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DEEP SPACE
DEEP OCEAN

Aramco Technology and Operational Excellence Forum

Session 3
Topic: "Telemedicine“

Wednesday, April 8, 2015

Session 3 Topic: "Telemedicine"

Moderator: Smith Johnston, M.D., Medical Director, NASA-JSC Aerospace and Occupational Medicine Clinics, NASA Johnson Space Center, Houston, Texas.

Discuss the challenges and solutions of providing health care to those stationed in low resource, extreme, and remote environments.

Address the use of telemedicine for remote health care needs, specifically identifying the challenges and solutions involved.

Demonstrate how telemedicine technologies are being applied to solve other operational challenges, and explore the adoption of these techniques across areas where co-development might be mutually beneficial.

The overview will be followed by a Q&A session.

Moderator: Smith Johnston, M.D., Medical Director, NASA-JSC Aerospace and Occupational Medicine Clinics

Speaker Panel:

Greg Rumph, M.D., Emergency Physician, The University of Texas Medical Branch (UTMB) at Galveston
"Capabilities and Challenges for Offshore Medical Care“

Bob Sanders, M.D., Crew Health and Safety Flight Surgeon, UTMB, NASA Johnson Space Center Neutral Buoyancy Laboratory (NBL), Topic:"Diagnosis and Treatment of DCS in the remotest location: Deep Space and Deep Oceans”

Sarah Bezek, M.D., Assistant Professor of Emergency Medicine, Baylor College of Medicine
"Low Resource Medical Care Delivery Potential for Synergy With Extreme Environment Medicine“

Victor Hurst, Ph.D., Research Scientist, Wyle Science, Technology and Engineering Group
"Future of Space Medicine“

Eric Richardson, Ph.D., Lecturer, Rice University Department of Bioengineering
"Advances in Medical Devices and Relevant Ongoing Development at Rice University“

Erik Antonsen, M.D., Ph.D., Assistant Professor of Emergency Medicine and Space Medicine, Baylor College of Medicine
"Extreme Environmental Medicine and Challenges of Integrating Medicine and Engineering“

Ashot Sargsyan, M.D., Space Medicine Physician, Wyle Life Sciences
"Remote Diagnosis With Limited Capabilities on ISS"

Historic Overview of Space Medicine/NASA and Telemedicine

Nov-1957 – The first use of telemetry in monitoring of a living being (a dog named Laika) by the Soviet Union on Sputnik 2.

Dec-1958 NASA sent a primate named Gordo into Space on a US Army Jupiter missile and recorded biomedical data, which helped demonstrate the launch and ballistic recovery physiologic parameters.

Soviet and US Manned missions monitored environmental and medical/cardiac (ECG) parameters.

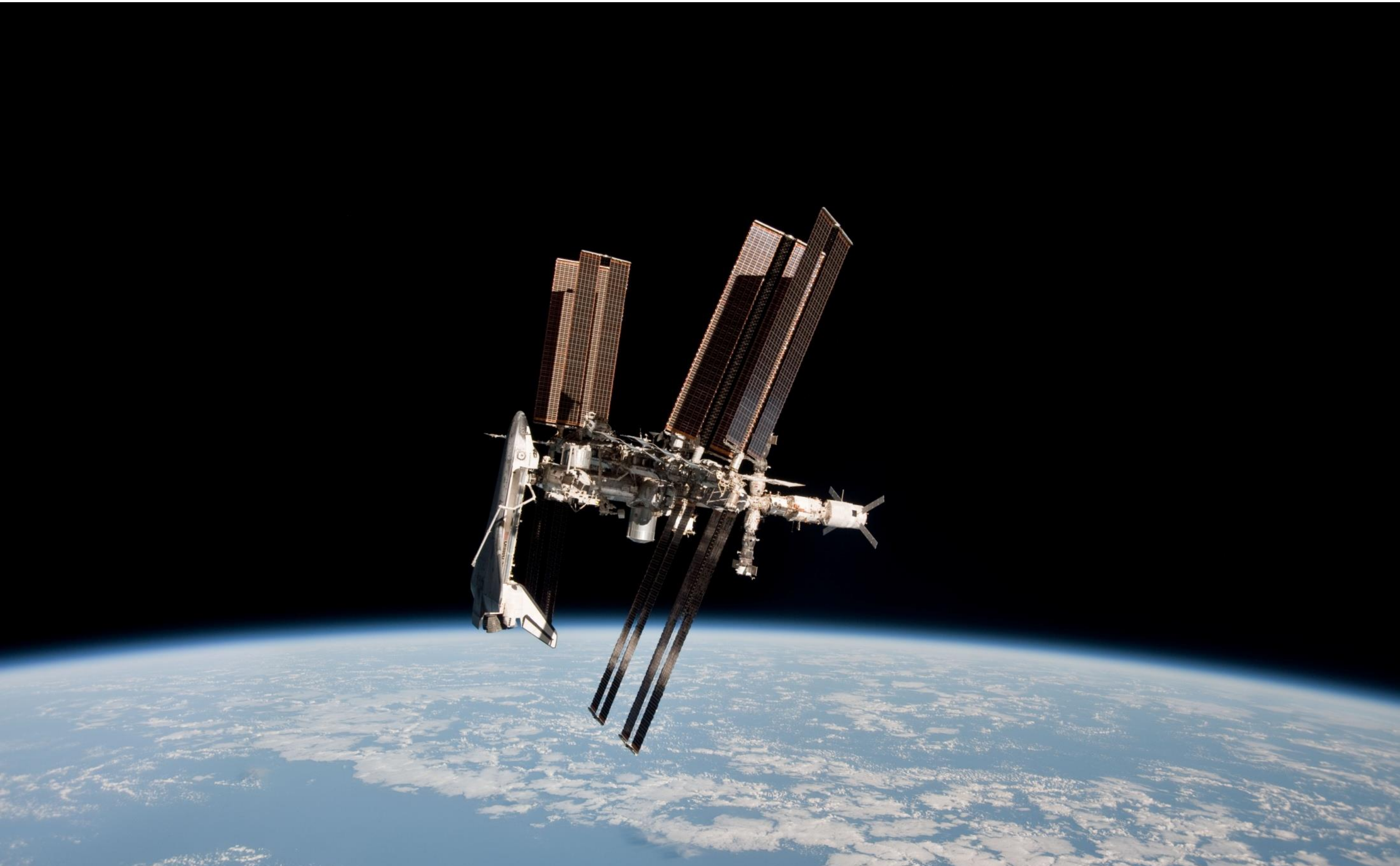
- 1964 – NASA/ Integrated Medical and Behavioral Laboratories and Measurement Systems (IMBLMS) which helped expand the measurement systems on the Mercury and Gemini flights
- NASA - Apollo/Skylab – Dr Joe Kerwin, MD, first physician Astronaut
- Advanced Systems for Shuttle and the International Space Station (ISS)

Ground Based Telemedicine Research Activities

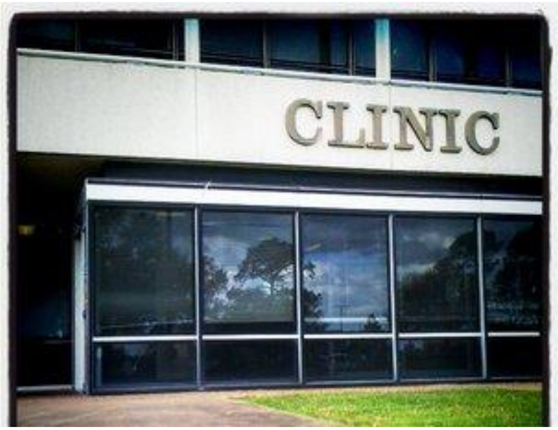
- INTELSAT for Apollo - Dr. Michael Debakey's Surgical work in Early Bird Program 1964
- NASA's Space Technology Applied to Rural Papago Advanced Health Care (STARPAHC) in 1974 in AZ.
- Armenian earthquake in 1988, with "Space Bridge to Armenia", then 1990s "Space Bridge to Moscow", and 1996, "Space Bridge to Russia".
- American Telemedicine Association 1993
- NASA Analogue Populations (e.g. South Pole)
- Russian, European, and Chinese Space Agencies Mars 500 Project 2011

The Future = Deep Space Ocean 2015!

Operational Space Medicine



What NASA Flight Surgeons Do



MCC and SIMs

Mission: Crew health and safety

Spaceflight Effects on Human Physiology

Dysregulation of the immune system

Fluid Redistribution to upper body

Plasma volume decreases, anemia

Elevated radiation may increase cancer risk

Otoliths in inner ear respond differently, eyes become main way to sense motion

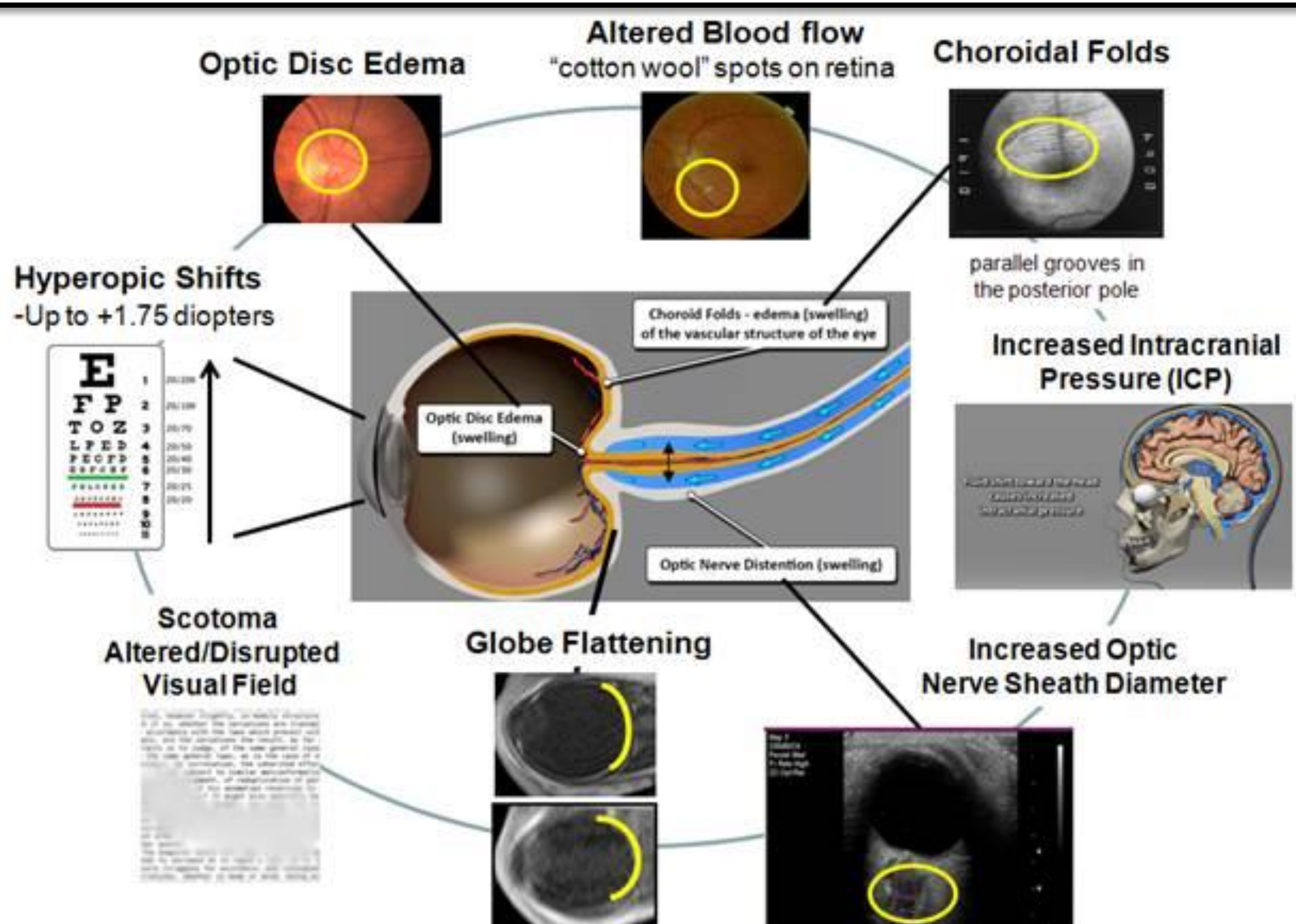
Muscle and bone weakening

Elevated kidney stone risk

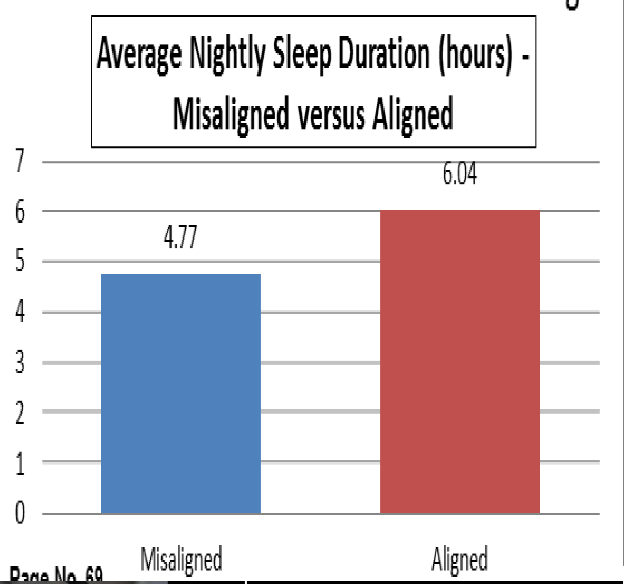
The Medical Challenges!

Vision Impairment/Intracranial Pressure (VIIP) – 1 Year ISS

Background: Astronauts on long-duration ISS missions have experienced ophthalmic anatomical changes, visual performance decrements of varying degrees and increased intracranial pressure (as measured post flight on 5 crew members).



Fluid Shift?



Gender

(Males)

Possible Contributors to Increased ICP

Other Factors:
Metabolic,
Genetic,
Anthropometry

Telemedicine
for Low Earth Orbit Space flights

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"Capabilities and Challenges for Offshore Medical Care“

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"Field Treatment of DCS - In-water Decompression or Saturation Diving“

Sarah Bezek, M.D., Assistant Professor of Emergency Medicine, Baylor College of Medicine

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"Remote Diagnosis With Limited Capabilities on ISS" aramco

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Diagnosis and Treatment of DCS in the remotest locations: Deep Space and Deep Ocean

Bob Sanders, M.D., FACEP

Crew Health and Safety Flight Surgeon, UTMB, NASA Johnson Space Center Neutral Buoyancy Laboratory (NBL),

Disclaimer

- The views expressed in this presentation are mine alone and not necessarily that of UTMB or NASA.

- While I personally have not had DCS,
  - I have seen and treated many cases

Who am I?

1983 Certified Naui & LA County Basic Scuba Diver

1987 Naui Instructor

1990 Began Service With United States Antarctic Program as research Diver (189 Dives)

1993 Joined USC/Catalina Hyperbaric Chamber Crew, Became a DMT

1994 Began Working for Film & Television Industry overseeing Health and Safety including Diving Operations (OSHA standards)

1995 Joined LA County Sheriff Marine Co 217 (Reserve dive team)

2005 Awarded MD degree, EM residency at UPMC Asst Medical Dir., Pittsburgh River Rescue

2008 Medical Officer, Assistant Clinical Professor, U of Hawaii Hyperbaric Treatment Center

2010 Achieved Board Certification in Undersea and Hyperbaric Medicine

2011 Medical Director, American Marine Services Group, American Hyperbaric Center

2014 Crew Health and Safety Flight Surgeon, UTMB/Wyle/NASA-JSC

Similarities between

Deep Space and Deep Oceans

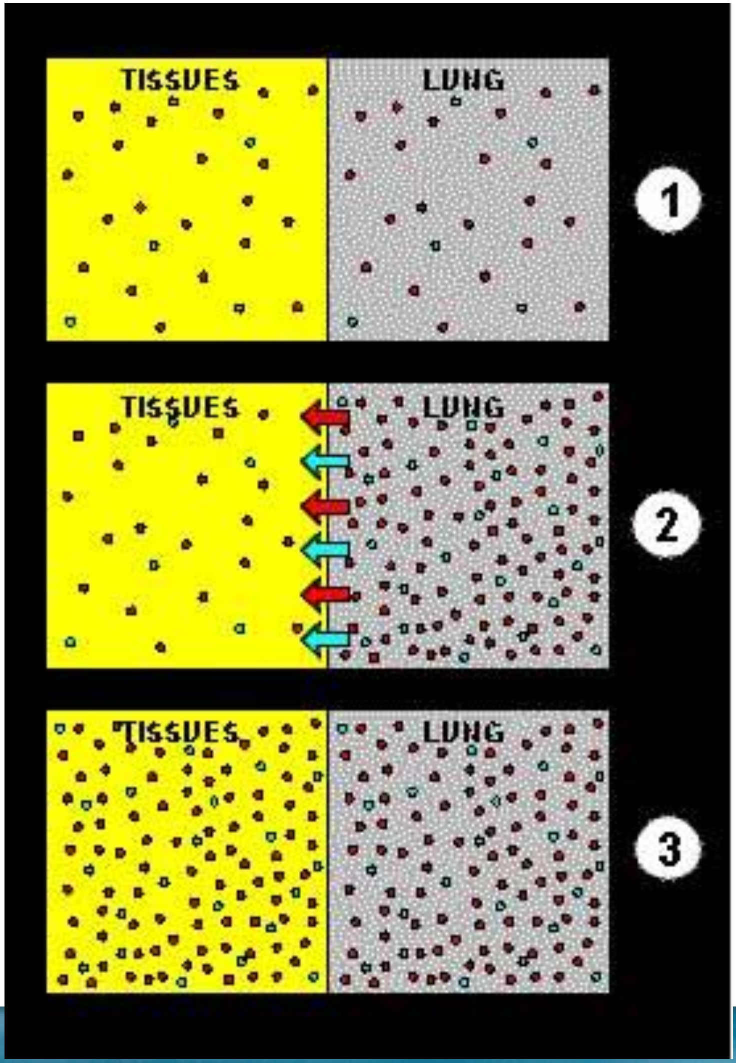
- Environmental Control / Habitat
    - Limited Gas
    - CO2 scrubbing
- Physiologic changes
    - Weakness, imbalance
        - Deep Space: fluid shifts & neurovestibular changes
        - Deep Ocean: decreased RBC's
- If you forget something, that's bad
- Evacuation is not an option

Differences between
Deep Space and Deep Oceans

- Gravity
- Pressure (up vs. down)

Decompression Sickness (DCS)

- • Henry's Law
  - States gas solubility is directly proportional to the pressure on that gas.



Decompression Sickness (DCS)

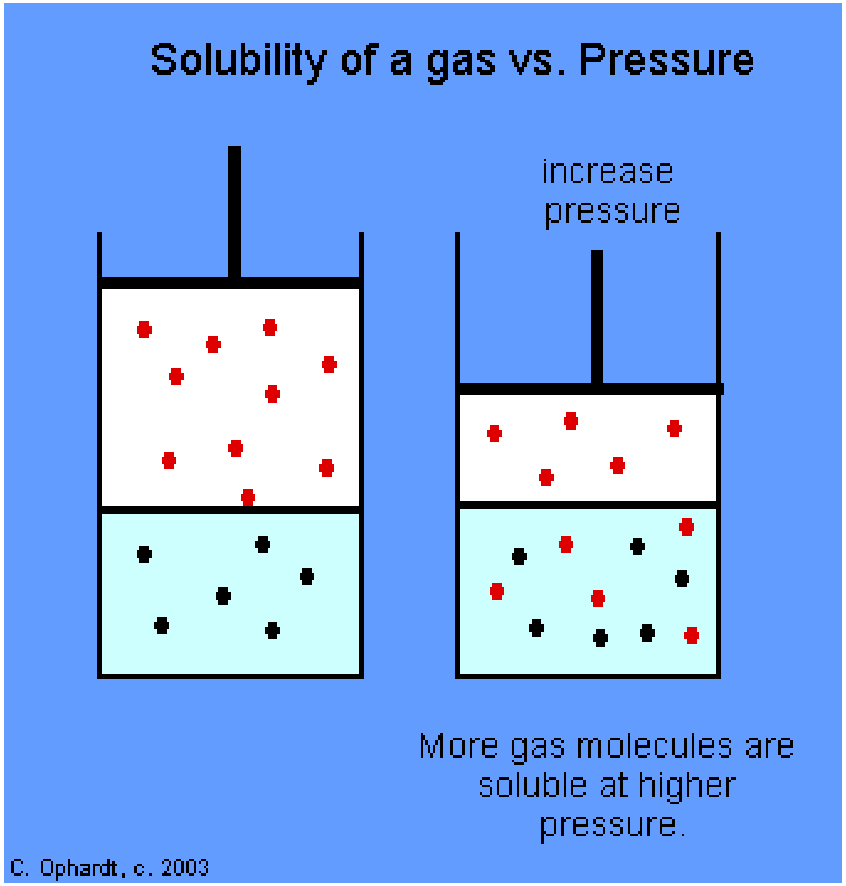
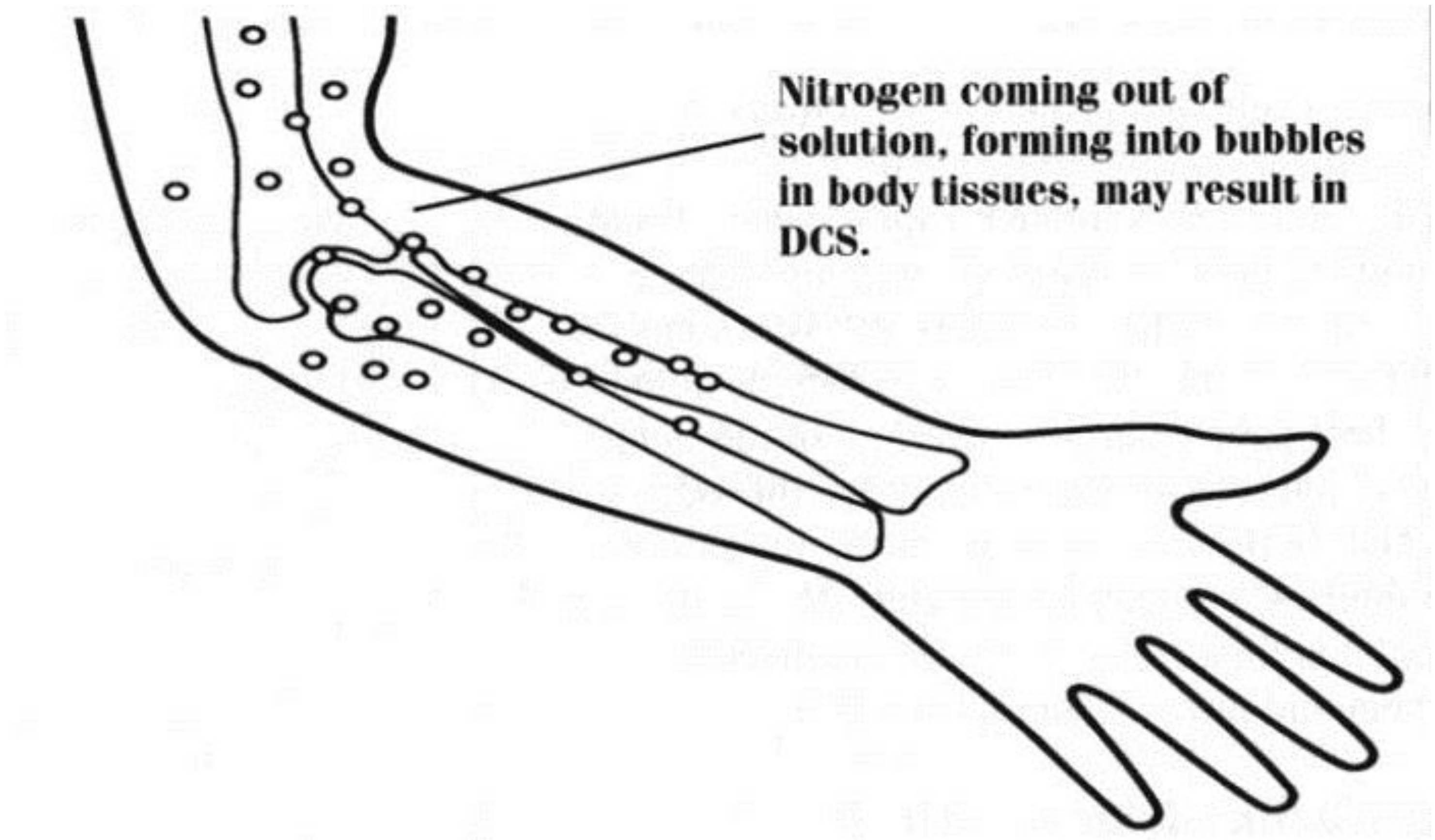


Figure 3, Henry's Law
www.elmhurst.edu

Gas solubility in a liquid is directly proportional to the pressure on that gas.

Decompression Sickness (DCS)



Decompression Sickness

- The diagnosis is difficult at best when the patient is sitting in front of you
  - But…
- 220 miles up or >50 meters below?
- Role of the Medical Director

Prevention

- This is key
  - Single case can cost literally millions of dollars
  - Prevention is key
    - Pre-Breathe (desaturation)
    - Saturation

DCS - Treatment

- Pressure & Oxygen
  - Increase by 2.8 – 6 ATA
- Both are challenges in DS & DO

Limitations to treatment

- Unlikely to have a physician on site
- LIMITED resources
  - BTA (Bends Treatment Apparatus)
    - EMU as Chamber
  - Change habitation pressure or lock out
    - Chamber module in Habitat and change of gas mix
  - Additional staff for hours
- *Affects entire mission*

Telemedicine

- Used for years in space
- Technology has revolutionized TM
- TM has revolutionized DS/DO
  - Now we can “see” so much more
  - Onsite practitioner can be our hands
- Benefits far beyond the txt of DCS

Future:

- Bringing Deep Space to the Deep Oceans
  - Understanding the human response
    - 1 year mission
    - Twin studies
  - Trends in EMS
  - Ultrasound Use
  - Increased (Confident) use of midlevels

Thank You

Future of space medicine

Victor Hurst IV, PhD

victor.hurst@nasa.gov

April 7, 2015

Outline

- Human Research Program (HRP)
  - 6 Elements; Exploration Medical Capability (ExMC)
- What does the ExMC do?
- How does ExMC address health risks for exploration class missions?
- Areas of Interest for ExMC
- HERA
- NEEMO
- MSL

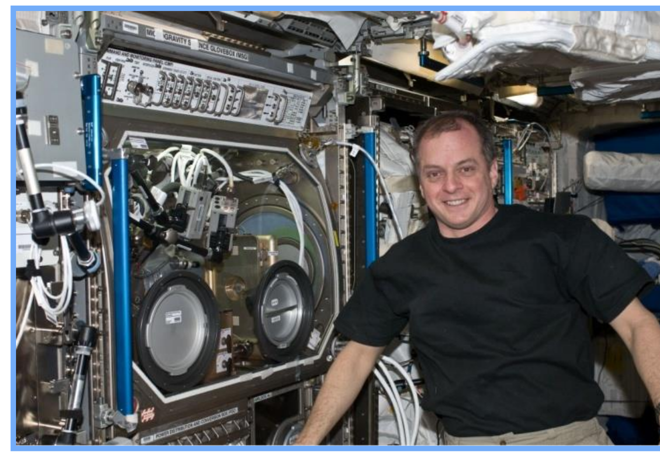
The Human Research Program

NASA's Human Research Program (HRP) conducts and coordinates research projects that provide human health and performance countermeasures, knowledge, technologies, and tools to enable safe, reliable, and productive human space exploration.

Clay Anderson centrifuges blood samples for a nutrition project aboard the ISS

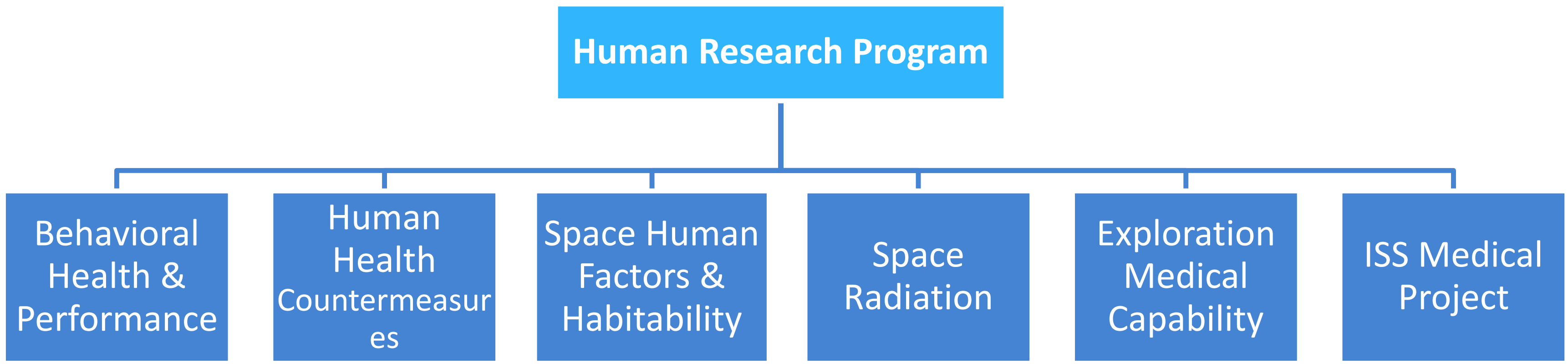
Example of a study on the effects of center of gravity on performance

Neutral Buoyancy Laboratory (NBL) at the NASA Johnson Space Center



TJ Creamer next to the IntraVenous Fluid GENeration (IVGEN) system after it was installed on ISS

HRP Organization & Elements

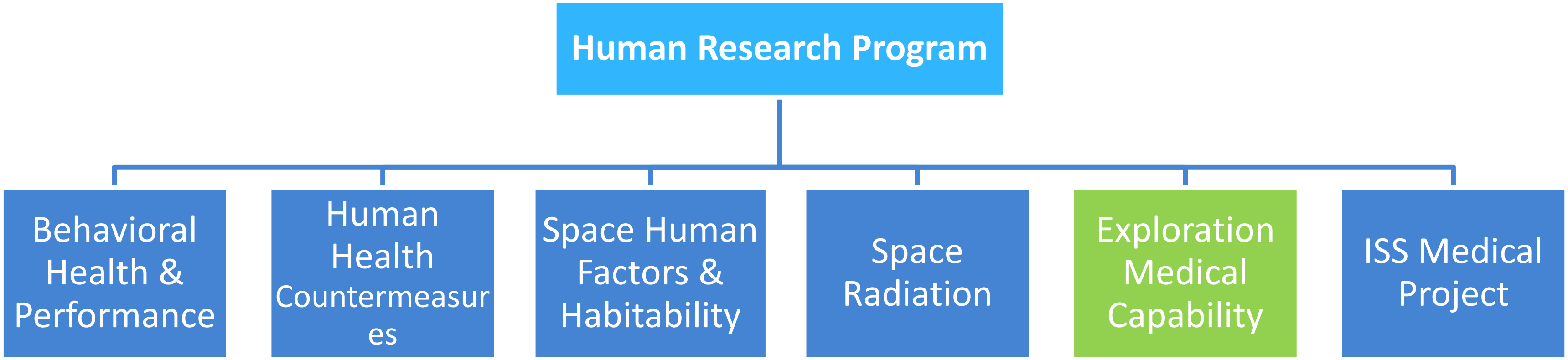


Divided into 6 major elements:

- Provide the Program's knowledge and capabilities to conduct research, addressing the human health and performance risks
- Advance readiness levels of technology and countermeasures to the point of transfer to customer programs and organizations

The National Space Biomedical Research Institute (NSBRI) partners with HRP

HRP Organization & Elements



ExMC Element

- The ExMC Element is charged with reducing the risk of *“unacceptable health and mission outcomes due to limitations of in-flight medical capabilities”* for exploration missions.

What does ExMC do, exactly?

- We're charged with developing the medical systems for exploration missions outside of low earth orbit
  - We need to understand what is likely to happen (events)
  - We need to minimize the chances of the event occurring
    - Screening, engineering, countermeasures, etc.
  - We need to plan for these events
    - What will we do (training, procedures)
    - What will we need (consumables)
  - We need to take steps to minimize consequences
    - How can we prevent a bad health outcome?
    - How can we prevent a bad mission outcome?

Who works within ExMC?

- Scientists – Physiology, Human Factors, Operations, Immunology, Nutrition
- Physicians – Aerospace Medicine, Internal Medicine, Emergency Medicine, Physical Medicine & Rehabilitation, Wilderness Medicine, Pain Medicine
- Engineers – Aerospace Engineering, Electrical Engineering, Mechanical Engineering, Biomedical engineering, Systems Engineering
- Project Managers

Exploration Medical Condition List

- Conditions of concern for exploration missions are identified in the Exploration Medical Condition List
- 2015 list includes 90 medical conditions, from several sources
- “Clinical Priority” assigned depending on the mission
- The medical condition list is a “living document”
- New conditions are added to the list during annual updates
- The priority of conditions on the list may be adjusted as screening, diagnosis, or treatment capabilities change

Exploration Medical Condition List

Revision: C	Document No: JSC-65722
Release Date: June 2013	Page: 12 of 22
Title: Exploration Medical Condition List	

Condition	Lunar Sortie Clinical Priority	Lunar Outpost Clinical Priority	NEA Clinical Priority
Shoulder Dislocation	0 - Not Addressed	0 - Not Addressed	0 - Not Addressed
Sinusitis	2 - Shall	2 - Shall	2 - Shall
Skin Abrasion	2 - Shall	2 - Shall	2 - Shall
Skin Laceration	2 - Shall	2 - Shall	2 - Shall
Skin Rash	2 - Shall	2 - Shall	2 - Shall
Smoke Inhalation	2 - Shall	2 - Shall	2 - Shall
Space Motion Sickness (Space Adaptation)	2 - Shall	2 - Shall	2 - Shall
Extremity Sprains/Strains	2 - Shall	2 - Shall	2 - Shall
Stroke	0 - Not Addressed	1 - Should	1 - Should
Sudden Cardiac Arrest	0 - Not Addressed	1 - Should	1 - Should
Surgical Treatment	0 - Not Addressed	0 - Not Addressed	2 – Shall
Toxic Exposure	2 - Shall	2 - Shall	2 - Shall
Upper Extremity Fracture	0 - Not Addressed	1 - Should	1 - Should
Urinary Incontinence (Space Adaptation)	1 - Should	1 - Should	1 - Should

Capabilities Needed for Screening, Diagnosis & Treatment

- The medical condition list is used to determine the medical capabilities needed for each exploration mission

- We identify gaps in technology and knowledge
  - A technology gap results in delivering requirements and/or a prototype system for integration
  - A knowledge gap results in data or evidence gathered that updates the Exploration Medical Condition List in preparation for the next gap analysis

- Tasks are assigned to address each technology or knowledge gap.

Areas of Interest

Biosensors

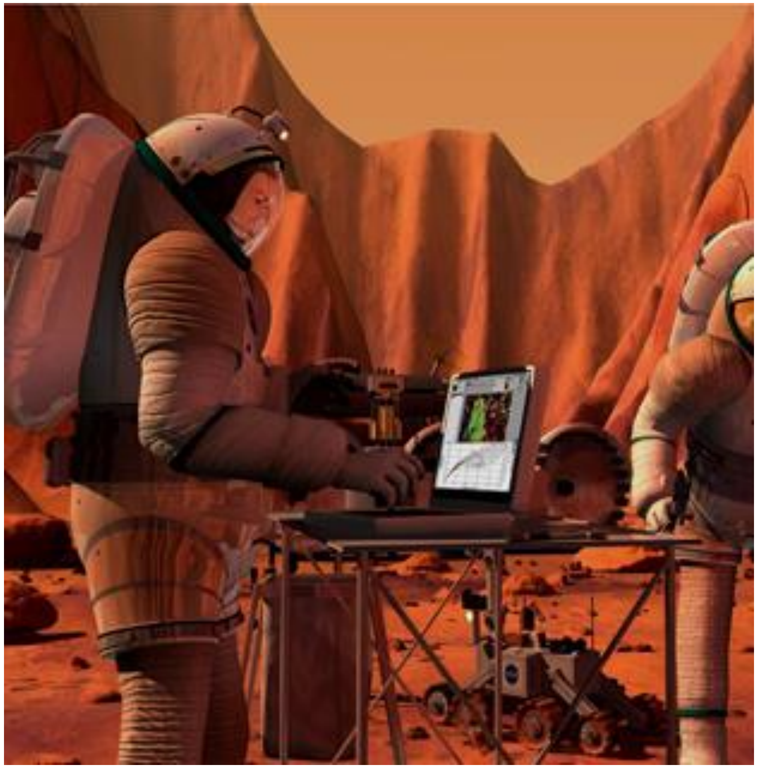
Lab Analysis

Imaging

Drug Packaging

Medical Training

Integrated Medical Systems



Source: NASA, Retrieved from: http://www.wired.com/wiredscience/2012/08/is-a-privately-funded-manned-mission-to-mars-possible/

Biosensors

- Non-invasive
- Wireless
- Integrated sensor suites
- Minimal skin preparation
- Easy to don/doff

Source: http://www.connectedhealthworld.com/products/218

Lab Analysis

- Point-of-care
- Handheld
- Minimal sample preparation
- Reagent shelf life > 3 yrs
- Minimal consumables
- Reusable components

Source: https://technology.grc.nasa.gov/SS-rHealth.shtm

Imaging

- Non-invasive
- Small footprint
- Flexible (software-based) platforms
- Radiation tolerant
- Diagnostic and therapeutic modalities

Source: https://str.llnl.gov/JulAug09/chang.html

Drug Packaging

- Shelf life > 3 yrs
- Minimized drug-packaging interactions
- Compatible with stability testing
- Tolerant of space flight conditions, i.e.
  - Radiation
  - Vibration

Source: Thinkstock.com, Retrieved: http://www.strategicsourceror.com/2010/10/rise-in-price-of-plastics-oil-drives-

Medical Training

- Simulation-based
- Remote guidance with communication delay
- Just-in-time training
- Virtual reality augmentation

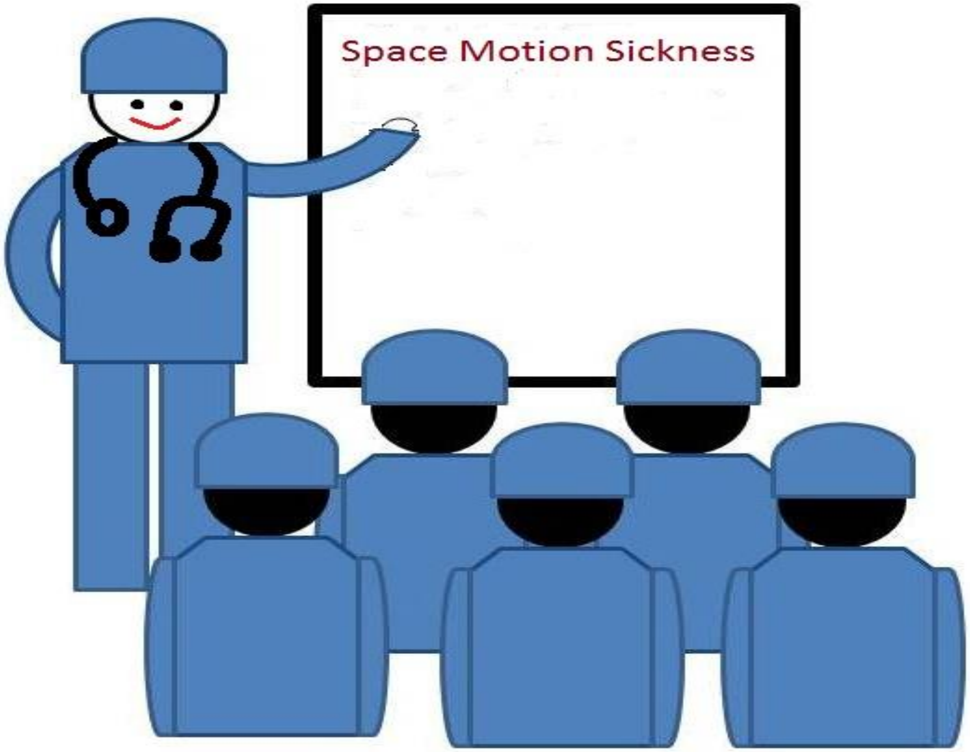


Image adapted from: http://www.nzsg.org.nz/cms2/news/7/15/Upcoming-Training/

Integrated Medical Systems

- Guided medical procedures
- Electronic medical records
- Medical inventory tracking
- Integrated wireless peripherals
  - Biosensors
  - Video conferencing

Source: http://scienceroll.com/2007/09/23/personalized-medicine-health-and-information-technology

Other Areas of Interest

- Sterile fluid generation
- Oxygen concentrators
- Sterilization techniques
- Minimally invasive surgical devices

Source: http://www.health.com/health/gallery/0,,20530252_13,

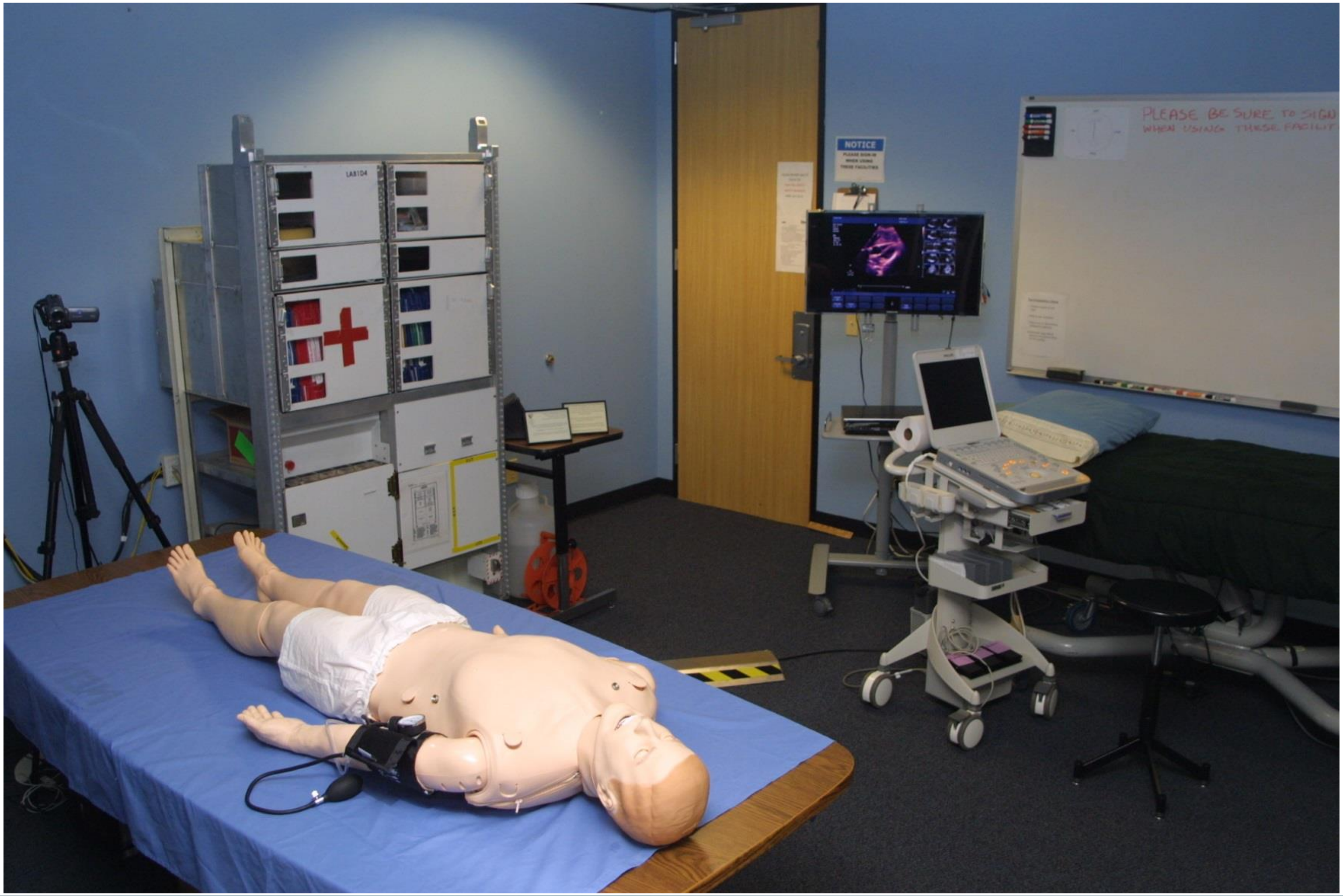
Human Exploration Research Analog (HERA)

Human Exploration Research Analog (HERA)

NASA Extreme Environment Mission Operation (NEEMO)

NASA Extreme Environment Mission Operation (NEEMO)

Medical Simulation Laboratory (MSL)



Medical Simulation Laboratory (MSL)

Summary

- Exploration Medical Capability is an element of the NASA Human Research Program
- ExMC works with various medical and science disciplines to develop the medical knowledge, technologies, and informatics needed for manned, long-duration missions beyond low Earth orbit
- The Exploration Medical Condition List provides the basis for ExMC gaps and research plan
- Evaluation of these medically-related technologies are conducted in various space flight relevant analogs.

Contact

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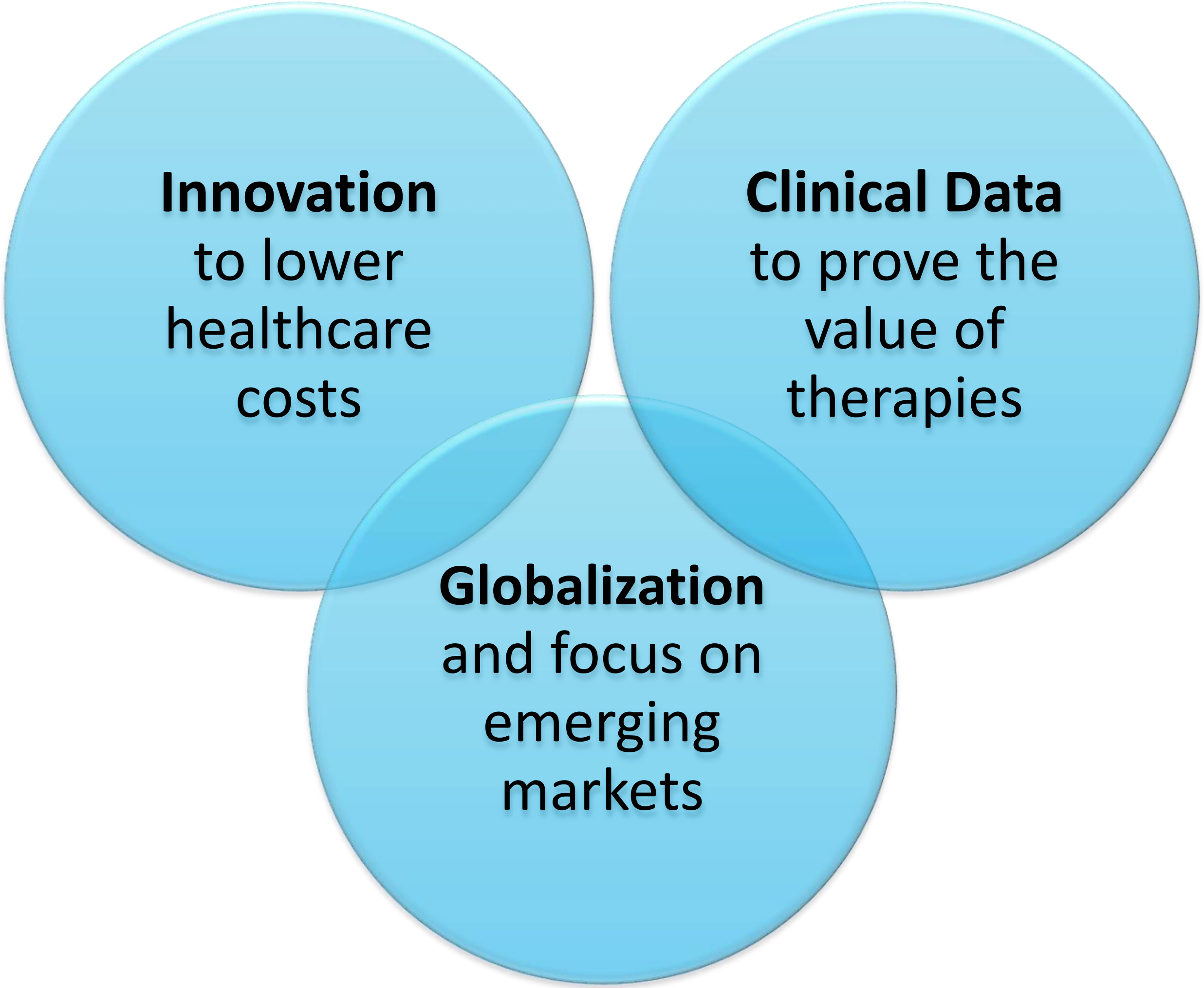
Advances in Medical Devices and Relevant Ongoing Development at Rice University

Or, What the Medtech Industry can learn from the Aerospace and Oil&Gas Industries

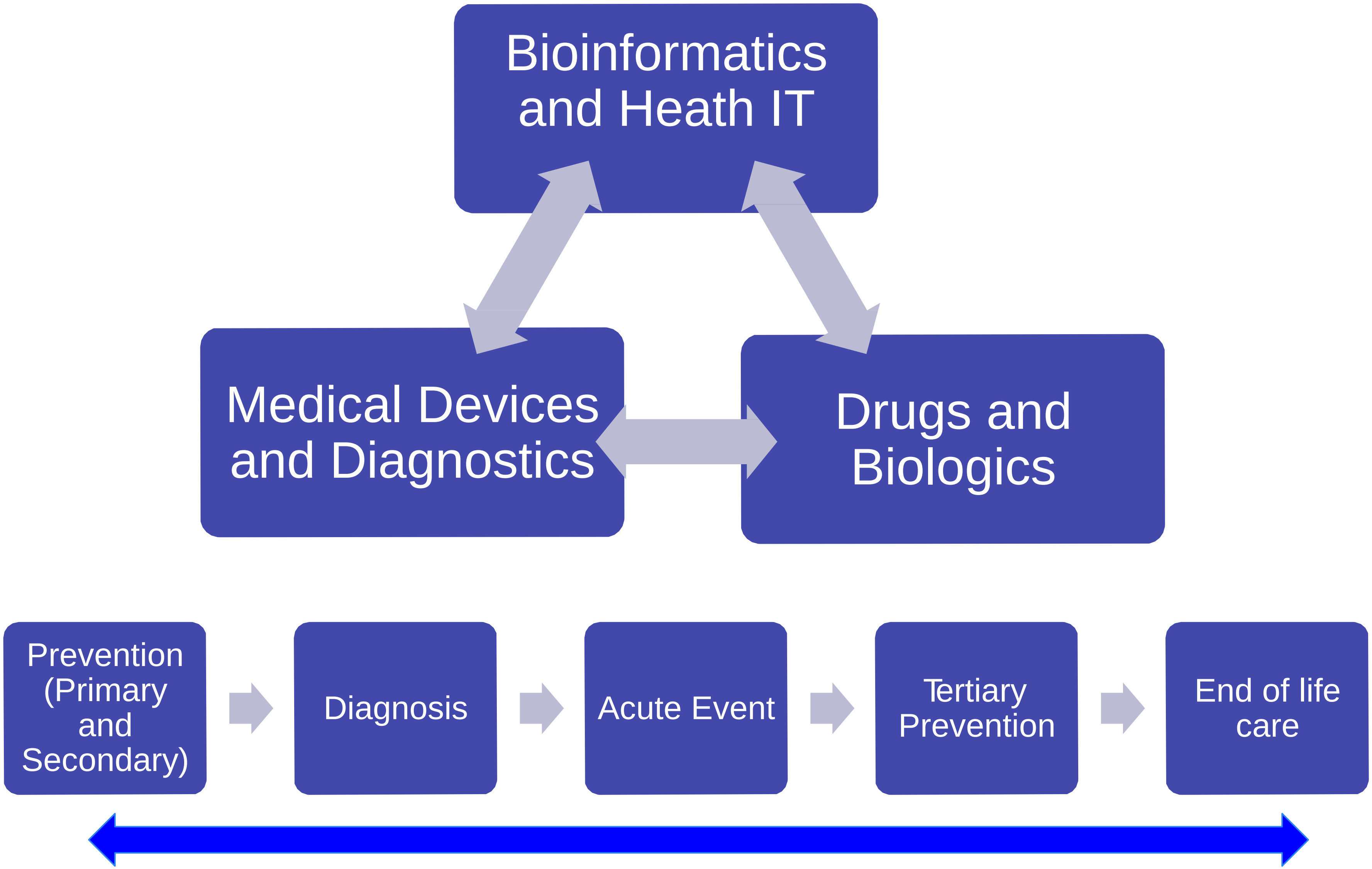
Eric Richardson, PhD
Dept. Of Bioengineering

The Changing Environment

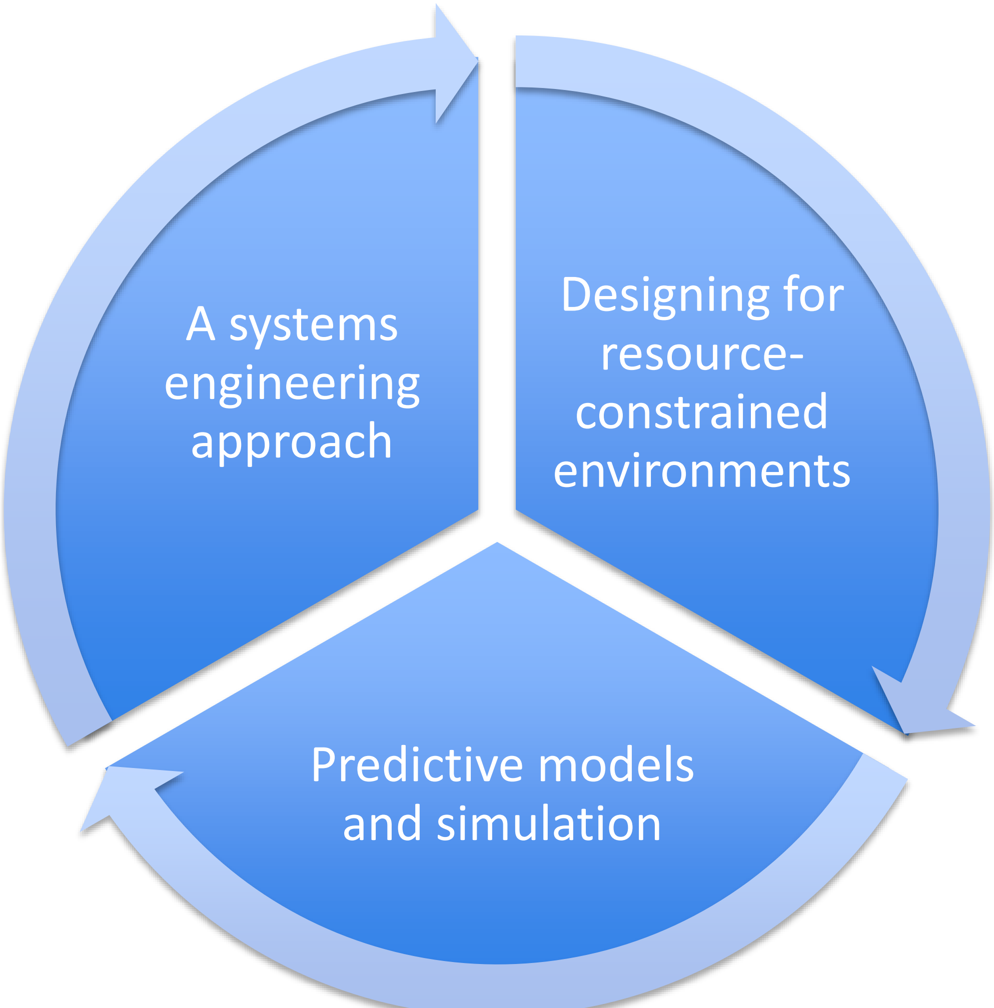


*1.www.**emergo**group.com/files/**2012**-medical-device-industry-**survey**.pdf*
2. http://annualreport.medtronic.com/2013/index.htm
3. Ernst and Young Pulse of the Industry: Medtech 2012
4. "Asia's Ascent — Global Trends in Biomedical R&D Expenditures" Chakma et al. NEJM, 2014

The Convergence of Industries



Learning Lessons from Aerospace and Oil & Gas



Learning Lessons from Aerospace and Oil & Gas

- Designing for resource-constrained environments:
  - Shortage of trained personnel
  - Lack of Infrastructure

Learning Lessons from Aerospace and Oil & Gas

- Predictive models and simulations
  - Long product development cycles
  - Costly prototypes
  - Challenges to simulate end-use conditions
  - Human lives at stake

MDIC

MEDICAL DEVICE INNOVATION CONSORTIUM

"MDIC aims to reduce the time and cost required to develop and approve medical innovation, while improving patient safety, through the consistent application of validated computational modeling and simulation in device development and regulation." – MDIC.org

Learning Lessons from Aerospace and Oil & Gas

- A Systems Engineering Approach
  - Complex and constrained systems, with the need to make informed trade-offs
  - Developing products to increase the efficiency of the whole system (instead of developing products independently and forcing the system to adapt)

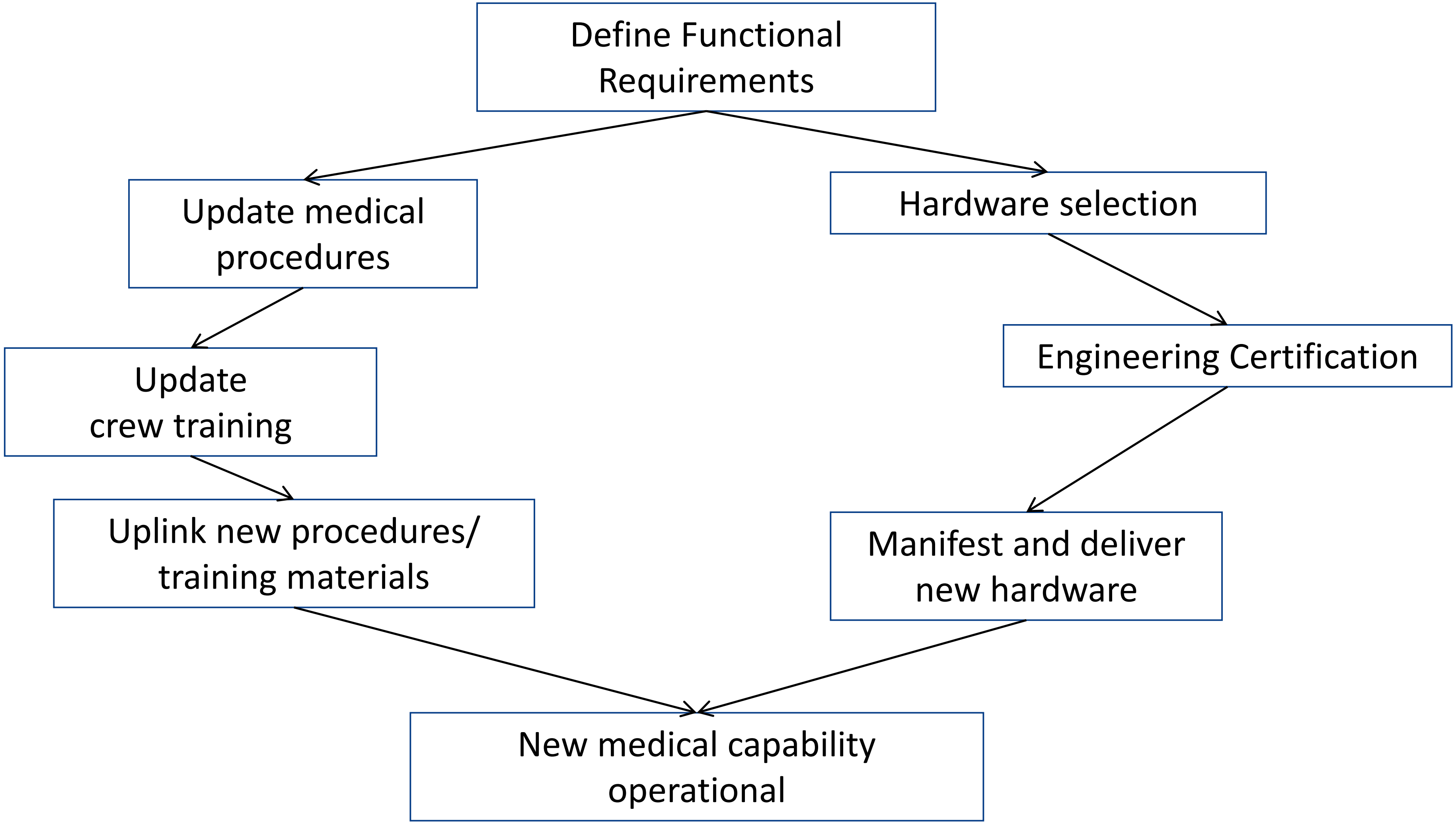
GE Healthcare

Medtronic

www.gehealthcare.com, www.medtronic.com

- Medical Goals for the Health Maintenance System
  - Maintain crew health, comfort, and performance
  - Restore crews to health
  - Make informed decisions on management and/or triage to:
- Design principles – Limited Resource Environment
  - Balance utility with size/weight/complexity
  - Minimize resupply and sterility requirements
  - Minimize crew training needs
  - Favor reliability and usability
  - Emphasize multipurpose equipment and techniques

Design Process (example of ISS medical kit redesign)



Required Diagnostic Capabilities (examples)

- Ability to evaluate health of crewmembers (periodic or as needed)
  - Expertise: Trained crew medical officer(s) (CMO)
  - Procedures: ISS Medical Checklist
  - Communications: Private Medical Conferences - PMC (AV)
  - No downlink for temperature, body mass, blood pressure, pulse rate, test positivity, and other numerical or categorical parameters (communicated during PMC)
  - Additional guidance: from ground
- Enhanced Diagnostic Capabilities
  - ECG, general imaging in support of a physical examination (use of nonmedical capabilities)
  - <u>Multipurpose Ultrasound (real-time and downlink)</u>
  - Battery of ocular assessment tools: Optical Coherence Tomography (OCT), Fundoscopy, perimetry, tonometry, etc.
  - Limited laboratory tests (hematocrit, urinalysis, blood chemistry)
    - Deep freezer for sample storage
    - Enhanced laboratory capabilities feasible for research purposes

Research
Occupational surveillance
Medical monitoring and/or Dx

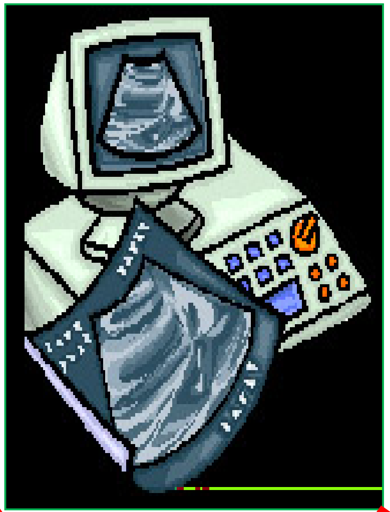
Limited-resource AND peculiar environment

- Limited medical capability
- Limited ability to replenish supplies
- Limited training and skills of the providers
- Limited access to "normal" medical facilities

- Peculiar environmental fa
- Modified physiology
- Mission considerations

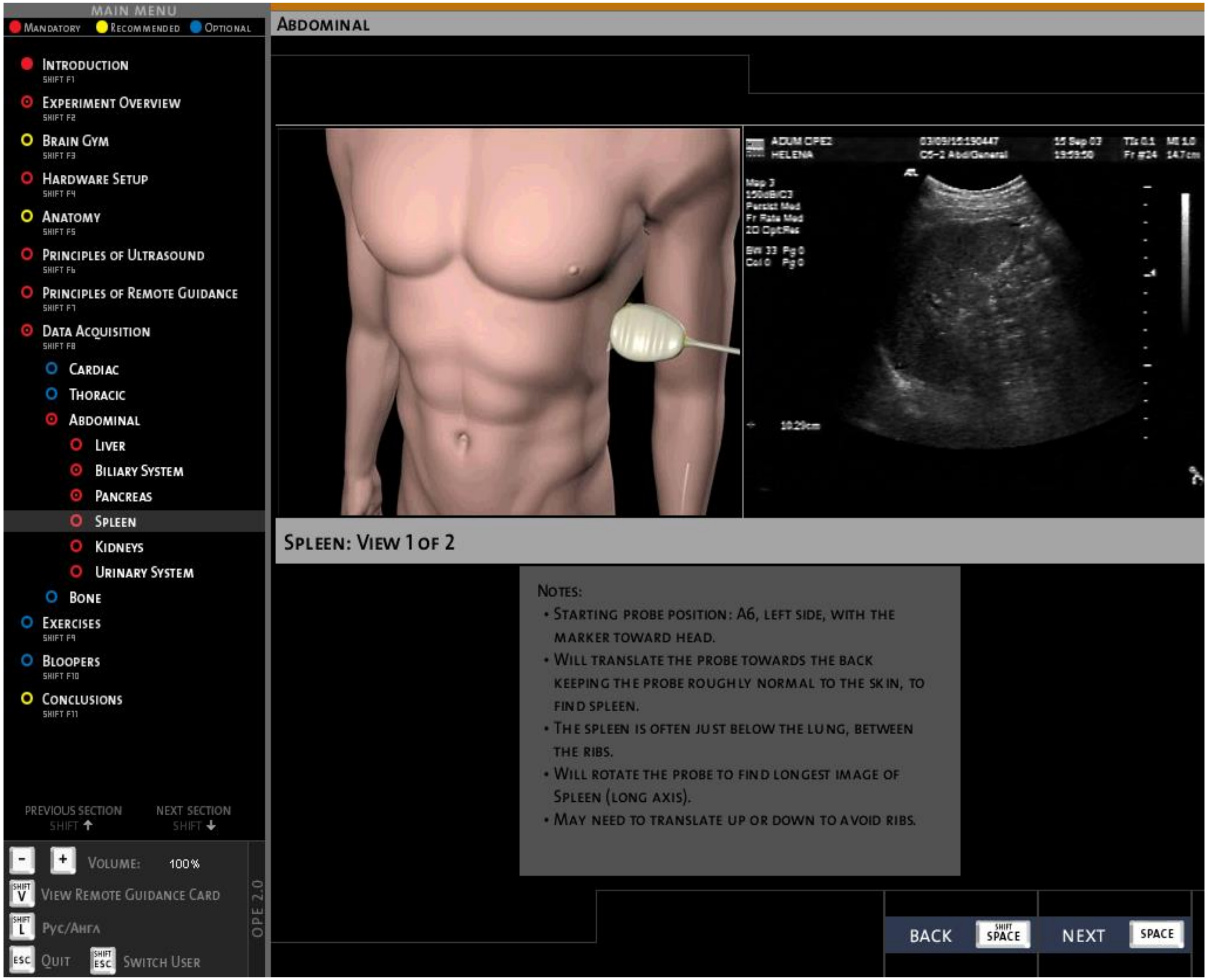
Ultrasound an ideal modality

- The only universal medical imaging modality in space flight
- No EMI potential, reasonable space & power needs
- Safe, Repeatable, Real-time, Universal
- Compressible/transmittable
- Proven to work in microgravity / space
- Doubles as a powerful non-invasive research modality



BEFORE, NOW, AND AFTER

- **<u>Before</u>:**
  - Crew trained to perform specific tasks independently
- **<u>Now</u>:**
  - Minimal training, reference and refresher tools
  - Remote real-time guidance with elements of virtual presence
- **<u>In the Future</u>:**
  - Minimal training
  - Guidance by technology
    - Integration of US system with vehicle resources
    - Probe position sensing and 3D volume operations
    - Interactive knowledge bank
    - Image recognition – based computer guidance
    - Robotic operation
    - (Possibilities are endless)


MAIN MENU
Mandatory Recommended Optional
Introduction
SHIFT F1
Experiment Overview
SHIFT F2
Brain Gym
SHIFT F3
Hardware Setup
SHIFT F4
Anatomy
SHIFT F5
Principles of Ultrasound
SHIFT F6
Principles of Remote Guidance
SHIFT F7
Data Acquisition
SHIFT F8
Cardiac
Thoracic
Abdominal
Liver
Biliary System
Pancreas
Spleen
Kidneys
Urinary System
Bone
Exercises
SHIFT F9
Bloopers
SHIFT F10
Conclusions
SHIFT F11
PREVIOUS SECTION SHIFT
NEXT SECTION SHIFT
Volume: 100%
View Remote Guidance Card
Рус/Англ
Quit
Switch User
OPE 2.0
Abdominal
Spleen: View 1 of 2
Notes:
• Starting probe position: A6, left side, with the marker toward head.
• Will translate the probe towards the back keeping the probe roughly normal to the skin, to find spleen.
• The spleen is often just below the lung, between the ribs.
• Will rotate the probe to find longest image of Spleen (long axis).
• May need to translate up or down to avoid ribs.
BACK
SHIFT SPACE
NEXT
SPACE

SPLEEN

What is different in space - Imaging Procedure

- *Positioning and restraining*
- *Use of water vs. gel in most applications*

- Remote guidance challenges
  - Discourse -Somebody else is holding the probe for you…
- Altered logic and sequence of image collection
  - Prioritization of views in several dimensions
    - Primary to secondary; Easy to difficult (?);
- Real-time modification of the procedure sequence due to time constraints, operational pressures

What is different in space – imaging results

- Space Physiology context (examples):
  - Chronic fluid shift cephalad
  - Increased venous filling in head/neck region
  - Altered flow patterns in certain vascular beds
  - Altered air/fluid/tissue interfaces
- Pathology:
  - Altered distribution of pathological fluid and gas
  - Lack of evidence for microgravity pathology
  - "Gray zone" between adaptation and disease
  - Maximize the information from US – often beyond the standard "terrestrial" protocols / evidence
- Interpretation: requires additional care/attention and expertise

Imaging Procedures / Protocols we use

Common procedures – “maximized”

Common procedures – modified

New procedures not practiced widely in medical systems

Diagnostic and Research Protocols Demonstrated / Used in Space

- Abdominal
- Genitourinary
- Central Vascular
- Peripheral Vascular
- TCD
- Soft Tissue
- Thoracic
  - Echocardiography
  - Pleural/Lung
- Musculoskeletal
  - Rotator Cuff
  - Knee, Ankle, Elbow
  - Spine
- Thyroid
- Dental, Sinus
- Eye – Diagnostic
- Eye/Orbit (ICP protocol)

Notable Advances / Contribution Areas

Focused ultrasound techniques for emergency medicine and critical care

Pleural and lung ultrasound, incl. pneumothorax

Eye and Orbit imaging with multipurpose devices

Cardiovascular physiology

Exercise physiology

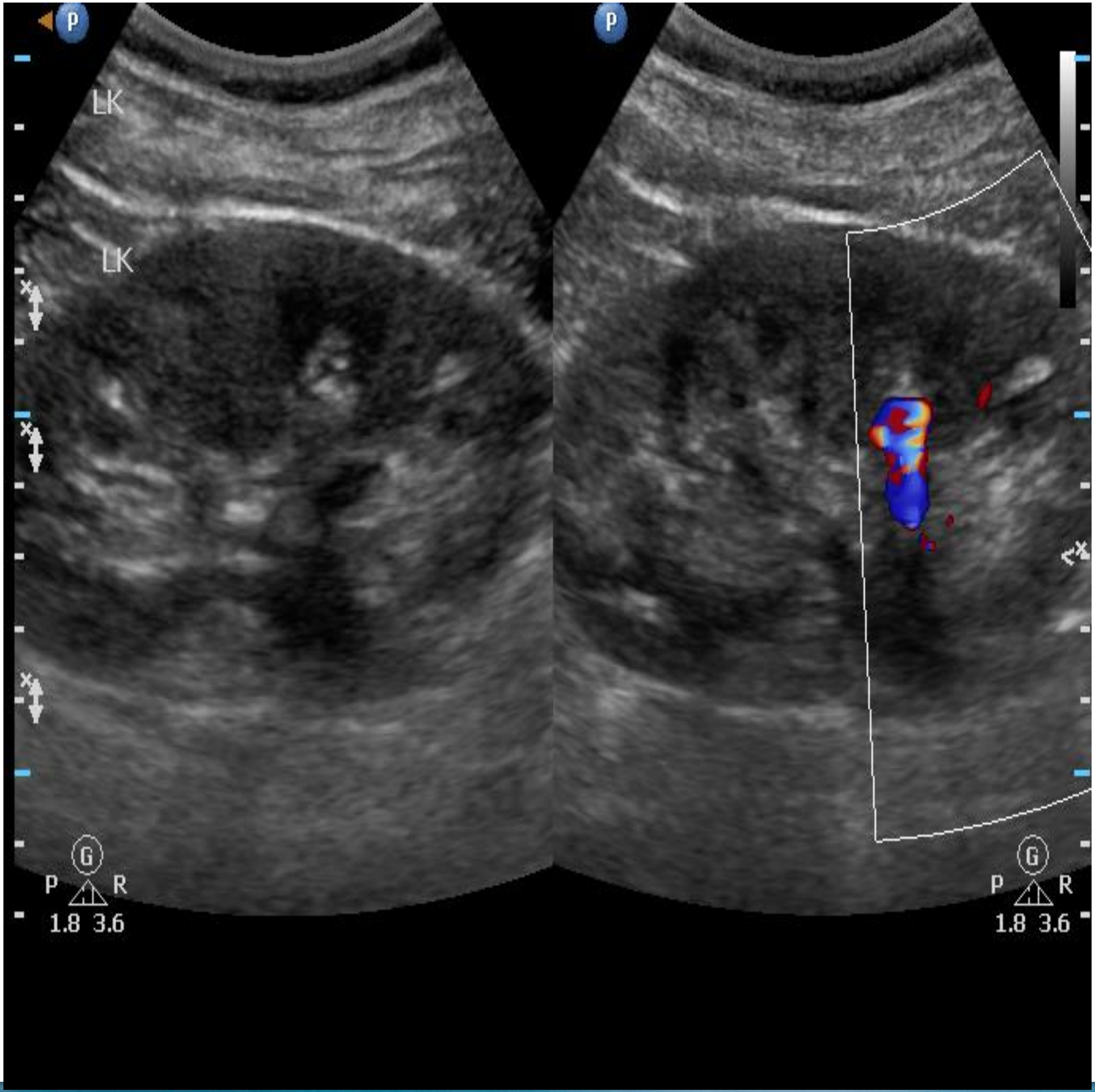
Telemedicine applications

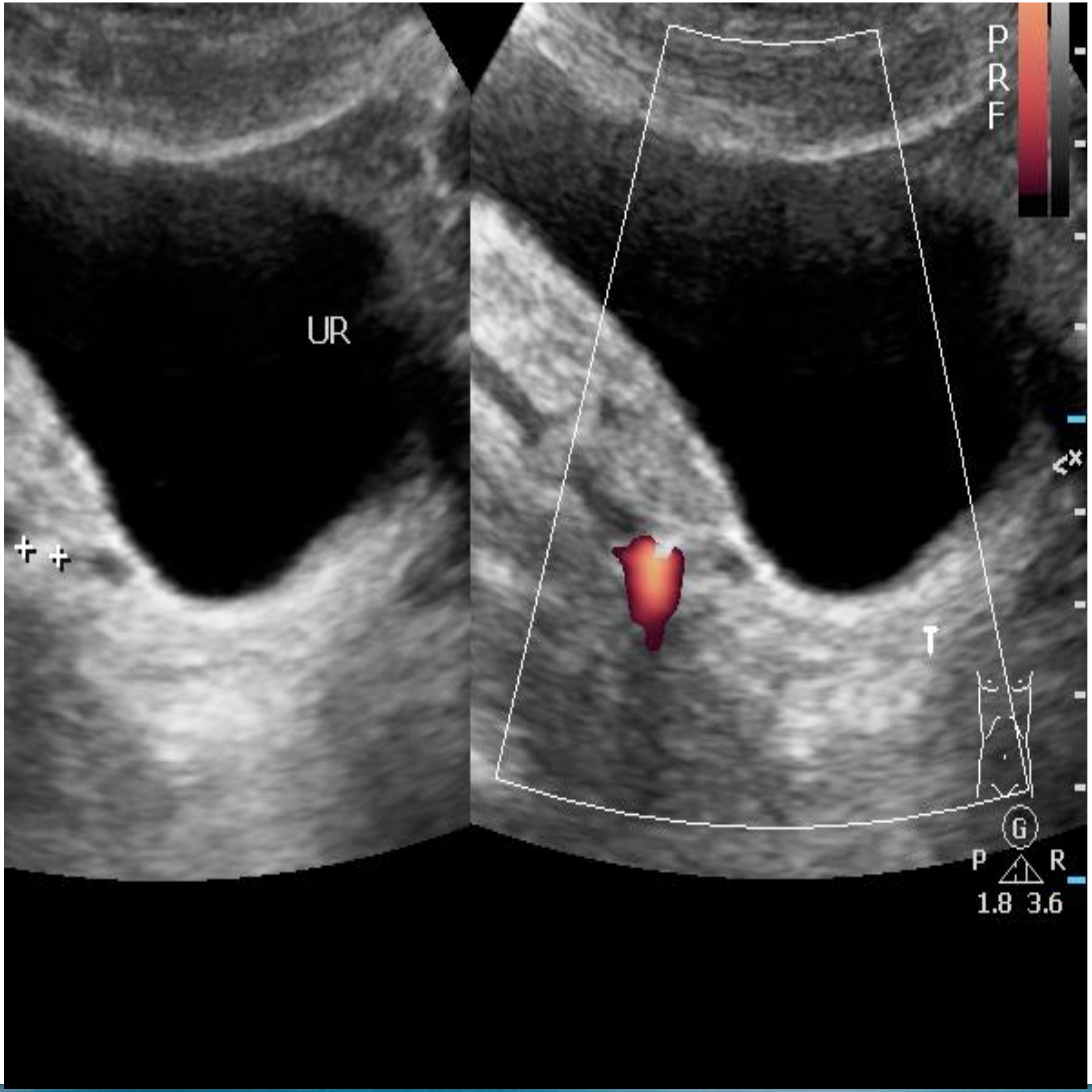
Medical education

Others

Example: Urolithiasis (urinary stone disease)

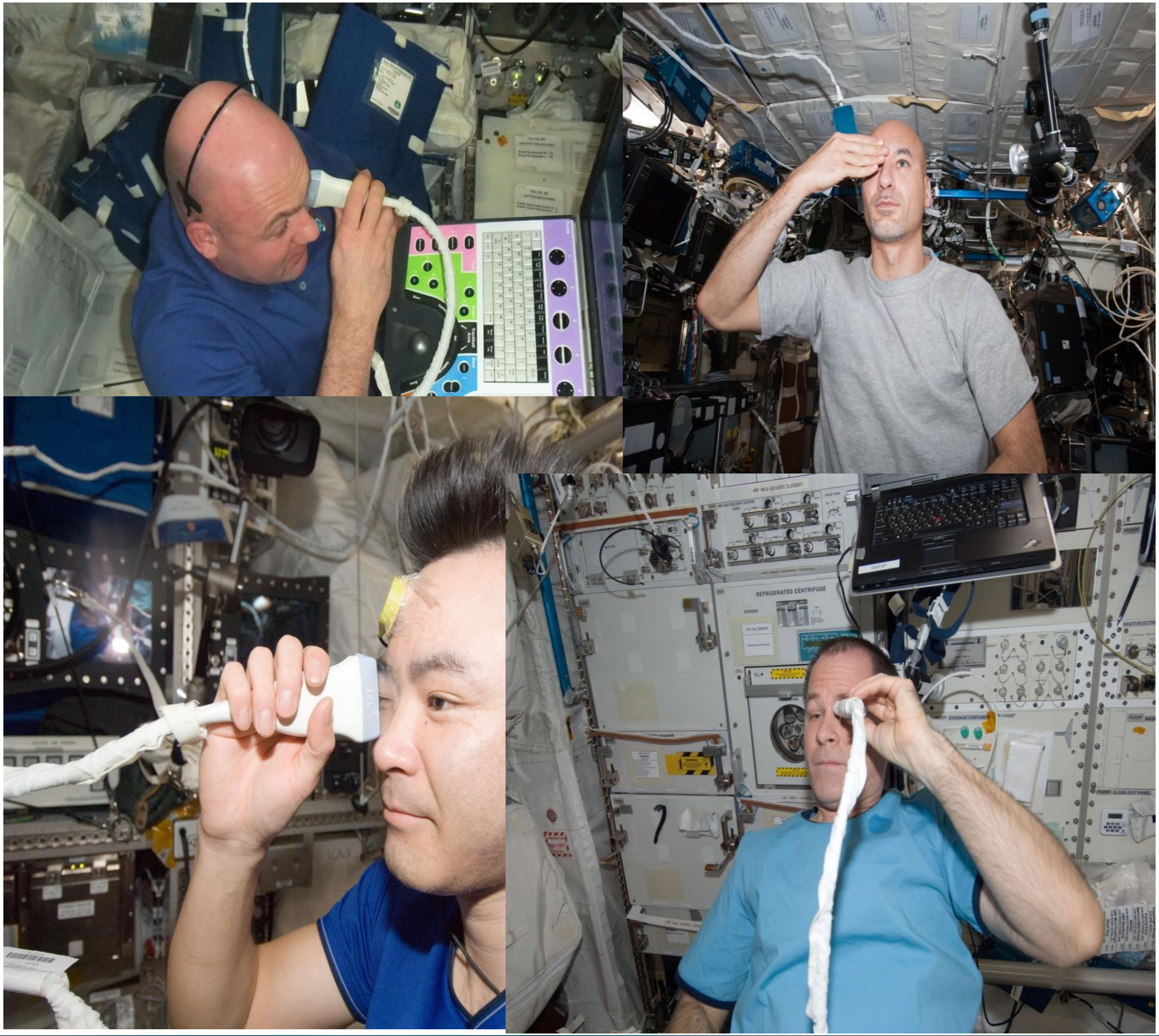
- More likely in space flight
- Inherent risk, individual predispositions
- Remote but real possibility of missed small stones during preflight screening
- Small-scale events have occurred in-flight and post-flight
- A major event in spacecraft would be a "mission-impacting event"

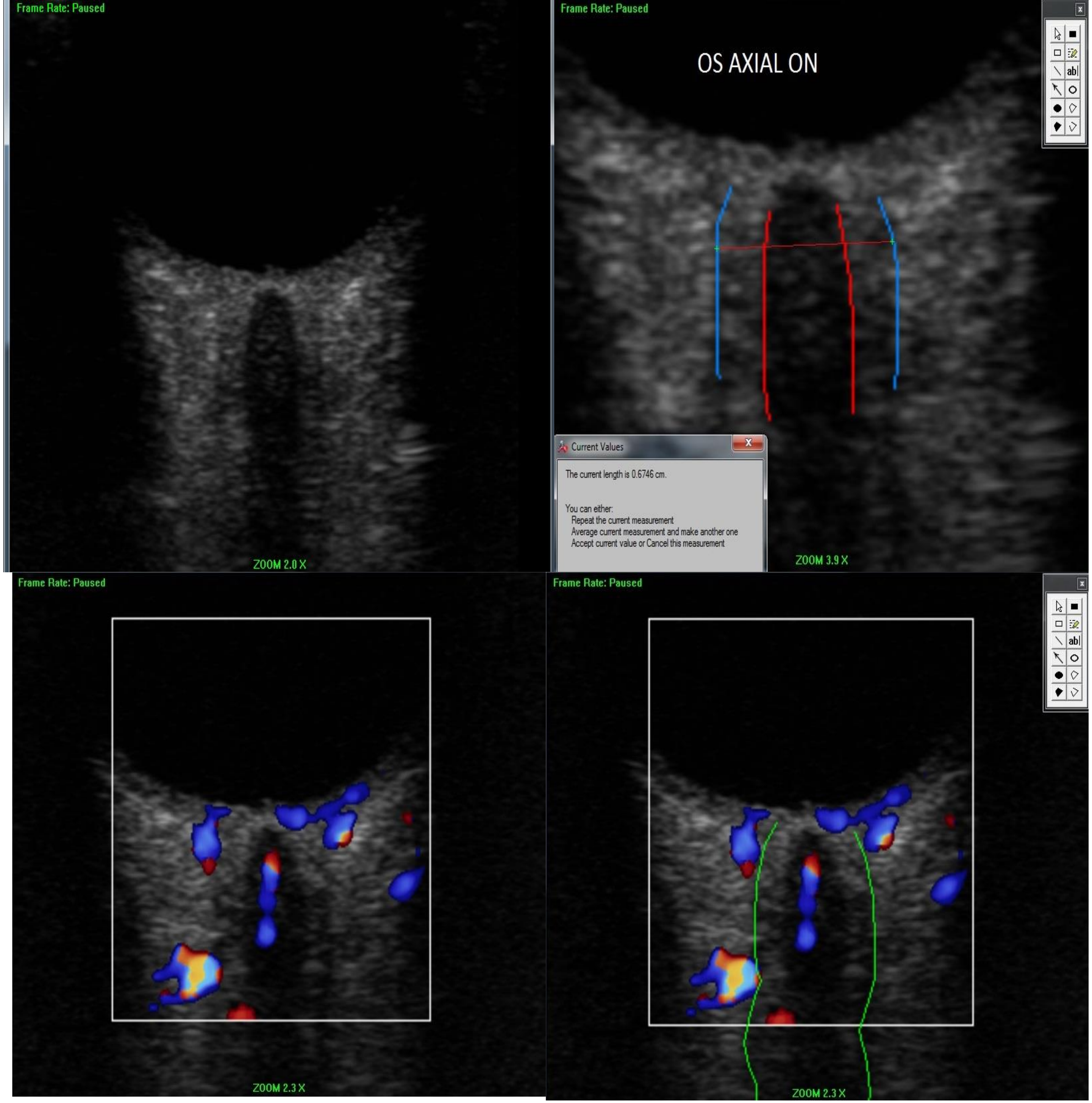

LK
LK
P R
1.8 3.6
P R
1.8 3.6


UR
PRF
P R
1.8 3.6

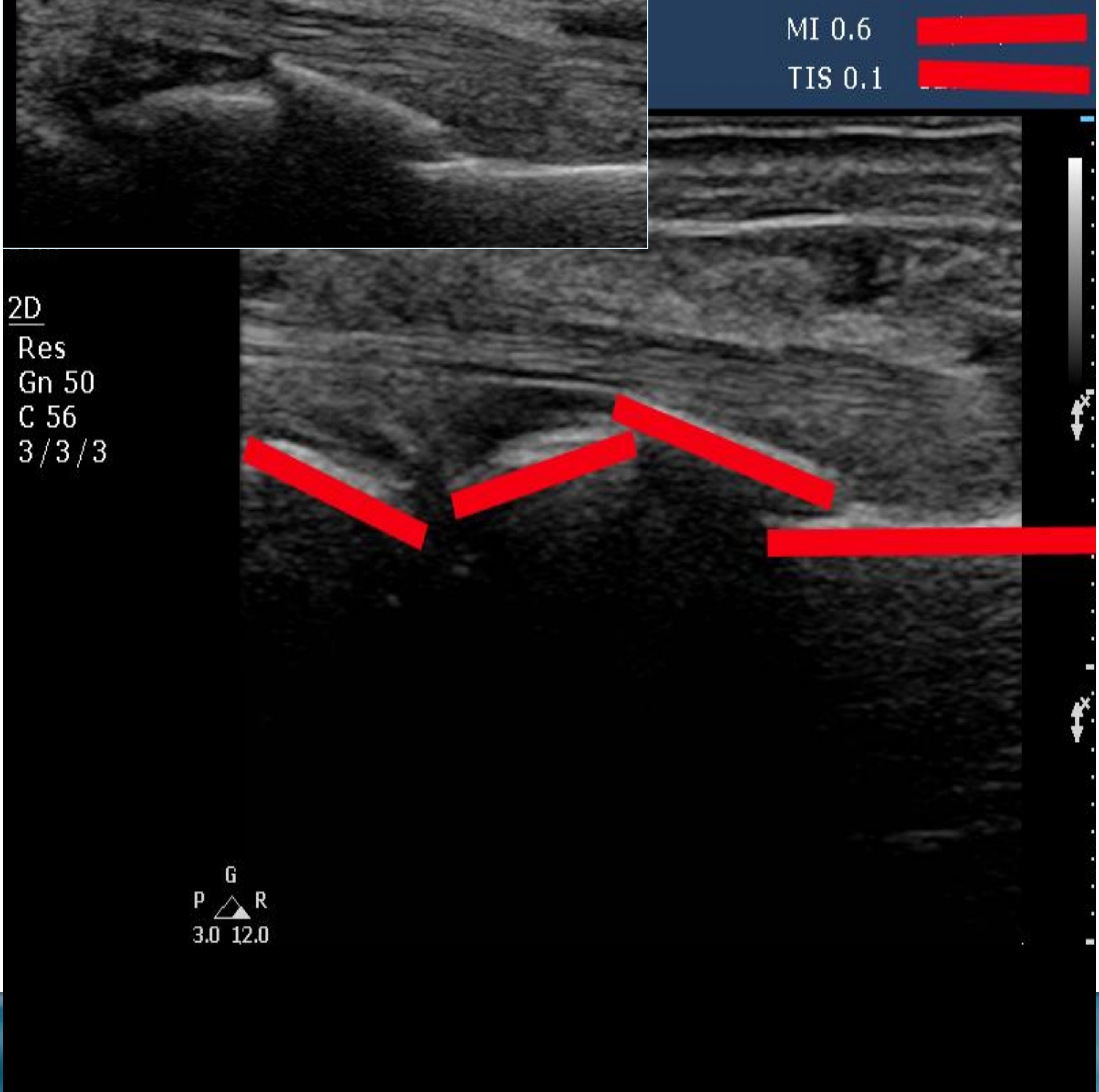
Eye/Orbit imaging

- Eye ultrasound tested on orbit in 2003 for trauma
- First imaging on orbit for vision changes reveals some structural changes
- An enhanced surveillance program was instituted
- Conducted in all crewmembers in all mission phases

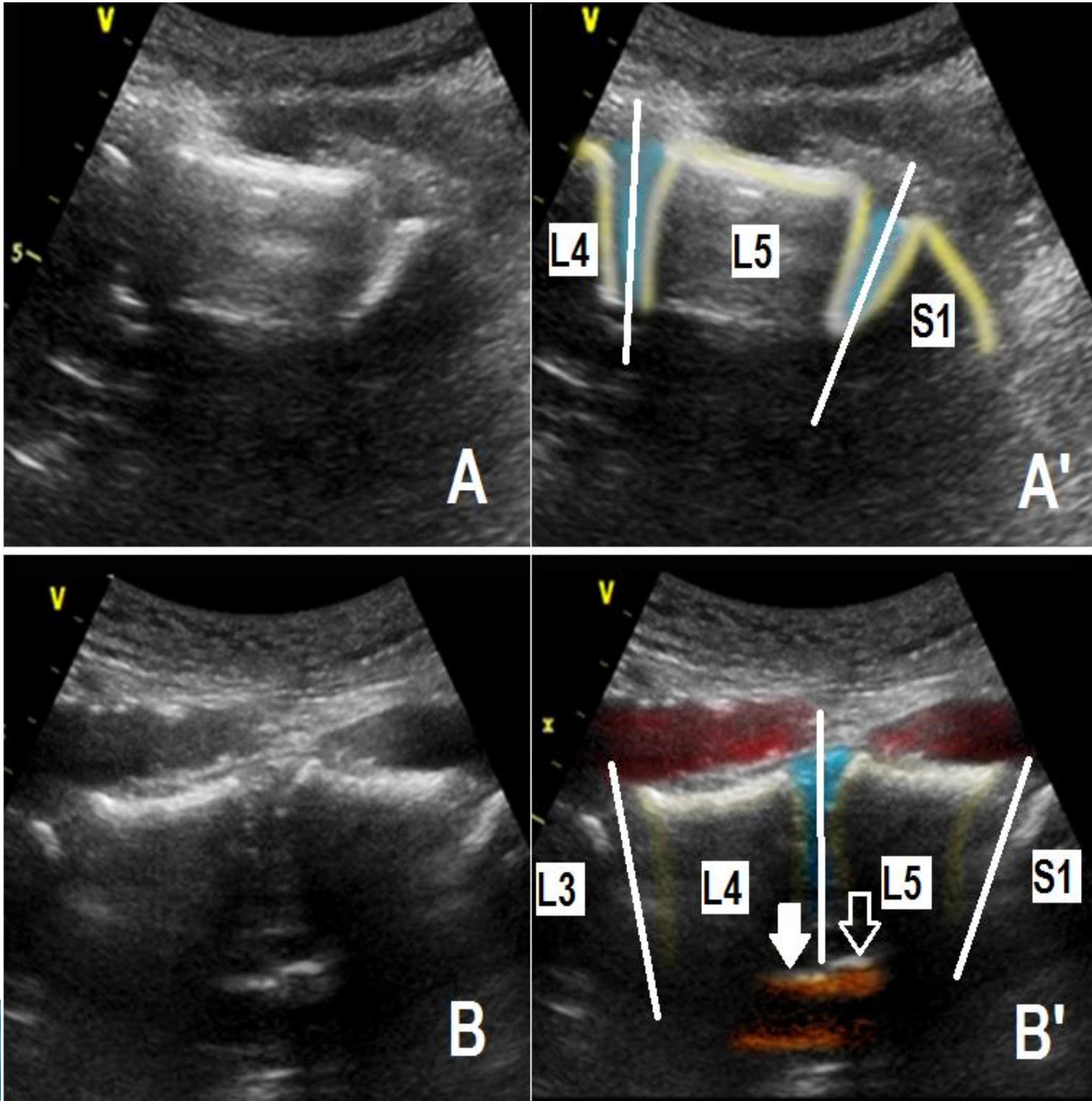

REFRIGERATED CENTRIFUGE


Frame Rate: Paused
ZOOM 2.0 X
Frame Rate: Paused
OS AXIAL ON
Current Values
The current length is 0.6746 cm.
You can either:
Repeat the current measurement
Average current measurement and make another one
Accept current value or Cancel this measurement
ZOOM 3.9 X
Frame Rate: Paused
ZOOM 2.3 X
Frame Rate: Paused
ZOOM 2.3 X

Musculoskeletal Ultrasound


MI 0.6
TIS 0.1
2D
Res
Gn 50
C 56
3/3/3
G
P
R
3.0 12.0


Spinal
Ultrasound
Sonographic Astronaut Vertebral Examination: Guide
Contains details about surveying anatomical areas along with target and pathology images.
PRINCIPLES OF ULTRASOUND
DATA COLLECTION
CUE CARDS
NASA



V
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A
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S1
A'
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B
V
L3
L4
L5
S1
B'

CONCLUSIONS

- Most current US applications are "space-ready" or "remote-ready"
- Ultrasound plays a great and growing role in
  - Space biomedical research
  - Occupational monitoring and risk management
  - Medical support of illness and injury
  - Design of medical systems for future missions
- NASA remote diagnostic experience is fully transferable to other medical systems

Questions