**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
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 Rover Cameras
Design Reference Architecture Mission Profile

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

Orion with 6 crewmembers

- Crew: 200 Days to Mars
- Cargo: 350 Days to Mars
- Crew: 500 Days at Mars
- 26 Months
- 30 Months
Life Support Requirements Mass Breakdown

5.02 - 30.74 kg per person-day

<table>
<thead>
<tr>
<th>DAILY INPUTS - NOMINAL</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>

Resources and Recycling

- Water Regeneration Reactors
- Air Revitalization Reactors
- Environmental Sensors (Chemical)
- Microbial Monitors

<table>
<thead>
<tr>
<th>DAILY OUTPUTS - NOMINAL</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>

11.3 Metric Tons Per Person-Year
Oxygen Generation System

RIP QDs
Nitrogen in

Feedwater in

Inlet DIonization Bed

3-way valve

Gas Sensors

Water ORU CV & MCV

Hydrogen Vent to space or Sabatier

Feedwater with air rejected to waste bus

Recirc Loop

Cell Stack

Pressure dome

Hydrogen and water

Rotary Separator Accumulator

Pump

200μ filter

Heat Exchanger

Coolant

-311 ACTEX

Oxygen Out

Oxygen to cabin

Water Adsorber

Hydrogen Sensor

Venturi sensors

200μ filter
Hygiene
Garbage Handling
Salt and Pepper
Candies in water bubble
Dinner at his Lap
Yummy Dinner
Refrigerators and freezers not available to maintain food safety and quality
Weightlessness
Weightlessness
Super-Woman
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

A. Jeevarajan/NASA
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%
- Consumer Products: 16%
- Occupational: 2%
- 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

- 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 radon exposure: 52%

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.

Fig. 3.5. Typical energy spectra for protons, helium ions, carbon ions, and iron ions from “top to bottom,” respectively, at solar minimum. The solid line is the local interstellar spectrum (Simpson, 1989a).
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'Neil 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: $\sim 0.04$ to $500$ MeV
- Electrons: $\sim 0.04$ 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

van Allen Belt Particles
Galactic Cosmic Radiation

Nuclear composition of galactic cosmic rays.

Log fluence rate vs. atomic number.

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

Magnitude of Decrement (Arbitrary Units)

Shuttle

Not shown: Behavioral Health & Performance

- Plasma Volume
- Red Blood Cell Mass
- Muscle
- Bone
- Radiation
- Sensorimotor

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

<table>
<thead>
<tr>
<th>Year</th>
<th>Outbound</th>
<th>On Mars</th>
<th>In-bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>2018</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2022</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Treadmill in a six-degree of freedom Platform
Variation in Distance and Communications Delay Between Earth and Mars

![Graph showing variation in distance and communications delay between Earth and Mars](image-url)
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 to +1.75 diopters
- Globe Flattening
  - Flattened Globe
  - MRI Orbital Image showing globe flattening
Flame Behaviour
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

Chicago

Dallas

Houston

Miami

Puerto Rico
T-38 and Guppy
Integrated Pre/In/Post-Flight VIIP Medical and Research Testing

Preflight Exams

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), A-Scan.

L-90/45 & R-90/45

L+10

L+30

L+60

L+100

R-30

R+1 to R+3

In-flight Exams

L+30 & R-30, L+100 if requested (+/- 7 days) & as clinically indicated

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), A-Scan.

L+10, 30, 60, 100 & R-30, (+/- 7 days)

Ultrasound Eye/Orbit

Fundoscopy - PanOptic Ophthalmoscope

Tonometry

Visual Acuity - Including Amsler Grid Testing

Blood Pressure

Vascular

Post flight Exams

R+1 to R+3

(or as soon as possible)

MRI of Brain and Orbits Without Contrast

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), A-Scan.