Human Space Exploration by Antony Jeevarajan

Abstract

The Mars probe, launched by India a few months ago, is on its way to Mars. At this juncture, it is appropriate to talk about the opportunities presented to us for the Human Exploration of Mars. I am planning to highlight some of the challenges to take humans to Mars, descend, land, stay, ascend and return home safely. The logistics of carrying the necessary accessories to stay at Mars will be delivered in multiple stages using robotic missions. The primary ingredients for human survival is air, water, food and shelter and the necessity to recycle the primary ingredients will be articulated. Humans have to travel beyond the van Allen radiation belt under microgravity condition during this inter-planetary travel for about 6 months minimum one way. The deconditioning of human system under microgravity conditions and protection of humans from Galactic cosmic radiation during the travel should be taken into consideration. The multi-disciplinary effort to keep the humans safe and functional during this journey will be addressed.
Human Space Exploration

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India’s Mars Mission
Mars Mission Exploration Tools

Lyman Alpha Photometer (LAP)
Lyman Alpha Photometer (LAP) is an absorption cell photometer. It measures the relative abundance of deuterium and hydrogen from Lyman-alpha emission in the Martian upper atmosphere (typically exosphere and exobase). Measurement of D/H (Deuterium to Hydrogen abundance Ratio) allows us to understand especially the loss process of water from the planet.

Methane Sensor for Mars (MSM)
MSM is designed to measure Methane (CH₄) in the Martian atmosphere with PPB accuracy and map its sources. Data is acquired only over illuminated scene as the sensor measures reflected solar radiation. Methane concentration in the Martian atmosphere undergoes spatial and temporal variations.

Mars Exospheric Neutral Composition Analyser (MENCA)
MENCA is a quadruple mass spectrometer capable of analysing the neutral composition in the range of 1 to 300 amu with unit mass resolution. The heritage of this payload is from Chandra’s Altitudinal Composition Explorer (CHACE) payload.

Mars Color Camera (MCC)
This tri-color Mars Color camera gives images & information about the surface features and composition of Martian surface. They are useful to monitor the dynamic events and weather of Mars. MCC will also be used for probing the two satellites of Mars - Phobos & Deimos. It also provides the context information for other science payloads.

Thermal Infrared Imaging Spectrometer (TIS)
TIS measure the thermal emission and can be operated during both day and night. Temperature and emissivity are the two basic physical parameters estimated from thermal emission measurement. Many minerals and soil types have characteristic spectra in TIR region. TIS can map surface composition and mineralogy of Mars.
Cluster of Galaxies

Galaxy Cluster Abell 1689
Hubble Space Telescope • Advanced Camera for Surveys

NASA, N. Benitez (JHU), T. Broadhurst (The Hebrew University), H. Ford (JHU), M. Clampin(STScI), G. Hartig (STScI), G. Illingworth (UGO/Lick Observatory), the ACS Science Team and ESA
STScI-PRC03-01a
Central Region of the Milky Way
NASA’s Great Observatories
Near-term Human Exploration Domains
Overview of Notional Mars Expedition

- Earth Arrival
- Mars Arrival
- Mars Departure
- Earth Departure

Earth-to-Mars transit: ~6 months
Mars surface stay: ~18 months
Mars-to-Earth transit: ~6 months
Mars Landing
Mars Rover Cameras

- Chemcam RMI
- Left Navcams (2)
- Left Mastcam (34 mm)
- Right Mastcam (100 mm)
- MAHLI
- Rear Hazcams Left and Right (2 pairs)
- Right and Left Front Hazcams (2 pairs)
- MARDI
Design Reference Architecture Mission Profile

1. Cargo Launches
2. Cargo: 350 Days to Mars
3. Cargo to Surface & Orbit
4. Cargo Launches
5. Crew: 200 Days to Mars
6. Crew: 200 Days to Mars
7. Ascend to Orbit
8. Crew: 200 Days to Earth
9. Earth Return

Orion with 6 crewmembers

26 Months
30 Months
### Daily Inputs - Nominal

<table>
<thead>
<tr>
<th>Resource</th>
<th>kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxygen</td>
<td>0.84</td>
</tr>
<tr>
<td>Food Solids</td>
<td>0.62</td>
</tr>
<tr>
<td>Water in Food</td>
<td>1.15</td>
</tr>
<tr>
<td>Food Prep Water</td>
<td>0.79</td>
</tr>
<tr>
<td>Drink</td>
<td>1.62</td>
</tr>
<tr>
<td>Hand/Face Wash Water</td>
<td>1.82</td>
</tr>
<tr>
<td>Shower Water</td>
<td>5.45</td>
</tr>
<tr>
<td>Clothes Wash Water</td>
<td>12.50</td>
</tr>
<tr>
<td>Dish Wash Water</td>
<td>5.45</td>
</tr>
<tr>
<td>Flush Water</td>
<td>0.50</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>30.74</strong></td>
</tr>
</tbody>
</table>

### Daily Outputs - Nominal

<table>
<thead>
<tr>
<th>Resource</th>
<th>kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Dioxide</td>
<td>1.00</td>
</tr>
<tr>
<td>Respiration and Perspiration Water</td>
<td>2.28</td>
</tr>
<tr>
<td>Urine</td>
<td>1.50</td>
</tr>
<tr>
<td>Feces Water</td>
<td>0.09</td>
</tr>
<tr>
<td>Sweat Solids</td>
<td>0.02</td>
</tr>
<tr>
<td>Urine Solids</td>
<td>0.06</td>
</tr>
<tr>
<td>Feces Solids</td>
<td>0.03</td>
</tr>
<tr>
<td>Hygiene Water</td>
<td>6.68</td>
</tr>
<tr>
<td>Clothes Wash Water</td>
<td>11.90</td>
</tr>
<tr>
<td>Clothes Wash</td>
<td>0.60</td>
</tr>
<tr>
<td>Latent Water</td>
<td></td>
</tr>
<tr>
<td>Other Latent Water</td>
<td>0.65</td>
</tr>
<tr>
<td>Dish Wash Water</td>
<td>5.43</td>
</tr>
<tr>
<td>Flush Water</td>
<td>0.50</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>30.74</strong></td>
</tr>
</tbody>
</table>

### Resources and Recycling
- Water Regeneration Reactors
- Air Revitalization Reactors
- Environmental Sensors (Chemical)
- Microbial Monitors

11.3 Metric Tons Per Person-Year

5.02 - 30.74 kg per person-day
Water and CO2 Recycling

**Water Recovery System (WRS)**

**Urine Processor Assembly (UPA)**

**WATER Processor Assembly (WPA)**

**Oxygen Generation System (OGS)**

**Oxygen Generator Assembly (OGA)**

**Sabatier**

**USOS Cabin**

- Crew
- Biological Payloads

**Power Supply Module (PSM)**

**Connections**

- Urine
- Wastewater
- Distillate
- Potable water
- Oxygen
- Carbon Dioxide
- Hydrogen
- Overboard
Hair-do
Garbage Handling
Salt and Pepper
Candies in water bubble
Dinner at his Lap
Yummy Dinner
Food for Space Missions

Refrigerators and freezers not available to maintain food safety and quality
Weightlessness
Weightlessness
Super-Woman
Sleep
Space Radiation Environment

- **Galactic Cosmic Rays (GCR):**
  - highly penetrating protons and heavy ions of extra-solar origin
  - large amounts of secondary radiation
  - largest doses occur during minimum solar activity in 11 year solar cycle
  - low level background radiation: protons (85%), Helium (14%) and HZE particles (1%)

- **Trapped Radiation in South Atlantic:**
  - medium energy protons and electrons
  - effectively mitigated by shielding

- **Solar Particle Events (SPE):**
  - medium to high energy protons
  - occur during maximum solar activity
  - Solar protons from the Coronal Mass Ejections and HZE
Solar Flare
Solar Flare Observed at Various Wavelengths

1600 Å  304 Å  171 Å  335 Å  94 Å  131 Å
Solar Flare/Aurora from Space/Earth
Van Allen Belt
Contribution to exposure from man-made Radiation sources in USA

- Medical X-rays: 58%
- Nuclear Medicine: 21%
- Occupational: 2%
- Consumer Products: 16%
- Fallout: 2%
- Nuclear Fuel Cycle: 1%

Natural background radiation: 82%
Man-made radiation: 18%

Data: BEIR VII 2006, NCRP 1987
Environmental exposure to natural background radiations: 2.4 mSv/year

- High-LET radon exposure: 52%
- Low-LET exposure from ingestion: 7%
- Low-LET exposure from earth: 20%
- Low-LET cosmic radiation exposure: 12%
- High-LET cosmic radiation exposure: 12%
- High-LET cosmic radiation exposure: 5%
- Environmental exposure to natural background radiations: 2.4 mSv/year
## Approximate Response of a single Mammalian Cell to 1 Gy of Radiation

<table>
<thead>
<tr>
<th>Radiation</th>
<th>Low-LET</th>
<th>High-LET</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tracks in nucleus</td>
<td>$10^3$</td>
<td>4</td>
</tr>
<tr>
<td>total SSB</td>
<td>$10^3$</td>
<td>$10^3$</td>
</tr>
<tr>
<td>total DSB</td>
<td>~ 40</td>
<td>&lt; 40</td>
</tr>
<tr>
<td>Complex DSB</td>
<td>20%</td>
<td>70%</td>
</tr>
<tr>
<td>DSB per lethal lesion</td>
<td>87</td>
<td>22</td>
</tr>
<tr>
<td>Chrom. Aberration</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Dicentric per cell</td>
<td>0.1</td>
<td>0.4</td>
</tr>
<tr>
<td>Cell Inactivation</td>
<td>30%</td>
<td>85%</td>
</tr>
</tbody>
</table>
Energy Spectra for protons, helium, carbon, and iron.
Repair of DSB induced by Low and High LET Radiation

- Gamma rays only
- Gamma rays + 0.5M DMSO
- Alpha particles only
- Alpha particles + 0.5M DMSO

Relative yield of DSBs vs. repair time (min)

O'Neill et al. (1995)
Fig. 3.2. The motion of a charged particle in a dipole magnetic field consists of three components; a helical trajectory about the magnetic field line, a bounce between polar mirror points, and a longitudinal drift around Earth (Hess, 1968).
Components:
- Protons: ~ 0.04 to 500 MeV
- Electrons: ~ 0.04 to 7 MeV
- Heavier Ions: Low Energies

Location of peak levels is energy dependent
Location of populations shifts with time
Average counts vary slowly with solar cycle
Counts may increase by orders of magnitude with magnetic storms
Galactic Cosmic Radiation

Nuclear composition of galactic cosmic rays.

Log fluence rate vs. atomic number.

Fig. 3.6. Nuclear composition of GCR (~2 GeV n$^{-1}$) (Mewaldt, 1988).
Changes during short-duration space flight

Magnitude of Decrement (Arbitrary Units)

Shuttle

Plasma Volume
Red Blood Cell Mass
Muscle
Bone
Radiation
Sensorimotor

Not shown: Behavioral Health & Performance

1 2 3 4 5 6
Bone Loss During Space Missions

Space flight n=22
2 years post-menopause, n=13 (for comparison only)

Mission Opportunities

2018-2022

Outbound | On Mars | In-bound
---|---|---
Outbound | On Mars | In-bound

Time (months)
Treadmill in a six-degree of freedom Platform
Variation in Distance and Communications Delay Between Earth and Mars
Integrated Visual Impairment/Intracranial Pressure

- **Choroidal Folds** - parallel grooves in the posterior pole
- **Optic Disc Edema** (swelling)
- **Altered Blood flow**
- **“cotton wool” spots**
- **Increased Optic Nerve Sheath Diameter**

- **Peripapillary Shifts**
  - +1.75 diopters

- **Flattening**
  - MRI Orbital Image showing globe flattening

- **Flatten Globe**

- **Globe Flatten**

- **Choroidal Fold**
  - parallel grooves in the posterior pole

- **Optic Disc Edema** (swelling)

- **Altered Blood flow**
  - “cotton wool” spots

- **Increased Optic Nerve Sheath Diameter**
Flame Behaviour
Shuttle Launch
International Space Station
The Vomit Comet
Zero-Gravity Aircraft
Space Simulation at Earth - Exercise
Two Shuttles in the Launch Pad
Apollo-1 Fire Accident
Apollo-1
Beautiful Fragile Blue Planet

With God’s grace, Make a difference
Earth at Night
Guppy
T-38 and Guppy
Integrated Pre/In/Post-Flight VIIP Medical and Research Testing

**Preflight Exams**
- L-90/45
- L-90/45 days
- Ultrasound Eye/Orbit
- Fundoscopy - PanOptic Ophthalmoscope
- Tonometry
- Visual Acuity - Including Amsler Grid Testing
- Other Tests - biomicroscopy (slit lamp), high resolution retinal photography, OCT (high resolution), and A-Scan.

**In-flight Exams**
- L+10
- L+30
- L+60
- L+100
- R-30
- L+30 & R-30, L+100 if requested (+/- 7 days) & as clinically indicated

**Post flight Exams**
- R+1 to R+3
- R+1 to R+3 (or as soon as possible)
- Ultrasound Eye/Orbit
- Fundoscopy - PanOptic Ophthalmoscope
- Tonometry
- Visual Acuity - Including Amsler Grid Testing
- Blood Pressure
- Vascular

MRI Of Brain and Orbits Without Contrast
- Ultrasound Eye/Orbit
- Fundoscopy - PanOptic Ophthalmoscope
- Tonometry
- Visual Acuity - Including Amsler Grid Testing