NAVSEA WARFARE CENTERS DAHLGREN

Automatic Hit Detection System for Real-Time Target Hit Feedback

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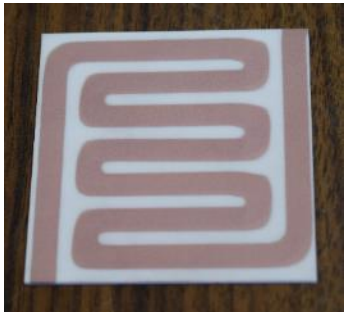
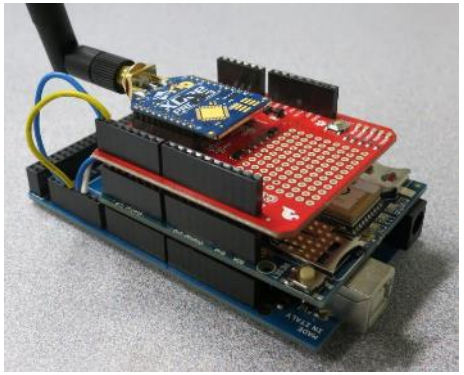
Presentation Overview

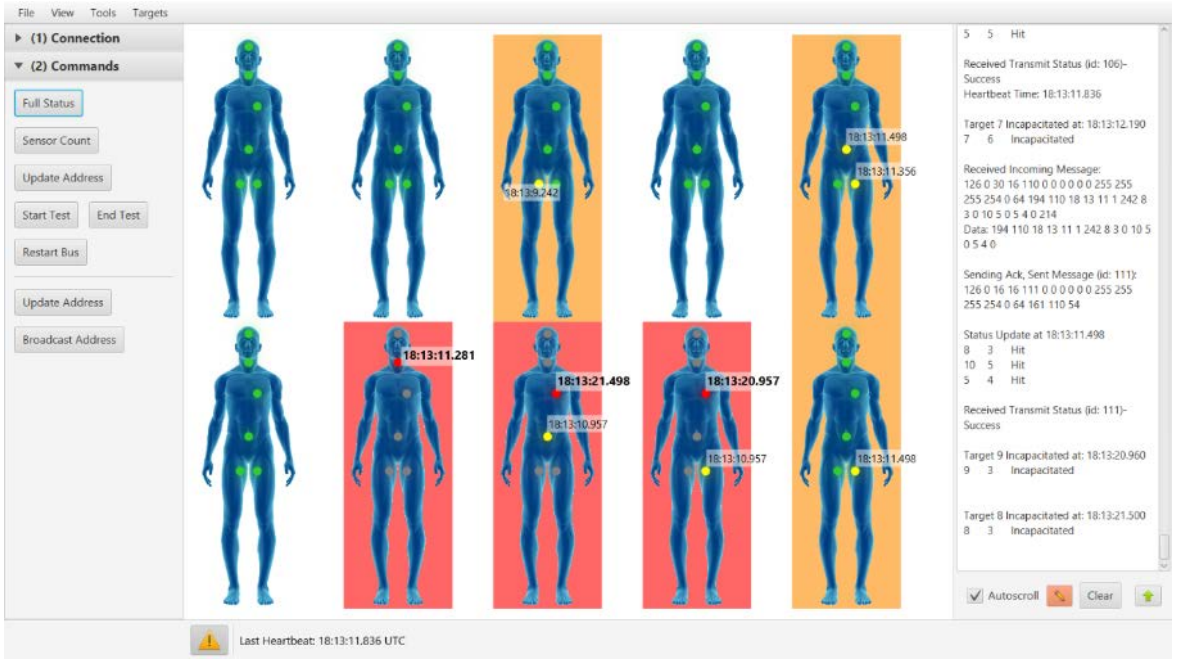
- Motivation and Goals
- System Architecture
- Remote Module
  - Sensor Devices
  - Master Controller
  - Communications
- Base Station
  - Communications
  - UI Software
- Test Results
- Future Development



Ceramic Impact Sensor



Remote Module (RM) Hardware



User Interface- Personnel Lethality Target Example

Motivation and Goals

Motivation: All branches of US Military execute live fire testing, from ammunition development to platform level requirements verification, LFT&E and OT

- Current technology lacks flexible/modular real-time hit detection for collecting data and supporting analyses
- Metrics and test objectives cannot be assessed real-time during test event
- Example: assessing functional kill types on targets during live fire testing and real-time shot placement during munitions testing

Goal: develop a flexible/modular hit-detection sensor and supporting system that allows real-time detection of target impact points

- Provide real-time hit-detection feedback of critical target locations
- System can be applied to a variety of test target configurations and support data collection for appropriate analyses
- Provide real-time threat assessments of project metrics and test objectives
  - Example includes casualty assessment of personnel targets

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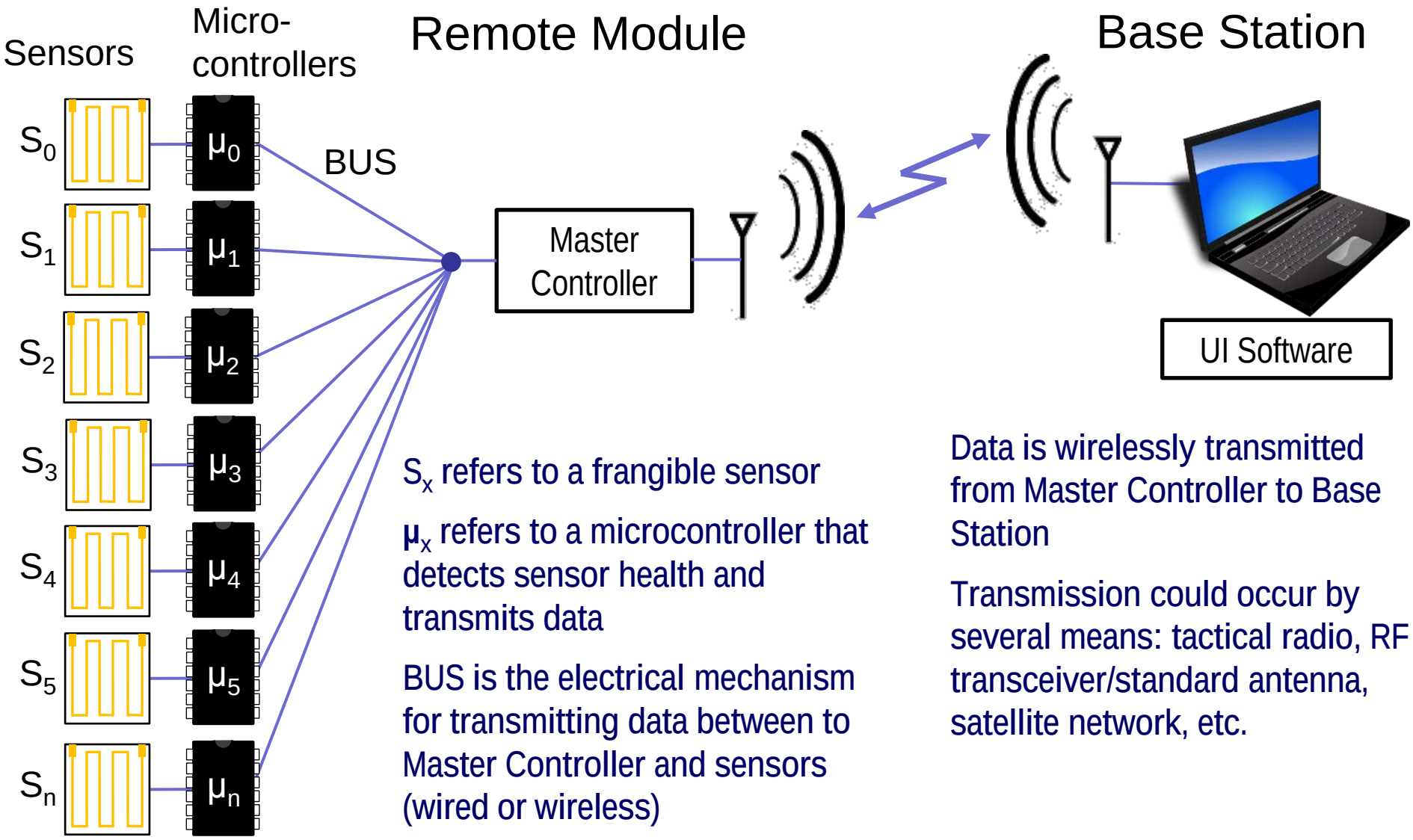
System Architecture



S_x refers to a frangible sensor

μ_x refers to a microcontroller that detects sensor health and transmits data

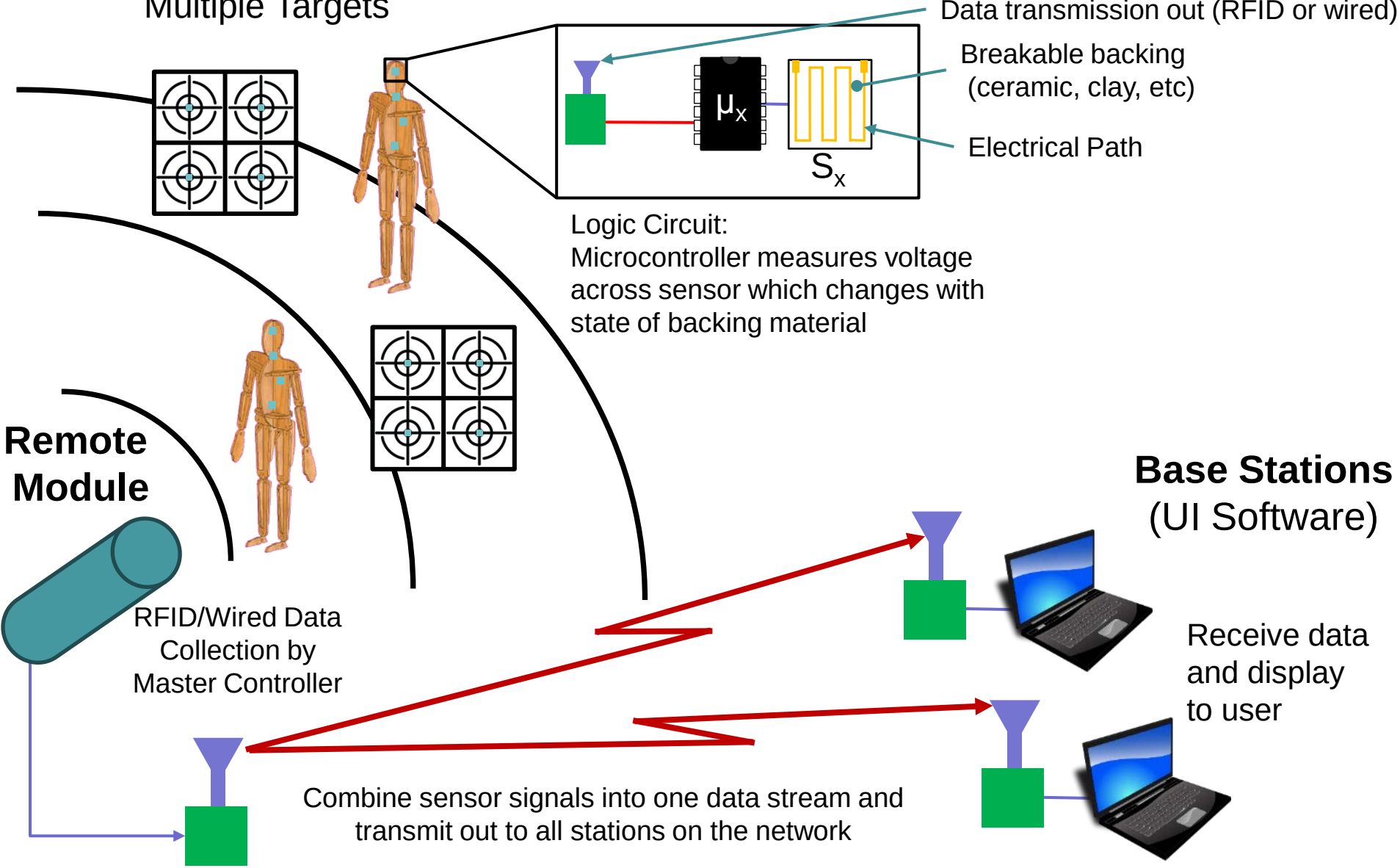
BUS is the electrical mechanism for transmitting data between to Master Controller and sensors (wired or wireless)

Data is wirelessly transmitted from Master Controller to Base Station

Transmission could occur by several means: tactical radio, RF transceiver/standard antenna, satellite network, etc.

System Schematic

Multiple Targets



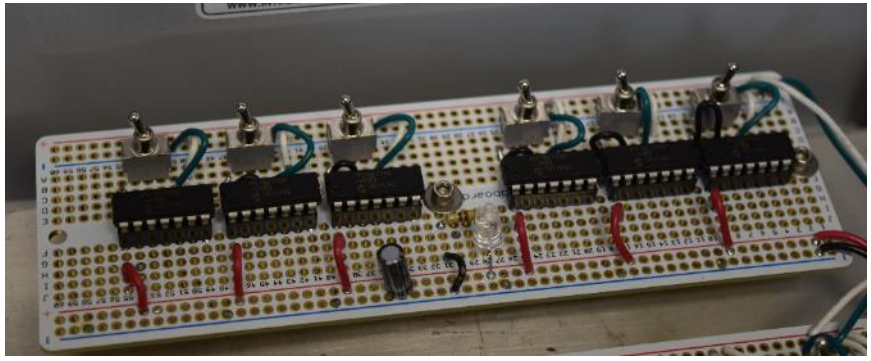
Remote Module- Sensor Devices

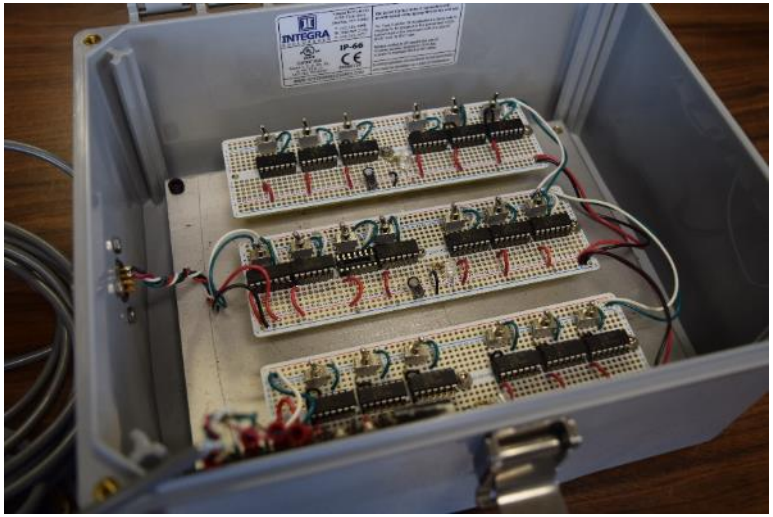
Sensor consists of breakable backing/substrate (ceramic, paper, etc.) overlaid with a conductive trace

Sensor microcontrollers (MCU) consist of inexpensive (~$1) 8-bit MCU, programmed with unique ID number

MCU measures voltage across sensor to determine health, and sends and receives data from Master Controller

http://www.mesoscribe.com/sensors/crack-detection-sensors/





Remote Module- Master Controller

Master Controller (MC) consists of Arduino Mega 2560 (~$46), which is the “brains” of the RM

Uses GPS module (~$68) to tag sensor impacts with GPS timestamps

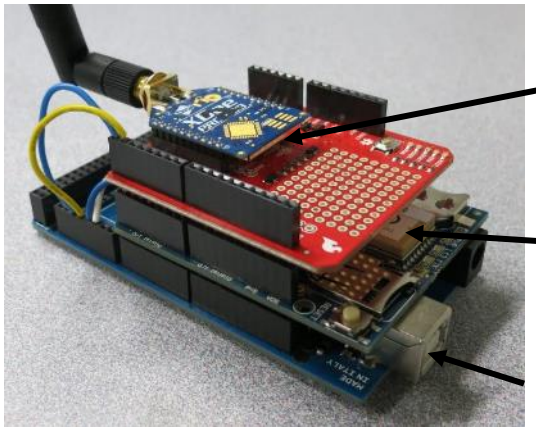
Communicates with sensor devices via wired or wireless electronic communications medium

Sends/receives data and commands from Base Station using RF Transceiver (~$75)

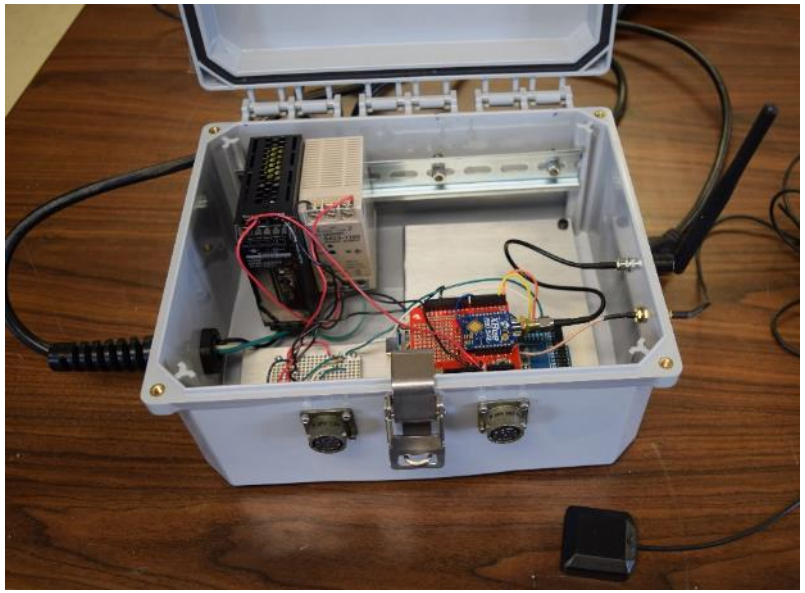
- 900 MHz, 200 kbps
- 6000 m range with basic whip antenna (upgradeable)

Modular Architecture

Comparable laptop solution (Labview, NI-Daq): >$3,000 vs Remote Module (~$190)



Master Controller Hardware (~$190)



Remote Module- Master Controller

Sensor Devices Comms
- On bootup, scan comms bus for all sensor devices
- Retrieves health status

UI Comms
- Sends sensor health updates
- Recevies and carries out commands
  - ❑ Full status request
  - ❑ Number of Targets/sensors
  - ❑ Start testing mode
  - ❑ Stop testing mode
  - ❑ Restart sensor device comms bus
  - ❑ Destination address change
- Send Heartbeat messages at period time intervals
- Stores critical outgoing messages in multiple-message buffer

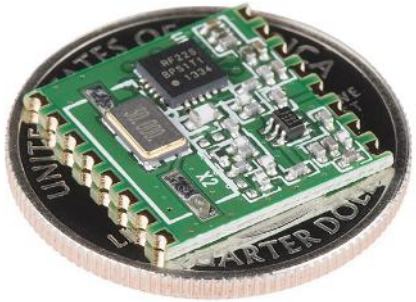
Resend Message Buffer
- Checks for RF Transmitter TX Status ack
- Checks for UI ack
- Resends message if acks not received within specified time

GPS Module
- Synchronize with NEMA strings periodically
- Synchronize with GPS second start pulse
- Timestamp all outgoing messages

Master Controller Software Loop

Remote Module Communications

Communications bus between Master Controller (MC) and sensor devices is used to send data and commands



Low power RF Transceiver (~$25)

Prototype system developed with wired solution:

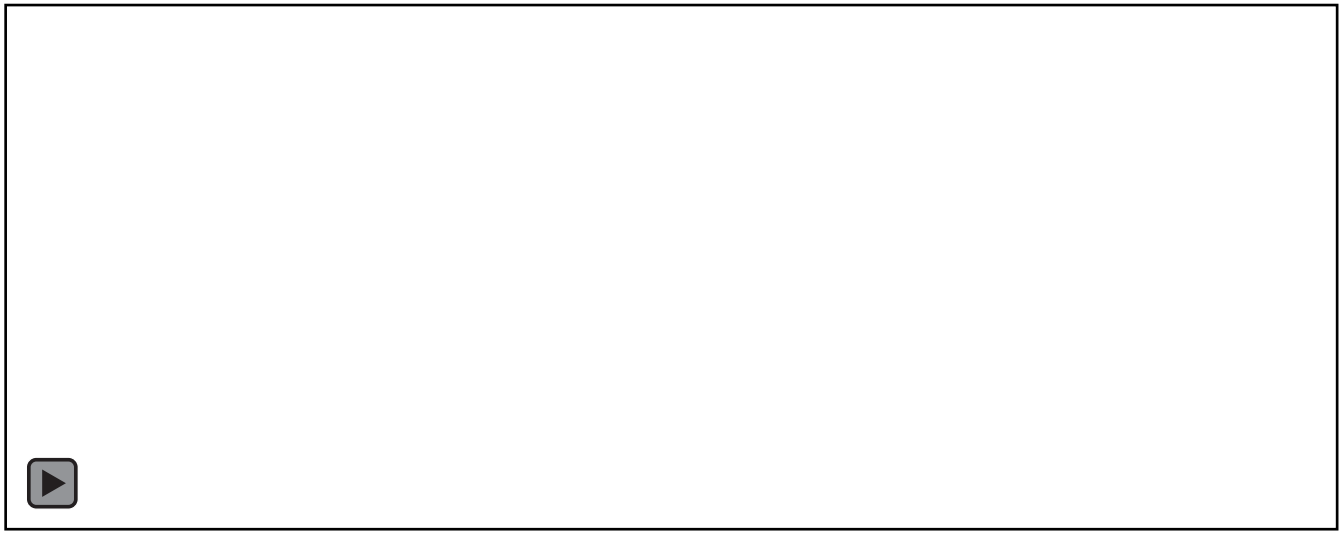
- Digital I2C Interface: allows MC to communicate with up to 120 sensor devices using 2 wires
- Data rates: 50 kbps – 800 kbps

Active RFID (wireless) solution currently under development (low power RF transceiver, 125 kbps)

- Proof of concept with Arduino sensor device
- Need to develop transceiver libraries/software for PIC MCU

Arduino Active RFID RM and Sensor Device proof of concept

Remote Module Demonstration



Pre-Impact Output:

```
0x16    3-1     1
0x17    3-2     1
0x18    3-3     1
0x19    3-4     1
0x1A    3-5     1
0x1B    3-6     1
0x1C    4-1     1
```

Post-Impact Output:

```
0x16    3-1     1
0x17    3-2     1
0x18    3-3     1
0x19    3-4     1
0x1A    3-5     1
0x1B    3-6     1
0x1C    4-1     0
Sending Message:
7E 0 18 10 EA 0 0 0 0 0 0 FF FF FF FE 0 40 C2
EA 0 A 1A 1 C8 4 1 0 2C
Message added to buffer slot: 0
```

Sensor Health Update: 4 1 0

GPS Timestamp: 0 A 1A 1 C8

Time: 00:10:26.456 UTC

Base Station Communications

Base station sends and receives data and commands from Remote Module using a wireless communications device

http://www.digi.com/products/xbee-rf-solutions/modules/xbee-pro-900hp

Line-of-sight applications: XBee Pro RF Transceiver

- 6000m range with low gain antenna
- 28 mile range with high gain antenna
- Low cost option: ~$75
- Data rate: 200 kbps

http://www.bluecosmo.com/satellite-tracking-monitoring

Non-line-of-sight applications: Iridium Satellite Network or equivalent

- Satellite network for worldwide data communication
- Higher cost option: >$2000 + data costs

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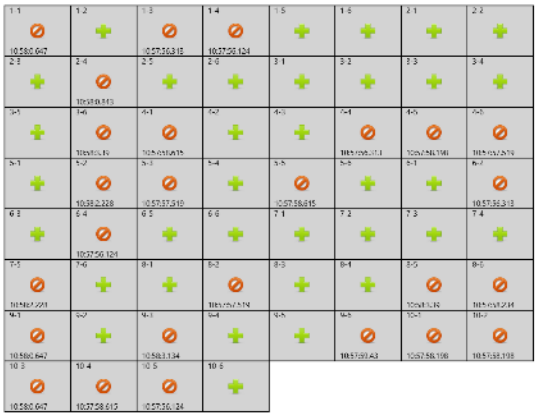
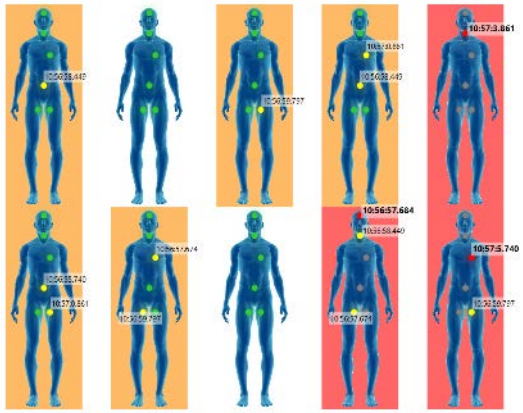
System Level Data Flow

Event	Base Station	Data Flow	Remote Module
System Initialization	Connect to comms device		• Connect to comms device • Synch with GPS • Initialize bus
Heartbeat Messages	Check communications with Remote Module	←	Send heartbeat message at predefined intervals
UI Full Sensor Status Request	Send full sensor status request command	→	Receive message, aggregate sensor data for all sensor
	Receive data, populate sensor/target graphics	←	Send sensor data
Sensor Impact	• Receive sensor update message • Record data, update sensor/target graphics	←	• Sensor microcontroller detects sensor break • Send sensor impact data and GPS timestamp
	Send received message acknowledgement	→	If no acknowledgement received, resend sensor impact message
		←	

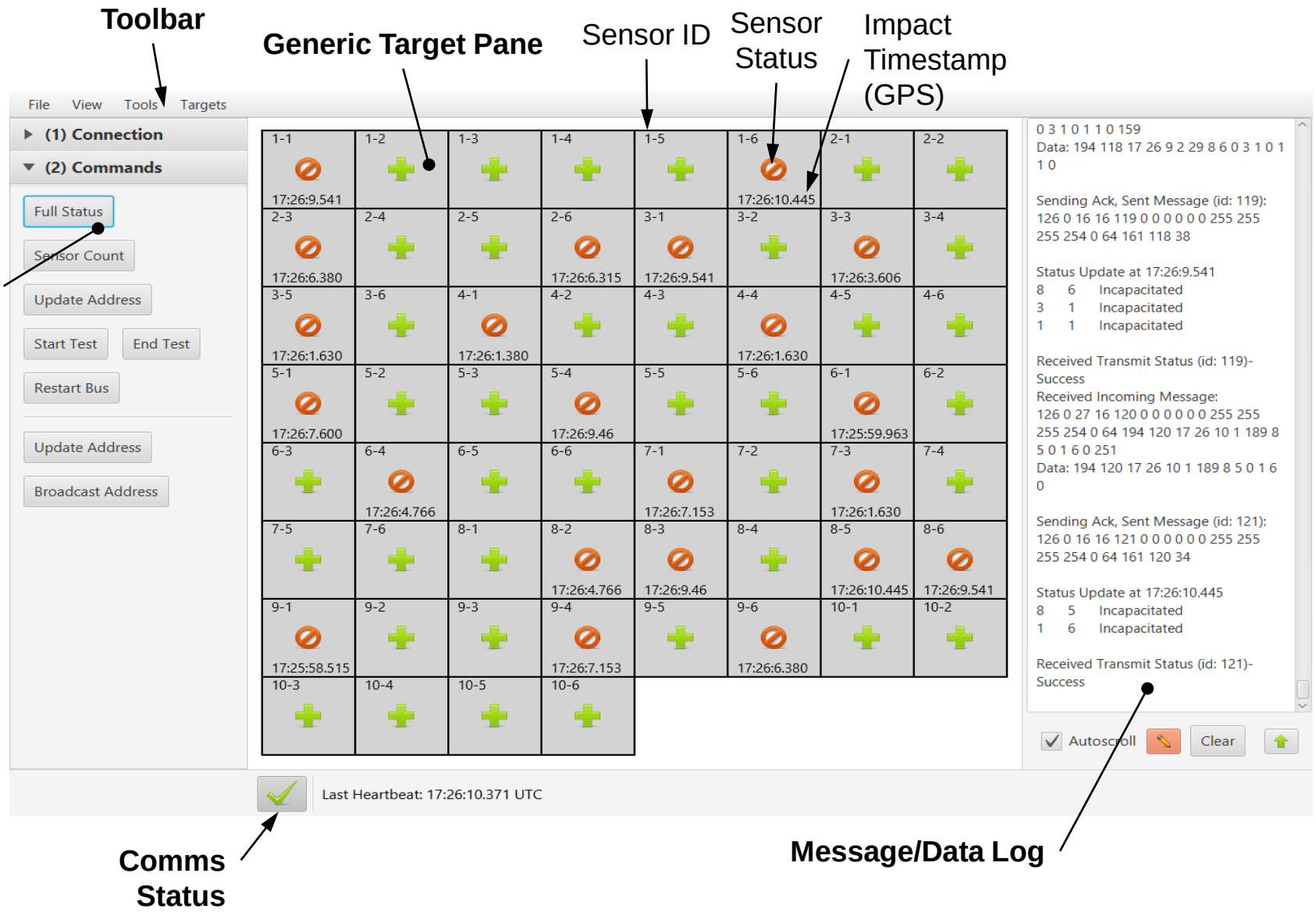
Base Station GUI

- GUI interfaces with communications device to send commands to RM, and receive sensor data from RM
- Written in JAVA programming language
  - No license required, free for any computer to run
  - Once program is compiled, capability to run on any computer platform
- GUI Features:
  - Displays custom graphical representation of target including target impact location and hit time
  - Logs all communications and sensor data to file
  - At end of test, sensor data is processed and sorted by hit time, and additional custom analyses can be performed that support assessment
  - Save screenshots or screen-videos of tests

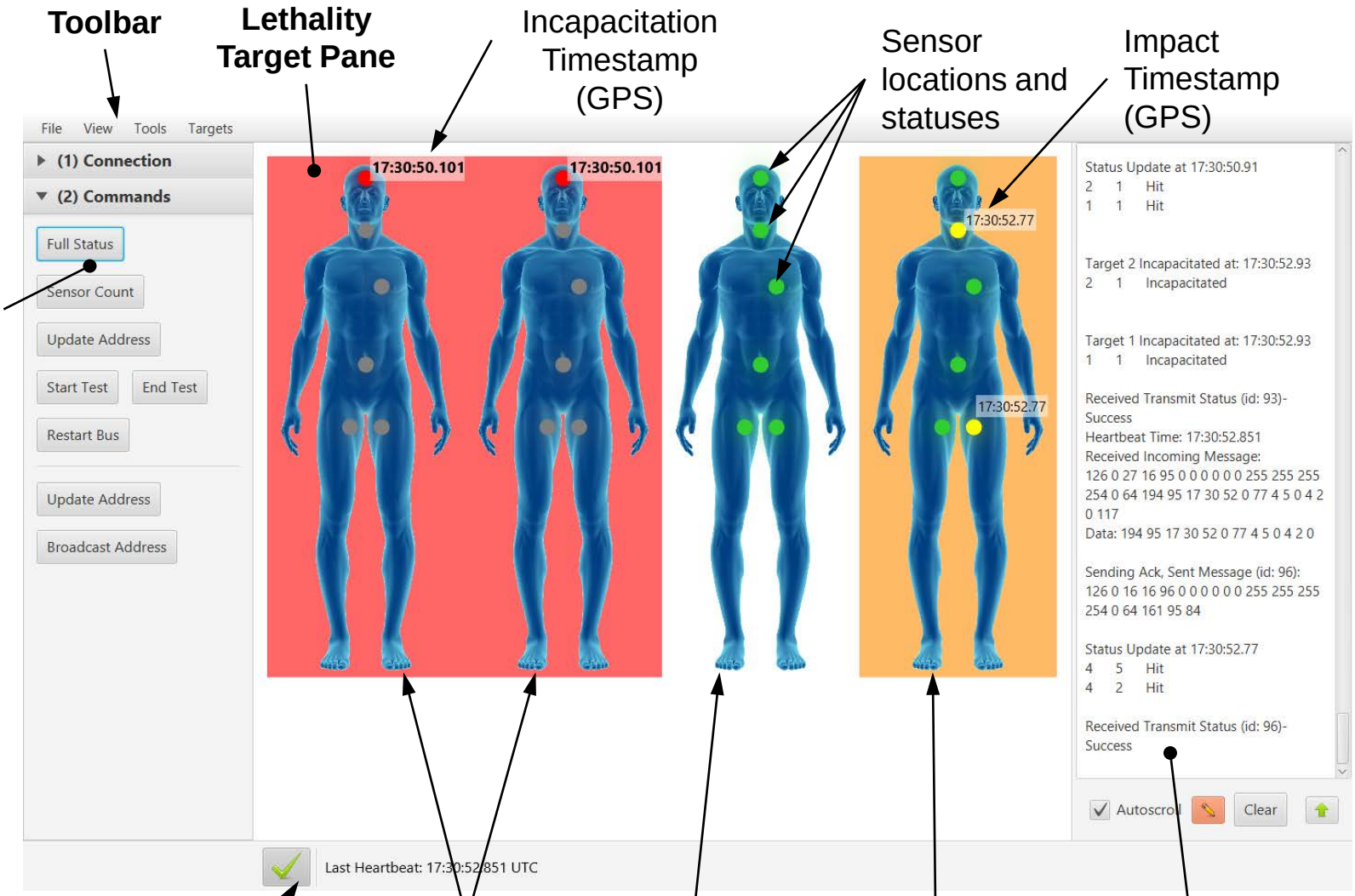




Base Station GUI- Generic Target Array Example



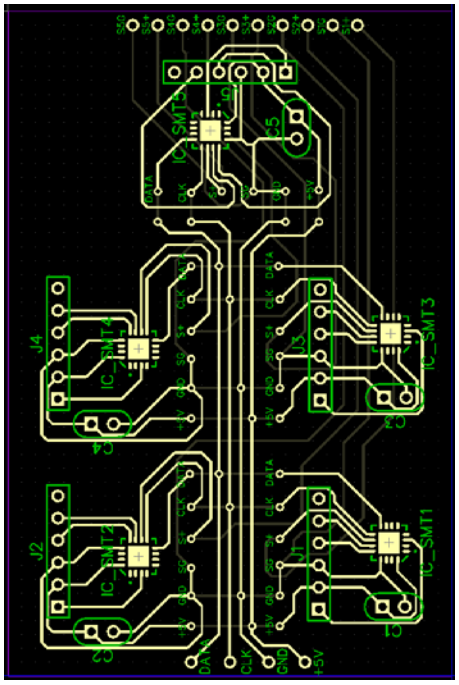
Base Station GUI- Personnel Lethality Example



Future Testing/Development

- Future Testing:
  - Substrate/barrier sensor testing/confirmation
  - Testing of a fully instrumented target at remote location

RFID Master Controller



Sensor Devices PCB Design

- Future Development:
  - Design/print custom electronics boards
  - Active RFID solution
  - Investigate Passive RFID solution
  - Iridium Satellite communications (non line of sight applications)