CREW HEALTH AND PERFORMANCE ON MARS

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Human Space Life Sciences Programs

JSC is lead center for Human Operations in Space, including:

- Space Medicine
- Biomedical Research and Countermeasures
- Advanced Human Support Technologies
  - Advanced Life Support
  - Advanced Human Engineering
  - Advanced Environmental Monitoring and Control
  - elements of Advanced EVA

Human Space Life Sciences Program Office (HSLSPO) coordinates these critical human research support functions for JSC as Lead Center.

Background

HSLSPO determines critical research areas to assure human health and performance capability to explore and develop space.

Mars Design Reference Mission is benchmark for determining content and direction of mid- and long-term research activities.

Near-term focus continues on tasks and techniques to expand human performance on Shuttle and ISS missions.

Elements of Human Health and Performance (HHP)

- Advanced Life Support (supply atmosphere, water, thermal control, logistics, waste disposal)
- Bone Loss (fractures, renal stones, joints, discs, osteoporosis, drug reactions)
- Cardiovascular Alterations(dysrhythmias, orthostatic intolerance, exercise capacity)
- Environmental Health (monitor atmosphere, water, contaminants)
- Food and Nutrition (malnutrition, food spoilage)
- Human Performance (psychosocial, workload, sleep)
- Immunology, Infection and Hematology (infection, carcinogenesis, wound healing, allergens, hemodynamics)
- Muscle Alterations and Atrophy (mass, strength, endurance)
- Neurovestibular Adaptations (monitoring and perception errors, postural instability, gaze deficits, fatigue, loss of motivation and concentration)
- Radiation Effects (carcinogenesis, damage to CNS, fertility, sterility, heredity)
- Space Medicine (in-flight debilitation, long term failure to recover, in-flight mis-diagnosis)

Why Mars?

Mars design reference mission requires most rigorous life sciences critical path of any crewed mission in foreseeable future.

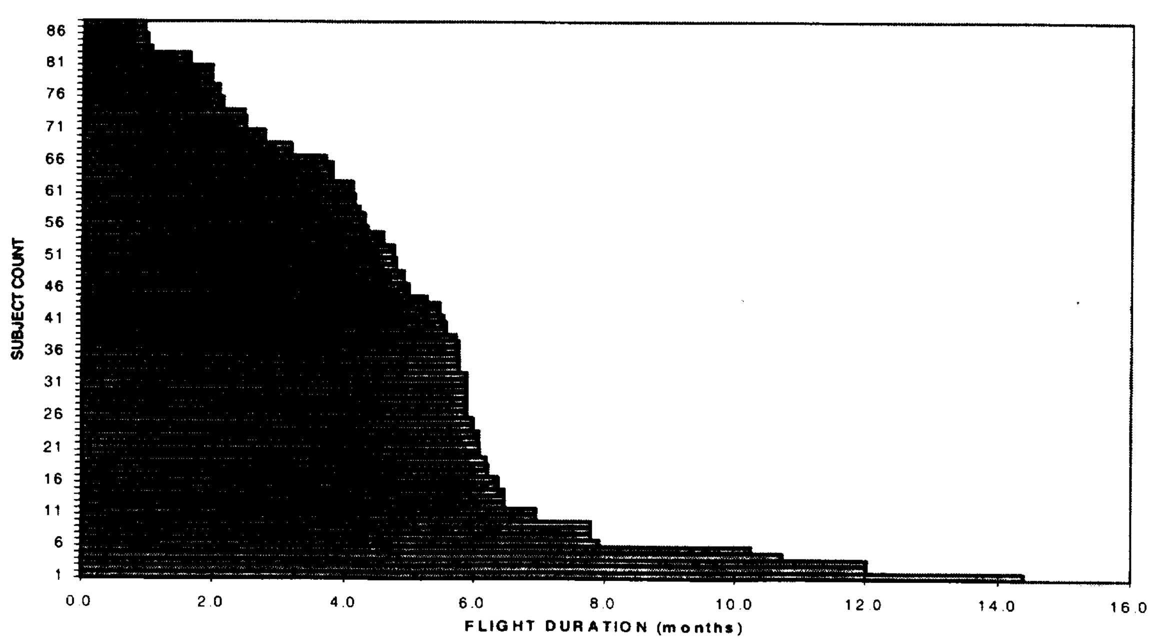
Mars DRM

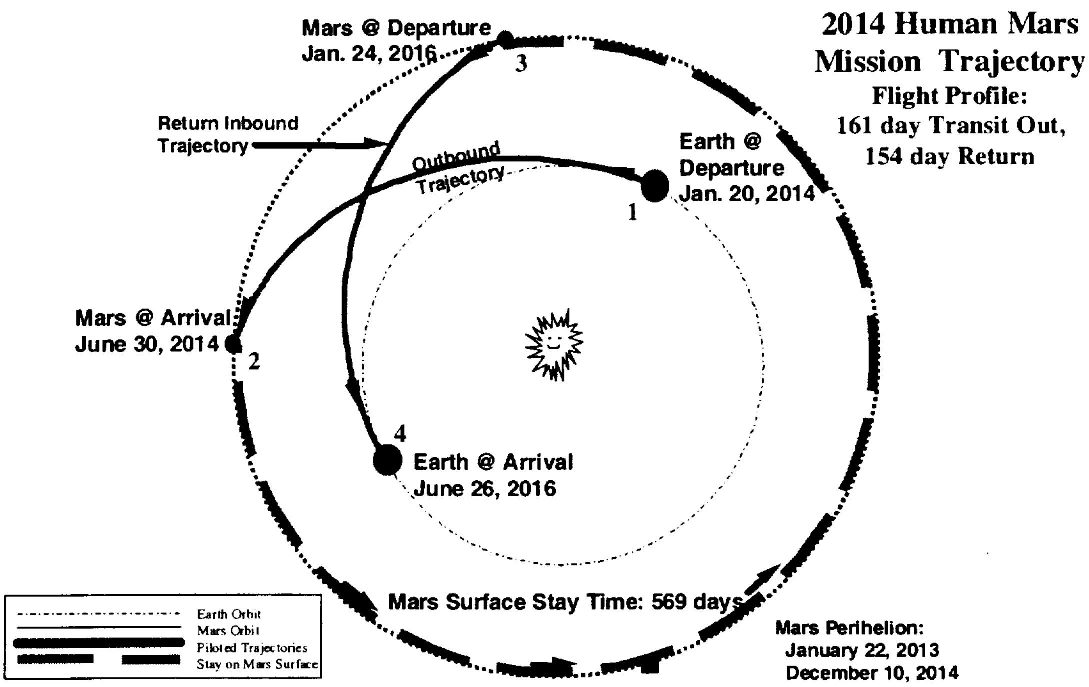
- 30 months round-trip
- four g-transitions: 1g to 0g; 0g to 1/3g; 1/3g to 0g; 0g to 1g
- two episodes of high (up to 5) g-load: Mars aerobrake; Earth aerobrake
- high physical demands of Mars surface EVA, possibly daily
- exposure to spacecraft, terrestrial and extraterrrestrial toxins
- largely autonomous; ground support limited to trending

Current Experience and ISS Requirements

- longest flight to date: 14 months ISS tours: 3-6 months
- two g-transitions: 1g to 0g; 0g to 1g
- one episode of low (1.5-2) g-load: Earth aerobrake (via Shuttle)
- orbital EVA; regular daily exercise
- exposure to spacecraft and terrestrial toxins only
- access to real-time ground support

Human Space Flight Experience Greater Than 30 Days (as of 1 Jan. 98





Physical Challenges to HHP: Gravity and Acceleration

	Earth Launch	Transit	Mars Landing	Mars Surface	Mars Launch	Transit	Earth Landing
G-Load	up to 3 g	0 g	3-5 g	1/3 g	TBD g	0 g	3-5 g
Notes	boost phase, 8 min.; TMI, minutes	4-6 months	aero-braking, minutes; parachute braking, 30 sec.; powered descent, 30 sec.	18 months	boost phase, minutes; TEI, minutes	4-6 months	aero-braking, minutes; parachute braking, minutes
Cumulative hypo-g	0		4-6 months		22-24 months		26-30 months
G Transition	1 g to 0 g		0 g to 1/3 g		1/3 g to 0 g		0 g to 1 g

Impacts of Extended Weightlessness on HHP

Physical tolerance of stresses during aerobraking, landing, and launch phases, and strenuous surface activities

- Bone loss
  - no documented end-point or adapted state
  - countermeasures in work on ground but not yet flight tested
- Muscle atrophy
  - resistive exercise being evaluated
- Cardiovascular alterations
  - pharmacological treatments for autonomic insufficiency
- Neurovestibular adaptations
  - vehicle modifications, including centrifuge
  - may require auto-land

"Artificial Gravity" as Countermeasure to Weightlessness

Question: Can AG preserve physiological function on long-duration missions?

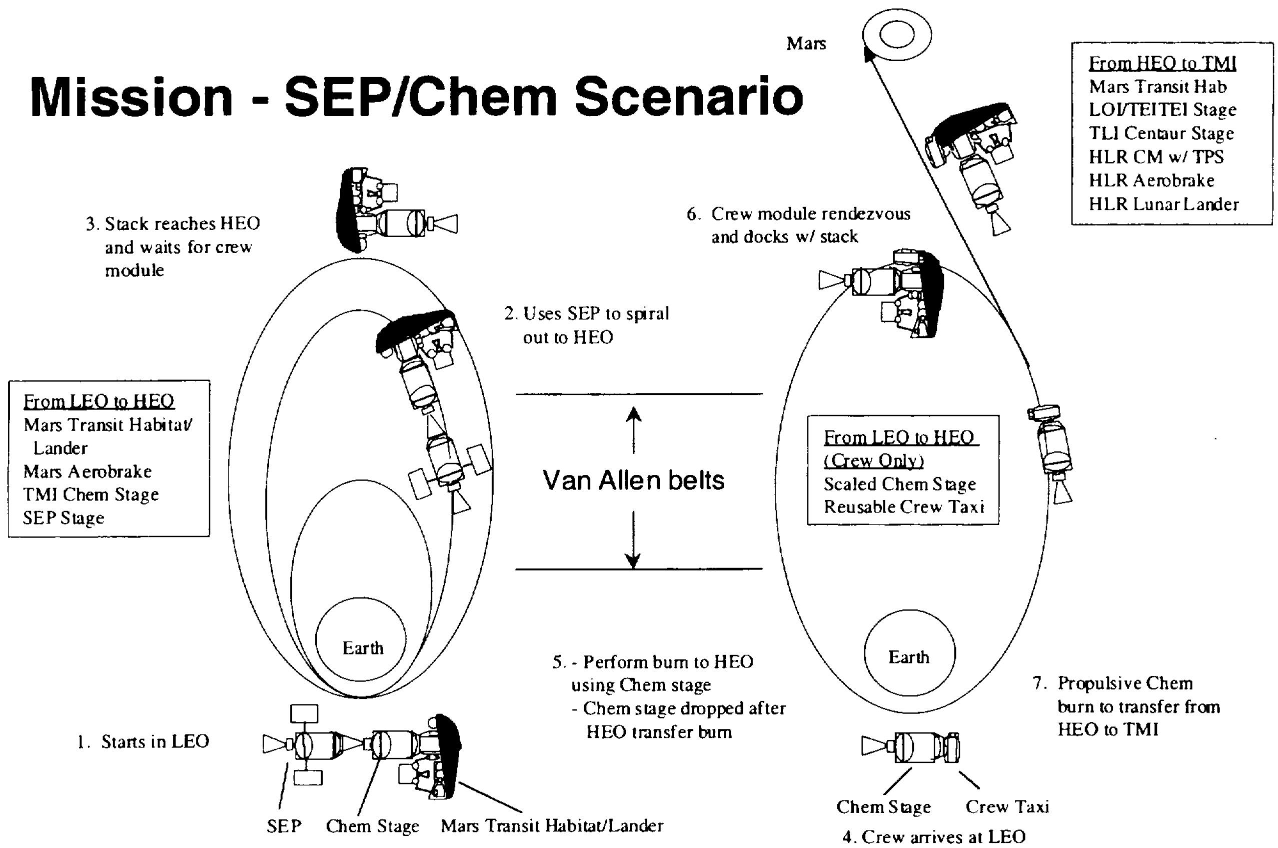
Implications:

- Can Mars DRM afford weight, power, cost of AG?
  - dual systems for 0 g and AG phases of transits?
- How will NASA validate approach?
  - ISS small-animal centrifuge not available before CY 2003
  - larger centrifuge not currently planned

Physical Challenges to HHP: Radiation

	Earth Launch	Transit	Mars landing	Mars Surface	Mars Launch	Transit	Earth Landing
Source	van Allen (trapped radiation) belts	GCR (quiet Sun); SPE (active Sun); nuclear power reactor		GCR (quiet Sun); SPE (active Sun); nuclear power reactor		GCR (quiet Sun); SPE (active Sun); nuclear power reactor	
Expo sure	SEP option: 3 passages or more	4-6 months		18 mon.; shielded by Mars' bulk and atmos.		4-6 months	
Cum. Exp.	hours-days		4-6 months		22-24 months		26-30 months

Mission - SEP/Chem Scenario



from SEP Team package, Nov., 1997

Peak Physical Challenges for HHP: Mars Surface Phase (Post-Landing through Pre-Launch)

<u>Assumption</u>

Mars surface gravity

- too low to be beneficial (bone integrity, etc.)
- too high to be ignored (g-transition vestibular symptoms)

<u>Challenges</u>

- physical
  - g-transition (first few days only?)
  - prolonged exposure to 1/3 g
  - high-intensity surface activity
  - EMU hypobaric environment
  - 70 kg EMU (partially self-supporting)
  - surface trauma risk
- no real-time MCC support
  - crew highly autonomous
  - Earth monitoring for trend analysis only

Peak Physical Challenges for HHP: Strategy for Mars Surface Ops

Background: anecdotal evidence suggests only ~50% of Russian Mir crewmembers are ambulatory with assistance immediately after landing, increasing to nearly 100% within hours

Assume: only 3 out of 6 Mars crewmembers ambulatory immediately after landing

Strategy: start with initial passive IVA tasks, then progress to strenuous EVA tasks
- first 1-3 days limited to IVA reconfig of lander/habitat, surface recon
- then, first EVA(s) in vicinity of lander (umbilical instead of PLSS?)
- next, use unpressurized rover for early, shorter excursions
- after a week or more, extended excursions possible

HHP Mars Surface Stay Requirements

Autonomous
- Medical care
- Nutrition
- Psych support
  - meaningful work
  - communications capability (surface, deep space)
- Habitat Facilities
  - exercise
  - workshop
  - recreation

Life Sciences on Mars Surface

Periodic (monthly?) health checks:
- bone integrity
- cardiovascular/cardiopulmonary function
- musculoskeletal fitness
- blood work

Assessments will also serve as applied research:
- probably longest period away from Earth to date
- probably longest exposure to hypogravity (1/3 g) environment to date

Space Medicine Issues

Based on US and Russian space flight data, and US astronaut longitudinal data, submarine experience, Antarctic winter-over experience, and military aviators:

Significant Illness or Injury = 0.06 per person per year (or PYE)
- requiring emergency room (ER) visit or hospital admission
- by US standards

For DRM of 6 crewmembers and 2.5 year mission, expected incidence is 0.90, about one person per mission

Subset requiring intensive care support (ICU) = 0.02 per PYE
Expected incidence is 0.30, about once per three missions

Space Medicine Issues:
Space Flight Incidence of Illness and Injury

Common (> 50%incidence)
- skin rash, irritation
- foreign body
- eye irritation, corneal abrasion
- headache, backache, congestion
- gastrointestinal disturbance
- cut, scrape, bruise
- musculoskeletal strain, sprain
- fatigue, sleep disturbance
- space motion sickness
- post-landing orthostatic intolerance
- post-landing neurovestibular symptoms

Incidence Uncertain
- infectious disease
- cardiac dysrhythmia
- trauma, burn
- toxic exposure
- psychological stress, illness
- kidney stones
- pneumonitis
- urinary tract infection
- spinal disc disease
- radiation exposure

data from R. Billica, Jan. 8, 1998

Space Medicine Issues:
Recommended Clinical Care Capability Development

Clinical Care
- imaging capability
- trauma care
- surgical capability
- noninvasive diagnostics
- respiratory care/advanced ventilation
- hyperbaric treatment
- medical informatics, telemedicine
- radiation treatment
- blood substitutes
- urologic diagnosis, treatment
- extended shelf-life pharmaceuticals
- body disposal, palliative treatment
- serological capabilities
- banked autologous marrow

Prevention and Countermeasures
- reconditioning, rehabilitation
- preventive medicine
- recycling of resources
- toxin dust management
- sterile water
- resistive exercise training
- radiation prophylactics
- microbiology

data from R. Billica, Jan. 8, 1998

Human Factors and Habitability

The following require engineering solutions to optimize HHP:
- clean air
- clean water
- waste management
- adequate food
  - long-duration storage
  - grain processing
- particulate analyzer
- microbial analyzer
- clothes washer
- lighting
  - intensity (threshold level)
  - periodicity (circadian rhythmicity)

Conclusions

- The human element is the most complex element of the mission design
- Mars missions will pose significant physiological challenges to crew members
- Some challenges (human engineering, life support) <u>must</u> be overcome
- Some challenges (bone, radiation) <u>may</u> be show-stoppers
- ISS will only indirectly address Mars questions before any "Go/No Go" decision
- Significant amount of ground-based and specialized flight research will be required — Critical Path Roadmap project will direct HSLSPO's research toward Mars exploration objectives