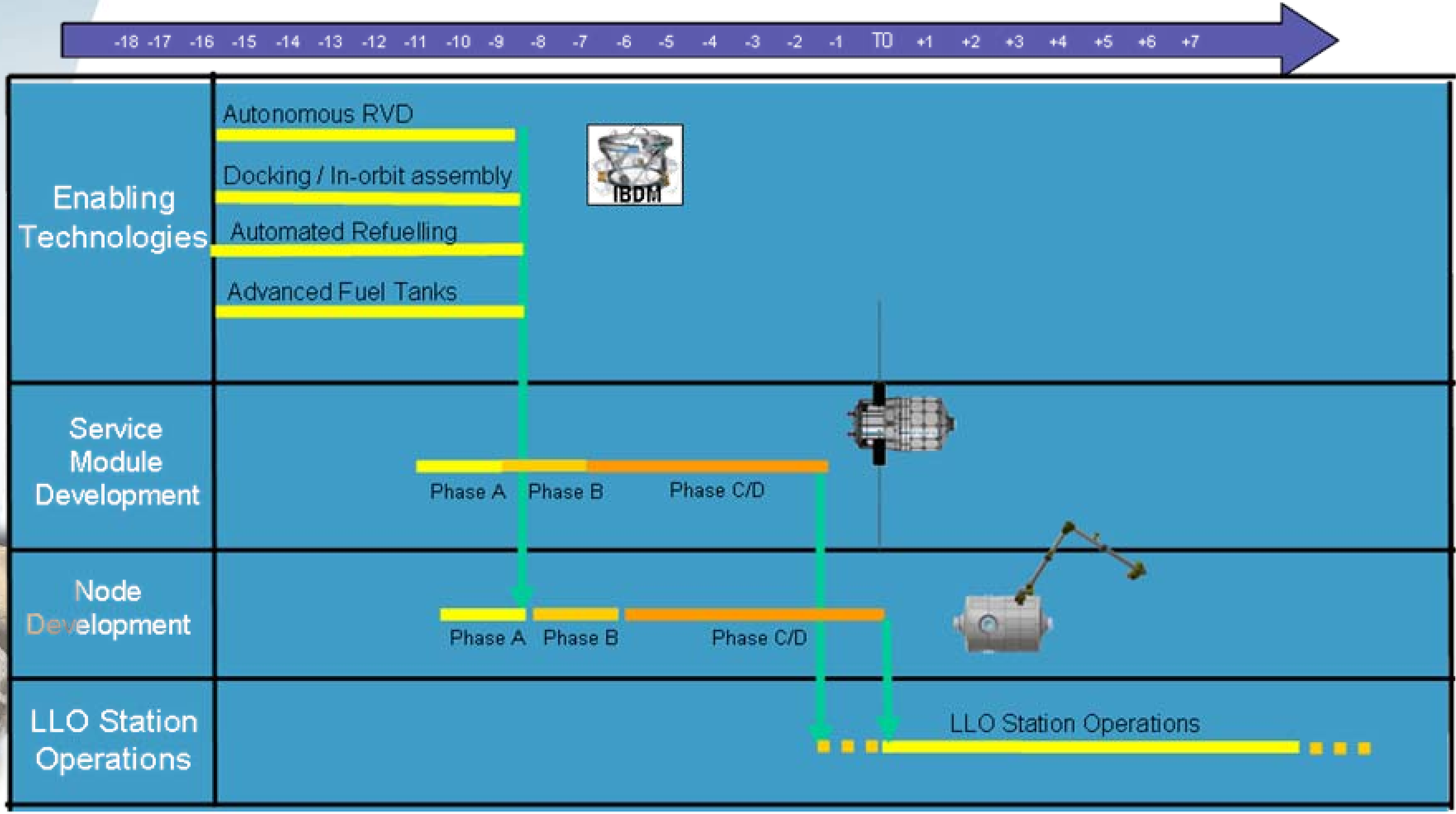
Habitation Roadmap



Pressurized Rover Roadmap



Lunar Space Station Roadmap



LEO Space Station Roadmap