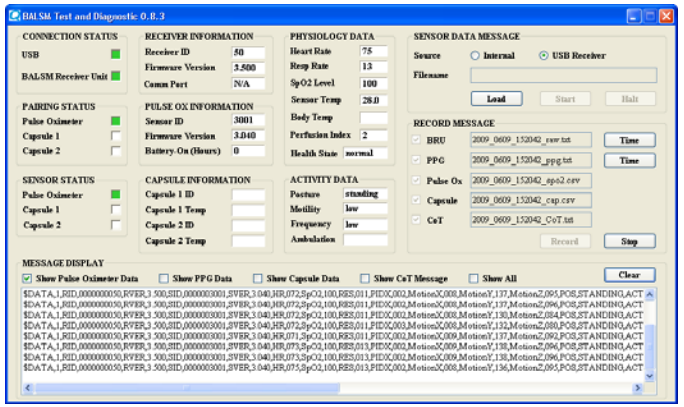


BALSM
Battlefield Automatic Life Status Monitor

A Presentation at the WPI Workshop on Precision Indoor Personnel Location and Tracking for Emergency Responders

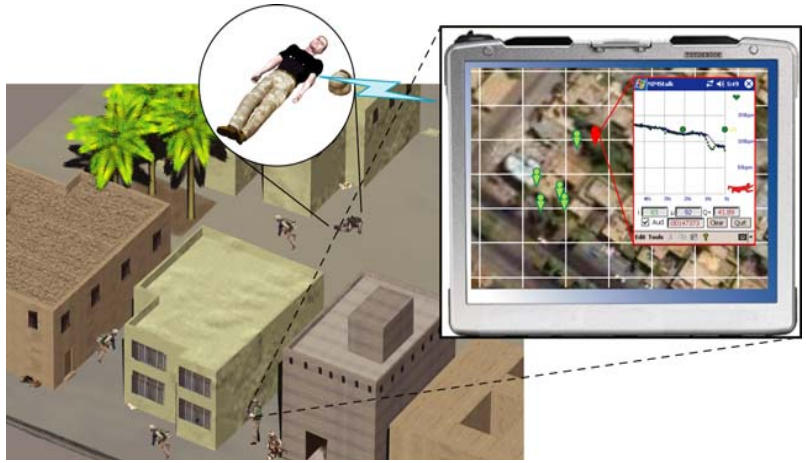
August 3rd, 2009

Peter Neumann
QinetiQ North America – Technology Solutions Group

Advanced Body Sensing

BALSM Project Objectives (May ’07)

- Development and fielding of a product to remotely monitor physiological signs for the purpose of triage, rescue or recovery and provide a health status history over time for each member of a Special Forces team.
  - Wearable device
  - Communicate individual’s physiologic status through existing data links
  - Wireless sensors should be battery powered
  - Receiver for sensors powered by ruggedized PC through USB connection

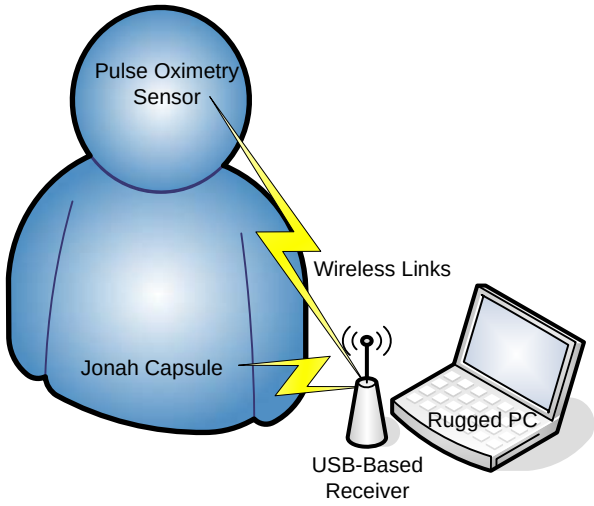


What Physiological Parameters Should Be Measured?

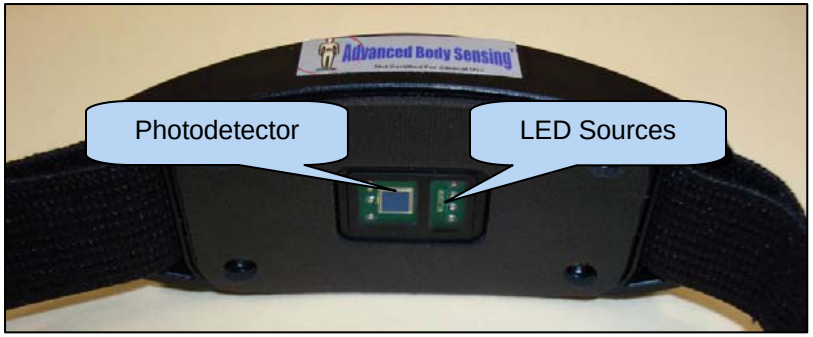
- How useful (valuable) is the sensor data to PJ's?
  - Feedback in call with PJ's in June 2007 ranked physiological parameters in the following order of importance:
    1. Heart rate
    2. Respiration rate
    3. Blood pressure
    4. Pulse oximetry level
    5. Core body temperature
    6. Raw ECG waveform
- Are the PJ's trained to use the provided sensor data?
  - PJ's are trained to utilize all six items listed above but do not normally carry the drugs needed to treat issues that would be diagnosed with an ECG waveform

BALSM 1st Year Design

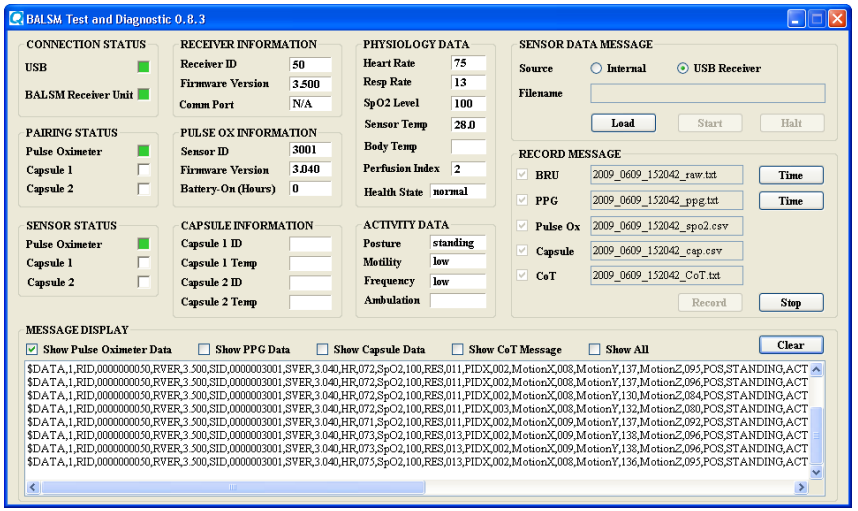
- Physiologic Sensors
  - Forehead worn pulse oximetry sensor (902 - 928 MHz ISM band)
    - SpO2 level
    - Heart rate and respiration rate derived from pulse oximetry (PPG) waveform
    - Activity level, ambulation, posture and frequency from three-axis accelerometer
  - Ingestible core body temperature capsule (40.66 – 40.70 MHz ISM band)
- BALSM receiver unit (BRU)
- BALSM software on PC platform
  - CoT physiological messages published by BALSM software to UDP data socket for transmission over PRC-148 (intra-squad) radio
  - GPS location handled by independent GPS receiver on CCT



BALSM 1st Year Sensors, Receiver and Software



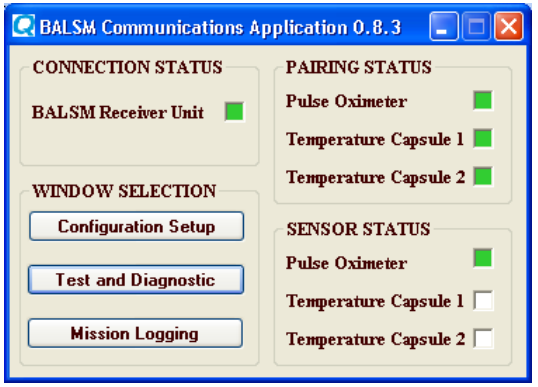
1st Year BALSM Pulse Oximetry Sensor



BALSM Software Test and Diagnostic Window

Jonah Core Body Temperature Capsule

1st Year BALSM Receiver Unit

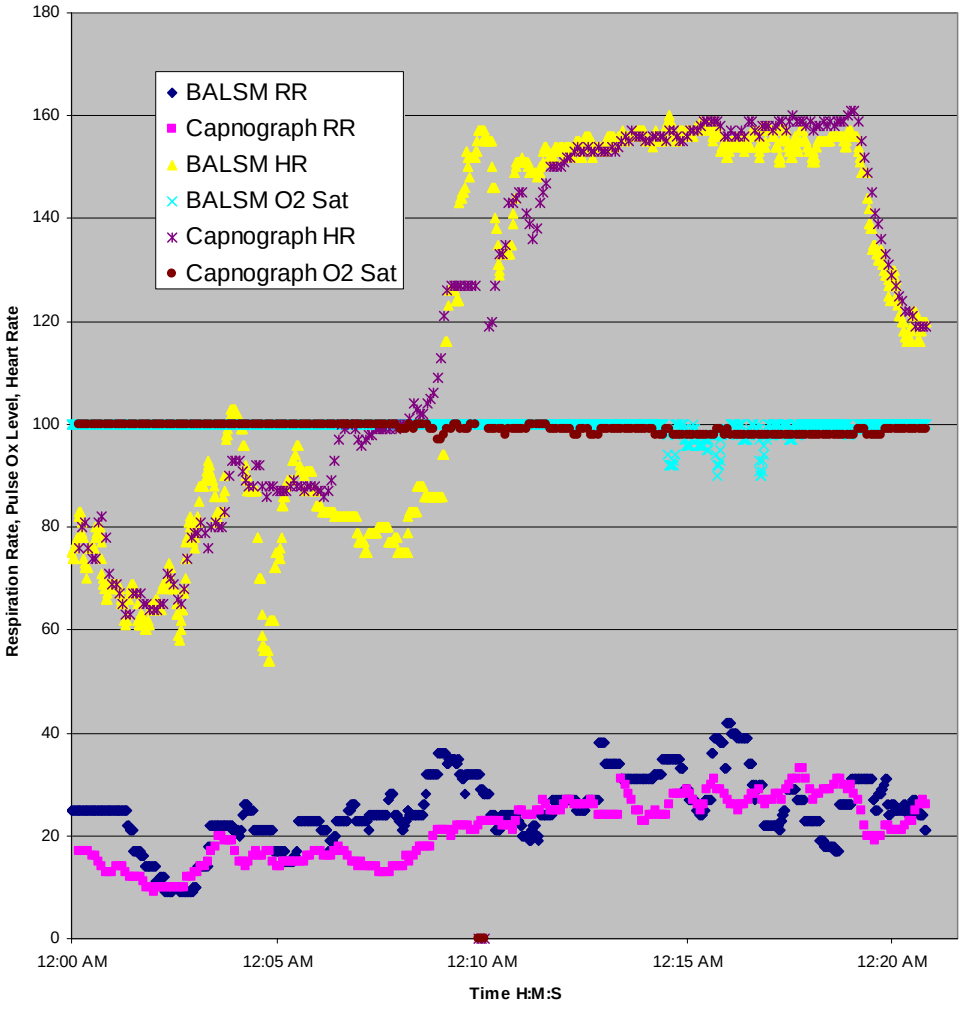


BALSM Software Main Window

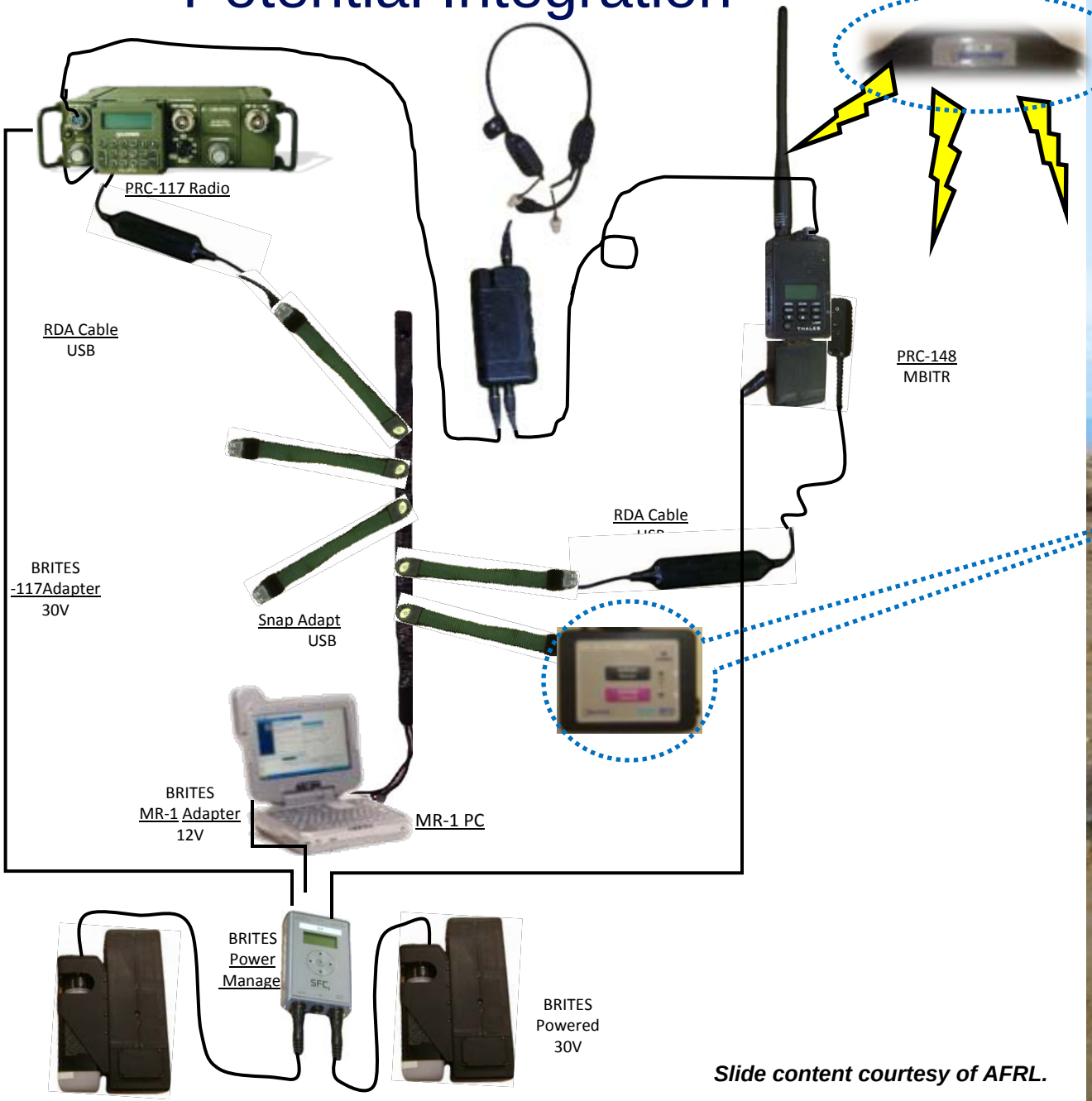
Jonah capsule in activation port

BALSM 1st Year System – Treadmill Testing

- Treadmill testing with BALSM system and capnograph (with finger-tip pulse ox sensor) produced elevated heart rate and respiration rate with test subjects
  - Heart rate and pulse ox levels compare favorably
  - Respiration rate from BALSM system does not track the capnograph respiration rate data as closely
    - Respiration rate accuracy varies between test subject



Potential Integration



Slide content courtesy of AFRL.

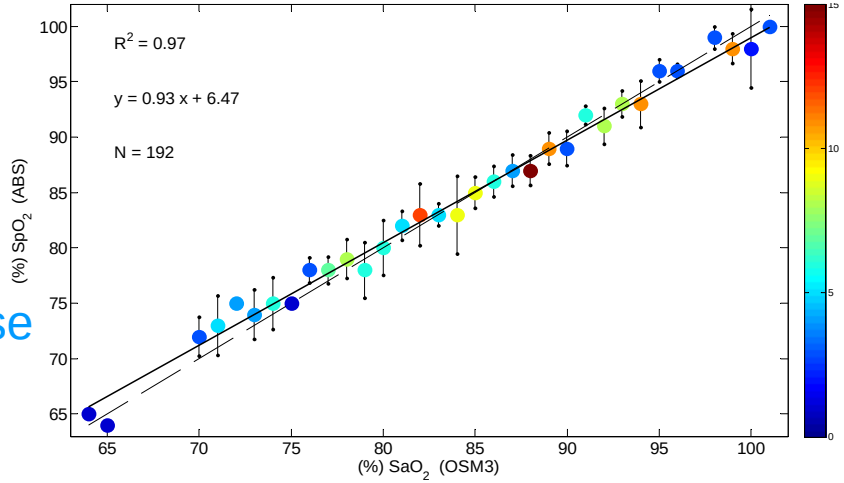
Mock-up of Vest Integration of BALSM Receiver

Slide content courtesy of AFRL.

BALSM 2nd Year System Improvements

- Dual-capsule support
  - Allows operator to ingest 2nd capsule and maintain continuous monitoring of core body temperature
- Clinical calibration of BALSM pulse oximetry sensor
  - Conducted in Nov '08 at UCSF* by Advanced Body Sensing
- Change to USBXpress from VCP for interface between BRU and PC
- Investigation of rechargeable battery option for BALSM pulse ox sensor
- End-user friendly BRU and BALSM pulse ox sensor firmware upgrade capability
- BALSM software upgrades

Photograph of the calibration study showing the BALSM Receiver Unit.



**** University of California San Francisco***

BALSM Pulse Oximetry Sensor Redesign

- Sponsor guidance to redesign BALSM pulse ox sensor so that it can be integrated into the brow pad of a helmet (ACH helmet)
  - Criteria for sensor was a maximum thickness of 10 mm (prefer 5 mm)
    - ✓ 2nd year alpha prototype sensor is ~ 8.5 mm thick with pad
  - Rechargeable battery integrated into sensor
    - ✓ Sensor uses a Li-Ion rechargeable pouch battery
  - Rechargeable battery with 24 hour endurance
    - ✓ Testing has shown 2nd year sensor battery life of 40-60 hours
  - Sensor recharging handled by BALSM Receiver Unit (BRU) preferred
    - × 2nd year systems have a separate USB powered recharger/programmer
  - Idea for optical sensor to be vertically off-center to allow for sensor to be worn inverted allowing some additional flexibility in sensor location
    - ✓ 2nd year alpha prototype has vertically offset optical sensor which allow for about 1 cm of adjustment in vertical location

BALSM Pulse Oximetry Sensor Redesign (cont'd)

BALSM 2nd Year Pulse Ox Sensor Prototype - Sensor Side

Charger/Programmer Connector Cover Removed

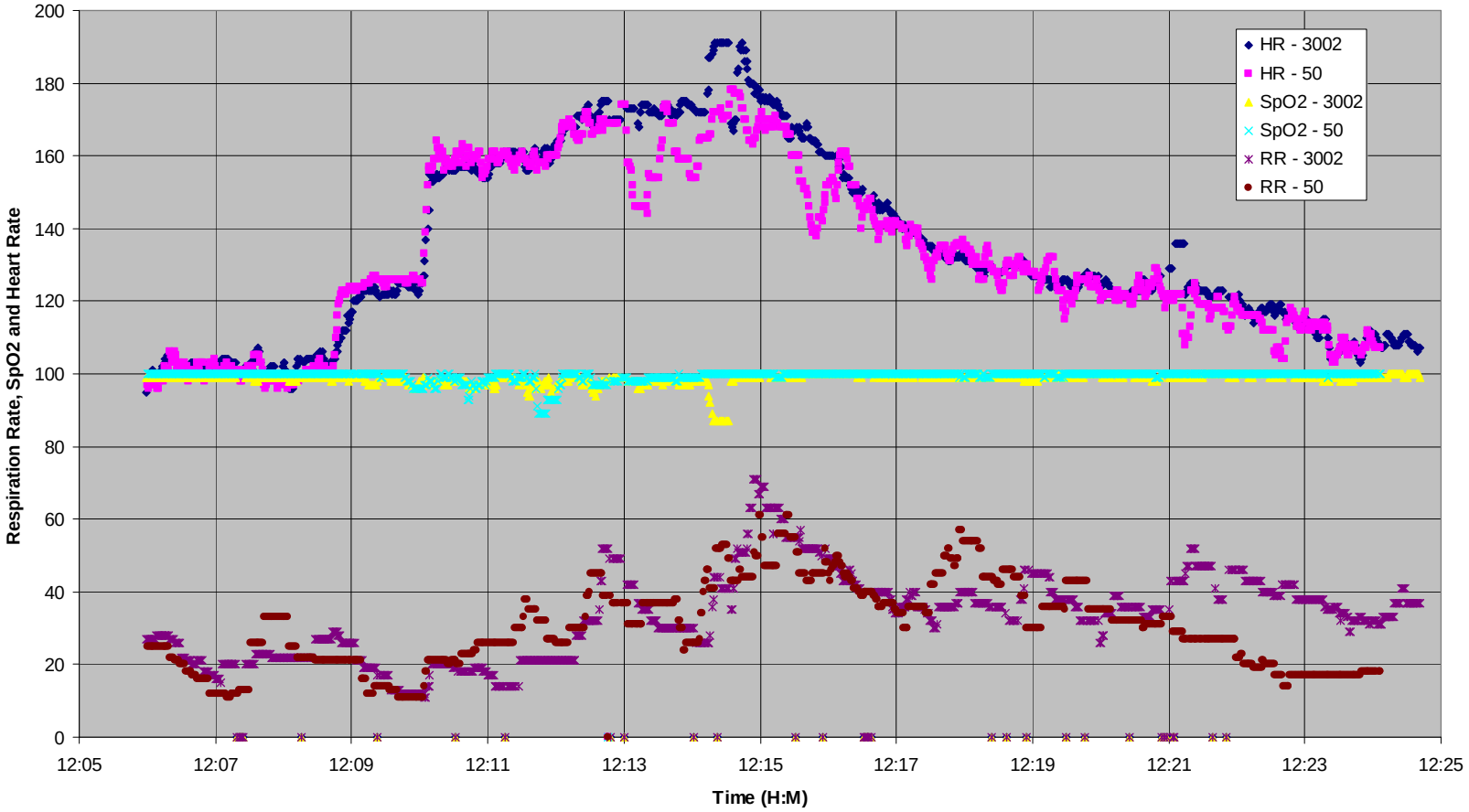
BALSM 2nd Year Pulse Ox Sensor Prototype - Top Side

Comparison Between 1st and 2nd Year Sensors

- Data from 1st and 2nd year sensors worn by a single test subject were recorded on separate PCs through separate BRUs

Testing with both 1st and 2nd year BALSM pulse ox sensors.

Comparison Between 1st and 2nd Year Sensors



Brow Pad Integration of 2nd Year BALSM Sensor

- Custom brow pad for ACH helmet fabricated to accommodate 2nd year BALSM pulse oximetry sensor
- Testing with custom brow pad begun in last week of July to determine effectiveness of sensor in this mounting configuration

Photo of custom brow pad with BALSM 2nd year pulse oximetry sensor model.

Potential Future Hardware/Software Upgrades to the BALSM System

- Hardware Upgrades
  - Integration of a higher G accelerometer could allow for detection of TBI (Traumatic Brain Injury) events
  - Potential to replace ingestible core body temperature with a helmet mounted thermistor to measure temperature at the temporal artery
    - Would remove the per use cost associated with the capsule and significantly reduce the receiver size
    - Significant questions in the literature about the accuracy of such approaches
- Software/Firmware Upgrades
  - Hypovolemia (low blood volume) detection through the PPG waveform
    - LBNP (Lower Body Negative Pressure) testing can simulate hypovolemia in a test subject and allow the effectiveness of the approach to be determined
    - Integration of hypovolemia detection algorithm into sensor firmware would be the eventual goal
  - Improvements to health state algorithm incorporating fuzzy logic

Non-DOD Applications of BALSM Project Technology

http://www.wpi.edu/Academics/Research/2008/seconds.html

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