

# Biomedical Sensor System for Continuous Wireless State-of-Health Determination in Cattle



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## Things We Know Are Related to Disease in Cattle

- Core body temperature
- Respiratory rate
- Heart rate
- Blood oxygen saturation
- Activity (feed/water intake)
- Body movement
- Ambient temperature and humidity
- Wind patterns

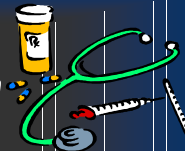


## Goals

- Create ambulatory instrumentation suite
  - Utilize biomedical sensors
  - Wireless data transmission
  - Data processing
  - Data analysis
  - Secured information infrastructure
- Has application in a wide variety of production environments
- Cost effective
- User friendly



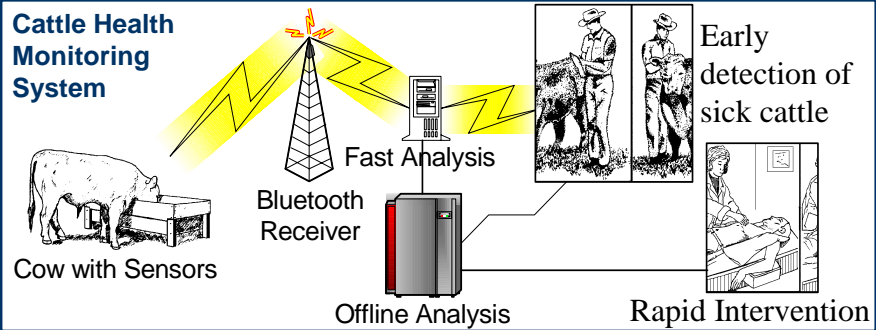
## Benefits of Animal Monitoring



- Animal identification/tracking
- Early disease detection
- Evaluate population dynamics
- Develop intervention strategies



# Project Overview



Producer with hand held computer (PDA)

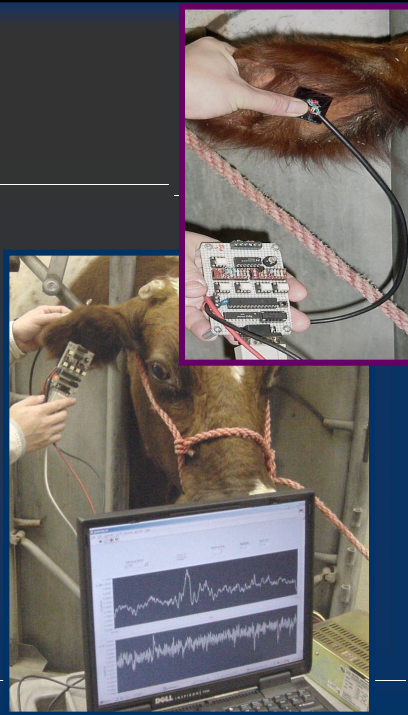
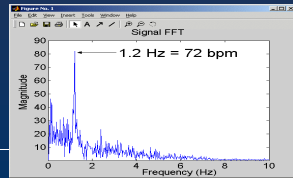
# Electronic Id

- Radio frequency identification tags (RFID)
- Tracking cattle from ranch to rail
- Types
  - ear tags
  - implants



# Pulse Oximeter

- Light-based Sensor
  - Red and Near-Infrared Light
- Measures:
  - Blood Oxygen Saturation (SpO<sub>2</sub>)
  - Pulse Rate
  - Respiration



# Core Body Temperature

1.
  - Core Temp Unit
  - Wireless Transmission from Bolus to Receiver
    - ~3 Foot Range
2.
  - Subcutaneous implants
  - (Digital Angel, Destron Technologies)



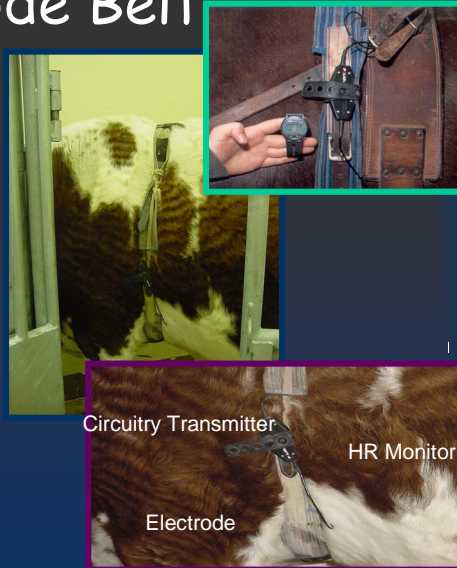
Ingestible bolus (placed via rumen fistula)



Commercial System  
HQI, Inc. Palmetto, FL

# Electrode Belt

- Measures Heart Rate
- Reads Electrical Signals from Skin Surface
- Wirelessly Transmits Data to CorTemp Receiver Unit
- Good for detecting stress and state-of-health changes
- Problems
  - thickness of hide
  - electrical resistance of hide
  - Outside environment
  - Electrodes and wires

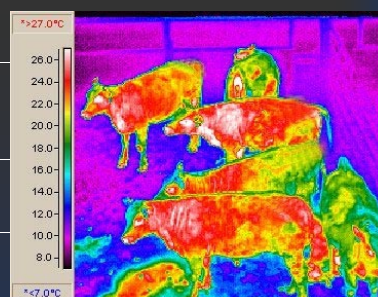
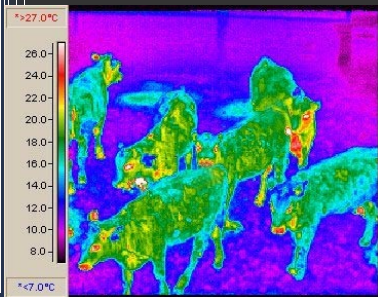


Commercial System (Polar®)  
Mill Valley, CA

# Thermal Profiling

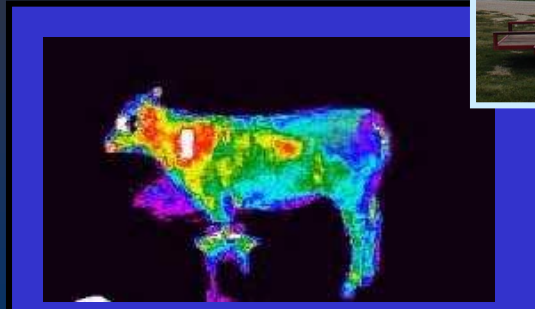
Pen A

Pen B



- Pen A - lower thermal profiles than the steers in Pen B.
  - Pen A - multiple pulls and therapeutic treatments.
  - Pen B - only one pull and no treatment among the group.
- Better performance (healthier and faster weight gain) - warmer profile.
- Screen for respiratory disease - cooler profile 2-3 days before sick due to fever.

# Injection Site Abscess



# Respiratory Rate

- Important indicator for illness, stress and state-of-health changes

## 6 Options

1. Airflow through the nostril.
2. Derive from pulse oximeter.
3. Derive from electrocardiogram.
4. Thermistor detecting temperature fluctuations in inspired versus expired air.
5. Acoustic sensor in rumen.
6. Strain gauge measurement of chest expansion.



Problem:

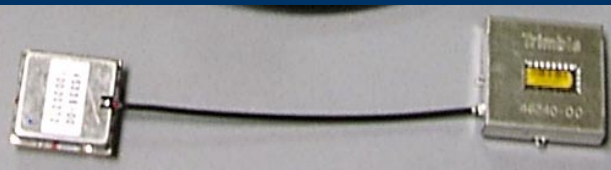
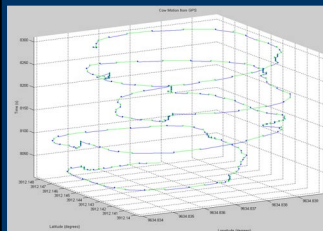
Response time of equipment is too slow

## Feed Intake and Water Consumption

- Healthy steers spend increased time eating (time at feed bunk) and drink more frequently
- Detect illness 3-4 days earlier
- Correlate time spent at feedbunk with position and movement of head (3-axes accelerometer and GPS)



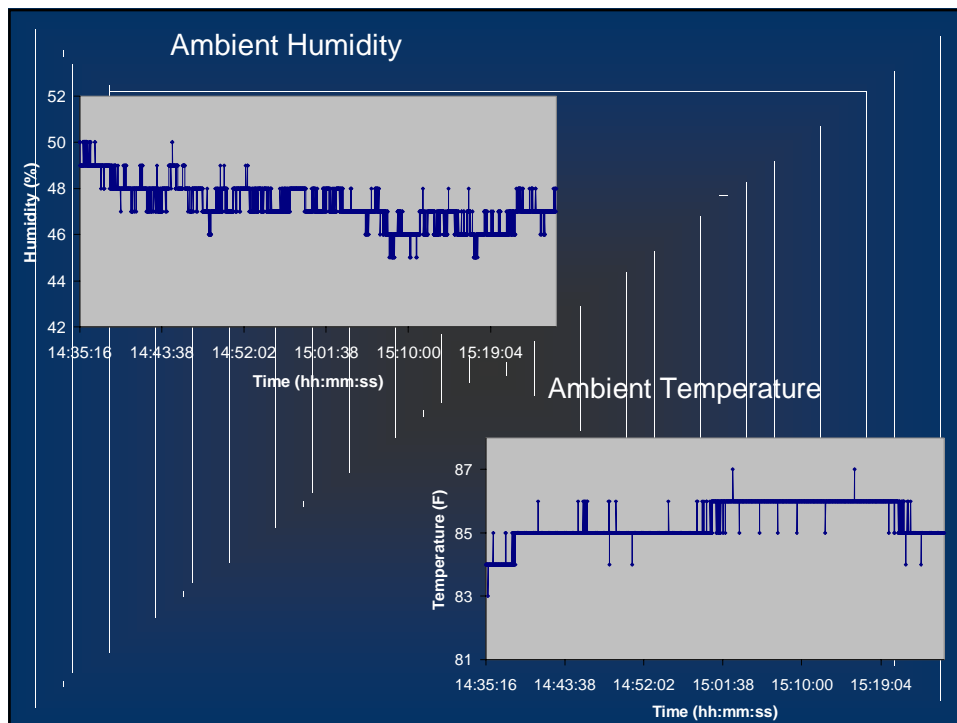
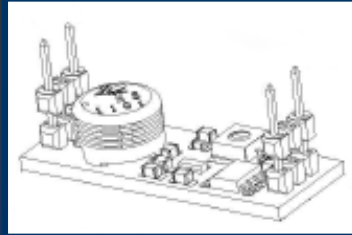
## Additional uses of GPS and Accelerometer



- Decreased movement/activity are correlated with increased sickness
- Location of cattle and herds (contact history)
- Estrus detection

# Ambient Temperature and Humidity along with Wind Speed

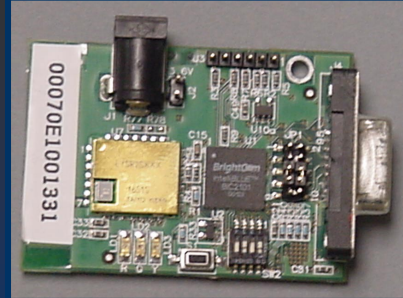
- Livestock react to environmental stressors that contribute to decreased performance, disease, and readiness to mate/conceive
- Airborne infections transfer diseases great distances





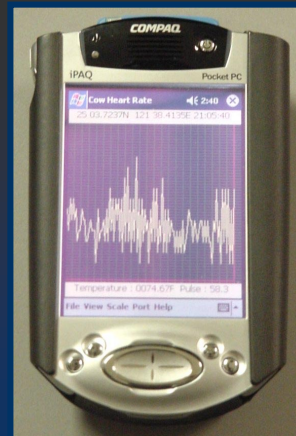
## Bluetooth Wireless Unit

- Bluetooth wireless link for information/data transmission to fixed base station or mobile platform
- Limitation
  - 30-Foot Range
  - High Power Consumption



## Mobile Base Station

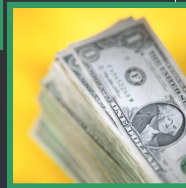
- PDA (hand-held computer) with a Bluetooth Receiver Flashcard
- Displays State-of-Health Data to User in Real-Time



## "Proof of Concept" Steer



Wearable (collar, cow bell, ear tag) or implantable (rumen bolus, subcutaneous) sensors and memory storage.



Refinements in technology and miniaturization will reduce cost.



## Software



- Creating Electronic Medical Record
- Clear discrimination between sick and healthy animals
- Develop decision models
  - Risk assessment
  - Trend analysis
  - Algorithms/Indices using human models



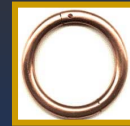
## Secure Internet Infrastructure

- Geographic health report
- Confidential data transfer
- GIS overlay - weather, animal populations, transportation routes
- Alerts and advisories



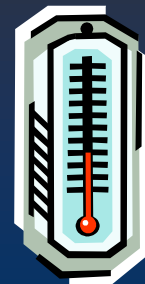
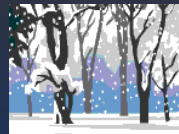
## Instrumentation Design Challenges

- Best parameters to measure
- Multitask sensor development
- Number of sensors in population
- Read range
- Sensor placement
- On board data storage and retrieval
- Measurement frequency
- Wireless data transfer and analysis
- Power usage for components

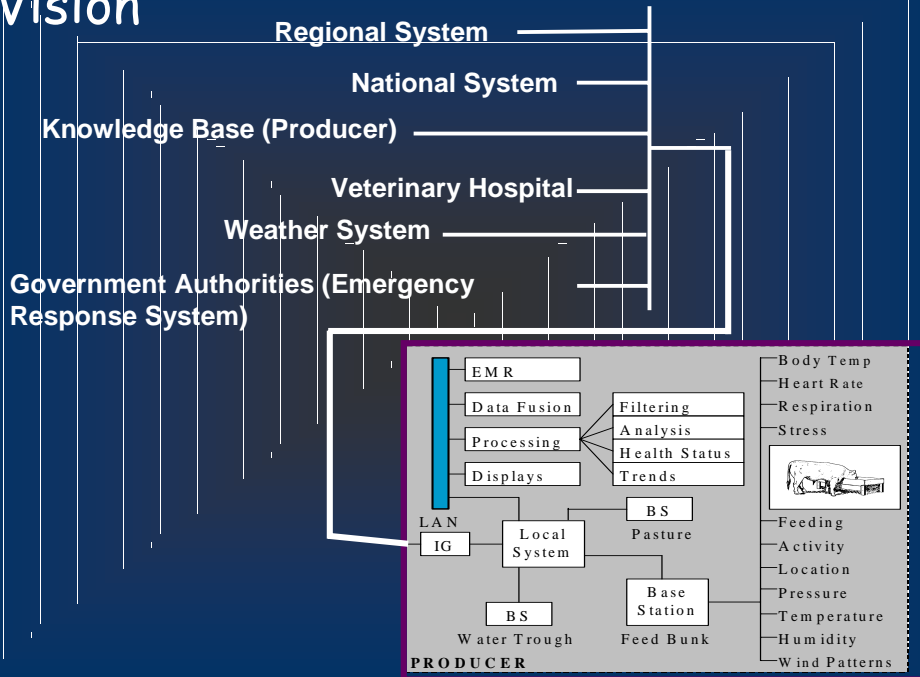


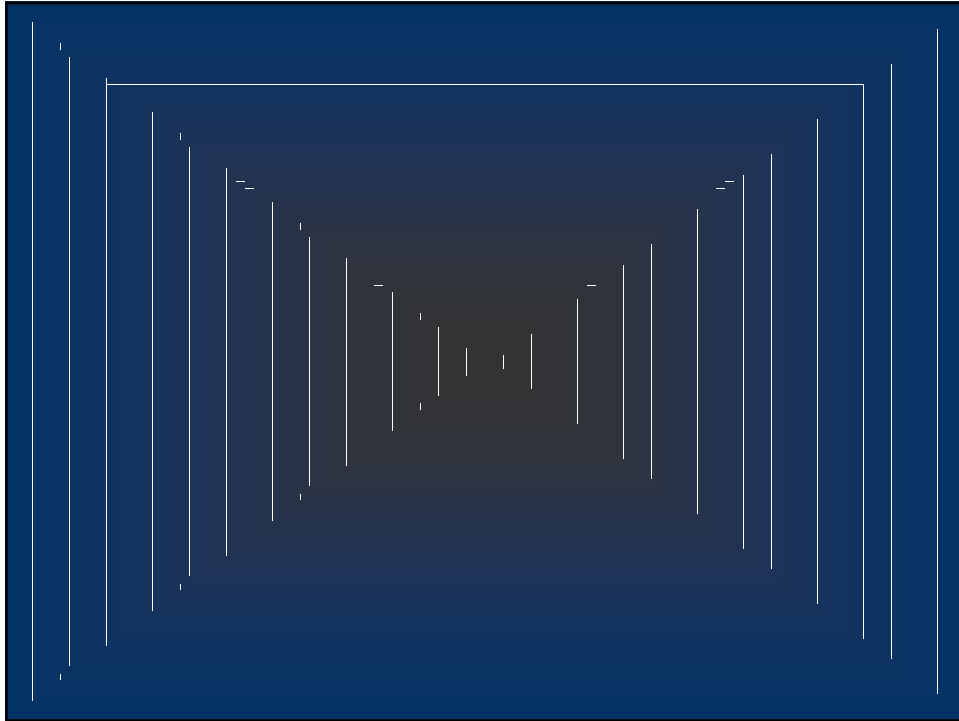
## Instrumentation Design Challenges

- Robust packaging/durability to withstand environmentally challenges and extremes
  - Snow
  - Rain
  - Heat
  - Mud
  - extreme humidity and temperature ranges
- Economic feasibility



# Vision



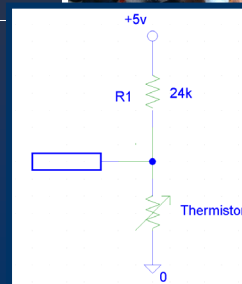


It All Comes Out in the Wash!

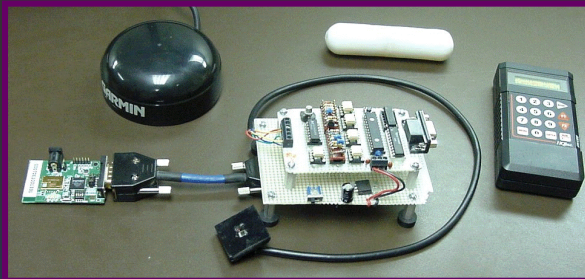


Questions?

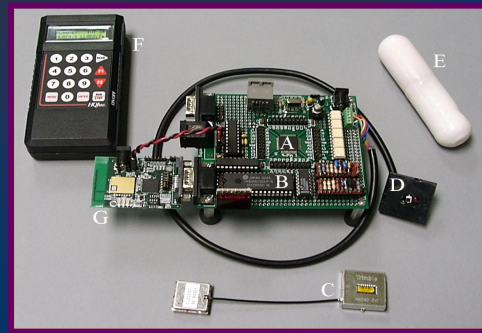
# Practical Applications



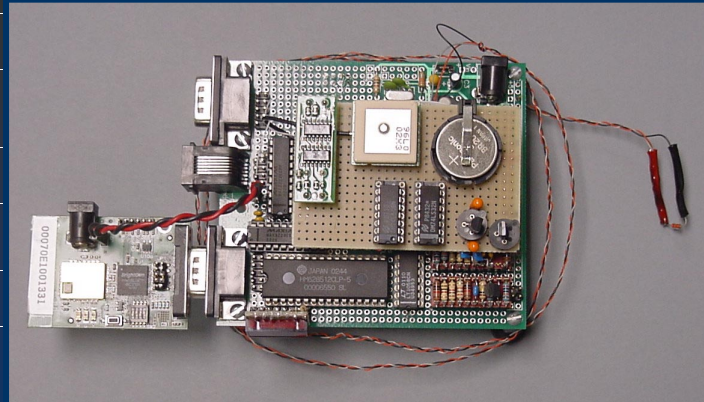
## Original Prototype



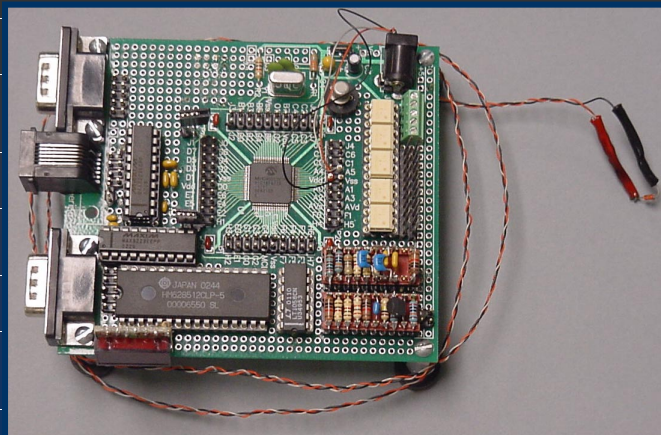
## Current Prototype



## Current Board, Complete



## Current Board, Core Only





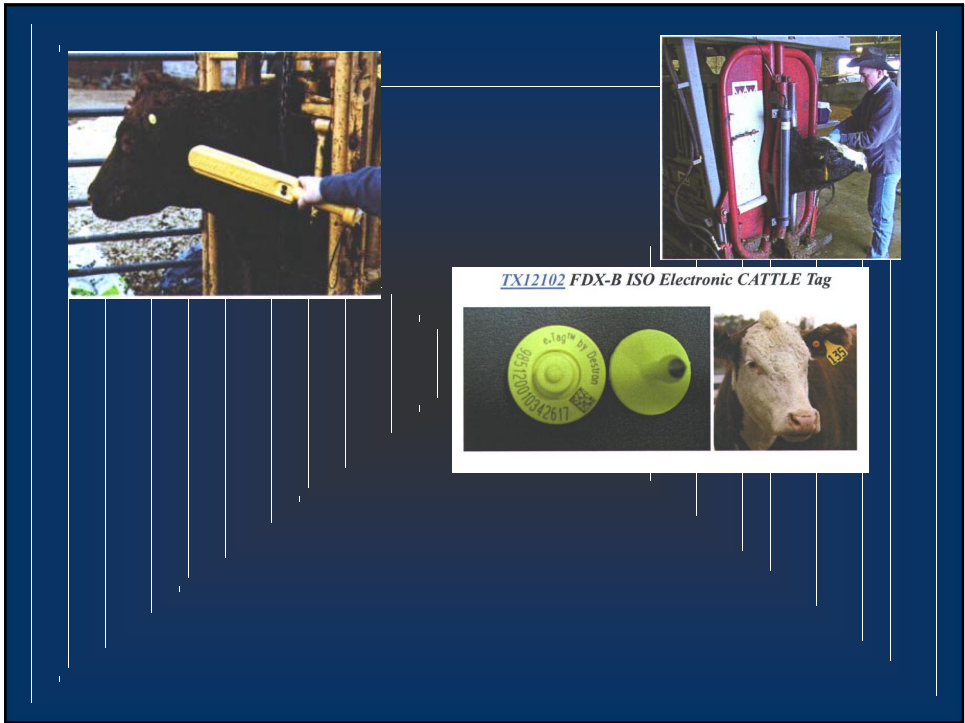
## Testing - Pulse Oximeter

- Light reflectance sensor heart rate data obtained by using Fast Fourier Transformation and a peak fundamental frequency.
- Verify accuracy using commercial technology (Polar® heart rate monitor).

## PIC 18F8720 Microcontroller

- Communicates with sensors to set sampling rate and frequency
- Processes and smoothes data
- Stores Data

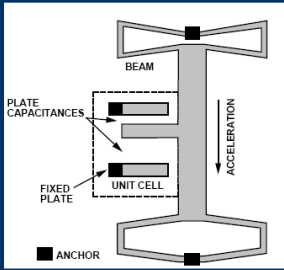




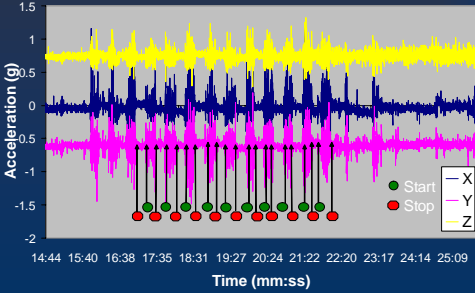
TX12102 FDX-B ISO Electronic CATTLE Tag

# Accelerometers

- 3 axis system
- Variable Capacitor
- Outputs Analog Voltage for Each Axis
  - $2.5V \pm 38mV/g$
- Feed and water intake using head position



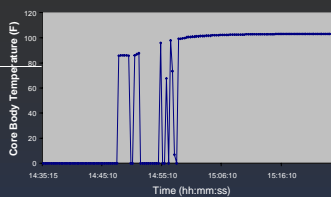
Acceleration vs. Time



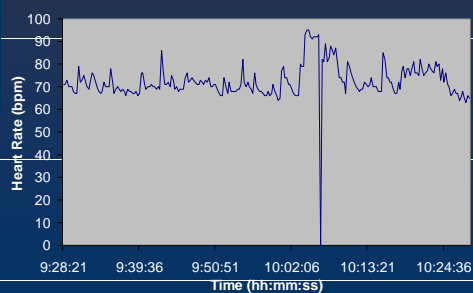
# Testing – CorTemp/Electrode Belt



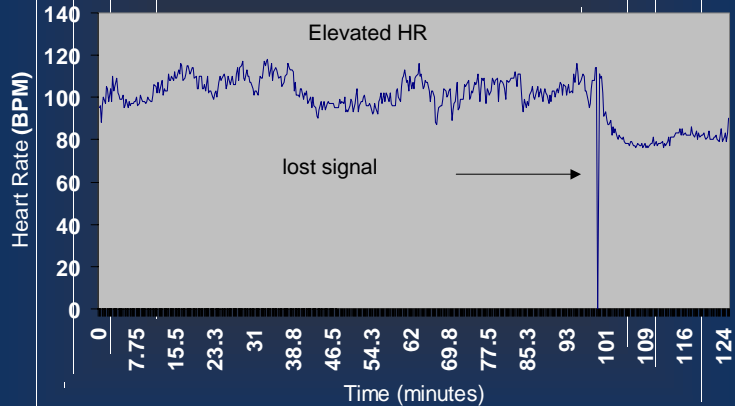
Core Body Temperature



Polar Heart Rate Data



## Elevated HR of Sick Cow



## Future Directions

- Injectable temperature (RR) and RFID transponders
- Replace microcontroller with more powerful unit improved data processing
- Acoustic sensors (HR, RR, BT)- more protected internal environment
- Transition from bulky to wireless system (implantable, multi-purpose, low profile sensors, external devices, cowbell/collar, ear tags)



## Summary



- Develop compact multitasking continuous and wireless monitoring suite
- Incorporate environmental influences
- Able to determine morbid and healthy cattle
- Producer friendly and economically feasible
- Increase producer profit and security of nation's livestock and safety of food supply

