Wireless Sensor Networks: From the Laboratory to the Field

dg.o 2002 BDEI Session

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The Scientific Challenge…

Understanding microclimates - the long-term weather trends in localized areas. Examples include:

- the effects of habitat fragmentation and restoration in the Southwest
- the interaction of insect activity, tree growth, and soil conditions in woodlands of the Colorado Plateau
- how microclimates influence the growth of redwoods in California

Our global environment is a mosaic of microclimates!

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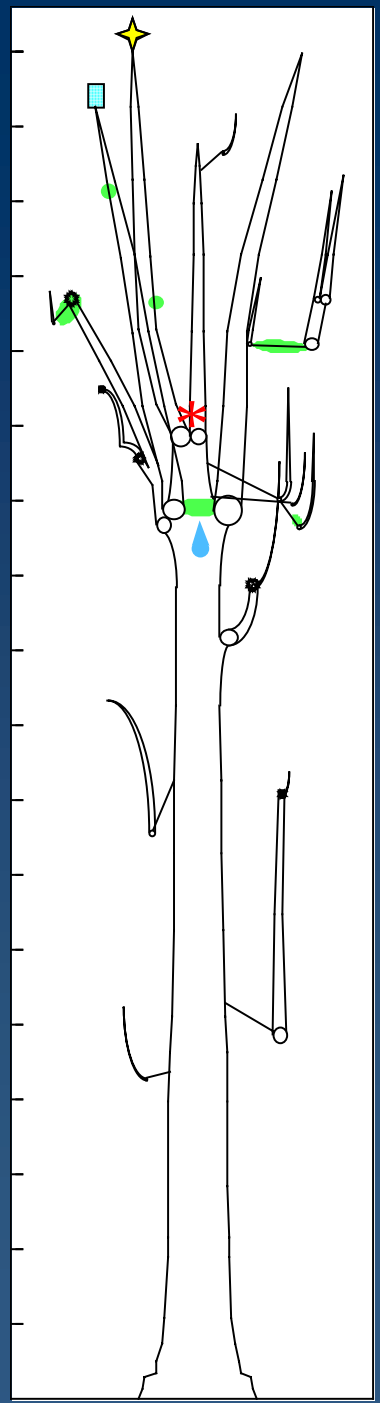

Microclimate System
light, air temperature, relative humidity, rainfall, humus temperature, humus moisture content

…Drives the Engineering Challenge

Need: **Dense array of small sensors** to monitor microclimate variables such as temperature and light. Standalone or wired sensor arrays are difficult to deploy and operate.

Opportunity: **Wireless networking** of the sensors

- dramatically improve coverage and spatial density, and ultimately, our understanding of microclimates...
- …while greatly reducing the total monitoring cost

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Requirements

- Accuracy – science mission removes lossy/unreliable computation-communication from consideration
- Low cost – to allow deployment in large numbers
- Low energy consumption – for practical field service life
  - metric is average bits/J, not bit/s/Hz-m^2

More Requirements

- Flexible data rate – must support low per-sensor, but high aggregate rates
- Centralized data access - automatic delivery to a central repository
- Reliability and autonomy - system must be robust to withstand long service intervals

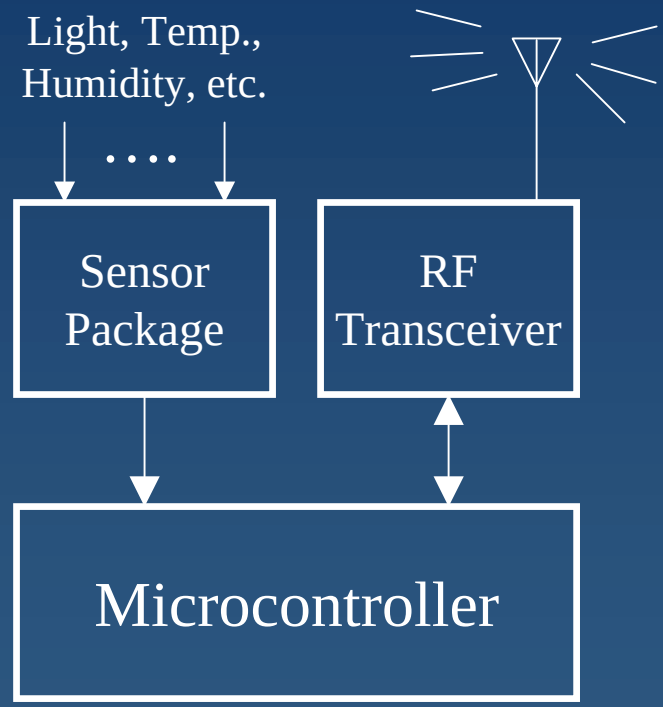
Approach

Key requirements can be met using a design which synthesizes:

- advances in environmental sensing (typified by current sensor/dataloggers)
- wireless networking infrastructure adapted to the environmental sensing regime

WISARD
(*Wi*reless *S*ensing *a*nd *R*elay *D*evice)

- Modular sensing, computation, and wireless communication/networking capability
- Integration of family of technologies---can exploit advances in each
- Adaptive frequency, information rate and transmit power to maximize energy efficiency



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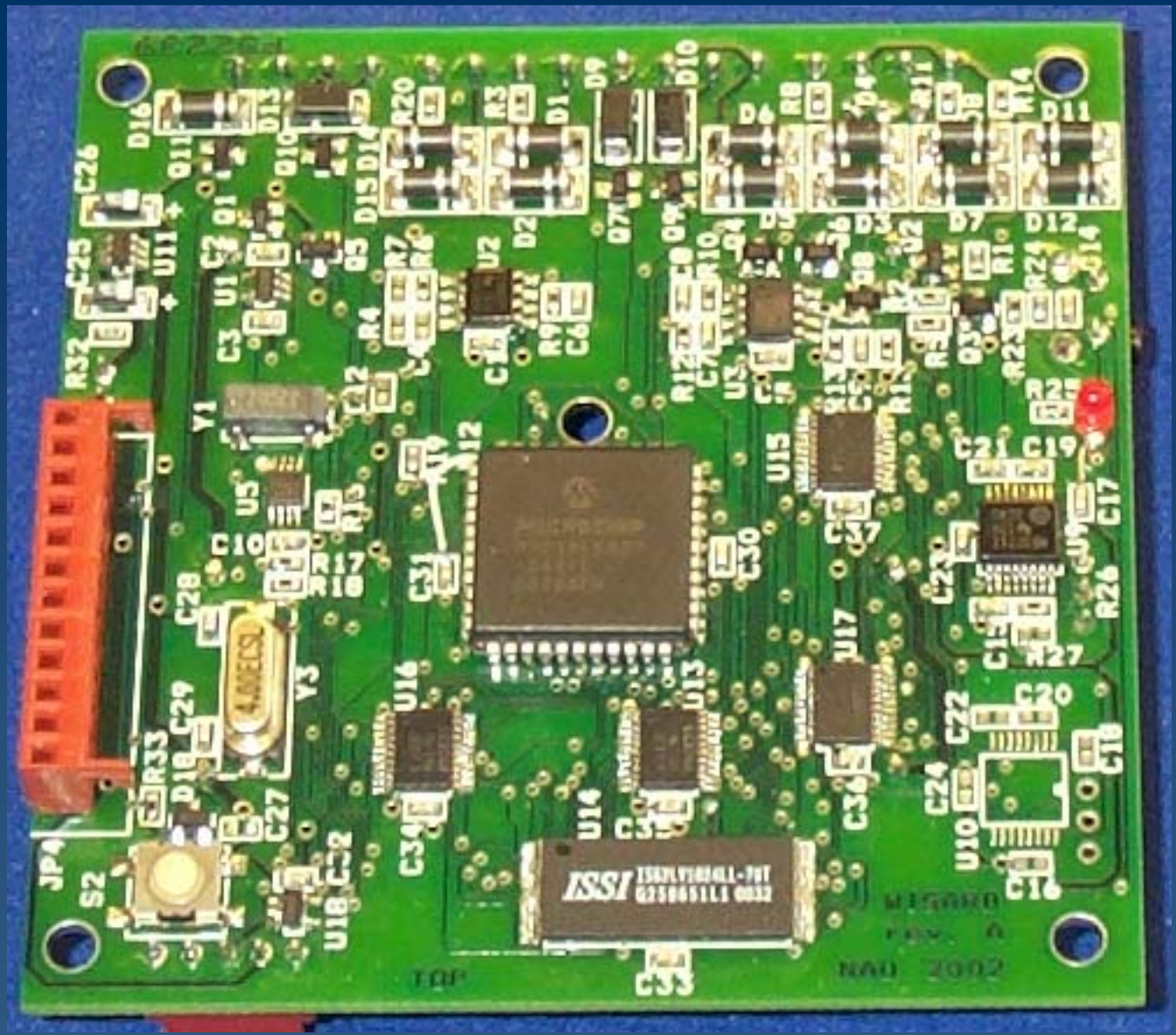

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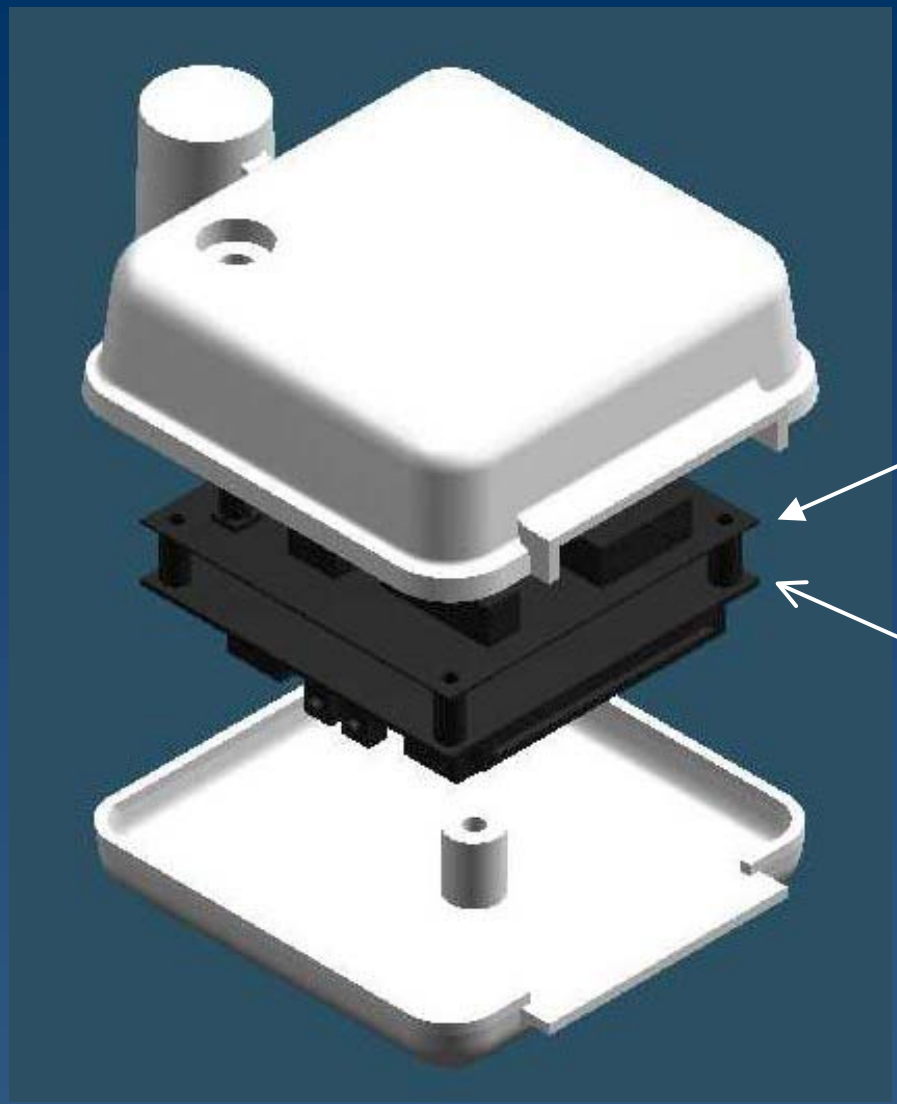
CAD Model



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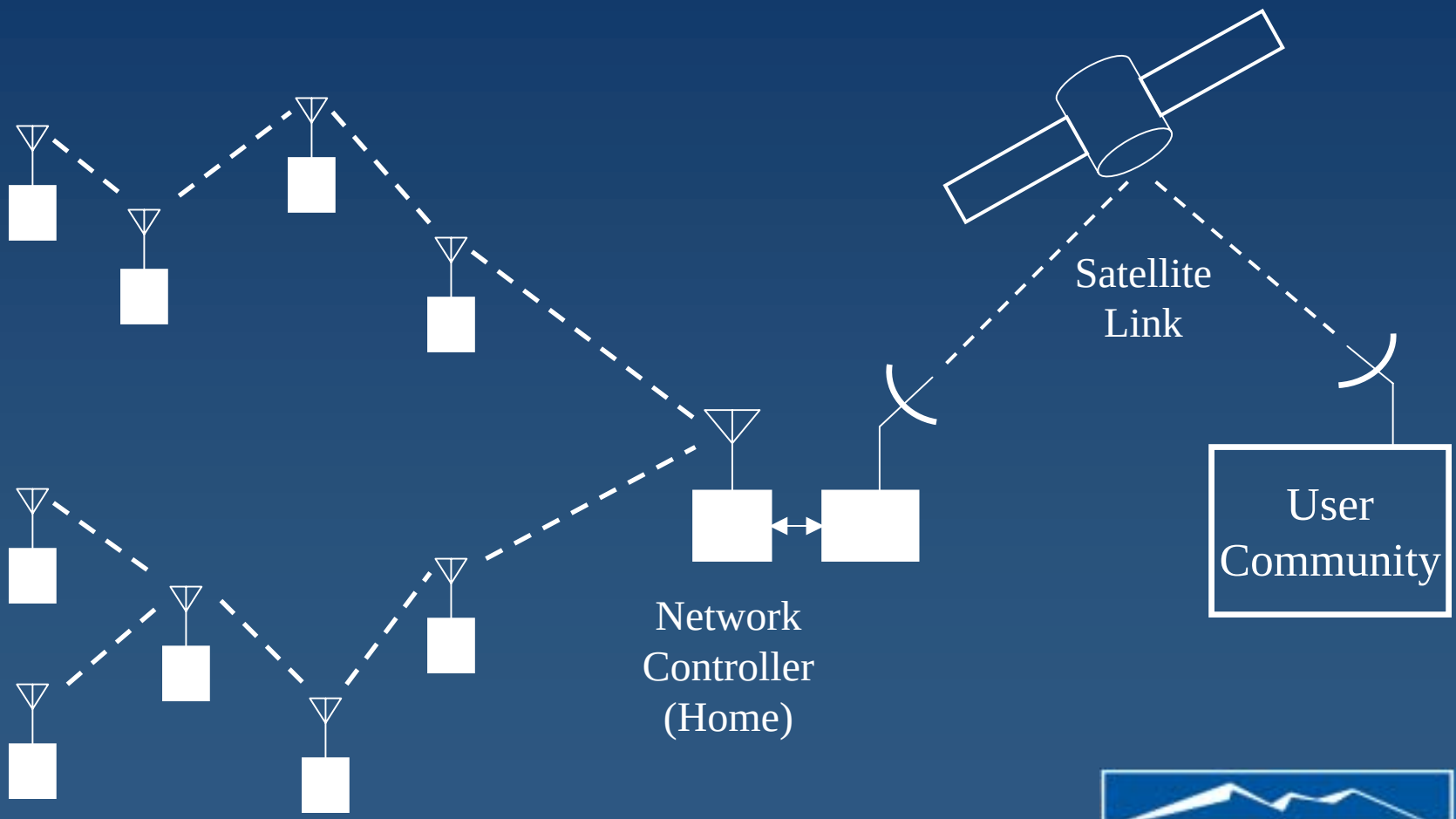
WISARDNet Concept



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Energy Aware Design

We plan to simulate our wireless sensor net:

- Agent-based, object-oriented approach
- Layer-based model integrating low-level energy accounting (a la MIT μAMPS JouleTrack) with high-level comp-comm algorithms
- Undergrad CpE student will start 1 July 02 funded by NSF and NASA Space Grant

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Open Research Issues

- Distributed, adaptive lossless source coding of spatio-temporally correlated vector processes
- Networking with cross-layer interaction
  - routing is PHY-layer sensitive
  - interaction of source/channel coding and routing
- Coded macrodiversity in multi-hop nets

Integrating Research and Education

- NAU *Communication and Robotics Lab*: students learn the fundamentals of embedded, networked devices.
- *Environmental Sciences and Informatics* - students learn how to develop and use technology for ecosystem monitoring and modeling – NSF CCLI proposal in preparation

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Team Members

Faculty

- George Koch – Biology
- Tom Sisk – Environmental Sciences

Graduate Students

- Brent West – digital/RF hardware design
- Bill Ruggeri – software design

Undergraduate Students

- Curtis Havran (EE) – software design
- Howard Bailey (ME) – packaging
- Dennis Miller (CpE) – simulation (starting 07/02)

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Project Sponsors

- National Science Foundation Biodiversity and Ecosystem Informatics Program
- NAU Department of Biological Sciences
- NAU Merriam-Powell Center for Environmental Research
- Microchip Technology