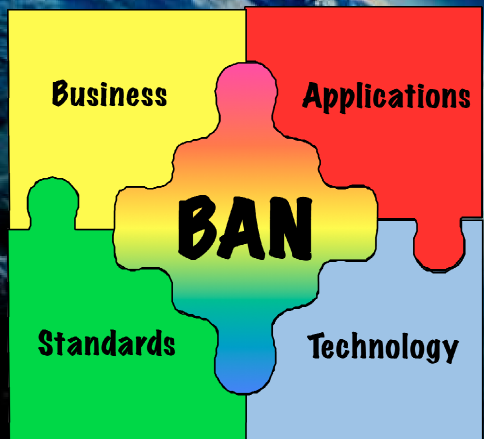
1st Invitational Workshop on
Body Area Network Technology and Applications
Future Directions, Technologies, Standards and Applications
June 19-20, 2011
Worcester Polytechnic Institute

BODY AREA NETWORKS
and
Wireless Medical Monitoring

Lessons Learned from Space Technology Development

1st Workshop on Body Area Network Technology and Applications
20 June, 2011



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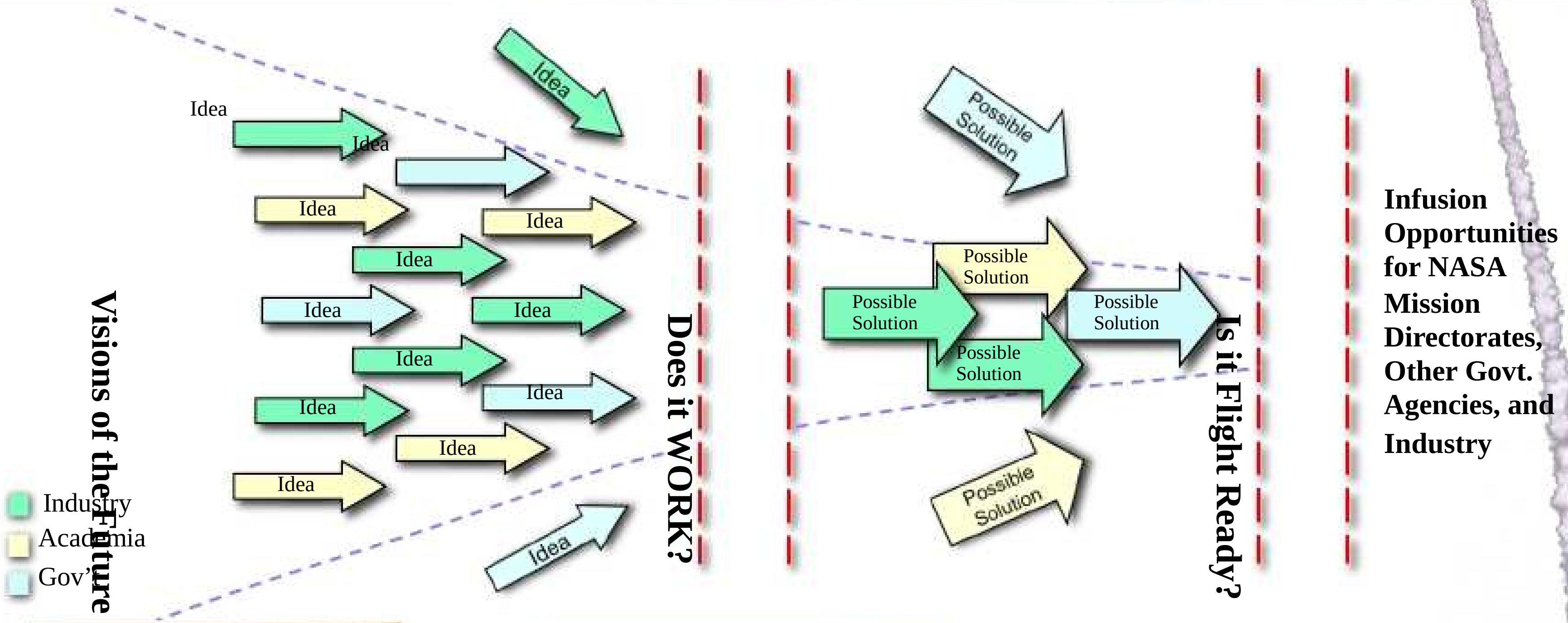
Ames Research Center
in Silicon Valley

NASA's Space Technology Program - Development Approach

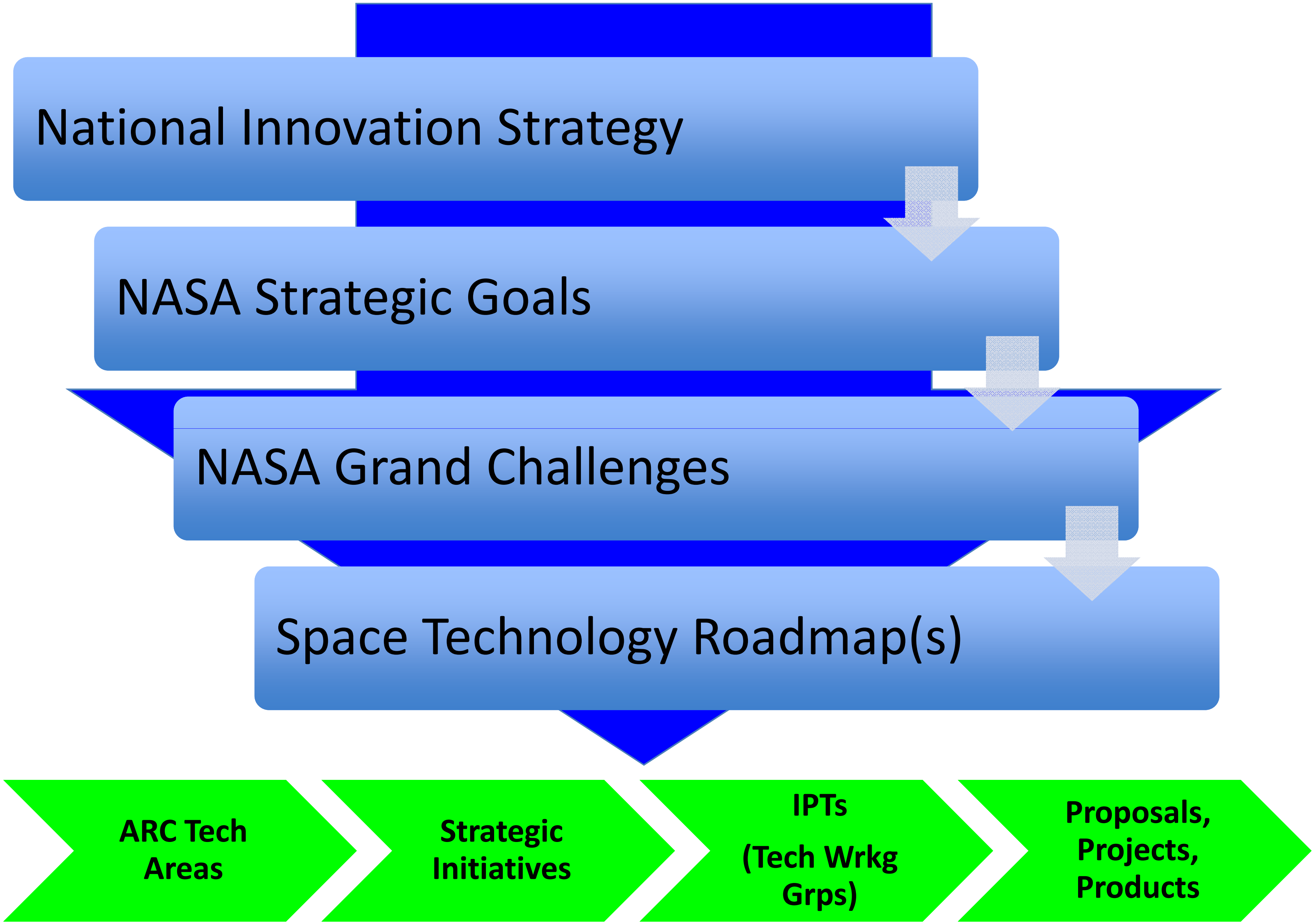


Creative ideas regarding future NASA systems or solutions to national needs.

Prove feasibility of novel, early-stage ideas with potential to revolutionize a future NASA mission and/or fulfill national need.

Mature crosscutting capabilities that advance multiple future space missions to flight readiness status

TECHNOLOGY & INNOVATION DEFINITION FLOWD



NASA's Space Technology Program

NASA-Ames Technology Elements

Definition – Development -- Infusion

Strategic Initiatives

- Transformational Small Spacecraft, Subsystems, and Mission Architectures
- Biological Technologies for Life Beyond Low Earth Orbit
- Low Cost, Off-the-Shelf Space Technologies
  - (ex: PhoneSat --COTS Sp Tech Utilization
- GREEN Technologies (Technologies for Sustainability)
- Emerging Aeronautics Systems and Technologies
- Other Recommended Initiatives ?
  - **Disaster/Homeland Security Monitoring, Mitigation, Training**
  - Autonomous Laboratories on Planetary Surfaces ?
  - Hybrid Systems Modelling and Analysis
  - Advanced Information, Robotics, and Autonomous Systems
- Graduates
  - Synthetic Biology
  - PhoneSat

Ames Research Center

Smart Healthcare Management Systems

Developing systems to monitor the health and performance of NASA personnel and the functional status of the systems that support them

ASTROBIONICS

JOHNSON SPACE CENTER

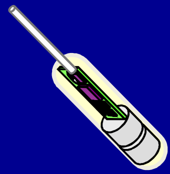
AMES Life Sciences

Ames Research Center

ATD Biosensors

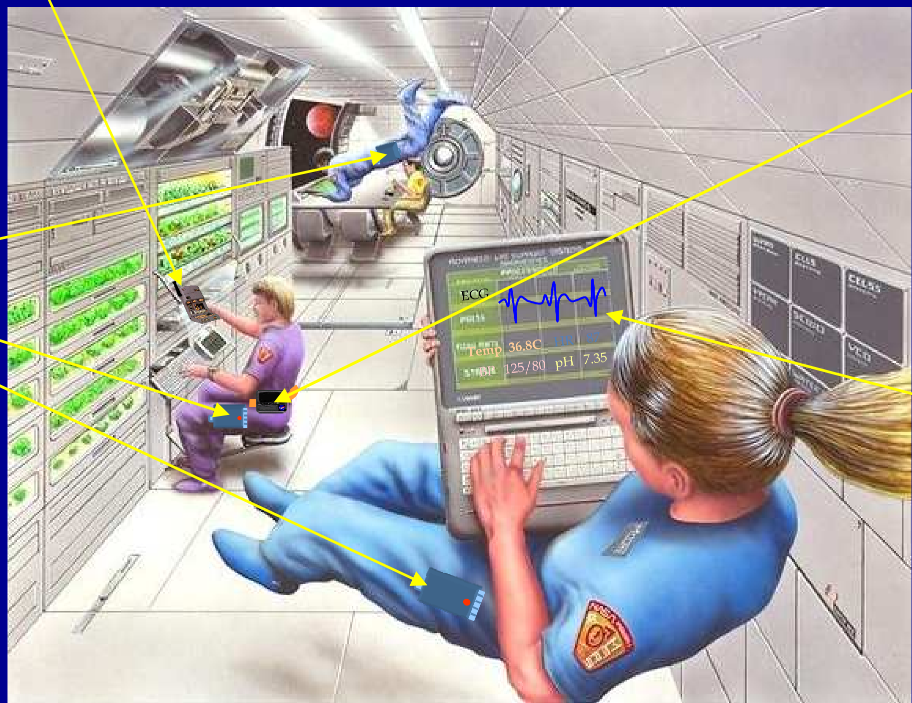
Physiological Monitoring of Astronauts

TriSponder quickly displays Health Status.



Biotelemeter implanted in amimals, or ingested by/attached to astronauts senses Body Temperature, Blood Pressure, Blood pH, and Heart Rate.

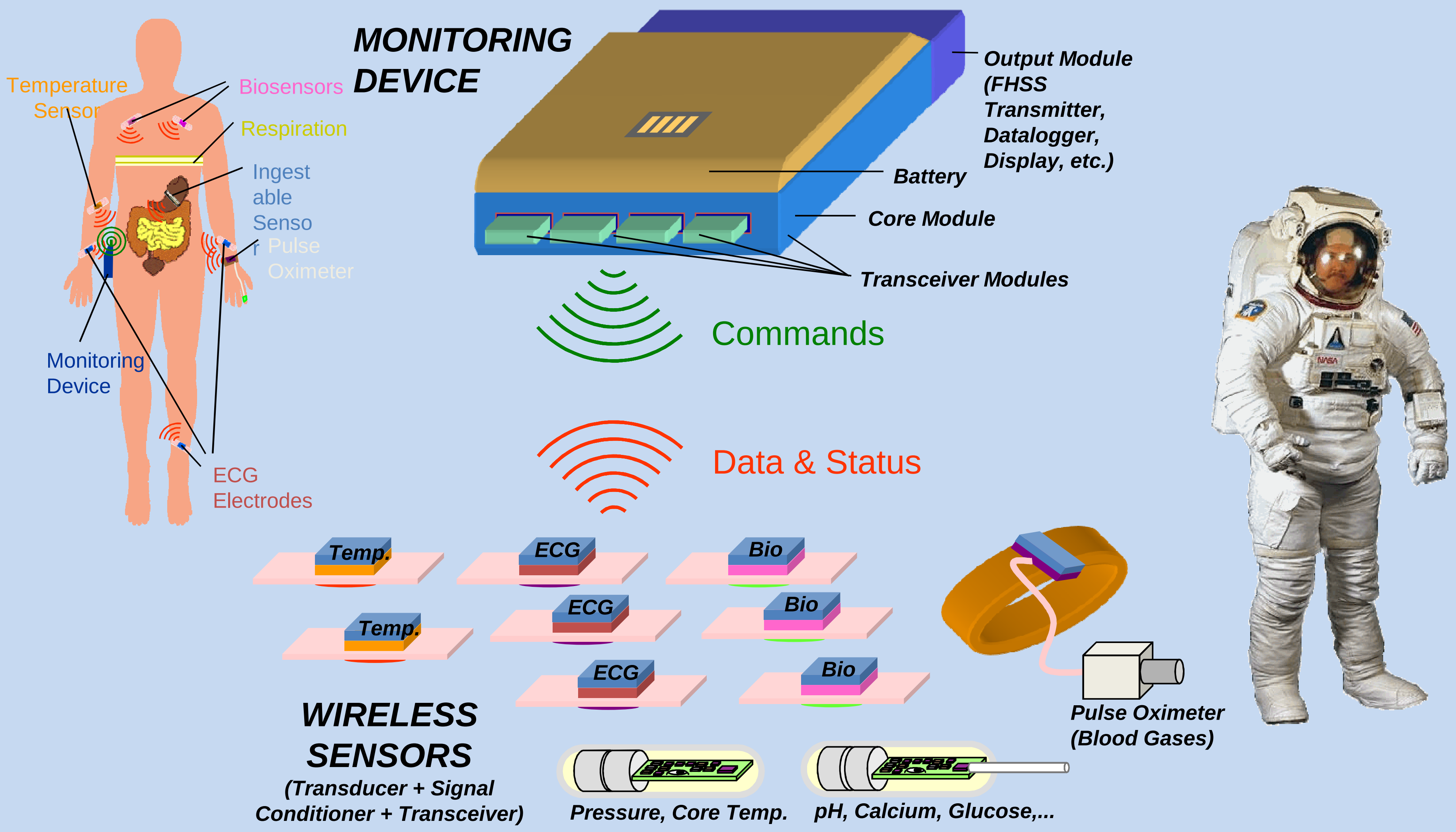
Transponder relays biotelemeter signal to other monitoring devices.



Physiological Signal Conditioner (PSC) acquires ECG, EEG, EMG, and EOG (and other bio-parameters of interest.

Laptop monitors and analyzes Physiological Parameters.

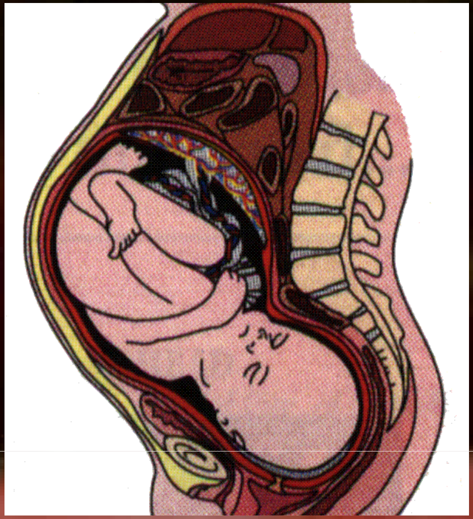
Wireless Sensor Network for Health Monitoring



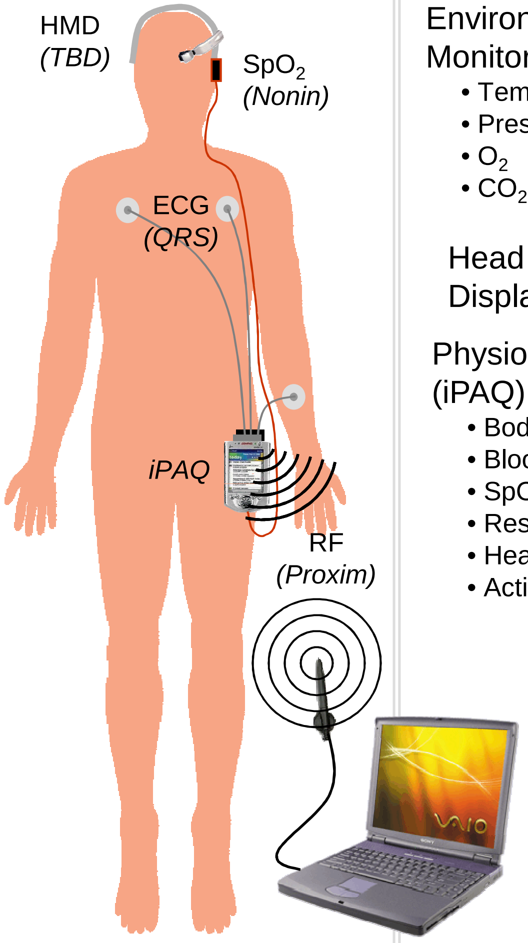
Fetal Biotelemetry System

Collaborative development efforts with UCSF Fetal Treatment Center

- *Fetal Health Status Monitor*
- *pH/temp/HR Fetal Biotelemetry System*
- *pH/temp/ECG/pressure Fetal Biotelemetry System*



Distributed Environmental and Physiological Monitoring

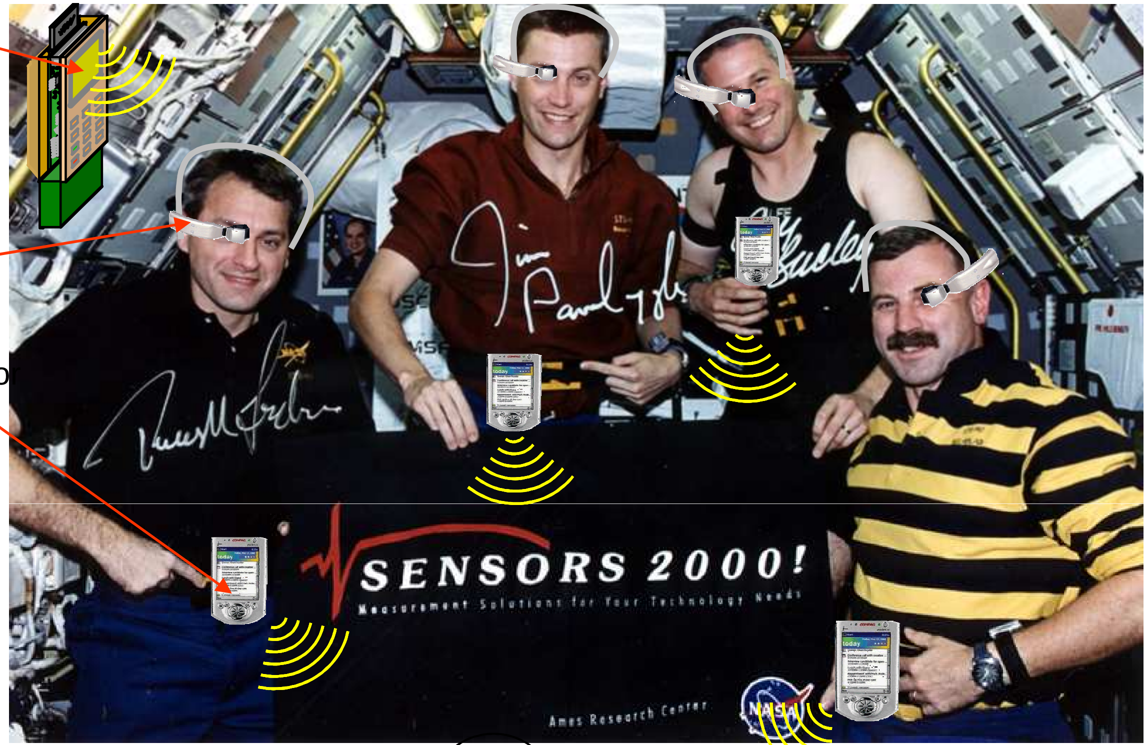


Dave Williams Demonstration

Environmental Monitor (MPM)
- Temp.
- Pressure
- O_2
- CO_2

Head Mount Display

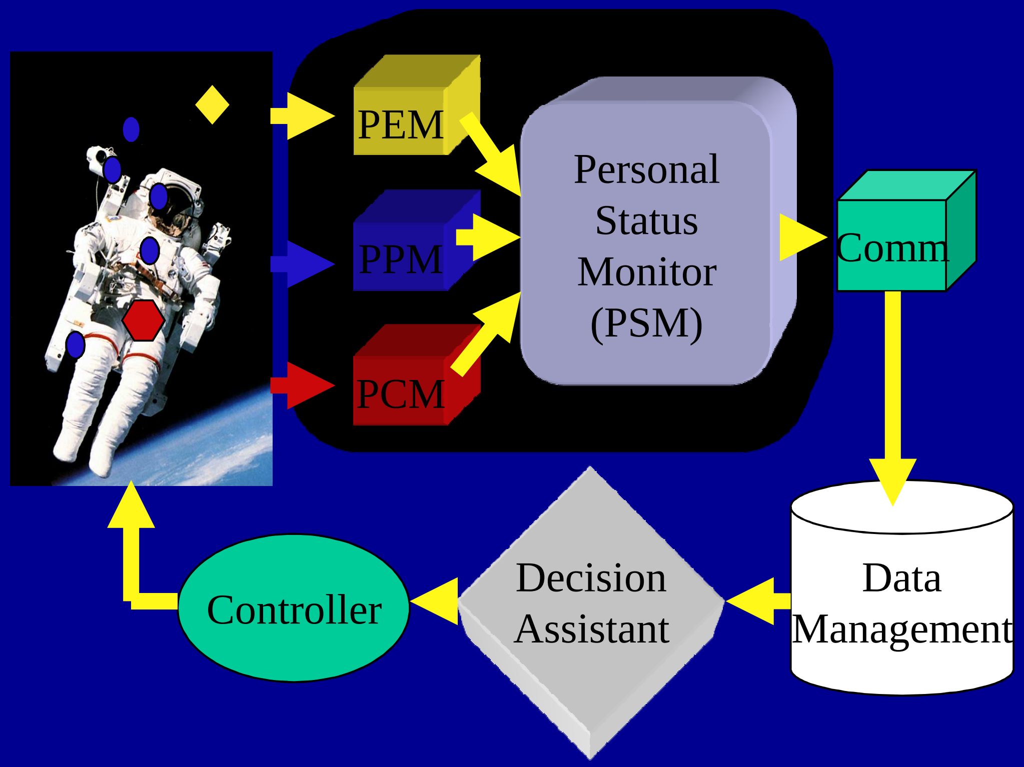
Physiological Monito (iPAQ)
- Body Temp.
- Blood Pressure
- SpO_2
- Respiration
- Heart Rate / ECG
- Activity



Space Station / Shuttle Scenario

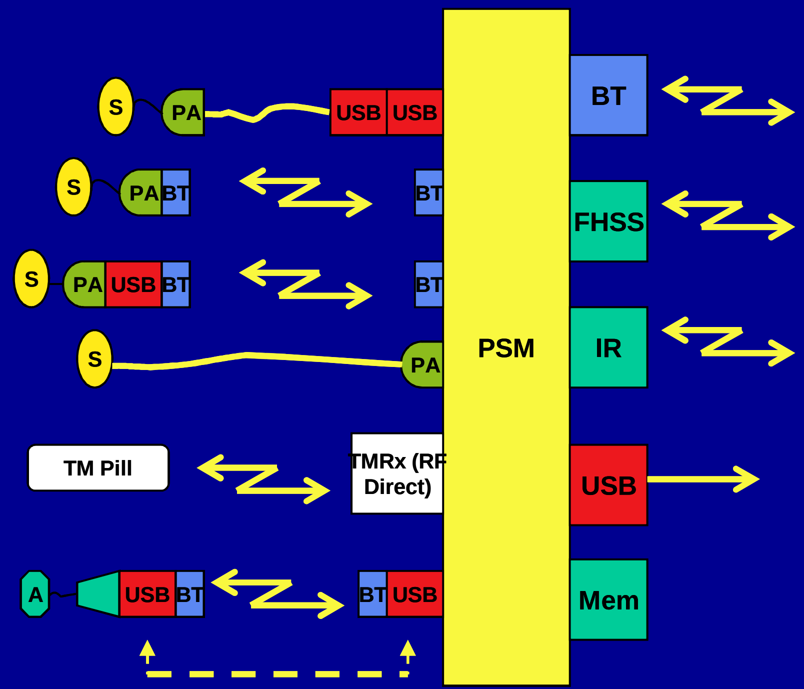
Server
- Data Display
- Data Distribution
- Data Analysis

Smart Healthcare Monitoring System

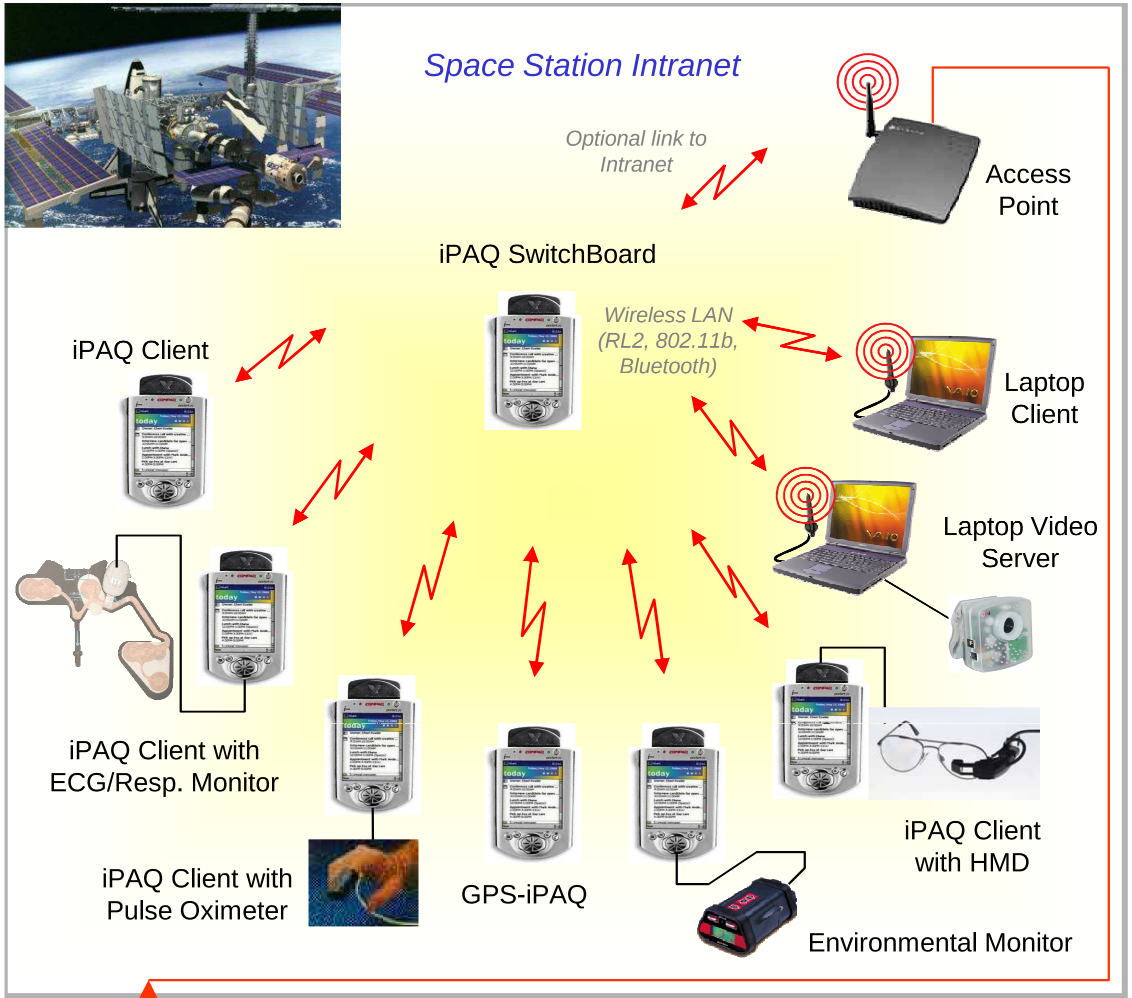


PSM: Personal Status Monitor
PPM: Personal Physiological Monitor
PEM: Personal Environmental Monitor
PCM: Personal Clinical Monitor

SHMS Interface Strategy

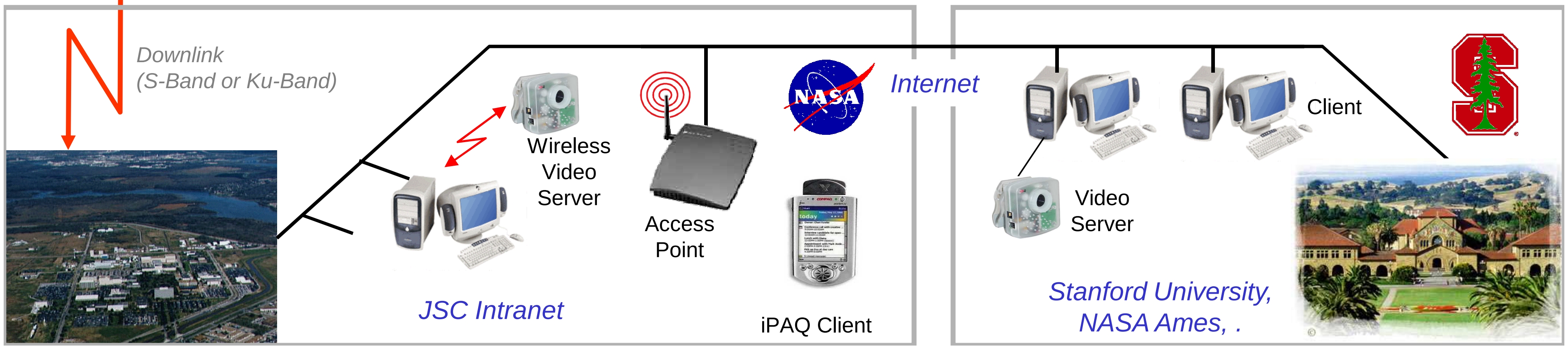


PSM: Personal Status Monitor
PA: PreAmplifier
S: Sensor
BT: BlueTooth
USB: Universal Systems Buss
A: Actuator
TM: Telemetry Transmitter Module
FHSS: Freq. Hopping Spread Spectrum
IR: InfraRed
Mem: Memory
TMRx: Telemetry Reveiver

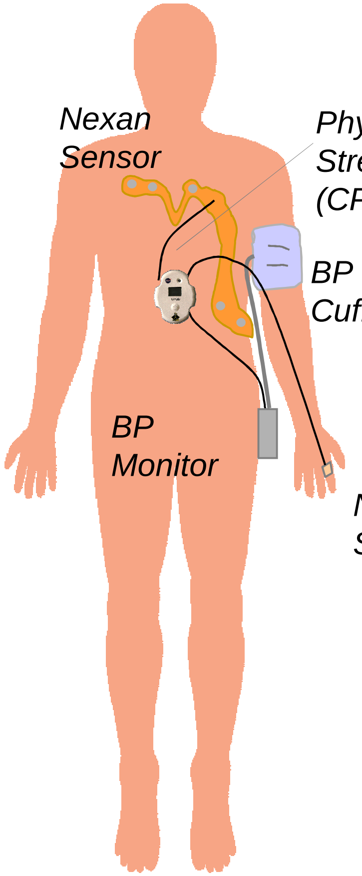


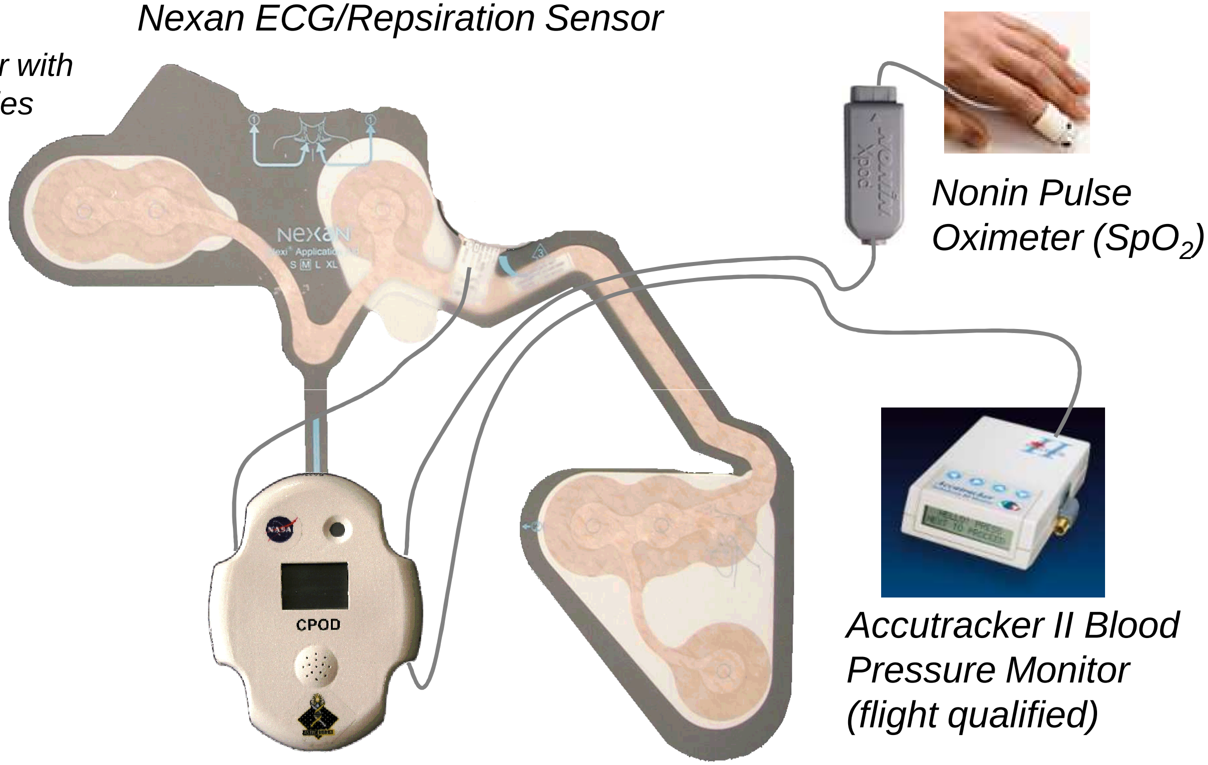
Prior System: Smart Health Care Management System (SHMS)

- ✓ Various Data Sources supported (Physiological and Environmental Sensors, Video (wired/wireless), GPS)
- ✓ Various Client Devices supported (Pocket PCs, HMDs, Laptops, PCs)
- ✓ Local ad-hoc Networking using iPAQ-SwitchBoard or Laptop-SwitchBoard
- ✓ Ad-hoc Network can be connected to Intranet as soon as Access Point is in range, as well as Internet
- ✓ Compatible with most Wireless LAN Technologies (RangeLAN2, 802.11b, Bluetooth)
- ✓ Low Bandwidth Requirement (128-kbps S-Band compatible)
- ✓ Modular, Flexible, Reliable, and Secure

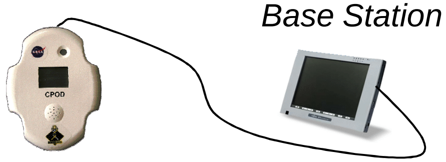


LifeGuard Monitoring System - Overview



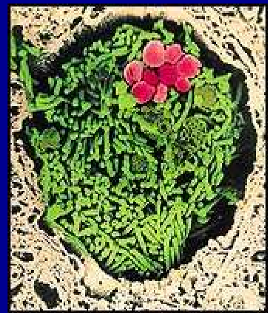


CPOD logs data. Download via RS-232 or wireless:



or

Non-NASA Application of SHMS: Homeland Security and Defense



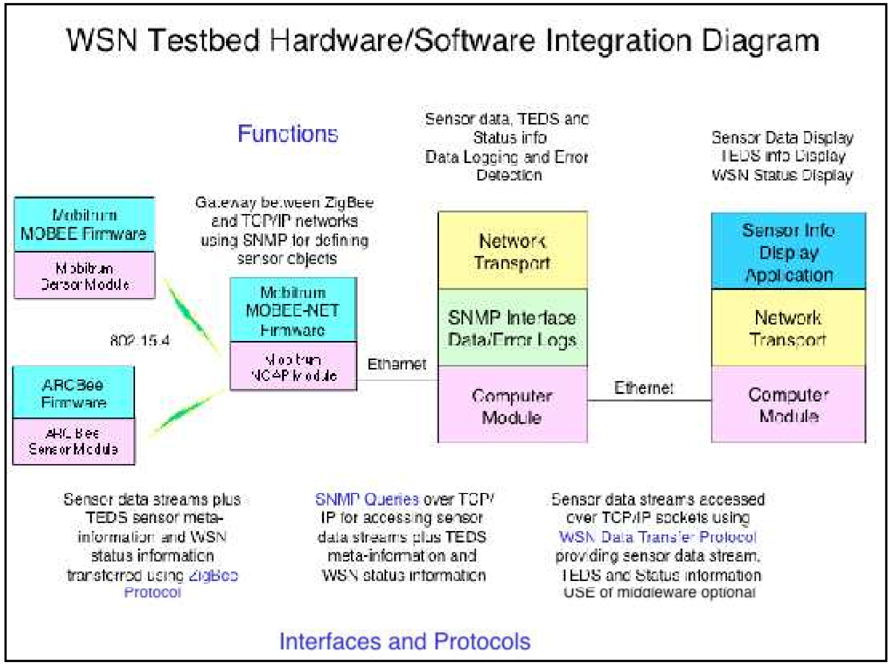
NASA DART Participation

Test, Applications, and Integration

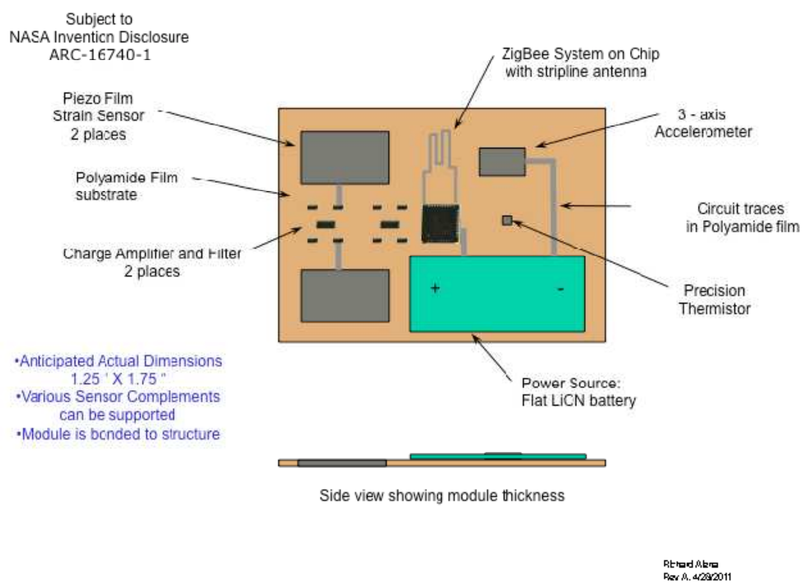
Testing, testing, and more testing

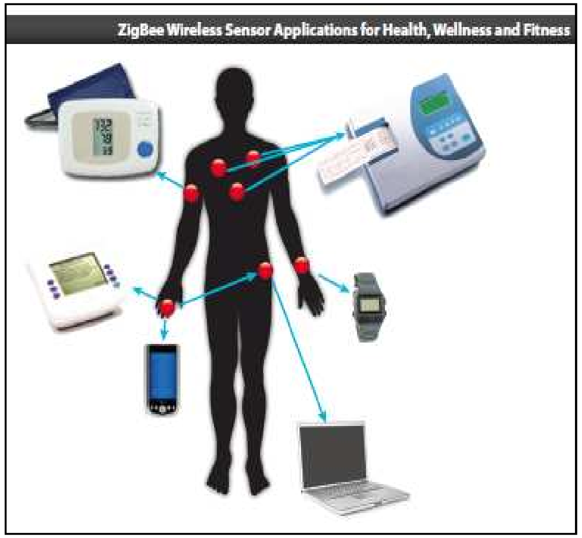
ARC Wireless Technology for Space

Discovery and Systems Health Technical Area



WSN Shroud Sensor Module (SSM) Design Concept





Wireless Sensor Network Testbed

Haughton Mars Project Field Work 2002

Desert Rats Field Simulations at Meteor Crater 2002

First Wireless LAN in Space – 1996
STS 76 / Mir 21

Mobile Agents at Mars Desert Research Station 2003

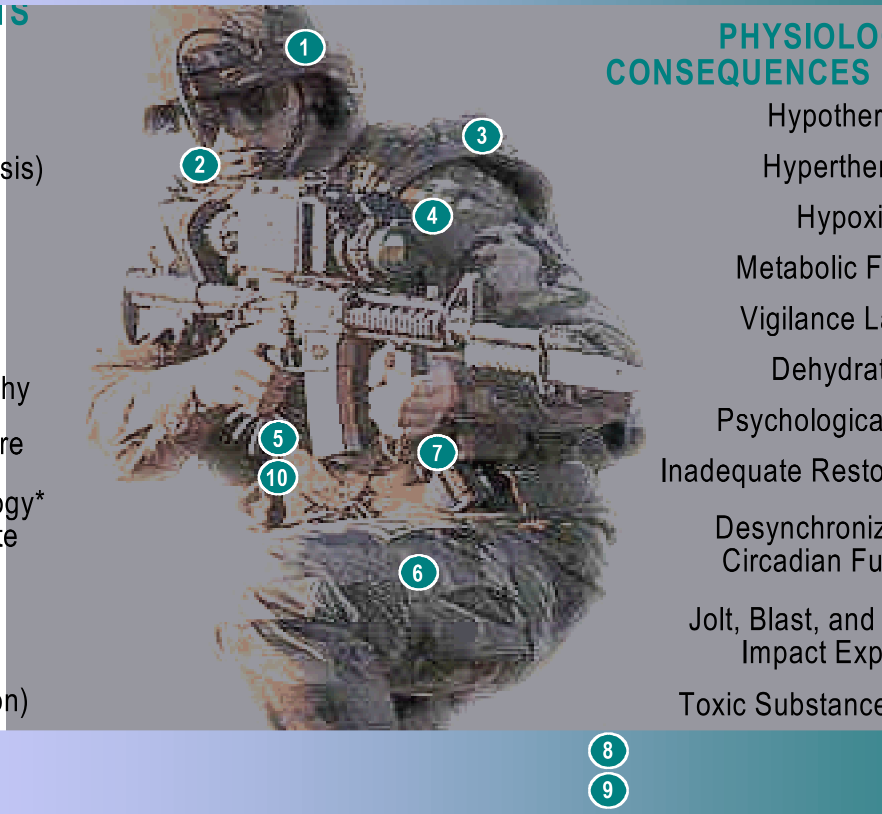
Warfighter Physiological Status Monitoring

"Tool Kit" to Understand Warfighter Physiology

CURRENT

SENSORS/ MEASUREMENTS

1. Headband EEG and Oximetry
2. Acoustic (Voice Stress and Content Analysis)
3. Dead Reckoning Module (3-Axis Accelerometer, GPS, Magnetometer, Altimeter)
4. EKG, EMG, and Thoracic Impedance Cardiography
5. Body Core and Skin Temperature
6. Near-Infrared (or Other) Technology* Tissue pH, Glucose, and Lactate
7. Wrist-Worn Actigraph
8. Boot-to-Boot Impedance*
9. Foot Contact (Weight/Locomotion)
10. Wireless



PHYSIOLOGICAL CONSEQUENCES OF CONCERN

Hypothermia

Hyperthermia

Hypoxia

Metabolic Fatigue

Vigilance Lapses

Dehydration

Psychological Stress

Inadequate Restorative Sleep

Desynchronization of Circadian Functions

Jolt, Blast, and Repeated Impact Exposure

Toxic Substance Exposure

Predict Significant Performance Degradation and Impending Casualty

FUTURE

Specifications for Minimal Sensor Set to Predict Warfighter Physiology

** Concept*

NASA – DHS – First Responder PSM

CURRENT

SENSORS/ MEASUREMENTS

1. Headband EEG and Oximetry
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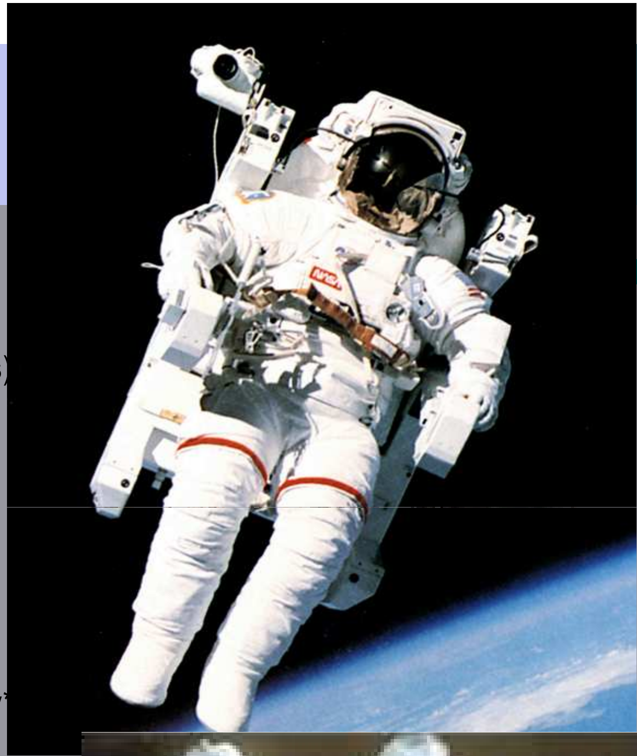

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Predict Significant Performance Degradation and Impending Casualty

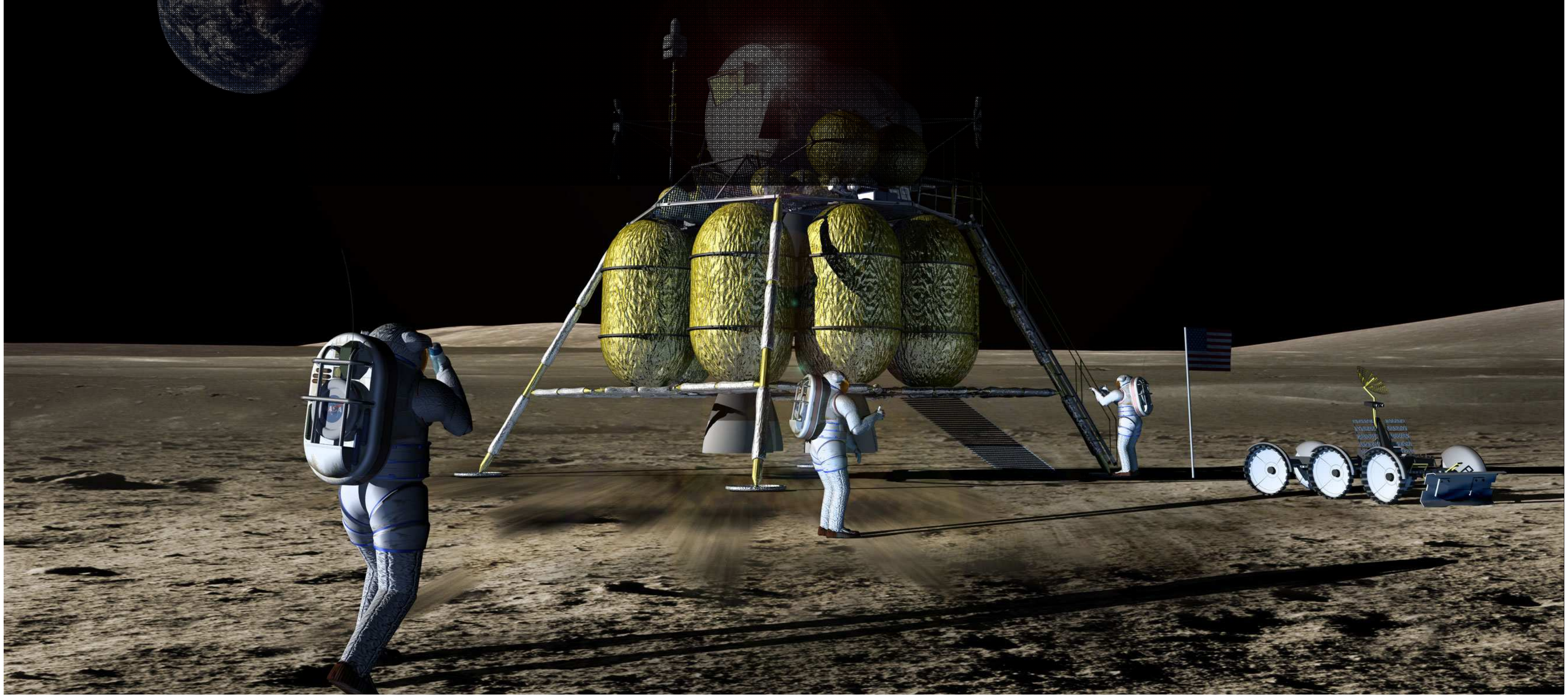
FUTURE

** Concept*

EVA and IVA Physiological Monitoring

- Keep crew safe, healthy, and performing optimally
- Prevent, recognize, diagnose, and treat illness and injury

❖ *IVA – medical exams, exercise, research, fitness evaluations*



EVA and IVA Physiological Monitoring Requirements

TABLE 10.5-1 MEASUREMENT OF PHYSIOLOGICAL PARAMETERS

Suit Parameter	Unpressurized Vehicle Pressure Options	Pressurized Options	Lunar Surface Options
Breathing gas flow rate (real time)	X	X	X
ppO_2	X	X	
Oxygen consumption rate (real time)			X
Suit pressure (real time)		X	X
$ppCO_2$ (real time)		X	X
Consumables (power, oxygen, water, etc., real-time)	X	X	X
Thermal load on EVA crewmember (calculated)			X
Heart rate (real time)		X	X
Metabolic rate (calculated)			X
Radiation Exposure Data			X

Notes:

For items noted, measurement parameters may be on an individual suit basis.
For a single gas environment, ppO_2 and suit pressure are identical and do not require separate sensors.

Requirements (Medical Operations)

Monitoring ECG	**Minimum of 2 independent channels for up to 48-hours**
Diagnostic ECG	12-lead for both 10-30 second "snapshot" mode, and 10-minute "full disclosure" mode
Heart Rate	0-250 beats per minute
Respiratory Rate	0-150 breaths per minute
Body Temperature	84.0 ° F to 108.0 ° F
Blood Pressure	Systolic 60-250 mmHg Diastolic 30-160 mmHg
Blood Oxygen Saturation	70-100%

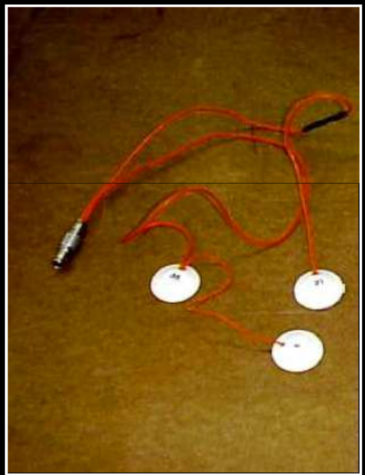
Requirements (Research)

Holter Monitor/ECG	**Minimum of 2 independent channels for up to 48-hours**
Diagnostic ECG	12-lead ECG for a minimum of 10 sequential minutes that employs 8 independent channels (using a standard 10-electrode configuration)
Cardiac Output	Continuous cardiac output for up to 24 hours
Continuous Blood Pressure	Continuous Blood Pressure for up to 24 hours
Body Temperature	84.0 ° F to 108.0 ° F

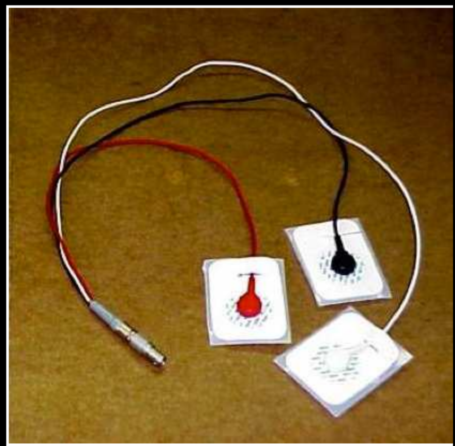
The Challenges

- Maximize the comfort, ease of use, reliability, and accuracy
- Minimize the equipment's mass, volume, power, and time for set-up and use

Apollo Sensors



Shuttle Sensors



Space Station Hardware

EVA HR Monitoring Requirements

Guiding Standard	ANSI EC-13 Cardiac Monitors, Heart Rate Meters
Requirement Name (#)	**Performance Requirements**
Accuracy (HR-01)	≤ +/- 10% or ≤ +/- 5.0 bpm (whichever is greater)
Range (HR-02)	0-250 bpm
HR Calculation Methods (HR-03)	Beat-to-beat (Required) Averaged over 5, 15, or 60 seconds (Desired)
Beat-to-Beat Accuracy (HR-04)	24 millisecond
Desirement Name (#)	**Performance Desirements**
Sensor Type and Placement (HR-05)	Minimize skin preparations Reduce don/doff time Avoiding wet gel electrodes Achieve accuracy during dynamic operational environment

EVA HR Technologies Recommendations

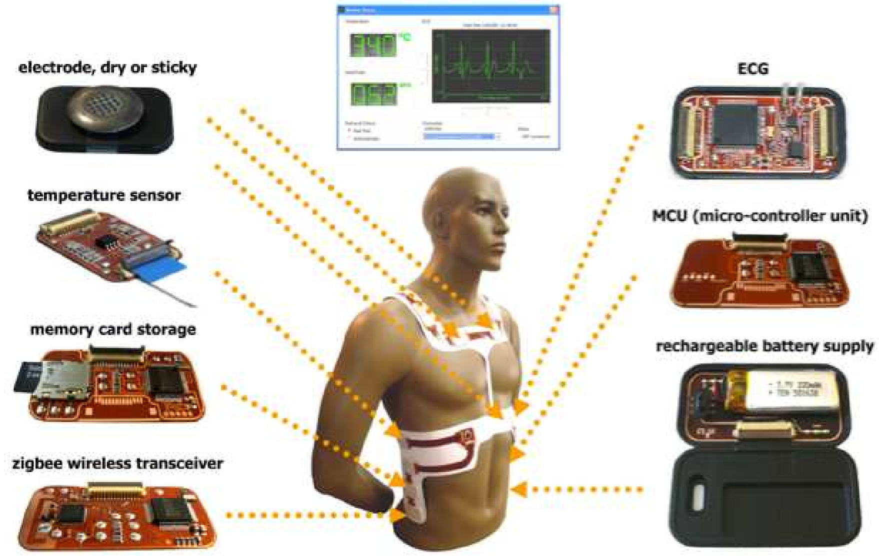
Recommendations based on:

- Market Studies
- Testing at the NCHP, ARC, JSC, GRC, and SBIRs

Sensor Type
E-textiles
Surface Protrusion
Flexible Rubber
Hard Button
Capacitive Electrode
Photopleth
Non-Contact (radar, laser)

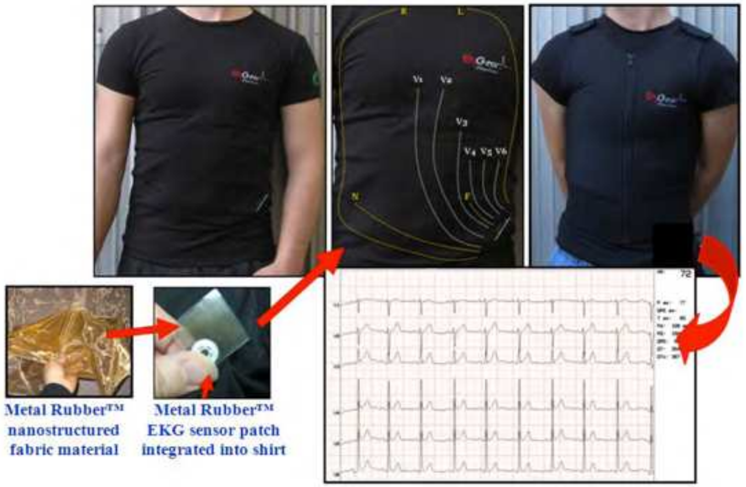
Nyx SBIR Prototype Delivery

Wearable Health Monitoring System



Nanosonic SBIR Prototype Delivery

Lightweight Metal Rubber™ Textile Sensor for In Situ Lunar Autonomous Health Monitoring

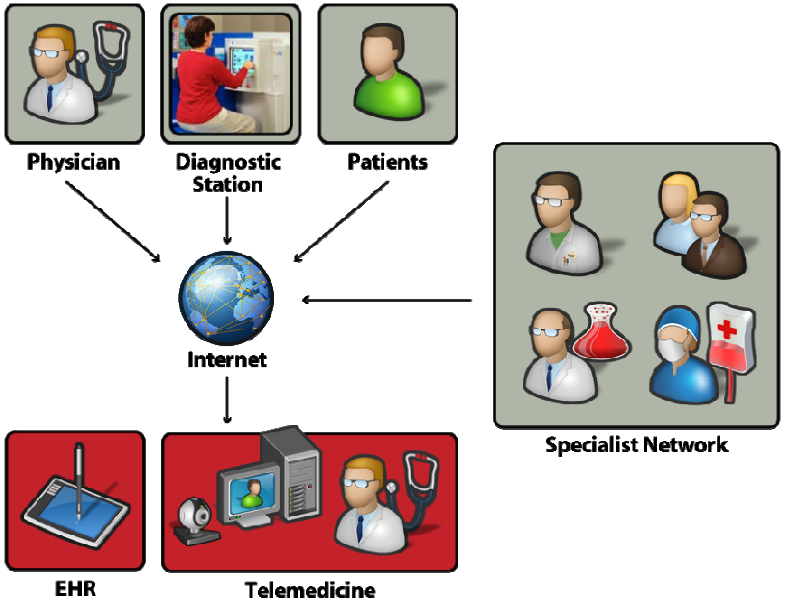


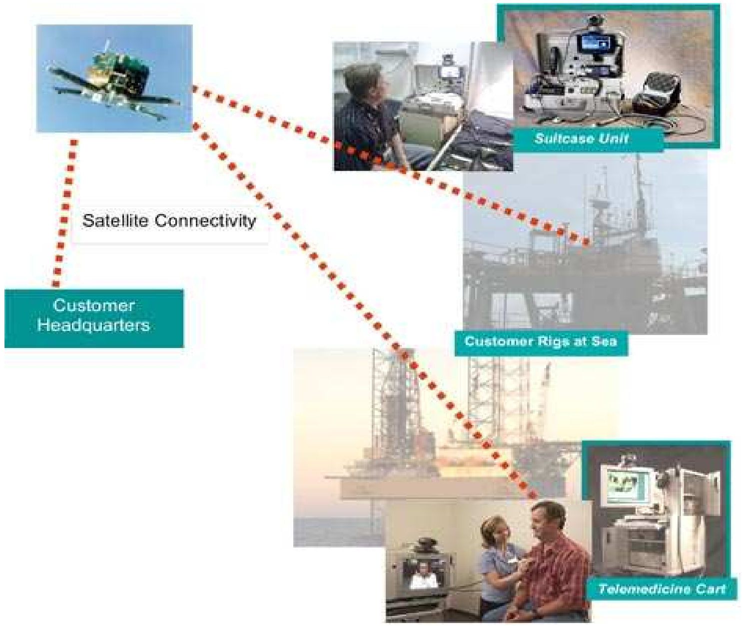
Orbital SBIR Prototype Delivery

Lunar Health Monitor

Market Survey/Lessons Learned

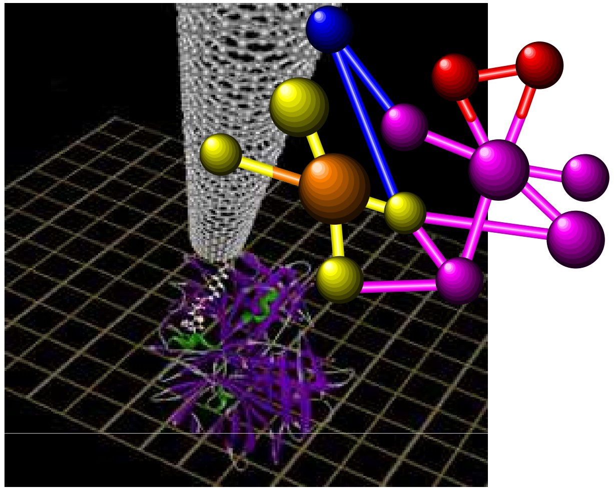
• Many systems rely on perspiration/moisture
• Nearby EMI can totally disrupt biomedical signals
• Not all systems have local display, ensure data is actually recording
• Have no buttons on the device that can be accidentally toggled
• The sensor is only the front end - many other factors contribute to final signal quality
• Motion artifact remains one of key problems
• Wireless an option - but many technical issues remain
• Some devices need attention to keeping them in place on the body
• Three considerations for sensor contact to skin
• Placement of sensors sometimes key
• Pick a financially viable company
• Get agreement on the definition of easy to don/doff


Physician
Diagnostic Station
Patients
Specialist Network
Internet
EHR
Telemedicine


Suitcase Unit
Satellite Connectivity
Customer Headquarters
Customer Rigs at Sea
Telemedicine Cart

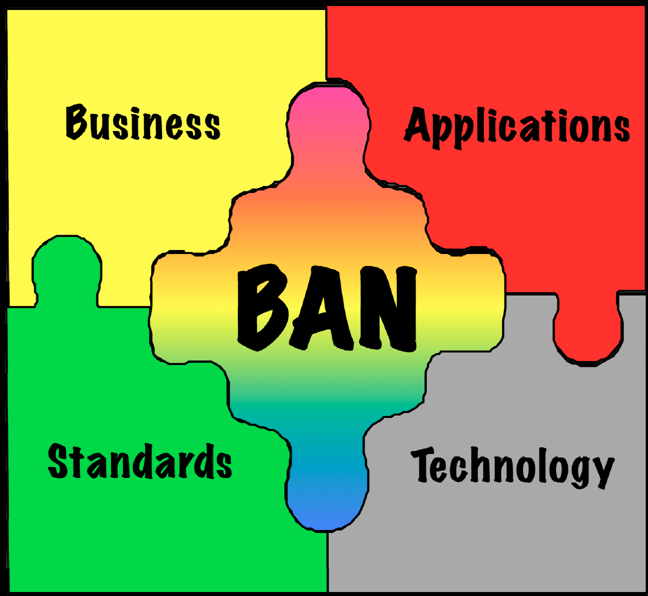
Future Space Medicine Health Care

- Portability and application of nano-technology
- Minimally/non-invasive, efficient diagnostic systems capable of detecting abnormal human function across all body systems
- Health care approaches capable of therapeutic intervention for a wide range of pathological and trauma scenarios



BAN / Wireless monitoring systems
problems for acceptance

- *hard to use*
- *don/doff*
- *attachment/motion artifact*
- *reliability*
- *communications*
- *Power-data interfaces*
- *data-info-decision*
- *ad-hoc network*
- *acceptance*
- *cost*

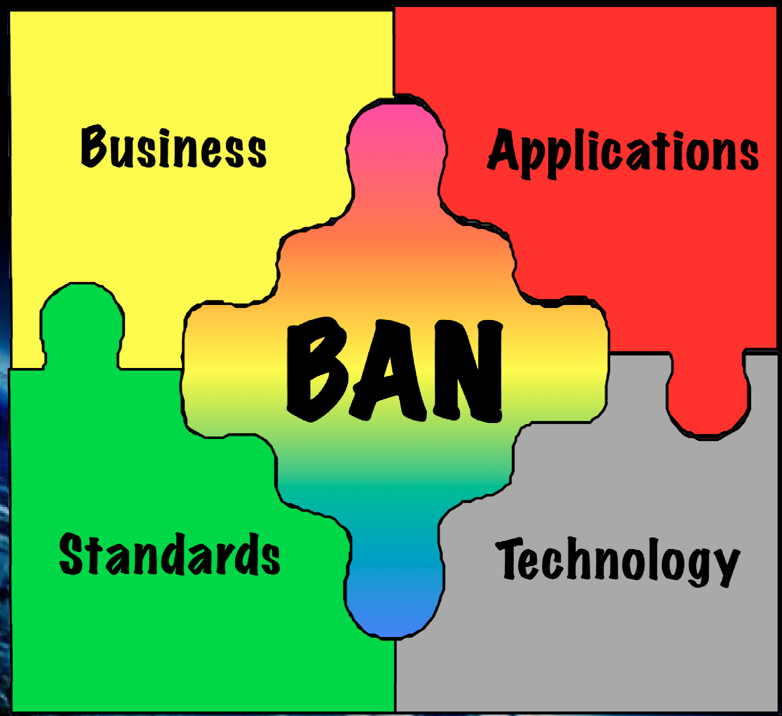


- *Sensing technologies and miniaturization is NOT the most critical issue*

Conclusion

Continue to improve the human to biomedical sensor interface

1st Workshop on Body Area Network Technology and Applications



Thank You!

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