Beyond Telemedicine: Infrastructures for Intelligent Home Care Technology

The Pre-ICADI Workshop on Technology for Aging, Disability, and Independence

The Royal Academy of Engineering, London, England

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Kansas State University

June 26-27, 2003

This material is based upon work supported by the National Science Foundation under grants BES–0093916, CCR/ITR–0205487, and EPS–9874732 (with matching support from the State of Kansas). Opinions, findings, conclusions, or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the NSF.

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Presentation Objectives

- Assess telemedicine system design
- Describe where home care is headed
  - Characteristics
  - Getting there
    - Research areas
    - Infrastructure development
- Early work
  - Component architectures
  - Standards-based devices

Where Home Health Care is Headed

Internet
e-Appliances
Home Nets

⇒ Patient-Centric Health Care ⇐

Telemedicine
EPRs
Novel Devices

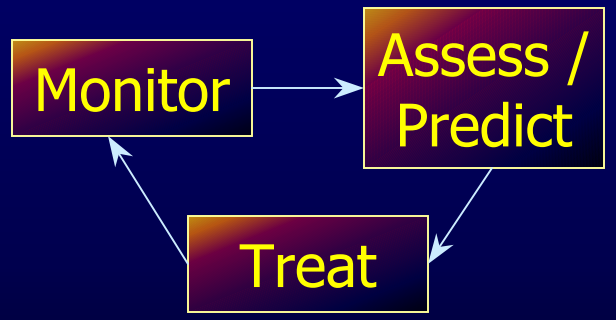
- In-person visits ⇒ telemedicine ⇒ smart sensors

Physician Station

Courtesy Dr. Richard Re, Ochsner Clinic

Patient Station

⇒



- "Virtual" medical systems: distributed, networked devices

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Telemedicine Technology Assessment

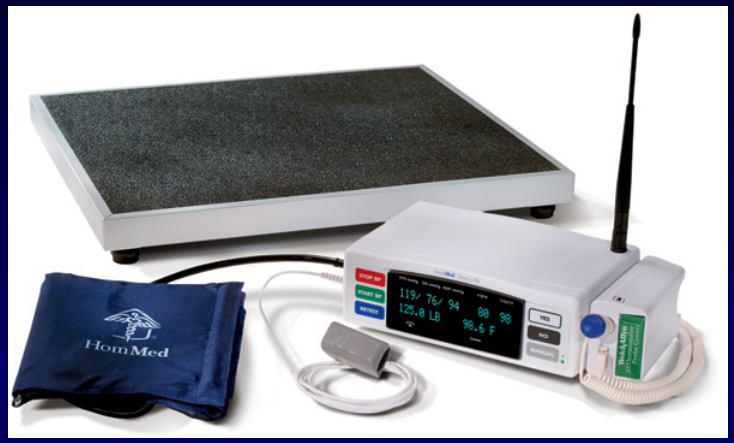
What is Telemedicine?

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

Provider Station

Patient Station

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



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, ...

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Typical Telemedicine Systems

- Point-to-point design
- Stovepipe systems (one vendor creates all) ⇒ expensive and inflexible
- Lack of standards for information exchange & plug-and-play operation
- Minimal surety mechanisms
- Limited read/write access to electronic patient records

Response

- Desirable point-of-care systems
  - Plug-and-play interoperability
    - vendor competition
    - flexible design
  - Surety (security++)
  - Commodity, commercial-off-the-shelf (COTS) components

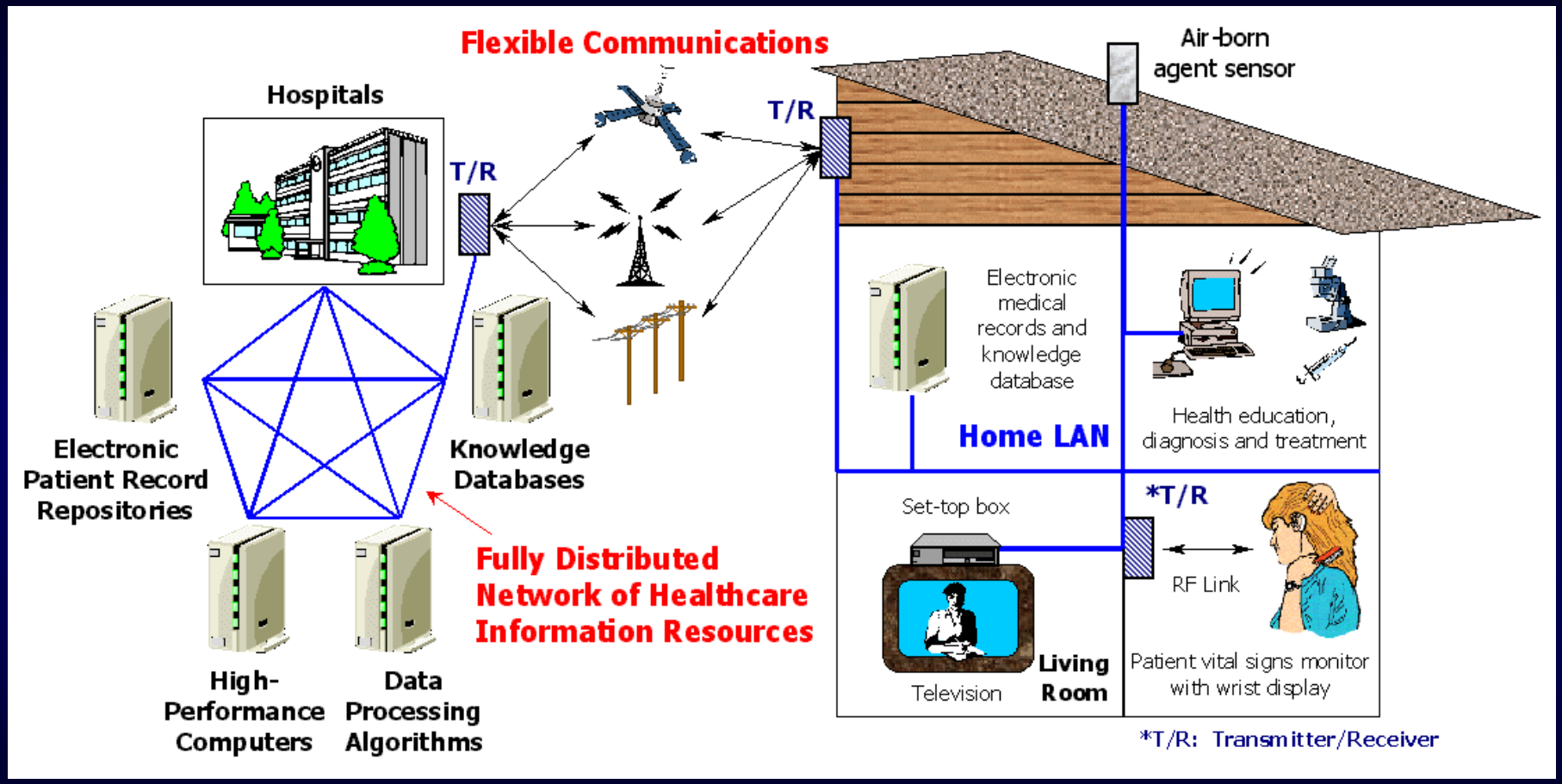
Reduce Cost

- Misconception:

  "Telemedicine" ⇔ real-time communication with a care provider

Future Home Care Systems

Future Home Layout



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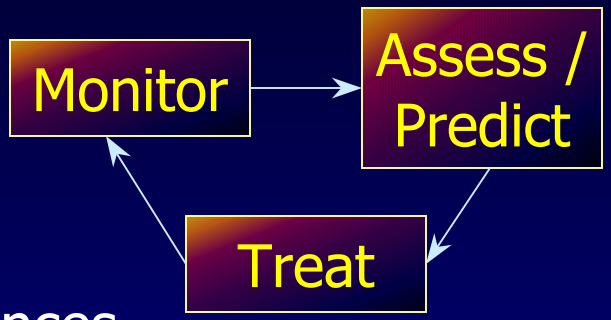
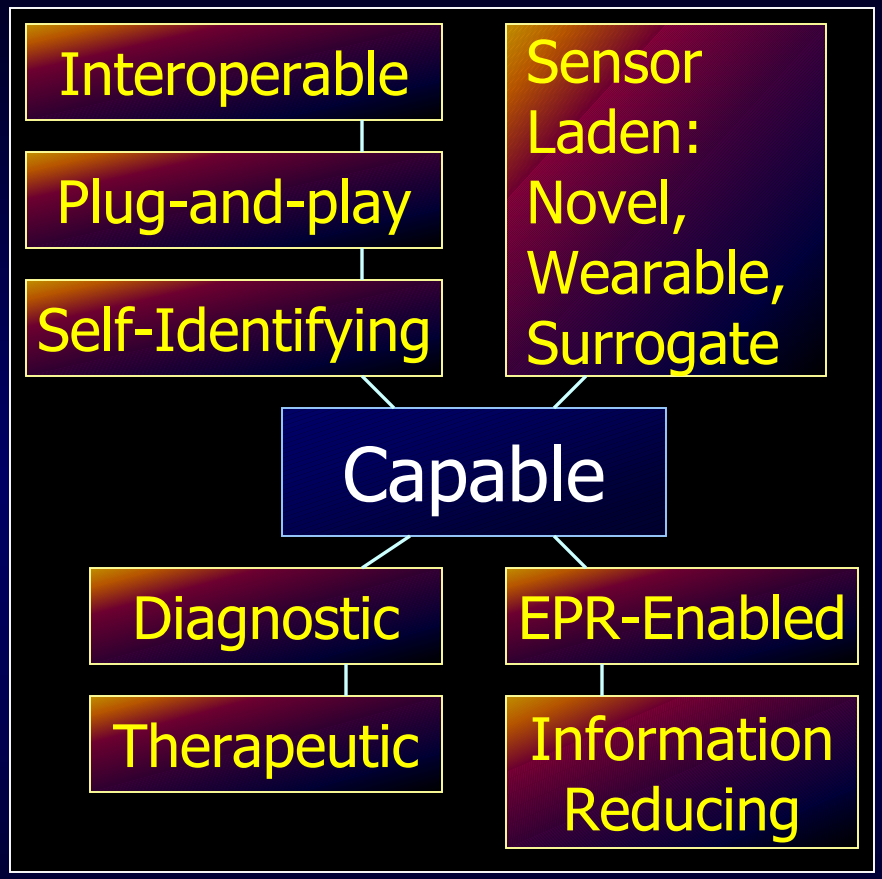
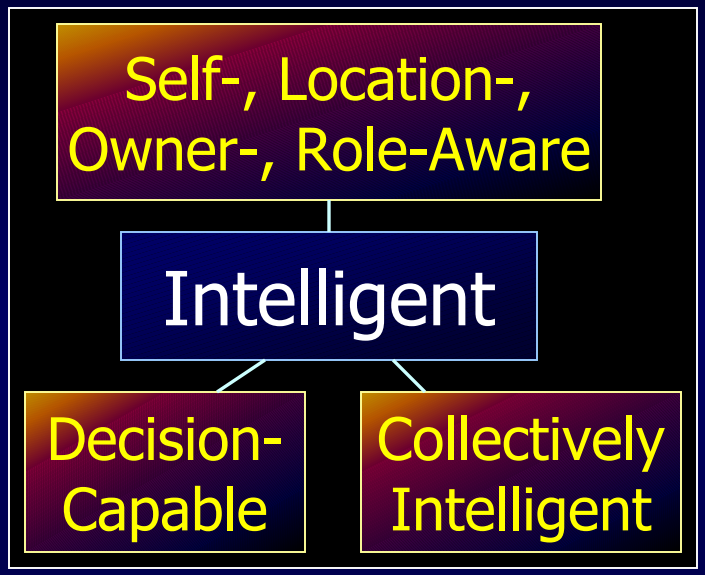
Characteristics of Future Home Care Delivery

- New Care Delivery Model
  - High risk patients: continuous monitoring, trend analysis
  - Health prediction
  - Patients: greater care roles
- Closed-Loop System
  - Non-traditional consultations
  - Care providers in exceptional circumstances
  - Systems seek & assimilate knowledge to make care decisions
- Pervasive Monitoring
  - Sensor webs within patient environments
  - Surrogate health indicators
  - Medical/environmental/behavioral/lifestyle data ⇒ EPRs

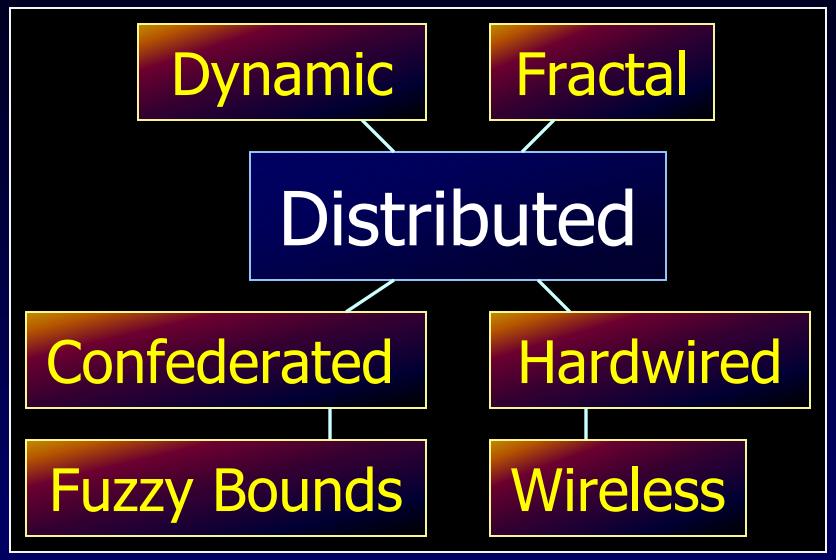


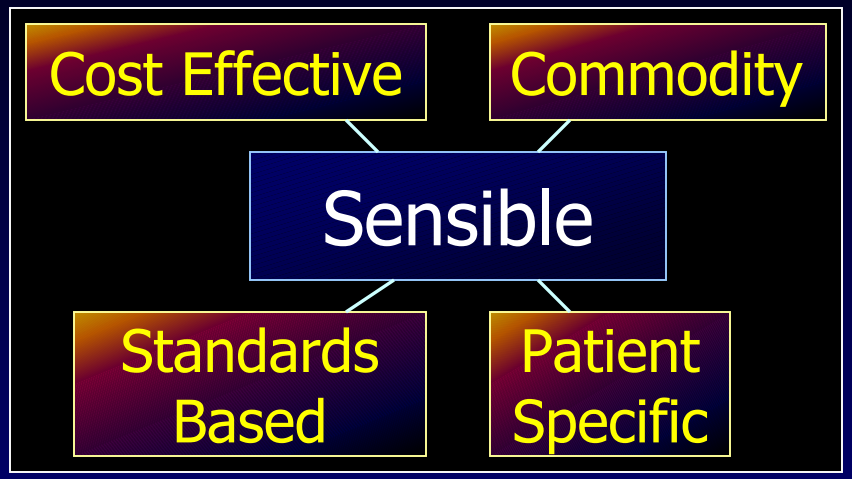
Characteristics of Future Home Care Systems

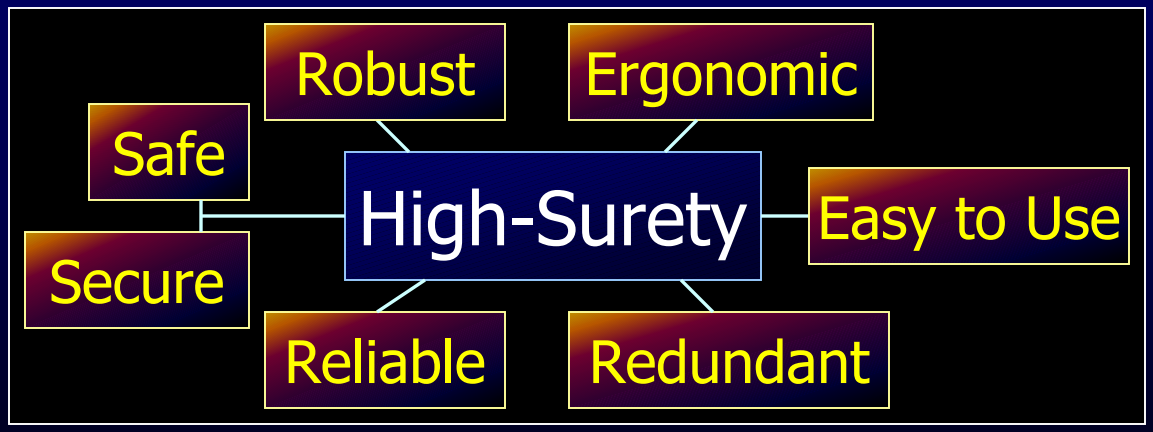




Characteristics of Future Home Care Systems (cont.)







Secure, Reliable Exchange of Medical Information

Home

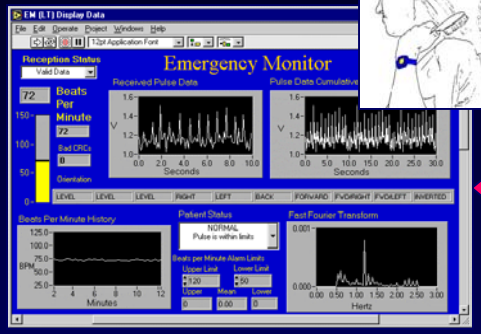
School

Clinic

Prison

Company

Battlefield



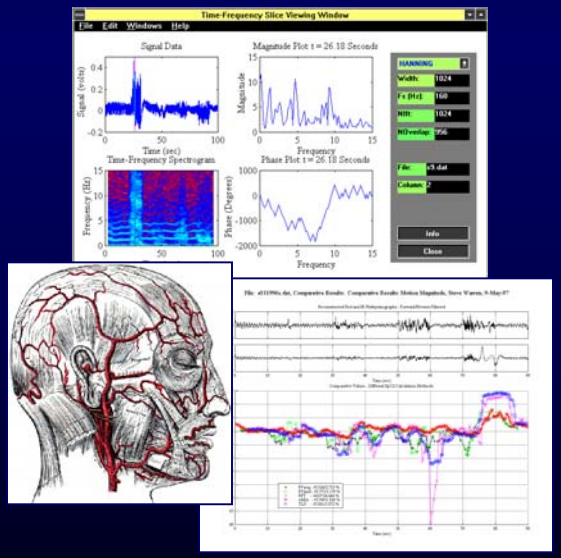
Distributed Medical Information Database

LSTAT™ , in this artist rendering, is under development by Northrop Grumman

Hospital

Emergency Scene

Research Facility



Beyond Telemedicine

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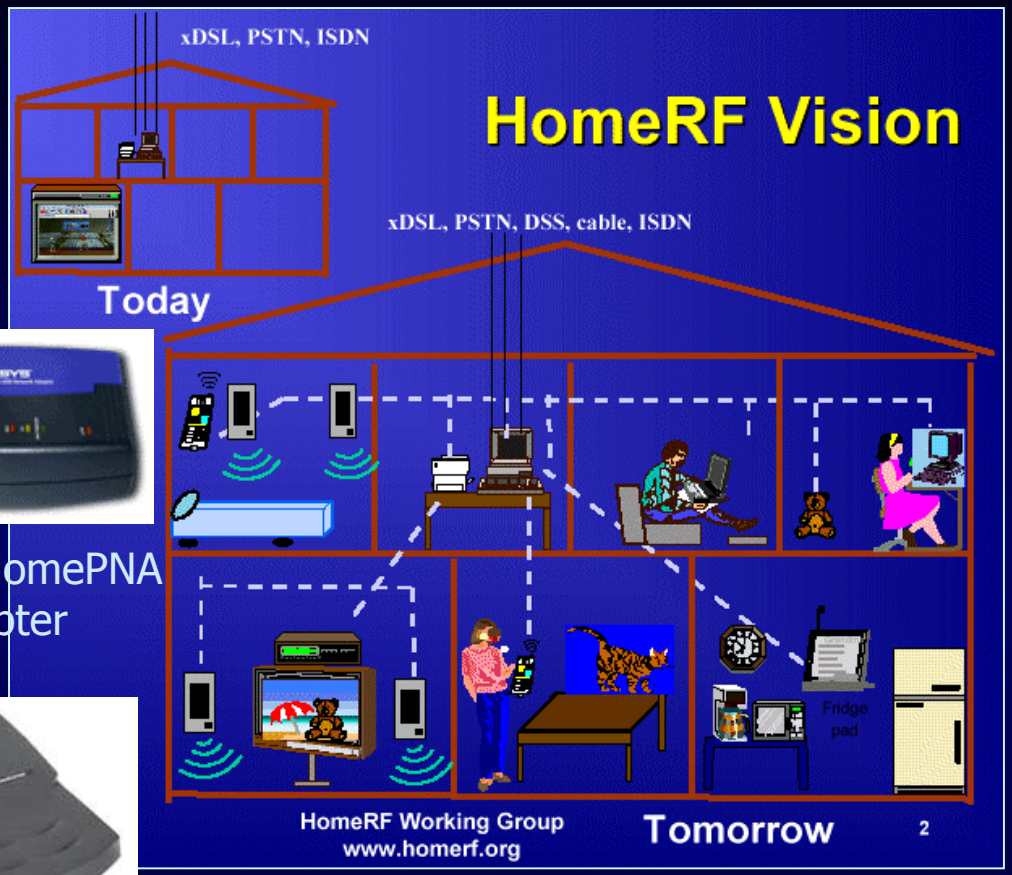
Getting There:
Infrastructure Development Approaches

Home Networking Standards & Initiatives

- HomeRF: Shared Wireless Access Protocol (disbanded January 2003)
- HomePNA (Home Phoneline Networking Association)
- Microsoft/3Com (and similar network adapters)
- Connected.Home (Intel)
- Home API (active thru 1999; status unknown)
- 802.11b
- Bluetooth
- X10
- IEEE 1394 (FireWire)

Linksys HomePNA Adapter

3Com HomeConnect Home Network Phoneline Adapter



http://www.homerf.org

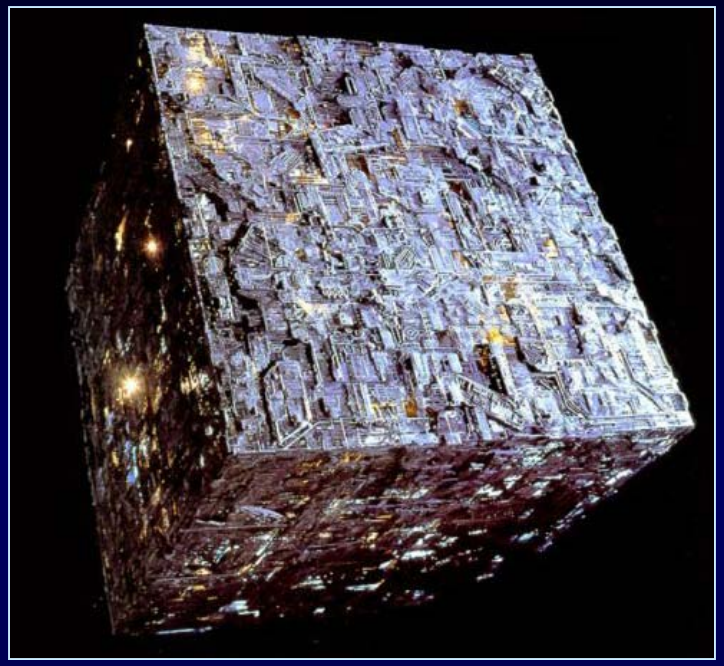
Interoperability Technology

- Architecture
  - CORBA [OMG]
  - Java (Java Beans, Jini, Enterprise Java) [Sun]
  - .NET [Microsoft]
  - Generic Web Services
  - uPnP [Microsoft]
  - Salutation
- Context
  - .NET My Services
  - Liberty Alliance
  - CCOW
- System/Device Bus
  - IP-based home LAN
  - IEEE 1394 (FireWire)
  - HAVi
  - 802.11b
  - Bluetooth*
  - IrDA
  - USB
  - PCMCIA
  - IEEE 1451 (Smart Sensors)
- Patient Record Access
  - Good European Health Record
  - HL7 CDA
  - OMG COAS, CIAS
  - CEN ENV
- Medical Interoperability
  - DICOM
  - IEEE 1073 (MIB)*
  - Point of Care Test
  - TWAIN
  - PTP

Telemedicine Interoperability Architecture http://telemedicine.sandia.gov (2/2003, Chapter 3)
Connecting for Health, Markle Foundation http://www.connectingforhealth.org/resources/DSWG_Report.pdf (6/5/2003)

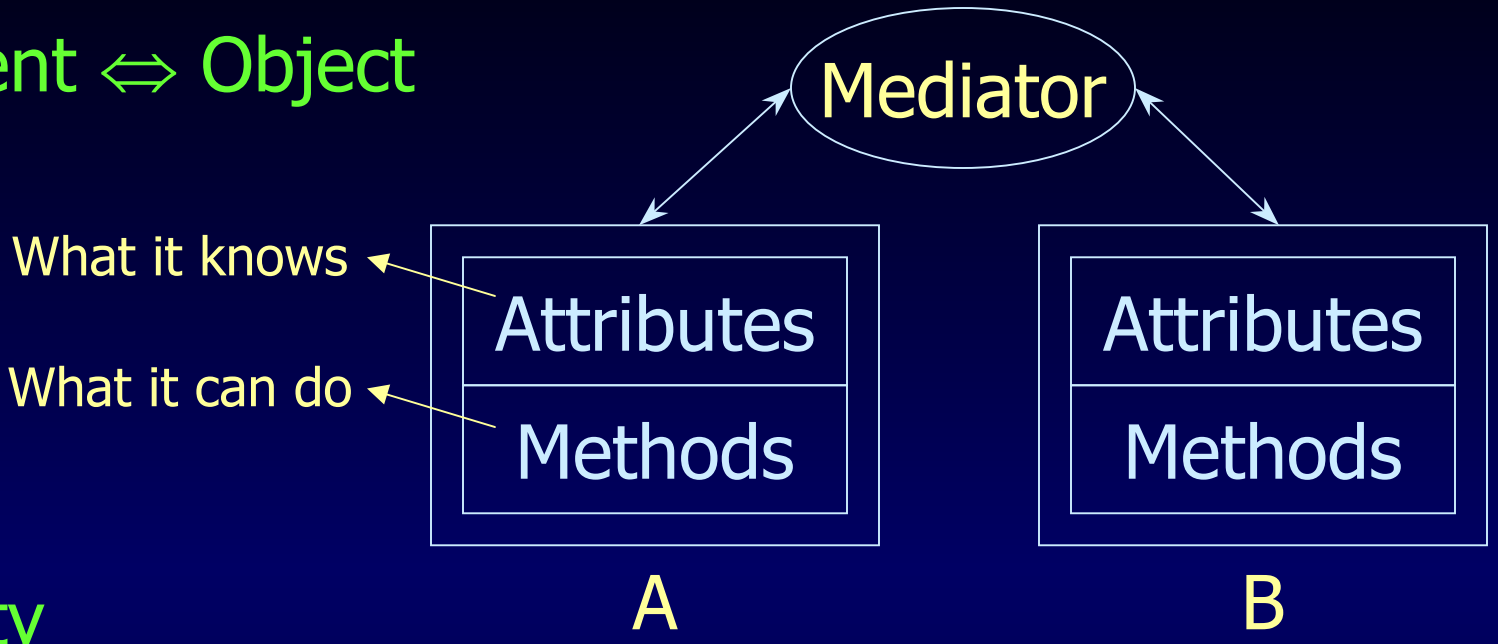
Component Confederacies

- Devices: smart, aware
- Collective Intelligence
- Distributed
- Dynamic
- Secure



Basic Component Interaction

Component ⇔ Object



- Beauty
  - Public interfaces; Private implementations
  - Standards: interaction
  - Object: client or server
  - Component-level security
  - Distributed (C++/Java ⇒ CORBA/Jini/DCOM)
  - Fractal: component = device, collection, etc.

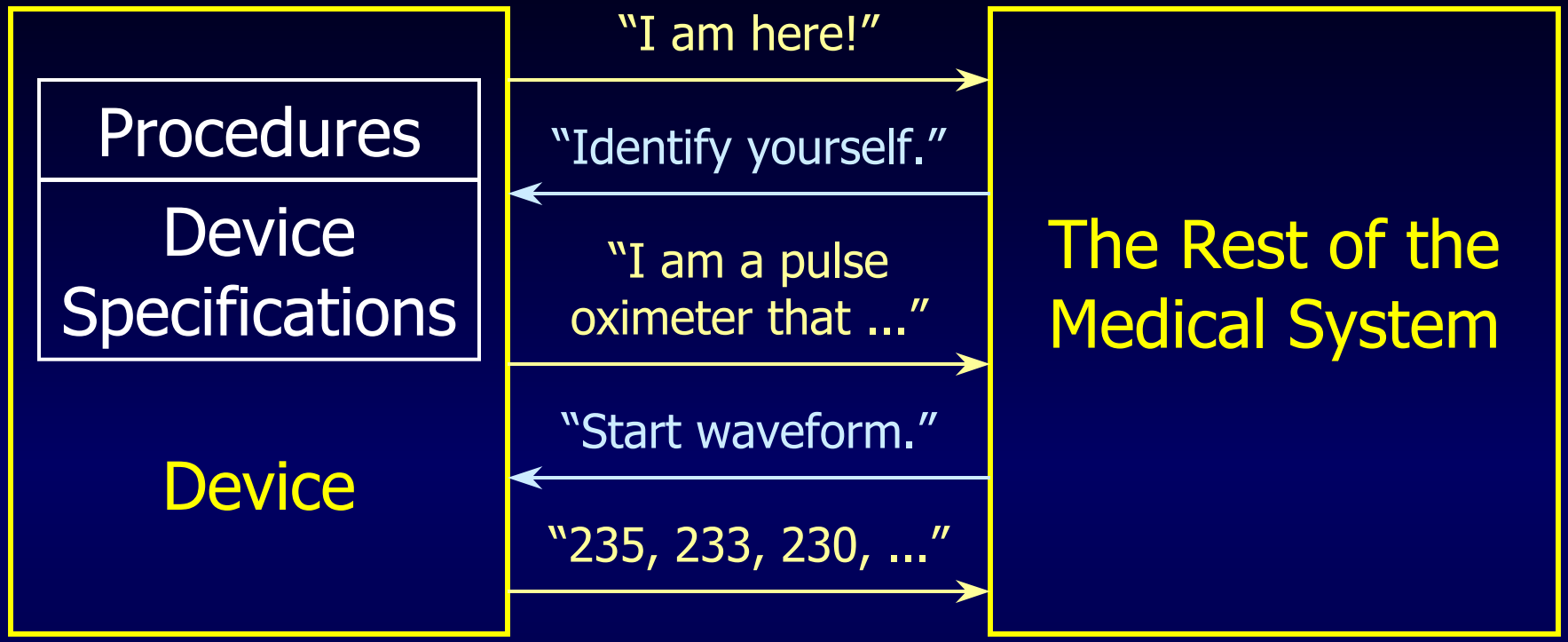
Requirements for Smart Home Care Systems

- Component Self-Awareness
- Component Interoperability
- Component-Level Security

Requirement: Component Self-Awareness

- Each component should know
  - … about itself …
    - What it can do
    - Its limitations
    - How to interpret its data
    - How to assess its condition
  - … about its context …
    - Who may use it and how it may be used
    - Roles/scenarios for valid data

Requirement: Component Interoperability



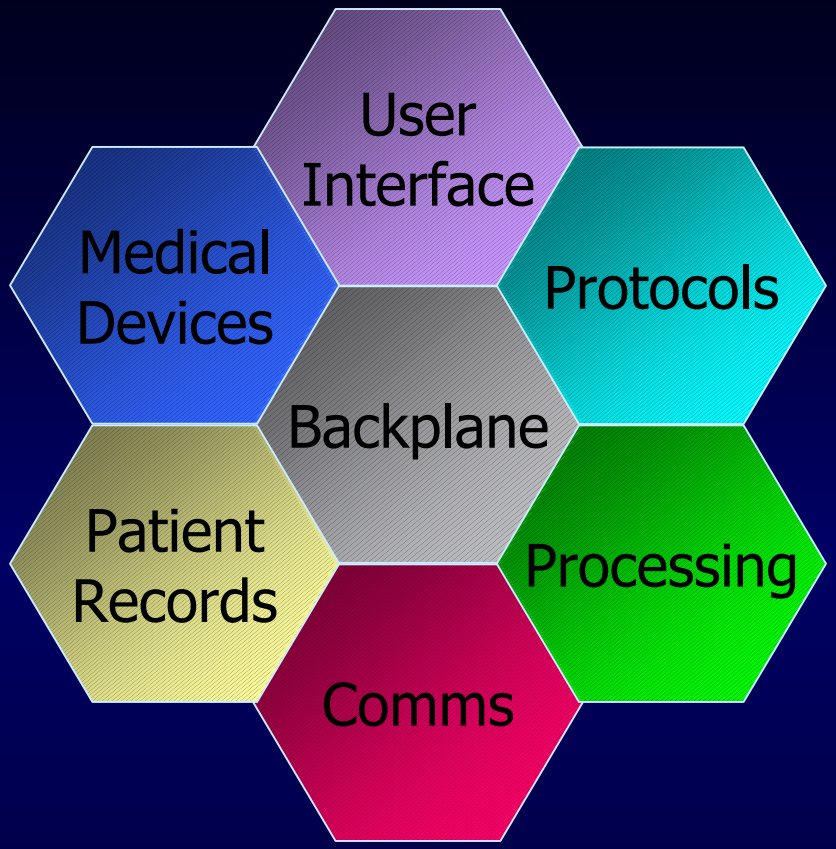
- Standard, vendor-independent interfaces
- Lego-like construction of diverse systems "on the fly"

Requirement: Component-Level Security

- Components will negotiate secure transactions
- Point-to-point systems: straightforward to secure
  - Small user population
  - Static network topologies
  - Limited range of technologies
- Distributed systems: security is more important/ problematic
  - Mass-market communications
  - Less emphasis on private networks
  - Legacy and leading-edge technologies

Early Work

Telemedicine Interoperability Architecture



"Lego-like" Component Interactions

Sandia National Laboratories

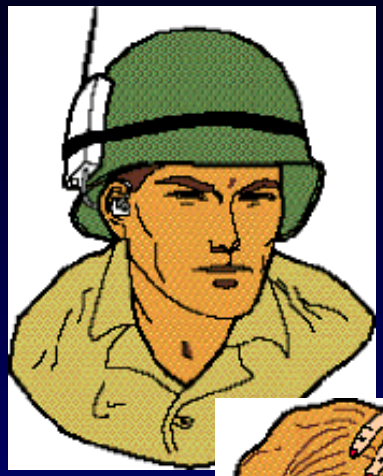
Goal: Create application-specific, distributed medical systems "on-the-fly"

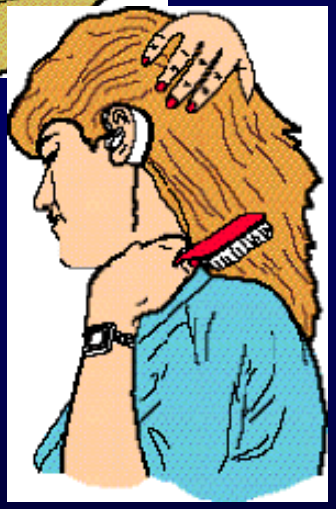
Benefits:

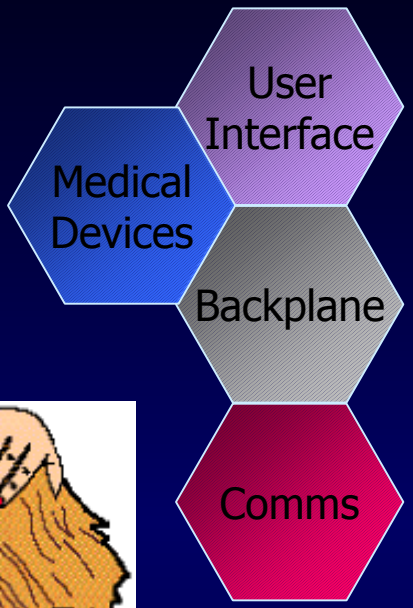
- Flexible
- Cost-effective
- Secure

Telemedicine Interoperability Architecture: http://telemedicine.sandia.gov
The Role of Technology in Reducing Health Care Costs: http://www.sandia.gov/CIS/6200/Telemedicine/

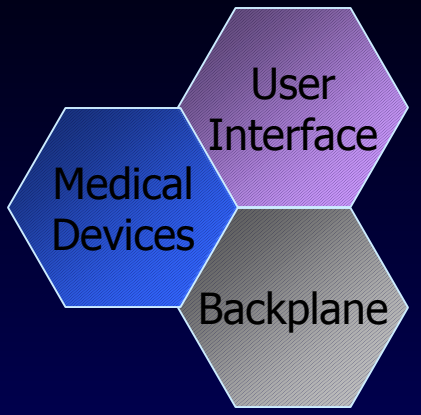
Smaller-Scale Systems







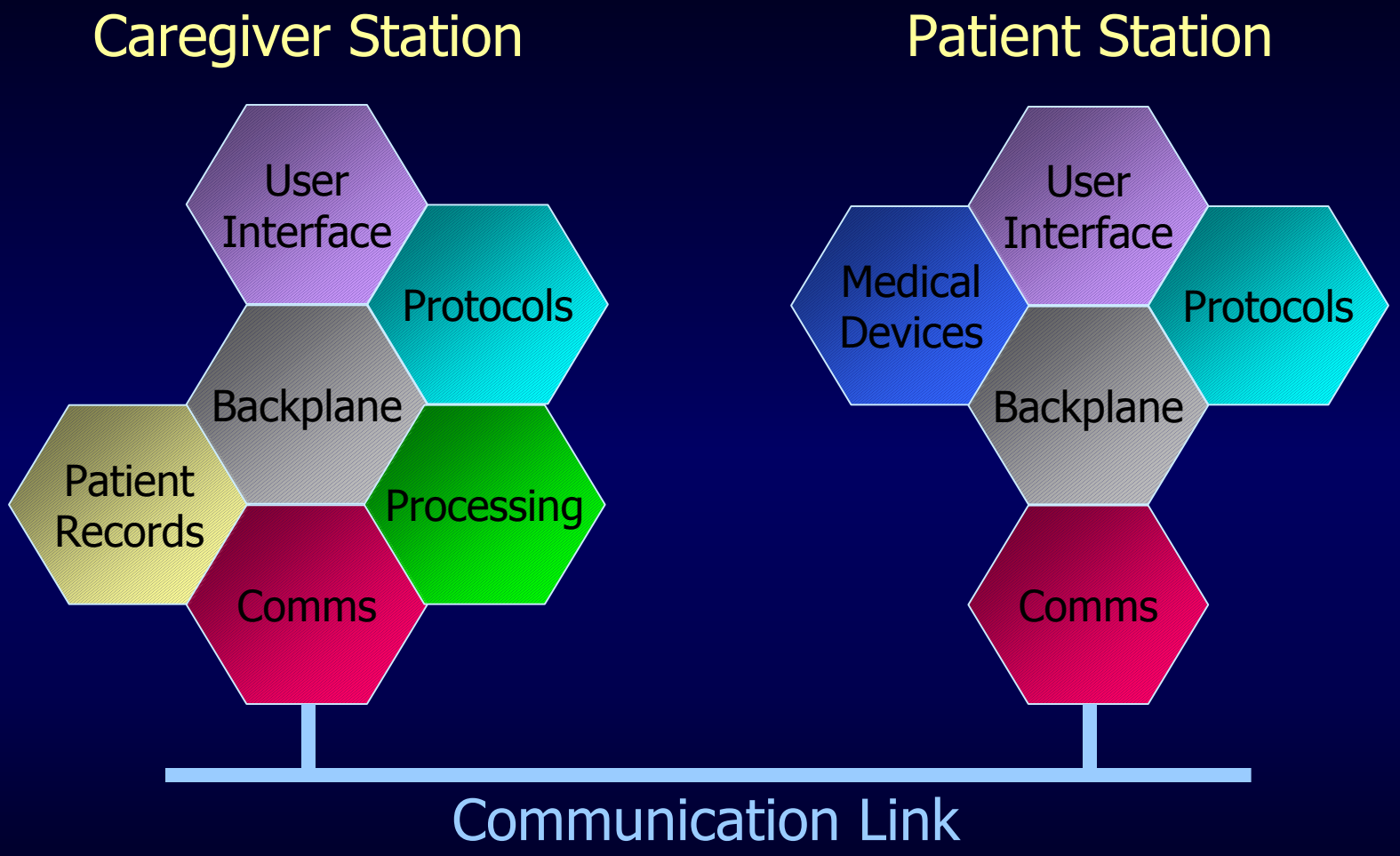
Personal Status Monitor



Ophthalmoscope/Otoscope

Thermometer

Typical Point-to-Point Telemedicine System



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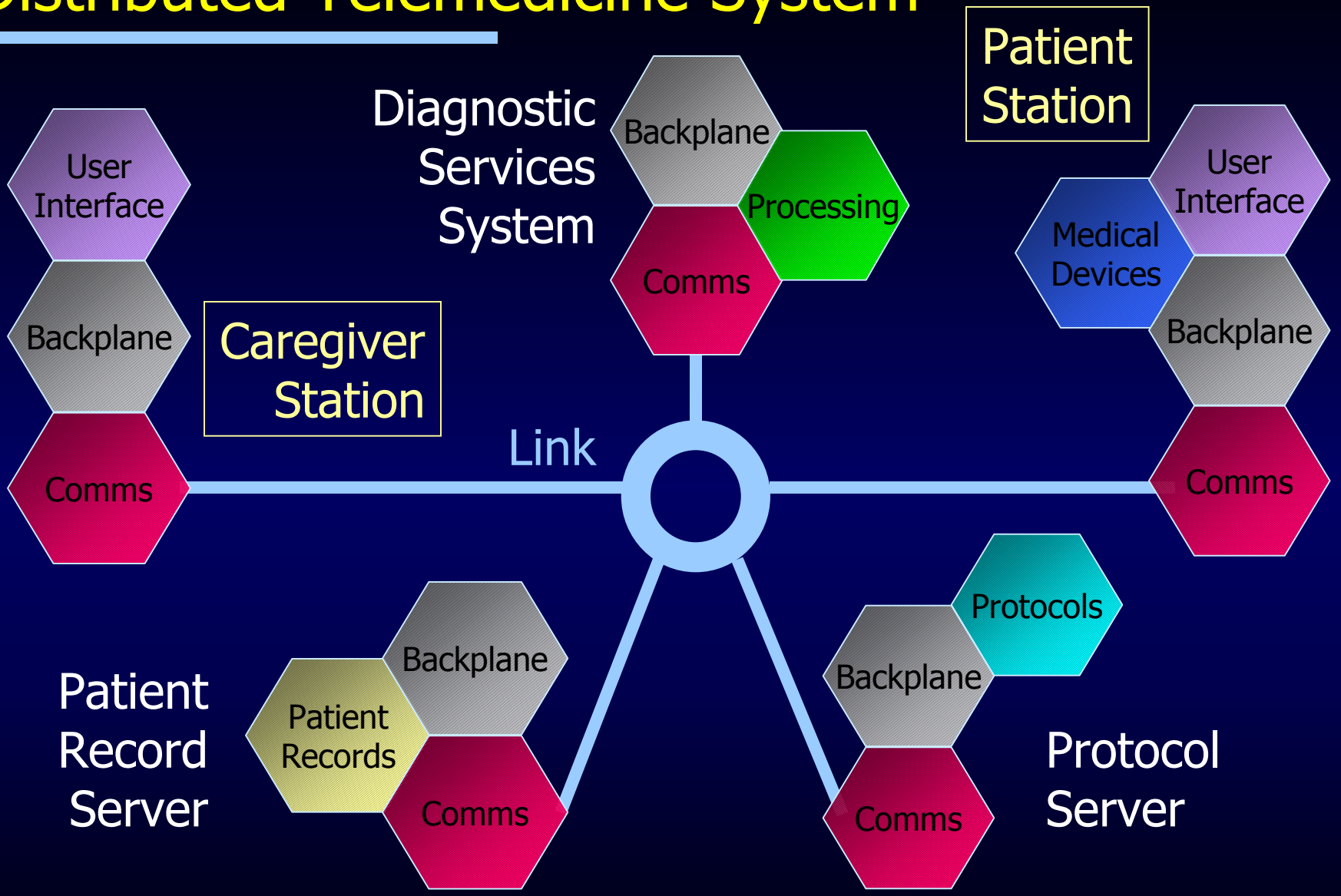
Distributed Telemedicine System



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Build 1 Patient Station

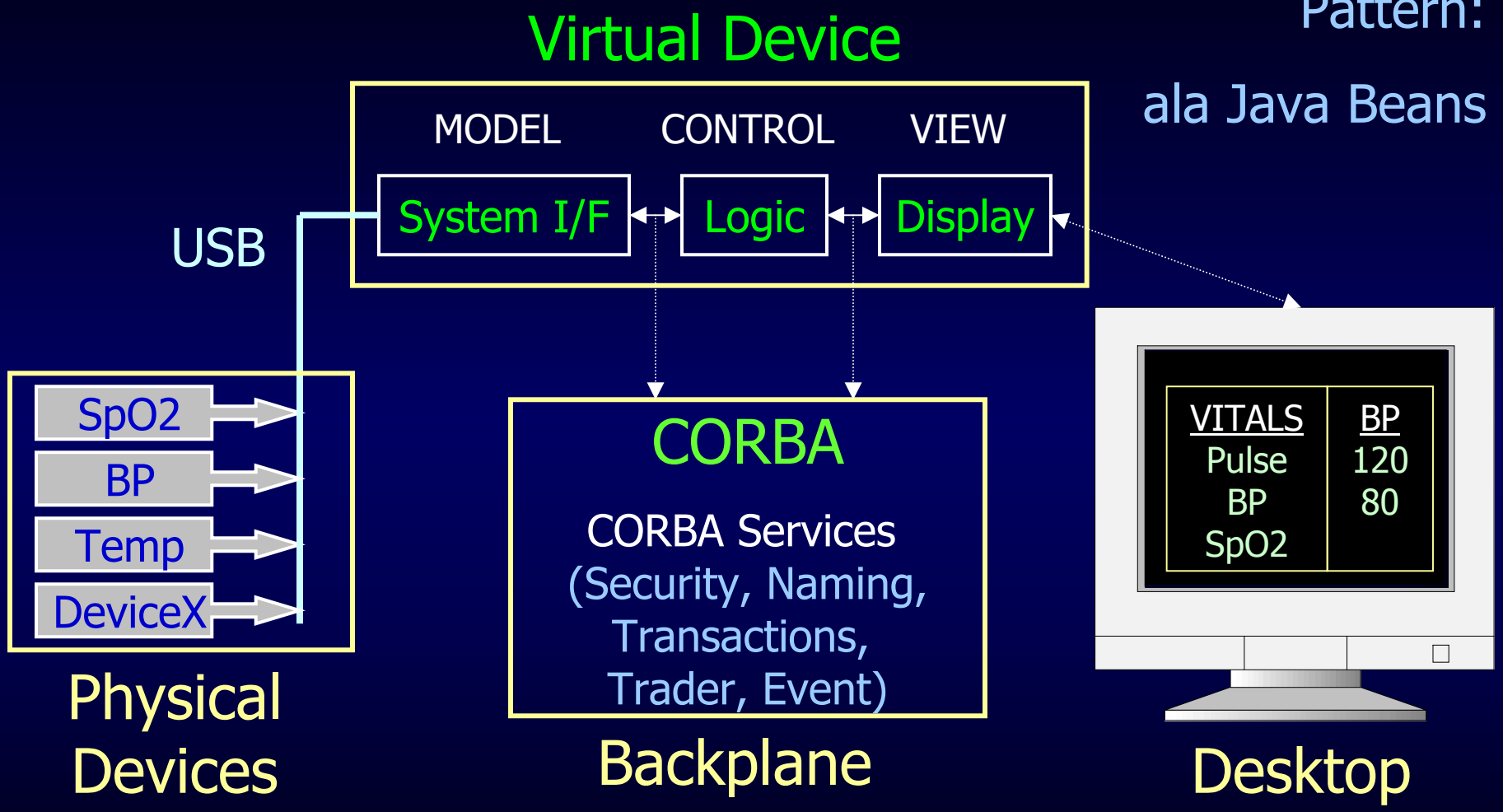
USB Hub:
Weight
Heart Rate
Blood O_2 Sat
Temperature
Blood Pressure
ECG
Stethoscope

Telemedicine Interoperability Architecture: http://telemedicine.sandia.gov
The Role of Technology in Reducing Health Care Costs: http://www.sandia.gov/CIS/6200/Telemedicine/; http://www.sandia.gov/CIS/6200/Telemedicine/index_tra.htm

Build 1 Architecture

Component Pattern:

ala Java Beans



Medical Component Design Laboratory

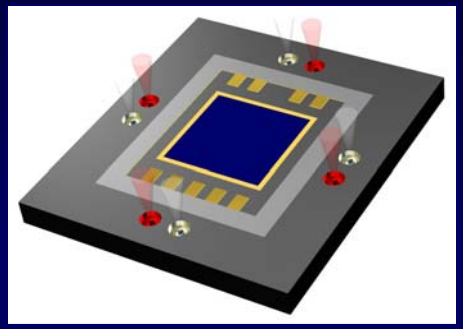
- Research Goals
  - Point-of-care system design
  - Plug-and-play component infrastructure
  - Medical devices ⇔ EPR's
  - Wearable light-based sensors
  - State of health assessment/prediction
- Education Goals
  - Project design space
  - New curriculum and web resources
  - Community outreach
- Support
  - National Science Foundation
  - Kansas EPSCoR Program
  - Sandia National Laboratories

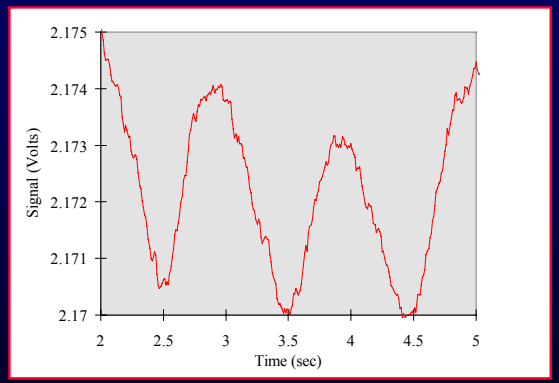
Bluetooth

http://www.bluetooth.com/

IEEE 1073

http://www.ieee1073.org/





NSF

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Beyond Telemedicine

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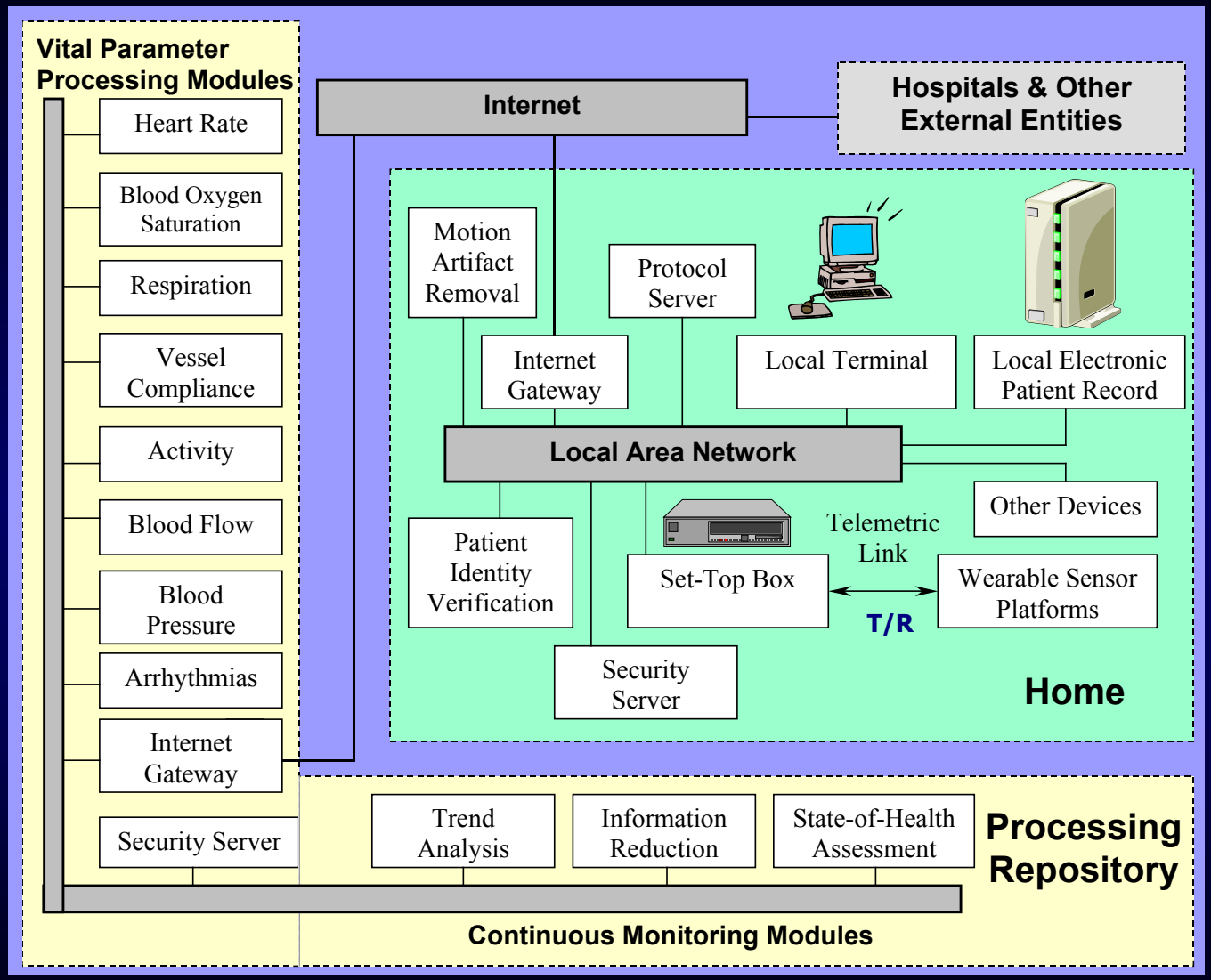
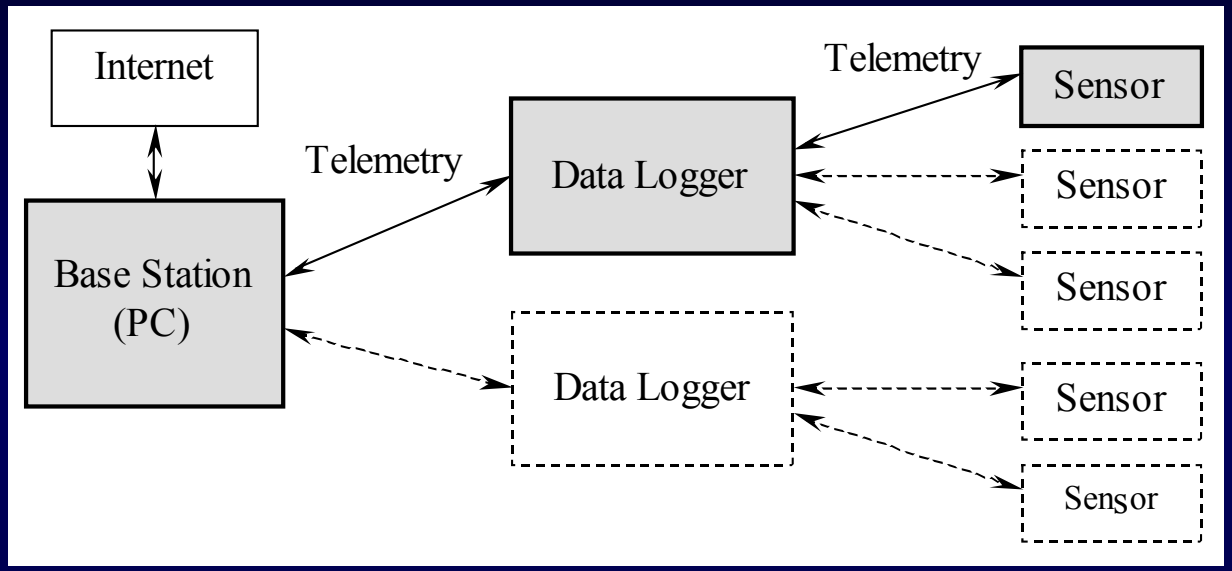
Technology Layout



Wearable Monitoring System

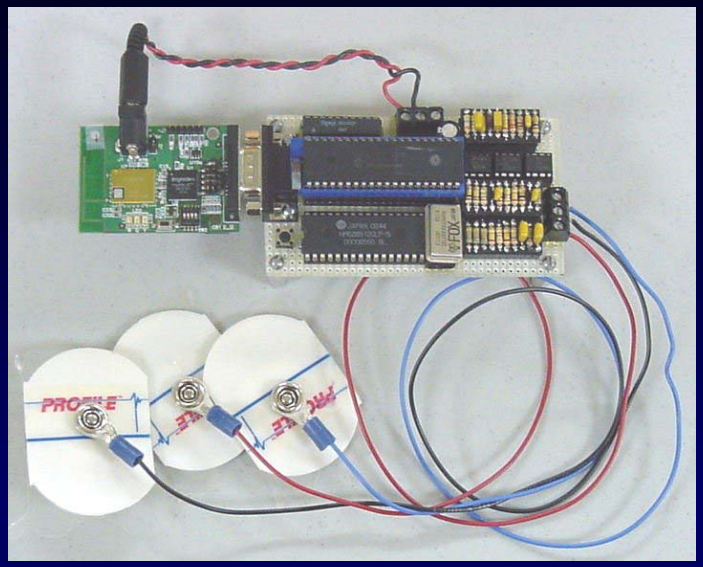
Ambulatory ECG & Pulse Oximeter;
Data Logger in a 'Fanny Pack'



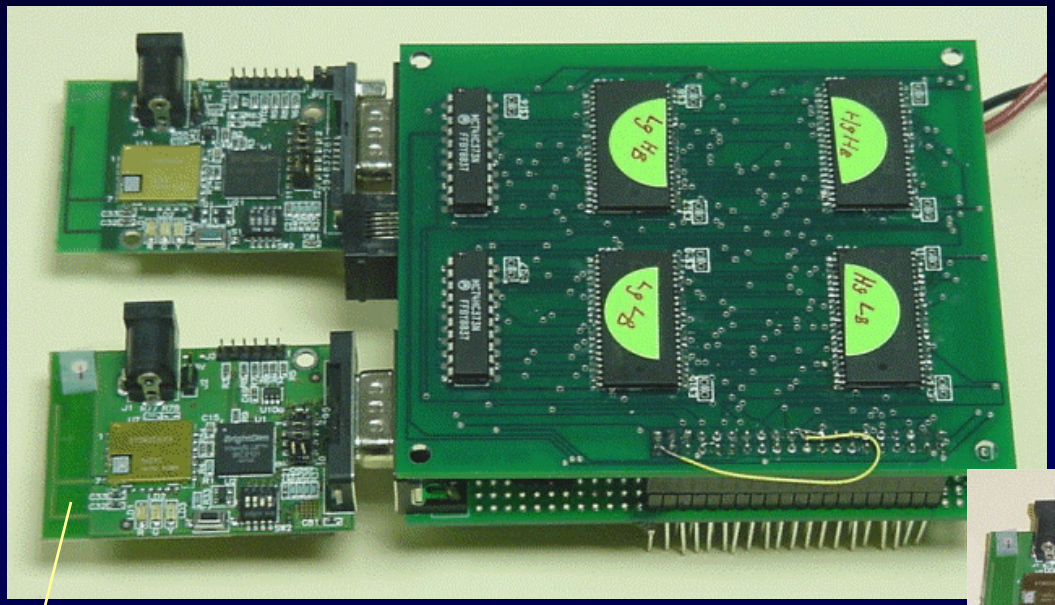
Nested Master/Slave Configurations
Bluetooth – Telemetry; Device discovery
MIB – Device Association; Nomenclature; Data exchange

Monitoring System Hardware

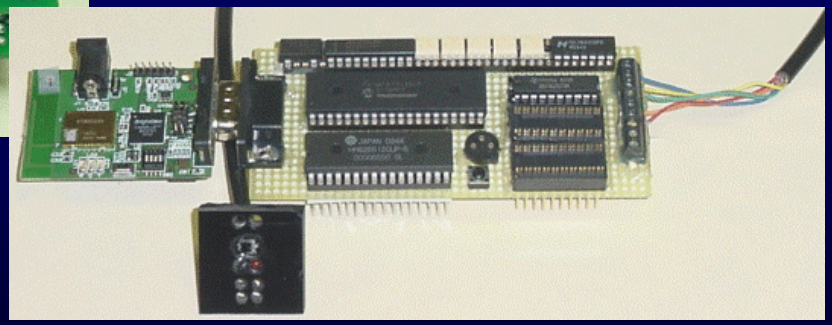
Electrocardiogram



Data Logger



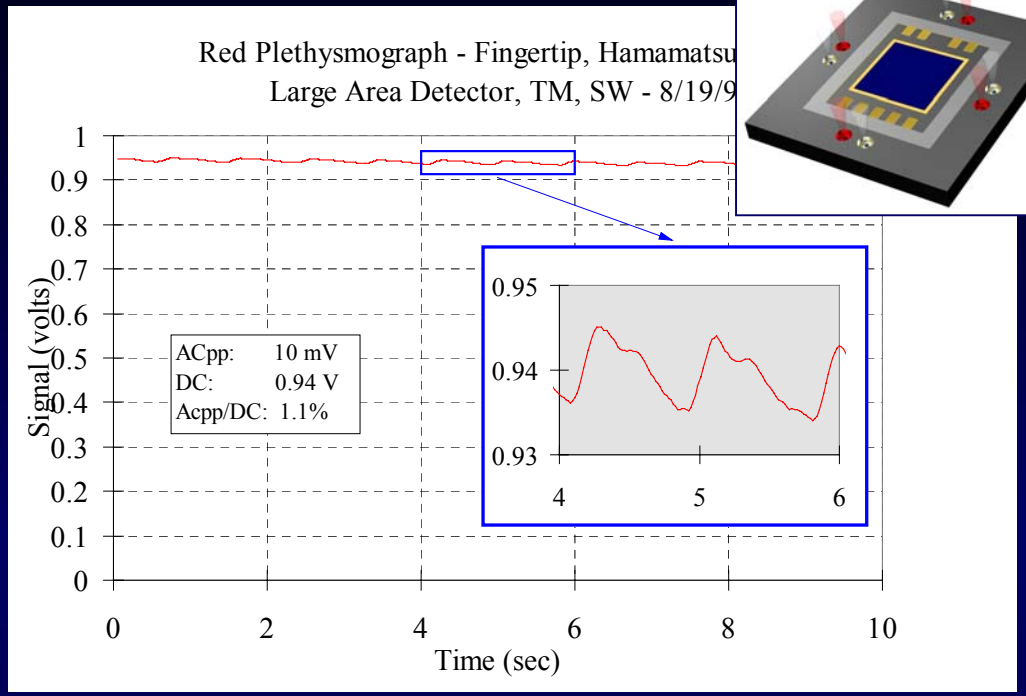
Bluetooth Telemetry – Brightcom Callisto II

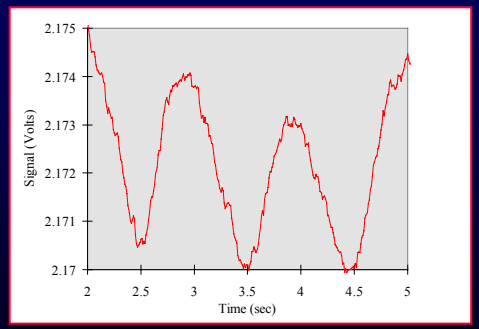


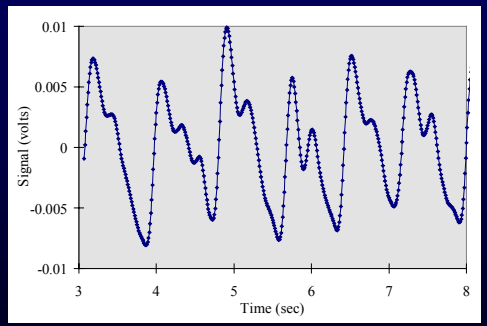
Pulse Oximeter

Light-Based Sensors

- Heart rate
- Oxygen saturation
- Respiration
- Motion (activity)
- Vessel hemodynamics
- Relative blood pressure
- Wearer identity
- Hemoglobin derivatives
- Hematocrit



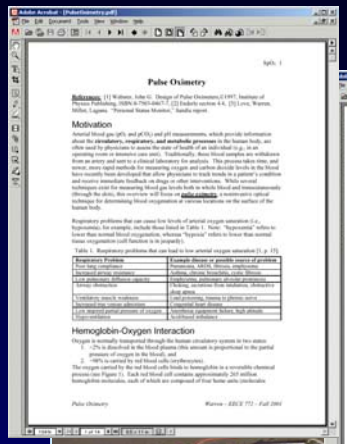


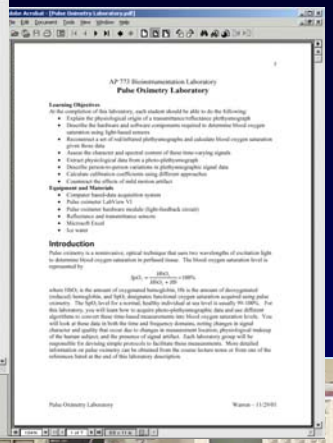


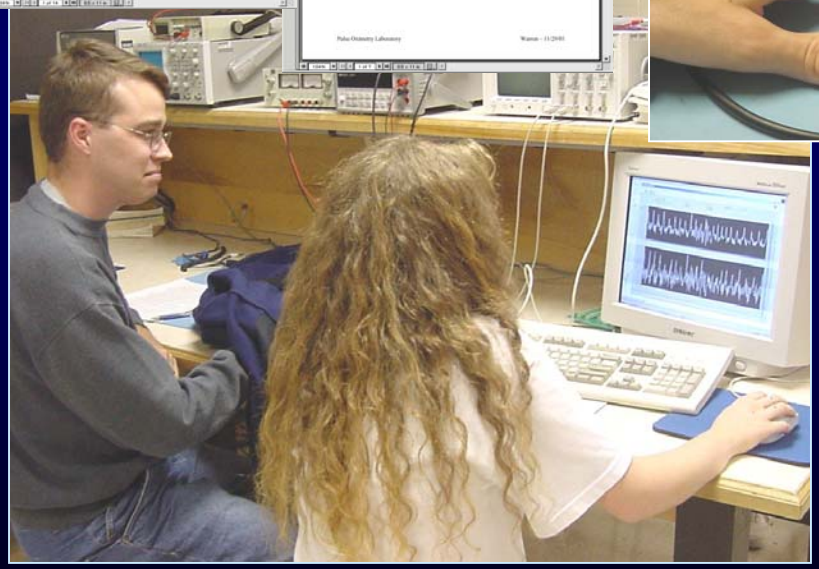
Components in Education

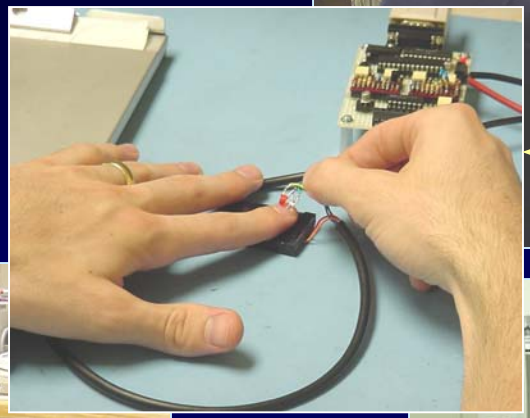
Lecture

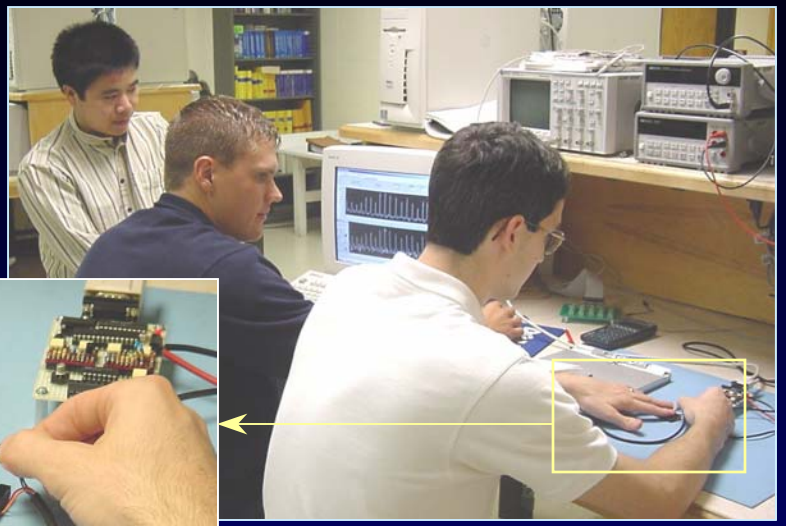
Laboratory











Community Outreach

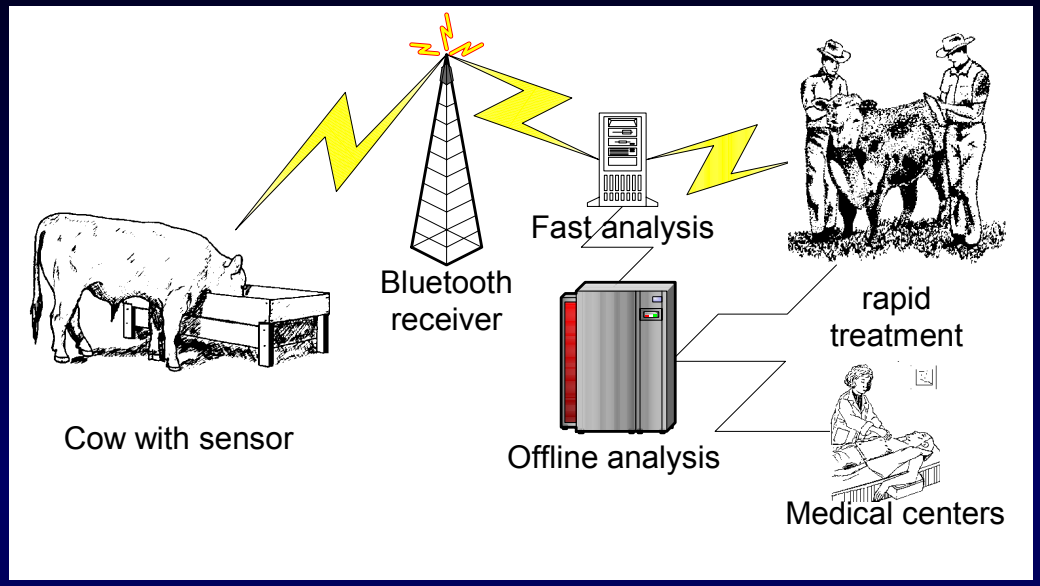
Girls Researching Our World

GROW Workshop:
Electric Signals from Our Bodies
June 19, 2002
Kansas State University

Light-Based Sensors to Indicate Hypertension

Application: Animal Monitoring

- 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:
  - Wearable/remote biomedical sensors, environmental sensors, and global positioning devices
  - Bluetooth-enabled monitoring stations
  - Regional information infrastructure

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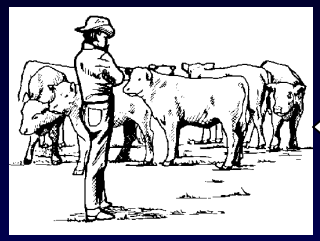
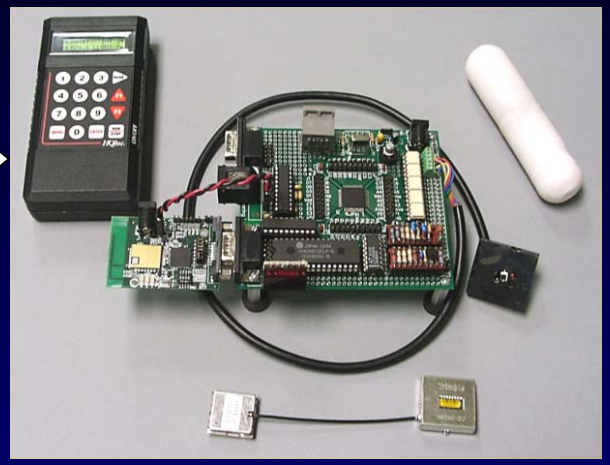
Prototype System

Mobile Monitoring Components



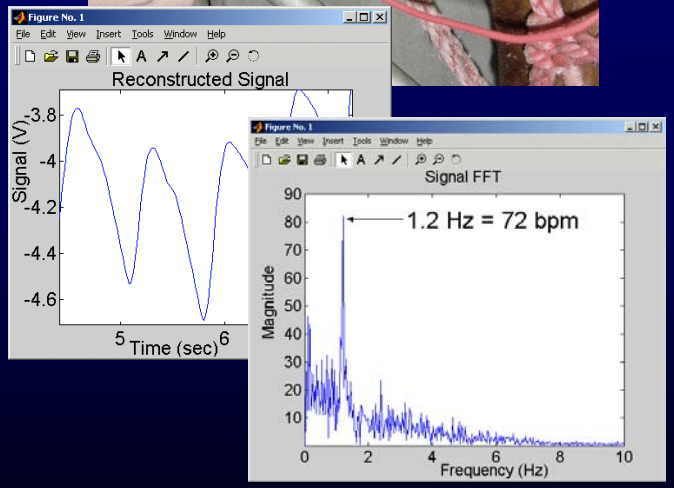


Handheld computer

Bluetooth telemetry link

GPS	HR	SpO_2	Core Temp
Microcontroller-based sensor module with serial communication to a Bluetooth telemetry module			
Activity	Ambient Temp	Humidity	

Ear Tags ⇒ Light-Based Sensors



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Concluding Remarks

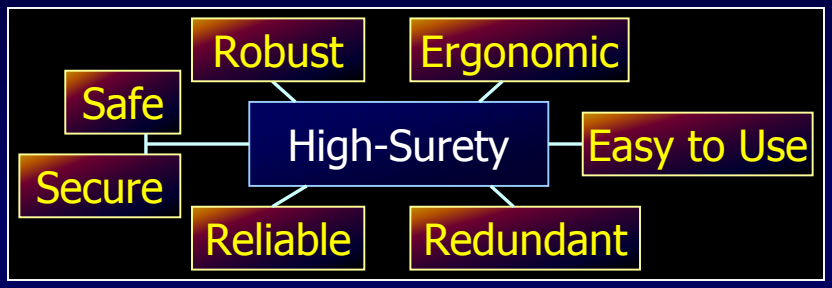
Key Messages

- Home health care
  - Reactive/episodic ⇒ preventative/predictive
  - Closed-loop systems: beyond "telemedicine"
  - Novel sensing technology & pervasive infrastructures
- Medical systems: Component confederacies
  - Ability: Smart, decision-enabled, and capable
  - Layout: Distributed and dynamic
  - Practicality: Cost-effective & high-surety

Interoperable & Secure ⇨ Vendor Competition & Economy of Scale ⇨ Cost ⇓

Challenges

- Standards
  - Require consensus from entities with competing goals
  - Difficult to define given quickly changing technology
- Surety & Regulation
  - Closed loop, high reliability systems constructed on-the-fly
  - Read/write access to secure information
  - Rules of engagement for role-based devices
  - Control of systems with nebulous boundaries
  - Unintended component interactions ("model checking")
  - Systems that incorporate non-medical devices
  - Inexperienced users



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