Psychophysiology of Spaceflight and Aviation

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Psychophysiology

- Investigates the relationship between physiology and behavior.
- Examines the impact of environment on health and performance

Primary Mission Goal of Space Human Factors

Enable a permanent human presence in space

Develop protocols to:

- Accurately assess spaceflight effects (zero-gravity, confinement) on crew health, safety, and performance.
- Evaluate and test countermeasures that will remedy these environmental effects.

Technical Background

- Extended spaceflight affects physiology with associated adverse effects on crew performance and health.
- Other factors like workload, isolation, fatigue, etc. are known to effect operational efficiency.
- There is a wide range in the ability of individuals to adapt to space and re-adapt to Earth.
- Future crew complements:men and women, multi-cultural, different professional backgrounds and physical condition.

Statement of Problem

Methods are needed:

- to examine individual differences in crew responses to extended spaceflight
- to evaluate the efficacy of countermeasures for individuals

Psychophysiological Research Laboratory

Assessment Tool: Converging Indicators

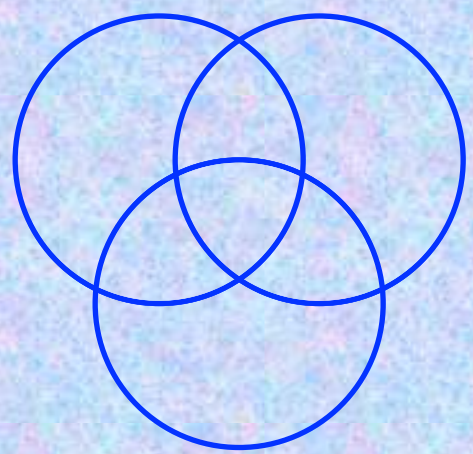
- physiological measures
- performance metrics
- standardized self-report scales

Correction Tool: Autogenic Feedback Training Exercise

- AFTE is a 6-hour physiological conditioning program

Converging Indicators

Physiology
(ANS and CNS responses)



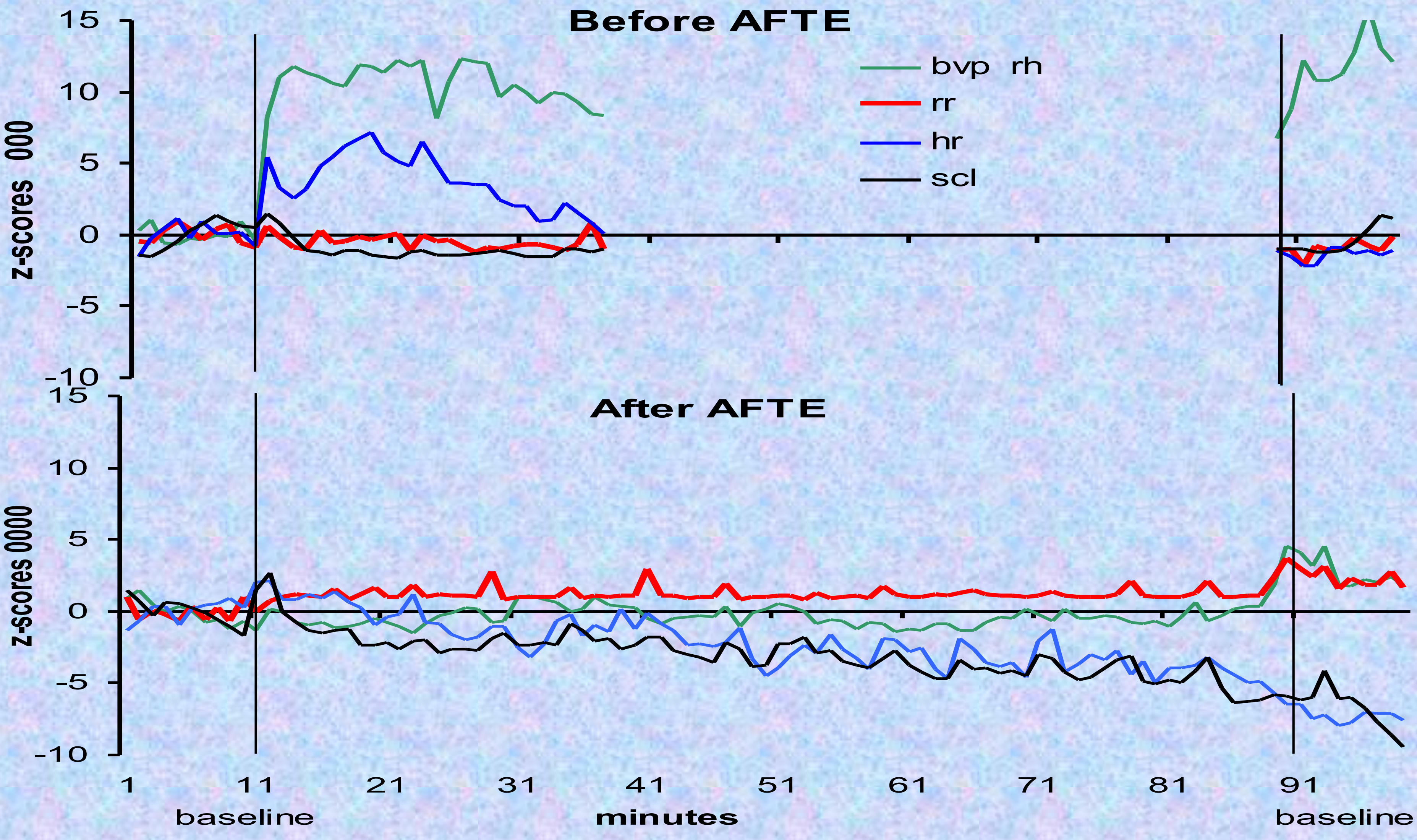
Subjective States
(mood, symptoms)

Performance
(cognitive, perceptual, neuromotor)

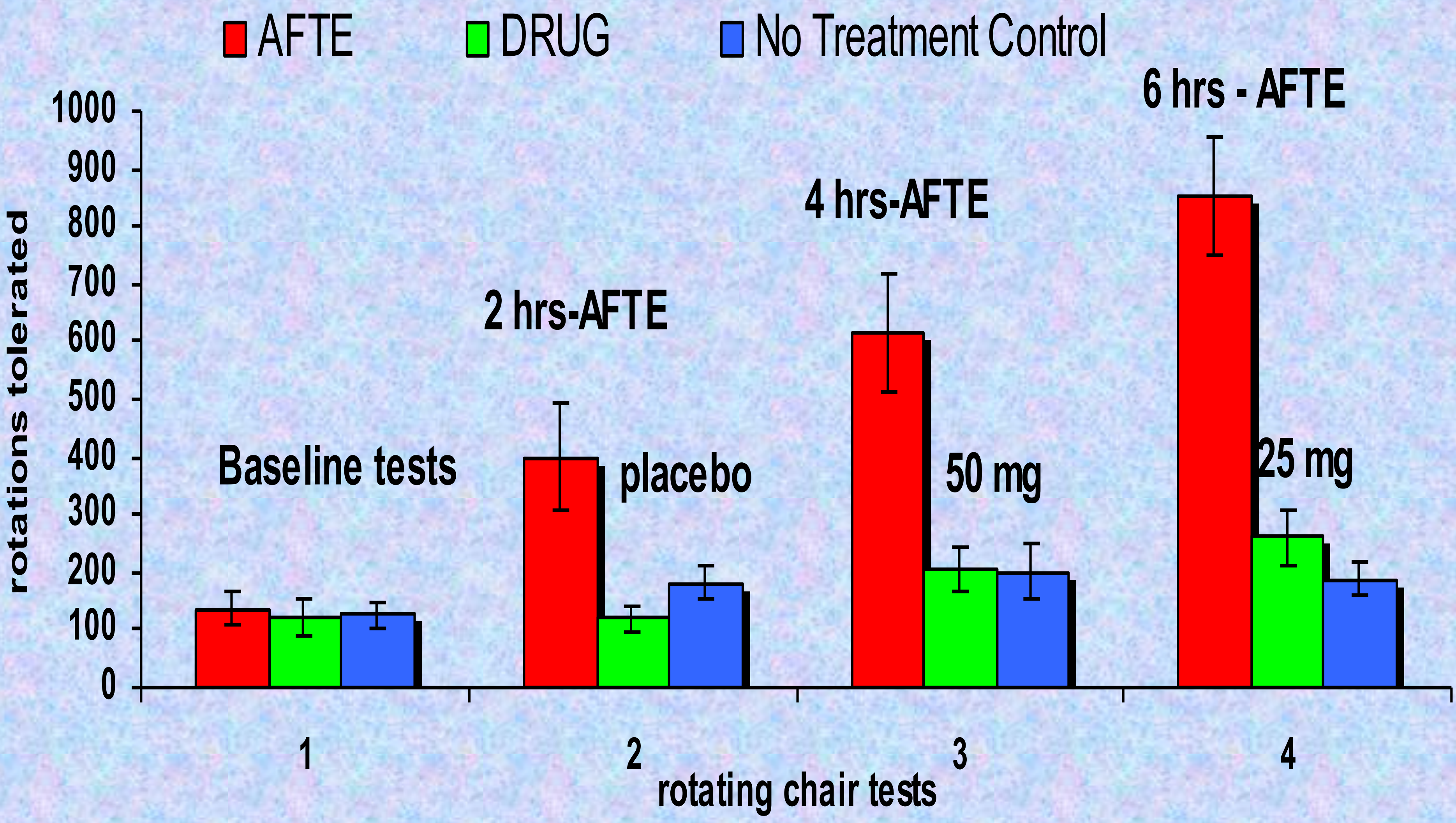
AFTE to Control Motion Sickness

- AFTE reduces physiological response levels to motion sickness stimuli
- Subjects tolerate rotating chair tests longer, at higher speeds, and with fewer symptoms

AFTE Reduces Physiological Responses to Motion Sickness Stimuli and Improves Tolerance



Changes in Motion Sickness Tolerance



Summary of Motion Sickness Research

- ✓ Total suppression of motion sickness in 65% of subjects.
- ✓ Significant improvement in tolerance in 85% of subjects
- ✓ No difference between men and women in learning symptom control.
- ✓ Learned autonomic control is retained up to 3 years with rapid relearning.
- ✓ Initial susceptibility to motion sickness is unrelated to training effectiveness.
- ✓ Control of motion sickness symptoms transfer across multiple environments.
- ✓ Training is an effective treatment for airsickness in military pilots flying high performance aircraft.

Preflight Training in 0-G Aircraft

Preflight Training During Shuttle Simulations

Background

Autogenic-Feedback Training Exercise: AFTE

A 6-hour training method used to teach voluntary control of physiological responses and normalize autonomic balance. Patented by NASA in 1997.

Spaceflight research

Originally tested as a countermeasure for space motion sickness

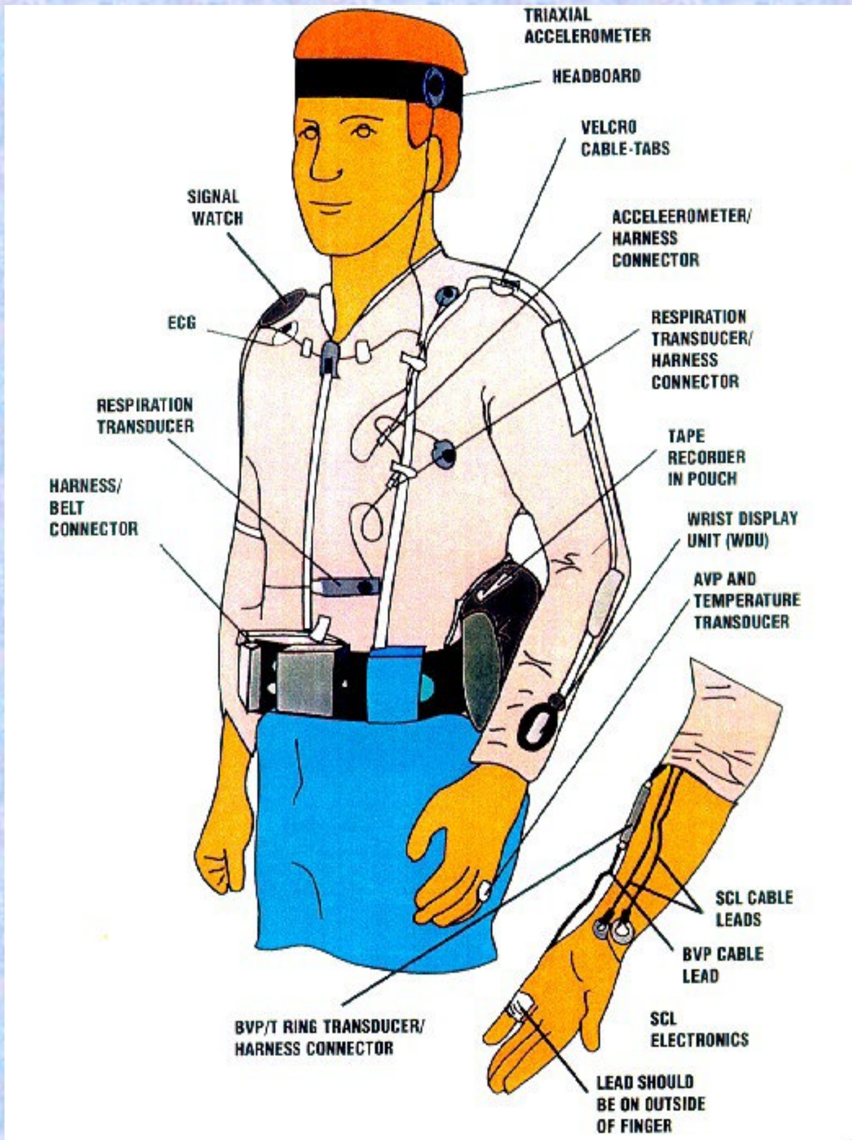
Ground-based research

- reduces or eliminates motion sickness
- improves pilot performance under emergency conditions
- relieves nausea and syncope in dysautonomia patients
- effective control for increasing blood pressure

Physiological Measures

Autogenic Feedback System-2

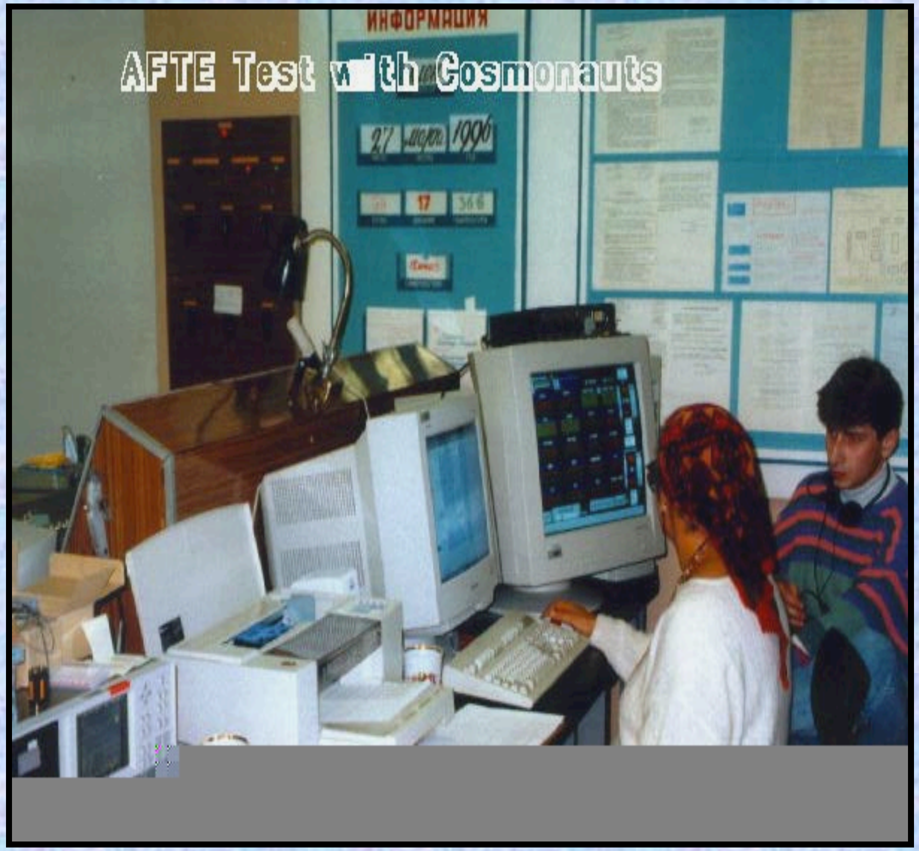
- skin temperature
- skin conductance level
- heart rate
- respiration rate



Special Equipment Used During Early AFTE Research

Autogenic Clinical Laboratory System
PC-Based Training

Autogenic Clinical Laboratory System
Training Cosmonauts in Russia

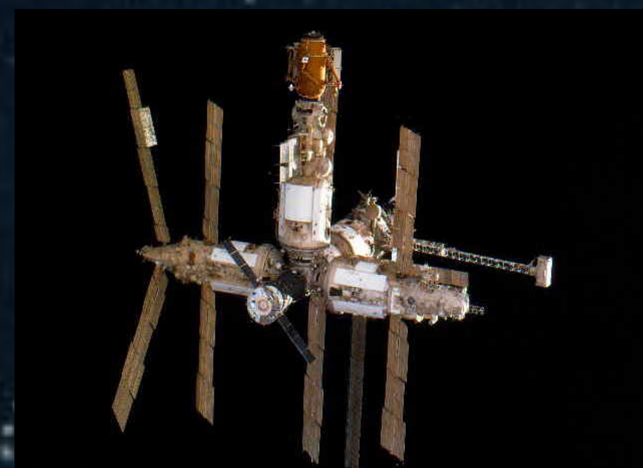


AFTE Trainer Controls 20 Displays

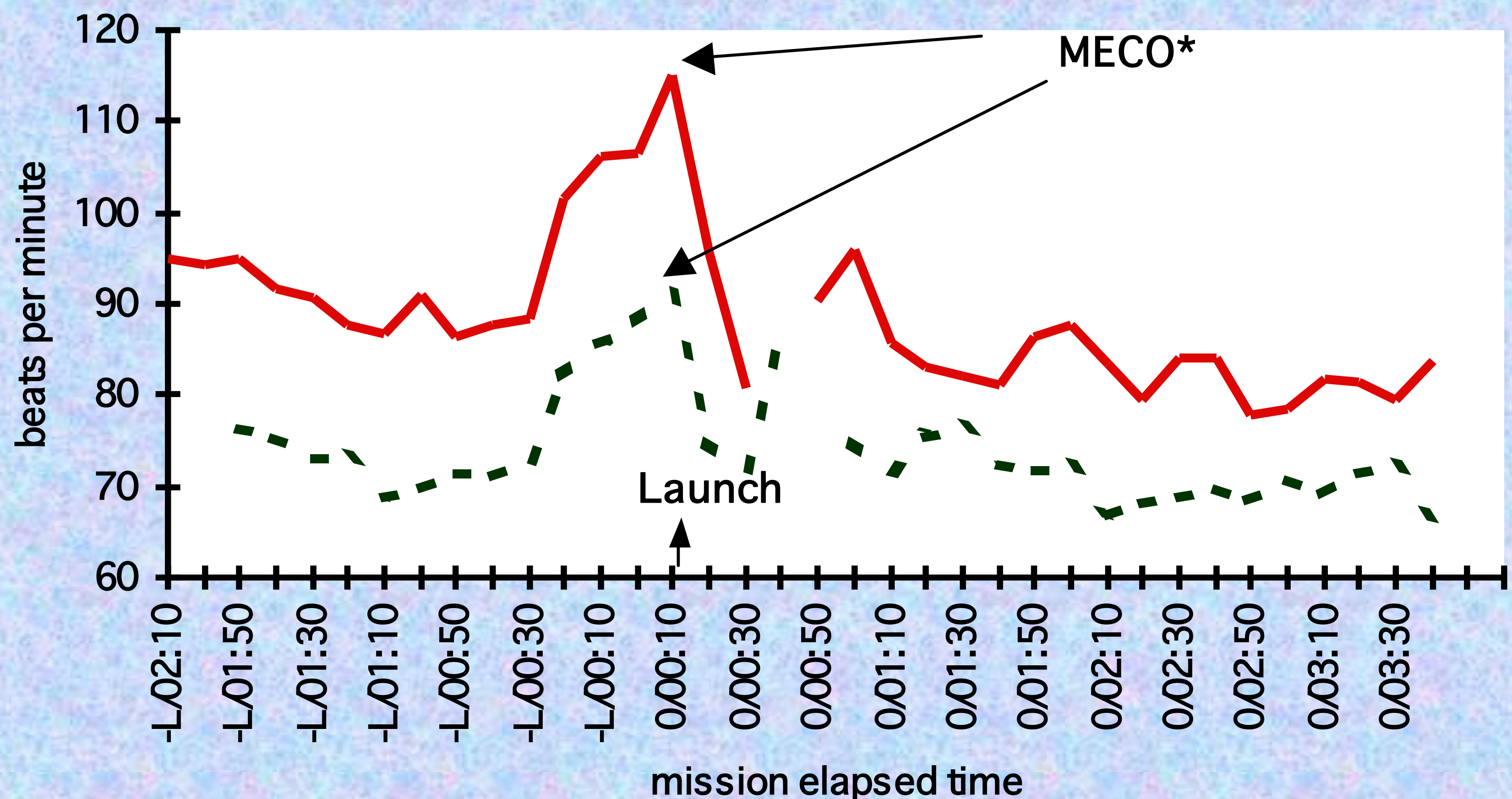
1. Blood Volume Pulse left hand
2. Blood Volume Pulse right hand
3. Respiration Rate
4. Heart Rate
5. Skin Conductance Level
6. Hand temperature
7. Blood flow – head
8. Blood flow – toe
9. EMG – left arm
10. EMG – right arm
11. EMG – left leg
12. EMG right leg
13. Systolic Blood Pressure
14. Diastolic Blood Pressure
15. Mean Arterial Pressure
16. Thoracic Fluid Volume
17. Stroke Volume
18. Cardiac Output
19. Total Peripheral Resistance
20. Vagal Tone

Exercising Smooth Muscle to Normalize Autonomic Balance

Human Responses on Earth and in Space

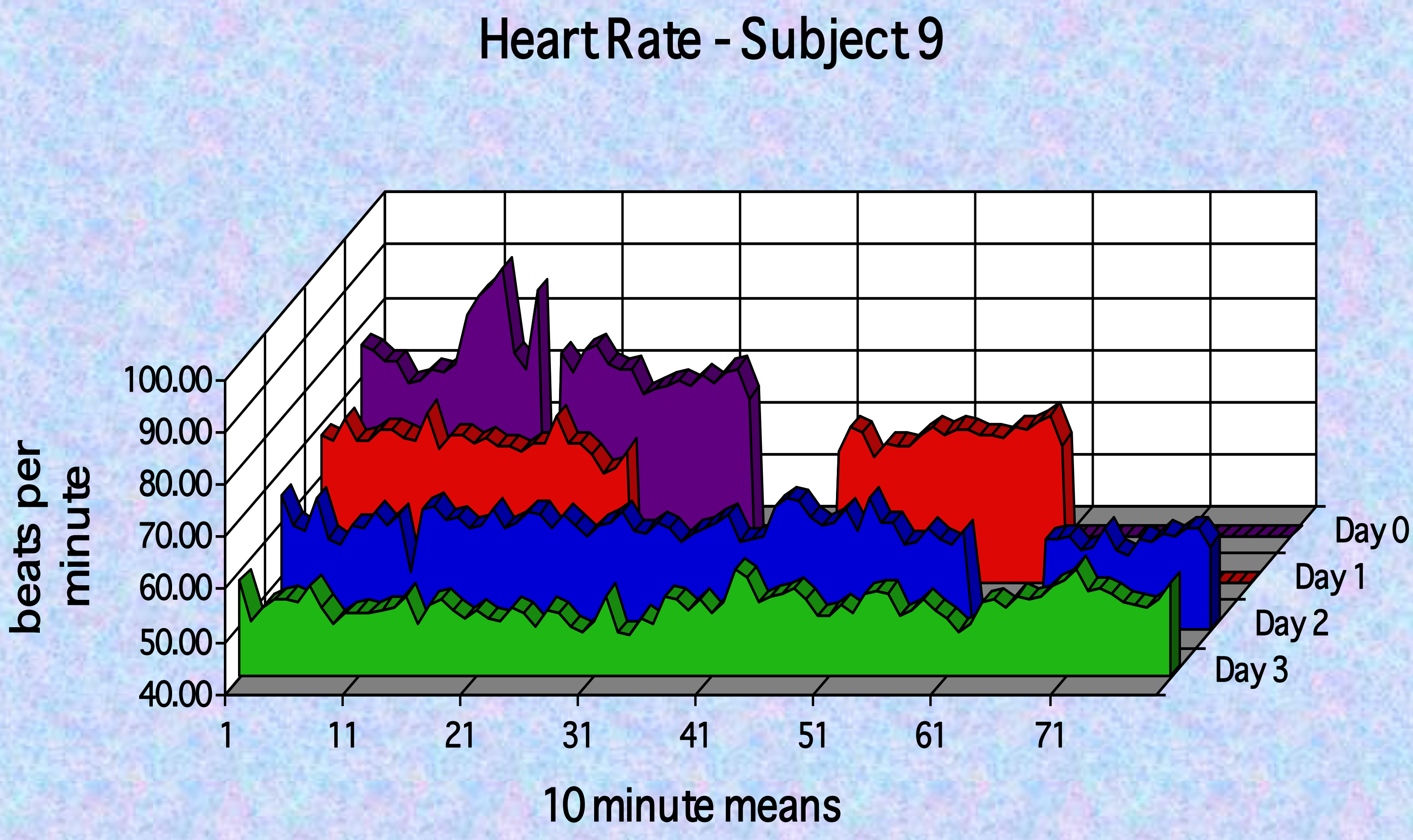


Heart Rate Response During a Space Shuttle Launch



*MECO= Main Engine Cut-Off

Heart Rate Decreases Over Days of Early Exposure to Microgravity



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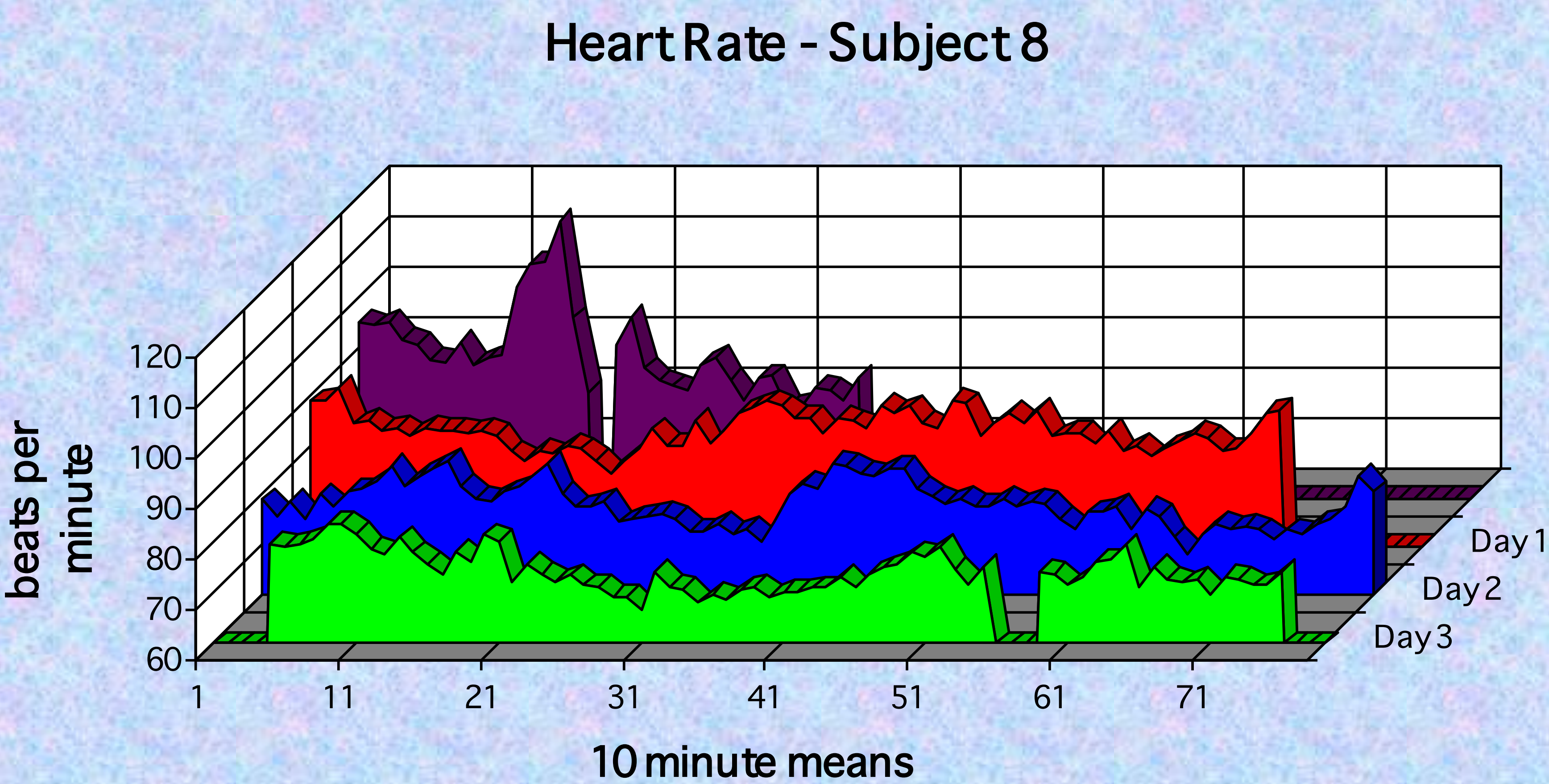

AFS-2 in Space

Donning and Doffing

Control of Autonomic Responses During Long-Duration Space Flight

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Objectives

- ✓ To facilitate adaptation to space and readaptation to Earth.
- ✓ To compare training effects on control of autonomic responses in space to those effects observed during ground-based AFTE
- ✓ To determine AFTE effects on postflight orthostatic tolerance.
- ✓ To examine AFTE effects on cognitive and psychomotor performance mood states, sleep quality, and motion sickness.

Methods

Preflight

- ✓ To provide 6 hours of preflight AFTE to cosmonauts
- ✓ To test training effects during tilt-table tests

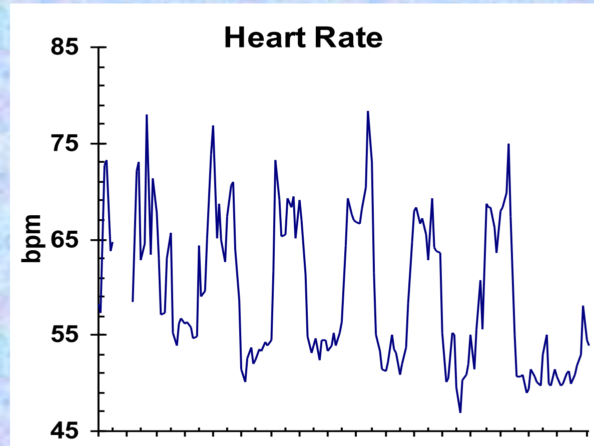
Inflight

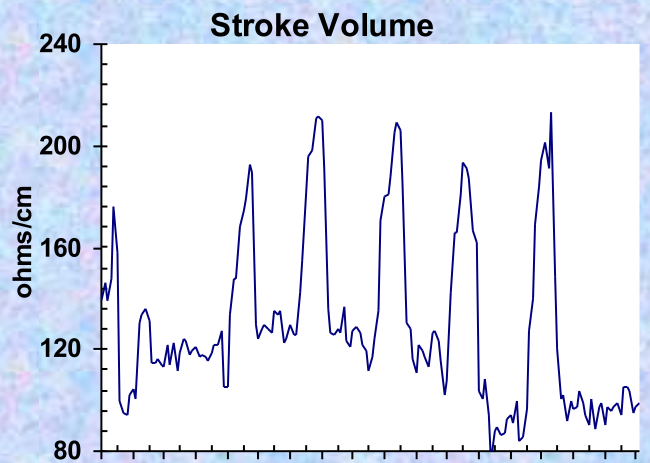
- ✓ 8-days of ambulatory monitoring (AFS-2) at 30-day intervals
- ✓ Each flight day included:
  - Three 15-minute AFTE sessions
  - Cognitive and psychomotor tasks
  - Vestibular perception tests
  - PC-based self-reports of mood states, sleep and symptoms

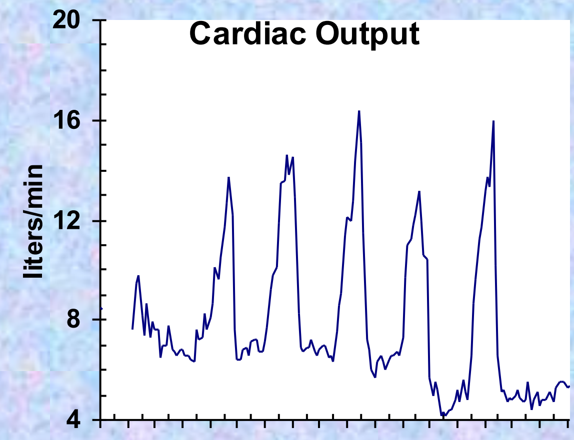
Postflight

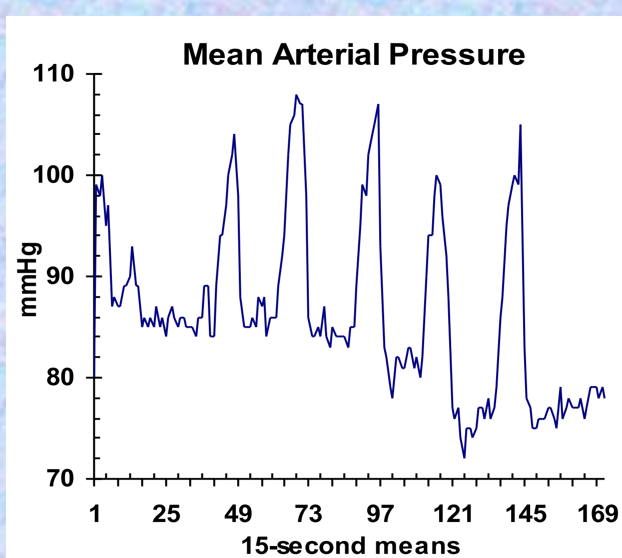
- ✓ Tilt-table tests of orthostatic tolerance
- ✓ Crew debriefings

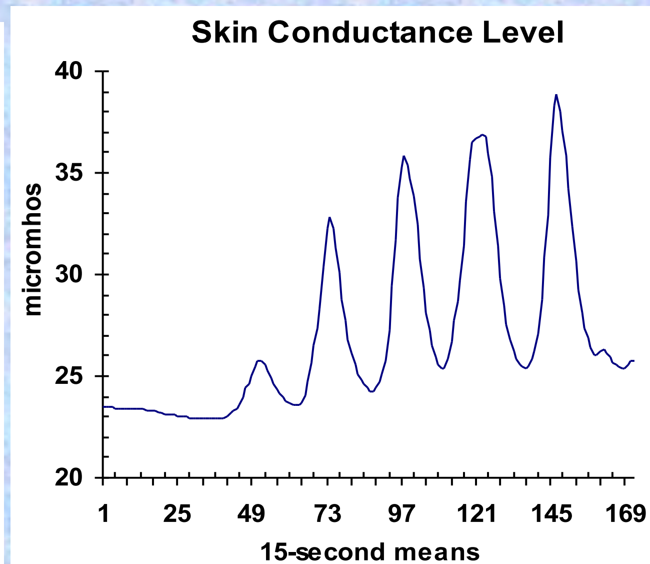
Subject 1 Final Preflight AFTE Session

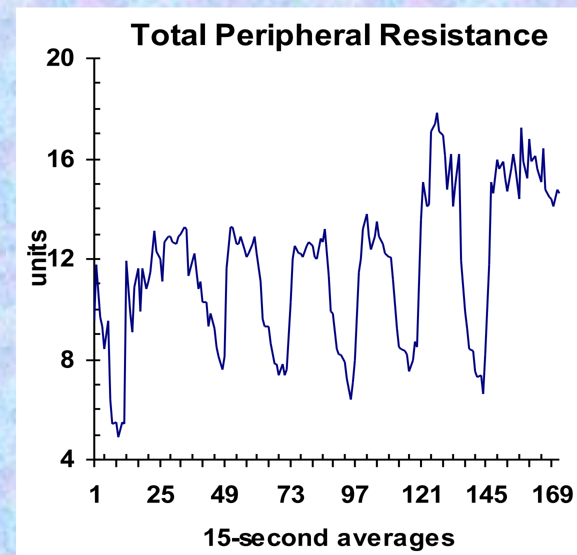




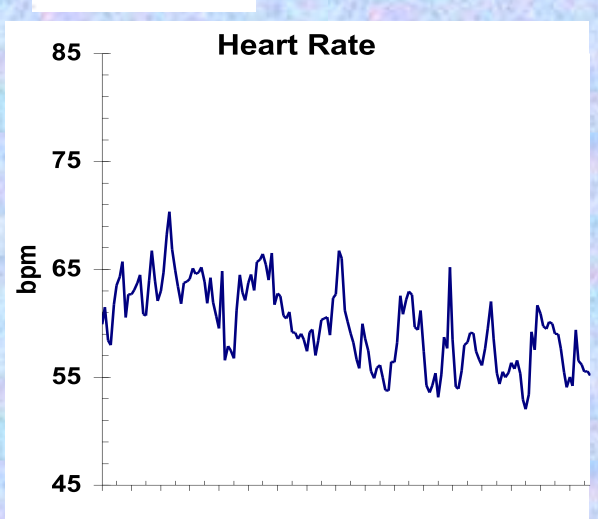


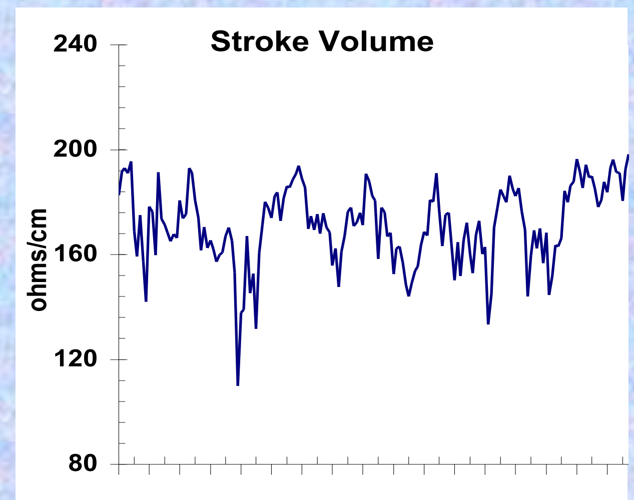


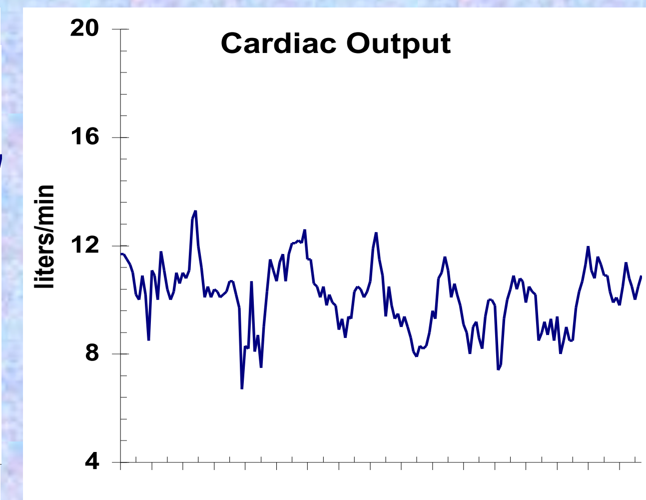


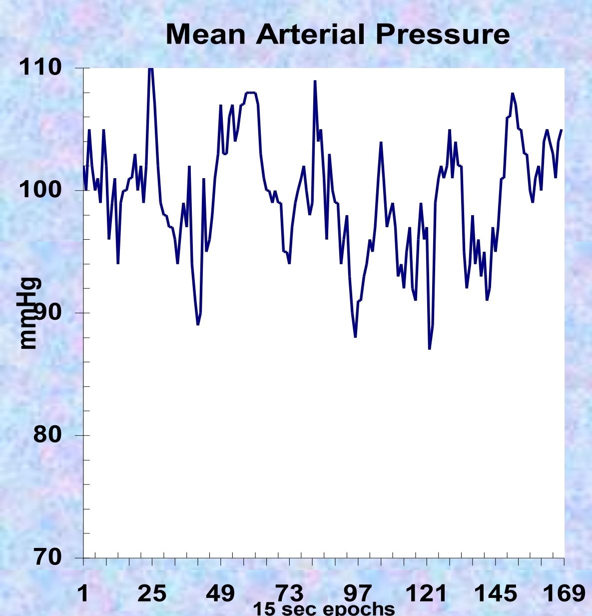


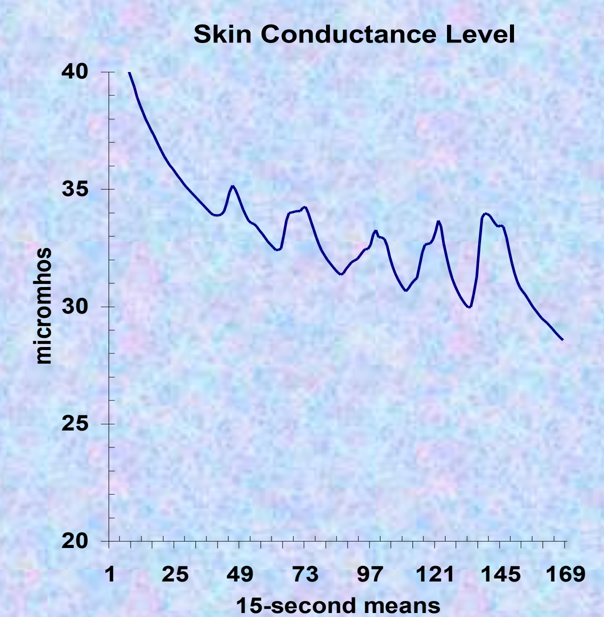
Subject 2 Final Preflight AFTE Session

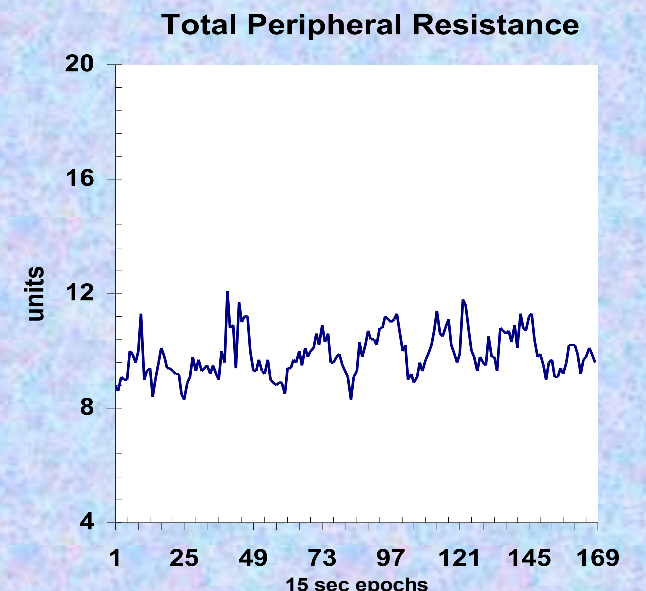




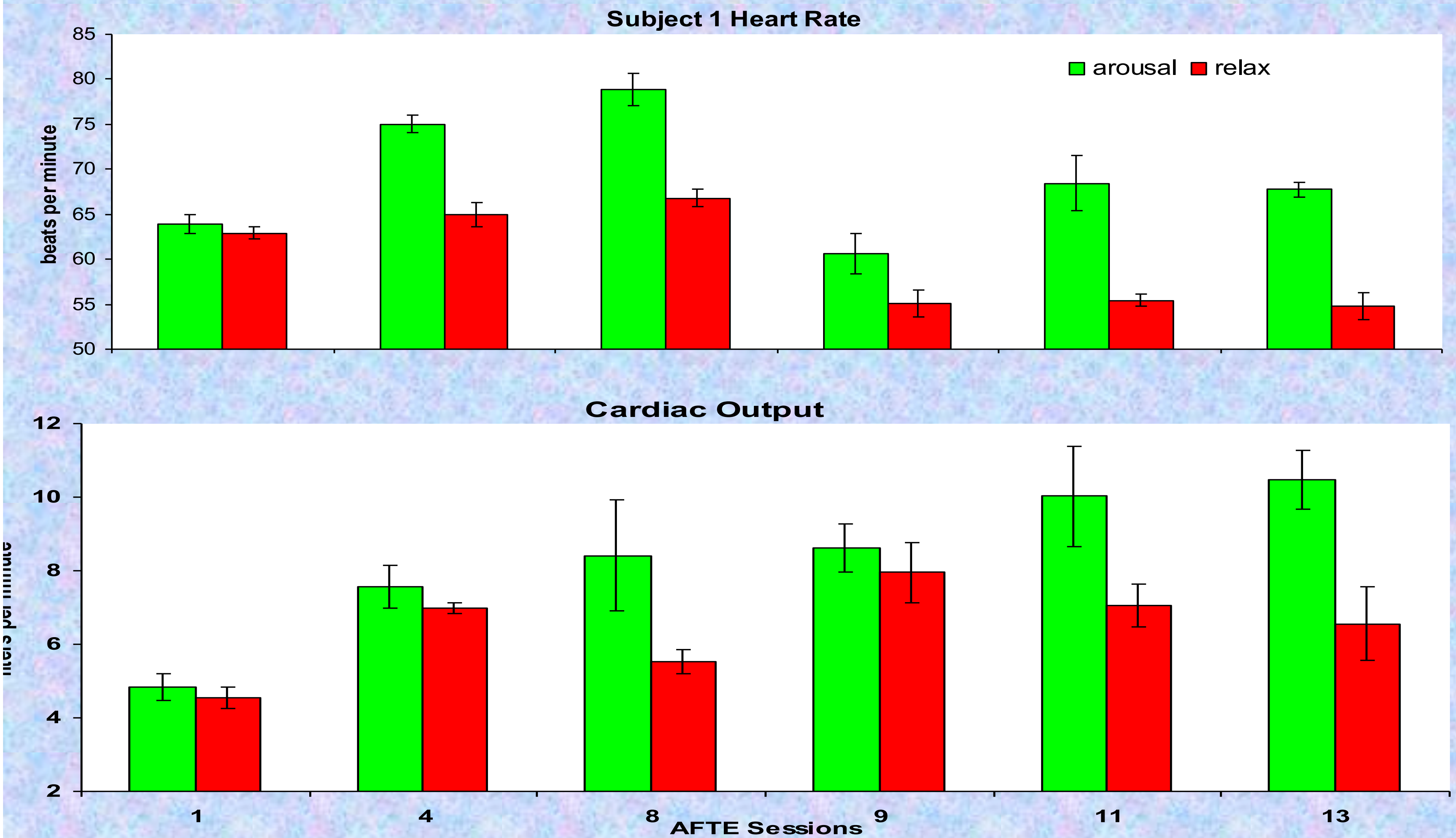




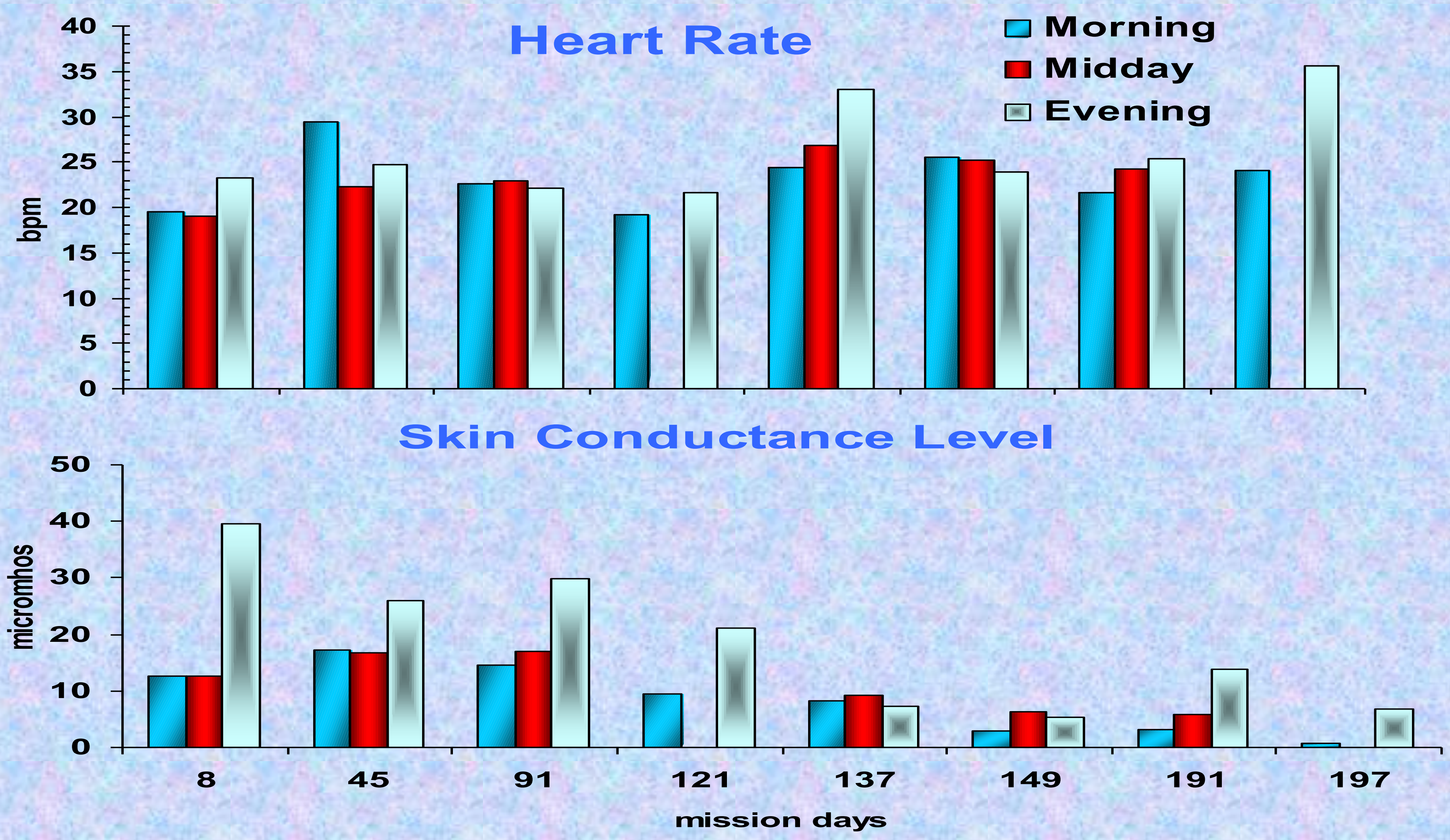




Preflight Learning Curve of Crewmember (16 months between sessions 8 and 9)



Subject 1: Autonomic Control in Space
(difference scores between arousal and relax trials)



Conclusions

- Converging Indicators method can accurately describe individual differences in environmental effects and countermeasure effectiveness

- Crewmembers can reliably maintain autonomic control during and after sustained exposure to space environment

- Preliminary results of AFTE indicate that it is effective for controlling space motion sickness and postflight orthostatic intolerance

- AFTE technology will be beneficial to future space crews

Autogenic Feedback Training Exercise Improves Pilot Performance During Search-and-Rescue Operations

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Ambulatory Monitoring and Controlling Autonomic Responses on Earth

- **Sustained Operations:** Fatigue, vigilance, sleep loss, contribute to human error accidents

- **Autonomous Mode Behavior:** A condition when a high state of physiological arousal is accompanied by a narrowing of the focus of attention

Participants

- 17 pilots, CG Air Station, Barbers Point, HI

  8 were given AFTE (4 HC-130 and 4 HH-65 pilots)

  9 served as Controls (3 HC-130 and 6 HH-65 pilots)

1. Pre-training flight 1 in HC-130 and HH-65 aircraft
2. AFTE – twelve 30-minute daily sessions

   control group received no treatment
3. Post-training flight 2

Two instructor pilots rated participant pilot performance:

IP not told group assignment of individual pilots

IP rated performance of same individual on both flights

IP provided instructions (simulated emergencies) to pilot

Simulated Emergency Flight Scenario: (HC-130)

Engine 1 fire during touch and go
Search and Rescue case (downed A-4 pilot, 20 miles offshore)
Engine 2 failure at 200 feet AGL
Airframe damage, minor fuel leak
AC bus failure, engine 1 fire
Landing gear malfunction

Simulated Emergency Flight Scenario: (HH-65)

Simulated engine stall at take off
Search and Rescue case (distressed boat with injured crew)
AC bus failure with loss of gyro, and pitch and roll
Servo-jam warning
hydraulic failure at 50 feet AGL
Engine 1 stall on short-final approach

Performance x Phases of Flight

flight 2 (post-training) group comparisons: AFTE vs Control

	Performance Dimensions			
	Crew Coordination and Communication	Planning and Situational Awareness	Stress Management	Aircraft Handling
Checklist execution	*			
Taxi/takeoff	*	*		
Initial cruise				
Touch & go		*	*	
Cruise search & rescue				+
Emergency initiation	*		*	
Emergency return to base			*	
Emergency approach & landing			*	

flight 1 (pre-training) group comparisons were not significant, except a higher score for Controls (+) on cruise search and rescue

* $p < 0.05$

Performance x Phases of Flight

flight 1 (pre-training) vs flight 2 (post-training): AFTE

	Performance Dimensions			
	Crew Coordination and Communication	Planning and Situational Awareness	Stress Management	Aircraft Handling
Checklist execution	*			
Taxi/takeoff				
Initial cruise				
Touch & go	+		*	*
Cruise search & rescue	*			*
Emergency initiation	*		*	*
Emergency return to base		*	*	
Emergency approach & landing		*	*	*

flight 1 vs flight 2 for Controls were not significant, except a lower score for touch and go (+) on flight 2

* $p < 0.05$

Summary

AFTE effects:

- improves overall performance and execution of duties
- Improves crew coordination and communication:
  - crew briefings
  - workload delegation
  - planning
  - overall technical proficiency
- may reduce physiological reactivity to stress
- may aid in successful use and expansion of CRM training

Future Applications of AFTE

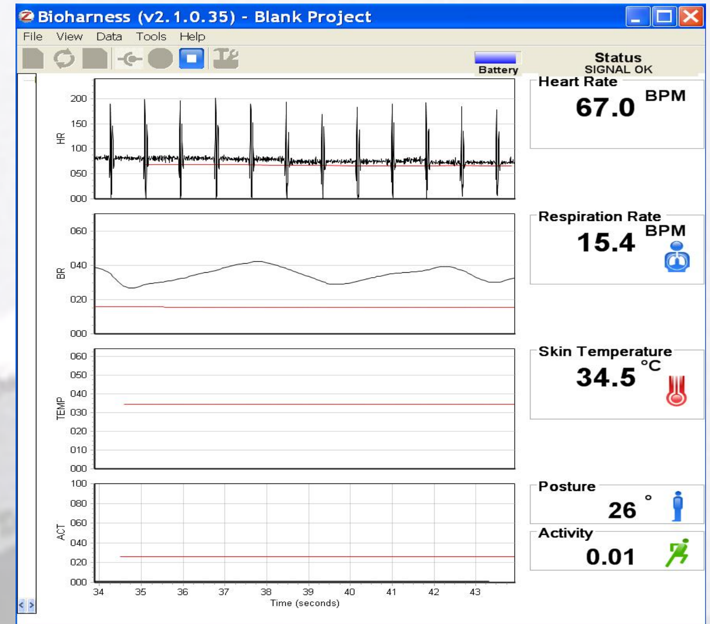
Transfer NASA Technology and Validation Studies

- Training of Polish Military Pilots
- Training of U.S. Naval Pilots for Airsickness Mitigation
- Training of U.S. Veterans as a Treatment for Post-Traumatic Stress Syndrome
- Training of Astronauts and Cosmonauts

Develop/ Test New Monitoring and Training Capabilities

- Stream-line software
- Neuro-feedback and autonomic coherence
- Unobtrusive physiological Monitoring

BioHarness and Software



Measures

- Electrocardiography
- Respiration
- Chest Skin Temperature
- Posture
- Activity
- Acceleration (XYZ), minimum and peak

BioHarness

- Requires non-skin contact sensors
- Can interface with a PC or cell phone
- No sensors for skin conductance, hand temperature, and blood flow, EMG