Ultrasound…

IN SPACE

Kathleen M Garcia, BS, FASE, RDCS, RVT

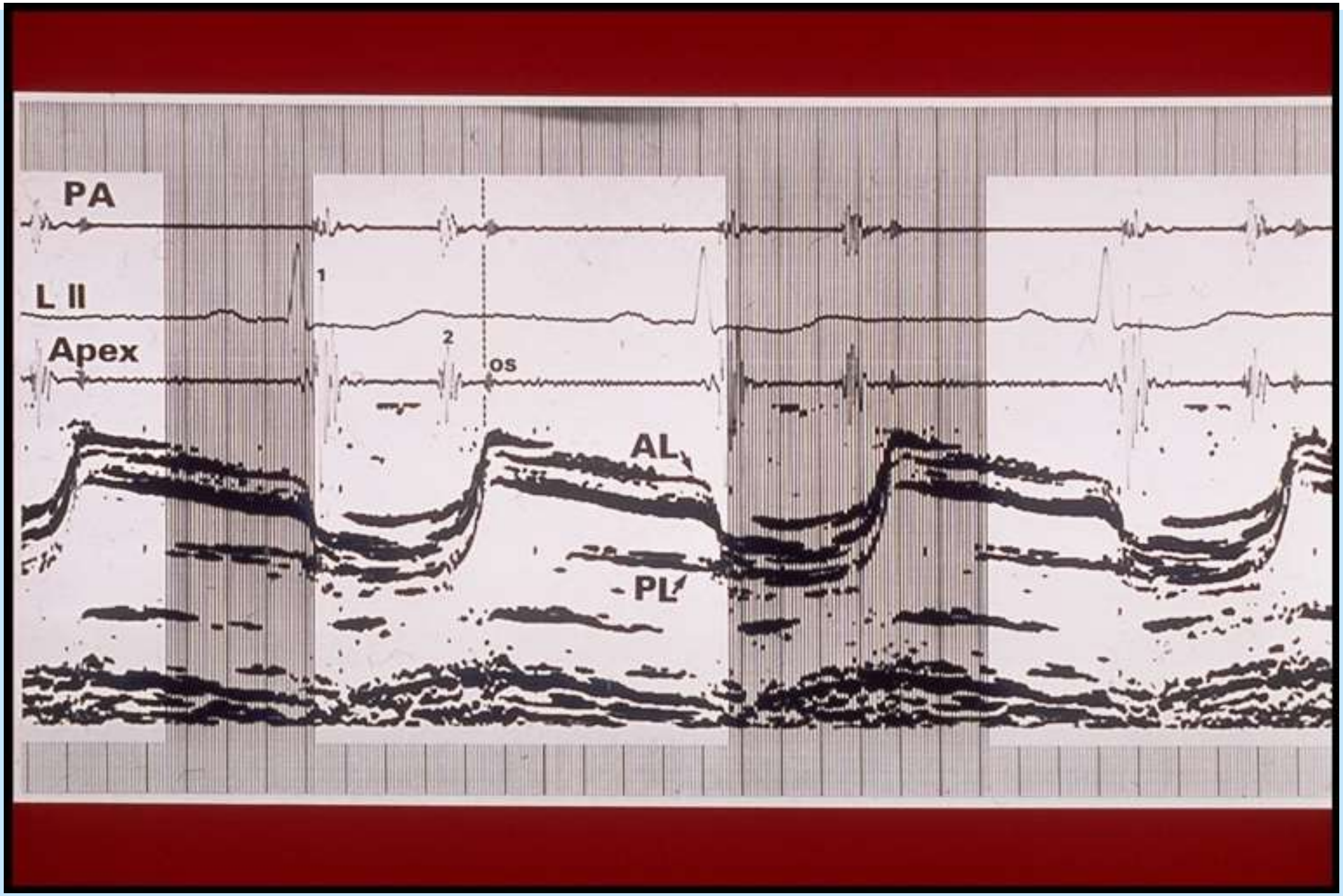
TIMELINE ULTRASOUD

- 1960's Early Ultrasound machine available
- 1970's Grey Scale becomes common
- 1980's Paradigm shift in ultrasound universally
  - Color flow, pulsed and continuous wave Doppler
  - Broadband transducers
  - World wide use and acceptance
  - Ultrasound as a professional career
  - Early portable ultrasound devices

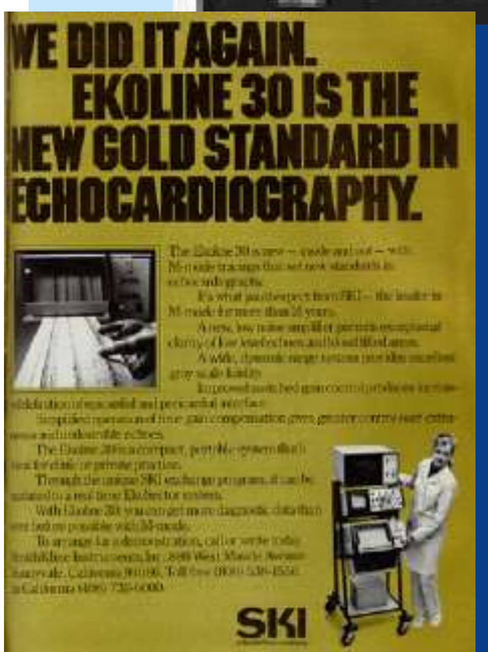
Space catches on here.....

- 1990's Ultrasound enters the emergency medicine's national curriculum
  - Harmonic imaging
- 2000's
  - The Digital evolution of ultrasound
  - Telemedicine becomes mainstream
  - Remote Guidance accepted for data acquisition on ISS

1970'S M-MODE AND PHONO DISPLAY



1970’S REAL-TIME GRAY SCALE ULTRASOUND



1976 FIRST REAL-TIME ECHO DUKE UNIVERSITY

PIONEERING BACK ON EARTH…

- 2 D and Doppler together 1981
- Aloka 1983 Color Doppler and 2D- First time avaliable

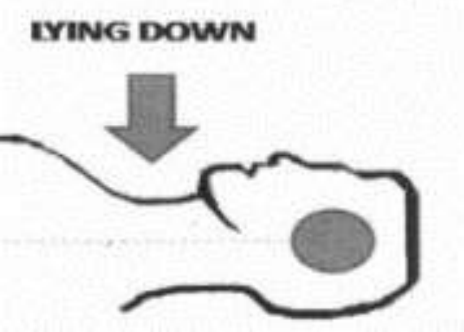
Early Microgravity Physiology

FLUID SHIFT PHYSIOLOGY

FACIAL PUFFINESS

BIRD LEGS

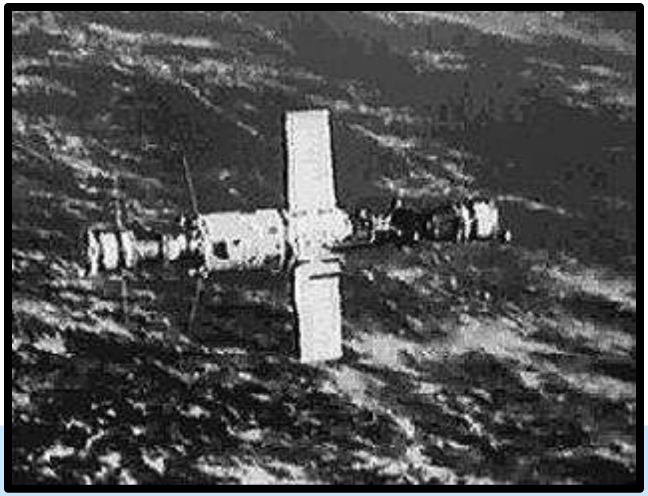
LOSS OF HYDROSTATIC DRAINAGE



FIRST ULTRASOUND IN SPACE, 'ARGUMENT'

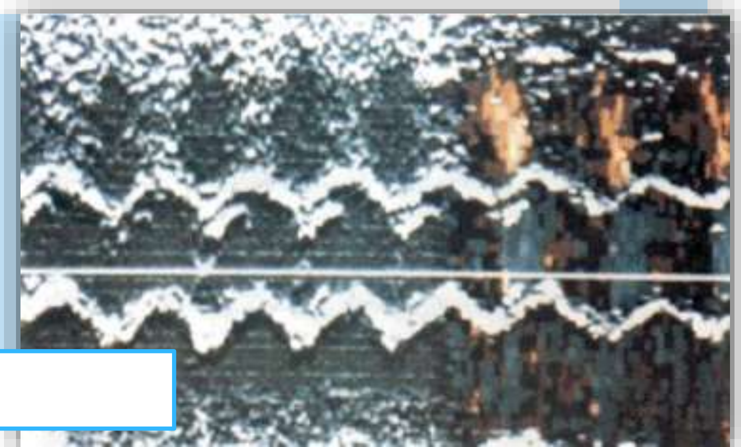
Aviation, Space, and Environmental Medicine • September, 1987

Ultrasound Techniques in Space Medicine



O. Yu. Atkov, M.D., V. S. Bednenko, M.D., and G. A. Fomina, Ph.D.

Institute for Biomedical Problems and Institute of Transplantology and Artificial Organs, Moscow, USSR



N=15 serial examinations of cosmonauts on orbit

FIRST ULTRASOUND, 'ARGUMENT'

Aviation, Space, and Environmental Medicine • September, 1987

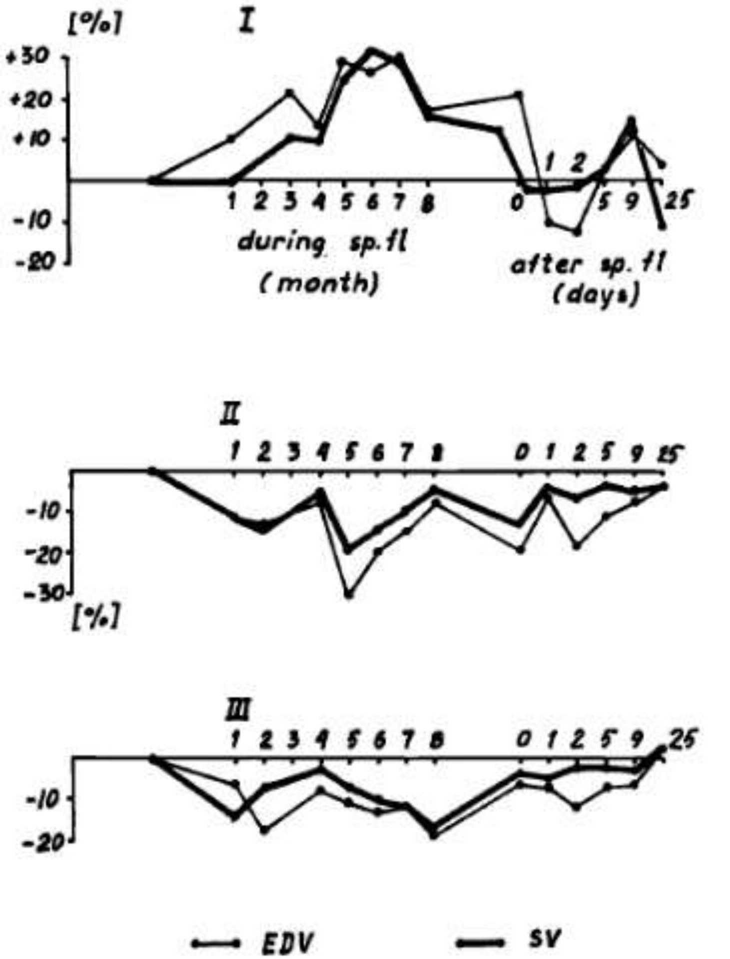


Fig. 1. Changes in end-diastolic volume and stroke volume at rest during a 237-day spaceflight and in the readaptation period. I = Cosmonaut I; II = Cosmonaut II; III = Cosmonaut III.

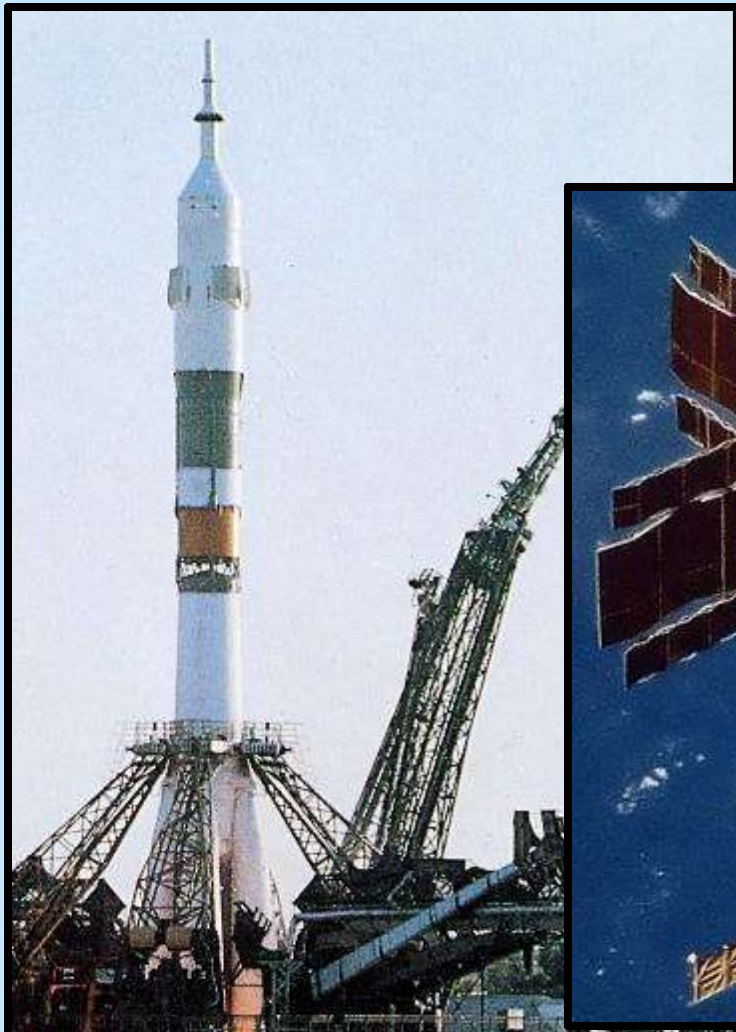
No Δ in cardiac contractility (8m)

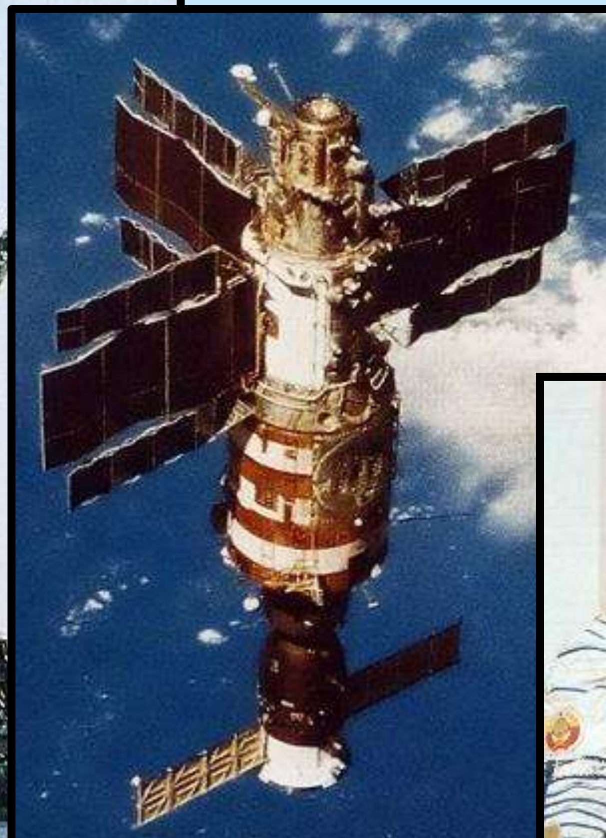
↓ EDV and SV, 2nd to ↓ blood volume

LBNP led to ↓ in CO – analogue to orthostasis instability

LOWER BODY NEGATIVE PRESSURE

2ND ULTRASOUND, 'ECHOGRAPH'

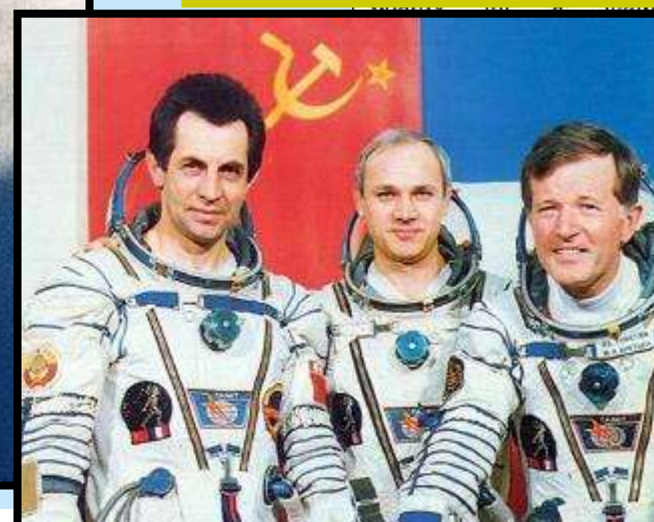




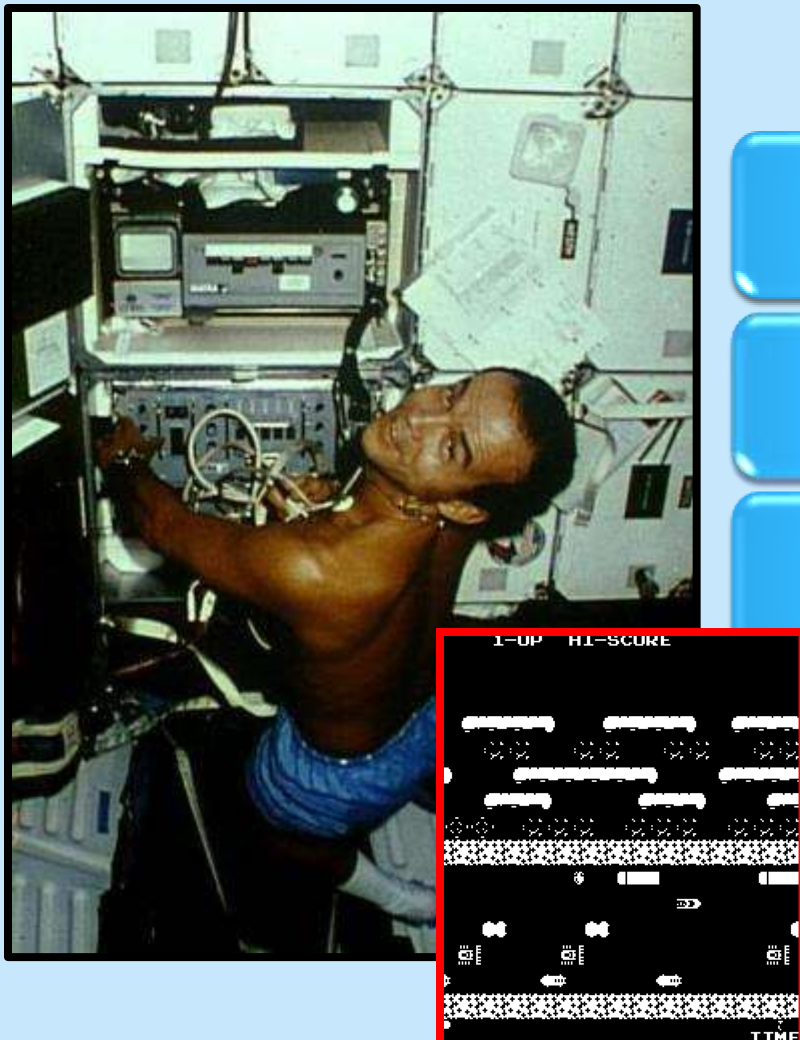
France to fly a man on Shuttle?

French space agency CNES has begun talking to Nasa about flying a Frenchman aboard Space Shuttle. At the same time, it is continuing discussions with the Soviet

Jean-Loup Chretien
1st French citizen in space



2ND ULTRASOUND, 'ECHOGRAPH'



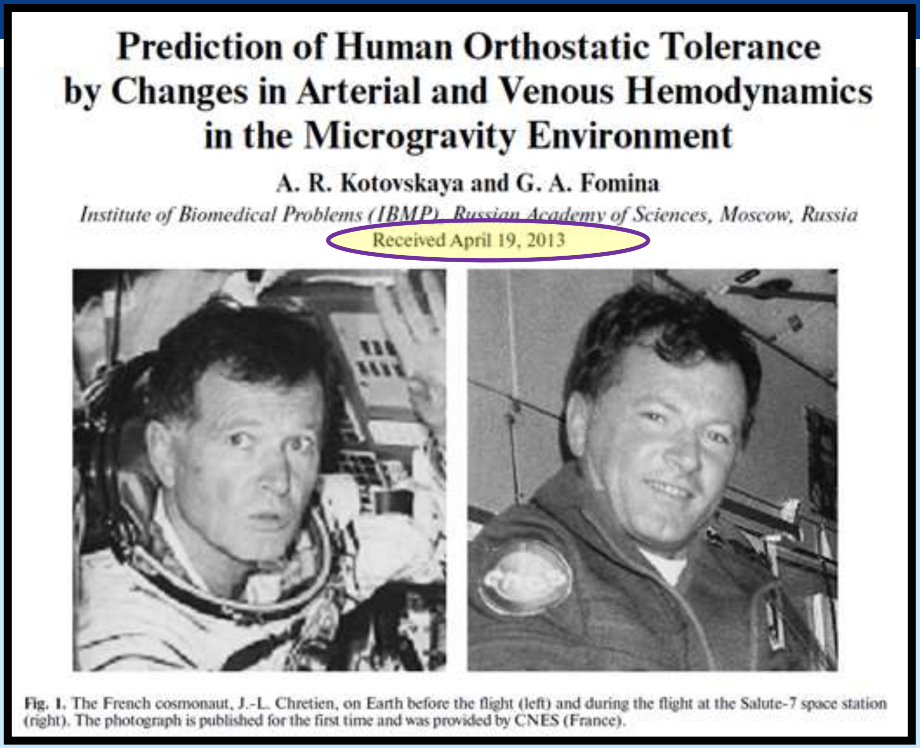
176 lbs

French Echograph experiment (FEE)

Salyut-7, STS-51G (1985)

- High frequency complex imaging PV Doppler
- Mir space station 1995 real-time remote guidance

2^{ND} ULTRASOUND, ‘ECHOGRAPH’



Prediction of Human Orthostatic Tolerance by Changes in Arterial and Venous Hemodynamics in the Microgravity Environment

A. R. Kotovskaya and G. A. Fomina

Institute of Biomedical Problems (IBMP), Russian Academy of Sciences, Moscow, Russia

Received April 19, 2013

Fig. 1. The French cosmonaut, J.-L. Chretien, on Earth before the flight (left) and during the flight at the Salute-7 space station (right). The photograph is published for the first time and was provided by CNES (France).

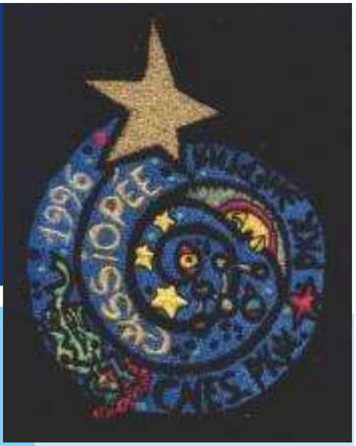
↓ femoral artery resistance

progressive

lack of arterial resistance = orthostatic intolerance

The redistribution of blood in microgravity initiates all subsequent hemodynamic changes in humans.

PHYSIOLOGIC INDIRECT ULTRASOUND



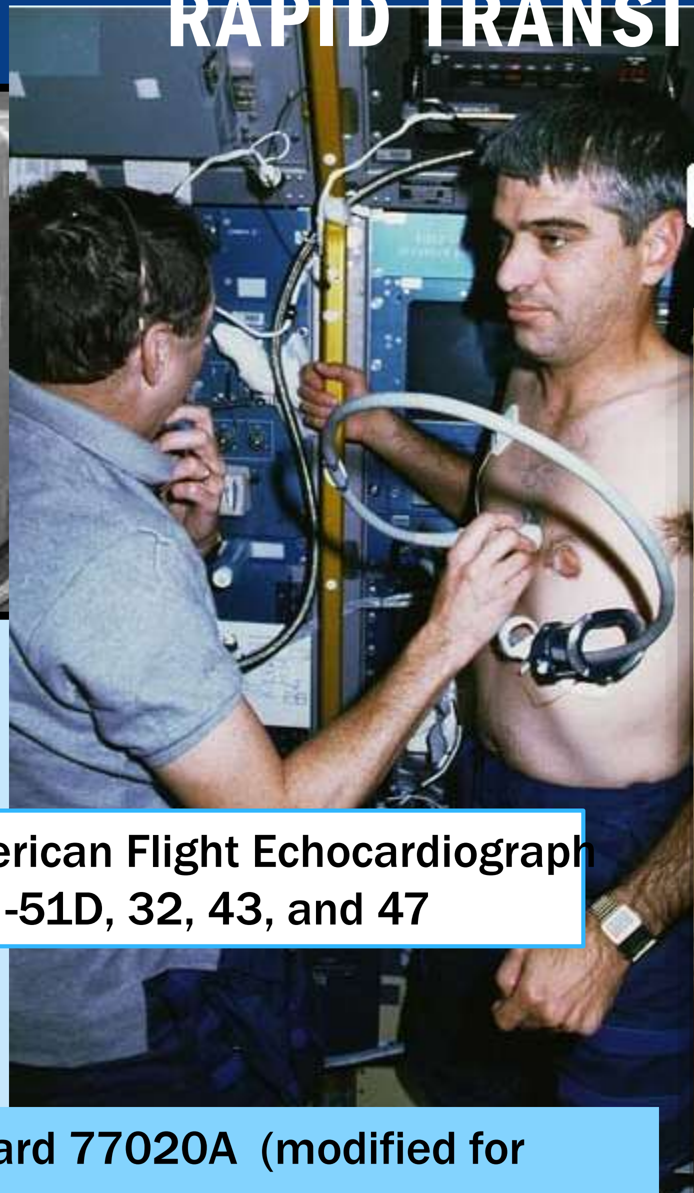
- Plethysmography had been used on MIR and Shuttle and consisted of strain gauge or impedance plethysmography to assess venous compliance.(Bonde-Petersen et al.1994, Buckey et al.1992, Convertinal et al.1990 a and b, Johnson et al.1977, Louisy et al. 1990, Thornton and Hoeffler 1977)

- During a 16 day mission on the MIR station 1996 Dr. Claudie Andre-Deshays used Air or Pneumo Plethysmography for the first comprehensive assessment of venous hemodynamics (filling time/venous distensibility/ arterial inflow) in an effort to understand "cardiovascular deconditioning syndrome"

RAPID TRANSITION

CNES Matra Echograph “As de Coeur”
Mir space station 1988-1995

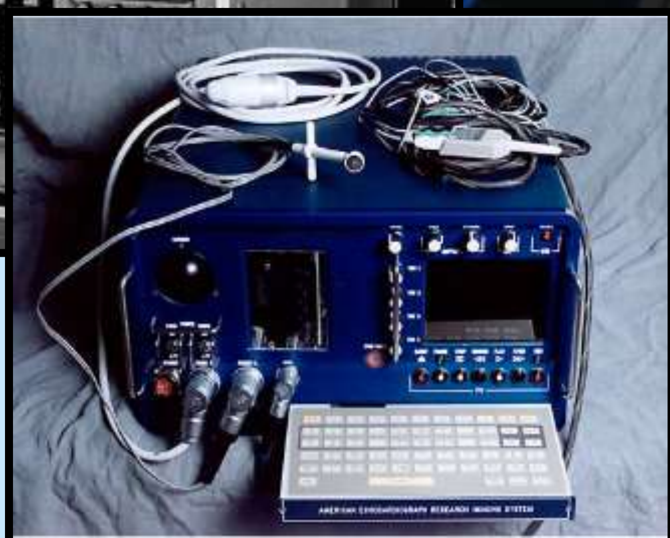
RAPID TRANSITION

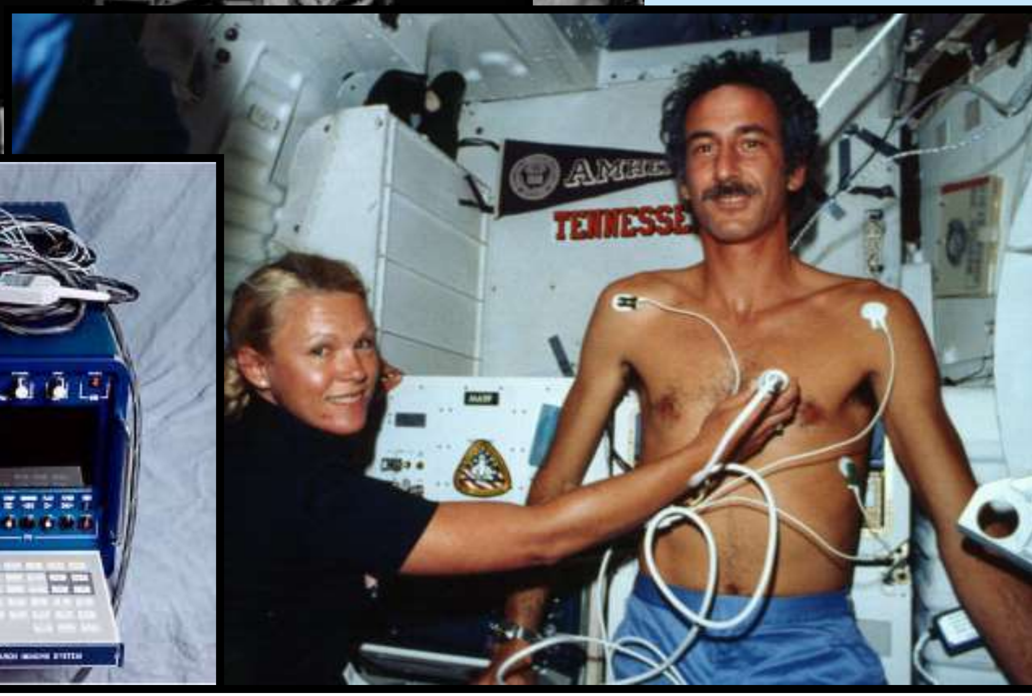


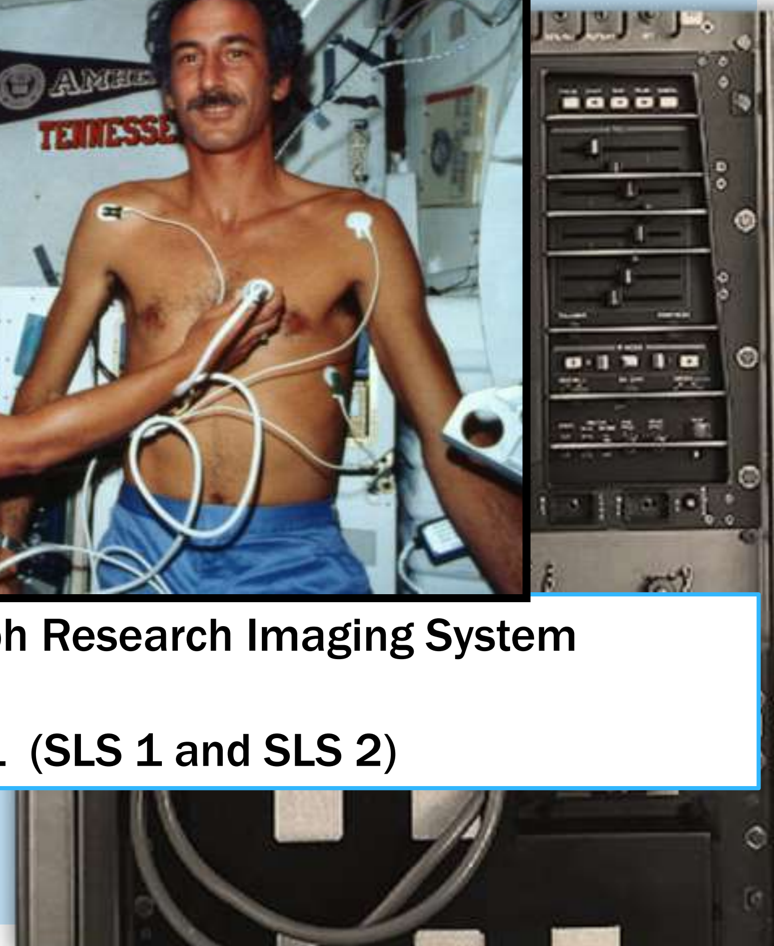
American Flight Echocardiograph
STS -51D, 32, 43, and 47

Hewlett-Packard 77020A (modified for Spaceflight)

RAPID TRANSITION







American Echocardiograph Research Imaging System (AERIS)
STS 47 (1992), 50, 65, 71 (SLS 1 and SLS 2)

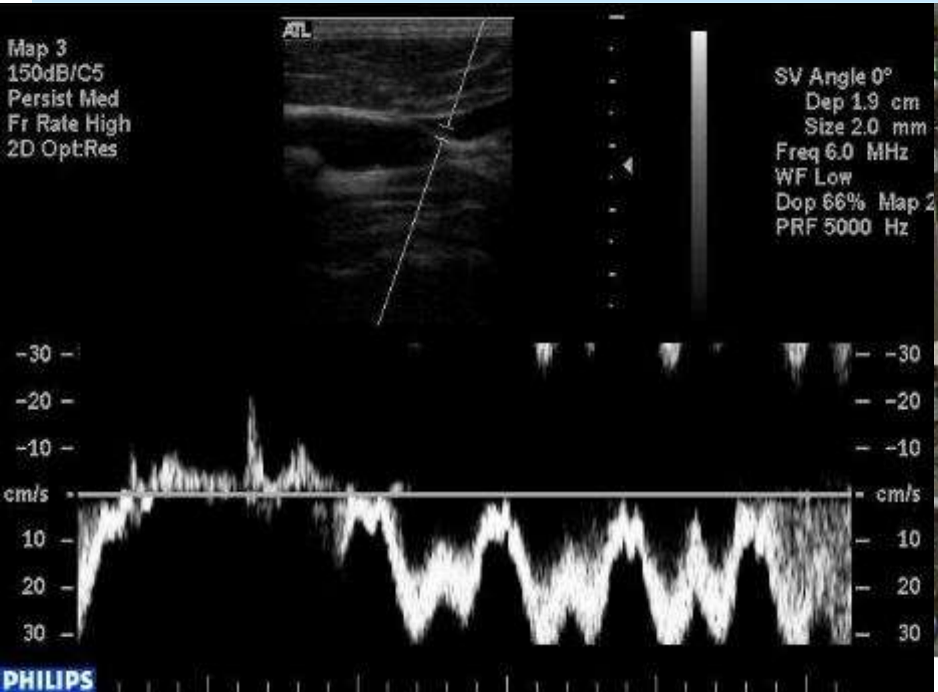
RAPID TRANSITION

One L12 MHz probe

ATL/Phillips HDI 5000
ISS 2001-2010

Setup: 90m +
Stowage: 45m+

- Med ops activation and checkout (11/13/2002)
  - Peggy Whitson /Exp 5. FAST exam, lung /pleural, renal, cardiac, vascular
  - First full-fledged remote guidance session, first checkout of all probes, modes to assess the system as a clinical capability
- HRP video quality assessment Exp 6 Echo,7 feasibility study



ISS005E22447

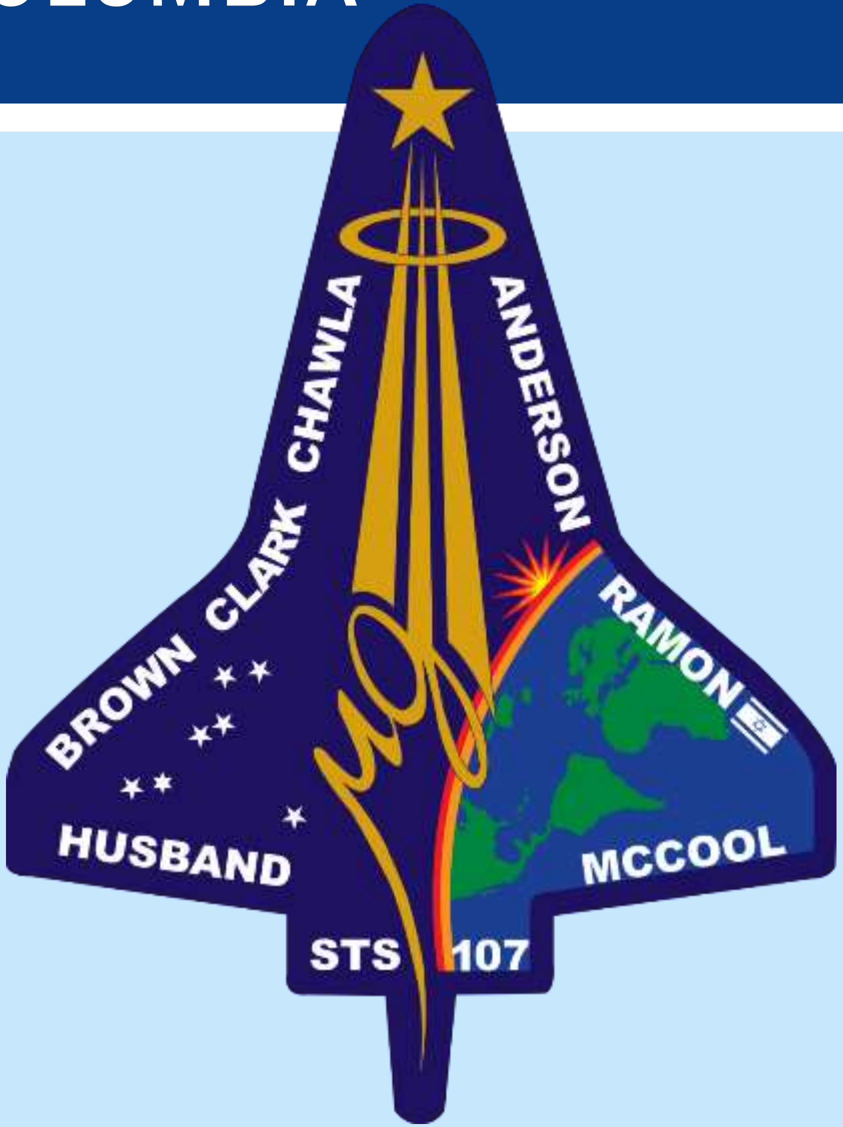
STRESS ECHO

- On ISS Expedition 7, a study demonstrated the feasibility of coupling the HRF US to the cycle ergometer to perform stress echocardiography
- What we learned: Ergonomics are oh so important Cabin video AND ultrasound scanhead video downlink soon followed…

The International Space Station [illegible]sound imaging capability overview for prospective users. Technical report.

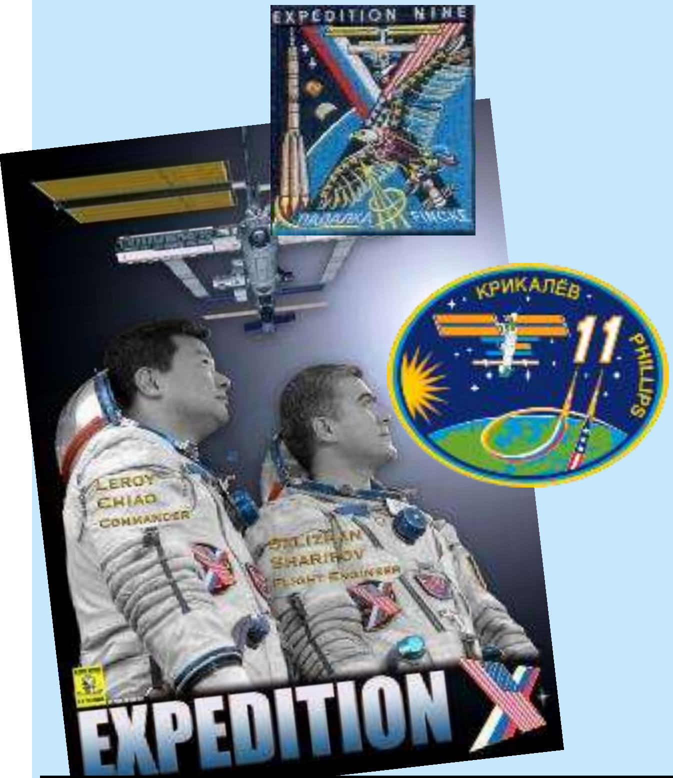
LOSS OF COLUMBIA

- February 1, 2003

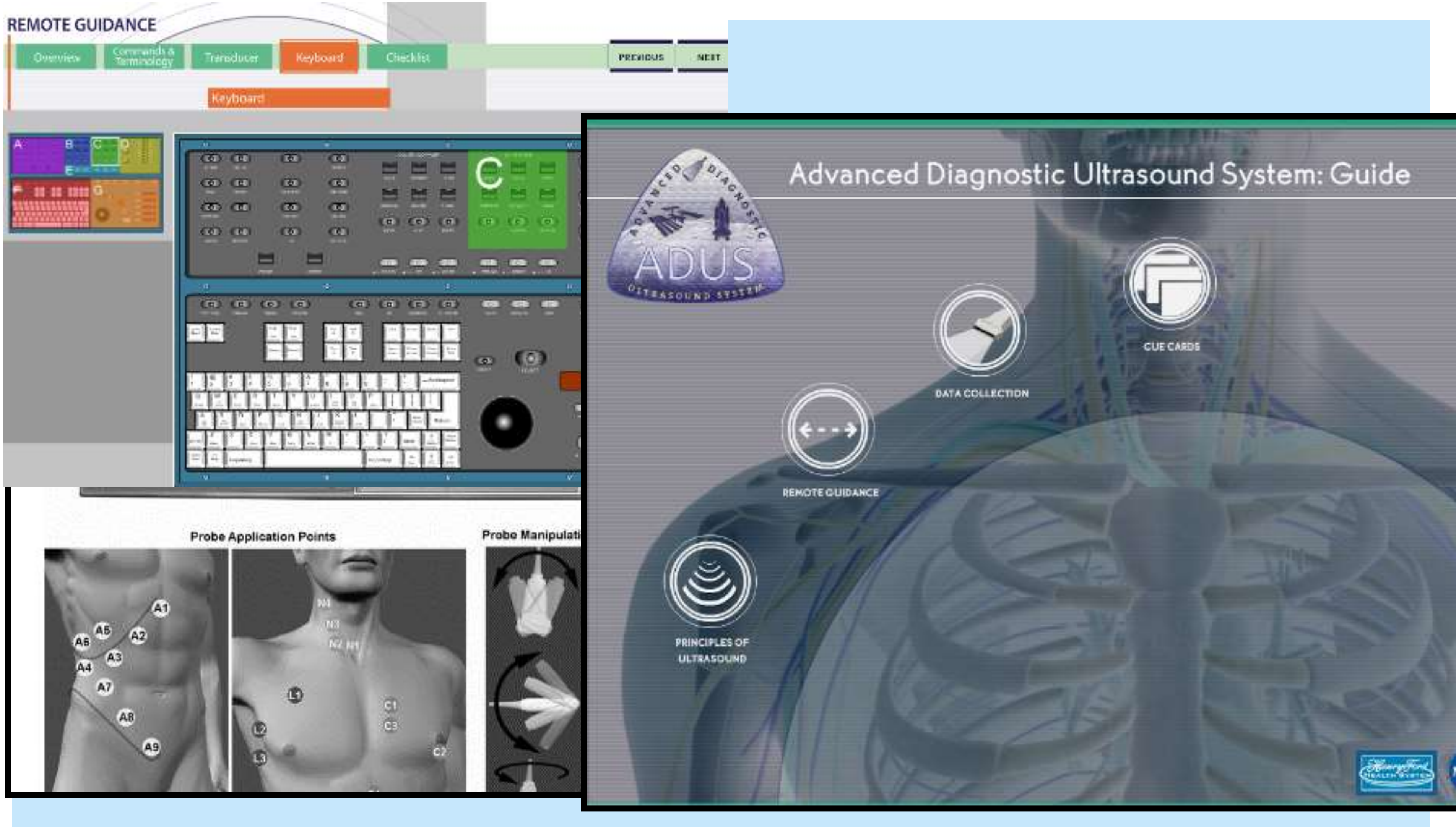


ADVANCED DIAGNOSTIC ULTRASOUND IN MICROGRAVITY (ADUM)

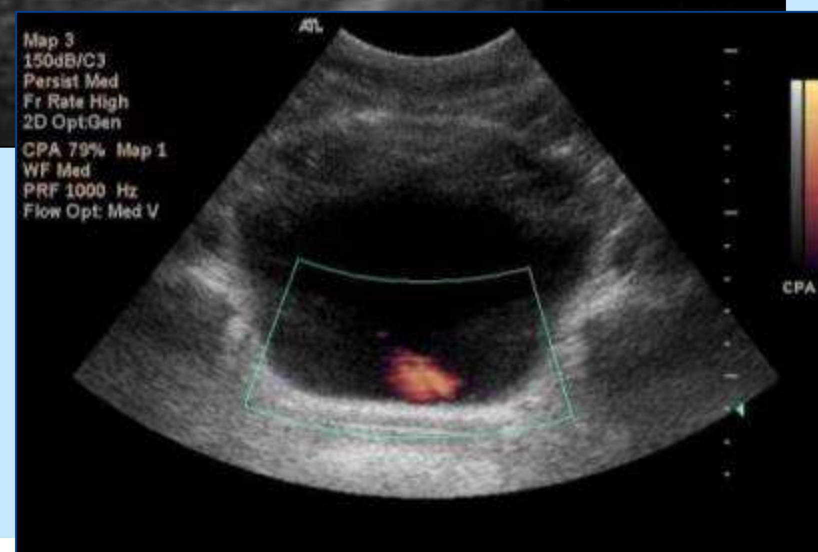
- Expedition 8-11
- 3.5 hours training low impact on reduced ISS crew



ADUM
INTRODUCING "JUST-IN-TIME TRAINING"

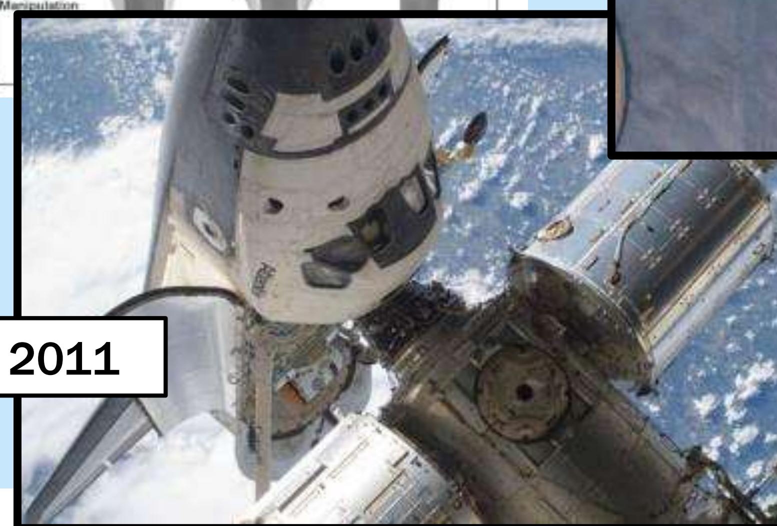



ATL


ATL
Map 3
150dB/C3
Persist Med
Fr Rate High
2D Opt:Gen
CPA 79% Map 1
WF Med
PRF 1000 Hz
Flow Opt: Med V
CPA

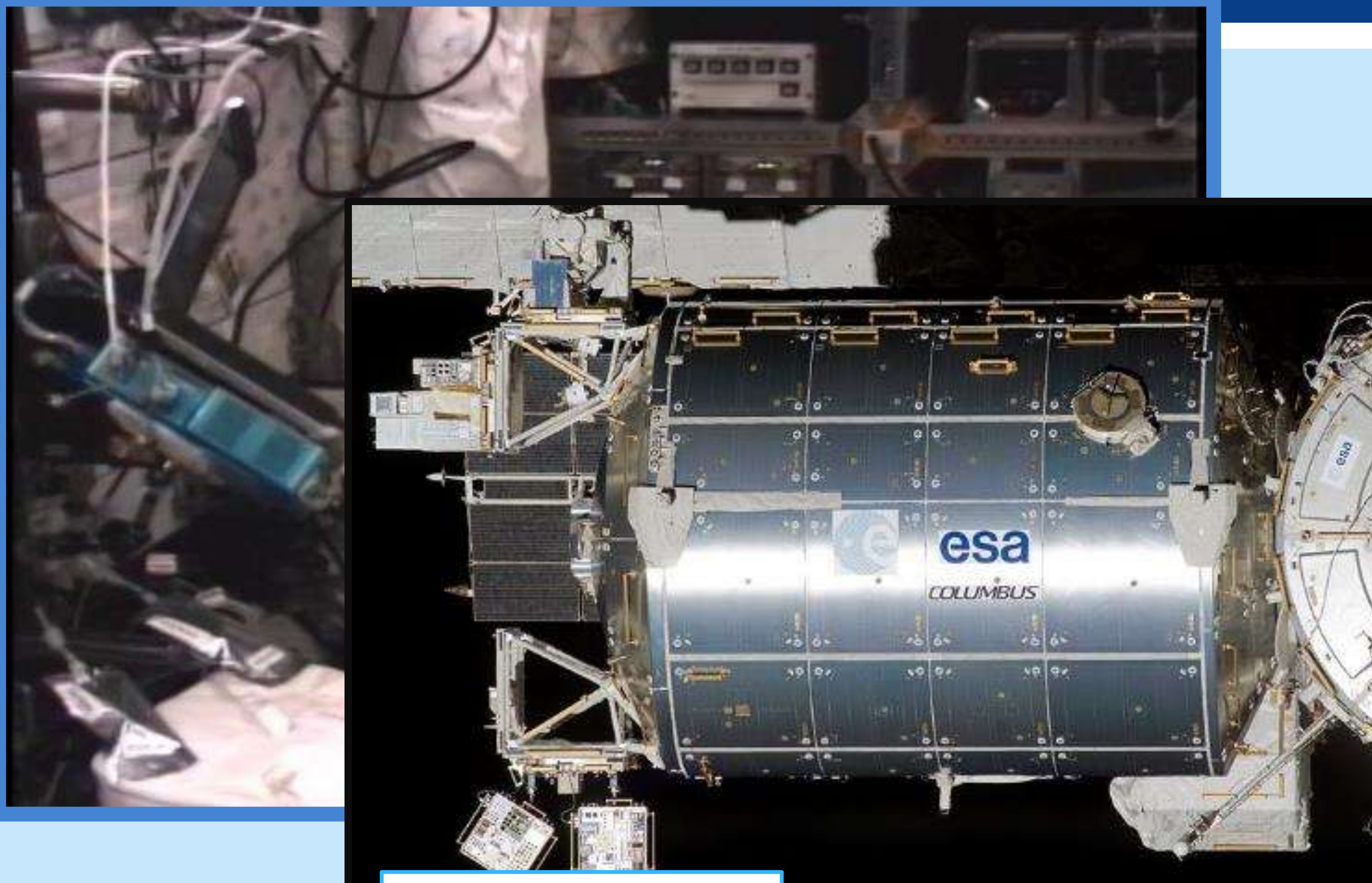
CURRENT ULTRASOUND

July 2011




WATER

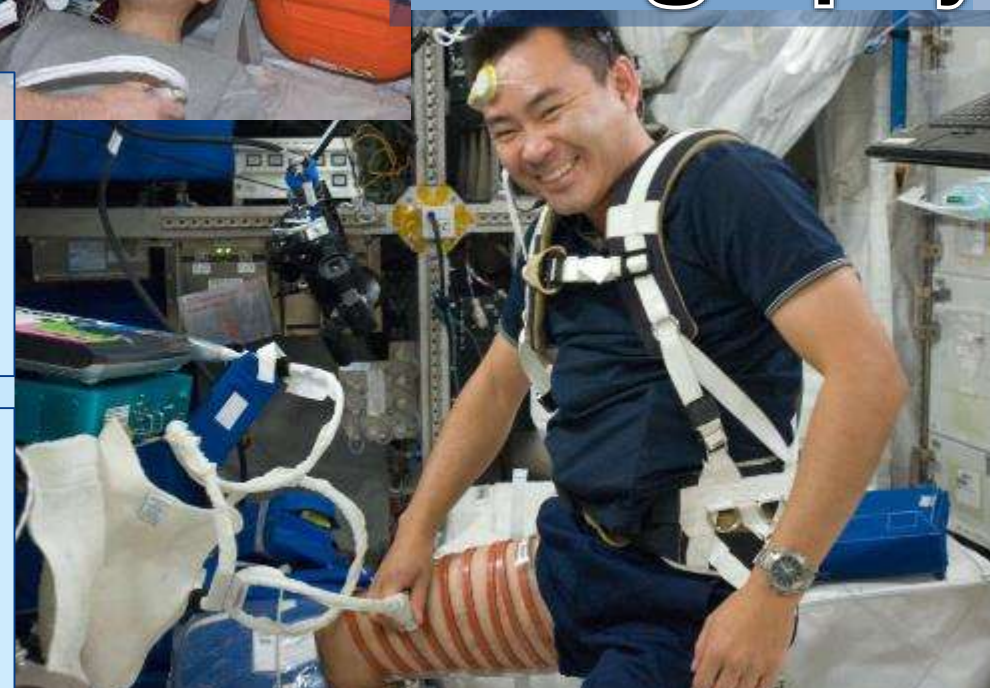
CURRENT ULTRASOUND



Setup: 30m/10m
Stowage: 15m/10m

RESEARCH THAT SPANNED TWO PLATFORMS

Vascular Echography



Integrated Cardiovascular

SPRINT-

integrated resistance and aerobic training

SPINAL ULTRASOUND

Assessing the dynamics of the unloaded spine

Demo of the tool ☺

The Journal of Emergency Medicine, Vol. 46, No. 1, pp. 61–70, 2014

0736-4679/$ - see front matter

ELSEVIER

http://dx.doi.org/10.1016/j.jemermed.2013.08.001

Ultrasound in Emergency Medicine

NEW HEIGHTS IN ULTRASOUND: FIRST REPORT OF SPINAL ULTRASOUND FROM THE INTERNATIONAL SPACE STATION

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*National Aeronautics and Space Administration, Johnson Space Center, Houston, Texas, †Canadian Space Agency, John H. Chapman Space Centre, Saint Hubert, Quebec, Canada, ‡Wyle Science, Technology & Engineering Group, Houston, Texas, and §Department of Surgery, Henry Ford Hospital, Detroit, Michigan

Reprint Address: Scott A. Dulchavsky, MD, PHD, Department of Surgery, CFP-1, Henry Ford Hospital, 2799 W. Grand Boulevard, Detroit, MI 48202

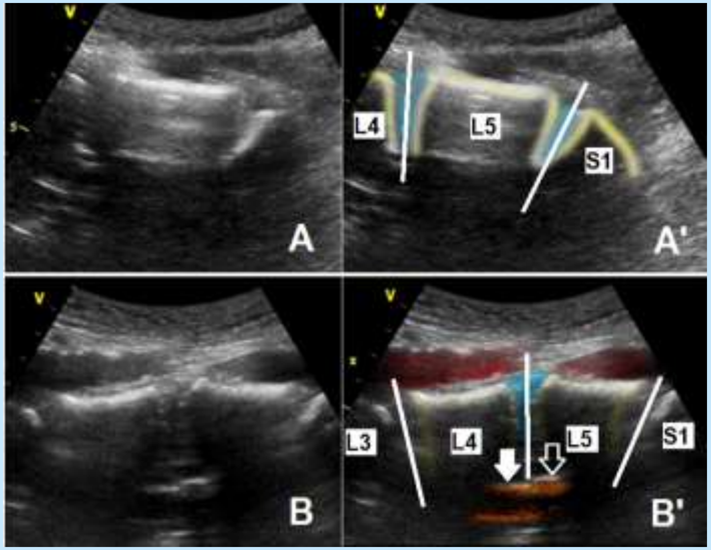
Abstract—Background: Changes in the lumbar and sacral spine occur with exposure to microgravity in astronauts; monitoring these alterations without radiographic capabilities on the International Space Station (ISS) requires novel diagnostic solutions to be developed. Study Objectives: We evaluated the ability of point-of-care ultrasound, performed by nonexpert-operator astronauts, to provide accurate anatomic information about the spine in long-duration crewmembers in space. Methods: Astronauts received brief ultrasound instruction on the ground and performed in-flight cervical and lumbosacral ultrasound examinations using just-in-time training and remote expert tele-ultrasound guidance. Ultrasound examinations on the ISS used a portable ultrasound device with real-time communication/guidance with ground experts in Mission Control. Results: The crewmembers were able to obtain diagnostic-quality examinations of the cervical and lumbar spine that would provide essential information about acute or chronic changes to the spine. Conclusions: Spinal ultrasound provides essential anatomic information in the cervical and lumbosacral spine; this technique may be extensible to point-of-care situations in emergency departments or resource-challenged areas without direct access to additional radiologic capabilities. © 2014 Elsevier Inc.

INTRODUCTION

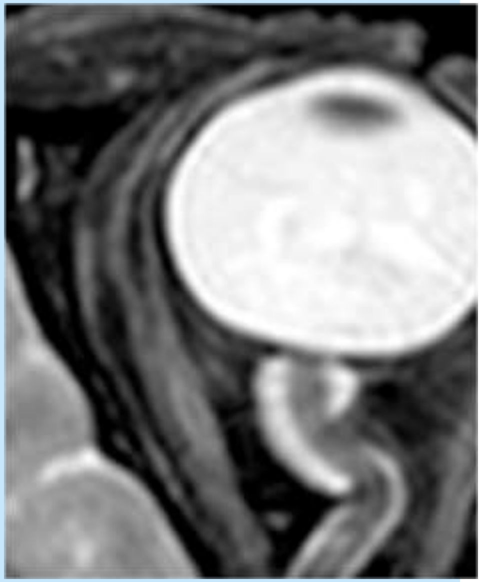
The International Space Station (ISS) medical support infrastructure has the capability to treat minor illness or injury for a crew of six members with a typical mission length of approximately 6 months. Although astronauts are screened for high-risk preexisting conditions, pathological processes may still evolve de novo during missions, and trauma is always a possibility. More common, however, are the variable and mostly transient changes associated with microgravity exposure. Among these, back pain in early days of flight and a pre- to postflight height gain of 2 inches or more is common. Spinal elongation is presumably due to an increase in intervertebral disk (IVD) volume and height, as well as straightening of the physiological curvatures of the spine. The changes to the vertebral column can conceivably increase the risk of trauma during resistive exercise and high-acceleration operations such as landing, especially if the seat configuration becomes suboptimal. Microgravity-induced changes of the spine have been described in literature based on pre- and postflight imaging and anthropometric measurements, but no in-flight spinal imaging has been attempted (1–7).

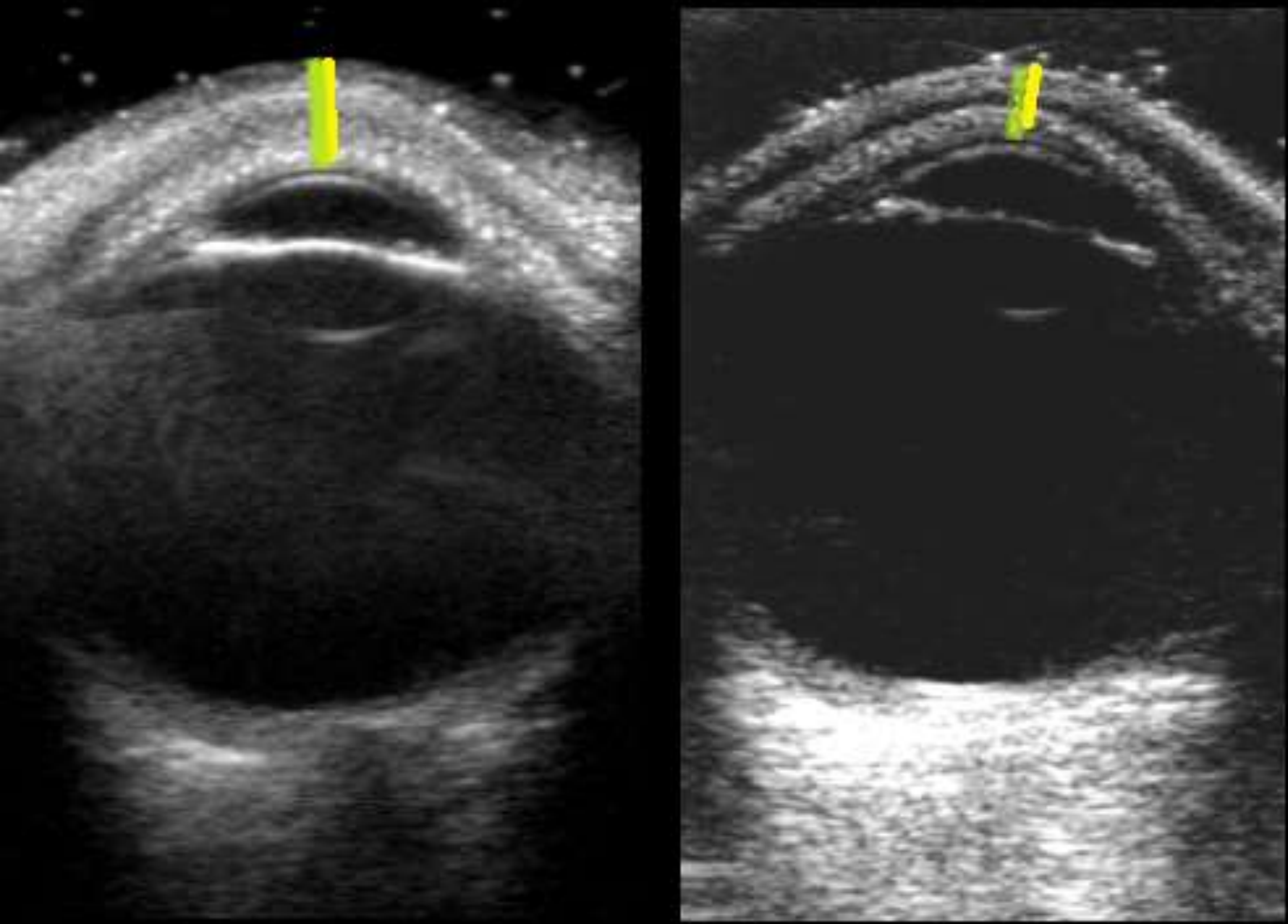
SPACE SPECIFIC TELE-ULTRASOUND EXAMS

- Measuring Microgravity Spinal Changes

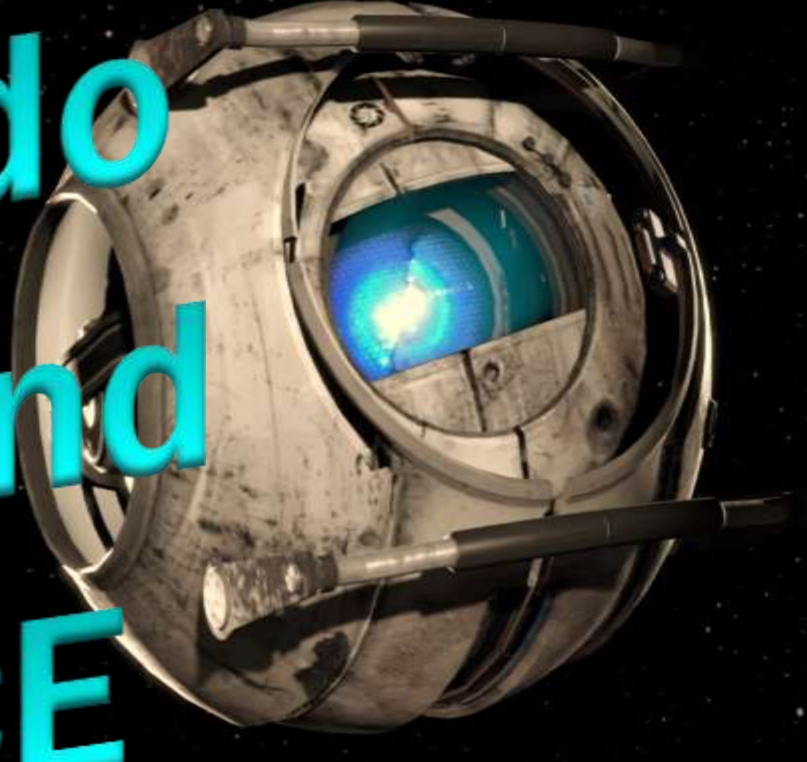


- Eye – ICP Changes

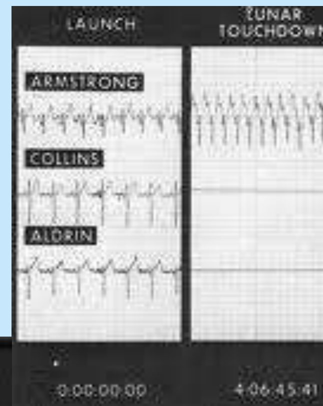


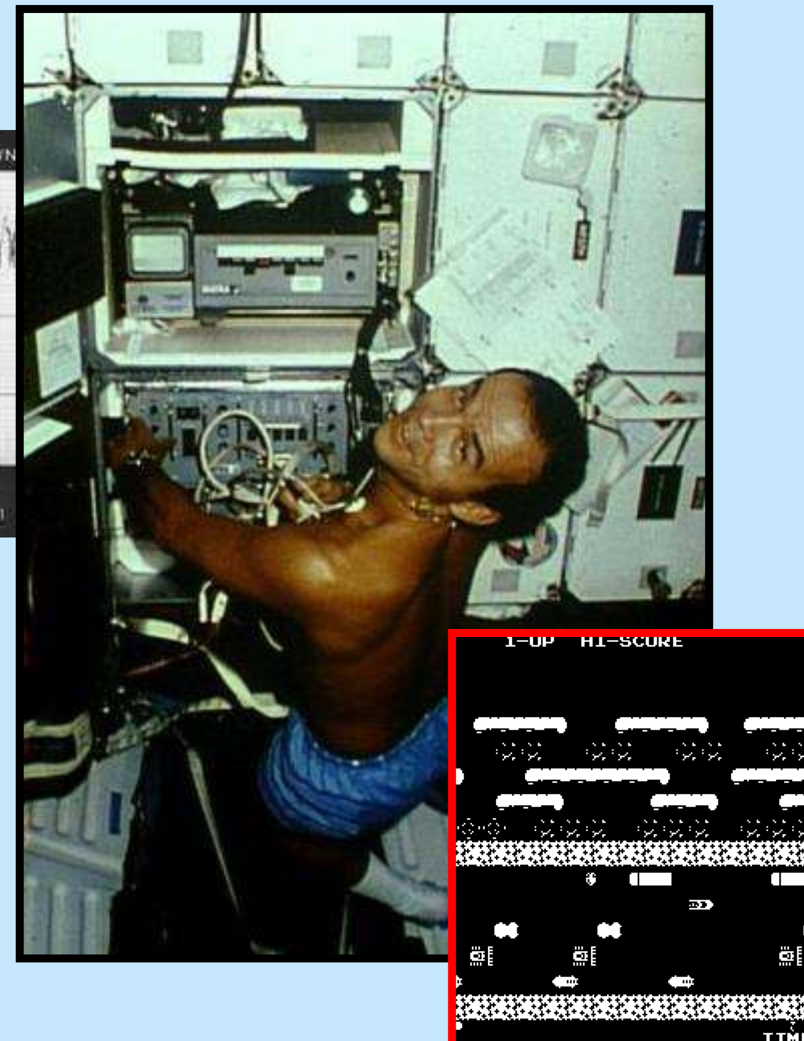


How to do Ultrasound in SPACE



SPACE MEDICINE =TELEMEDICINE

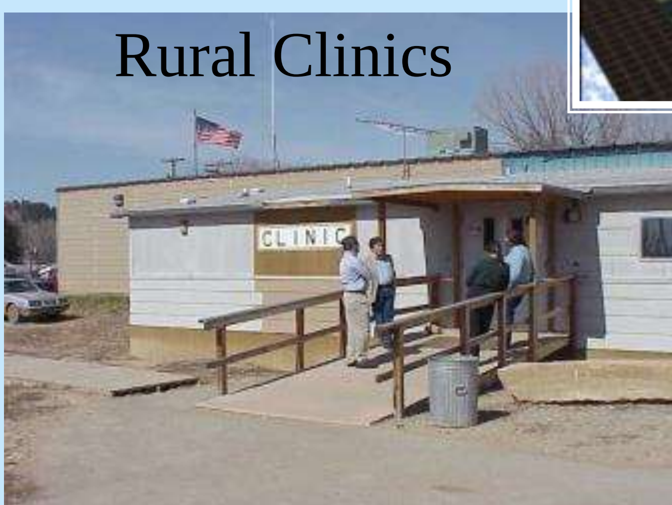





Research Expeditions


Battlefield/ First
Echelon/Disaster Relief


SPACE STATION


Rural Clinics


Offshore Rigs

TRAINING AND MEDICAL U/S

2.5 hours basic training

1. Generic equipment training is shared among all current research and Medical Operations

2. Experiment specific training- training time 60-120m /each experiment

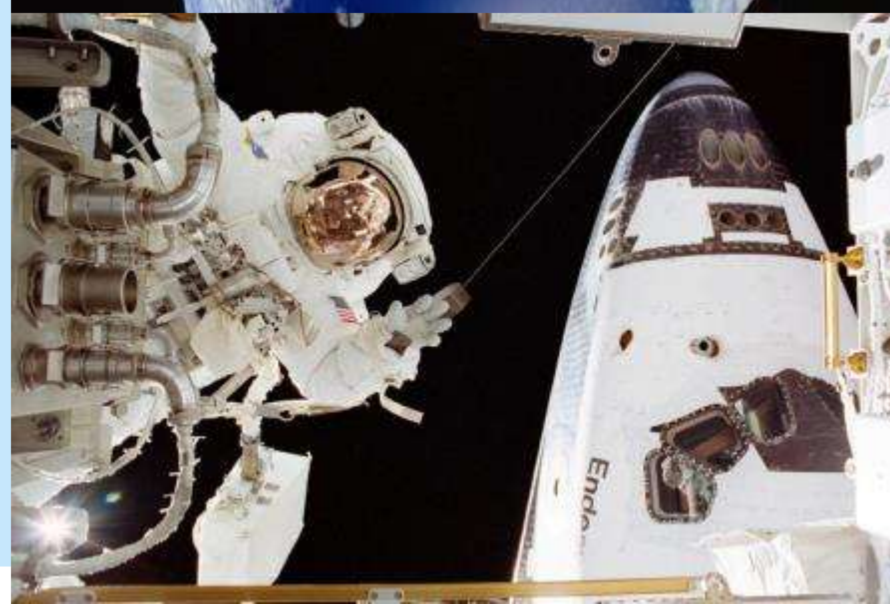
Ocular Health, Spinal Ultrasound, Sprint, Vascular .....

TRAINING

- Operator
  - Some familiarity with hardware
  - At least one hands on session
    - Especially important for non-clinical operators
    - Builds confidence more than skill
  - Just-in-time training
- Remote Guidance Expert
  - Ultrasound expert is not automatically a tele-ultrasound expert
  - Intimate knowledge of hardware
  - Ability to communicate changes in probe position
  - Ability to recognize frustration in operator
  - Quick and concise commands
  - Practice, practice, practice

WHAT IS A CREW MEDICAL OFFICER

- Most are non-physicians
- 30-60 hours medical training (1-2 hours of ultrasound)
- Training can occur up to 18 months before flight
- Very little hands-on experience
- Buddy Medicine
- Secondary Role



ULTRASOUND EXPERTISE DISTRIBUTION

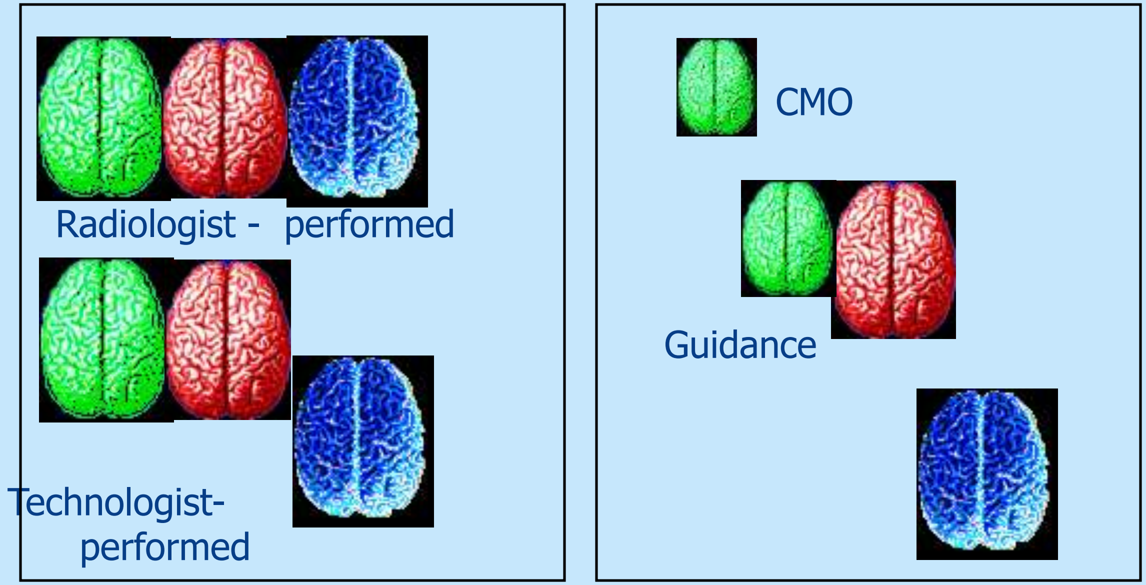
Operation of hardware
scanning technique

Scanning protocols/
data acquisition

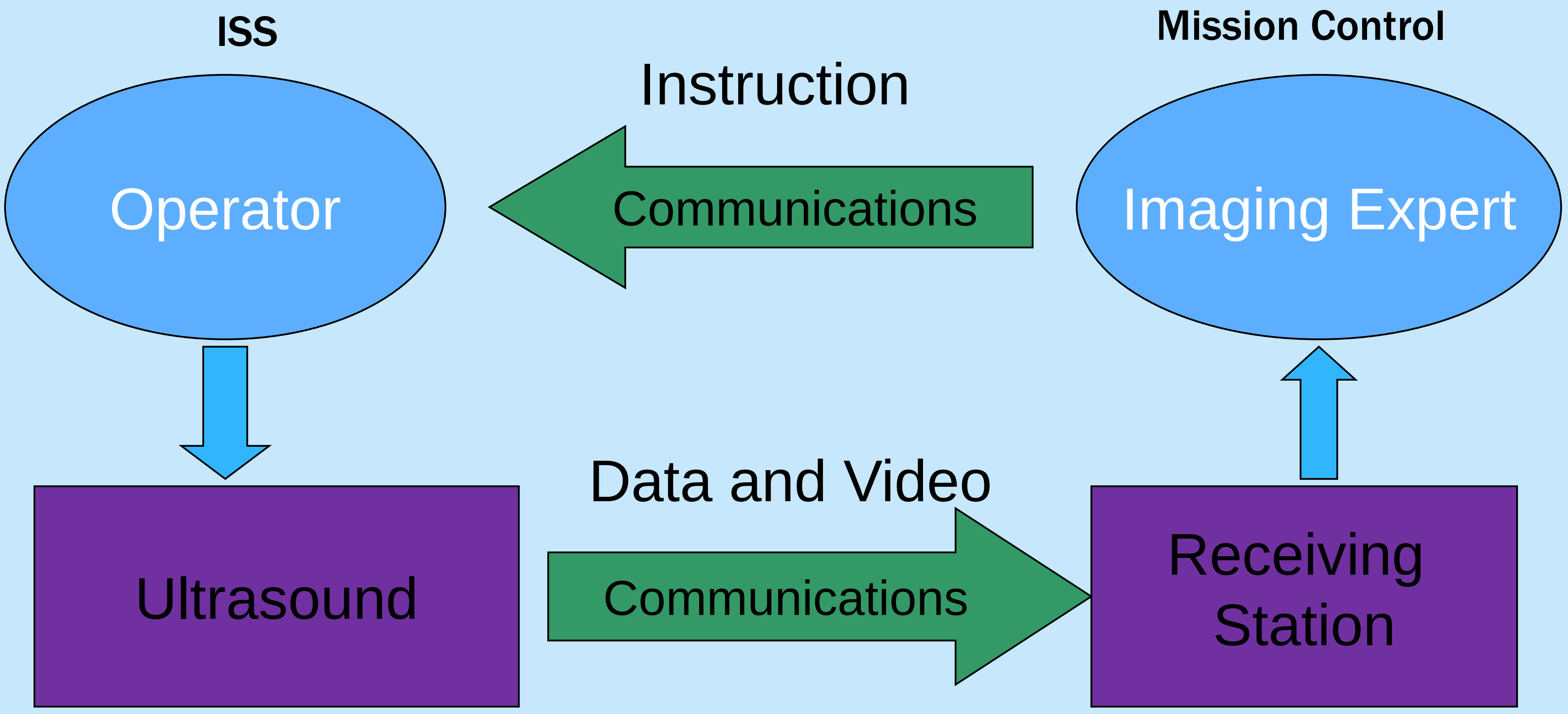
Final Interpretation ,
imaging report

Terrestrial models

“Remote” Model
- current ISS



TELE-ULTRASOUND



ISS COMMUNICATIONS INFRASTRUCTURE

- Big pipe
  - 150 Mbps down
  - 25 Mbps up
- Availability
  - 2-second delay
  - Guaranteed intermittent coverage

COMMUNICATIONS TIME LINE

7 Hours

= KU=VIDEO

= S=AUDIO

TOOLS FOR REMOTE GUIDANCE

- Common terminology
  - Clinical/non-clinical operator
- Common references
  - Cue Cards
  - Reference (Target) Image sets
- Pre-event Training
- Computer-Based Training
- Focused Protocols

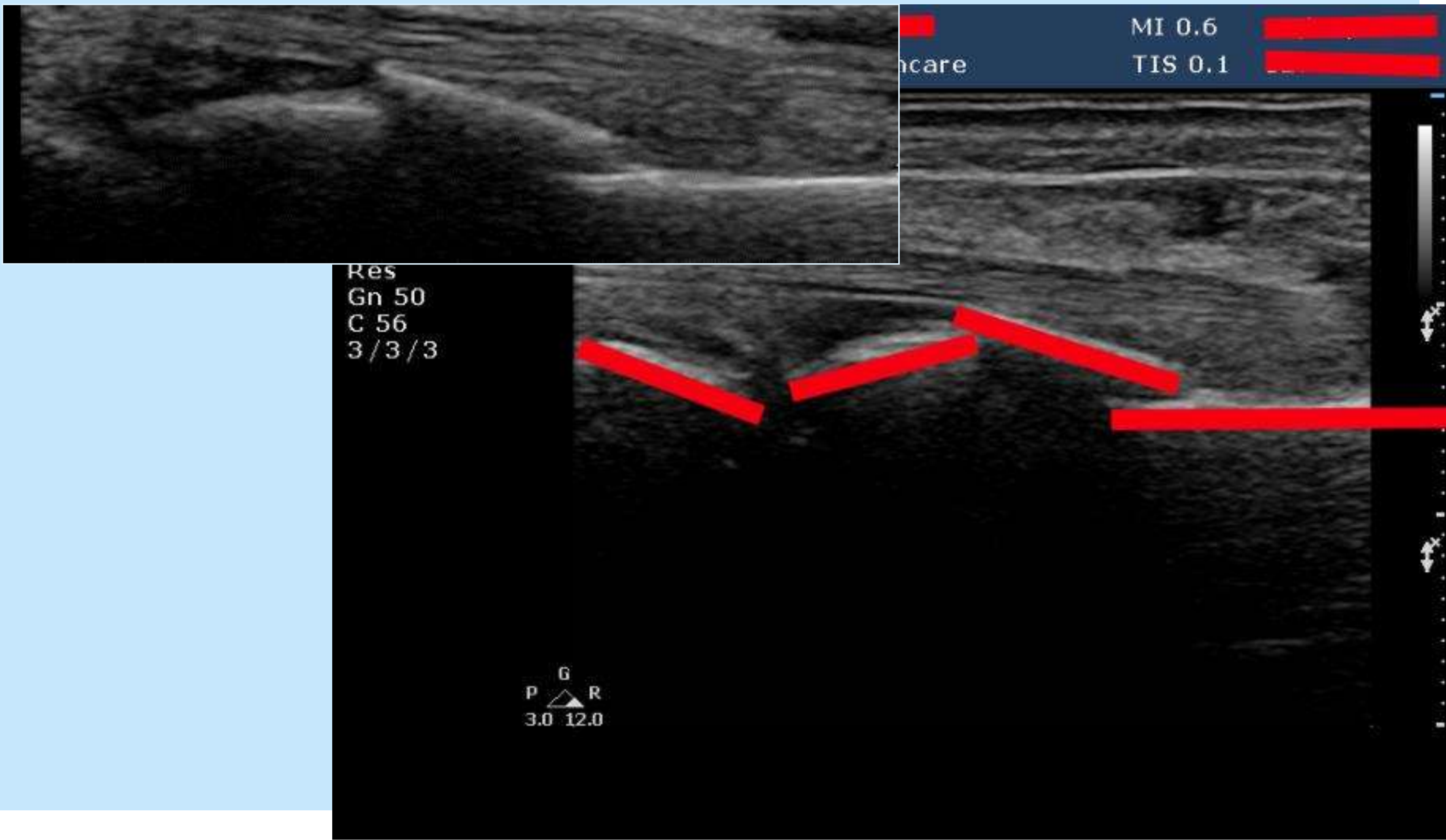
FOCUS ON THE QUESTIONS TO BE ANSWERED

- Clinical Questions
  - Can we narrow the diagnosis?
  - What treatments are necessary?
  - Can we treat on ISS or not?
- Operational Questions
  - Do we need to transport to the ground?
  - Can the patient continue working?
  - Do we need to stop the mission?

FOCUSED TELE-ULTRASOUND EXAMS

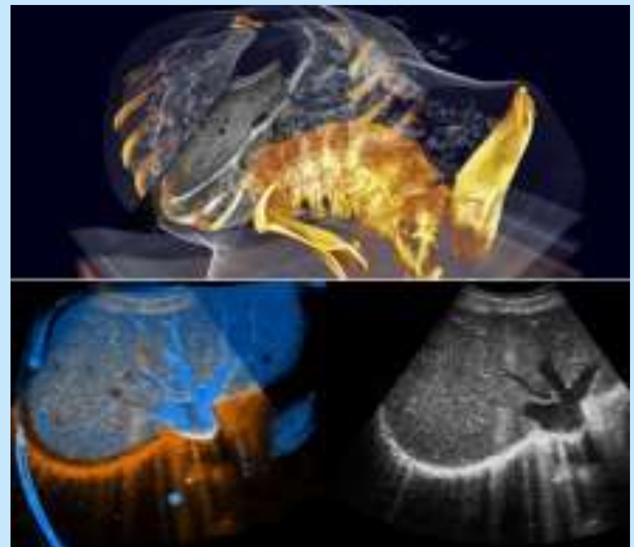
- Looking for overt changes
- Just enough data to answer the questions
  - If time permits additional information can be gathered
- Make decisions on the information available
  - "Results are indeterminate – clinical correlation recommended" - Not an option

FRACTURE



MOVING BEYOND ISS

- Re-think Tele-ultrasound/telemedicine
  - Communication delay 5-20 minutes
  - Return - weeks, if not impossible
  - Limited re-supply
- Requires clinical expertise on board
- Smarter medical devices/image recognition
- Diagnosis and Decision Support
- Store and Forward support from the ground



SUMMARY

Ultrasound: since 1982

ISS: Permanent capability since 2002

- Available for any investigations – standalone or multi-modality
- Medical requirement since 2003
- Occupational surveillance use (VIIP) since 2009

Equipment sophistication → more science

More science → smarter protocols and efficiency/lower cost per experiment (assumed)

Increasing the scientific output of ISS

CITATIONS AND REFERENCES

Slide	References
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