Technologies for Human Exploration
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Bret G. Drake
NASA Lyndon B. Johnson Space Center

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Mars Challenges
Technology Focus for Staying Healthy

**Life Support**
- High reliability systems
- O₂ recovery and reducing logistics
- Water recovery loop closure
- Processing of solid waste to recover water
- Store nutritionally-adequate food for years

**Space Suits**
- Low mass suit and power pack
- Lower torso mobility
- Enhanced dexterity
- Compatible with Mars environment
- Increase information system capabilities
- In-situ suit repair

**Microgravity Countermeasures**
- Exercise equipment for muscle and cardiovascular atrophy, and bone loss
- Low-mass, rapid deploy, low-maintenance systems

**Autonomous Medicine**
- Advanced medical diagnosis, prognosis and treatment capabilities
- In-situ analysis of biomedical samples

**Environmental Control**
- In-flight analysis capabilities
- Rapid detection and mitigation of environmental hazards
- Detect contaminants introduced via surface activities
- Automated recovery
- Fire suppression
Mars Challenges
Technology Focus for Transportation

Access to Space
- Space Launch System heavy lift for large mass and volume
- Orion crew vehicle for crew delivery to and return from deep space

Chemical Propulsion
- $\text{O}_2$/Hydrocarbon ($\text{CH}_4$) propulsion for in-space, landing and ascent
- Integrated main and reaction control propulsion systems
- Ability to maintain cryogenic fluids for long durations

Advanced Propulsion
- Advanced capabilities to improve mass delivery and trip time
- Under investigation
  - Solar Electric
  - Advanced Chemical
  - Nuclear Thermal
  - Nuclear Electric

In-Situ Resource Utilization
- Production of $\text{O}_2$ from the atmosphere for Mars ascent
- Production of life-support consumables
- Construction of surface infrastructure from local resources

Entry, Descent, Landing & Ascent
- Hypersonic inflatable or deployable decelerators
- Supersonic retro-propulsion
- Precision landing
- Plume blast mitigation
- High-speed Earth re-entry
- Occupant protection
Mars Challenges
Technology Focus for Working in Space

Humans & Robots Working Together
- Human/machine coordination to improve productivity & reduce risk
- Robots performing routine tasks (inspection, logistics)
- Robotic Explorers (reconnaissance and risk reduction)

Autonomous Operations
- Independent, self-reliant crew can operate with up to 40 minute time delay
- Highly automated vehicle operable by minimal crew
- MCC automation (strategic/analysis role)
- Automated rendezvous & docking

In-Flight Maintenance
- Component-based design for maintainability & reliability
- Vehicle-wide diagnostics, prognostics & recovery
- In-space repair & manufacturing

Exploration Mobility
- Routine surface exploration
- Maximize time spent and distance traveled
- Minimize "time to get out the door"
- Environmental protection including dust abatement

Power Generation
- Production of high, continuous, latitude independent power for crew operations
- Mobile power systems for robust exploration