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Monday, June 9

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**Session MP5**  
**Room 5**  
**2:30 - 5:30 p.m.**

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**Life Sciences Issues for a Mission  
to Mars**

## CARDIOVASCULAR CONCERNS FOR A MARS MISSION: AUTONOMIC AND BIOMECHANICAL EFFECTS

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### INTRODUCTION

From the perspective of the cardiovascular system there seems limited concern that the crew could survive the exposure to weightlessness necessary to achieve a Mars destination. The greatest obstacle extant is to deliver a crew to the surface, possessing a functional capacity permitting routine and emergency operations once planetfall is achieved.

Within moments of entering weightlessness, the cardiovascular system begins responding to the new environment. Altered baseline physiologic parameters have consistently been observed in flight. To date, these have not proved to impact adversely on mission objectives. However, the exact mechanism effecting these changes are not completely understood. A relatively stable steady-state is achieved in the short term. With longer duration missions, there has been some evidence of increased ventricular and supraventricular ectopy, the basis of which is unknown. Possible explanations include electrolyte abnormalities, autonomic dysfunction, hormonal influences and/or mechanical alterations. The cardiovascular response to stress and exertion is different in longer duration flights. These alterations have not become clinically significant nor have they hindered mission objectives. With missions of even greater duration planned however, these physiologic changes become a point of great concern. Not enough information is available to adequately predict long term cardiovascular changes and the health impact on the crew.

### RESULTS

Crews returning to Earth from short and long duration space flights have demonstrated a reversible form of autonomic dysfunction. Recent studies have suggested that this is a major component of the sometimes severe orthostatic intolerance and syncope experienced by crew members once they return to gravity's domain. Too little is understood about the autonomic nervous system and its influence on cardiovascular fitness to predict what long term consequences would be, once this system is perturbed from long duration exposure to weightlessness.

An artificial cardiovascular system has been developed to observe the biomechanical effects of microgravity isolated from the autonomic/nervous influences. Results of parabolic flight-induced microgravity experiments, which segregate the vascular and ventricular contractile and compliance forces and pressures from inherent cardiovascular reflexes, will be discussed.

### CONCLUSION

Incomplete knowledge of the mechanisms effecting cardiovascular change is a significant obstacle in devising effective countermeasures. Interventions should be developed to ensure a degree of cardiovascular fitness sufficient to permit crews landing on Mars the ability to rapidly carry out mission objectives and be able to negotiate any emergency situations that arise.

## REDUCING THE RISK OF SPACE RADIATION INDUCED BIOEFFECTS- VEHICLE DESIGN AND PROTECTANT MOLECULES

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### ENVIRONMENT

The space environment poses many significant challenges to mission planners of exploratory class missions to the moon and Mars. Radiation exposures received by the crew and spacecraft are a function of the location (LEO, free space, planetary surface), the time of flight with respect to the Solar Cycle, and whether or not solar particle events are being experienced in each of these different environments. Current knowledge of these different environments have uncertainties in the range of 2 to 4 times actual values. These uncertainties need to be reduced for proper mission planning and risk amelioration for exploratory class space flight.

### SPACECRAFT DESIGN

Risk assessment must deal with biological impacts associated with human exposure to the space radiation environment as well as potentially harmful effects to spacecraft electronic systems due to damaging interactions with the space particulate radiation. Additionally, spacecraft design must use mass effectively to provide adequate shielding of crew and components during the long duration flight times envisioned in the exploratory class flight scenarios.

### BIOEFFECT MODULATION

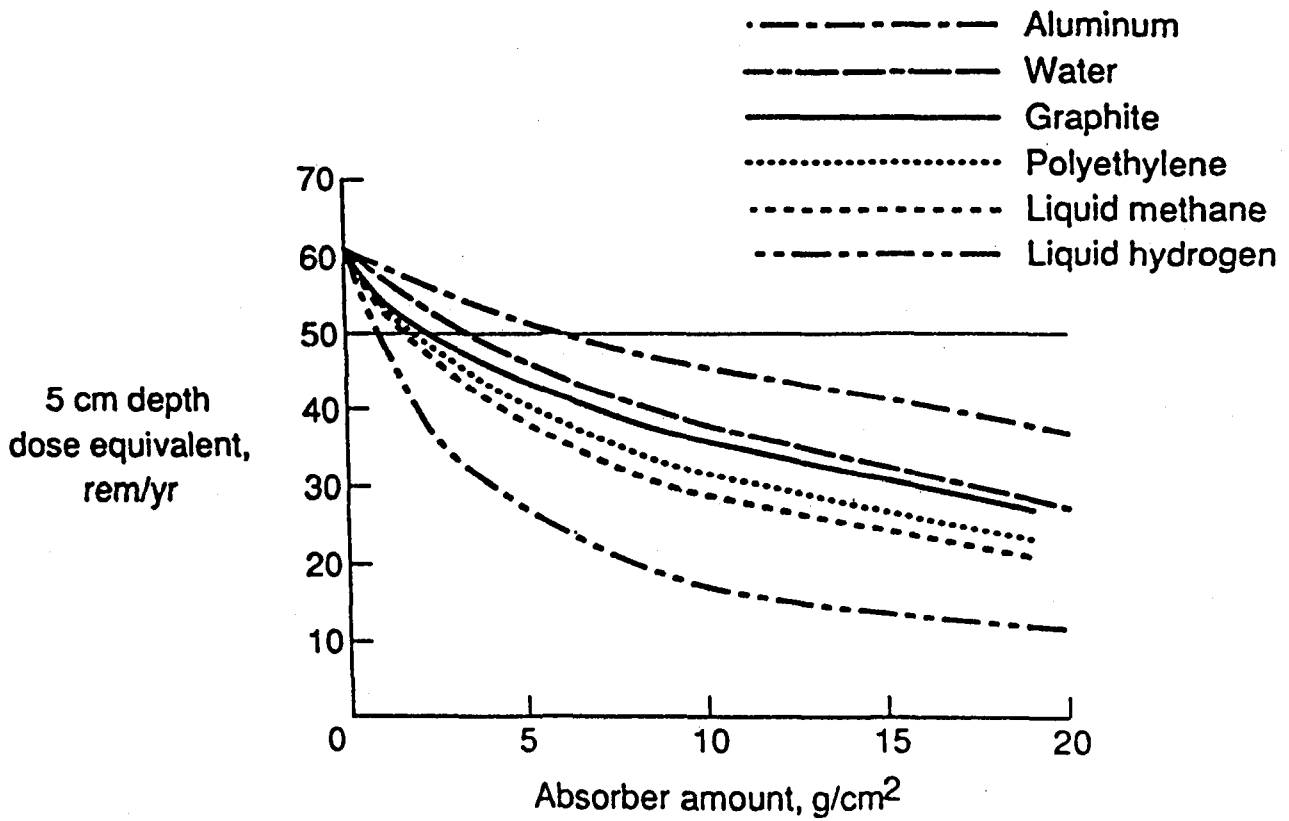
Space radiation bioeffects are often described both in terms of dose delivery to the organism: acute high dose vs. chronic low dose, as well as by the source of emanation: galactic cosmic rays(GCR) vs. Solar Particle Events(SPE's). Characterizing both the quality and quantity of radiation expected along the planned transfer route and on the Martian surface, is paramount in defining the radiation exposure risk. Developing improved measurement models(e.g. via onboard active dosimeters) for predicting SPE exposure and intervention strategies will also prove to be invaluable in a Mars mission. Shielding design may lower the crew's exposure and thus their chances of developing acute radiation sickness resulting from the delivery of a greater than 300 rem dose that might be expected from a high fluence SPE. However, the stochastic effects such as carcinogenesis, resulting from a long term exposure to daily GCR or from the secondary radiation events produced by HZE particle fragmentation by spacecraft shielding in deep space, may not have been adequately studied or mitigated to date. A number of radioprotectant molecules have been evaluated in the past, mainly by groups interested in lessening the effects on humans of nuclear explosions or therapeutic radiation for cancer treatment. Although some of these agents have been shown to reduce radiation toxicity, their side effects and delivery mode have limited their potential utility for flight crews. Newer, less toxic agents are showing promise in lessening the effects of ionizing radiation on eukaryotic DNA and cellular processes.

### DISCUSSION

This session will discuss current thinking on the space radiation issue as well as pose some interesting ideas concerning the future work required in a radiation health/assessment program. Data shows that shielding effectiveness of certain materials, such as hydrogen and water, will impact the final design of an exploratory spacecraft to best utilize these materials in the overall shielding strategy(see Figure). Also strategies for potential reduction of bioeffects by molecules designed to limit the impact of ionizing radiation on mammalian cells will be discussed.

# GALACTIC COSMIC RAYS - SOLAR MINIMUM

(Depth vs. Dose Functions for Selected Materials)



## MUSCULOSKELETAL ISSUES FOR LONG DURATION MISSION: MUSCLE MASS PRESERVATION, RENAL STONE RISK FACTORS, COUNTERMEASURES, AND CONTINGENCY TREATMENT PLANNING

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### INTRODUCTION

One of the greatest physiologic challenges to long duration space flight is the maintenance of muscle mass and bone density. This would be especially true for a crew who would be required to rapidly establish a life support base on the Martian surface following an extended time in microgravity. Muscle atrophy and weakness occur even on short duration shuttle flights of 10-16 days duration. A greater effect is seen with extended stays in LEO. The potential consequences of bone and muscle weakness include inability to egress (in nominal and contingency situations), increased orthostatic intolerance, bone fractures, muscle injury, hypercalcemia, urinary lithiasis. With planned extended stay missions to orbiting space stations and potentially manned missions to Mars, there has been a concentrated effort to develop countermeasures to prevent bone and muscle loss.

Significant physiological changes occur in astronauts upon exposure to microgravity and the readaptation process that follows their return to Earth. Some well-documented changes that result from space flight, including increased urinary calcium and phosphorus excretion and decreased fluid intake/urine output, result in a urinary chemical environment in which there is a greater risk of renal stone formation.

### RESULTS

Our studies have indicated that risk factors in addition to those previously anticipated contribute to an increased risk for renal stone formation during and after space flight. In particular, low urinary pH and hypocitraturia increase the renal stone-forming risk of uric acid and calcium-containing stones. Immediately after space flight the relative supersaturation for uric acid or calcium oxalate is greater than 2 times a normal non-stone forming population. During space flight, the risk is significantly elevated for calcium oxalate and brushite stones. These alterations in risk factors are reversible 7-14 days after return to Earth. Duration of space flight has not indicated greater risk as a function of mission duration; in general, the data are consistent for long and short duration space flights. Urine volumes greater than 2 liter/day were found to reduce the risk of stone formation in astronauts immediately after space flight as compared to those astronauts with urine volumes less than 2 liters/day. Although urine volume appears to be sufficient as a countermeasure to reduce stone-forming potential immediately after flight when the body is readapting to the Earth environment, hydration as a countermeasure may not be sufficient to reduce stone formation during flight where hypercalciuria and hypocitraturia are an ongoing problem. (See Table 1)

### DISCUSSION

The panel will present an overview of the findings of countermeasure studies to date and discuss current and future countermeasure strategies for long duration space flight. Potential countermeasures for maintaining muscular and skeletal integrity include various resistance and endurance exercise regimens, and augmentation of these protocols with drugs, "penguin suits", or electrical stimulation. The potential of utilizing oral potassium citrate therapy will be discussed as a countermeasure to reduce renal stone formation during space flight. Finally potential contingency stone management strategies will be outlined.

**Table 1. Renal Stone Risk in Astronauts Before, During and After Space Flight.**

	PRE	Group 1 POST (n=279)	PRE	Group 2 IN-FLT (n = 6)	POST	
<b>Calcium (mg/day)</b>	191 (5.8)	241 (7.2)*	166 (32.7)	132 (22.0)	222 (34.4)	245 (70.2)*
<b>Total Volume (l/day)</b>	2.01 (0.06)	1.94 (0.06)	1.68 (0.09)	0.80 (0.08)	1.30 (0.17)	1.52 (0.35)
<b>pH</b>	6.01 (0.03)	5.68 (0.03)*	6.01 (0.18)	5.95 (0.19)	5.92 (0.13)	5.14 (0.05)*
<b>Citrate (mg/day)</b>	708 (17.5)	609 (19.1)*	718 (115)	469 (109)	522 (66)	456 (82)
<b>Urinary Relative Supersaturation</b>						
<b>Calcium Oxalate</b>	1.64 (0.06)	2.32 (0.06)*	1.52 (0.40)	2.95 (0.65)*	2.78 (0.47)*	2.07 (0.40)
<b>Brushite</b>	1.35 (0.07)	0.98 (0.06)	1.11 (0.32)	2.20 (0.32)*	2.10 (0.43)*	0.32 (0.07)
<b>Sodium Urate</b>	2.71 (0.14)	1.48 (0.08)	1.83 (0.47)	2.66 (0.50)	1.77 (0.42)	0.66 (0.42)
<b>Struvite</b>	2.04 (0.37)	0.56 (0.08)	1.29 (0.78)	3.46 (1.44)	0.99 (0.28)	0.05 (0.04)
<b>Uric Acid Saturation</b>	1.95 (0.10)	2.69 (0.11)*	1.96 (0.69)	2.31 (0.75)	1.68 (0.31)	2.84 (0.76)

For Group 1, the data represent the mean +/- sem obtained 10 days prior to launch (PRE) and on landing day (POST). For Group 2, the values for PRE are the means +/- sem from two separate preflight urine collections. In-Flt represents two separate urine collections during the early phase of the missions (flight days 3-4) and during the late phase of the mission (flight days 11-13). \* denotes significant differences from before flight, p < 0.05.

## PSYCHOLOGICAL ISSUES AND CREW SELECTION FOR A MARS MISSION: MAXIMIZING THE MIX FOR THE LONG HAUL

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### INTRODUCTION

Historically, the process of mission specific crew selection for space flights has been severely limited. Mainly oriented towards ruling out pathology and maximizing specific field-relevant expertise, all other factors (e.g., gender, race, culture) have oftentimes been driven by political processes rather than attention to maximizing team processes.

### RESULTS

Growing evidence from psychosocial research and a body of experience with long-term exposure to the space environment, indicate that the time has come to move towards identifying those individuals who are best suited to maintain maximal health and performance under conditions characterized by close confinement, reduced stimulation, weightlessness, isolation and extreme environmental danger. Evidence has clearly indicated problematic areas in which group functioning has been compromised to some extent by the presence of communication breakdowns, interpersonal conflict, individualized responses to environmental stresses and conflicts over authority and control. A renewed focus on psychosocial factors is beginning to yield information regarding crew size, gender mix, composition, structure and the necessary interpersonal skills required for effective group performance in extreme environments.

Lessons learned from military and remote outpost team member observational studies indicate that the pressures on individuals required to work and live together in extreme environments, could raise the need to address personality and behavior issues, not otherwise required in more limited missions. Group living training pre-flight may play a role in providing crew members with a variety of coping skills and strategies to effectively handle these personality/behavioral issues as they arise. Further research on the role of pre-flight mission simulation with proposed crews may provide insight into the factors predicting potential interpersonal conflicts during the mission. Mental health monitoring tools need to be developed that provide real-time assessment of behavioral conflicts and possible secondary somatization symptomatology. Defining resources that crews may have for intervention during periods of defined stress may prove invaluable for maximizing crew performance.

### DISCUSSION

Pertinent issues for guiding psychological and behavioral factors in crew selection for long-duration missions will be discussed. Mental health monitoring and support strategies will be evaluated. Finally discussion will be made of interactive psychological appraisal tools used in monitoring assigned crews in the Antarctic and remote outposts.

## ISSUES IN CREW HEALTH, MEDICAL SELECTION AND MEDICAL OFFICER(CMO) TRAINING FOR A MISSION TO MARS

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Crew medical selection criteria and plans for medical care should both derive from mission guidelines defining acceptable risk. Acceptable risk for events affecting mission completion, and for events affecting individual career completion should both be given proper weight. Low earth orbital missions and interplanetary missions expose crew members to categorically similar risks; but markedly increased return times and the absence of radiation shielding provided by Earth's magnetosphere greatly increase the magnitude of some categories of risk. These risks can be ameliorated by careful attention to habitat design, medical selection criteria, onboard medical capability and remote medical consultation capability. Habitat design must be carefully analyzed and incorporated into spacecraft design at the earliest stages in order to achieve the best cost/benefit ratio. Mission duration significantly influences the appropriate mix of medical personnel training, experience and skill and knowledge redundancy. Interplanetary communication lag times impose significant limitations on the use of earth based consultation. A discussion of needed Crew Medical Officer credentials, experience, and training in order to effectively liaison with ground-based flight surgeons will be conducted.

A Crew Health Maintenance Plan including transfer and surface requirements will be outlined. Special problems associated with medical diagnostics and treatment associated with potential lowered gravity environments will be discussed. Also included will be a summary of circadian physiology, crew rest and possible pharmacological and light-based countermeasures.