EXPLORATION TECHNOLOGY DEVELOPMENT PROGRAM

Commercial Development Summit

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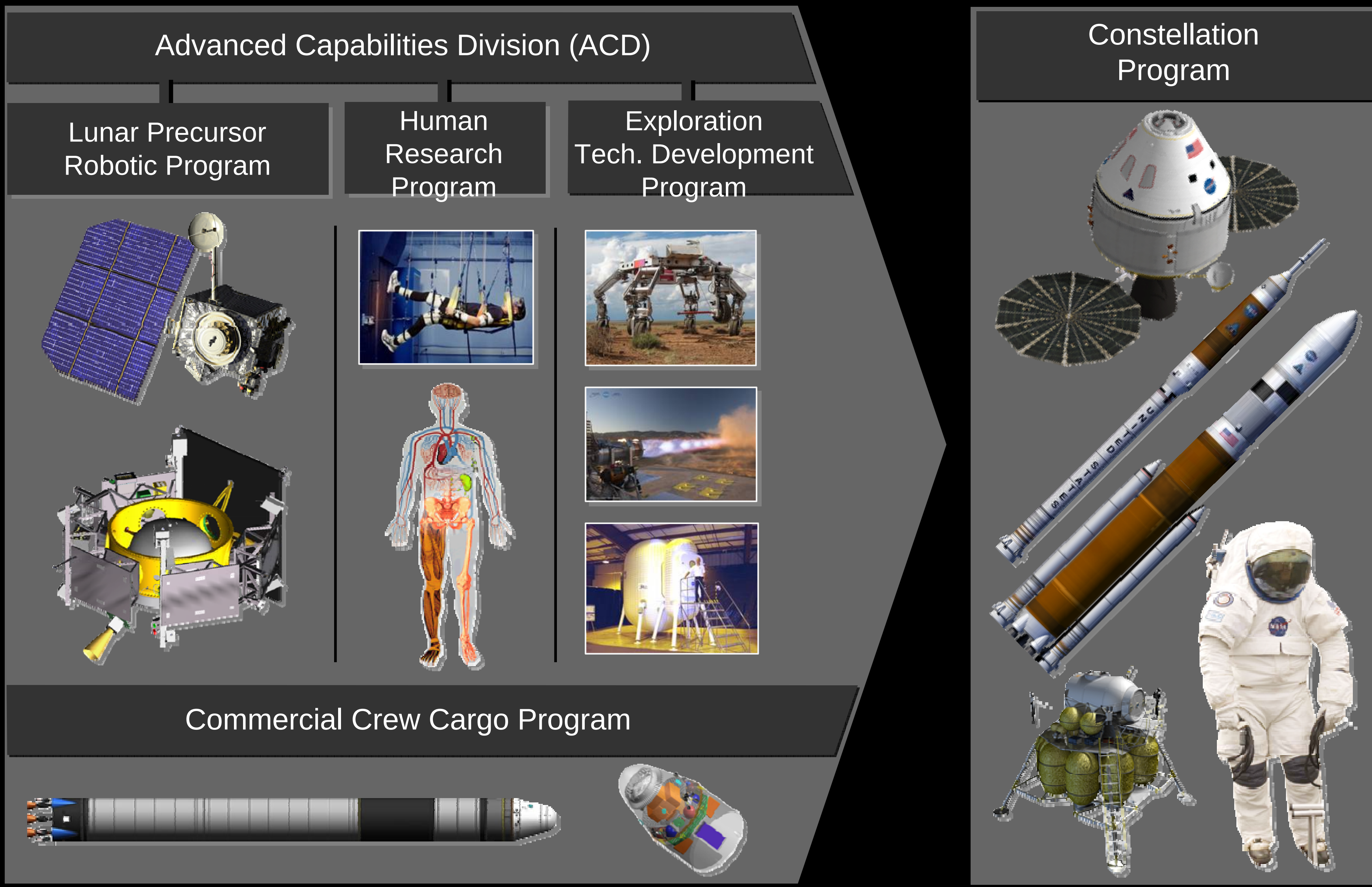
NASA Headquarters

NASA Programs Enabling Exploration



Exploration Technology Development Program

- **Objectives:**
  - Reduce human and robotic exploration mission risk by developing advanced technologies and capabilities.
  - Mature critical near-term technologies to support development of the Orion Crew Exploration Vehicle and Ares I launch vehicle
  - Develop long-lead technologies to support a sustainable lunar outpost.
  - Conduct research and test technologies for exploration on the International Space Station.

- **ETDP consists of 22 focused projects managed by the NASA Centers.**

- **NASA Langley is responsible for overall program management.**

- **ETDP content is aligned with technology priorities identified by ESAS, Constellation Program, and Lunar Architecture Team.**

Exploration Technology Development Program

- **Exploration Technology Development Program** – Frank Peri, Director
  - **Diane Hope - Program Element Manager**
    - LaRC – **Structures, Materials & Mechanisms** – Judith Watson
    - GRC – **Propulsion and Cryogenic Advanced Development (PCAD)** – Mark Klem
    - GRC – **Cryogenic Fluid Management System (CFM)** – Sue Motil
    - GRC – **Energy Storage and Power Systems** – Carolyn Mercer
    - MSFC – **High Performance and Radiation Hardened Electronics (RHESE)** – Andrew Keys
    - GRC – **Fission Power Systems (FSP)** – Don Palac
    - JSC – **In-Situ Resource Utilization (ISRU)** – Jerry Sanders
    - LaRC – **Supportability** – Barmac Taleghani
    - JSC – **Human Robotic Systems (HRS)** – Rob Ambrose
    - ARC – **Thermal Protection System (TPS)** – James Reuther
  - **Dana Gould - Program Element Manager**
    - GRC – **Dust Mitigation** – Mark Hyatt
    - JSC – **Thermal Control for Surface Systems** – Ryan Stephan
    - ARC – **Integrated System Health Management (ISHM)** – Serdar Uckun
    - ARC – **Autonomy for Operations (A4O)** – David Alfano
    - ARC – **Intelligent Software Design (ISD)** – Joe Coughlin
    - JSC – **Autonomous Landing & Hazard Avoidance Technology (ALHAT)** – Chirold Epp
    - JSC – **Automated Rendezvous & Docking (AR&D) Sensors** – Jennifer Mitchell
    - JSC – **Exploration Life Support (ELS)** – Dan Barta
    - JPL – **Advanced Environmental Monitoring & Control (AEMC)** – Darrell Jan
    - GRC – **Fire Prevention, Detection, & Suppression (FPDS)** – Gary A. Ruff
    - JSC – **Extra Vehicular Activity (EVA) Technology** – David Westheimer
    - GRC – **ISS Research** – Fred Kohl

Constellation Technology Prioritization Process

- **CxP determines and prioritizes its technology development needs to support annual ESMD budget planning process**
  - Goal is to ensure tech investments are traceable to Program or Level I requirements

- **Tech Development Needs are collected from Requirements Owners in CxP projects, and then grouped by timeframe and criticality.**

- **Timeframes:** Initial Capability (IC), lunar transport, lunar surface, and Mars forward
- **Criticalities:** critical, highly desirable (HD), and desirable

Initial Capability	***Lunar Transport***	***Lunar Surface***	***Mars***
Critical	Critical	Critical	Critical
Highly Desirable	Highly Desirable	Highly Desirable	Highly Desirable
Desirable	Desirable	Desirable	Desirable

- **Needs are ranked within each of these groups**

- **ETDP projects are planned to address critical CxP needs resulting from the TPP.**

Lunar Transport - Top Priorities

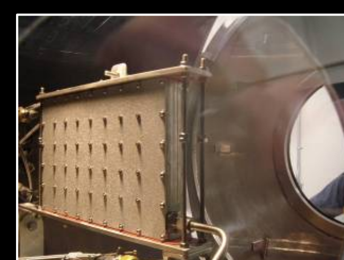
TPP Rank	Criticality	Title	ROO
1	critical	462: High reliability LOX/LH2 Throttling Engine	Lander
2	critical	463: Cryogenic Fluid Management	Lander
3	critical	524: Large Composite Manufacturing	Ares
4	critical	464: LO2/LCH4 Main Engine & RCS	Lander
5	critical	527: Long-term Cryogenic Storage	Ares
6	critical	538: Composite Primary Structure Technology	Lander
7	critical	387: CEV Parachute Materials	Orion
8	critical	542: Suit Ventilation	EVA
9	critical	526: HTPB Propellant	Ares
10	critical	537: Hazard Detection and Avoidance	Lander
11	critical	124: Phase Change Material	Thermal/ECLSS SIG
12	critical	544: Suit Power	EVA
13	critical	303: Composite Carrier Structure	Orion
14	critical	390: Robust Ablative Heat Shield Architecture	Orion
15	critical	543: PLSS Packaging	EVA
16	critical	525: TVC architecture development to minimize operations (EHA)	Ares
17	critical	601: Airlock /habitat hatches that are dust sealing, long life, common, etc.	LSS
18	critical	541: Radiation Effects Mitigation and Environmental Hardness	Lander
19	critical	302: Alternate Weight Saving Window Materials	Orion
20	critical	545: Suit Oxygen Supply	EVA
21	critical	546: Suit Thermal Control	EVA
22	critical	607: CO2 & Moisture Removal System	Lander
23	critical	531: Liquid Level Measurement	Ares
24	critical	532: Multi-layer Insulation	Ares
25	critical	594: Advancd Airlock/ Suitlock with Dust Filtration	LSS

Technology Development for Orion

Ablative TPS: Qualifying thermal protection system materials in arcjet tests and developing a prototype heat shield.

AR&D Sensors: Characterizing optical and laser sensors that measure the range and orientation of a target vehicle during autonomous rendezvous and docking.

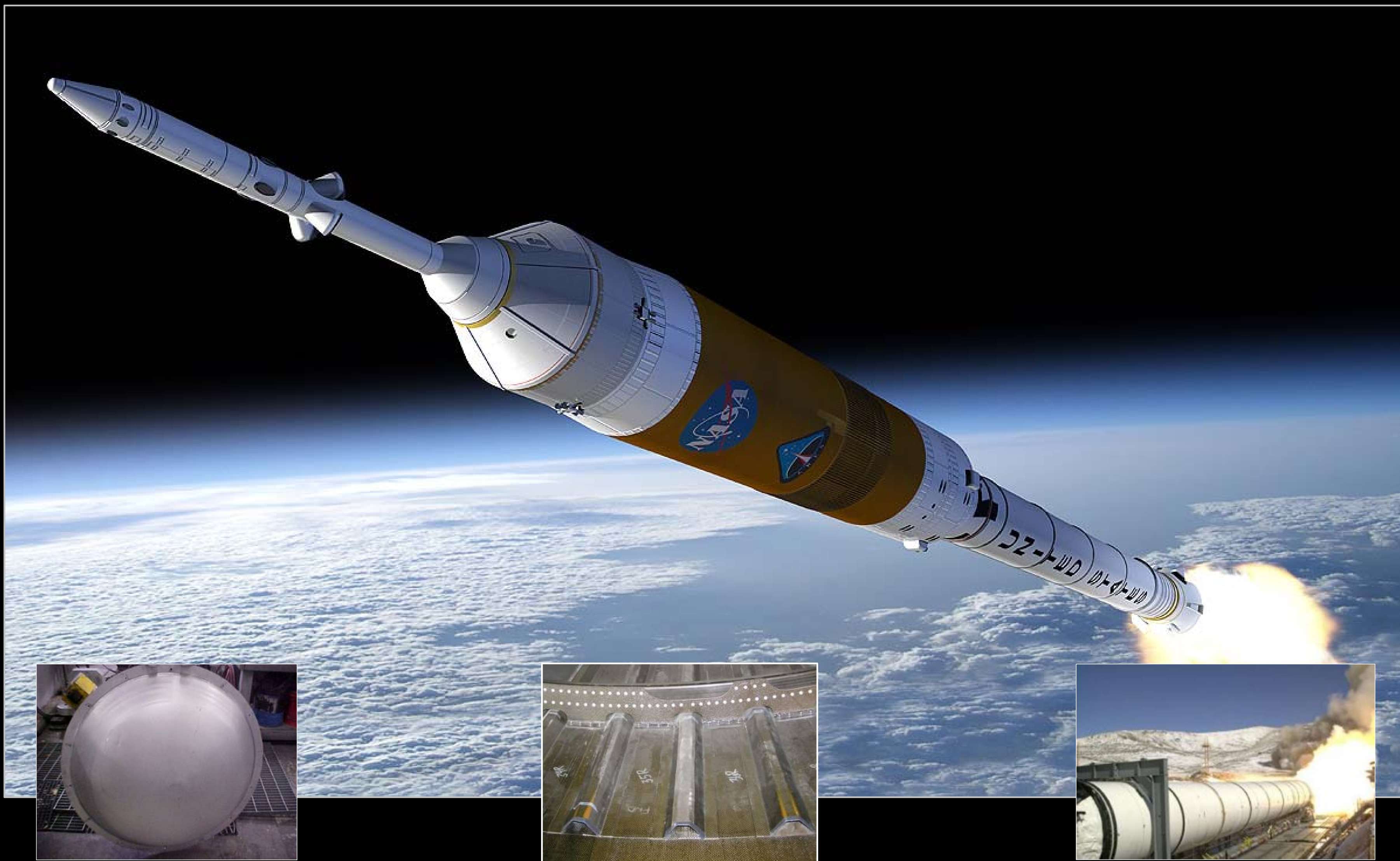
Structures & Materials: Developing lightweight, high-strength parachute materials.



Thermal Control: Developing prototype flash evaporator, sublimator, and composite radiator for thermal control during different phases of mission.

Exploration Life Support: Developing a prototype carbon dioxide and moisture removal system.

Technology Development for Ares Launch Vehicles

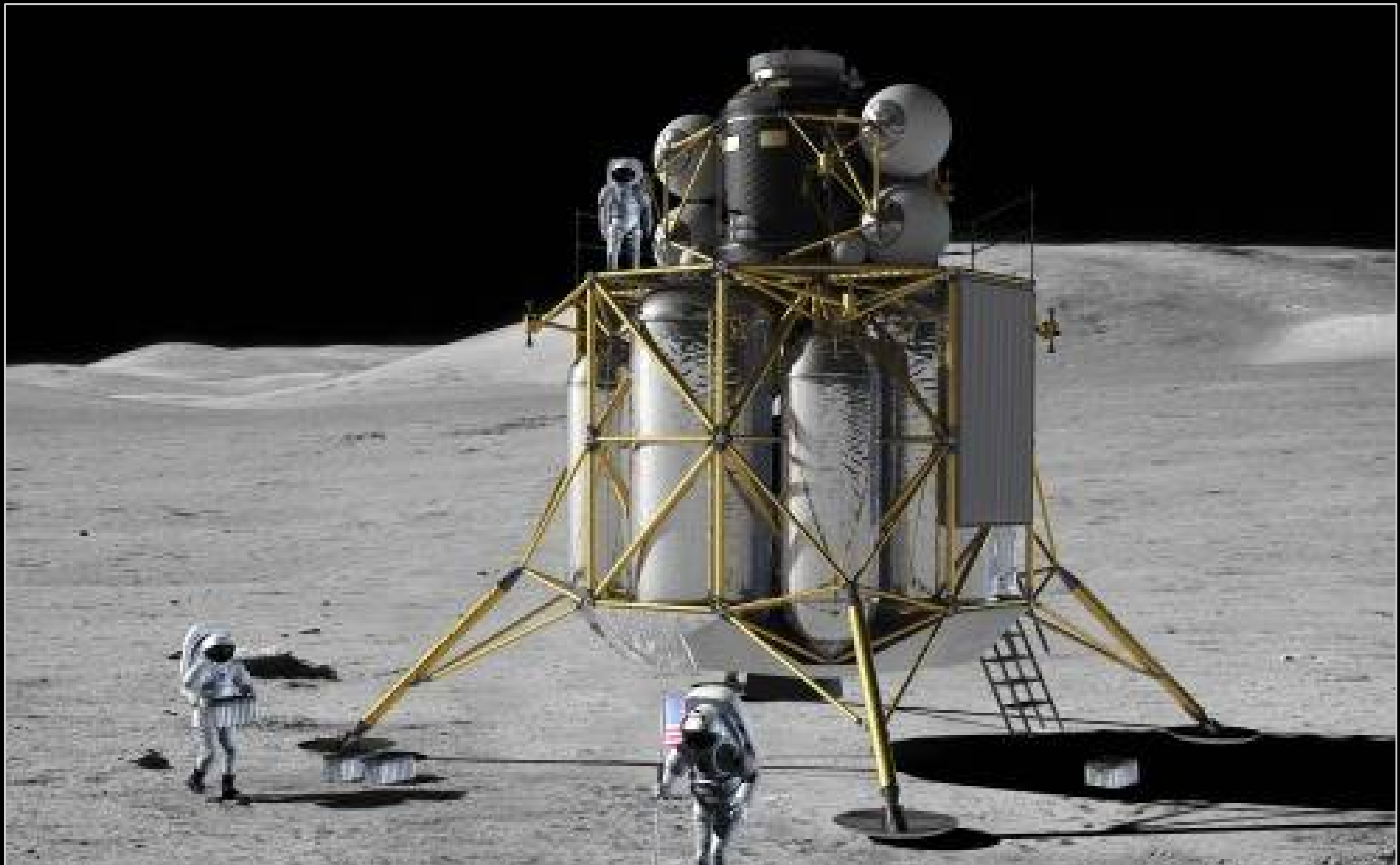


Structures & Materials: Developing friction stir welding and spin forming manufacturing processes for Ares I Upper Stage propellant tanks.

Structures & Materials: Developing lightweight composite structures for Ares V.

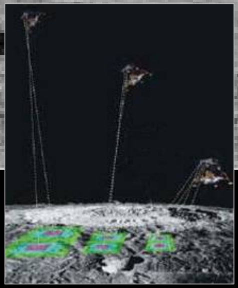
Integrated Systems Health Monitoring: Developing health monitoring system for Solid Rocket Motor.

Technology Development for Altair Lunar Lander

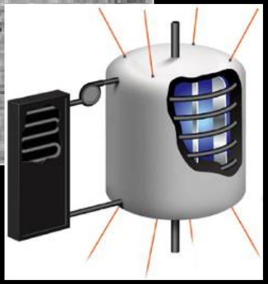


Propulsion & Cryogenics: Prototype LOX-Methane engine for ascent stage

Propulsion & Cryogenics: Prototype deep throttling RL-10 engine for descent stage

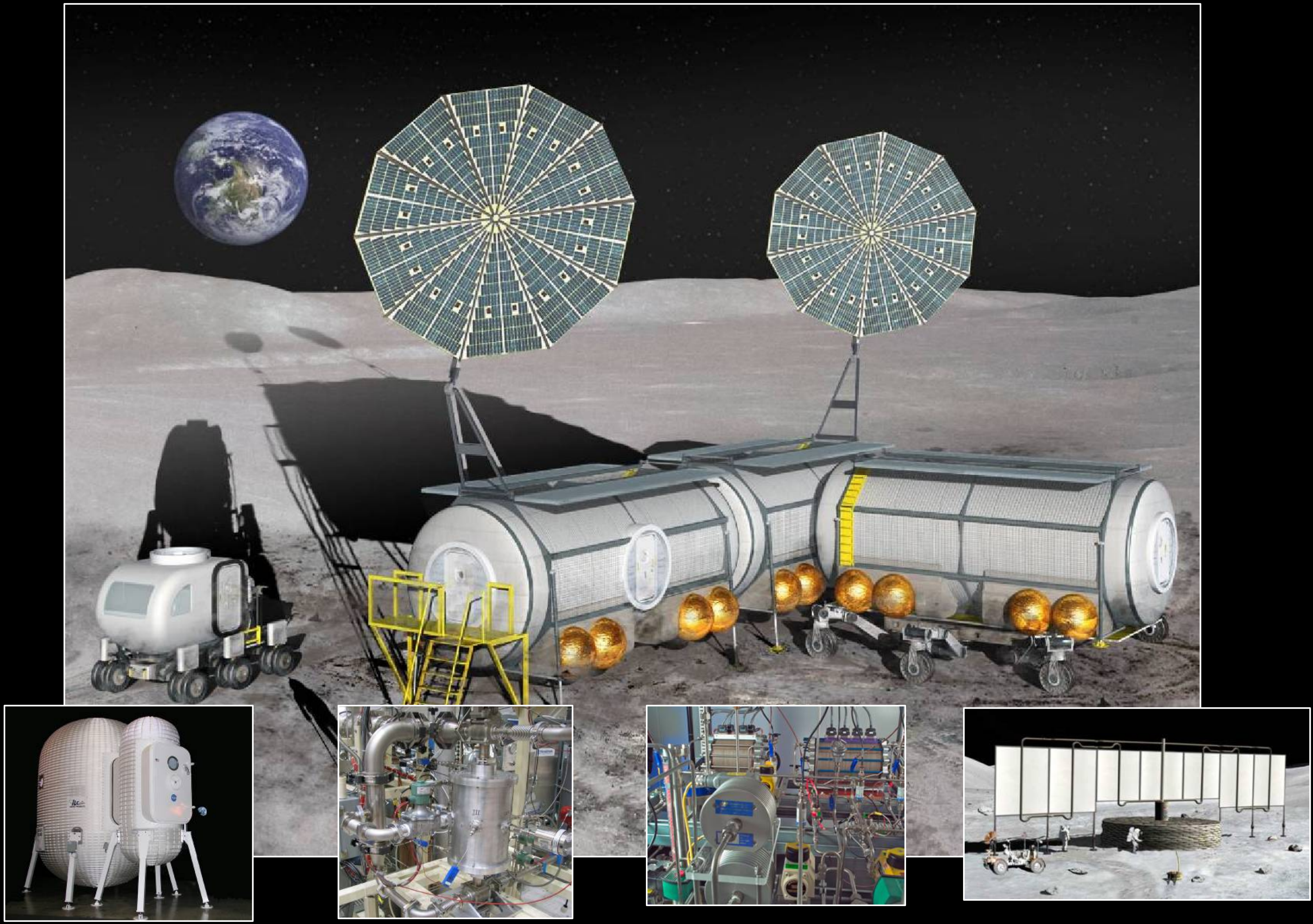


Autonomous Precision Landing: Guidance algorithms and lidar sensors to enable precision landing and hazard avoidance.



Propulsion & Cryogenics: Zero boil off cryogenic propellant storage to enable long duration missions

Technology Development for the Lunar Outpost



Structures & Materials: Inflatable habitats to reduce launch volume

Life Support: Closed-loop life support systems to reduce consumables

Energy Storage: Regenerative fuel cells to store energy during the lunar night.

Power: Affordable fission surface power systems

Technology Development for Lunar Surface Operations

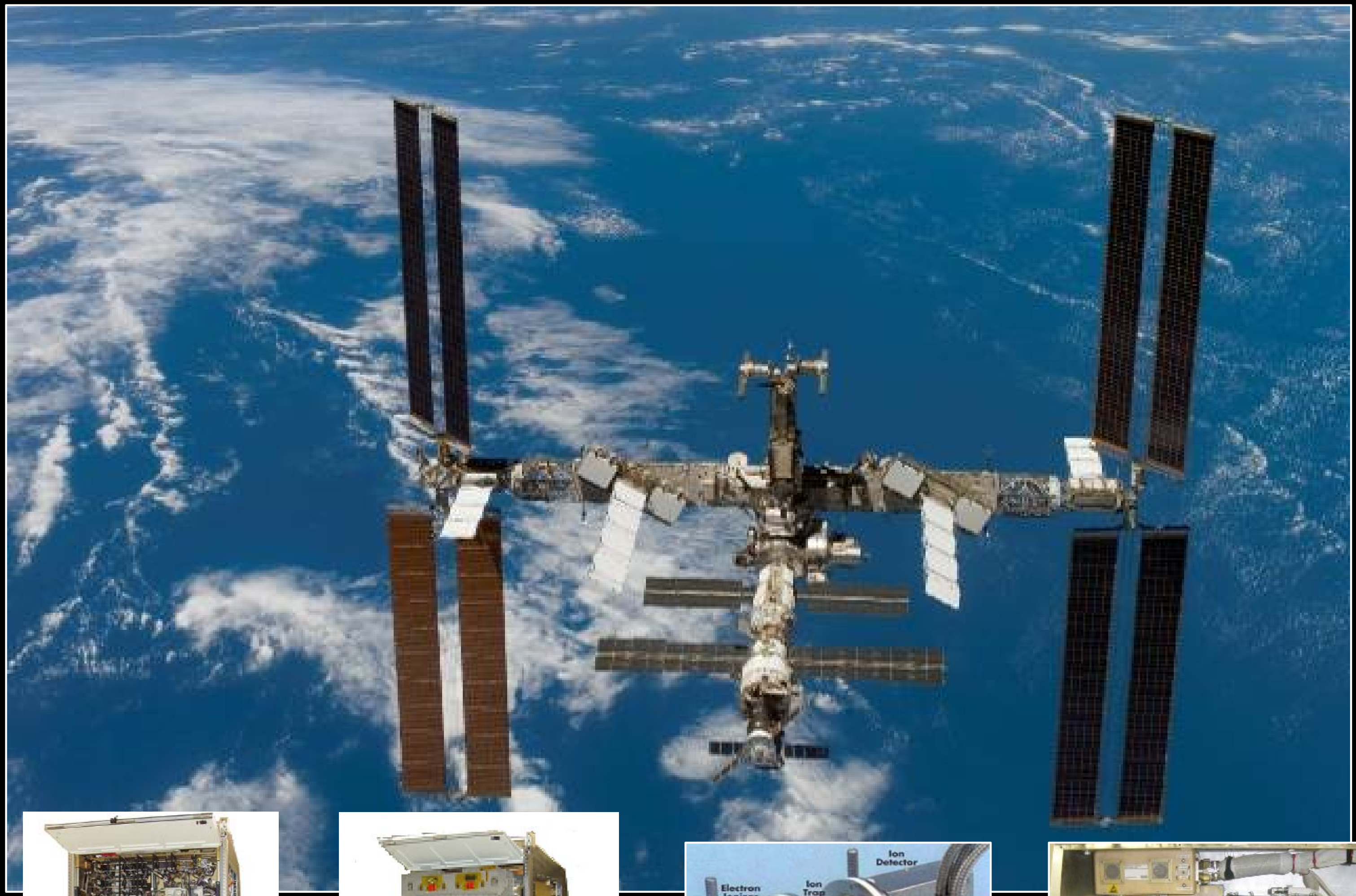
Robotic Systems: Small pressurized rover for sorties 200 km beyond the lunar outpost

EVA: Advanced surface suit with enhanced mobility and duration

Dust Mitigation: Preventing dust accumulation and degradation of surface systems

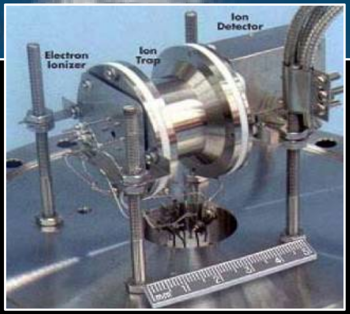
In-Situ Resource Utilization: Producing oxygen, water, and propellants from lunar resources

Technology Development for ISS



Combustion Integrated Rack

Fluids Integrated Rack



Vehicle Cabin Air Monitor

Smoke Aerosol Measurement Experiment

Exploration Technology Development Program (ETDP)

and Exploration Systems Mission Directorate (ESMD) Milestones

	2007	2008	2009	2010	2011	2012	2013
Constellation Program Milestones							
• Program Reviews	SRR		PDR		CDR		
• Orion Crew Exploration Vehicle	SRR	PDR	CDR				Orion 1
• Ares I Launch Vehicle	SRR	PDR	Ares 1-X	CDR		Ares 1-Y	
• Lunar Lander						SRR	PDR
• EVA	SRR		PDR		CDR		
ETDP Reviews	IA (NRC)	PSR	PSR	IA	PSR	PSR	IA
ETDP Project Milestones							
• Structures, Materials, & Mechanisms				▽ Structural concepts for lunar habitats			
• Protection Systems		▽ Prototype ablative heat shield for Orion					
• Non-Toxic Propulsion				▽ Zero boiloff cryo propellant storage		▽ Prototype propulsion systems for Lunar Lander	
• Energy Storage & Power Systems	▽ Demo Lithium-ion battery for EVA suit			▽ Prototype regen fuel cells			
• Thermal Control		▽ Radiator for Orion					
• Avionics & Software						▽ Precision landing & hazard avoidance system for Lunar Lander	
• Env. Control & Life Support		▽ Prototype CO2 & moisture removal system for Orion	▽ Deliver ENose & VCAM for flight to ISS				
• Crew Support & Accommodations						▽ Advanced EVA surface suit	
• ISS Research & Operations		▽ Deliver CIR for flight to ISS	▽ Deliver FIR for flight to ISS				
• In-Situ Resource Utilization (ISRU)		▽ Demo O2 production from regolith					
• Robotics, Ops, & Supportability		▽ Payload handling crane		▽ Demo lunar surface mobility systems			
• Fission Surface Power Systems						▽ Test 40 kW FSPS with reactor simulator	

ESMD Strategic Objectives for Participating in Lunar Precursor Missions of Opportunity

- **Primary Objectives (Landing, Communications, & Environments)**
  - Provide descent imaging to validate terrain relative navigation algorithms, to characterize plume effects, and to aid in the development of landing simulations for crew training.
  - Demonstrate an autonomous precision landing and hazard avoidance system that will reduce risk for future cargo landers needed to construct the lunar outpost.
  - Demonstrate advanced communications technologies for relay of data from lunar orbit to Earth, or for communications between assets on the lunar surface.
  - Characterize the lunar dust, lighting, temperature, charging, micrometeoroid, and radiation environments to prepare for human missions.
  - Validate LRO orbital data with ground truth, and conduct topographical surveys of potential sites for the lunar outpost.

- **Secondary Objectives (Materials & Components, Potential for ISRU)**
  - Determine the effects of the lunar surface environment on the properties of various materials needed for the design of future systems.
  - Validate low-temperature batteries, rad hard electronics, and mechanisms to enable sustained operations in the lunar polar regions.
  - Verify the presence of hydrogen and other volatiles in the lunar polar regions for In-Situ Resource Utilization.

- **Other Objectives (Prototype Systems)**
  - Demonstrate prototype lunar surface mobility and regolith excavation systems.
  - Demonstrate solar and radioisotope power systems for long-duration missions.
  - Demonstrate the ability to store cryogens for long periods on the lunar surface to enable cryogenic ascent stage propulsion systems.
  - Demonstrate or emplace navigation beacons to guide future precision landings.
  - Demonstrate the production of oxygen from lunar regolith.