

APPENDIX D: ENABLING QUESTIONS TABLES

Human Health and Countermeasures (HH&C)

Crosscutting Area:		Human Health and Countermeasures (HH&C)			
Discipline:		Bone Loss			
Risk:		(1) Accelerated Bone Loss and Fracture Risk			
EQ No	Enabling Question	EQ DRM Priority			EQ Category
		ISS	Lunar	Mars	
1a.	What is the relative risk of sustaining a traumatic and/or stress fracture for a given decrement in bone mineral density or alteration in bone geometry in an astronaut-equivalent population who are physically active?	3	5	1	Risk Assessment
1b.	Will a period of rapid bone loss in hypogravity be followed by a slower rate of loss approaching a basal bone mineral density? What are the estimated site-specific fracture risks as one approaches this minimal BMD?	2	5	1	Risk Assessment
1c.	Is there an additive or synergistic effect of gonadal hormone deficiency in men or women on bone loss during prolonged exposure to hypogravity?	1	5	5	Risk Assessment
1d.	What pharmacological agent(s) will most effectively minimize the decrease in bone mass with extended exposure to hypogravity?	1	5	1	Countermeasures
1e.	What are the specifics of the optimal exercise regimen with regard to mode, duration, intensity and frequency, to be followed during exposure to hypogravity so as to minimize decreases in bone mass? Is impact loading an essential element and, if so, how can it be produced in hypogravity?	1	3	1	Countermeasures
1f.	What combination of exercise and a pharmacological agent(s) will prevent bone loss during exposure to hypogravity?	1	5	1	Countermeasures
1g.	What are the important predictors for estimating site-specific bone loss and fracture risk during hypogravity exposure, especially with reference to ethnicity, gender, age, baseline bone density and geometry, nutritional status, fitness level and prior microgravity exposure?	1	5	1	Risk Assessment
1h.	Does the hypogravity environment change the nutritional requirements for optimal bone health?	3	3	2	Mechanisms
1i.	What diagnostic tools can be utilized during multi-year missions to monitor and	2	5	1	Medical Diagnosis &

	quantify changes in bone mass and bone strength?				Treatment
1j.	What systemic adaptations to hypogravity are important contributory factors to bone loss, evaluations of which are essential to effective countermeasure development (e.g., fluid shifts, altered blood flow, immune system adaptations)?	3	5	2	Mechanisms Countermeasures
1k.	Are hypogravity-induced changes in bone density, geometry and architecture reversible upon encountering partial Gravity exposure, or on return to full gravity (1-G)?	1	5	1	Risk Assessment
1l.	What regimen (exercise, pharmacological or biomechanical including impact loading or artificial gravity exposure) will most effectively hasten restoration of bone mass and bone strength (geometry and architecture) to pre-flight values in returning crewmembers?	2	5	2	Countermeasures

Crosscutting Area: Human Health and Countermeasures (HH&C)					
Discipline: Bone Loss					
Risk: (2) Impaired Fracture Healing					
EQ No.	Enabling Question	EQ DRM Priority			EQ Category
		ISS	Lunar	Mars	
2a.	Is the rate of fracture healing and the integrity of the healed fracture altered under microgravity or unloaded conditions?	1	1	1	Risk Assessment
2b.	Are there site-specific differences, or differences in healing diaphyseal bone versus metaphyseal bone under microgravity or partial-gravity conditions?	3	3	3	Risk Assessment
2c.	Which cellular and biochemical changes in bone cell biology alter fracture healing under microgravity conditions?	4	4	4	Mechanisms
2d.	Does the presence of microgravity-induced alteration in bone remodeling and/or osteoporosis affect fracture callus remodeling?	2	2	2	Mechanisms
2e.	How does altered muscle biology contribute to altered fracture healing in microgravity?	4	4	4	Mechanisms
2f.	Do biophysical modalities play a role in improving fracture healing in a microgravity environment?	2	2	2	Mechanisms
2g.	Do biophysical modalities play a role in improving fracture healing in the	2	2	2	Mechanisms

	presence of bone loss in a microgravity environment?				
2h.	Are there anabolic agents, growth factors or cytokines that will speed fracture repair during microgravity, in combination with active bone loss due to unloading?	1	1	1	Countermeasures
2i.	What technologies will be used to diagnose fractures of the axial and appendicular skeleton in a space environment?	1	1	1	Medical Diagnosis & Treatment
2j.	Will different technologies be needed to treat either open or closed fractures in a space environment?	1	1	1	Medical Diagnosis & Treatment

Crosscutting Area:		Human Health and Countermeasures (HH&C)			
Discipline:		Bone Loss			
Risk:		(3) Injury to Joints and Intervertebral Structures			
		EQ DRM Priority			
EQ No.	Enabling Question	ISS	Lunar	Mars	EQ Category
3a.	What is the cause of the back pain commonly experienced by crewmembers upon return to 1-G?	2	3	2	Mechanisms
3b.	Is damage to joint structure or intervertebral discs incurred during or following hypogravity exposure?	2	3	1	Risk Assessment
3c.	What countermeasures will protect joint and intervertebral soft tissues from microgravity or partial Gravity-related damage?	2	2	1	Countermeasures
3d.	What rehabilitative measures will hasten recovery of soft tissue damage in a partial Gravity environment or upon return to Earth's gravity?	2	2	1	Medical Diagnosis & Treatment

Crosscutting Area:		Human Health and Countermeasures (HH&C)			
Discipline:		Bone Loss			
Risk:		(4) Renal Stone Formation			
		EQ DRM Priority			
EQ No.	Enabling Question	ISS	Lunar	Mars	EQ Category
4a.	What diagnostic measures permit detection of renal calcification during extended- duration space flight?	4	1	1	Medical Diagnosis & Treatment
4b.	What nutritional and/or pharmacological countermeasures adequately minimize risk of stone formation in-flight and upon return to 1G?	3	2	2	Countermeasures
4c.	What is the time course of increased risk for renal stone formation abating upon return to 1G?	3	3	2	Risk Assessment

Crosscutting Area:		Human Health and Countermeasures (HH&C)			
Discipline:		Cardiovascular			
Risk:		(5) Occurrence of Serious Cardiovascular Dysrhythmias			
EQ No.	Enabling Question	EQ DRM Priority			EQ Category
		ISS	Lunar	Mars	
5a.	Does space flight increase susceptibility to serious cardiac dysrhythmias?	1	1	1	Risk Assessment
5b.	What conditions of space flight (e.g., Microgravity, disruption of physiological rhythms, nutrition, environmental factors and radiation) may be responsible?	1	1	1	Risk Assessment
5c.	What mechanisms are involved?	1	1	1	Mechanisms
5d.	Can risk of serious cardiac dysrhythmias be predicted for individual crewmembers?	1	1	1	Risk Assessment
5e.	What countermeasures may prevent or reduce the occurrence of serious cardiac dysrhythmias during long-term space flight?	1	1	1	Countermeasures
5f.	Can susceptibility to and occurrence of serious cardiac dysrhythmias be effectively diagnosed and treated during space flight?	1	1	1	Risk Assessment
5g.	Which cardiovascular diseases are likely to be aggravated by space flight?	1	1	1	Risk Assessment
5h.	What mechanisms are involved?	1	1	1	Mechanisms
5i.	What improved screening methods on the ground and in-flight might identify crewmembers with underlying cardiovascular disease, which may be aggravated by space flight?	1	1	1	Countermeasures
5j.	What countermeasures may be effective in mitigating the risk?	1	1	1	Countermeasures

Crosscutting Area:		Human Health and Countermeasures (HH&C)			
Discipline:		Cardiovascular			
Risk:		(6) Diminished Cardiac and Vascular Function			
EQ No.	Enabling Question	EQ DRM Priority			EQ Category
		ISS	Lunar	Mars	
6a.	Does long-duration space flight lead to diminished cardiac function?	1	1	1	Risk Assessment
6b.	What mechanisms are involved?	1	1	1	Mechanisms
6c.	Is the process reversible?	1	1	1	Risk Assessment
6d.	What is the extent of reduction in cardiac function and/or mass associated with long-duration space flight? Can susceptibility to reduced cardiac function be predicted for individual	1	1	1	Risk Assessment

	crewmembers?				
6e.	Can susceptibility to reduced cardiac function be predicted for individual crewmembers?	2	2	2	Risk Assessment
6f.	What countermeasures may be effective in mitigating the risk?	1	1	1	Countermeasures
6g.	What are the physiological and environmental factors by which space flight decreases orthostatic tolerance?	1	1	1	Mechanisms
6h.	How does duration of space flight affect the severity and time course of orthostatic intolerance and what are the mechanisms?	2	2	2	Risk Assessment Mechanisms
6i.	Is orthostatic intolerance likely to develop on the surface of Mars or the moon?	1	1	1	Risk Assessment
6j.	Can space flight-induced orthostatic intolerance be predicted for individual crewmembers?	1	1	1	Risk Assessment
6k.	What countermeasures can be developed to overcome or prevent orthostatic intolerance?	1	1	1	Countermeasures
6l.	What are the physiological and environmental factors by which space flight decreases aerobic exercise capacity?	1	1	1	Mechanisms
6m.	How does duration of space flight affect the severity of limitation of exercise capacity?	1	1	1	Risk Assessment
6n.	Can aerobic exercise capacity limitation be predicted for individual crewmembers?	1	1	1	Risk Assessment Countermeasures
6o.	What countermeasures can be developed to overcome aerobic exercise capacity limitation?	1	1	1	Countermeasures
6p.	What are the physiological and environmental factors by which space flight decreases orthostatic tolerance?	1	1	1	Mechanisms
6q.	Is orthostatic intolerance likely to develop on the surface of Mars or the moon?	1	1	1	Risk Assessment

Crosscutting Area:		Human Health and Countermeasures (HH&C)			
Discipline:		Environmental Health			
Risk:		(7) Define Acceptable Limits for Trace Contaminants in Air and Water			
EQ No.	Enabling Question	EQ DRM Priority			EQ Category
		ISS	Lunar	Mars	
7a.	What are the most likely sources of severe air pollution specific to ISS, lunar, and Mars missions and what methods can be used to control these sources over long periods of time?	1	1	1	Risk Assessment
7b.	What are the tolerance limits in terms of quantity and type of microorganisms in air, water, and food and on surfaces?	1	1	1	Risk Assessment
7c.	What approaches to setting exposure standards may be used when insufficient data are available to allow prediction of acceptable exposure levels?	1	1	1	Risk Assessment
7d.	What is the requirement for determining how rapidly acceptable air quality can be recovered after a severe pollution condition and what effect that recovery has on humidity condensate and the water recovery system?	1	1	1	Risk Assessment
7e.	Can automated real-time systems be used to monitor air quality for lunar and Mars missions and can the crew interpret results without ground support?	1	1	1	Countermeasures
7f.	How can traditional limited-time exposure and human toxicological data be used to predict acceptable values for inhalation exposures to single chemicals and/or to mixtures?	2	2	2	Risk Assessment
7g.	What impact do space flight-induced biological, physiological, and immunological changes have on the susceptibility of crewmembers to infectious agents and toxic substances in the air?	2	2	2	Risk Assessment
7h.	What are the effects of exposure to ultra fine and larger (respirable and non-respirable) particles (e.g., lunar dust) on crew health, safety and performance?	N/A	2	2	Risk Assessment
7i.	What are the interactions of microbes, chemicals and plants in CELSS on air quality?	N/A	2	2	Mechanisms
7j.	To the extent that plants are critical to mission success, will the potential for phytotoxicity be adequately addressed in the evaluation of air quality?	N/A	N/A	2	Risk Assessment
7k.	Is there the potential for increased	N/A	2	2	Risk Assessment

	heterogeneity in terms of the distribution of air contaminants in the relatively larger lunar and Mars habitats? If so, what additional monitoring resources and/or strategies are necessary to protect crew health?				Countermeasures
--	--	--	--	--	-----------------

Crosscutting Area:		Human Health and Countermeasures (HH&C)			
Discipline:		Immunology, Infection and Hematology (IIH)			
Risk:		(8) Immunodeficiency / Infection			
EQ No.	Enabling Question	EQ DRM Priority			EQ Category
		ISS	Lunar	Mars	
8a.	What are the molecular and cellular mechanisms of innate and acquired immunity that become compromised with space flight conditions of radiation, microgravity, isolation, stress, microbial contamination, sleep deprivation, extreme environments and nutritional deficiency?	1	1	1	Mechanisms
8b.	Is it possible to predict the summary effects of each component condition and duration (1 year SSS, 30-day lunar, 18 month Martian) of space flight that compromises the immune system?	1	1	1	Risk Assessment
8c.	What types of infections are likely to occur in astronauts exposed to space flight conditions of different missions and durations?	1	1	1	Risk Assessment
8d.	Are there detection systems that can assess surrogate markers of immune function so that therapeutic interventions could be planned/during space flight?	2	2	2	Risk Assessment Countermeasures
8e.	Will it be possible to use immune protection measures to prevent infection aboard spaceships and to use antimicrobial therapies and immunological treatments to cure infections and prevent their complications?	2	2	2	Countermeasures
8f.	Will nutritional supplements be able to boost immune responses in space flight to counteract the infectious complication of compromised immune function?	1	1	1	Countermeasures

Crosscutting Area: <i>Human Health and Countermeasures (HH&C)</i>					
Discipline: <i>Immunology, Infection and Hematology (IIH)</i>					
Risk: <i>(9) Virus-Induced Lymphomas and Leukemia</i>					
		EQ DRM Priority			
EQ No.	Enabling Question	ISS	Lunar	Mars	EQ Category
9a.	What are the molecular and genetic mechanisms of host defense cells and latent virus genomes that become altered with immunosuppression produced by space flight conditions and latent virus reactivation, leading to lymphoid tumor production?	1	1	1	Mechanisms
9b.	Will the degree of immune compromise, latent virus reactivation and lymphoid malignancy vary with the space mission and its duration (1-year ISS, 30-day lunar, 18 month Martian)?	1	1	1	Risk Assessment
9c.	Is it possible to predict the summary effects of each component condition and duration of space flight that produce lymphoid malignancies?	1	1	1	Risk Assessment
9d.	What are the types of lymphoid malignancies (lymphomas, leukemias) that are likely to occur in immunosuppressed astronauts with reactivated latent viral infections?	1	1	1	Risk Assessment
9e.	Are there virus quantitation assays to predict those astronauts who will develop malignancies and who would benefit from immune intervention?	2	2	2	Countermeasures
9f.	Will it be possible to use anti-viral and anti-tumor agents aboard spaceships to reduce viral burden and abort forbidden clone development?	2	2	2	Countermeasures
9g.	Will it be possible to develop nutritional supplements to augment anti-viral and anti-tumor therapy?	2	2	2	Countermeasures
9h.	Will it be possible to restore immunity in a severely immunocompromised astronaut with autologous stem cell transplants?	3	3	3	Medical Diagnosis & Treatment

Crosscutting Area: <i>Human Health and Countermeasures (HH&C)</i>					
Discipline: <i>Immunology, Infection and Hematology (IIH)</i>					
Risk: <i>(10) Anemia, Blood Replacement & Marrow Failure</i>					
		EQ DRM Priority			
EQ No.	Enabling Question	ISS	Lunar	Mars	EQ Category
10a.	What are the methods for space based	3	2	1	Medical Diagnosis

	therapy for blood replacement? What new technologies are needed for blood replacement in space?				& Treatment
10b.	What are the nutritional requirements for adequate red cell production in microgravity? What are the contributory factors and how do they inter-relate in the development of space anemia (radiation, unloading, nutrition, fluid shift, changes in sex hormones, etc.)?	2	2	2	Risk Assessment Countermeasures
10c.	How can aplastic anemia be treated during space missions?	5	5	3	Medical Diagnosis & Treatment

Crosscutting Area:		Human Health and Countermeasures (HH&C)			
Discipline:		Immunology, Infection and Hematology (IIH)			
Risk:		(11) Altered Host Microbial Interactions			
		EQ DRM Priority			
EQ No.	Enabling Question	ISS	Lunar	Mars	EQ Category
11a.	What diagnostic and environmental monitoring laboratory technologies need to be developed for the detection and diagnosis of infectious disease in space?	1	1	1	Medical Diagnosis & Treatment
11b.	Does the spacecraft environment exert a selective pressure on environmental microorganisms that presents the crew with increased health risks (e.g., Helicobacter and ulcers)?	1	1	1	Mechanisms Risk Assessment
11c.	Does space flight alter microbial growth rates, mutation rates, or pathogenicity?	1	1	1	Mechanisms Risk Assessment
11d.	Does space flight alter the exchange of genetic material between microorganisms?	1	1	1	Mechanisms Risk Assessment
11e.	Does space flight alter host-microbe balance?	1	1	1	Mechanisms Risk Assessment
11f.	Can molecular and genetic testing of pathogenetic microbial organisms during space flight be accomplished on a real-time basis to prevent development of infections in astronauts?	2	2	2	Countermeasures
11g.	Do microorganisms associated with biological life support systems or biological waste treatment systems enter the general spacecraft environment with consequent increase in health risks?	1	1	1	Risk Assessment

Crosscutting Area: <i>Human Health and Countermeasures (HH&C)</i>					
Discipline: <i>Immunology, Infection and Hematology (IIH)</i>					
Risk: <i>(12) Allergies and Autoimmune Diseases</i>					
EQ No.	Enabling Question	EQ DRM Priority			EQ Category
		ISS	Lunar	Mars	
12a.	What are the molecular and genetic mechanisms of loss of immunoregulation and immune tolerance in that occur with the exposure to the space flight conditions of radiation, microgravity, isolation, stress, microbial contamination, sleep deprivation, extreme environments and nutritional deficiency?	1	1	1	Mechanisms
12b.	Is it possible to predict the summary effects of each component condition on duration of space flight (1-year ISS, 30-day, 18-month Martian) that leads to immune dysregulation and loss of immune tolerance?	1	1	1	Risk Assessment
12c.	What are the allergies and autoimmune diseases that are likely to occur in astronauts exposed to space flight conditions of different missions and durations?	1	1	1	Risk Assessment
12d.	Are there detection systems that can detect the first alterations in immune regulatory networks so that therapeutic intervention could be planned?	2	2	2	Risk Assessment Countermeasures
12e.	Will it be possible to use new immune regulatory agents to prevent immune imbalance with the expressions of allergies and autoimmune conditions?	2	2	2	Countermeasures
12f.	Will it be possible to use nutritional supplements to boost the immunoregulatory agents used therapeutically?	2	2	2	Countermeasures

Crosscutting Area: <i>Human Health and Countermeasures (HH&C)</i>					
Discipline: <i>Muscle</i>					
Risk: <i>(13) Skeletal Muscle Atrophy Resulting in Reduced Strength and Endurance</i>					
EQ No.	Enabling Question	EQ DRM Priority			EQ Category
		ISS	Lunar	Mars	
13a.	What is the time course of skeletal muscle atrophy during an ISS, lunar, and Mars mission?	1	1	1	Mechanisms
13b.	Does muscle atrophy of the lower	1	1	1	Risk Assessment

	extremity muscles contribute to orthostatic hypotension due to deficiencies in the muscle pump?				Mechanisms
13c.	Does skeletal muscle atrophy contribute to the accelerated rate of bone loss in the central and peripheral skeleton because of reduced forces at the tendon insertion sites during long-duration space missions?	1	1	1	Mechanisms
13d.	What hardware and/or technologies are currently available, or need to be developed for an ISS, lunar, or Mars mission in order to simulate the type of musculoskeletal loading experienced here on Earth to preserve muscle structure and function?	3	3	3	Countermeasures
13e.	What are the effects of skeletal muscle atrophy on whole body metabolism (e.g., insulin and glucose tolerance)?	1	3	1	Mechanisms
13f.	Are the deleterious changes that occur in skeletal muscle (atrophy, alterations in contractile phenotype, etc.) during long-duration space flight missions completely reversible upon return to Earth?	3	3	3	Risk Assessment Mechanisms
13g.	What combination of exercise and/or hormonal/pharmacological, nutritional and micronutrient supplements are effective in preserving muscle structure and function during ISS, lunar, and Mars missions?	1	1	1	Countermeasures
13h.	What are the appropriate prescription modalities (exercise regimens, artificial gravity, etc.) and the compliance factors needed during an ISS, lunar, and Mars mission to minimize losses in muscle mass and strength?	1	1	1	Countermeasures
13i.	What are the effective resistance exercise modalities (contraction modes) and exercise prescriptions (frequency, intensity, duration) needed to maintain skeletal muscle structure and function during an ISS, lunar, and Mars mission?	1	1	1	Countermeasures
13j.	What are the appropriate prescription modalities (exercise regimens, physical therapy, etc.) and the compliance factors needed to facilitate skeletal muscle rehabilitation in crewmembers returning from microgravity, 1/3-gravity, or 1/6-gravity to Earth gravity?	1	1	1	Countermeasures
13k.	What cellular processes/signaling pathways in skeletal muscle can be identified and targeted (pharmacological, gene therapy,	3	3	3	Mechanisms

	hormones, etc.) to prevent or attenuate fiber atrophy during ISS, lunar, or Mars missions?				
13l.	What practical diagnostic tools (e.g., biochemical markers, ultrasound) can be used during ISS, lunar, and Mars missions to monitor and quantify changes in muscle structure and function?	3	3	3	Medical Diagnosis & Treatment
13m.	Is the capacity of skeletal muscle to grow or regenerate (satellite cells) compromised during or after a mission because of conditions (e.g., radiation exposure, reduced muscle tension) associated with an ISS, lunar, and Mars mission?	3	2	1	Risk Assessment
13n.	What are the temporal relationships between the changes in structure and function of the tendon, muscle and muscle-tendon interface?	2	2	2	Mechanisms
13o.	How do the deficits in skeletal muscle strength associated with long-duration space flight affect the structural/functional properties of the sensory system and motor nerves?	1	1	1	Mechanisms
13p.	Can those resistance exercise paradigms and other activity modalities aimed at counteracting atrophy processes maintain those deficits in muscle strength that appear to occur independent of the atrophy process?	1	1	1	Countermeasures
13q.	What are the bioenergetic, metabolic and substrate-processing factors that contribute to the reductions in skeletal muscle endurance associated with muscle atrophy?	1	1	1	Mechanisms
13r.	Can endurance exercise activities that normally enhance skeletal muscle endurance under weight bearing conditions effectively maintain this property in atrophying muscle when they are performed in microgravity environments?	2	2	2	Countermeasures
13s.	How does the atrophy process affect the structural and functional properties of connective tissue (tendons), the fiber-tendon interface and the tendon-bone interface?	2	2	2	Mechanisms
13t.	Do resistance-training paradigms that counteract muscle atrophy processes improve the structure-function properties of connective tissue systems? (countermeasure)	2	2	2	Countermeasure
13u.	Do strength-training programs that	1	1	1	Countermeasures

	minimize atrophy processes and strengthen muscle tendon properties that are performed in states of unloading prevent injury from occurring during the return to normal weight bearing states?				
13v.	What are the appropriate prescription modalities (exercise regimens, physical therapy, etc.) and the compliance factors needed to facilitate skeletal muscle rehabilitation in crewmembers returning from the ISS, Moon, or Mars to Earth gravity?	1	1	1	Countermeasures
13w.	What combination of exercise and/or hormonal/pharmacological, nutritional and micronutrient supplements are effective in preserving muscle structure and function during missions to the ISS, Moon, and Mars?	2	2	2	Countermeasures
13x.	What hardware and/or technologies are currently available, or need to be developed for an ISS, lunar, and Mars mission in order to simulate the type of musculoskeletal loading experienced here on Earth to preserve muscle structure and function?	TBD	TBD	TBD	Countermeasures
13y.	To what extent should transcutaneous electrical stimulation be used as a countermeasure for preserving skeletal muscle structure and function during space flight?	TBD	TBD	TBD	Countermeasures
13z.	If a muscle injury occurs during a space flight mission, what criteria will be used to determine when it is safe for a crewmember to resume exercise?	TBD	TBD	TBD	Risk Assessment
13aa.	Are there assistance devices/technologies that can compensate for losses in muscle mass and strength and prevent injury during a space mission?	TBD	TBD	TBD	Countermeasures
13bb.	What are the effects of skeletal muscle atrophy on whole body metabolism?	TBD	TBD	TBD	Mechanisms
13cc.	What are the effects of muscle atrophy on thermoregulation?	TBD	TBD	TBD	Mechanisms

Crosscutting Area: *Human Health and Countermeasures (HH&C)*
Discipline: *Muscle*
Risk: *(14) Increased Susceptibility to Muscle Damage*

EQ No.	Enabling Question	EQ DRM Priority			EQ Category
		ISS	Lunar	Mars	
14a.	If a muscle injury occurs during an ISS, lunar or Mars mission, what criteria can	1	1	1	Risk Assessment

	be used to determine when it is safe for a crewmember to resume exercise or perform dynamic activities associated with the mission (e.g., EVA/exploration)?				
14b.	Do strength-training programs that minimize atrophy processes and strengthen muscle tendon properties that are performed in states of unloading prevent injury from occurring during a mission and upon return to weight bearing states (e.g., 1-G)?	1	1	1	Risk Assessment
14c.	Do resistance-training paradigms that counteract muscle atrophy processes improve the structure-function properties of connective tissue systems?	2	2	2	Mechanisms
14d.	How does the atrophy processes affect the structural and functional properties of connective tissue (tendons), the fiber-tendon interface and the tendon-bone interface?	3	3	3	Mechanisms
14e.	Are the deleterious changes that occur in skeletal muscle (atrophy, alterations in contractile phenotype, etc.) during long-duration space flight missions completely reversible upon return to Earth?	3	3	3	Mechanisms
14f.	Do the deficits in skeletal muscle associated with long-duration space flight affect the structural/functional properties of the sensory system and motor nerves (e.g., motor unit recruitment strategies within a muscle, altered muscle recruitment strategies for a given joint)?	1	1	1	Mechanisms
14g.	What are the appropriate ground-based space flight analog environments that can be used as test beds for evaluating neurological adaptation time constants, adverse operational implications, countermeasures and impacts of adaptation on other anatomical and physiological systems?	1	1	1	Risk Assessment Countermeasures Mechanisms

Crosscutting Area:		<i>Human Health and Countermeasures (HH&C)</i>			
Discipline:		<i>Neurovestibular Adaptation</i>			
Risk:		<i>(15) Vertigo, Spatial Disorientation and Perceptual Illusions</i>			
		EQ DRM Priority			
EQ No.	Enabling Question	ISS	Lunar	Mars	EQ Category
15a.	What are the physiological bases for spatial disorientation, perceptual	1	1	1	Mechanisms

	illusions, and vertigo?				
15b.	What combinations of visual, vestibular, and haptic cues cause spatial disorientation, perceptual illusions, and vertigo during and after g-transitions?	2	2	2	Mechanisms
15c.	Can g-transition-related spatial disorientation, perceptual illusions, and vertigo be predicted from mathematical models?	3	3	3	Risk Assessment
15d.	What individual physiological and behavioral characteristics contribute to the large inter-individual differences in neurovestibular symptoms and signs?	1	1	1	Risk Assessment Mechanisms
15e.	What individual physiological and behavioral characteristics will best predict susceptibility and adaptability	3	3	3	Risk Assessment Mechanisms
15f.	What is the physiological basis for context-specific-adaptation?	1	1	1	Mechanisms
15g.	To what extent can neurovestibular adaptation to weightlessness and/or artificial gravity take place in context-specific fashion, so crewmembers can be adapted to multiple environments and switch between them without suffering disorientation or motion sickness?	2	2	2	Risk Assessment
15h.	What preflight training techniques (e.g. virtual reality simulations, parabolic flight) can be used to alleviate the risks of spatial disorientation, perceptual illusions, and vertigo as astronauts launch, enter, and adapt to 0-G?	2	2	2	Countermeasures
15i.	What in-flight training techniques (e.g. virtual reality simulations, treadmill with vibration isolation system, artificial gravity) can be used to alleviate the risks of vertigo, disorientation, and perceptual illusions as astronauts land and (re)adapt to Earth, Moon, or Mars gravity?	3	3	3	Countermeasures
15j.	How can voluntary head movements during entry and landing be used to accelerate re-adaptation?	3	3	3	Countermeasures
15k.	Is adaptation to the lunar gravity environment sufficient to reduce incidence of landing vertigo upon return to Earth?	N/A	3	N/A	Risk Assessment
15l.	What artificial gravity exposure regimens (g level, angular velocity, duration, and repetition) will ameliorate the bone, muscle, cardiovascular, and vestibular deconditioning associated with hypogravity during surface operation phases of a mission?	N/A	5	5	Countermeasures

15m.	What artificial gravity exposure regimens (g level, angular velocity, duration, and repetition) will ameliorate the bone, muscle, cardiovascular, and vestibular deconditioning associated with hypogravity during transit phases of a mission?	N/A	5	5	Countermeasures
15n.	What level of supervisory control will mitigate the landing vertigo risk in landing on the Moon, Mars, and Earth?	4	4	4	Countermeasures
15o.	How can traditional clinical vestibular rehabilitation techniques be employed to usefully accelerate readaptation following g-transitions?	3	3	3	Countermeasures
15p.	What objective assessment techniques can be used to determine crew readiness to return to normal activities following g transitions?	2	2	2	Risk Assessment

Crosscutting Area:		Human Health and Countermeasures (HH&C)			
Discipline:		Neurovestibular Adaptation			
Risk:		(16) Impaired Movement Coordination Following G-Transitions			
		EQ DRM Priority			
EQ No.	Enabling Question	ISS	Lunar	Mars	EQ Category
16a.	What are the physiological bases for disruption of balance, locomotion, and eye-head coordination following g-transitions?	1	1	1	Mechanisms
16b.	Can disruption of balance, locomotion, and eye-head coordination following g-transitions be predicted from mathematical models?	3	3	3	Risk Assessment
16c.	What individual physiological and behavioral characteristics contribute to the large inter-individual differences in neurovestibular symptoms and signs?	1	1	1	Risk Assessment
16d.	What individual physiological and behavioral characteristics will best predict susceptibility and adaptability?	3	3	3	Mechanisms
16e.	What is the physiological basis for context-specific-adaptation?	1	1	1	Mechanisms
16f.	To what extent can neurovestibular adaptation to weightlessness and/or artificial gravity take place in context-specific fashion, so crewmembers can be adapted to multiple environments and switch between them without suffering impaired balance control and/or movement coordination?	2	2	2	Risk Assessment
16g.	What in-flight training techniques (e.g.	3	3	3	Countermeasures

	virtual reality simulations, treadmill with vibration isolation system, artificial gravity) can be used to alleviate the risks of impaired balance control and movement coordination as astronauts land and (re)adapt to Earth, Moon, or Mars gravity?				
16h.	Is adaptation to the lunar gravity environment sufficient to reduce incidence of sensory-motor balance and coordination problems upon return to Earth?	N/A	TBD	N/A	Risk Assessment
16i.	What artificial gravity exposure regimens (g level, angular velocity, duration, and repetition) will ameliorate the bone, muscle, cardiovascular, and vestibular deconditioning associated with hypogravity during surface operation phases of a mission	N/A	TBD	TBD	Countermeasures
16j.	What artificial gravity exposure regimens (G level, angular velocity, duration, and repetition) will ameliorate the bone, muscle, cardiovascular, and vestibular deconditioning associated with hypogravity during transit phases of a mission?	N/A	N/A	TBD	Countermeasures
16k.	How can traditional clinical vestibular rehabilitation techniques be employed to usefully accelerate readaptation following g-transitions?	TBD	TBD	TBD	Countermeasures
16l.	What objective assessment techniques can be used to determine crew readiness to return to normal activities following g transitions?	TBD	TBD	TBD	Risk Assessment
16m.	How can preflight or in-flight sensory-motor training or sensory aids improve post-landing postural and locomotor control and orthostatic tolerance?	TBD	TBD	TBD	Countermeasures
16n.	To what extent can crew “learn how to learn” by adapting to surrogate sensory-motor rearrangements?	TBD	TBD	TBD	Countermeasures
16o.	What are the relative contributions of sensory-motor adaptation, neuromuscular deconditioning, and orthostatic intolerance to postflight neuro-motor coordination, ataxia, and locomotion difficulties?	TBD	TBD	TBD	Risk Assessment Mechanisms
16p.	What posture, locomotion and gaze deficits result from transition to Mars gravity and Moon gravity?	TBD	TBD	TBD	Risk Assessment

Crosscutting Area:		Human Health and Countermeasures (HH&C)			
Discipline:		Neurovestibular Adaptation			
Risk:		(17) Motion Sickness			
EQ No.	Enabling Question	EQ DRM Priority			EQ Category
		ISS	Lunar	Mars	
17a.	What are the physiological mechanisms that trigger vomiting in space motion sickness?	1	1	1	Mechanisms
17b.	What is the physiological basis of the emetic linkage between vestibular and emetic centers?	2	2	2	Mechanisms
17c.	What individual physiological and behavioral characteristics contribute to the large inter-individual differences in neurovestibular symptoms and signs?	1	1	1	Mechanisms
17d.	What individual physiological and behavioral characteristics will best predict susceptibility and adaptability?	3	3	3	Mechanisms Risk Assessment
17e.	What is the physiological basis for context-specific-adaptation?	1	1	1	Mechanisms
17f.	To what extent can neurovestibular adaptation to weightlessness and/or artificial gravity take place in context-specific fashion, so crewmembers can be adapted to multiple environments and switch between them without suffering disorientation or motion sickness?	3	3	3	Risk Assessment
17g.	What preflight training techniques (e.g. virtual reality simulations, parabolic flight) can be used to alleviate the risks of space motion sickness?	4	4	4	Countermeasures
17h.	What in-flight training techniques (e.g. virtual reality simulations, treadmill with vibration isolation system, artificial gravity) can be used to alleviate the risks of space motion sickness as astronauts land and (re)adapt to Earth, Moon, or Mars gravity	4	4	4	Countermeasures
17i.	Is adaptation to the lunar gravity environment sufficient to reduce incidence of motion sickness upon return to Earth?	N/A	4	N/A	Risk Assessment
17j.	Is adaptation to the lunar gravity environment sufficient to reduce incidence of motion sickness upon return to Earth?	N/A	5	5	Countermeasures
17k.	What artificial gravity exposure regimens (g level, angular velocity, duration, and repetition) will ameliorate	N/A	N/A	5	Countermeasures

	the bone, muscle, cardiovascular, and vestibular deconditioning associated with hypogravity during transit phases of a mission?				
17l.	How does susceptibility to motion sickness due to Coriolis forces and cross-coupled canal stimuli vary as a function of g-levels between 0-G and 1-G, and also on RPM, radius, and head orientation during AG?	N/A	1	1	Risk Assessment
17m.	What are the best methods for quantifying the symptoms and signs of motion sickness and associated performance decrements and drug side effects in a non-intrusive way?	2	2	2	Risk Assessment
17n.	What better ways can be found to administer anti-motion sickness drugs to provide more rapid and reliable relief, with fewer objectionable side effects?	3	3	3	Countermeasures
17o.	Do scopolamine and promethazine prevent or impair sensory-motor adaptation to 0-G?	4	4	4	Mechanisms Countermeasures
17p.	What new drugs will more specifically prevent nausea, fatigue, memory and vigilance deficits without side effects?	4	4	4	Countermeasures
17q.	Can drugs be developed to effectively block the emetic linkage without unacceptable side effects?	4	4	4	Countermeasures Mechanisms
17r.	Can operationally practical, non-pharmacologic techniques be developed that are effective against motion sickness?	4	4	4	Countermeasures
17s.	Is 1/6-G lunar gravity or 3/8-Mars gravity adequate to prevent all cases of motion sickness?	4	4	4	Risk Assessment

Crosscutting Area:		Human Health and Countermeasures (HH&C)			
Discipline:		Nutrition			
Risk:		(18) Inadequate Nutritional Requirements			
		EQ DRM Priority			
EQ No.	Enabling Question	ISS	Lunar	Mars	EQ Category
18a.	What are the nutritional requirements for extended stay ISS missions, including (but not limited to): calories, protein, calcium, iron, antioxidants, iodine, vitamin D, sodium, potassium?	1	1	1	Countermeasures
18b.	What are the potential impacts of countermeasures on nutritional requirements or nutritional status?	1	1	1	Countermeasures

18c.	What are the decrements in nutritional status due to long-term LEO, lunar, and exploration missions?	1	1	1	Risk Assessment Countermeasures
18d.	What are the means of monitoring nutritional status during the mission?	3	3	3	Risk Assessment Medical Diagnosis & Treatment
18e.	What monitoring (biochemical, anthropometric, clinical assessments) during rehabilitation is required?	3	3	3	Medical Diagnosis & Treatment
18f.	What level of dietary counseling is needed for crewmembers during rehabilitation?	3	3	3	Countermeasures
18g.	Can general nutrition or specific nutrient countermeasures mitigate the negative effects of space flight on bone, muscle, cardiovascular and immune, systems and protect against damage from radiation?	1	1	1	Countermeasures
18h.	What is the role of adequate nutrition/weight maintenance on crew health (specifically bone, muscle and cardiovascular adaptation)?	1	2	1	Mechanisms
18i.	What level of dietary counseling is needed for crewmembers pre-flight?	1	2	1	Countermeasures
18j.	How does on-orbit exercise affect nutritional requirements and vice versa?	1	2	1	Countermeasures
18k.	Can nutrition mitigate radiation induced cataractogenesis and carcinogenesis?	1	1	1	Countermeasures Risk Assessment
18l.	Are there long-term effects of disease risk post-flight and can nutritional countermeasures be preventative? [	1	2	1	Countermeasures Risk Assessment

Autonomous Medical Care

Crosscutting Area:		Autonomous Medical Care (AMC)			
Discipline:		Clinical Capabilities			
Risk:		(19) Monitoring and Prevention			
		EQ DRM Priority			
EQ No.	Enabling Question	ISS	Lunar	Mars	EQ Category
19a.	Define the key parameters for health screening and early detection.	4	2	1	Medical Diagnosis & Treatment
19b.	Identify what resources and technologies are required for routine health monitoring, including examination, laboratory, imaging and adaptation for operation in reduced-G environments	4	2	1	Medical Diagnosis & Treatment
19c.	What diagnostic imaging technologies and procedures need to be developed and/or adapted to support the primary, secondary and tertiary prevention of illness and injury?	3	2	1	Medical Diagnosis & Treatment
19d.	Identify the parameters and sensors needed to monitor health and performance in crewmembers performing EVA	4	2	2	Medical Diagnosis & Treatment
19e.	Identify the investigations needed to discriminate between terrestrial and space flight norms in order to allow early detection of illness and injury.	3	2	2	Medical Diagnosis & Treatment
19f.	What is space-normal physiology?	4	3	3	Medical Diagnosis & Treatment
19g.	What are the signs, symptoms or abnormal examination findings (including laboratory) associated with illness and injury in reduced-G?	TBD	TBD	TBD	Medical Diagnosis & Treatment
19h.	How do alterations in space flight-associated physiology interact across body systems?	4	3	3	Medical Diagnosis & Treatment
19i.	Identify the appropriate informatics tools to automate monitoring crew health (i.e., prompting screening evaluations, off-nominal value detection, intelligent diagnostic work-up), in order to free-up crew time.	2	1	1	Medical Diagnosis & Treatment
Prophylaxis/Disease Prevention					
19j.	Identify the ideal set of nutritional and medical prophylaxis and primary and secondary preventive measures to reduce the risk of space illness. (such as medical countermeasures for known conditions e.g., bisphosphonates for loss of BMD).	3	2	2	Countermeasures
19k.	Identify the primary, secondary and tertiary prevention strategies needed to	2	1	1	Countermeasures

	mitigate the risk of anticipated environmental exposures to toxic substances and radiation.(i.e., shielding, nutritional and medical prophylaxis such as agents to augment cellular defenses, immune surveillance, etc.).				
19l.	What are the essential technologies, resources, procedures, skills and training necessary to provide effective primary prevention strategies to mitigate each of the conditions listed in the SMCCB-approved Space Medicine Condition List (catalogued in the online Patient Condition Database)?	4	3	2	Countermeasures
19m.	What are the essential technologies, resources, procedures, skills and training necessary to provide effective secondary prevention strategies to mitigate each of the conditions listed in the SMCCB-approved Space Medicine Condition List (catalogued in the online Patient Condition Database)?	4	3	2	Countermeasures

Crosscutting Area: <i>Autonomous Medical Care (AMC)</i>					
Discipline: <i>Clinical Capabilities</i>					
Risk: <i>(20) Major Illness & Trauma</i>					
		EQ DRM Priority			
EQ No.	Enabling Question	ISS	Lunar	Mars	EQ Category
20a.	What are the essential technologies, resources, procedures, skills and training necessary to provide effective tertiary prevention strategies to mitigate each of the conditions listed in the SMCCB-approved Space Medicine Condition List (catalogued in the online Patient Condition Database)?	3	1	1	Medical Diagnosis & Treatment
Major Illness Diagnosis					
20b.	Identify the technologies for employing decision support techniques for diagnostic assistance of the crew medical personnel, emphasizing autonomy in decision-making from ground resources and based on known space flight illnesses and injuries and expedition analog experience.				Medical Diagnosis & Treatment
20c.	Define the appropriate role and resources required for telemedical consultation for the diagnosis and management of major illnesses.	3	2	1	Medical Diagnosis & Treatment
Major Illness Treatment					
20d.	Identify and adapt for reduced-G	2	1	1	Medical Diagnosis

	operation the resources, procedures and technologies are required for treatment of major illnesses, emphasizing autonomy from ground resources and based on known space flight illnesses and injuries and expedition analog experience.				& Treatment
20e.	Identify appropriate synergistic and alternative management strategies for reducing the morbidity of major illnesses during space flight.	TBD	TBD	TBD	Medical Diagnosis & Treatment
20f.	What procedures and protocols are necessary for rehabilitation after an acute medical illness or trauma?	4	3	1	Medical Diagnosis & Treatment
CPR/BCLS/ACLS (Cardiac Life Support)					
20g.	What is the most effective means of conducting life support operations in the space flight milieu, to include identification and modification of the resources and procedures for reduced-G?	3	2	1	Medical Diagnosis & Treatment
20h.	Identify the optimal resources and procedures for post-resuscitation management of the ill/injured crewmember and modify for reduced-G operations.	2	1	1	Medical Diagnosis & Treatment
BTLS/ATLS (Trauma Life Support)					
20i.	What are the resources and procedures needed to perform basic and advanced management of trauma?	3	1	1	Medical Diagnosis & Treatment
20j.	What are resources required for telemedical consultation for the diagnosis and management of major trauma?	3	2	1	Medical Diagnosis & Treatment
Decompression Illness (DCS) & Other Environmental Illness					
20k.	What is the most effective pre-EVA DCS prevention strategy to include pre-breathe with various gases, exercise and other medical measures?	5	N/A if 5 psi base	N/A if 5 psi base	Countermeasures
20l.	What are the appropriate screening procedures to minimize predispositions for DCS?	4	N/A if 5 psi base	N/A if 5 psi base	Countermeasures
20m.	Identify the resources and techniques for early diagnosis of DCS signs and symptoms, including the use of Doppler U/S and other bubble detection technologies.	4	N/A if 5 psi base	N/A if 5 psi base	Medical Diagnosis & Treatment
20n.	What are the best methods for predicting DCS risk and for reducing the risk, based on understanding of the physiological mechanism for bubble formation and propagation, employing	4	N/A if 5 psi base	N/A if 5 psi base	Risk Assessment

	best available knowledge from flight and analog environment experience?				
20o.	Identify and adapt for reduced-G operations the most effective yet energy and space-efficient, as well as safe means of managing DCS in the space flight milieu, including the use of hyperbaric oxygen delivery and other promising technology. [ISS 3, moon 2, Mars 1]	3	2	1	Medical Diagnosis & Treatment
20p.	What is the actual risk of space-related DCS? (from both de novo physiological causes and through acute environmental insult – e.g., leaking module or damaged EMU etc.?)	3	3	3	Risk Assessment
20q.	What are the operational and medical impacts of off-nominal performance of DCS countermeasures?	4	3	3	Countermeasures
20r.	What are the risk factors that can increase the likelihood of DCS, such as the presence of Patent Foramen Ovale (PFO)?	4	3	2	Risk Assessment
20s.	What is the likelihood of surviving an acute environmental insult severe enough to cause damage to the vehicle or spacesuit?	2	2	2	Risk Assessment
20t.	Is it possible and what are the DCS risk mitigation options for interplanetary EVA (e.g., moon and Mars) given that a tri-gas breathing mixture including argon is present?	4	4	4	Countermeasures
20u.	What is the role of individual susceptibility, age and gender on the risk of DCS during NASA operations involving decompression?	4	3	3	Risk Assessment
20v.	What are the available and new technologies needed to provide hyperbaric treatment options on the ISS and future habitats (or vehicles) beyond LEO (e.g., on the moon or Mars)?	3	2	1	Medical Diagnosis & Treatment
20w.	What is the correlation between the detection/existence of gas phase creation in the bloodstream and development of clinically significant DCS?	4	3	3	Mechanisms
Toxic Exposure Detection					
20x.	Identify the signs and symptoms secondary to toxic chemical exposure and radiation in reduced-G environments.	2	1	1	Risk Assessment
Toxic Exposure/Management					
20y.	What are the resources and procedures for the mitigation of toxic exposures?	3	1	1	Countermeasures
20z.	What primary prevention strategies	3	2	2	Countermeasures

	(such as crew screening and selection criteria) should be developed and implemented to identify individuals who are at increased risk for developing hypersensitivity or allergies to space flight compounds, exposures, or payloads?				
20aa.	What secondary prevention strategies (i.e., countermeasures) should be developed and implemented to prevent adverse reactions to toxic exposures (e.g., sleep, nutritional, medications, stress reduction, shielding, protective equipment, etc.)?	3	2	2	Countermeasures
Surgical Management					
20bb.	What are the resources and procedures needed for surgical management of illness and injury and major trauma?	3	1	1	Medical Diagnosis & Treatment
20cc.	What are the appropriate roles and resources required for telemedical consultation for the surgical management of major illnesses?	3	2	1	Medical Diagnosis & Treatment
20dd.	What are the issues surrounding wound care? [ISS 4, moon 2, Mars 2]	4	2	2	Countermeasures Medical Diagnosis & Treatment
Medical Waste Management					
20ee.	What are the most effective means of management and disposal of medical waste within the surgical milieu?	2	1	1	Medical Diagnosis & Treatment

Crosscutting Area:		Autonomous Medical Care (AMC)			
Discipline:		Clinical Capabilities			
Risk:		(21) Pharmacology of Space Medication Delivery			
		EQ DRM Priority			
EQ No.	Enabling Question	ISS	Lunar	Mars	EQ Category
Pharmacodynamics/Pharmacokinetics					
21a.	What are the effects of space flight and reduced-G on the absorption, distribution, metabolism, clearance, excretion, clinical efficacy, side effects and drug interactions for medications used in primary, secondary and tertiary prevention of conditions stated in the Space Medicine Condition List?	2	2	1	Medical Diagnosis & Treatment
21b.	How should the crew and medical team be trained and prepared to recognize and deal with side effects and interaction effects of commonly used medications?	3	3	2	Medical Diagnosis & Treatment
21c.	What diagnostic, therapeutic and laboratory technologies are necessary to predict (model) and manage medication side effects, interactions and	3	3	3	Medical Diagnosis & Treatment

	toxicity during space flight?				
21d.	What effect does space adaptation have on drug bio-availability and how can efficacy be enhanced?	2	2	1	Medical Diagnosis & Treatment
Drug Storage/Utilization/Replenishment					
21e.	What is the effect of long-duration space flight on drug stability and what measures can be employed to extend the duration of drug efficacy?	3	1	1	Medical Diagnosis & Treatment
21f.	Identify appropriate on-orbit/on-station means of drug and intravenous (IV) fluid replenishment appropriate for space operations	3	1	1	Medical Diagnosis & Treatment
21g.	What are Biomedical models for drug efficacy?	4	3	3	Medical Diagnosis & Treatment
Drug Use Optimization					
21h.	Define the optimal dosages and routes of administration for space flight/ reduced-G clinical effectiveness.	3	2	2	Medical Diagnosis & Treatment
21i.	Identify efficient means of monitoring drug levels for therapeutic effect and toxicity and to minimize cross-reaction and negative synergy.	4	3	3	Medical Diagnosis & Treatment

Crosscutting Area: <i>Autonomous Medical Care (AMC)</i>					
Discipline: <i>Clinical Capabilities</i>					
Risk: <i>(22) Ambulatory Care</i>					
		EQ DRM Priority			
EQ No.	Enabling Question	ISS	Lunar	Mars	EQ Category
Minor Illness Diagnosis					
22a.	Identify and adapt for reduced-G operations the resources for establishing the diagnosis of minor illnesses, emphasizing autonomy in decision-making from ground resources and based on known space flight illnesses and injuries and expedition analog experience.	4	2	1	Medical Diagnosis & Treatment
22b.	Define the appropriate role and resources required for telemedical consultation for the diagnosis and management of minor illnesses.	4	3	2	Medical Diagnosis & Treatment
Minor Illness Management					
22c.	Identify and adapt for reduced-G operation the resources and procedures required for treatment of minor illnesses, emphasizing autonomy from ground resources and based on known space flight illnesses and injuries and expedition analog experience.	4	3	2	Medical Diagnosis & Treatment
22d.	Identify appropriate synergistic and alternative management strategies for reducing the morbidity of minor illnesses during space flight.	TBD	TBD	TBD	Medical Diagnosis & Treatment

Minor Trauma Management					
22e.	Identify and adapt for reduced-G operations the resources and procedures required for the treatment of minor trauma, emphasizing autonomy from ground resources and based on known space flight illnesses and injuries and expedition analog experience.	3	1	1	Medical Diagnosis & Treatment

Crosscutting Area: Autonomous Medical Care (AMC)					
Discipline: Clinical Capabilities					
Risk: (23) Return to Gravity/Rehabilitation					
		EQ DRM Priority			
EQ No.	Enabling Question	ISS	Lunar	Mars	EQ Category
23a.	What are the primary, secondary and tertiary preventive strategies needed to ensure post-landing performance for all DRMs?	4	4	1	Countermeasures Medical Diagnosis & Treatment
23b.	What are the essential technologies, resources, protocols, skills and training necessary for post landing rehabilitation (including psychological, cardiovascular, neurosensory, musculoskeletal and nutritional)?	4	4	1	Medical Diagnosis & Treatment

Crosscutting Area: Autonomous Medical Care (AMC)					
Discipline: Clinical Capabilities					
Risk: (24) Insufficient Data/Information/Knowledge Management & Communication Capability					
		EQ DRM Priority			
EQ No.	Enabling Question	ISS	Lunar	Mars	EQ Category
24a.	What decision support technologies are needed to support clinical care?	4	2	1	Medical Diagnosis & Treatment
24b.	What informatics systems and technology are needed, both for crew and ground support, to optimize medical care?	3	1	1	Medical Diagnosis & Treatment
24c.	What are the impacts of communication latency on the ability to provide primary, secondary and tertiary prevention during space flight?	4	4	1	Medical Diagnosis & Treatment

Crosscutting Area: <i>Autonomous Medical Care (AMC)</i>					
Discipline: <i>Clinical Capabilities</i>					
Risk: <i>(25) Skill Determination and Training</i>					
EQ No.	Enabling Question	EQ DRM Priority			EQ Category
		ISS	Lunar	Mars	
25a.	What are the necessary clinical skills/knowledge for a space medicine physician?	4	1	1	Medical Diagnosis & Treatment
25b.	How can the clinical skills and knowledge of space medical care providers be maintained during missions?	2	2	1	Medical Diagnosis & Treatment
25c.	What is the optimum crew complement (size, skill sets, etc.) to provide the appropriate medical care for the primary, secondary and tertiary care for the conditions in the Space Medicine Condition List?	4	3	1	Countermeasures
25d.	What techniques can be used to train and maintain the skills of the crew medical personnel to perform specific medical procedures when needed?	3	1	1	Countermeasures

Crosscutting Area: <i>Autonomous Medical Care (AMC)</i>					
Discipline: <i>Clinical Capabilities</i>					
Risk: <i>(26) Palliative, Mortem and Post-Mortem Medical Activities</i>					
EQ No.	Enabling Question	EQ DRM Priority			EQ Category
		ISS	Lunar	Mars	
Palliative Care					
26a.	What are the specific techniques, resources, protocols, training curricula, skills and equipment (technology) necessary to implement palliative care protocols for in-flight use?	4	2	1	Medical Diagnosis & Treatment
26b.	What is the policy and procedure for determining a “Do Not Resuscitate” (DNR) status on a Martian mission?	3	1	1	Medical Diagnosis & Treatment
Declaring Death					
26c.	What are the criteria for death during missions?	4	3	2	Medical Diagnosis & Treatment
26d.	What are procedures for pronouncing death during missions?	4	3	2	Medical Diagnosis & Treatment
26e.	What resources and procedures are needed to determine cause of death during a mission?	4	3	3	Medical Diagnosis & Treatment
26f.	What is the policy and procedure for termination of a “Code” on a Martian mission?	3	1	1	Medical Diagnosis & Treatment

	Cadaver Management				
26g.	What resources, procedures, protocols and technology are required to handle deceased crewmembers?	3	1	1	Medical Diagnosis & Treatment
	Managing Remaining Crew				
26h.	Identify the strategies for psychological stress management and maintaining morale and acceptable functioning and safety of the remaining crewmembers	3	1	1	Countermeasures

Behavioral Health and Performance

Crosscutting Area:		Behavioral Health and Performance (BH&P)			
Discipline:		Human Behavior and Performance			
Risk:		(27) Human Performance Failure Due to Poor Psychosocial Adaptation			
		EQ DRM Priority			
EQ No.	Enabling Question	ISS	Lunar	Mars	EQ Category
27a.	What are the fundamental behavioral and social stressors during long-duration missions that will most likely affect crew performance, both individual and team and how can they be tested in Earth analogue environments, to be eliminated or accommodated?	1	1	1	Mechanisms
27b.	What factors contribute to the breakdown of individual and team performance and team coordination with mission support with regard to scheduling, prioritization of work activities and control of timelines?	1	1	1	Risk Assessment
27c.	What behaviors, experiences, personality traits and leadership styles in crewmembers most contribute to optimal performance? How are these factors related to performance of individuals and teams?	2	2	2	Mechanisms
27d.	What criteria can be identified during the selection process and be used to select and assemble the best teams for long-duration missions?	2	2	2	Countermeasures
27e.	What factors in crew design, composition, dynamics and size will best enhance the crew's ability to live and work in the space environment? How are these factors different from shorter duration missions?	2	2	2	Countermeasures
27f.	How can attitudes and behaviors of agency management, ground controllers, crewmembers and their families be modified to maintain and improve individual and group performance?	2	2	2	Countermeasures

Crosscutting Area:		Behavioral Health and Performance (BH&P)			
Discipline:		Human Behavior and Performance			
Risk:		(28) Human Performance Failure Due to Neurobehavioral Problems			
EQ No.	Enabling Question	EQ DRM Priority			EQ Category
		ISS	Lunar	Mars	
28a.	What are the best select-out tools of astronaut candidates and best select-out tools for selection of individuals to teams for specific missions to avoid possible neuropsychiatric and psychological incompatibility with the mission and fellow team members?	1	1	1	Countermeasures
28b.	What are the long-term effects of exposure to the space environment (microgravity, isolation, stress) on human neurocognitive and neurobiological functions (from cellular to behavioral levels of the nervous system)?	2	2	2	Mechanisms
28c.	What are the long-term effects of exposure to the space environment on human emotion and psychological responses, including emotional reactivity, stress responses, long-term modulation of mood and vulnerability to affective and cognitive disorders?	3	3	3	Mechanisms
28d.	What objective techniques and technologies validly and reliably identify when astronauts are experiencing distress that compromises their performance capability in space?	1	1	1	Medical Diagnosis & Treatment
28e.	What are the best behavioral, technological and pharmacological countermeasures for managing cognitive dysfunction, neuropsychiatric and behavior problems in space?	3	3	3	Countermeasures
28f.	What are the best behavioral, psychological, technological and pharmacological countermeasures for managing emotional and stress-related problems in space?	3	3	3	Countermeasures
28g.	What are the best techniques and technologies for identification and treatment of cognitive disorders, neuropsychiatric and behavior problems in space?	4	4	4	Medical Diagnosis & Treatment

Crosscutting Area:		Behavioral Health and Performance (BH&P)			
Discipline:		Human Behavior and Performance			
Risk:		(29) Mismatch Between Crew Cognitive Capabilities and Task Demands			
EQ No.	Enabling Question	EQ DRM Priority			EQ Category
		ISS	Lunar	Mars	
29a.	What crew size and composition is required to provide the amount of information, variety of skills, etc. required to accomplish the design reference mission?	2	1	1	Countermeasures
29b.	What is required to counteract the negative effects of communications lags on human performance?	1	1	1	Risk Assessment Countermeasures
29c.	What information systems, interface designs, intelligent systems and other tools to enable autonomy are required to enable human performance to be maintained at an acceptable level over the design reference missions (Shared – Integrated Testing supports)?	2	1	1	Risk Assessment
29d.	What types and techniques of training are required and within what timeframes, to enable the crewmembers to accomplish the mission with increased effectiveness, efficiency and safety?	1	1	1	Countermeasures
29e.	What principles of task design, procedures, job aids and tools and equipment, are required to enable crewmembers to accomplish nominal and emergency perceptual and cognitive tasks	2	1	1	Countermeasures
29f.	How can crewmembers and ground support personnel detect and compensate for decreased cognitive readiness to perform?	1	1	1	Countermeasures
29g.	What scheduling constraints are required to reduce the risk of human error due to fatigue? (Share with Sleep and Circadian Rhythm)?	2	2	2	Countermeasures
29h.	What tools and techniques will maintain the crew's situational awareness at a level sufficient to perform nominal and emergency tasks?	2	1	1	Countermeasures
29i.	What characteristics of equipment, tool and computer displays; instructions, procedures, labels and warning; and human-computer interaction designs will maintain critical sensory and cognitive capabilities?	2	2	2	Countermeasures

29j.	What approaches to human computer interactions will maintain crew critical capabilities to assess, control and communicate?	2	2	2	Countermeasures
29k.	What decision-support systems are required to aid crew decision-making?	2	2	2	Countermeasures
29l.	What design considerations are needed to accommodate effects of changes in gravity on perception (Launch, lunar landing, lunar launch, Earth return)?	N/A	1	1	Countermeasures

Crosscutting Area:		Behavioral Health and Performance (BH&P)			
Discipline:		Human Behavior and Performance			
Risk:		(30) Human Performance Failure Due to Sleep Loss and Circadian Rhythm Problems			
		EQ DRM Priority			
EQ No.	Enabling Question	ISS	Lunar	Mars	EQ Category
30a.	What are the acute and long-term effects of exposure to the space environment on biological rhythmicity on sleep architecture, quantity and quality and their relationship to performance capability?	1	1	1	Mechanisms
30b.	Which countermeasures or combination of behavioral and physiological countermeasures will optimally mitigate specific performance problems associated with sleep loss and circadian disturbances during the design reference missions?	1	1	1	Countermeasures
30c.	What are the long-term effects of countermeasures employed to mitigate pre-, in- and post-flight performance problems with sleep loss and circadian disturbances?	3	4	2	Countermeasures
30d.	What are the best methods for in-flight monitoring of the status of sleep, circadian functioning and light exposures for assessing the effects of sleep loss and circadian dysrhythmia on performance capability that are also portable and non-intrusive in the space flight environment? (e.g., actigraphy)	2	2	2	Risk Assessment Medical Diagnosis & Treatment
30e.	What work, workload and sleep schedule(s) will best enhance crew performance and mitigate adverse effects of the space environment?	1	1	1	Countermeasures
30f.	What individual biological and behavioral characteristics will best predict successful adaptation to long-term space flight of sleep, circadian	4	5	1	Countermeasures

	physiology and the neurobehavioral performance functions they regulate?				
30g.	What mathematical and computational models should be used to predict performance associated with sleep-wake, schedule, work history, light exposure and circadian rhythm status and also provide guidelines for successful countermeasure strategies?	1	1	1	Risk Assessment Countermeasures

Radiation

Crosscutting Area:		Radiation			
Discipline:		Radiation			
Risk:		(31) Carcinogenesis			
EQ No.	Enabling Question	EQ DRM Priority			EQ Category
		ISS	Lunar	Mars	
31a.	What are the probabilities for increased carcinogenesis from space radiation as a function of NASA's operational parameters (age at exposure, age, latency, gender, tissue, mission, radiation quality, dose rate and exposure protraction)?	1	1	1	Risk Assessment
31b.	How can tissue specific probabilities for increased carcinogenesis risk from space radiation be best evaluated and what molecular, genetic, epigenetic and abscopal (effect that irradiation of a tissue has on remote non-irradiated tissue) or other factors contribute to the tissue specificity of carcinogenic risk?	1	1	1	Medical Diagnosis & Treatment
31c.	How can the individual's sensitivity to radiation carcinogenesis be estimated?	2	2	1	Risk Assessment
31d.	How can effective biomarkers of carcinogenic risk from space radiation be developed and validated?	3	3	2	Risk Assessment
31e.	What are the most effective biomedical or dietary countermeasures to mitigate cancer risks? By what mechanisms are the countermeasures expected to work and do they have the same efficiency for low- and high-LET radiation?	3	3	1	Countermeasures
31f.	How can animal models (including transgenics) of carcinogenesis be developed to improve estimates of cancers from space radiation and what longitudinal studies are needed?	2	2	1	Risk Assessment
31g.	What improvements can be made to quantitative procedures or theoretical models in order to extrapolate molecular, cellular, or animal results to determine the risks of specific cancers in astronauts? How can human epidemiology data best support these procedures or models?	3	3	2	Risk Assessment
31h.	Are there significant combined effects from other space flight factors (microgravity, stress, altered circadian rhythms, changes in immune responses, etc.) that modify the carcinogenic risk	5	5	3	Risk Assessment

	from space radiation?				
31i.	What are the probabilities that space radiation will produce damage at specific sites on DNA including clustered DNA damage?	3	3	2	Mechanisms Risk Assessment
31j.	What mechanisms modulate radiation damage at the molecular level (e.g., repair, errors in repair, signal transduction, gene amplification, bystander effects, tissue microenvironment, etc.) that significantly impact the risk of cancers and how can the understanding of mechanisms be used to predict carcinogenic risks from space radiation?	2	2	1	Mechanisms
31k.	What space validation experiments could improve estimates of carcinogenic risks for long-term deep-space missions?	5	5	3	Risk Assessment
31l.	What are the most effective shielding approaches to mitigate cancer risks	1	1	1	Countermeasures
31m.	What new materials or active shielding methods can be used for reducing space radiation cancer risks?	1	1	1	Countermeasures

Crosscutting Area:		Radiation			
Discipline:		Radiation			
Risk:		(32) Acute and Late CNS Risks			
		EQ DRM Priority			
EQ No.	Enabling Question	ISS	Lunar	Mars	EQ Category
32a.	Is there a significant probability that space radiation would lead to immediate or acute functional changes in the CNS due to a long-term space mission and if so what are the mechanisms of change?	3	3	1	Risk Assessment Mechanisms
32b.	Is there a significant probability that space radiation exposures would lead to long-term or late degenerative CNS risks? If so what are the mechanisms of change?				Risk Assessment Mechanisms
32c.	How does individual susceptibility including hereditary pre-disposition (Alzheimer's, Parkinson's, apoE) and prior CNS injury (concussion or other) alter significant CNS risks?				Risk Assessment
32d.	What are the most effective biomedical or dietary countermeasures to mitigate CNS risks? By what mechanisms do the countermeasures work?				Countermeasures Mechanisms
32e.	How can animal models of CNS risks, including altered motor and cognitive				Risk Assessment

	function, behavioral changes and late degenerative risks be best used for estimating space radiation risks to astronauts?				
32f.	Are there significant CNS risks from combined space radiation and other physiological or space flight factors (e.g., bone loss, microgravity, immune-endocrine systems or other)?				Risk Assessment
32g.	What are the molecular, cellular and tissue mechanisms of damage (DNA damage processing, oxidative damage, cell loss through apoptosis or necrosis, changes in the extra-cellular matrix, cytokine activation, inflammation, changes in plasticity, micro-lesion (clusters of damaged cells along heavy ion track, etc.) in the CNS?				Mechanisms
32h.	What are the different roles of neural cell populations, including neuronal stem cells and their integrative mechanisms in the morphological and functional consequences of space radiation exposure?				Mechanisms
32i.	Are there biomarkers for detecting damage or susceptibility to/for radiation-induced CNS damage?				Risk Assessment
32j.	What quantitative procedures or theoretical models are needed to extrapolate molecular, cellular, or animal results to predict CNS risks in astronauts? How can human epidemiology data best support these procedures or models?				Risk Assessment
32k.	What are the most effective shielding approaches to mitigate CNS risks?				Countermeasures
32l.	What space validation experiments could improve estimates of CNS risks for long-term deep-space missions?				Countermeasures

Crosscutting Area:		Radiation			
Discipline:		Radiation			
Risk:		(33) Other Degenerative Tissue Risks			
		EQ DRM Priority			
EQ No.	Enabling Question	ISS	Lunar	Mars	EQ Category
33a.	What are the probabilities for degenerative tissue risks from protons and HZE ions as a function of NASA's operational parameters (age at exposure, age and time after exposure, gender, tissue, mission, radiation quality, dose	2	2	1	Risk Assessment

	rate)?				
33b.	What are the mechanisms of degenerative tissues risks in the heart, circulatory, endocrine, digestive, lens and other tissue systems?	2	2	1	Mechanisms
33c.	How can the latency period for degenerative tissue risks, including sub-clinical diseases, following space radiation exposures be estimated?	3	3	1	Risk Assessment
33d.	What are the most effective biomedical or dietary countermeasures to degenerative tissue risks? By what mechanisms do the countermeasures work?	3	3	1	Countermeasures Mechanisms
33e.	What quantitative procedures or theoretical models are needed to extrapolate molecular, cellular, or animal results to predict degenerative tissue risks in astronauts? How can human epidemiology data best support these procedures or models?	4	4	2	Risk Assessment

Crosscutting Area:		Radiation			
Discipline:		Radiation			
Risk:		(34) Heredity, Fertility and Sterility Risks			
		EQ DRM Priority			
EQ No.	Enabling Question	ISS	Lunar	Mars	EQ Category
34a.	What are the risks of hereditary, fertility or sterility effects as a result of exposure to space radiation?	4	3	2	Risk Assessment
34b.	Is there a transmissible risk for neurodegenerative or other non-cancer/non-CNS diseases to the offspring of those exposed to radiation?	3	3	3	Risk Assessment

Crosscutting Area:		Radiation			
Discipline:		Radiation			
Risk:		(35) Acute Radiation Syndromes			
		EQ DRM Priority			
EQ No.	Enabling Question	ISS	Lunar	Mars	EQ Category
35a.	How can predictions of acute space radiation events be improved?	5	3	3	Risk Assessment
35b.	Are there synergistic effects arising from other space flight factors (microgravity, stress, immune status, bone loss, damage to intestinal cells reducing their ability to absorb medication? etc.) that modify	4	3	3	Risk Assessment

	acute risks from space radiation including modifying thresholds for such effects?				
35c.	What are the molecular, cellular and tissue mechanisms of acute radiation damage (DNA damage processing, oxidative damage, cell loss through apoptosis or necrosis, cytokine activation, etc.)?	4	3	3	Mechanisms
35d.	Does protracted exposure to space radiation modify acute doses from SPEs in relationship to acute radiation syndromes?	4	3	3	Risk Assessment
35e.	What are the most effective biomedical or dietary countermeasures to mitigate acute radiation risks? By what mechanisms do the countermeasures work?	4	3	3	Countermeasures Mechanisms
35f.	What quantitative procedures or theoretical models are needed to extrapolate molecular, cellular, or animal results to predict acute radiation risks in astronauts? How can human epidemiology data best support these procedures or models?	4	3	3	Risk Assessment
35g.	What are the most effective shielding approaches to mitigate acute radiation risks?	1	1	1	Countermeasures

Advanced Human Support Technology (AHST)

Crosscutting Area:		Advanced Human Support Technology (AHST)			
Discipline:		Advanced Environmental Monitoring and Control (AEMC)			
Risk:		(36) Monitor Air Quality			
EQ No.	Enabling Question	EQ DRM Priority			EQ Category
		ISS	Lunar	Mars	
36a.	What technologies can be used to detect slow, gradual changes in the chemical and microbial environment (work with Environmental Health)?	1	1	1	Technologies
36b.	What set of technologies and data can be used to make the diagnosis of potentially hazardous event from chemical data quickly (work with Environmental Health, ALS)?	1	1	1	Technologies
36c.	How can environmental information be used to assist in-flight biomonitoring for health and performance of the astronauts (supporting Biomedical monitoring)?	3	3	3	Operations & Training
36d.	What technologies must be developed to rapidly detect and address fire in space?	1	1	1	Technologies
36e.	How can technology help make appropriate response to a hazardous event be achieved in a timely manner (needed for automated systems)?	2	2	2	Technologies Operations & Training
36f.	What set of technologies and data can be used to detect and diagnose hardware malfunction, in such systems as life support or in situ resource utilization by assessment of environmental (air, water, or surfaces) changes (work with ALS)?	2	2	2	Technologies Operations & Training

Crosscutting Area:		Advanced Human Support Technology (AHST)			
Discipline:		Advanced Environmental Monitoring and Control (AEMC)			
Risk:		(37) Monitor External Environment			
EQ No.	Enabling Question	EQ DRM Priority			EQ Category
		ISS	Lunar	Mars	
37a.	What sensors are required to monitor hazardous conditions in the extra-vehicular environment (work with AEVA)?	1	1	1	Technologies Requirements/Specifications

Crosscutting Area: <i>Advanced Human Support Technology (AHST)</i>					
Discipline: <i>Advanced Environmental Monitoring and Control (AEMC)</i>					
Risk: <i>(38) Monitor Water Quality</i>					
EQ No.	Enabling Question	EQ DRM Priority			EQ Category
		ISS	Lunar	Mars	
38a.	What technologies can be used to detect slow, gradual changes in the chemical and microbial environment (work with ALS and Environmental Health)?	1	1	1	Technologies
38b.	What set of technologies and data can be used to make the diagnosis of potentially hazardous event from chemical data quickly (work with ALS and Environmental Health)?	1	1	1	Technologies
38c.	How can technology help make appropriate response to a hazardous event be achieved in a timely manner (needed for developing automated system)?	2	2	2	Technologies Operations & Training
38d.	What set of technologies and data can be used to detect and diagnose hardware malfunction by assessment of environmental (air, water, or surfaces) changes (work with ALS)?	1	1	1	Technologies Operations & Training

Crosscutting Area: <i>Advanced Human Support Technology (AHST)</i>					
Discipline: <i>Advanced Environmental Monitoring and Control (AEMC)</i>					
Risk: <i>(39) Monitor Surfaces, Food and Soil</i>					
EQ No.	Enabling Question	EQ DRM Priority			EQ Category
		ISS	Lunar	Mars	
39a.	What technologies can be used to detect slow, gradual changes in the chemical and microbial surface environment? (work with Environmental Health and ALS)	1	1	1	Technologies
39b.	What set of technologies and data can be used to make the diagnosis of potentially hazardous event involving surfaces quickly? (work with Environmental Health and Life Support)	1	1	1	Technologies Operations & Training
39c.	What technologies are required to meet the radiation monitoring requirements of a mission?	TBD	TBD	TBD	Technologies

39d.	What sample acquisition and preparation technologies can meet the requirements of the gaseous, aqueous and solid-phase matrices monitoring?	TBD	TBD	TBD	Technologies Operations & Training
39e.	What research is required to validate design approaches for multiphase flow for monitoring systems in varying gravity environments?	TBD	TBD	TBD	Requirements/Specifications

Crosscutting Area: *Advanced Human Support Technology (AHST)*
Discipline: *Advanced Environmental Monitoring and Control (AEMC)*
Risk: *(40) Provide Integrated Autonomous Control of Life Support Systems*

EQ No.	Enabling Question	EQ DRM Priority			EQ Category
		ISS	Lunar	Mars	
40a.	How do we design an effective control system with flexibility, modularity, growth potential, anti-obsolescence and accommodate varied, new, & unknown test articles, taking advantage of standards (work with Integrated Testing)?	1	1	1	Requirements/Specifications
40b.	How does a control system manage and plan for the long time constants of certain biological processes that lead to changes days, months later; and reconciles between discrete events, continuous processing and varying time constants (work with Integrated Testing)?	1	1	1	Requirements/Specifications Operations & Training
40c.	How do we assure that human situation awareness is at a high level when needed, while offloading the crew workload for most of the time (work with SHFE and Integrated Testing)?	2	2	2	Requirements/Specifications Operations & Training
40d.	How can a control system support strategic decisions; launch readiness/abort/return home decisions and procedures (work with SHFE and Integrated Testing)?	1	1	1	Requirements/Specifications Operations & Training
40e.	How can we develop real time prognostic capabilities to predict failures before they occur and degradations before they have	1	1	1	Technologies

	impact (work with ALS and Integrated Testing)?				
40f.	How do we allocate efficiently and safely between space-based control and ground-based control (work with SHFE and Integrated Testing)?	1	1	1	Requirements/Specifications Operations & Training
40g.	In very large and complex systems, how can we synchronize system states across subsystems (work with Integrated Testing)?	1	1	1	Requirements/Specifications Operations & Training
40h.	How do we trade between buffers and controls to ensure safe and reliable system (work with ALS and Integrated Testing)?	1	1	1	Design Tools Requirements/Specifications
40i.	How can understanding process control help determine which sensors may be missing and where sensors should be placed (work with Integrated Testing)?	1	1	1	Design Tools Requirements/Specifications

Crosscutting Area:		Advanced Human Support Technology (AHST)			
Discipline:		Advanced Extravehicular Activity (AEVA)			
Risk:		(41) Provide Space Suits and Portable Life Support Systems			
		EQ DRM Priority			
EQ No.	Enabling Question	ISS	Lunar	Mars	EQ Category
41a.	What EVA system design can be developed to reduce the pre-breath requirement?	N/A	1	1	Requirements/Specifications Operations & Training
41b.	What suit and PLSS technology must be developed to meet mission requirements for EVA mobility? [	N/A	1	1	Technologies
41c.	How do we protect against planetary surface dust through suit and airlock system design?	N/A	1	1	Technologies Requirements/Specifications
41d.	How do we protect against toxic fluids and contaminants?	2	2	2	Technologies Requirements/Specifications
41e.	How do we design space suits to fit multiple crewmembers of various sizes and shapes? [	1	1	1	Design Tools Requirements/Specifications
41f.	How do we improve glove dexterity?	1	1	1	Technologies
41g.	What technologies can be	N/A	1	1	Technologies

	developed to provide passive or active thermal insulation in various environments, including deep-space and lunar vacuum?				
41h.	What technologies must be developed to meet mission non-venting and non-contaminating requirements?	N/A	2	2	Technologies
41i.	How do we provide and manage increased information to EVA crewmember, including suit parameters, systems status, caution and warning, video, sensor data, procedures and text and graphics?	N/A	2	2	Requirements/Specifications Operations & Training
41j.	How do we achieve EVA and robotic interaction and cooperation?	N/A	1	1	Technologies Requirements/Specifications
41k.	What biomedical sensors are needed to enhance safety and performance during EVAs?	N/A	2	2	Technologies Requirements/Specifications
41l.	How can space suit design accommodate crewmember physical changes after long time in microgravity?	N/A	1	1	Technologies
41m.	What technology can be developed to monitor EVA crewmember thermal status and provide auto-thermal control?	N/A	1	1	Technologies Requirements/Specifications
41n.	Can a practical EMU containment receptacle for emesis be developed? If a vomiting episode occurs, is there a way of refurbishing the suit during the mission? How can suit life support systems be designed to be more resistant to vomiting episode?	1	1	1	Technologies Requirements/Specifications Operations & Training

Crosscutting Area:	Advanced Human Support Technology (AHST)				
Discipline:	Advanced Food Technology (AFT)				
Risk:	(42) Maintain Food Quantity and Quality				
		EQ DRM Priority			
EQ No.	Enabling Question	ISS	Lunar	Mars	EQ Category
42a.	What procedures (e.g., storage, processing,	1	1	1	Operations & Training

	preparation, clean-up), such as HACCP, need to be developed to assure a safe food system?				
42b.	What are the allowable limits of microbial and chemical contamination in the food?	1	1	1	Requirements/Specifications
42c.	How does space radiation affect the functionality and nutritional content of the stored staple ingredients for food processing?	N/A	1	1	Requirements/Specifications
42d.	What food processing technologies are required when using stored staple ingredients to ensure a food system that is nutritious, safe and acceptable?	N/A	1	1	Technologies Requirements/Specifications
42e.	What food packaging materials will provide the physical and chemical attributes, including barrier properties, to protect the food from the outside environment and assure the 3-5 year shelf life?	1	1	1	Technologies Requirements/Specifications
42f.	What food packaging material will be biodegradable, easily processed, or be lighter in mass than the current packaging and can still provide the physical and chemical attributes including barrier properties to protect the food from the outside environment and assure the 3-5 year shelf life?	1	1	1	Technologies Requirements/Specifications
42g.	What food preservation technologies will provide prepackaged food items with a shelf life of 3-5 years?	2	2	2	Technologies Requirements/Specifications
42h.	What are the impacts of reduced Gravity and atmospheric pressure on the food processing activities?	N/A	2	1	Requirements/Specifications Operations & Training
42i.	What are the impacts of reduced Gravity and atmospheric pressure on the food preparation activities?	3	2	1	Requirements/Specifications Operations & Training
42j.	What nutritional content and sensory attributes changes (including radiation induced effects) in the prepackaged	2	2	2	Requirements/Specifications Design Tools

	food items will occur over the shelf life of the food?				
42k	What food system technology selection criteria will be used to effectively reduce critical resources such as air, water, thermal, biomass and solid waste processing, during a mission?	2	2	2	Requirements/Specifications Design Tools
42l.	What are the changes (taste, odor, etc.) that occur in crewmember's sensory perceptions during space flight that would affect food acceptability?	3	3	3	Requirements/Specifications
42m.	What are the physical and chemical requirements for each of the stored staple ingredient items to assure effective processing into acceptable, safe and nutritious food ingredients?	N/A	2	2	Requirements/Specifications
42n.	What level of acceptability in the food system is required to provide psychosocial well being of the crew?	3	3	2	Requirements/Specifications
42o.	What level of variety (e.g., number of food items, length of menu cycle) in the food system is required to provide psychosocial well being of the crew?	3	3	2	Requirements/Specifications
42p.	What modeling techniques can be used to measure the subjective portions of the food system such as palatability, nutrition, psychological issues and variety?	3	3	2	Design Tools Requirements/Specifications

Crosscutting Area: <i>Advanced Human Support Technology (AHST)</i>					
Discipline: <i>Advanced Life Support (ALS)</i>					
Risk: <i>(43) Maintain Acceptable Atmosphere</i>					
		EQ DRM Priority			
EQ No.	Enabling Question	ISS	Lunar	Mars	EQ Category
43a.	What system will meet all the requirements for controlling atmospheric pressure, O ₂ and CO ₂ partial pressure?	1	1	1	Technologies Requirements/Specifications

43b.	What method for recovering O ₂ from CO ₂ is most effective in an integrated ECLS?	2	2	2	Technologies Design Tools
43c.	What is the proper trace contaminant load and performance model to drive the design and operation of a trace contaminant system?	2	2	2	Design Tools
43d.	What sensors are required to provide environmental data, monitor performance and provide inputs to control systems (AEMC)?	2	2	2	Technologies
43e.	What monitoring and control system can provide semi-to-total autonomous control of Life Support Systems (AEMC)?	2	2	2	Design Tools Requirements/Specifications
43f.	How can microbes and candidate crop species be engineered to perform better and fulfill multiple functions in a bioregenerative system?	N/A	3	1	Technologies
43g.	What are the interfaces between the biological and physical chemical life support subsystems for a specified mission?	N/A	3	1	Requirements/Specifications Design Tools
43h.	Can viability and genetic integrity of the biological components be maintained for the duration of different missions?	N/A	3	2	Technologies
43i.	What are the effects of radiation on biological components of the life support system?	N/A	3	1	Requirements/Specifications Design Tools
43j.	What research is required to validate design approaches for multiphase flow and particulate flows for air revitalization systems in varying gravity environments?	TBD	TBD	TBD	Technologies Requirements/Specifications

Crosscutting Area:		Advanced Human Support Technology (AHST)			
Discipline:		Advanced Life Support (ALS)			
Risk:		(44) Maintain Thermal Balance in Habitable Areas			
EQ No.	Enabling Question	EQ DRM Priority			EQ Category
		ISS	Lunar	Mars	
44a.	What heat transport fluids meet the requirements for specified missions?	1	1	1	Technologies Design Tools
44b.	What materials and designs will meet the heat acquisition (cold plates, heat exchangers, cooling jackets, etc.) requirements for specified missions?	1	1	1	Technologies Design Tools
44c.	What materials and designs will meet the heat transport (pumps, two-phase loops, heat pumps, etc.) requirements for specified missions?	1	1	1	Technologies Design Tools
44d.	What materials and designs will meet the heat rejection (radiators, sublimators, evaporators, etc.) requirements for specified missions?	1	1	1	Technologies Design Tools
44e.	What materials and designs will meet the humidity control requirement requirements for specified missions?	1	1	1	Technologies Design Tools
44f.	What thermal system sensors will meet the requirements to provide monitoring and data collection for specified missions?	2	2	2	Technologies Design Tools
44g.	What monitoring and control system hardware and design will meet the requirements for specified missions? (AEMC)	2	2	2	Technologies Design Tools

Crosscutting Area:		Advanced Human Support Technology (AHST)			
Discipline:		Advanced Food Technology (AFT)			
Risk:		(45) Manage Waste			
EQ No.	Enabling Question	EQ DRM Priority			EQ Category
		ISS	Lunar	Mars	
45a.	What system will meet the storage and/or disposal requirements for specified missions?	1	1	1	Technologies Design Tools
45b.	What system will meet requirements for processing wastes to recover resources for specified missions?	1	1	1	Technologies Design Tools
45c.	What waste management will handle complex waste streams such as packaging,	2	2	2	Technologies Design Tools

	paper, etc. in order to meet mission requirements? [
45d.	What waste management will handle medical wastes such as blood, tissues and syringes etc. in order to meet mission requirements?	N/A	2	2	Technologies Design Tools
45e.	What system will separate wastes (inedible plant biomass, trash and/or paper, feces, etc.) in order to meet compatibility mission requirements for waste management?	1	1	1	Technologies Design Tools
45f.	What system will meet the requirements for managing residuals for planetary protection?	N/A	2	2	Technologies
45g.	How can microbes and candidate crop species be engineered to perform better and fulfill multiple functions in a bioregenerative system?	N/A	3	1	Technologies
45h.	What are the interfaces between the biological and physical chemical life support subsystems for a specified mission?	N/A	3	1	Requirements/Specifications Design Tools
45i.	Can viability and genetic integrity of the biological components be maintained for the duration of different missions?	N/A	3	2	Requirements/Specifications Design Tools
45j	How do partial and microgravity affect biological waste processing?	N/A	3	1	Requirements/Specifications Design Tools
45k	What are the effects of radiation on biological components of the life support system?	N/A	3	1	Requirements/Specifications Design Tools
45l.	What sensors are required to monitor performance and provide inputs to control systems (AEMC)?	2	2	2	Technologies Design Tools
45m.	What monitoring and control system can provide semi to total autonomous control to relieve the crew of monitoring and control functions to the extent possible (AEMC)?	2	2	2	Technologies Design Tools
45n.	Could any of the solid waste be recycled in such a way to provide building material for	N/A	3	3	Technologies

	habitability features needed in subsequent phases of the mission?				
45o.	What research is required to validate design approaches for multiphase flows for solid waste management and resource recovery in varying gravity environments.	TBD	TBD	TBD	Design Tools
45p.	What resources are required to manage waste disposal as an environmental risk during long and remote missions (from EH)?	TBD	TBD	TBD	Technologies Requirements/Specifications

Crosscutting Area:		Advanced Human Support Technology (AHST)			
Discipline:		Advanced Food Technology (AFT)			
Risk:		(46) Provide and Maintain Bioregenerative Life Support Systems			
		EQ DRM Priority			
EQ No.	Enabling Question	ISS	Lunar	Mars	EQ Category
46a.	What are the optimal methods of plant growth for a specified mission, including development of appropriate hardware, management of light, water, nutrients, gas composition and pressure, trace contaminants, horticultural procedures and disease risks?	2	2	1	Technologies Design Tools
46b.	How can microbes and candidate crop species be engineered to perform better and fulfill multiple functions in a bioregenerative system?	N/A	3	1	Technologies
46c.	What mechanized or automated systems are required for planting and harvesting crops and monitoring and control for a specified mission?	N/A	3	2	Technologies Design Tools
46d.	Can viability and genetic integrity of the biological components be maintained for the duration of different missions?	N/A	3	2	Requirements/Specifications Design Tools
46e.	What are the interfaces between the biological and physical chemical life support subsystems for a	N/A	3	1	Requirements/Specifications Design Tools

	specified mission?				
46f.	How do partial and microgravity affect plant growth and crop yield?	N/A	3	1	Requirements/Specifications Design Tools
46g.	What are the effects of radiation on biological components of the life support system?	N/A	3	1	Requirements/Specifications Design Tools
46h.	What percentage of crew food needs should be attributed to ALS plant products for specified missions?	N/A	3	2	Requirements/Specifications Design Tools
46i.	What capabilities and associated hardware are required for processing and storing plant products for a specified mission?	N/A	3	2	Technologies Design Tools
46j	Can the plant production rates and ALS functions be sustained for the duration of the mission?	N/A	3	1	Requirements/Specifications Design Tools
46k	Can plant yields and ALS functions measured during low TRL (fundamental) testing be scaled up for large bioregenerative systems?	N/A	3	1	Technologies
46l.	What sensors and monitoring systems will be required to measure environmental conditions and crop growth parameters and health for a specified mission (AEMC)?	3	3	2	Technologies Design Tools Requirements/Specifications
46m.	What control system hardware and software technologies will be required to monitor and control crop systems for a specified mission (AEMC)?	3	3	2	Technologies Design Tools Requirements/Specifications

Crosscutting Area: <i>Advanced Human Support Technology (AHST)</i>					
Discipline: <i>Advanced Life Support (ALS)</i>					
Risk: <i>(47) Provide and Recover Potable Water</i>					
		EQ DRM Priority			
EQ No.	Enabling Question	ISS	Lunar	Mars	EQ Category
47a.	What system meets all requirements for supplying potable water needs?	1	1	1	Technologies Requirements/Specifications
47b.	What mechanisms to collect and transport wastewater	1	1	1	Technologies Requirements/Specifications

	meet the mission requirements?				
47c.	What methods for the removal of organic, inorganic and microbial contaminants in wastewater meet all mission requirements for efficiency and reliability?	1	1	1	Technologies Requirements/Specifications
47d.	What method to store and maintain portability of recycled water meets all requirements for specified missions?	1	1	1	Technologies Requirements/Specifications
47e.	What sensors are required to provide water quality parameters, monitor performance and provide inputs to a control system (AEMC)?	2	2	2	Technologies Requirements/Specifications
47f.	What control system meets all mission requirements (AEMC)?	2	2	2	Technologies Requirements/Specifications
47g.	How can microbes be engineered to perform better and fulfill multiple functions in a bioregenerative system? [	N/A	3	1	Technologies
47h.	What are the interfaces between the biological and physical chemical life support subsystems for a specified mission?	N/A	3	1	Requirements/Specifications Design Tools
47i.	Can viability and genetic integrity of the biological components be maintained for the duration of different missions?	N/A	3	2	Requirements/Specifications Design Tools
47j.	How do partial and microgravity affect biological water processing?	N/A	3	1	Design Tools Requirements/Specifications
47k.	What are the effects of radiation on biological components of the life support system?	N/A	3	1	Requirements/Specifications Design Tools
47l.	What research is required to validate design approaches for multiphase flows for Water recovery systems in varying gravity environments?	1	1	2	Design Tools

Crosscutting Area: <i>Advanced Human Support Technology (AHST)</i>					
Discipline: <i>Advanced Human Support Technology (AHST)</i>					
Risk: <i>(48) Inadequate Mission Resources for the Human System</i>					
		EQ DRM Priority			
EQ No.	Enabling Question	ISS	Lunar	Mars	EQ Category
48a.	What technologies can meet expected mission requirements for both monitoring and efficiency?	1	1	1	Technologies Design Tools
48b.	How is the total mass of the EVA system reduced significantly (portable life support system and the pressure garment)?	2	2	2	Technologies Design Tools
48c.	What is the best method for minimizing space suits consumables through advanced subsystems designs (thermal control, CO2 removal, humidity control, trace contaminants)?	2	2	2	Technologies Design Tools
48d.	How do we increase reliability and maintainability of space suits?	1	1	1	Technologies Design Tools
48e.	What levels of hardware, software and operations commonality are desirable and feasible to enhance likelihood of mission success and reduce mission mass, risk and cost?	2	2	2	Technologies Operations & Training
48f.	How can the effectiveness, efficiency and safety of integrated human systems in space missions be measured and analyzed (Supports SHFE)?	1	1	1	Technologies Design Tools
48g.	What food system technology selection criteria will be used to effectively reduce critical resources such as air, water, thermal, biomass and solid waste processing, during a mission?	2	2	2	Technologies Design Tools

Crosscutting Area: <i>Advanced Human Support Technology (AHST)</i>					
Discipline: <i>Space Human Factors Engineering (SHFE)</i>					
Risk: <i>(49) Mismatch Between Crew Physical Capabilities And Task Demands</i>					
		EQ DRM Priority			
EQ No.	Enabling Question	ISS	Lunar	Mars	EQ Category
49a.	What are the effects of microgravity, 1/6-gravity, or 1/3-gravity on requirements for habitable volume and architecture?	2	2	2	Requirements/Specifications Design Tools
49b.	What designs of workspace, equipment, tool and clothing will accommodate differences	2	2	2	Design Tools Requirements/Specifications

	in crew anthropometry?				
49c.	What are the effects of duration of exposure to microgravity, 1/6-gravity, 1/3-gravity on human physical performance?	1	1	1	Design Tools Operations & Training
49d.	What tools, equipment and procedures will enable crew physical performance to accommodate the effects of exposure to different gravity levels?	2	2	2	Requirements/Specifications Operations & Training
49e.	How can crewmembers and ground support personnel detect and compensate for decreased physical readiness to perform during a mission?	2	3	3	Technologies Operations & Training
49f.	What scheduling constraints are required to reduce the risk of human performance failure due to physical fatigue to an acceptable probability?	2	2	2	Requirements/Specifications Operations & Training
49g.	What principles of task design and function allocation will result in operations concepts that meet crew performance requirements for the mission?	2	2	2	Requirements/Specifications Design Tools
49h.	What limitations are required on physical workload to enable crewmembers to complete physical tasks with an acceptable probability?	1	1	1	Requirements/Specifications Design Tools
49i.	What crew size, composition and task allocations are required to accomplish the design reference missions?	1	1	1	Requirements/Specifications Design Tools
49j.	What design considerations are needed to accommodate effects of changes in gravity, including launch, reentry, lunar landing, lunar launch, Mars landing, Mars launch, and Earth return?	1	1	1	Requirements/Specifications Design Tools

Crosscutting Area:		Advanced Human Support Technology (AHST)			
Discipline:		Space Human Factors Engineering (SHFE)			
Risk:		(50) Mis-assignment of Responsibilities within Multi-Agent Systems			
EQ No.	Enabling Question	EQ DRM Priority			EQ Category
		ISS	Lunar	Mars	
50a.	What crew size and composition is required to accomplish the design reference mission (Shared – Integrated Testing supports)?	2	1	1	Requirements/Specifications Design Tools
50b.	What principles and algorithms for allocating tasks to human crewmembers, ground support and onboard automated systems will reduce the probability of significant errors (Shared – Integrated Testing supports)?	1	1	1	Design Tools Operations & Training
50c.	What automated tools and equipment are required to enable the crewmembers to accomplish the mission?	2	2	2	Technologies Requirements/Specifications
50d.	How do crew size, communications restrictions, crew skills, scheduling constraints and design reference mission task requirements affect the requirements for automation?	1	1	1	Requirements/Specifications Design Tools
50e.	What combinations of crew, ground and on-board automation capabilities will increase the likelihood of a successful mission (Shared – Integrated Testing supports)?	1	1	1	Requirements/Specifications Design Tools
50f.	What training and operational readiness assurance processes and implementations will increase likelihood of mission success?	2	2	2	Operations & Training Design Tools

50g.	What principles of task assignment workload and automation need to be developed to facilitate critical team performance?	2	2	2	Requirements/Specifications Operations & Training
50h.	What tools and procedures are needed to determine the appropriate level of automation and crew control for the various tasks in the DRM?	1	1	1	Technologies Operations & Training

APPENDIX E: CONFIGURATION CONTROL PANEL CHARTER
(CHARTER TO BE REVISED BY BSMT)

BIOASTRONAUTICS
CRITICAL PATH
CONTROL PANEL
CHARTER

Aug. 30, 2000
(Updated August 28, 2002;
in revision July 30, 2003
in revision April 2004)

Approved by

Charles M. Stegemoeller
Associate Director, Bioastronautics
Bioastronautics Program Office
NASA Johnson Space Center

CHARTER

CRITICAL PATH CONTROL PANEL

Bioastronautics Program Office
Johnson Space Center
National Aeronautics and Space Administration

1.0 PURPOSE

1.1 The Critical Path Control Panel (CPCP) will maintain the content of the Bioastronautics Critical Path Roadmap (BCPR) including review and approval of changes to that content and the issuance of directives communicating any such changes. All CPCP directives will be reflected in the content of the BCPR baseline document and the BCPR Website.

1.2 The CPCP will review and approve updates to the content of the BCPR following discussion by all participants at scheduled meetings of the CPCP. All items submitted to the CPCP must first be reviewed within each of the discipline area teams, signed by the team co-lead(s) and formally submitted as a change request (CR) to the CPCP for review and disposition. The CR form is included in Attachment 1. CRs may be submitted at any time to the Executive Secretary of the CPCP. All CR forms and any supporting materials will be collated and

distributed to panel members for their review in advance of CPCP meetings. The discipline area team leads will maintain an inventory of all CRs submitted to their team with their recommended disposition of all items. This list will be submitted to the CPCP prior to their scheduled meetings. The CPCP will consider the CRs for approval during scheduled panel meetings. Decisions regarding the disposition of BCPR changes will be based on a majority vote. Minority opinions regarding BCPR changes will be documented for the record.

1.3 The BCPR content and any recommended changes to that content, will be the responsibility of the discipline area team leads and the members of those teams. The teams will review and update the information in their areas (including representative references) and develop new information in support of the BCPR. Recommendations to change the content of the BCPR will be made through the CR process.

1.3.1 The discipline area teams will consist of members from the NASA Johnson Space Center (JSC) Bioastronautics Program Office (BPO) and the National Space Biomedical Research Institute (NSBRI), to be appointed by and serve at the discretion of, each organization. Two co-leads, one each from JSC BPO and NSBRI, will chair each of the teams where applicable. The discipline areas will include the following:

- Advanced Human Support Technology (AHST)
- Bone Loss
- Cardiovascular Alterations
- Environmental Health
- Food & Nutrition
- Human Behavior & Performance
- Immunology, Infection & Hematology
- Muscle Alterations & Atrophy
- Neurovestibular Adaptation
- Radiation Health
- Clinical Capabilities

1.4 The CPCP will prepare a baseline document of the content of the BCPR. The CPCP chair and deputy chair will have signature authority with concurrence by the Assistant Director for Bioastronautics.

1.5 The CPCP will review the BCPR content annually at a minimum and as needed. The CPCP will ensure that changes to the BCPR content are thoroughly reviewed, appropriately dispositioned, officially documented and communicated to the Assistant Director for Bioastronautics, and other program management and risk area team leads.

1.6 The CPCP will periodically evaluate NASA-funded research and technology activities in the area of human space life sciences in relation to the BCPR. The CPCP will also recommend changes in program content or direction, as appropriate, to the BPO and other Program management leads.

2.0 SCOPE AND AUTHORITY

2.1 The CPCP is authorized through the BPO Control Board (BCB); the Chairs report to Assistant Director for Bioastronautics, BPO.

2.2 The CPCP will establish, through the BCB, a baseline document of the BCPR within 30-days of Charter approval.

2.3 The baselined document will be applicable to all NASA-funded research and technology activities in the area of human space life sciences.

2.4 The baselined document will define the elements of the BCPR to be controlled by the CPCP.

2.5 The CPCP will establish a support team to handle the administrative and functional responsibilities of the CPCP. The support team will consist of NASA JSC BPO and contractor personnel. Operations of the support team will be managed by the Executive Secretary of the CPCP.

2.6 The JSC and NSBRI members of the CPCP, appointed by BPO and the NSBRI respectively, will serve for a three-year term. All members are voting members.

3.0 RESPONSIBILITIES

3.1 The CPCP will be responsible for reviewing changes and approving all BCPR content, including, discipline risk areas, risks, risk types, risk rankings, EQs, critical question priorities, risk area roadmaps, deliverables, risk mitigation requirements, risk resolution timelines and other BCPR content-related items.

3.2 The CPCP will be responsible for developing a BCPR congruence tool for the NASA and NSBRI Program Managers to assess the overall strength of association of individual ground and flight projects and tasks with the BCPR. The CPCP will periodically review and report on the status of NASA-funded research and technology activities in the area of human space life sciences with regard to BCPR congruence and progress and provide recommendations for future emphasis and funding. A report on BCPR congruence will be issued annually.

3.3 The CPCP Chairperson and Deputy Chairperson will lead all CPCP meetings, resolve conflicts, disposition all changes and issue CPCP actions and directives.

3.4 The CPCP will determine the type of review process necessary to properly disposition CRs to the BCPR content, the type of instrument needed to assess NASA-funded research and technology activities in the area of human space life sciences with regard to BCPR congruence and progress, and the type or format of the annual report assessing the congruence of those efforts with the BCPR.

- 3.5 CPCP Support Team Responsibilities Schedule and conduct meetings.
- Establishing official communications channels between the CPCP and BPO and other external programs, including, but not limited to, the NSBRI, the NASA Headquarters Offices of Biological and Physical Sciences (Bioastronautics Research Division), the Chief Health and Medical Officer, Space Flight (International Space Station Program and Space Shuttle Program) and other necessary Program offices.
 - Receive and process all submitted program changes and documentation for review and evaluation.
 - Process all CPCP change requests submitted by potential requesters for review, evaluation, decision-making and distribution and .
 - Issue directives identifying the CPCP decisions.
 - Issue minutes of all CPCP proceedings.
 - Transmit, track and actions closure for actions issued by the CPCP.
 - Establish and maintain a change and action accounting system that maintains a record of all CPCP proceedings, directives, actions and baselined documentation.
 - Archive CPCP records.
 - Interact with Website personnel to assure the integrity of the Website content per the existing directives of the CPCP.

3.6 Members of the CPCP will attend all CPCP meetings when possible. When absent, voting is permissible via telephone, videoconference, or proxy. Panel members are responsible for ensuring that all CPCP directives and actions are responded to in a timely fashion. The CPCP

will consist of twelve members, as described below. A quorum will consist of no fewer than seven members, including no fewer than two of the four NSBRI members.

- CPCP Chairperson (JSC)
- Executive Secretary
- JSC BPO Members (3)
- Human Health and Countermeasures (1)
- Autonomous Medical Care (2)
- Advanced Human Space Technology Program (2)
- NSBRI Members (3)
- Astronaut Office (2)
- JSC BPO Chief Scientist
- NASA Headquarters Office of Biological and Physical Research Life Sciences Bioastronautics Research Division representative (3)

All internal NASA JSC Directorate and Flight Programs (including ISS, Space Shuttle and Exploration) are invited and encouraged to participate in open CPCP activities.

3.7 The discipline teams will meet formally or informally during the course of the year, at the discretion of their respective team leads, to review the BCPR content in their areas and develop new information to provide to the CPCP through the CR process. Discipline team leads and members may attend CPCP meetings to discuss upcoming CRs, or to provide information related to the progress of BCPR risk reduction and mitigation in their respective areas. The BCPR discipline team leads will maintain an inventory of all CRs submitted to their team with the recommended disposition of all items. This inventory will be provided to the CPCP prior to scheduled meetings.

1. CR Number ____	OFFICE OF BIOASTRONAUTICS CRITICAL PATH CONTROL PANEL CHANGE REQUEST FORM	2. Page 1 of ____
3. CR Title	4. INITIATOR	
	ORGANIZATION	
	PHONE	
	EMAIL	
5. CR TYPE (Administrative use only)		
<input type="checkbox"/> CROSS CUTTING AREA		
<input type="checkbox"/> RISK		
<input type="checkbox"/> RISK FACTOR		
<input type="checkbox"/> ENABLING QUESTION		
<input type="checkbox"/> DELIVERABLE		
<input type="checkbox"/> TASKS		
<input type="checkbox"/> ROADMAPS		
<input type="checkbox"/> TIMELINES		
<input type="checkbox"/> OTHER _____		
6. Description of Change (Use a separate CR for each change request. Explain what is being changed using “Change to” and “Change from” language to describe each change). If more space is needed, use the next page.		
7. Justification for Change (Include impact if change not incorporated). If more space is needed, use the next page.		
8. Documentation to Support Change (List specific references and/or data sets, or cite levels of evidence, if applicable). If more space is needed, use the next page.		
<p>9. Disposition of CR and Signature of Discipline Team Co-leads</p> <p>NASA: <input type="checkbox"/> Concur <input type="checkbox"/> Do not concur*</p> <p>Signature: _____</p> <p style="padding-left: 100px;">Date: _____</p> <p>NSBRI: <input type="checkbox"/> Concur <input type="checkbox"/> Do not concur*</p> <p>Signature: _____</p> <p style="padding-left: 100px;">Date: _____</p> <p>If you do not concur, provide justification (next section)</p>	10: Comments	

Use the space provided below to complete one or more of the sections on Page 1 if you need more space.

A large, empty rectangular box with a thin black border, intended for providing additional space to complete sections from Page 1.

Current Guidelines of Practice for Clinical Levels of Evidence

Level 1 = Evidence obtained from a systematic review of all relevant randomized controlled trials

Level 2 = Evidence obtained from a least one properly designed randomized controlled trial

Level 3-1 = Evidence obtained from well-designed controlled trials without randomization

Level 3-2 = Evidence obtained from well-designed cohort or case control analytical studies, preferably from more than one center or research group

Level 3-3 = Evidence obtained from multiple time series with or without the intervention

Level 4 = Opinions of respected authorities, based on clinical experience, descriptive studies, or reports of expert committees

APPENDIX F: ARTIFICIAL GRAVITY TOPIC

The design reference missions used in the Bioastronautics Critical Path Roadmap (BCPR) assume that spacecraft that will take astronauts to and from Mars will have no provision for artificial gravity (AG). Consequently, the risk estimates assume that single system countermeasure approaches will be primarily used to reduce or prevent the deleterious effects of microgravity on the human body. For many decades, AG was considered as a multi-system approach to mitigating the harmful effects of space flight on the bone, muscle, cardiovascular and neurovestibular/sensory-motor systems. It may also have some salutary effects on the immune system and on some aspects of psychological effects. Some studies have indicated that including the capability for AG may increase spacecraft cost only 5-20%. Although this approach may be attractive on some levels, it should be noted that AG cannot mitigate some space flight risks, including radiation health, remote medical care and the psychological and environmental effects associated with living in a closed, confined environment. Additionally, rotation may produce unwanted side effects such as nausea, disorientation, eye-hand coordination and other human factors concerns.

Spacecraft design depends on how much gravity is needed because the amount of centripetal force produced will depend on the radius of the rotator and the rate of rotation ($R=a/w^2$). The issue for spacecraft designers is to determine how large the radius of the spacecraft must be. The first two questions spacecraft designers usually pose are:

1. How much gravity is needed and
2. How much rotation can be tolerated?

The answer to the first question is probably not more than 1-G. Decades of human space flight have shown that microgravity has deleterious effects on most major systems of the body, especially the musculoskeletal, cardiovascular and nervous systems. No data exist on the effects of exposure to fractional gravity, and precious few on the effects of intermittent 1-G exposure. However, we do know that gravity alone will not prevent the physiological deconditioning of fit individuals. Just as individuals on Earth must exercise to maintain fitness, exercise would also be necessary to maintain fitness in a 1-G artificial gravity spacecraft. Finally, physical exercise has many benefits aside from maintaining fitness. For all of these reasons, research on exercise in space will continue to be important for astronaut health and performance.

Experience has shown that initial design goals are often compromised during development; thus, spacecraft developers will likely ask if less than 1-G will suffice. One of the benefits of extended stays on the Moon would be to provide data pertaining to the biomedical effects of fractional (1/6) gravity. This could be very valuable for determining AG requirements. Another fractional gravity question is how will humans be respond to the 1/3 gravity of Mars after months of space flight? Here again no data exists. We have some documentation of the performance limitations of crewmembers upon their return to Earth after months in microgravity. Presumably the physiological challenge of 1/3 Earth's gravity would be considerably less than that of a full 1-G, but this is speculation. Nevertheless, some spacecraft designers have proposed using 1/3-G as the gravity load for an AG spacecraft because it would precondition humans planning to land on Mars to the Martian gravitational

environment. Upon return to Earth, astronauts would not have to function autonomously and medical support would be available to facilitate readapting to Earth's gravity.

With respect to how much rotation can be tolerated, some data exists from studies of slowly rotating rooms. Graybiel, who pioneered this work in the 1960s in Pensacola, reported that six revolutions per minute (rpm) produced signs of motion sickness in most subjects while two rpm produced motion sickness in only a few subjects. However, subjects were able to adapt to continuous rotation over two to three days. It is not clear how to project the incidence of motion sickness provoked by rotation on Earth to the incidence of "rotation" sickness in space. Pre-flight testing for susceptibility to rotation-induced motion sickness does not predict who will suffer space motion sickness. In fact, despite years of study, we have found there are no accurate predictors of who will be susceptible to space motion sickness. This is noted because we cannot predict with certainty from ground studies what rotation rates in space will be provocative other than to say that slower is better. On the other hand, data from the Skylab M-131 experiment suggests that subjects might be immune to rotational sickness in space. Further, it is important to note that human data from truly chronic exposure (weeks and months) to a rotating environment do not exist. Before an optimal design for an AG vehicle can be developed, further in-space tests of humans should be performed. To guide research facilitating AG as a multi-system countermeasure for exploration vehicles, an additional set of risks and enabling questions needs to be developed. NASA's Bioastronautics Research Division (Code UB) is currently developing a directed research project to investigate the potential of AG as a multi-system countermeasure. Along with our international partners, we are beginning to ground test a short radius centrifuge (SRC) to explore the degree to which intermittent exposure to AG plus exercise is beneficial. NASA is developing an SRC to test whether use of this device for a short period each day can prevent the deconditioning effects of bed rest on Earth. Should these tests prove efficacious, NASA plans to test the SRC on the ISS as a potential countermeasure. Data concerning the efficacy of daily exposures to AG in terrestrial simulations should be available in 2006 or 2007. Early tests of intermittent AG could be conducted on ISS early in the next decade. Other aspects of the directed research project will evaluate long-radius centrifuges, parameters of adaptation to continuously rotating environments, human factors issues, G-gradient issues and context-specific adaptation.

REFERENCES

1. NASA Advisory Council, Aerospace Medicine Advisory Committee. *Strategic Considerations for Support of Humans in Space and Moon/Mars Exploration Missions: Life Sciences Research and Technology Programs*. Volumes I and II. June 1992.
2. Space Science Board, National Research Council. *A Strategy for Space Biology and Medical Sciences for the 1980s and 1990s*. National Academy Press, Washington D.C., 1987.
3. Aeronautics and Engineering Board, National Research Council. *Advanced Technology for Human Support in Space*. National Academy Press, Washington D.C., 1987.
4. Space Studies Board, National Research Council. *A Strategy for Research in Space Biology and Medicine in the New Century*. National Academy Press, Washington D.C., 1998.
5. NASA Office of Life and Microgravity Sciences and Applications. *Task Force on Countermeasures: Final Report*. May 1997.
6. National Council on Radiation Protection and Measurements. *Guidance on Radiation Received in Space Activities. Recommendations of the National Council on Radiation Protection and Measurements. NCRP Report No. 98. July 31, 1989*.
7. Ball, J.R., and Evans, C.H., Board on Health Sciences Policy, Institute of Medicine. *Safe Passage: Astronaut Care for Exploration Missions*. National Academy Press, Washington, D.C., 2001.
8. NASA Office of the Chief Health and Medical Officer, Bioastronautics Strategy, January 27, 2003.
9. NASA Biological and Physical Research Enterprise Strategy, October 1, 2003.
10. NASA Space Flight Enterprise Strategy, November 1, 2003.
11. NASA Biological and Physical Research, *Report by the Research and Maximization and Prioritization (ReMAP) Task Force to the NASA Advisory Council*, August 2002.