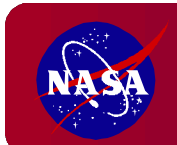

Human Exploration Systems and Mobility Capability Roadmap Progress Review

Chris Culbert, NASA Chair
Jeff Taylor, External Chair
March 29, 2005

Agenda

- Capability Roadmap Team
- Capability Description and Capability Breakdown Structure
- Benefits of the Human Systems and Mobility Capability
- Roadmap Process and Approach
- Drivers and Assumptions for the whole team
  - Current State-of-the-Art, Assumptions and Requirements will be covered in the appropriate sections
- Capability Presentations by Leads under Roadmap (Repeated for each capability under roadmap)
  - Capability Description, Benefits, Current State-of-the-Art
  - Capability Requirements and Assumptions
  - Roadmap for Capability
  - Capability Readiness Level
  - Technology Readiness Level
  - Figures of Merit
- Summary of Top Level Capability
- Significant Technical Challenges
- Summary and Forward Work

Human Exploration Systems and Mobility Capability Roadmap Team

Advanced Planning & Integration Office

Co-Chairs

- NASA: Chris Culbert, NASA/JSC
- External: Jeff Taylor, University of Hawaii

Team Members

– Government

Ken Baker, NASA/JSC
John Dorsey, NASA/LaRC
Rick Eckelkamp, NASA/JSC
David Kohrsmeyer, NASA/ARC
Dennis Lawler, NASA/JSC
Wendell Mendell, NASA/JSC
Rud Moe, NASA/GSFC
Jeff Patrick, NASA/JSC
June Zakrajsek, NASA/GRC
Wayne Zimmerman, NASA/JPL

– Academia/Industry

David Adlis, Aerospace Corp.
Jim Blacic, Los Alamos Labs
David Carrier, Bromwell & Carrier
Wendell Chun, Lockheed Martin
Mark Henley, Boeing
Jud Heddgecock, Oceaneering
Larry Taylor, Univ. of Tennessee
Robert Yowell, Aerospace Corp.

Coordinators

Directorate: Betsy Park and Doug Craig, NASA/HQ/ESMD
APIO: Tom Inman, NASA/MSFC

9.0 Capability Description

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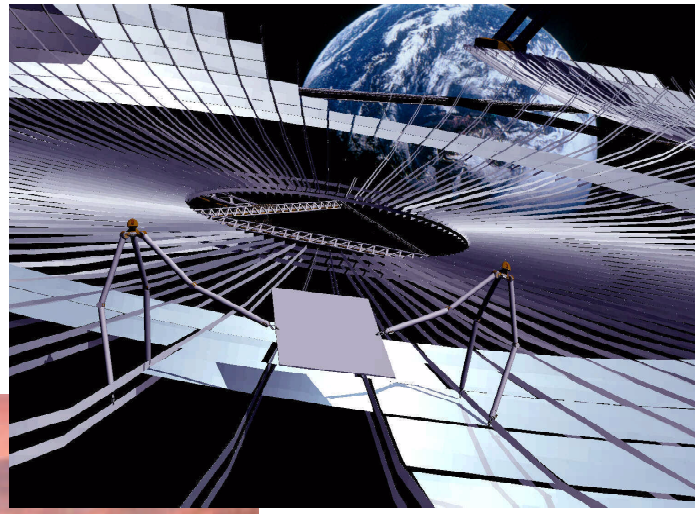
Supports human exploration activities in space and on planetary surfaces. Includes a wide range of capabilities to allow scientific observations, instrument deployment, and resource exploration. Divided into four major categories:

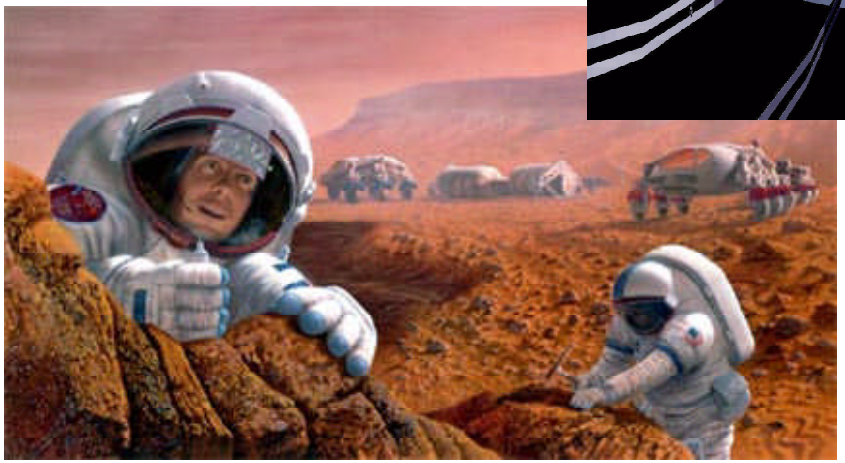


9.1 Exploration Activities

9.2 Mobility

9.3 Assembly and Deployment

9.4 Servicing



Capability Breakdown Structure

9.0
Human Systems and Mobility
Chair: Chris Culbert, JSC
Co-chair: Jeff Taylor, U. Hawaii

- **9.1 Exploration Activities Coordinator: Rick Eckelkamp, JSC**
  - 9.1.1 Access to Exploration Targets
  - 9.1.2 Observation
  - 9.1.3 Analyze
  - 9.1.4 Operate
  - 9.1.5 Command and Control and Information
- **9.2 Mobility Coordinator: Jeff Taylor, U. Hawaii; June Zakrasjek, NASA/Glenn**
  - 9.2.1 In Space Mobility
  - 9.2.2 Surface Mobility
- **9.3 Assembly and Deployment Coordinator: Ken Baker, JSC**
  - 9.3.1 Staging
  - 9.3.2 Storage
  - 9.3.3 Preparation for Assembly
  - 9.3.4 Construction
  - 9.3.5 Local Transport
  - 9.3.6 Positioning and Alignment
  - 9.3.7 Joining
  - 9.3.8 Verification
  - 3.9 Planning, Logistics, Nav, Comm, etc.
- **9.4 Servicing Coordinator: Dennis Lawler, JSC**
  - 9.4.1 Inspection and surveying
  - 9.4.2 Detect&Isolate Faults
  - 9.4.3 Perform Planned Maintenance
  - 9.4.4 Perform Unplanned Repair
  - 9.4.5 Install Upgrades
  - 9.4.6 Planning, Logistics, Nav Comm, etc.

Benefits of Human Systems and Mobility

Human Exploration systems are required to:

- Support human presence for long-duration spaceflight or missions to planetary surfaces
- Allow deployment of complex scientific instrumentation in space, such as large interferometric telescopes
- Allow installation of instrumentation and sophisticated scientific facilities on planetary surfaces
- Enhance human access to scientific targets on planetary surfaces
- Provide global access on the Moon, Mars, and other planetary bodies
- Enhance human-robot partnerships to make the most efficient and effective use of each

Roadmap Process and Approach

- **Team members chosen to represent wide range of expertise and experience (including Apollo experience) for this broad topic**
- **Devise CBS and choose working groups through a series of telecons, email exchanges, and meetings**
- **Details of subcapabilities fleshed out by working groups, vetted by entire team**
  - Define capabilities and appropriate levels of subcapabilities, their benefits, figures of merit, and estimate of the amount of development needed
  - Assessment of technologies required and when they will be needed
- **Working groups use the above to devise roadmap for each capability, with review by whole team**
- **Presentation to NRC**
- **Revise plan based on comments**
- **Write detailed capability document**

Requirements /Assumptions for Human Exploration Systems and Mobility

Advanced Planning & Integration Office

General drivers

- Long duration (> 180 day) human presence on the Lunar surface
- Short duration (< 180 day) human presence on the Mars surface
- Assume reliable access to all ‘useful’ points in the Earth – Mars area
- Gateway type facility on-orbit for Moon (assembly, refueling, staging, etc.)
- Infrastructure rich locations on the surface with ‘sorties’ going out from them
- Power readily available (100s of KW available to bases)
- Thermal control, heat rejection technologies considered by other teams
- Communications – very high bandwidth will be provided at least locally
- Human safety considerations are critical; systems will be fault tolerant
- Human productivity/efficiency considerations – no more than 25% of human time spent on routine maintenance & housekeeping
- Systems are capable of at least supervised autonomy

General drivers (cont'd)

- Radiation shielding provided for normal environment & solar flares. Environment protection also provided for:
  - Dust
  - Meteorites/orbital debris
  - Secondary ejecta
  - Electric fields on the moon
- Locally information rich and information accessible
- Local science analysis capability is necessary and some sample return is still necessary
- Assume design for modularity, assembly and maintenance will be used and standards developed for broad application and commonality
- Payload size and mass will not significantly change over the next 20 – 25 years. In other words, we won't have a 100 metric ton lift vehicle with significantly larger shroud size than today's launch options.

Assumptions on Dates

Date Assumptions

- In the absence of specific mission definitions, the team reviewed existing material on the Vision for Space Exploration and the Spiral development models and defined a rough outline of dates (below) for development needs.

	Beyond LEO	Moon	Mars
Initial Presence			
Robotic Precursors	2008-2015	2008-2015	2012-2022
Initial Human Presence		2015-2020	2022-2030
Infrastructure Operational Deployment			
In Space	2015-2025		
Surface		2012-2020	2020-2025
Long Duration Human Presence			
Exploration Sorties		2015-2030	
ISRU Production	2020-2030	2017-2030	2020-2030
Facility Operation and Maintenance	2020-2030	2020-2030	

Significant Technical Challenges

Key technical challenges:

- **We will summarize the most significant technical challenges, across all of the technical areas.**

Do the Capability Roadmaps have connection points to each other when appropriate?

- **Have not done much work in this area yet, and won't really address until after the NRC discussion.**

Summary/ Forward Work

- Make changes to roadmaps based on verbal feedback from NRC review
- Consider overlap with other Capability Roadmap teams and eliminate duplication
- Receive the draft Strategic Roadmaps
- Review and Assess all applicable Strategic Roadmaps and their requirements for Human Exploration Systems
- Make changes to Human Exploration Systems roadmaps to ensure consistency with Strategic Roadmaps requirements
- Develop rough order of magnitude cost estimates for the Human Exploration Systems Roadmap
- Prepare for 2nd NRC Review which will address 4 additional questions:
  - Are there any important gaps in the capability roadmaps as related to the strategic roadmap set?
  - Do the capability roadmaps articulate a clear sense of priorities among various elements?
  - Are the capability roadmaps clearly linked to the strategic roadmaps, and do the capability roadmaps reflect the priorities set out in the strategic roadmaps?
  - Is the timing for the availability of a capability synchronized with the scheduled need in the associated strategic roadmap?