

Wearable and Wireless: Distributed, Sensor-Based Telemonitoring Systems for State of Health Determination in Cattle

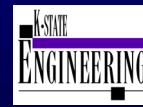
9th Annual Talbot Informatics Symposium

AVMA Annual Convention

Philadelphia, PA, July 24-27, 2004

KSU College of Engineering

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Outline

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- Directions in human telemonitoring technology
- Wearable device trends
- Project description
- Early work
- Concluding Remarks

I. Directions in Human Telemonitoring Technology

What is Telemedicine?

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- **Telemedicine:** a technology-rich alternative to a traditional, face-to-face, patient/physician consultation.



Provider Station

American Telecare (<http://www.americantelecare.com>)



Integrated Video Display, Microphone and Speaker



HomMed (<http://www.hommed.com>)

- **Audio/video** interaction
- **Data exchange:** real-time / store-and-forward
- Multimedia electronic patient records (EPRs)
- **Medical devices:** blood pressure cuff, pulse oximeter, stethoscope, glucose meter, weight scale, temperature probe, electrocardiogram, ...

Wearable Telemonitoring Systems for Cattle

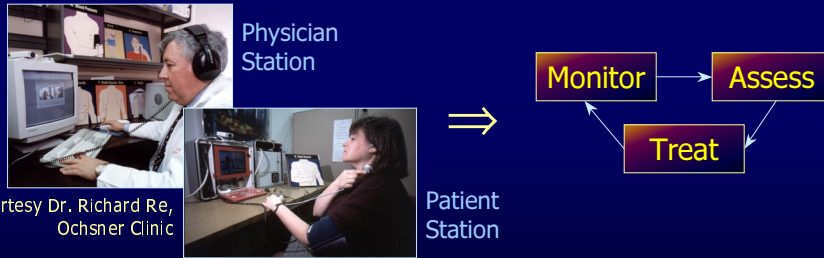
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Where Health Care is Headed

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- In-person visits ⇒ telemedicine ⇒ smart sensors



- "Virtual" medical systems: distributed, networked devices
- Drivers: lower care cost, improved quality, & better access

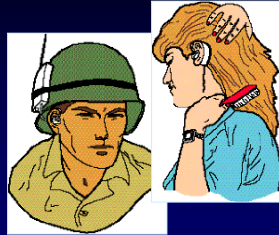
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II. Wearable Device Trends

Early Wearable Monitoring Efforts

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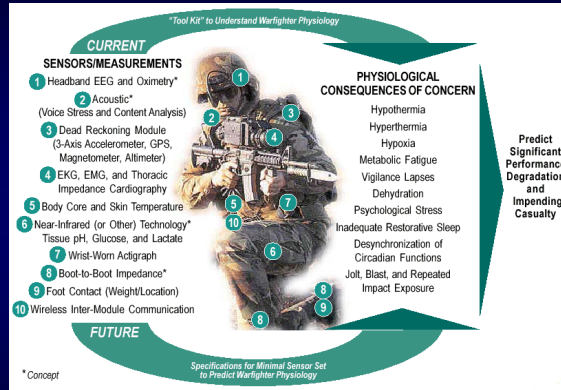


Personal Status Monitor
Sandia, 1994



Personal Status Monitor
Sarcos/DARPA, 1994

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Warfighter Physiological Status Monitoring

USAMRMC, <http://www.usariem.army.mil/wpsm/>,
http://momrp.org/publications/WPSM_supp.pdf, 2001

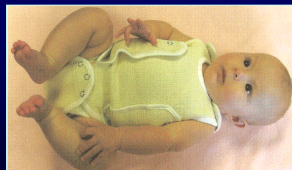


Other Recent Efforts

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Polar Heart Rate Monitors
<http://www.heartmind.net/polar/index.htm>



SIDS Suit Prototype
Sensatex Inc., IEEE Spectrum, 10/2003

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Vivometrics Lifeshirt System

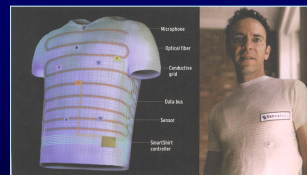
<http://www.vivometrics.com>, 2002



30+ cardiopulmonary parameters



MIT Ring Sensor
<http://www.mit.edu/people/sokwoo/home.html>, 2002

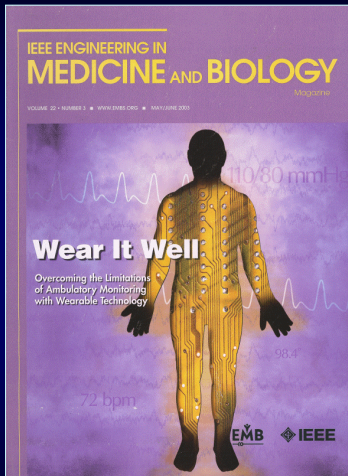


SmartShirt Gear
Jayaraman/Park, Georgia Institute of Technology, IEEE Spectrum, 10/2003



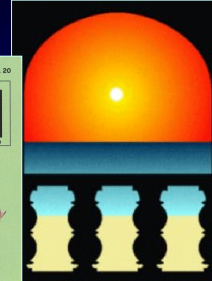
Recent Attention

9



IEEE EMBS Magazine
May/June 2003

IEEE Spectrum
October 2003



CANCUN 2003

25th Annual
IEEE EMBS
Conference
Cancun, Mexico
September 2003

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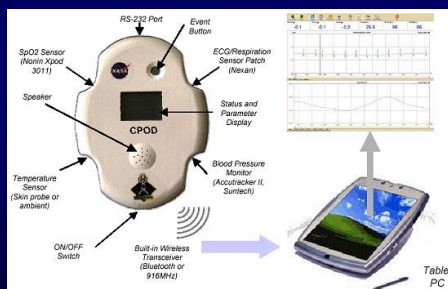
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Body Area Networks

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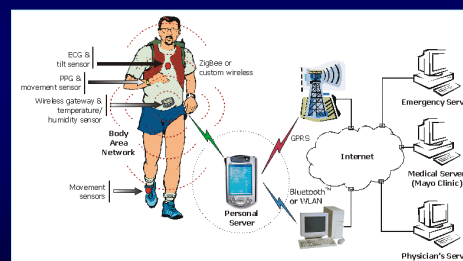
Trends

- Smaller, lighter, and 'invisible' sensors
- PDAs: data loggers and device managers
- Wireless communication



NASA/Stanford C-POD

http://lifeguard.stanford.edu/lifeguard_flyer.pdf



Wireless Body Area Network

Emil Jovanov (University of Alabama, Huntsville), 2003

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III. Project Description

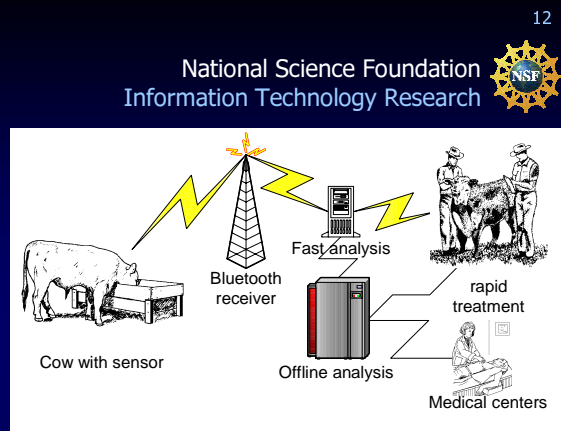
Project Goals

- **Goal:** Continuously assess and predict cattle state of health
- **Impact:** Improve the ability of the livestock industry to react to and predict disease onset and spread

- **Mechanisms**

- On-animal collation of wearable/remote physiological, behavioral, and environmental sensor data
- Wireless access points for data uploads
- Regional information infrastructure
- Health assessment algorithms

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IV. Early Work

Model: Wearable Human Monitoring System

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Medical Component Design Laboratory
Kansas State University



National Science Foundation
CAREER Program

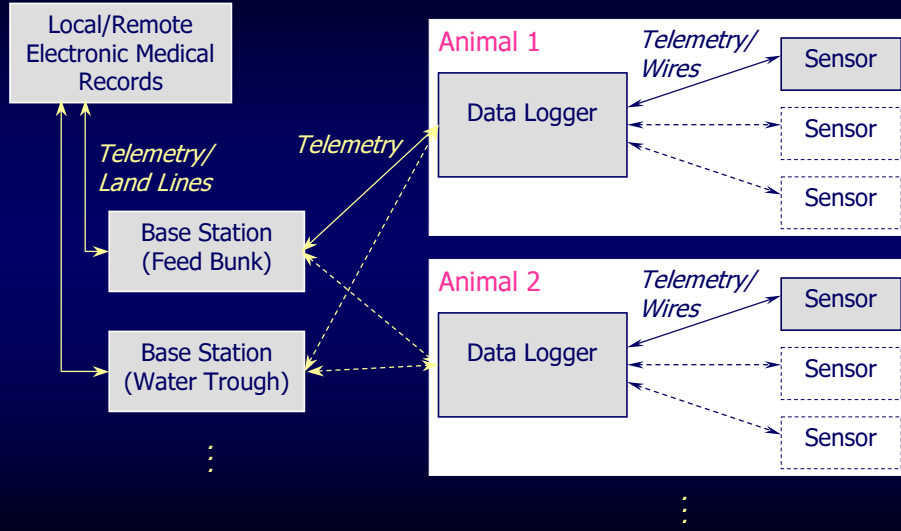


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Animal/System Connectivity

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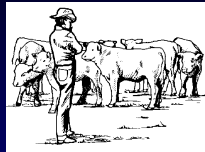


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Early Approach

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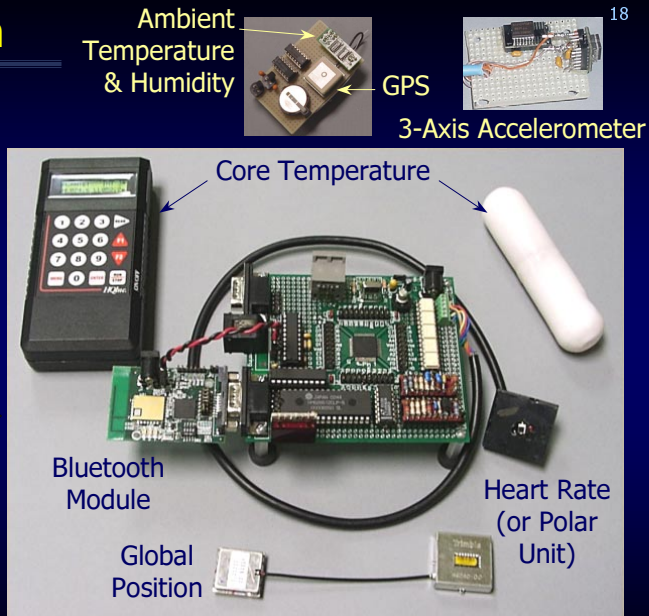


Farmer with Handheld Computer (Base Station)



Compaq iPaq PDA

Bluetooth telemetry link

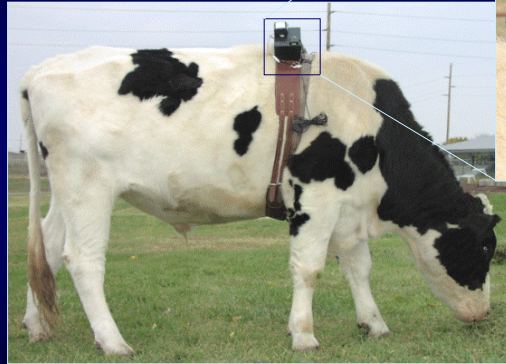


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Field Tests

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Ambulatory data acquisition with real-time transmission to a base station (personal computer running LabView)

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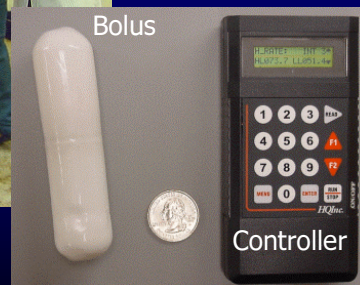


Core Body Temperature

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Acquired via a telemetric link between a temperature-sensitive bolus and a small transceiver box



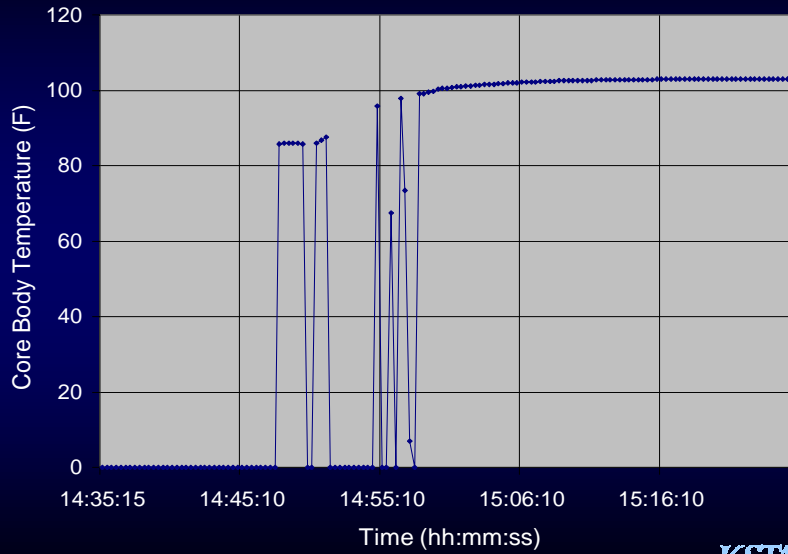
CorTemp, HQI Inc.

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Representative Core Body Temperature Data

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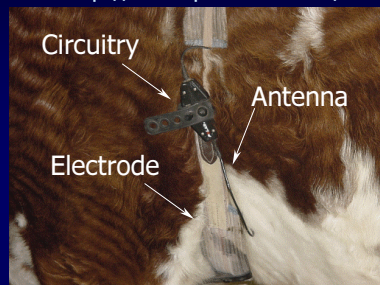
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Heart Rate

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Polar Heart Rate Monitor
<http://www.polarusa.com/>



Design application: heart rate monitoring during race horse training



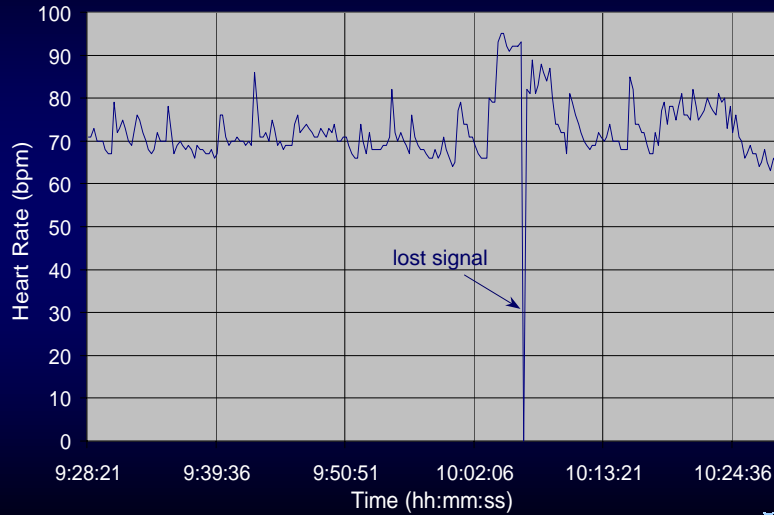
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Representative Heart Rate Data: Healthy Animal

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Average HR: 74 bpm



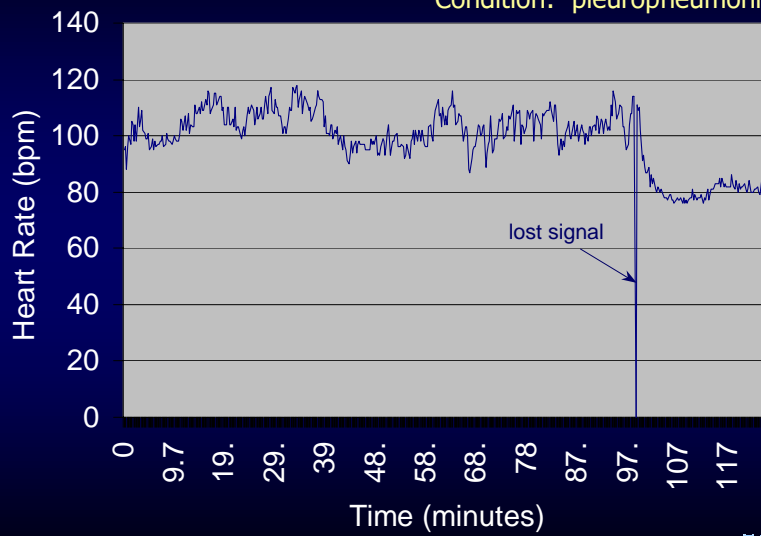
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Representative Heart Rate Data: Sick Animal

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Condition: pleuropneumonia



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Light-Based Sensors

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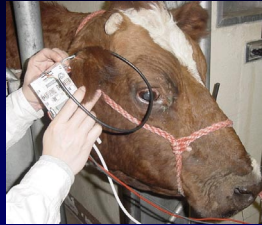
Primary Benefits

- Acquire heart rate in a small, surface-worn form factor with no electrical connection to the animal
- Comfortable and inexpensive
- Potentially: blood oxygen saturation, hemodynamic parameters, and animal authentication

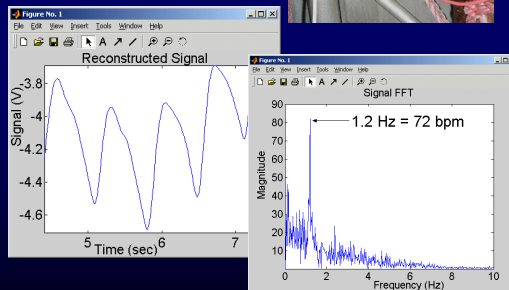
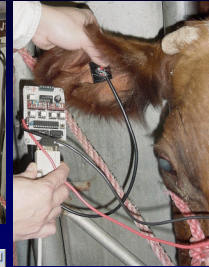
Primary Drawbacks

- Inconsistent animal-to-animal performance
- Sensitivity to motion artifact and ambient light
- Hard to secure in place

Transmittance



Reflectance



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Global Position

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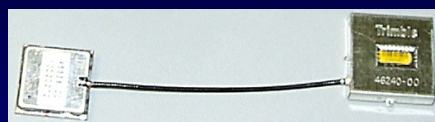
Version 1



Garmin GPS 16-LVS



Version 2



Trimble Lassen SQ

Motivation

- Location tracking (resource management)
- Contact history
- Sickness \leftrightarrow Decreased overall activity
- Data for correlation with weather patterns

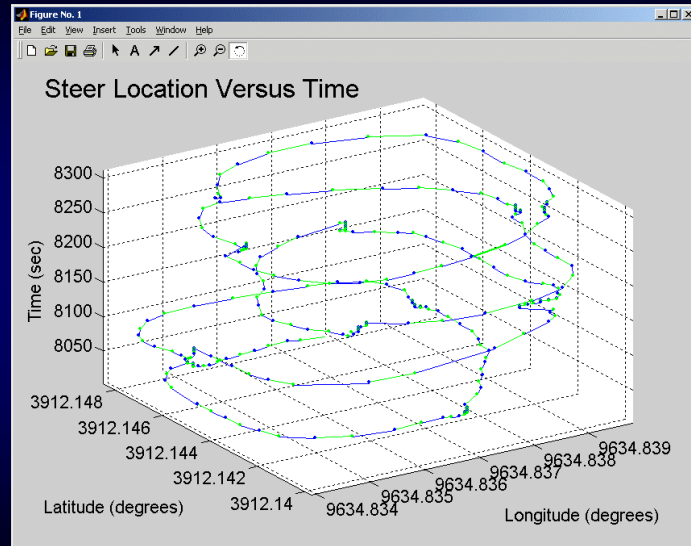
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Representative GPS Data

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Resolution:
3 m



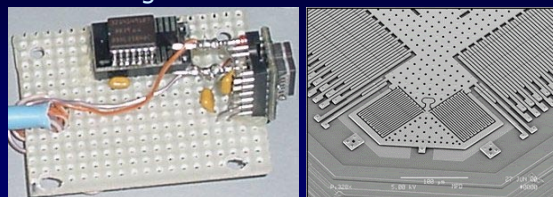
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3-Axis Acceleration

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3-Axis Analog Devices iMeMs Accelerometer



<http://www.analog.com>

□ Motivation

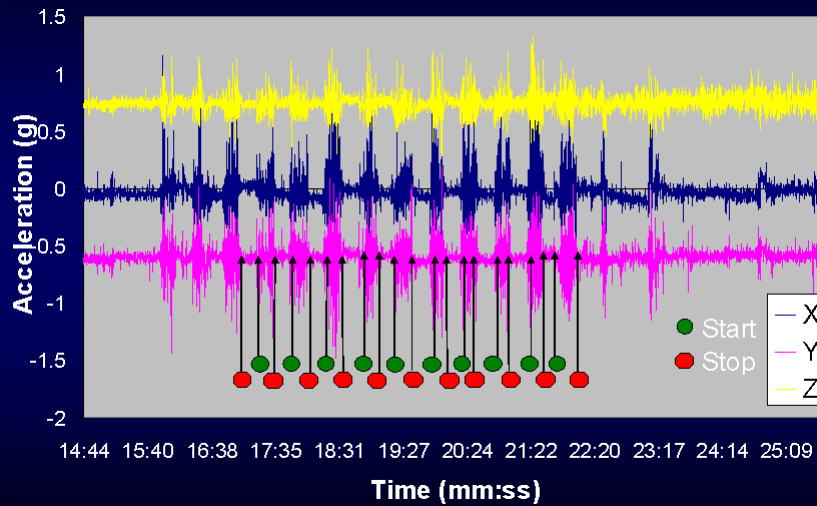
- Feed/water intake monitoring (e.g., head position)
- Attitude (upright, lying down, ...)
- Sickness \leftrightarrow Decreased or abnormal local activity

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Representative Accelerometer Data

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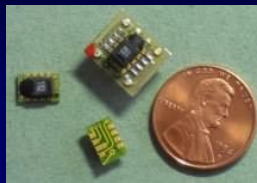
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Ambient Temperature/Humidity

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Sensirion SHT11 Temperature/Humidity Sensor



<http://www.emesys.com/OL2sht1x.htm>

□ Motivation

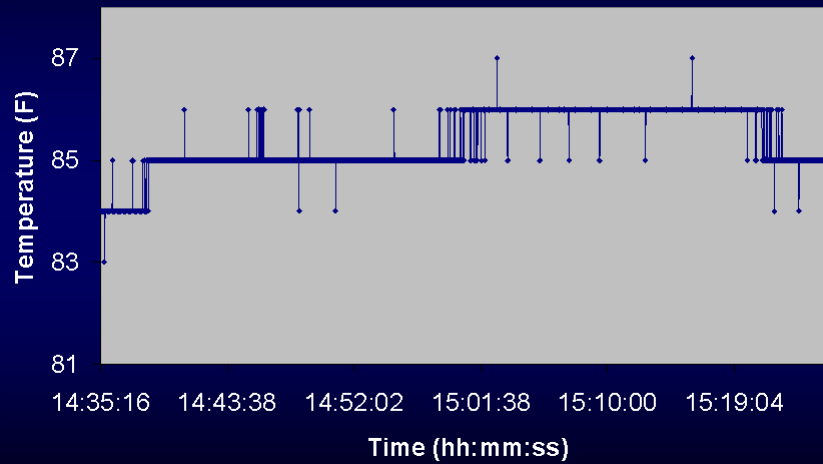
- Environmental stressors contribute to animal disease, reduce performance, and affect readiness to mate/conceive
- Baseline ambient data can help to calibrate measured values of core body temperature

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Representative Ambient Temperature Data

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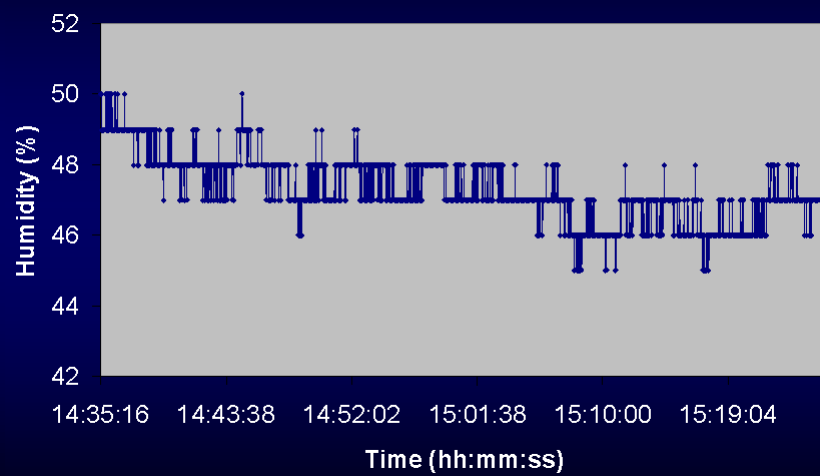


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Representative Ambient Humidity Data

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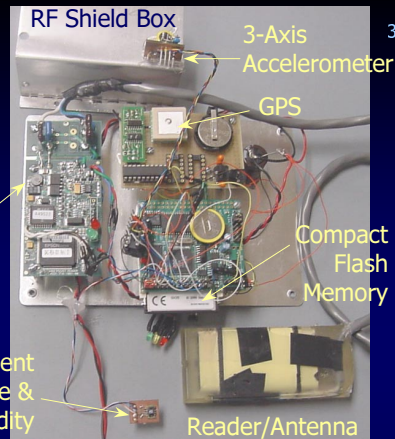


Current Approach

- Gather primarily **environmental/behavioral** data while researching heart rate & respiration technology
- **Updates**
 - More capable processor
 - 256 MB compact flash card (65 hours of storage)
 - Power-saving mode
 - Smaller/cheaper/more accurate accelerometers
 - Core body temperature with Digital Angel implantable chips

Digital Angel Reader Board

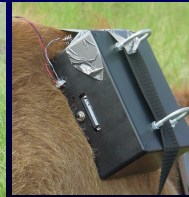
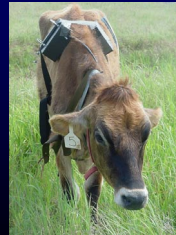
Ambient Temperature & Humidity



Implant Form Factor



<http://www.nationalband.com/chip1.pdf>
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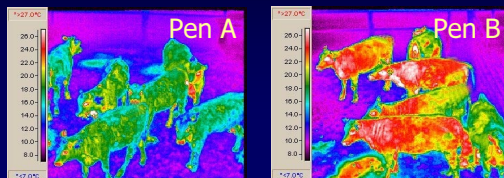


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Infrared Imaging

- **Goal:** correlate data gathered by animal-worn units with data observed via remote sensing technologies



Warmer profile ⇒ Better performance

(healthier; faster weight gain; less likely to be sick)

- Pen A - lower thermal profiles; multiple pulls & treatments (6 animals; 66 pounds of feed per day)
- Pen B – higher thermal profiles; one pull and treatment (6 animals; 112 pounds of feed per day)

Application: Screen for respiratory disease (animals exhibit a change in thermal profile 2-3 days before they are observed to be sick)

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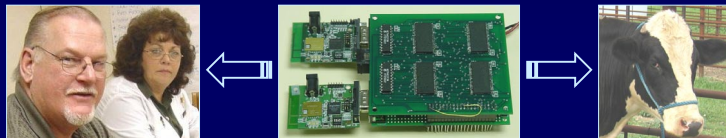
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V. Concluding Remarks

Key Messages

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- Human & animal **care model**
 - Reactive/episodic ⇒ preventive/predictive
 - Closed-loop systems: beyond “telemedicine”



- Human & animal monitoring systems: **shared requirements**
 - Low-cost wearable & remote sensors
 - Health prediction based on trend data
 - **Subjects:** may be unable to interact intelligently with devices
 - Secure electronic medical records

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Challenges

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□ Technical

- Sensor selection & placement
- Reliable signal acquisition
- Data interpretation
- Battery life
- Animal compliance
- Robust packaging (weather; animal behavior)
- Security (e.g., information control ⇒ owners of sick animals)
- Data integrity (e.g., animal A's data logger cannot store animal B's data)
- Usability

□ Non-Technical

- Economic feasibility
- Producer acceptance



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Contributors

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- Electrical & Computer Engineering, KSU College of Engineering
- Anatomy & Physiology, KSU College of Veterinary Medicine
- Computing & Information Sciences, KSU College of Engineering
- Digital Angel, Inc.
- HQI, Inc.

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