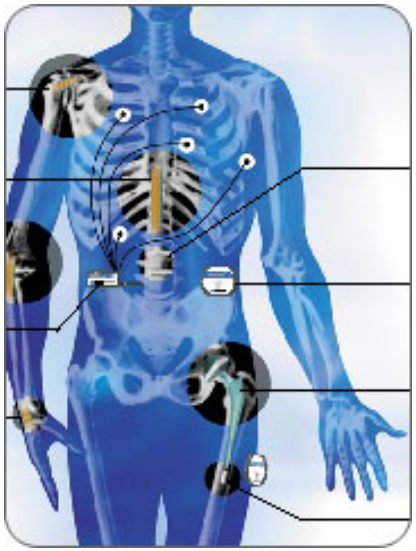
Wireless Strain Gauging

Ian Ramage

Techni Measure



BSSM seminar for Advanced Strain Gauge Applications, March 31st 2009, Southampton University.

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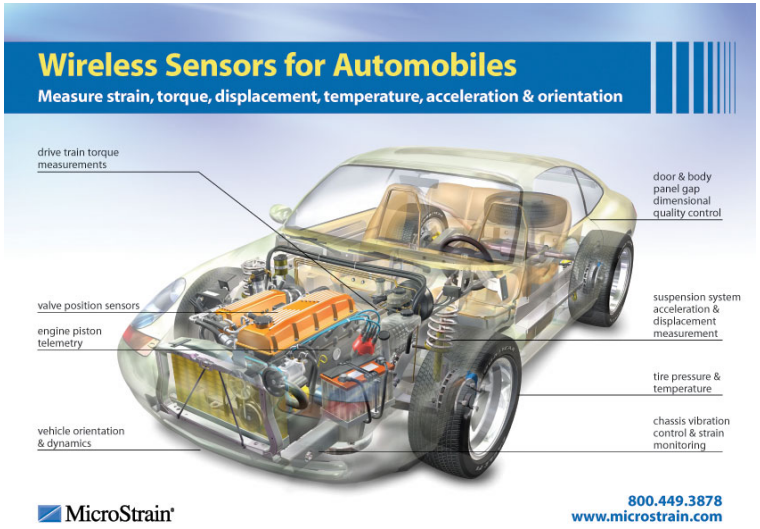
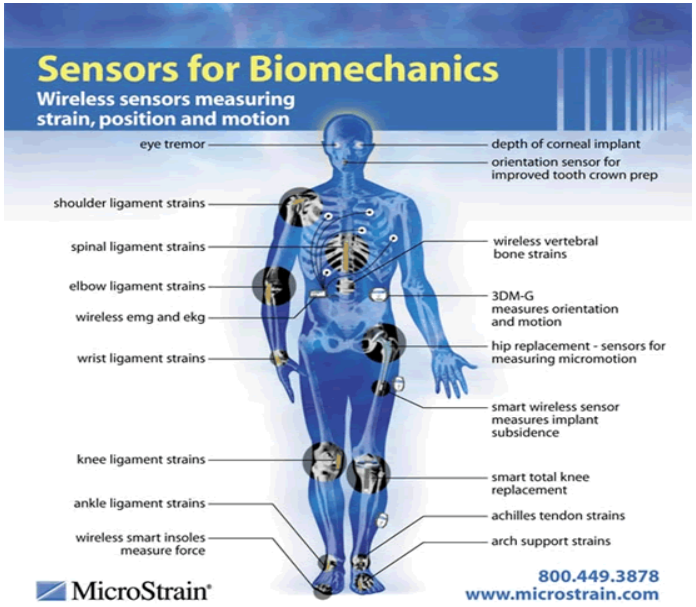
Sensors for Wireless Technology





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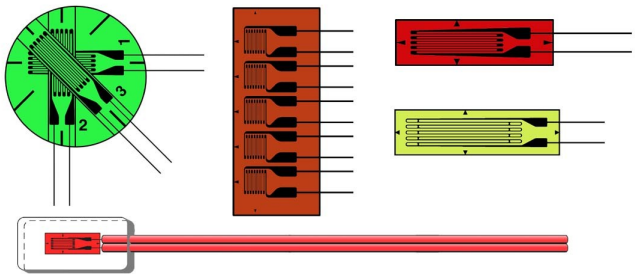
Strain Gauges or Transducers?



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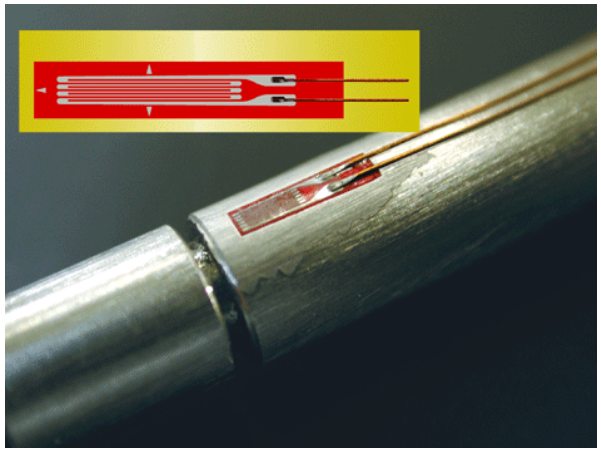
Requirements for Wireless Strain Gauges

- Regulated bridge excitation
- Offset adjust
- Gain adjust
- Shunt calibration
- Control of sample rates

All wireless?



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Wireless Strain Amplifier Node

- 4 differential channels
- 3 single ended channels
- 1 internal temperature sensor
- Programmable gain and offset
- Optional on-board bridge completion resistors
- On-board shunt calibration

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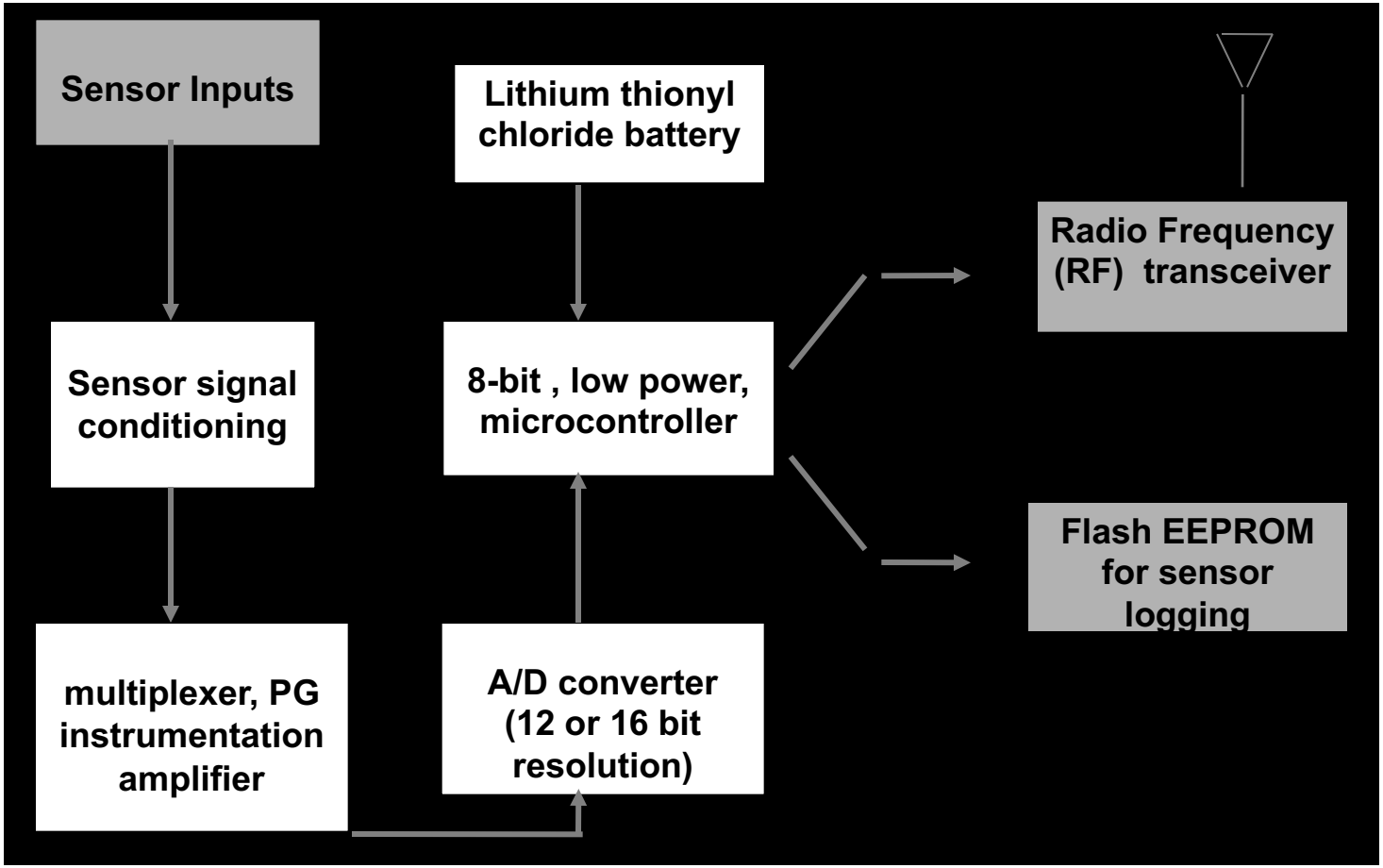
What is a Wireless Sensor Node



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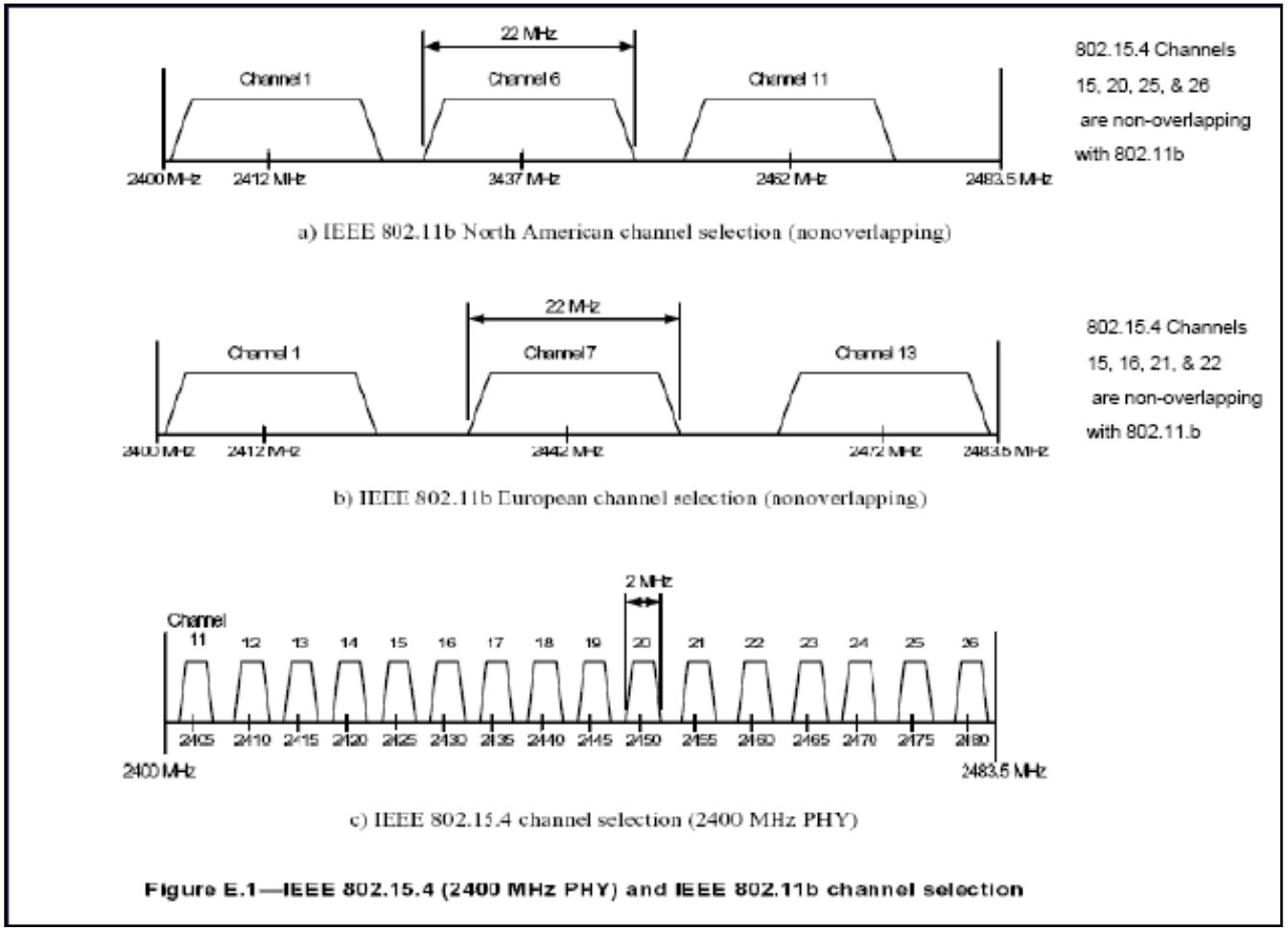
2.4 GHz licence free bands



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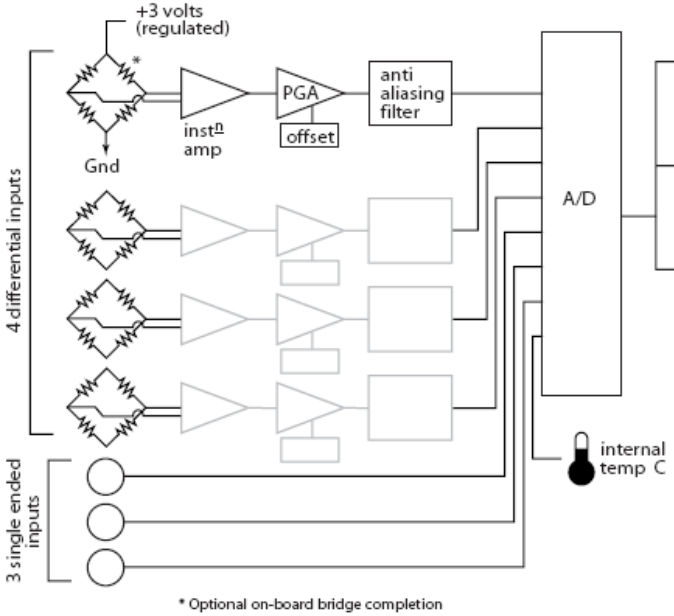
Wireless Strain System



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MicroStrain Inc.
310 Hurricane Lane, Unit 4
Williston, VT 05495 USA
ph: 800-449-3878
fax : 802-863-4093

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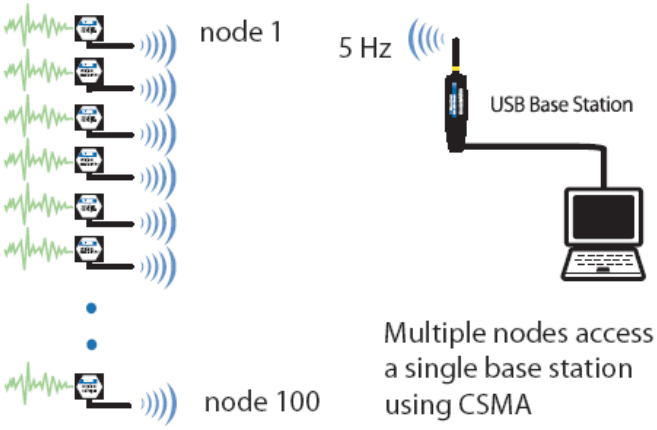
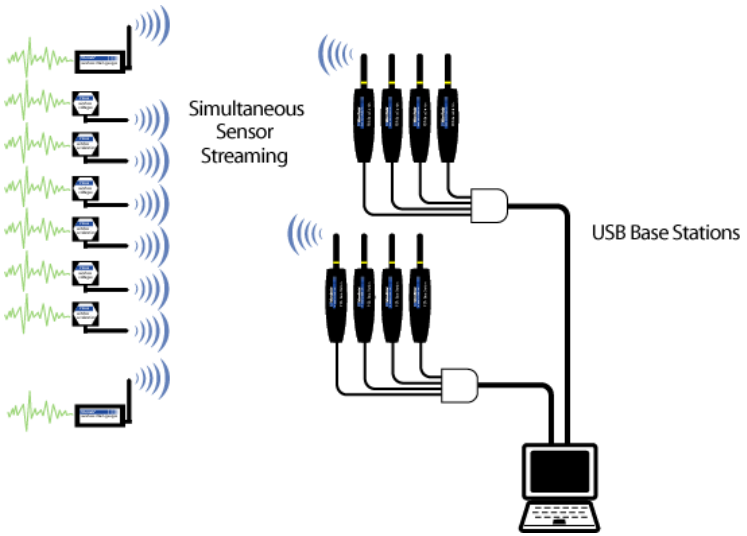
Wireless networks



Carrier Sense Multiple Access (CSMA)



Frequency Division Multiple Access (FDMA)

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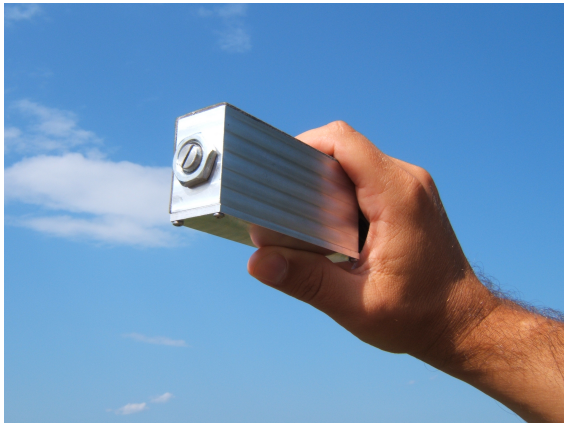
Dead Batteries – Power Solutions

- Harvest & store energy from the environment eg. light, strain, motion
- Use power management to balance the energy "checkbook"
- Use embedded processors to compress data, classify operations, estimate fatigue life



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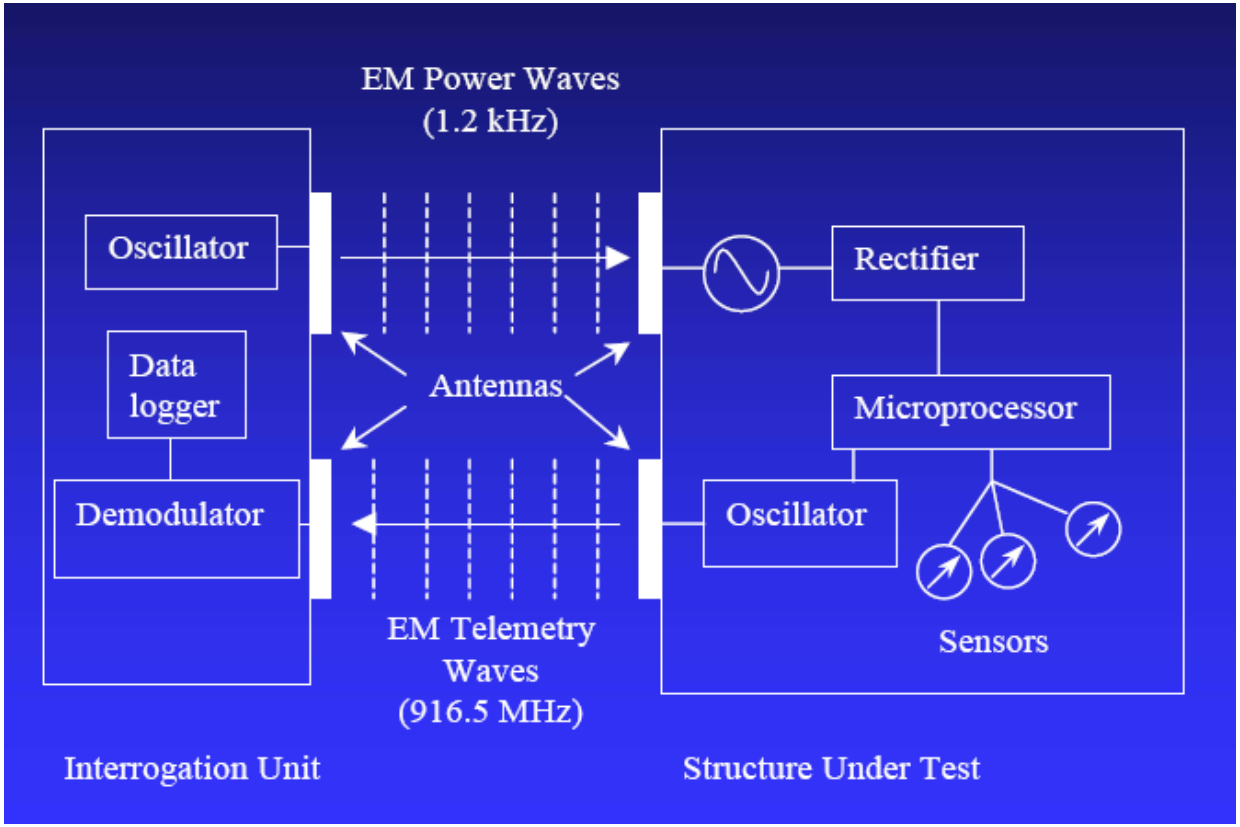
Remote power and communications



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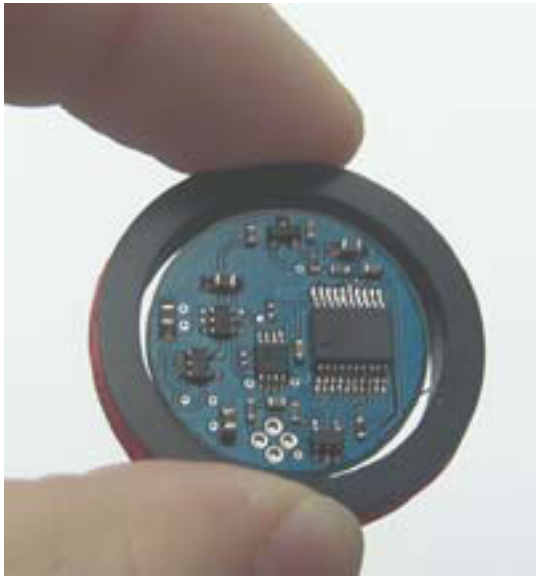
EmbedSense

- EmbedSense node with power coil around periphery
- Circular PCB with strain gauge amplification
- Coil to coil separation up to 30mm



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Sensor transponders

- No batteries required
- Small size
- Close range

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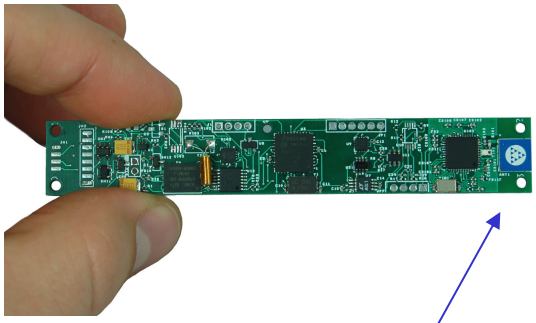
Embedded firmware optimised for strain gauges

- Wireless offset adjust
- Wireless gain adjust
- Wireless time synch - 0.1 msec
- Wireless control of sample rates
- Wireless shunt cal – bits to microstrain
- Low tempco's: offset: -.007%/C , span: .004%/C
- Mux'd, pulsed & regulated bridge excitation



Fractal antenna

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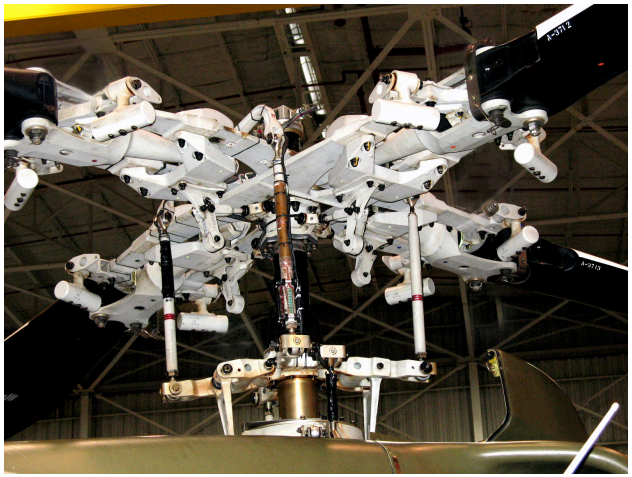
Bell Helicopter & Microstrain

- Structural health monitoring of commercial & military aircraft
- Fatigue tracking of rotating components (pitch link)
- Pitch link loads vary strongly with usage severity



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Pitch Link w/ Energy Harvesting, Sensing, Data Storage, & Wireless Communications

RF antenna

Circuit board module, microprocessor, and electrochemical battery

Piezoresistive strain gauge

Electrical insulation, EMI shielding, & protective covering

Piezoelectric energy harvesting elements

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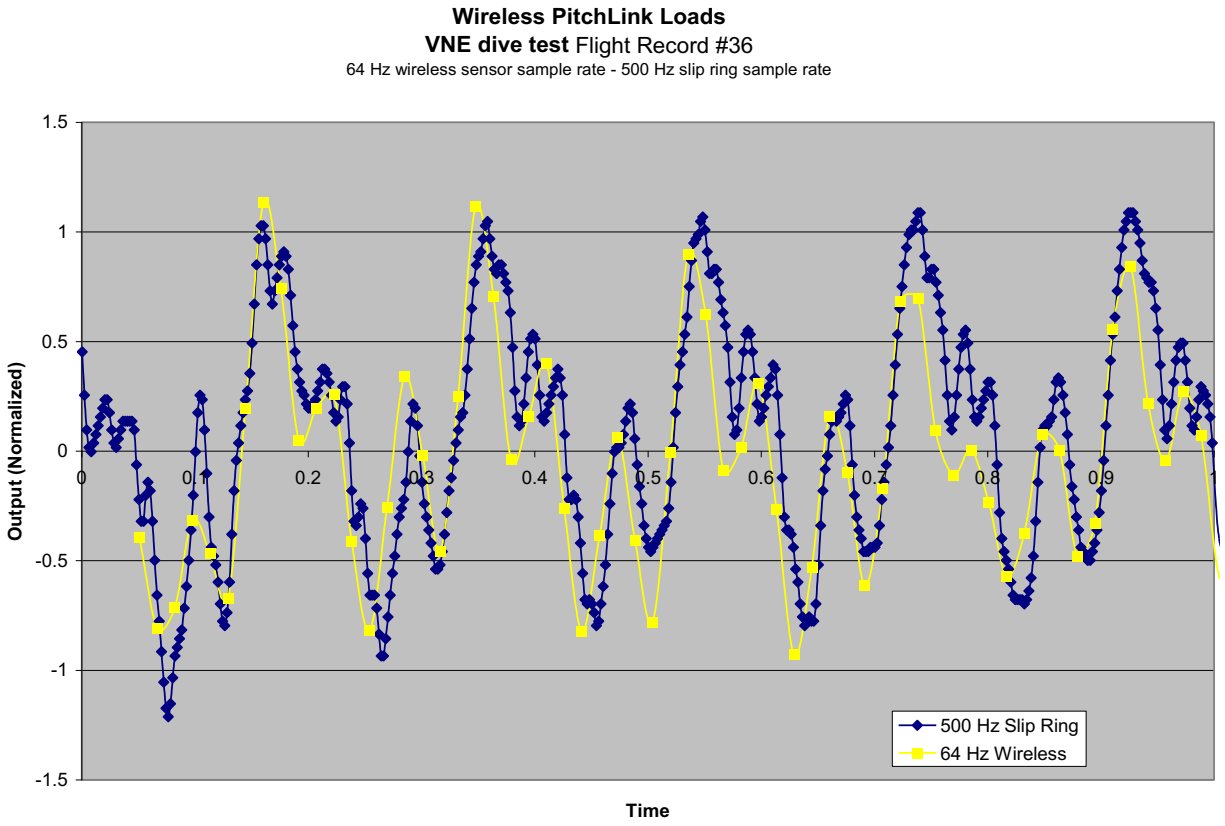
Wired vs. Wireless Flight Data



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Lockheed Martin Aerospace

- Requires thousands of strain gauges
- Wiring adds labor cost, reduces reliability
- Wire weight is significant (5000 lb)

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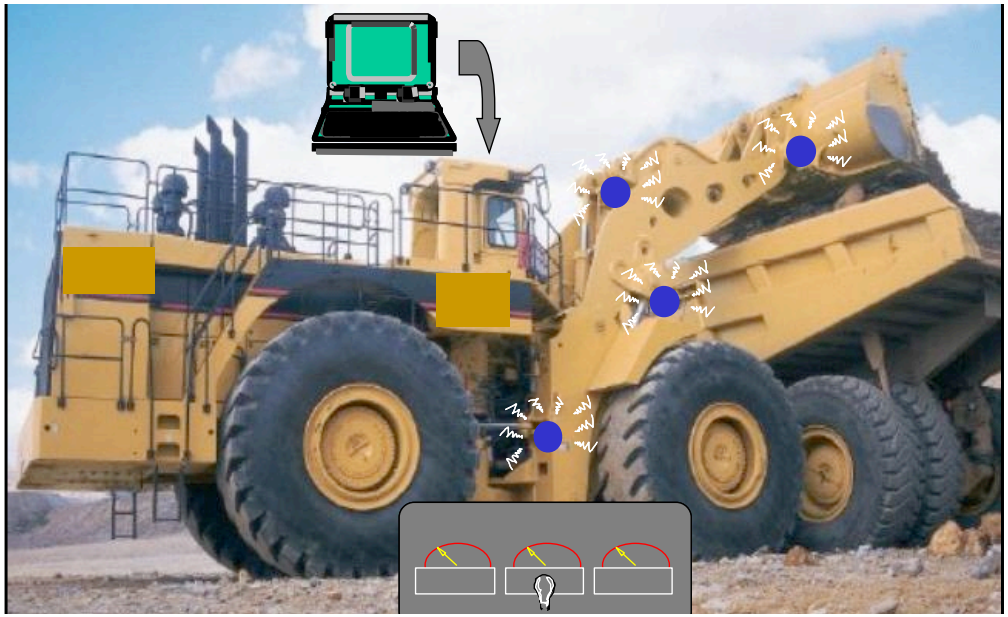
SHIELD Joint Venture –

Caterpillar/MicroStrain/Motorola/NA Tech

Structural Health Integrated Electronic Life Determination System

- MicroStrain provided wireless strain nets and vertical gyros
- Wireless sensor networks are the "nervous system"
- System estimates loads & predicts failures on-board



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Concrete Production

- Study feasibility of using wireless sensors in concrete production facility to monitor curing and handling
- Wireless nodes were used to measure temperature and strain during 12 hour curing cycle

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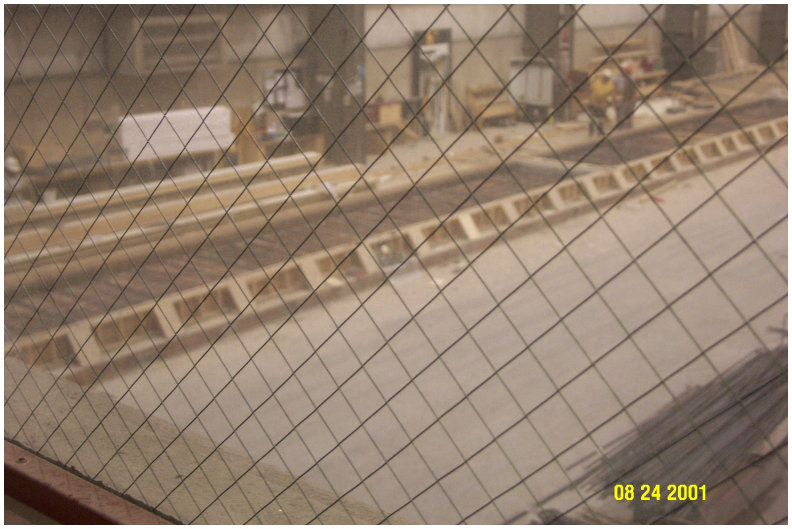
Hardwired System Vs Wireless



- Hardwired system was difficult to protect from the environment (cable breakage, moisture, dust)
- Wireless nodes were quickly installed and non-intrusive during production
- Wireless data transmitted to office location

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Capitol Visitor Centre

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Study & Technology

- Monitor strain & temperature in selected beams over 6 months (Winter 2005). A very congested site meant that wireless technology was required
- Strain gauge pairs spot welded on either side of each beam near the observed anomalies
- Every pair of gauges were connected to a data logger, that collected data at 0.25 Hz
- Data loggers wirelessly linked to data collection PC in the site offices through a base station and repeater

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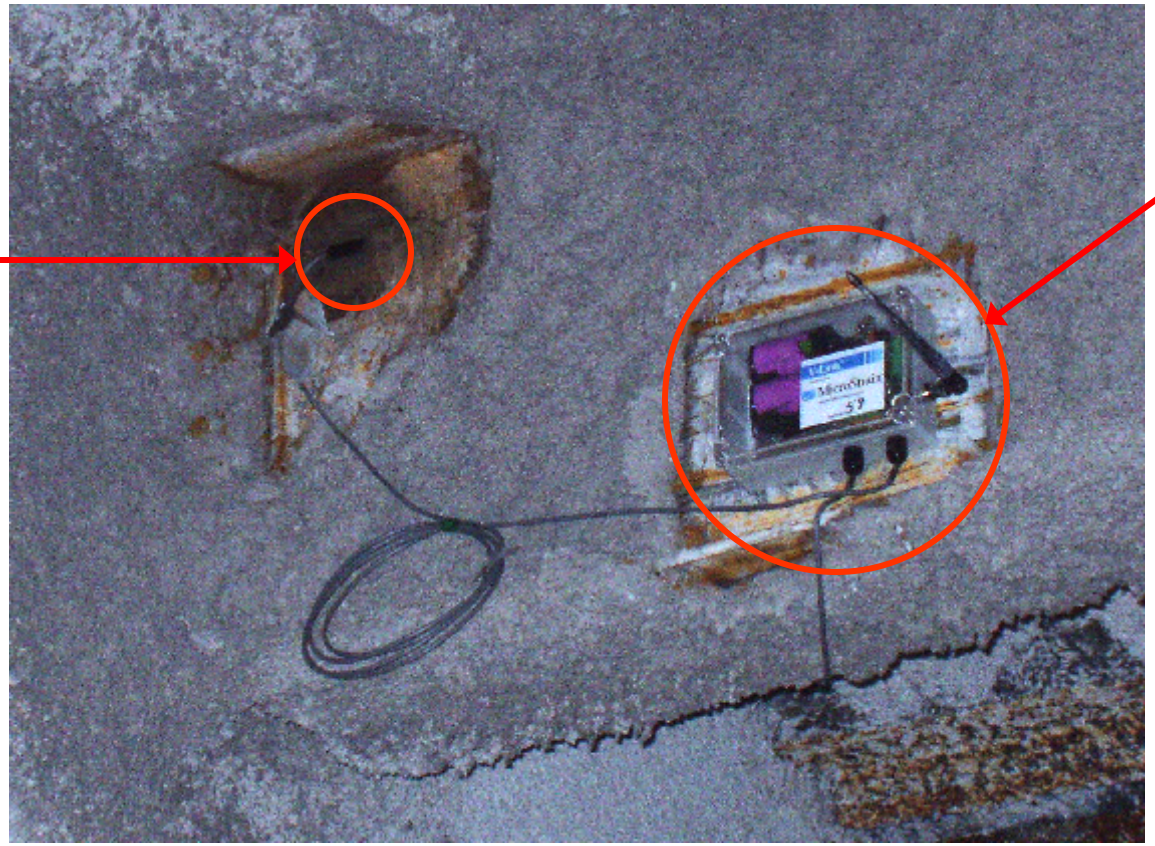
Strain Gauge Mounting

Strain gauge mounted above connection angle



V-Link connected to strain gauge to transmit data

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Moving the Liberty Bell

- Protect the Liberty Bell during move
- Batteries must last for 12 hours
- Continuous, high speed data transmission from multiple sensor nodes required

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Ben Franklin Bridge

Strain sensing nodes go from low power level to high data rate strain acquisition when passenger trains are detected

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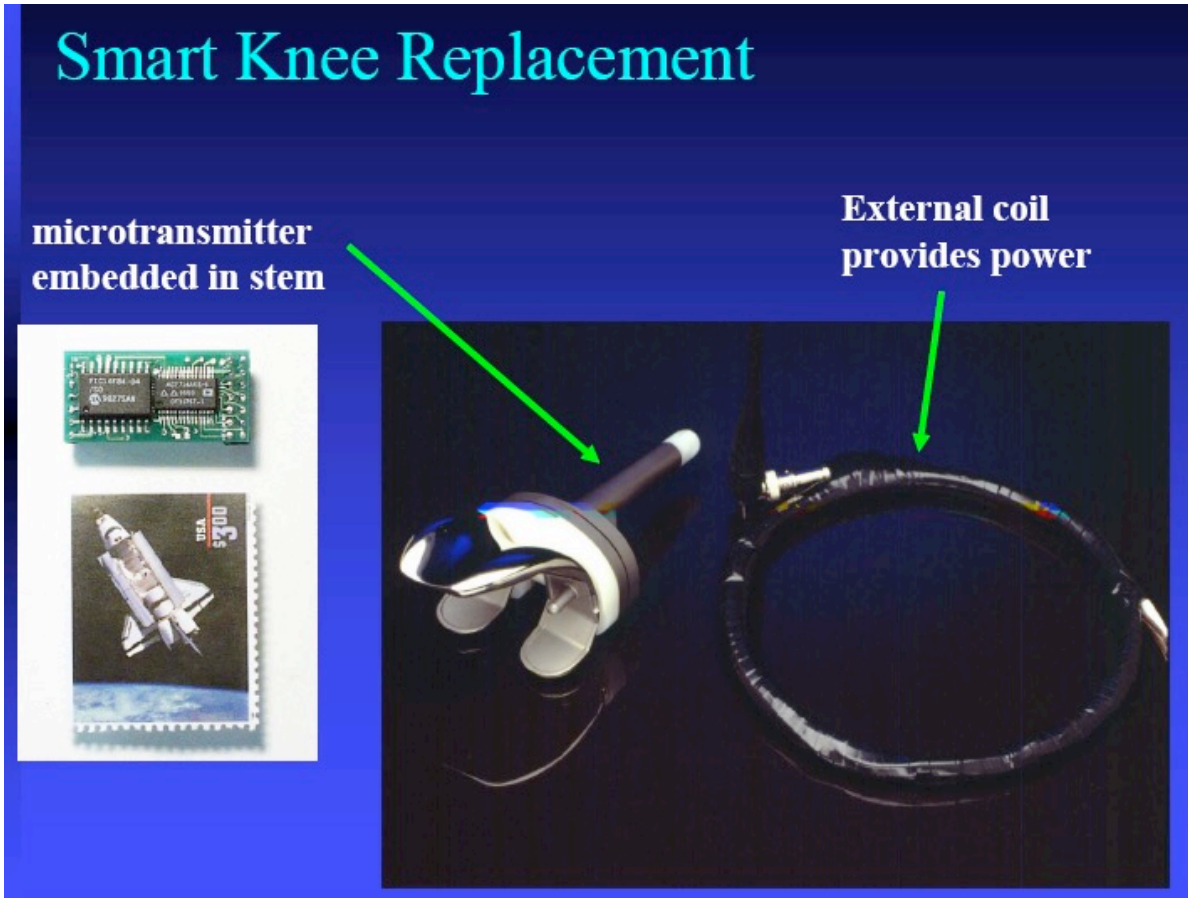
Smart Knee Replacement



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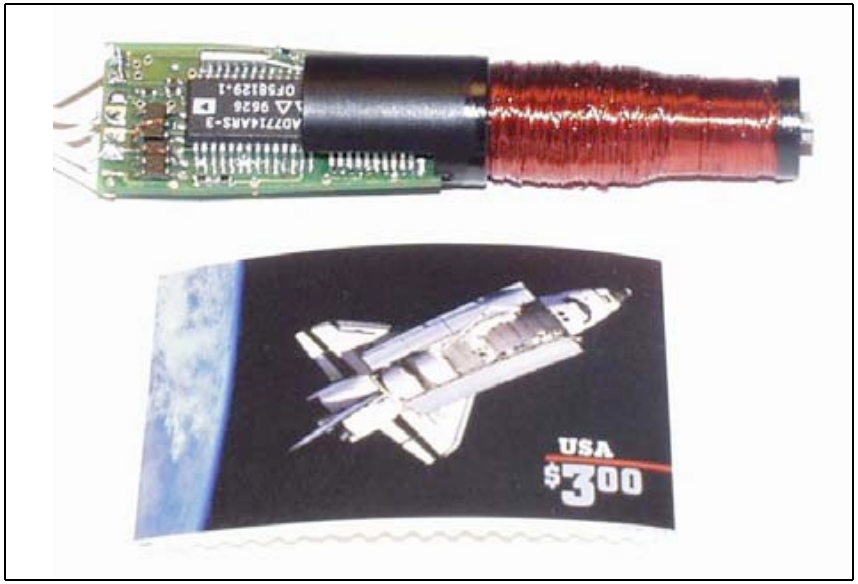
Telemetry electronics and power coil

- Power induction coil wound inside stem
- Microprocessor and data communication mounted on PCB
- Load cells mounted at four positions



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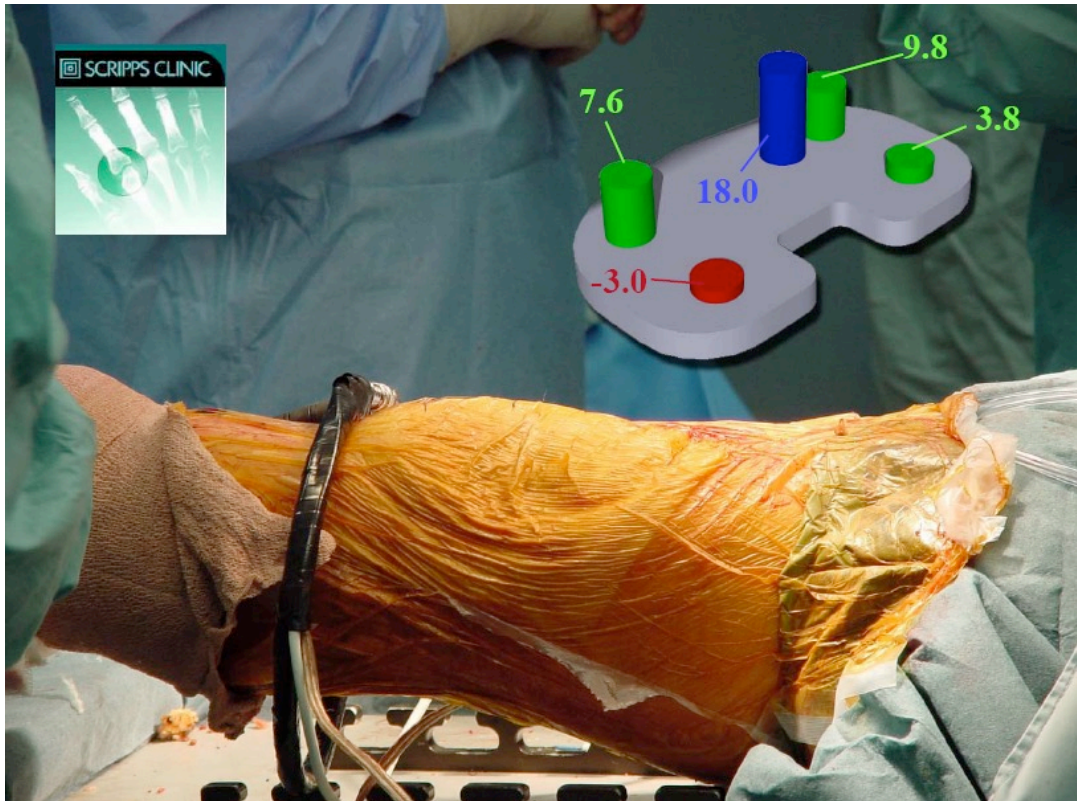
Smart Knee Replacement

Forces (lbs) with no applied load



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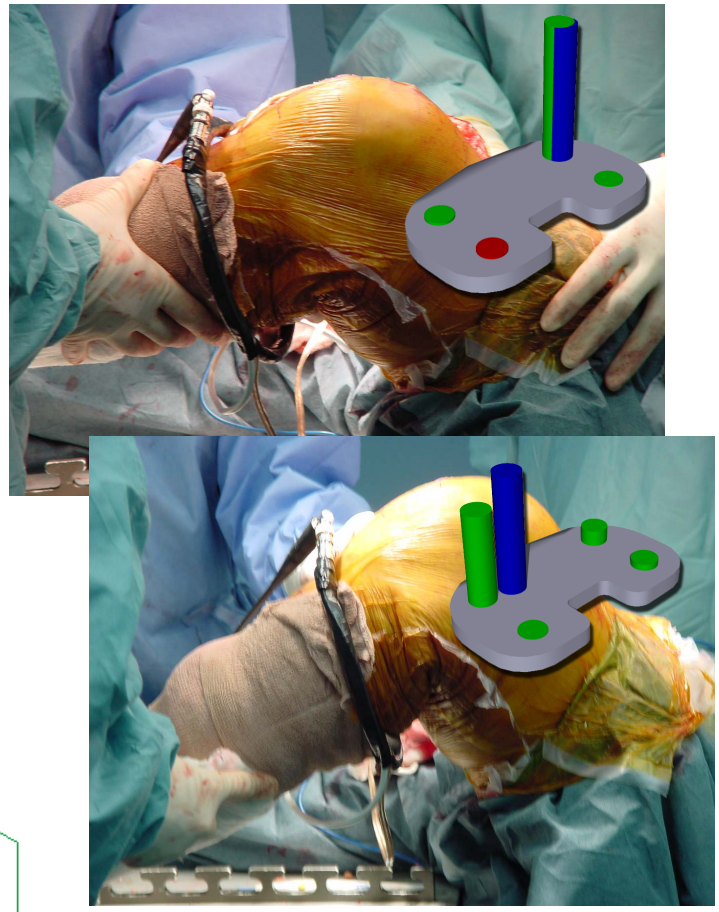
Smart Knee Replacement



- Measurements taken whilst twisting to the right and left
- Regular replacement made after tests

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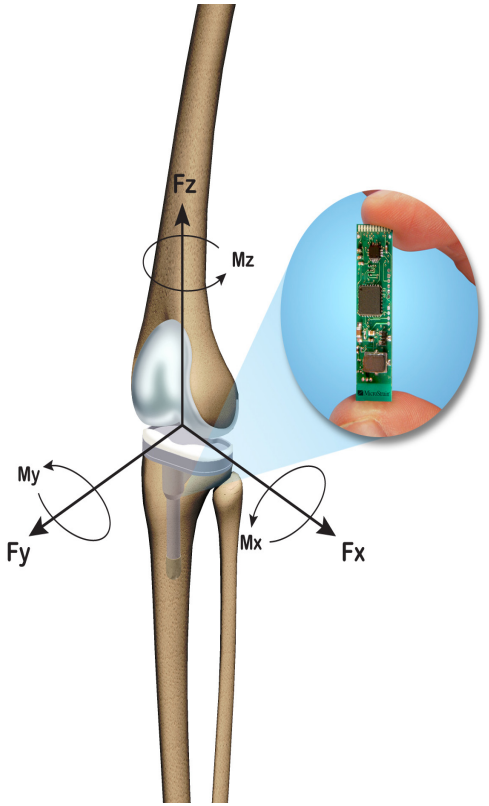
2nd Generation Smart Knee Replacement

- 2nd generation implant (2006)
- 12 channels of strain gauges
- Twisting, bending, compressive and shearing forces
- Monitored dynamically *in vivo*



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Sensing the Future

Wireless sensors, in the billions, will be deeply integrated within structures, machines, and the environment.

Sensed information will be automatically compressed & forwarded for condition based maintenance.

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Synchronizing Wireless Networks

MicroStrain's Data Aggregator™

Synchronizes both wireless & wired sensor nets *

* S.W. Arms et al., "Energy Harvesting, Wireless Structural Health Monitoring System", 4th ESHM, Cracow, Poland, Jul 2008

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Data Aggregator Features

- Synchronizes wired and wireless networks
- Data from various sensors, at different sample rates are collected into a single, scalable data base
- Synchronizing beacon at start of test provides approx. 5ms timing accuracy over 2 hours
- Synchronizing with periodic (60s) beacon provides 0.05 ms timing accuracy over 13 hours
- Linux operating system

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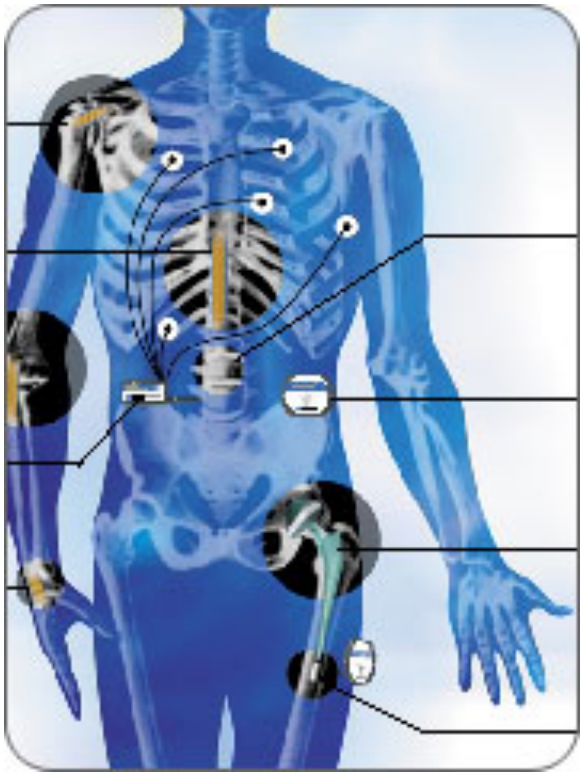
Questions?



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