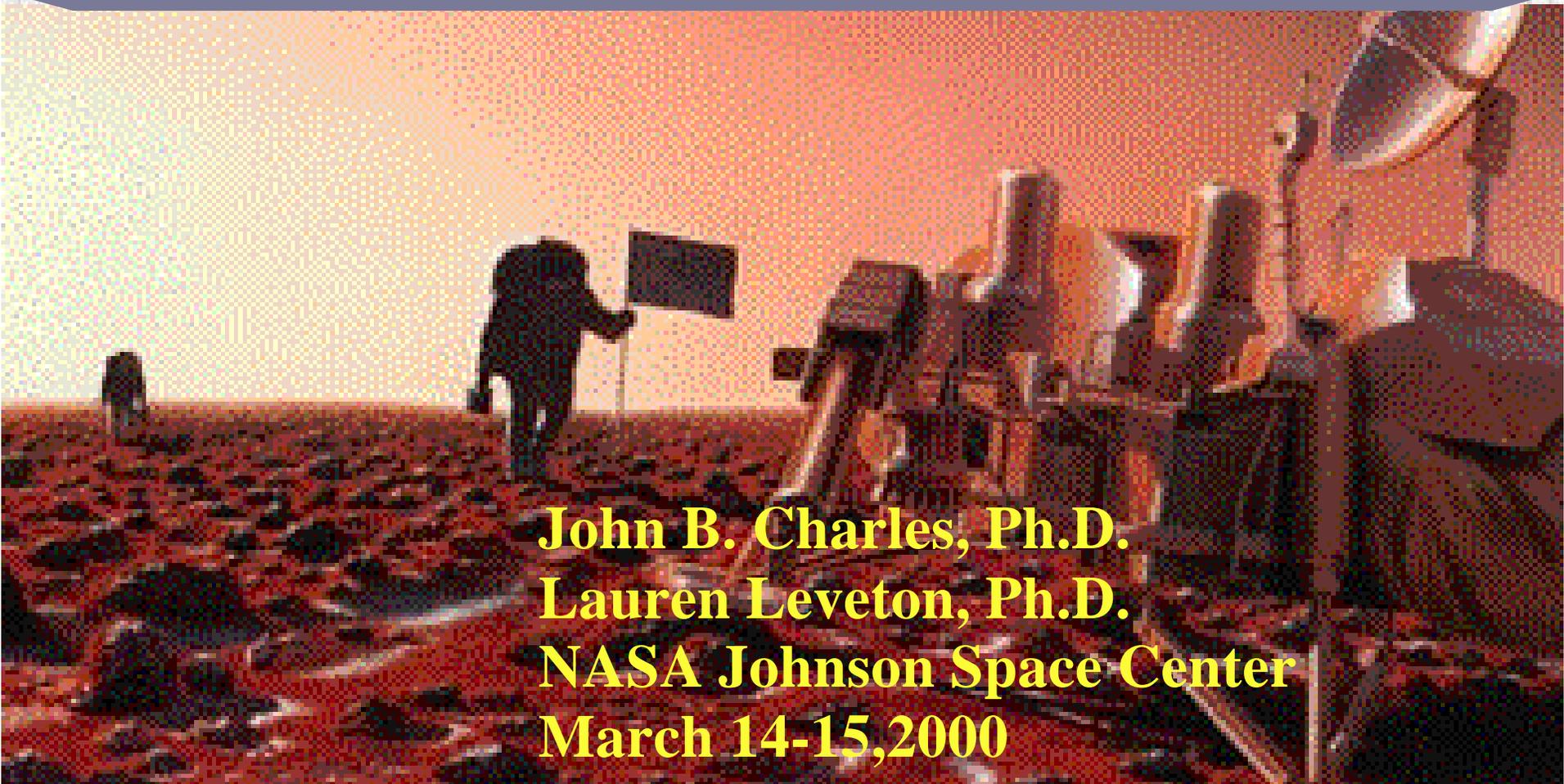




Human Space Life Sciences Critical Path Roadmap: Reducing the Risks for Human Exploration-class Missions

A photograph of an astronaut in a spacesuit standing on the reddish surface of Mars. The astronaut is holding a black flag. In the background, there is a large, complex piece of scientific equipment, likely a rover or lander, with various instruments and antennas. The sky is a hazy, orange-brown color.

**John B. Charles, Ph.D.
Lauren Leveton, Ph.D.
NASA Johnson Space Center
March 14-15, 2000**

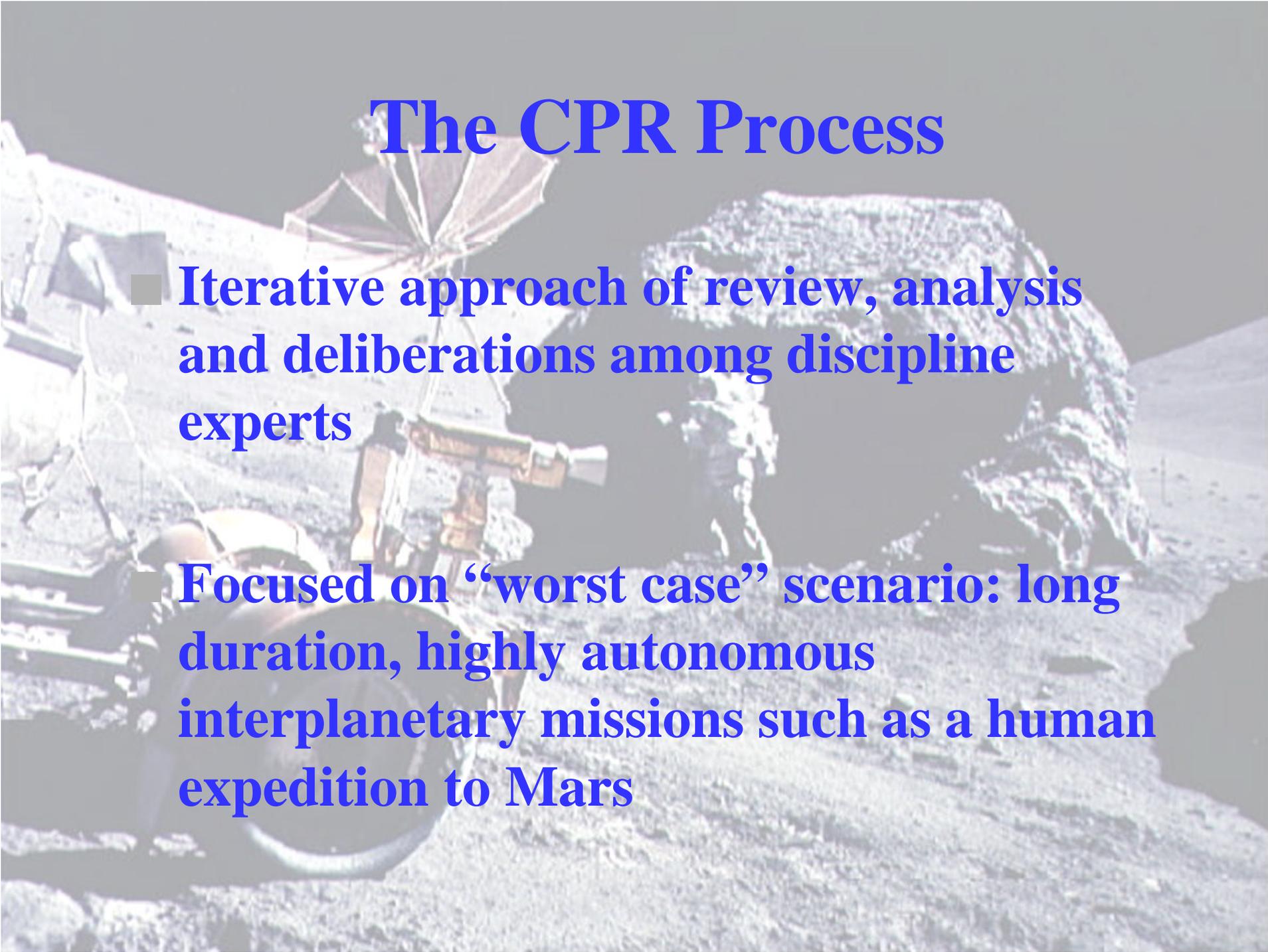
Critical Path Roadmap* Approach to Risk Mitigation

*CPR

- To the extent permitted by available resources, including funding, flight access, etc.:
 - Identify the risks
 - Understand the risks
 - Manage the risks
 - Prevent them, OR
 - Reduce their effects to acceptable levels
 - To endure safety, health and performance
 - During and after spaceflight

Critical Path Roadmap

Human Exploration
Development of Space



The CPR Process

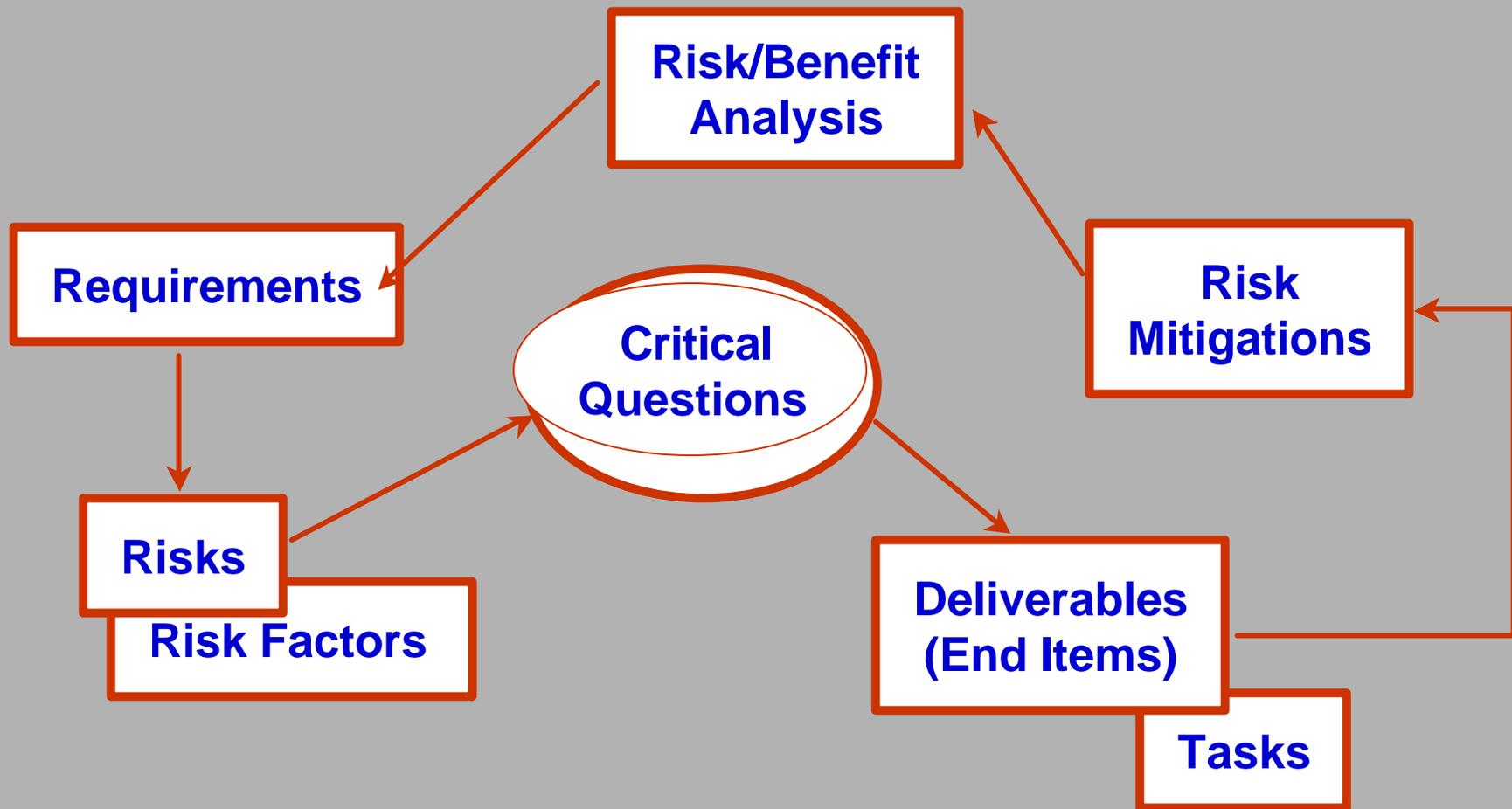
- Iterative approach of review, analysis and deliberations among discipline experts
- Focused on “worst case” scenario: long duration, highly autonomous interplanetary missions such as a human expedition to Mars



Joint NASA and NSBRI Research Area Teams January 1998

- **Habitation Systems**
 - **Advanced Life Support**
 - **Environmental Health**
 - **Food & Nutrition**
 - **Human Behavior & Performance**
- **Human Adaptation and Countermeasures**
 - **Bone Loss**
 - **Cardiovascular Alterations**
 - **Human Behavior & Performance**
 - **Immunology, Infection & Hematology**
 - **Muscle Atrophy and Alterations**
 - **Neurovascular Adaptation**
 - **Radiation Effects**
- **Health Care Systems**
 - **Clinical Capabilities**

Key Elements of The Critical Path Roadmap



Ranking the Risks within each Risk Area

■ Each research area team rank-ordered each of its risks using five criteria:

- Probability of occurrence without countermeasures
- Probability of occurrence with countermeasures
- Severity of impact on accomplishing mission objectives
- Severity of impact on crew health and safety

■ Results of Risk Ranking

- Identified 55 risks (across all risk areas)
- Rank order #1 (including all risk areas): 17
- Identified 361 critical questions
- Priority #1 (including all risk areas): 125

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Rating Across Risk Areas

- Subsequent to the risk ranking within risk areas, a panel of experts characterized risks across discipline areas, based on:
 - Rank-ordering within each risk area
 - Scores assigned for each risk
 - Extensive deliberations by the experts
- This risk characterization resulted in assignment of each risk to one of four “type” categories
 - “Type” is based on uncertainties in both the risk and its potential mitigation

Electronics interface

Gas supply

Cooling fans

Valves

Rotating

Vessel

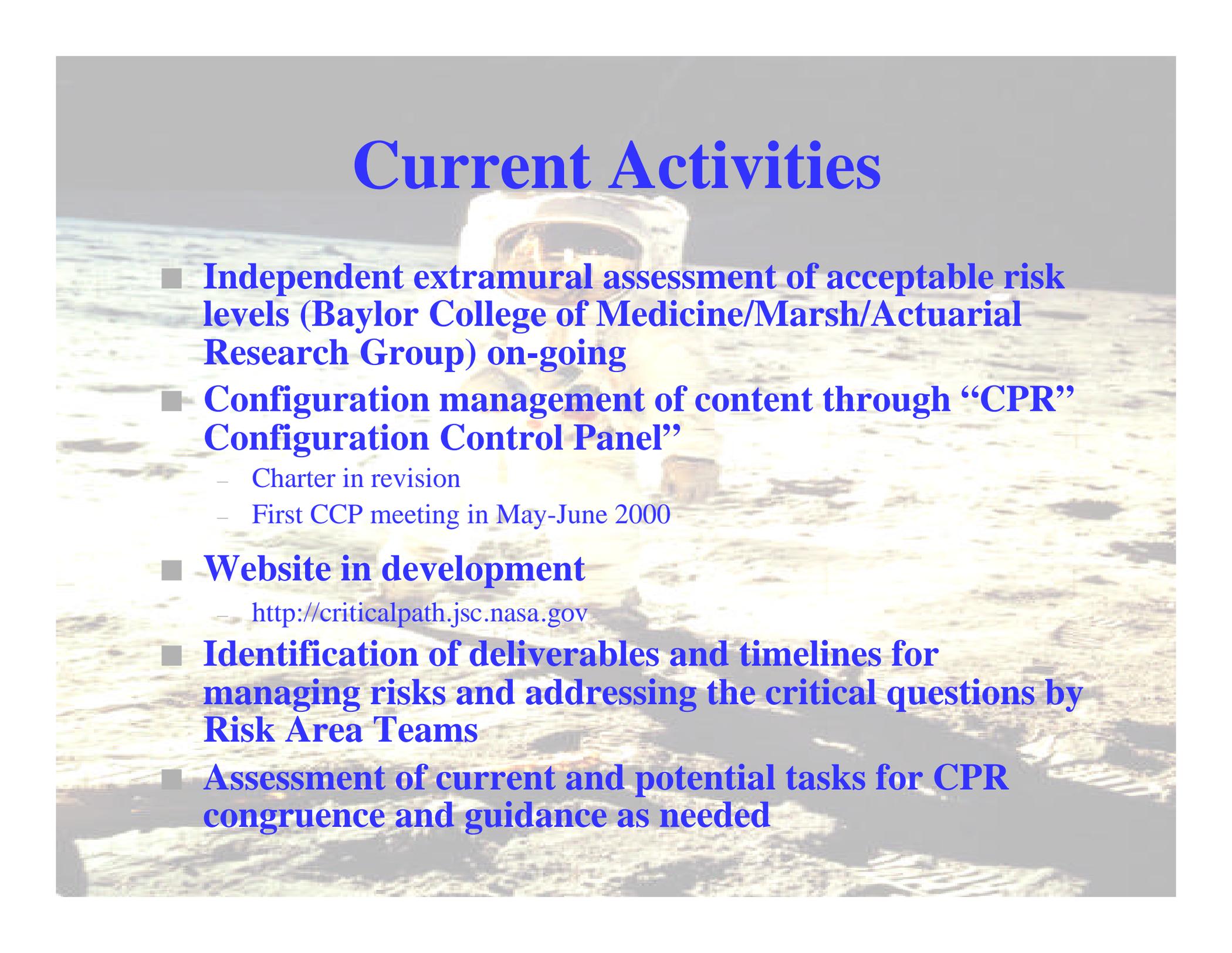
CPRP Risk Type Summary

	Demonstrated Serious Problem	Suspected Serious Problem	Demonstrated Problem	Suspected Problem
No Countermeasure Concept	I	II	II or III	III
Countermeasure Concept but No Ground Validation	II	II	II or III	III
Countermeasure Concept but No Space Flight Verification	III	III	III	III
Effective Operational Countermeasure	IV	Not Applicable	IV	Not Applicable

Critical Path Roadmap: Critical Risks

	BONE LOSS	CARDIOVASCULAR ALTERATIONS	HUMAN BEHAVIOR & PERFORMANCE	IMMUNOLOGY, INFECTION & HEMATOLOGY	MUSCLE ALTERATIONS & ATROPHY	NEUROVESTIBULAR ADAPTATION	RADIATION EFFECTS	CLINICAL CAPABILITY	OTHER	
Type I	Acceleration of Age-Related Osteoporosis (1) - 9		Human Performance Failure Because of Poor Psychosocial Adaptation (1) - 18				Carcinogenesis Caused by Radiation (1) - 38	Trauma & Acute Medical Problems (1) - 43		Severe Risks
Type II	Fractures (Traumatic, Stress, Avulsion) & Impaired Fracture Healing (2) - 10	Occurrence of Serious Cardiac Dysrhythmias (1) - 13 Impaired Cardiovascular Response to Orthostatic Stress (1) - 14	Human Performance Failure Because of Sleep and Circadian Rhythm Problems (2) - 19		Loss of Skeletal Muscle Mass, Strength, and/or Endurance (1) - 28 Inability to Adequately Perform Tasks Due to Motor Performance, Muscle Endurance, and Disruptions in Structural and Functional Properties of Soft and Hard Connective Tissues of the Axial Skeleton (1) - 29	Disorientation and inability to perform landing, egress, or other physical tasks, especially during/after g-level changes (1) - 33 Impaired neuromuscular coordination and/or strength. (2) - 34	Damage to Central Nervous System from Radiation Exposure (2) - 39 Synergistic Effects from Exposure to Radiation, Microgravity and Other Spacecraft Environmental Factors (3) - 40	Toxic Exposure (2) - 44 Altered Pharmacodynamics and Adverse Drug Reactions (3) - 45	Inadequate Nutrition (Malnutrition) 7, 8, 53 Post-Landing Alterations in Various Systems Resulting in Severe Performance Decrements and Injuries 49	Very Serious Risks
					Inability to Sustain Muscle Performance Levels to Meet Demands of Performing Activities of Varying Intensities (2) - 30		Early or Acute Effects from Radiation Exposure (4) - 41		Habitation and Life Support 1,2,3,4,5,6,51,52	
Type III	Injury to Soft Connective Tissue or Joint Cartilage, and/or Intervertebral Disc Rupture With or Without Neurological Complications (3) - 11	Diminished Cardiac Function (2) - 15	Human Performance Failure Because of Human System Interface Problems and Ineffective Habitat & Equipment Design, etc. (3) - 20	Immunodeficiency/ Infections (1) - 22	Propensity to Develop Muscle Injury, Connective Tissue Dysfunction, and Bone Fractures Due to Deficiencies in Motor Skill, Muscle Strength and Muscular Fatigue (3) - 31	Impaired cognitive and/or physical performance due to motion sickness symptoms or treatments, especially during/after g-level changes. (3) - 35	Radiation Effects on Fertility, Sterility and Heredity (5) - 42	Illness and Ambulatory Health Problems (4) - 46		Serious Risks
	Renal Stone Formation (4) - 12	Manifestation of Previously Asymptomatic Cardiovascular Disease (3) - 16	Human Performance Failure Because of Neurobehavioral Dysfunction (4) - 21	Carcinogenesis Caused by Immune System Changes (1) - 23	Impact of Deficits in Skeletal Muscle Structure and Function on Other Systems (NR) - 32	Vestibular contribution to cardioregulatory dysfunction. (4) - 36		Development and Treatment of Decompression Illness Complicated by Microgravity-Induced Deconditioning (5) - 47		
		Impaired Cardiovascular Response to Exercise Stress (4) - 17			Altered Hemo- & Cardio- dynamics from Altered Blood Components (1) - 24 Altered Wound Healing (2) - 25 Altered Host-Microbial Interactions (3) - 26 Allergies and Hypersensitivity Reactions (3) - 27		Possible chronic impairment of orientation or balance function due to microgravity or radiation. (5) - 37		Difficulty of Rehabilitation Following Landing (6) - 48,54	

Current Activities

A background image of an astronaut in a white spacesuit standing on the lunar surface. The astronaut is in the center, looking towards the camera. The ground is covered in lunar dust and rocks, and the horizon of the moon is visible in the distance under a dark sky.

- **Independent extramural assessment of acceptable risk levels (Baylor College of Medicine/Marsh/Actuarial Research Group) on-going**
- **Configuration management of content through “CPR” Configuration Control Panel”**
 - Charter in revision
 - First CCP meeting in May-June 2000
- **Website in development**
 - <http://criticalpath.jsc.nasa.gov>
- **Identification of deliverables and timelines for managing risks and addressing the critical questions by Risk Area Teams**
- **Assessment of current and potential tasks for CPR congruence and guidance as needed**

Science Readiness Levels of Currently Funded Code UL Tasks

RISK AREA	Science Readiness Levels (SRL)							Total No. Projects
	Pre-Phase A	Phase A	Phase B	Phase C	Phase D	Phase E	Unknown	
	SRL 1 Advanced Studies/ Feasibility	SRL 2 Preliminary Analysis	SRL3 Definition	SRL 4 Design	SRL 5 Development	SRL 6 Operations	(?)	
Advanced Life Support	4	26	6	0	0	0	2	38
Bone Loss	14	35	2	0	0	0	0	51
Cardiovascular Alterations	11	25	0	0	0	0	2	38
Environmental Health	2	19	1	0	0	0	1	23
Food and Nutrition	4	6	0	0	0	0	0	10
Human Behavior and Performance	24	25	3	0	0	0	0	52
Immunology, Infection and Hematology	8	35	0	0	0	0	0	43
Muscle Alterations and Atrophy	8	19	0	0	0	0	0	27
Neurovestibular Adaptation	21	28	0	0	0	0	0	49
Radiation Effects	3	29	1	0	0	0	2	35
Clinical Capabilities	2	7	1	0	0	0	0	11
TOTAL	101	254	14	0	0	0	7	377
Percent	27	67	4	0	0	0	2	100

Defining “Deliverables”

Specific end-items associated with each risk and critical questions

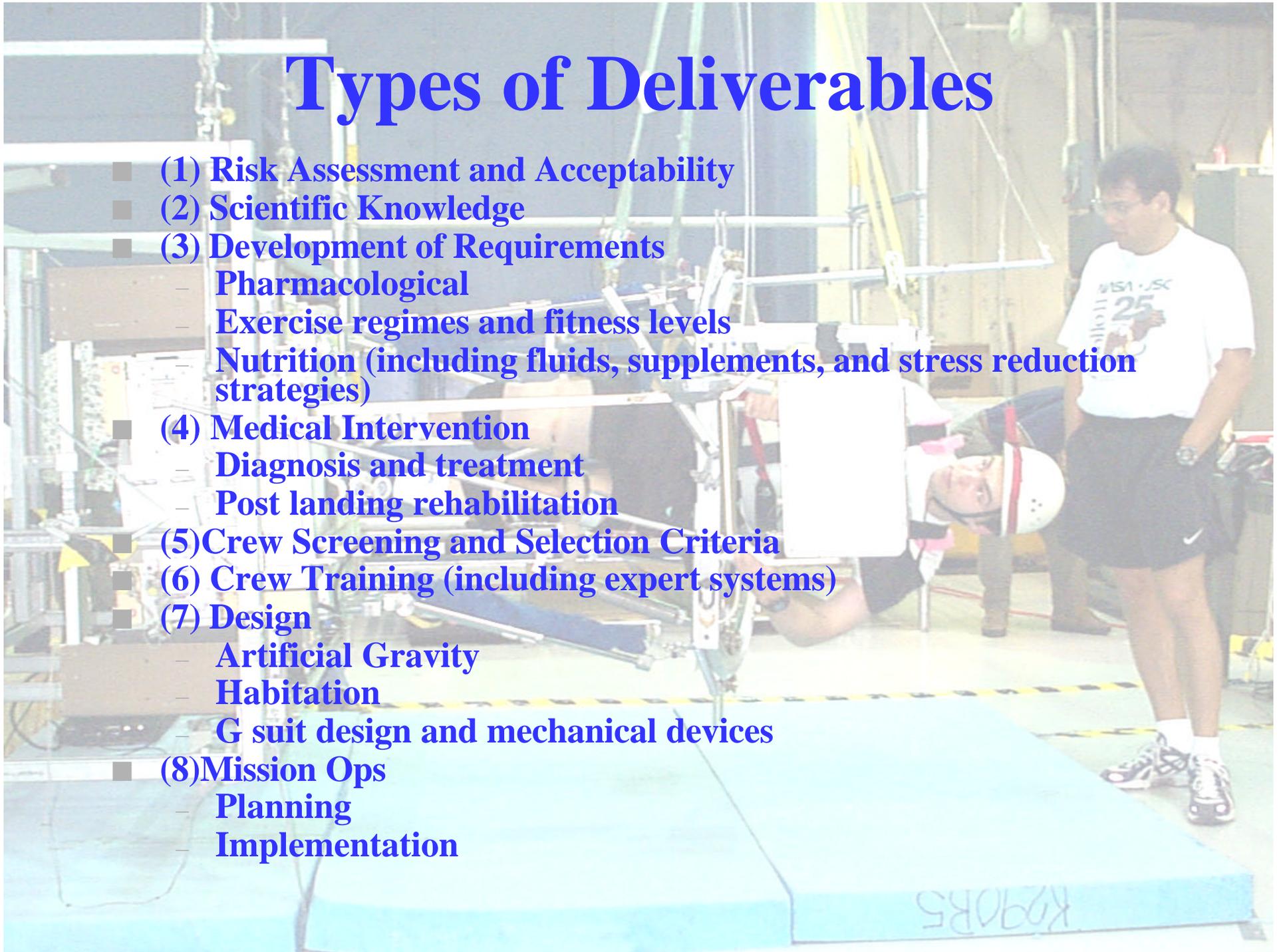
Technologies (models, instruments, devices, equipment, systems, hardware or software)

Scientific knowledge (underlying mechanisms & processes), procedures, or processes

Results in, or provides critical knowledge for, risk mitigation requirements

Types of Deliverables

- (1) Risk Assessment and Acceptability
- (2) Scientific Knowledge
- (3) Development of Requirements
 - Pharmacological
 - Exercise regimes and fitness levels
 - Nutrition (including fluids, supplements, and stress reduction strategies)
- (4) Medical Intervention
 - Diagnosis and treatment
 - Post landing rehabilitation
- (5) Crew Screening and Selection Criteria
- (6) Crew Training (including expert systems)
- (7) Design
 - Artificial Gravity
 - Habitation
 - G suit design and mechanical devices
- (8) Mission Ops
 - Planning
 - Implementation



CPR

A detailed illustration of the Space Shuttle Columbia in orbit above Earth. The shuttle is shown from a perspective that highlights its large solar panel arrays and the external tank. The Earth's blue and white atmosphere is visible in the background.

- For current 55 risks, identify and validate countermeasures and/or risk mitigations
 - for one-half by the year 2006
 - for all by the year 2010