JSC/EC5 U.S. Spacesuit Knowledge Capture (KC) Series Synopsis

**Topic:** EVA Physiology & Medical Considerations Working in the Suit

**Date:** January 24, 2012  
**Location:** Johnson Space Center (JSC), Houston, TX

**Presenter:** Scott Parazynski, M.D.

**Synopsis:** This “EVA Physiology & Medical Considerations Working in the Suit” presentation covers several topics related to the medical implications and physiological effects of suited operations in space from the perspective of a physician with considerable first-hand Extravehicular Activity (EVA) experience. Key themes include EVA physiology – working in a pressure suit in the vacuum of space, basic EVA life support and work support, Thermal Protection System (TPS) inspections and repairs, and discussions of the physical challenges of an EVA. Parazynski covers the common injuries and significant risks during EVAs, as well as physical training required to prepare for EVAs. He also shares overall suit physiological and medical knowledge with the next generation of Extravehicular Mobility Unit (EMU) system designers.

**Biography:** Dr. Scott Parazynski is a physician and a physiologist with expertise in human adaptation to stressful environments, having been graduated from Stanford University and Stanford Medical School. He went on to train at Harvard University and in Denver in preparation for a career in emergency medicine and trauma. In 1992 he was selected to join NASA’s Astronaut Corps and eventually flew five Space Shuttle missions and conducted seven spacewalks (EVAs). In October 2007, Parazynski led the EVA team on STS-120, a highly complex space station assembly flight, during which he performed four EVAs. The fourth and final EVA is regarded by many as one of the most challenging and dangerous ever performed. In his 17 years as an astronaut, he also served in numerous senior leadership roles, including EVA branch chief and the lead astronaut for Space Shuttle Thermal Protection System Inspection & Repair (in the aftermath of the Space Shuttle Columbia tragedy). He has the distinction of being the only person to both fly in space and stand on top of the planet, the summit of 29,035-foot Mount Everest. He served as chief technology officer and chief medical officer at The Methodist Hospital Research Institute in Houston, Texas.

**Video Length and Size:** 1:36:32 (1.59 GB)
EVA Physiology & Medical Considerations Working in the Suit

Scott Parazynski, MD
“US Spacesuit Knowledge Capture Series”
24 January 2012

www.parazynski.com
“US Spacesuit Knowledge Capture Series”

1. “EVA Physiology & Medical Considerations Working in a Suit” --- Tuesday, January 24, 2012
Sir, you’re no Jack Kennedy Admiral Stockdale!
“Parazynski” is like “Smith” or “Doe” in Poland...
HUMANS ARE EVEN MORE COMPLEX THAN THE SPACECRAFT YOU’RE BUILDING

- Height
- Weight
- Mechanical Aptitude
- Native Language
- Susceptibility to SAS
- Handedness
- Situational Awareness
- Depth of Knowledge (Preparedness)
- Fast vs. Slow Twitch
- Pain (Discomfort) Tolerance
- Gender
- Operational Background
- Cultural Differences
- Reaction Time (Scan Pattern)
- Verbal Clarity & Fluency
- www.parazynski.com

Strength
Visual Acuity
Underlying Medical Conditions
Arm Reach
G-Tolerance
Auditory Acuity
Endurance
Lessons Learned on the Job

• “EVA Cadre” selected to do the majority of development testing
• Led to acceptance of some hardware and tasks that could not be accomplished by a broad cross section of the Astronaut Corps
• Once recognized as an issue, crew consensus testing became actively more inclusive
Fluid “Quick Disconnects”
Wall of EVA: Summit Success

- ISS “Wall of EVA”: not enough qualified crew for the volume of work ahead
- Developed the “EVA Skills Training Program”
  - Defined “Gold Standards” of EVA performance
  - Gave trainees additional time to work towards these goals
  - Ultimately a huge success: ISS assembly complete, many maintenance successes by ISS crews

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• Crew Evaluators Should Include:
  – Broad Range of Anthropometrics
  – Matching Skill & Experience Levels of Anticipated Crews

• Early Crew Input:
  – Saves Time Pre-Flight
  – Saves $$$
  – Increases On-Orbit Efficiency
  – Enhances Maintenance Capability On-Orbit
Space Medicine 101

- Wide Variability in Adaptation to 0-G
  - Motion Sickness
  - Fluid Shifts
  - Back Pain
- Med Kit Contents & Exercise: Based on Probabilistic Risk Assessments
- Return to 1-G Physically More Challenging
  - Neurovestibular
  - Musculoskeletal
  - Cardiovascular

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Space Adaptation Syndrome

- SAS, a.k.a. Space Motion Sickness
- Generally Limited to First 1-2 Days On-Orbit
- Otoliths “Unweighted”
- Preemptive Meds Helpful (Phen-Dex)
- Avoid Rapid Head Motions on Arrival
- Treat with Intramuscular Phenergan at Bedtime

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Fluid Shifts

• No Gravity → No Hydrostatic Gradient
  – Puffy Faces
  – Runny Noses
  – Mild Headaches
  – “Bird Legs”
  – SAS?

• Return to 1-G:
  – Orthostatic Intolerance
  – G-suit, Fluid Loading

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Musculoskeletal & Kidney

• “Antigravity” Muscles & Bones Respond to Loading History
• Without Loading in Space → Atrophy
• Also Leads to:
  – Ca++ kidney stones
  – Premature Osteoporosis
  – Secondary Injuries

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Back Pain

- Unloading Results in Intervertebral Disc Swelling
- Low Back Pain On-Orbit is Very Common
- Sleeping in Fetal Position Often Helpful
- May Predispose Astronauts to Disc Disease Later in Life

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Other Aeromed Considerations

- **Accleration ("G’s"):**
  - Many CSF Vehicles >> Shuttle Accelerations

- **Non-Gov. Crew:**
  - Older, Younger?
  - Less Medical Screening
  - More Underlying Illness?

- **Urinary Retention**
- **Infections, ↓Immune f(n)**
- **Respiratory & Eye Irritation**
- **Visual Acuity**

[Graph showing Space Shuttle Launch Profile]

[Logos and images from various companies related to space exploration]
Engineering for Success

- Human Diversity & Complexity: must take into account for safe & efficient spacecraft design, development, test and flight operations
- Early Crew Involvement: pays huge dividends in all phases of development & operations
- Human Physiology and Medical Issues: are fairly well understood & should be factored into spacecraft architecture (systems, provisioning)

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EVA: The Final Frontier

- EVA Work Environment
- Suit and Systems
- EVA Training
- EVA Physiology
- EVA Risks
- EVA Injury
- Injury Prevention & Rx
- The Future of Space Exploration: BEO EVA
EVA Work Environment

Temperatures: $\sim-200^\circ\text{F}$ to $+300^\circ\text{F}$ (orbital night/orbital day variation)

External Pressure: Vacuum ($\sim10^{-8}$)

Suit Pressure: 4.3 psia (100% O$_2$)

Orbiting Earth at $\sim17,500$ mph
EVA Job Description

- 6-8 hour spacewalks the norm
- Often very confining workspaces
- Physically demanding: upper body strength and endurance
- Work often requires great precision/tactility/dexterity
- Best view in the Universe!
95th% crewmembers optimal work envelope to be used as the optimum one-handed work envelope

26 in. Dia

16 in. Dia

18 in.

5 in.

13 in.

55 in.

54 in.

5th% crewmembers optimal work envelope. To be used as the optimum one-handed work envelope

Origin at the pattern on the S18 PFR (where the base plate bolts to the pitch and roll joint) PFR pitched forward 15 deg
Extravehicular Mobility Unit

- Protection from vacuum, temperature extremes, orbital debris
- Communications with crew, MCC
- Active cooling/passive heating
- Biomedical monitoring (ECG, passive dosimetry)
- Video monitoring
- Tool platform/storage
- Drinking water (no food)
- Oxygen delivery (with b/u)
- CO2 scrubbing
- EMU “health monitoring”
- Propulsion (“Simplified Aid for EVA Rescue”)

EMU: a personal spacecraft
EVA Training Environments

- Neutral buoyancy facilities
  - Choreograph timelines
  - Integrate EVA-robotics
  - 0-G analog (water drag a major difference)
  - Nitrox used to increase bottom time
- Virtual Reality Lab
- Air Bearing Floor
- Vacuum Chambers
- EMU Systems Simulations
- Integrated Simulations with Mission Control
- The Gym!
Weightless Environment Test System (WETS)
Tsukuba, Japan
Mass Handling: difficult to train on Earth --- water drag, buoyancy effects
Unusual Training Attitudes: risk of shoulder injuries --- simple bruises to rotator cuff tears; barotrauma; orthostatic intolerance; disorientation
EVA Physiology:

• Pressure changes with similarity to diving → risk of DCS and barotrauma (during both real and simulated EVA)

• EVA preparations: 4 hour in-suit prebreathe on 100% oxygen, “campout,” or exercise prebreathe protocol

• Incidence of DCS in space << diving DCS
EVA Risks:

• Decompression Sickness
• Orbital Debris/suit leak
• Fire in 100% Oxygen
• Radiation Exposure
• Frostbite/Superficial Burn
• Separation from vehicle
• Dehydration/low glucose
EVA Injuries:

- Nerve Compression; Foot Pain, other hot spots

- Shoulder Injuries:
  - Rotator Cuff Tears
  - Superior Labral Tear from Anterior to Posterior (SLAP)
  - Tendonitis/Bursitis

- Fingernail Delamination

- Eye Irritation

- Barotrauma

- Orthostatic Intolerance

- DCS (Type 1 and Type 2)
Injury Prevention/Rx:
- Optimum Suit Fit
- Preflight Conditioning
- Avoiding Prolonged Inverted Ops (pool)
- Proper Fingernail Care (trim, keep dry); Custom Gloves; Glue
- Knowledge of and Working within the Work Envelope of the Planar Hard Upper Torso (HUT)
- Prebreathe, Bends Treatment Adapter for DCS
Strength & Conditioning

• Key element to flight preparation

• Injury prevention

• Development of strength and endurance --- especially important for forearm, wrist and hand intrinsics

• Strength and Conditioning coaches work directly with crew; mandatory for EVA crewmembers to exercise 3x/week

• Also important: flexibility and aerobic capacity
Miscellaneous:

- Astronauts are physically very active; some have preexisting orthopedic injuries; some get hurt before flight (softball!)

- Size and strength an asset because of physical nature of the job; difficult to scale gloves to smaller sizes

- Flying after diving is often required; special tables for Nitrox have been developed for our use

- Russian “Orlan” suit used on ISS --- 5.7 psia
Implications for BEO

- Planetary EVA ≠ LEO EVA ≠ Asteroid EVA

- Planetary EVA Considerations:
  - Center of Mass
  - Ground Reaction Force
  - Dust

- Asteroid EVA Considerations:
  - “Microgravity Geology”
  - Newton’s Laws

- Need to ↓ ops overhead
QUESTIONS/DISCUSSION

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