"WHAT DO WE REALLY NEED FOR A MARS MISSION?" -TECHNOLOGY -

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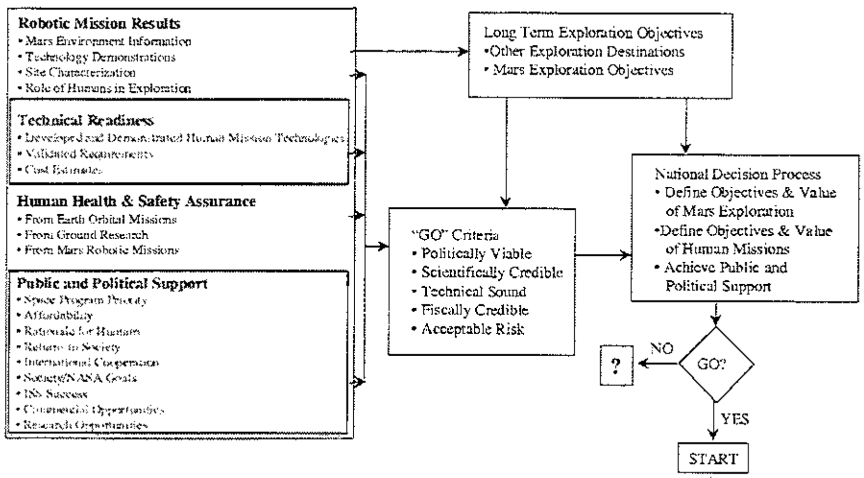
Boeing

The Route to "Go/No Go"



Technical Readiness

- Developed and demonstrated human mission technologies
  - Have we demonstrated the technologies required for a Mars mission?
    - Mission safety and assurance demand multiple technology demonstrations with whatever means are available
    - Include Shuttle, Space Station, and ground demonstrations
- Validated requirements
  - Have we performed precursor missions and simulations to understand the requirements?
  - Do we have the operations experience to assure success?
- Cost estimates
  - Do we have a clear baseline?
  - Is the technology readiness level high enough to accurately estimate costs?
  - Do we have the political support to maintain schedule (and thereby control costs)?

Earth to Orbit Transportation

- Mars Reference Mission requires either 200-225 tonnes to LEO or 110-120 tonnes on a split mission
  - Current capability does not exist
  - Several design concepts evolve from Shuttle Cargo Vehicle or Delta family
- Smaller vehicles require orbital rendezvous, assembly, and checkout of multiple launch payloads
  - Stresses capability of launch operations and propellant storage

Space-based Transportation

- Positive progress being made on solar propulsion - both electric and thermal
  - Technology risks mostly involve scaling up power
- Minimal activity on nuclear propulsion - technology is achievable, but political barriers may be insurmountable
- Earth-return vehicle is a major risk in the reference mission
  - Everything to remain in operating readiness for 4 years
  - Maintain liquid hydrogen for 4 years
  - MAV orbit rendezvous and capture

Mars Landing and Ascent

- The details of aerocapture have yet to be developed
  - Plan for multiple designs and demonstrations before sending crew to aerocapture mission
- Use of propellant generated in situ
  - Adds risk in precision landing
  - Adds multiple non-recoverable failure modes
    - TMI and Trans-Mars coast
    - Failure to capture in proper orbit at Mars
    - Lander disabled during descent
    - Unsuccessful rendezvous with TEI stage

Regenerative Life Support Systems

- Open loop systems not workable for Mars transfer
- Bioregenerative systems are essential
  - Activities underway at JSC, KSC, ARC on bioregenerative life support systems
  - Several years of ISS demonstrations will be required
- Substantial development still required, but ...
- No real technology roadblocks exist

Key Technologies for Human Exploration

Regenerative Life Support Systems
- Loop closure (air, water and food)
- Environmental monitoring & control
- Trash and waste collection/Processing

In Situ Resource Utilization
- Extraction processes and chemistry
- Materials handling

Transportation and Propulsion
- Advanced chemical systems
- Nuclear propulsion
- Aerocapture/aerobraking
- Lightweight/advanced structures

EVA and Surface Mobility
- Durable, lightweight, high mobility suit and gloves
- Lightweight, serviceable PLSS
- Long range surface transportation

Surface Power Generation and Storage
- Regenerative fuel cells
- Surface nuclear power systems
- High-efficiency solar arrays

Health and Human Performance
- Biomedical countermeasures
- Health care
- Radiation health
- Environmental health
- Space human factors

Cryogenic Fluid Systems
- Long-term storage
- Lightweight, high efficiency cryogenic liquefaction
- Zero-g handling and transfer

Teleoperation and Advanced Operations
- Tele-exploration and virtual reality systems
- Automated system control and advanced electronics

Surface Habitation and Construction
- Inflatable structures
- Seal materials and mechanisms

In Situ Resource Utilization

- Multiple processes can be made to work for CH_4 & O_2 propellants
  - Sabatier + electrolysis; Bosch; reverse water gas shift
  - Similar processes can be used for LSS oxygen
- System reliability and endurance still must be demonstrated in reference environment
- Reference mission technology achievable if architecture can solve abort risk issues
- Additional in situ resources should be considered
  - Especially consider use of Lunar resources

Surface Power Generation and Storage

- Initial deployment of > 50 kWe at Mars surface required before in situ resources can be generated
  - Must be deployed years before crew arrives, therefore autonomously
  - Major challenge
- More power will be required when crew arrives
- Solar power will require larger arrays than have ever been flown
- Nuclear power will require compact reactor that can be acceptance tested before leaving Earth vicinity

Cryogenic Fluid Systems

- Multiple technology aspects have yet to be demonstrated
  - Very long term storage of cryogens
  - Microgravity fluid handling
  - Stable heat balance

Surface Habitation and Construction

- Inflatable or rigid?
- Autonomous deployment?
- Must be immediately operable after long hiatus
- Technology must be demonstrated with high reliability before Mars mission
  - Either at ISS or Lunar surface

EVA Surface Mobility

- Both systems absolutely essential for mission success an crew safety
- No human-rated rover has yet been designed to meet reference mission requirements
  - Human rating assures crew safety
  - Human presence allows field repairs
- Trade off between mobility requirements and accuracy of landing location

Teleoperation and Advanced Operations

- Technology still to be developed for lag times of minutes or more
- Many issues remain for advanced operations
  - Rendezvous and docking
  - System checkout and maintenance
  - In-space assembly of Mars vehicles
  - Deployment of habitats, propellant production, and power systems at Martian surface
  - Routine crew operations for long missions with long lag times

Public and Political Support

- Space Program Priority
- Affordability
- Rationale for Humans
- Returns to Society
- International Cooperation
- Society/NASA Goals
- ISS Success
- Commercial Opportunities
- Research Opportunities

Commercial Market Considerations

- ISS-based demonstrations and operations
- Orbital fuel and services
- Space tug
- Lunar and asteroidal resources
- Mars fuel for rovers and ascent vehicles
- Lunar/Mars service provider

Program Challenges

- As a public agency, NASA executes the will of the people.
  - Excitement of human exploration and development
  - Continuation of scientific research for humankind
  - Technology development to improve life on Earth
- A long-term, multi-billion dollar program needs sustained public support.
  - Sell the program
  - Keep it sold

Program Needs

- A vision of human exploration and development that stimulates the public, the funding sources, the program participants, and the users and customers
- A public outreach program that is active, responsive, and an integral part of the planning process
- Understanding of the trade options
  - Costs, timing, technology risk
  - Moon, Mars, asteroids
  - Metrics that include robustness and public excitement
- Technological development
- International participation that involves mutual benefits and reduced individual costs
- An approach that encourages synergies with commercial investment

HEDS
A Contractor's View of the Pivotal Programmatic Questions

- Single mission or sustained campaign
  - i.e. few landings with footprints vs. multiple landings, destinations, and missions
- Sustained, stable requirements and funding
- Sustained public support
- Complementary and enhanced international cooperation
- Opportunities for applying technology, systems, and services to multiple uses
  - Commercial, military, other government uses
  - Consider commercial purchase of data and services
- Integrated product teams with government, academia, and industry