



Wireless Embedded Sensor Networks and Applications in Ecology

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System Administrator

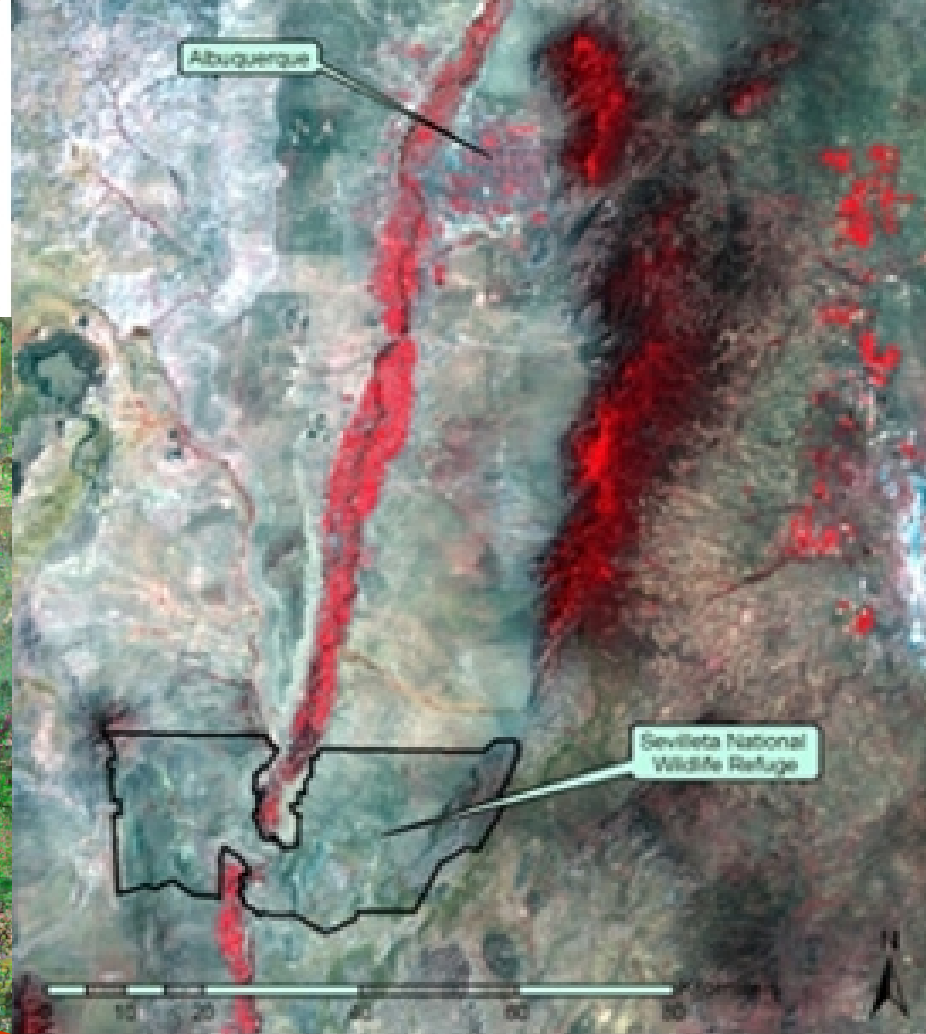
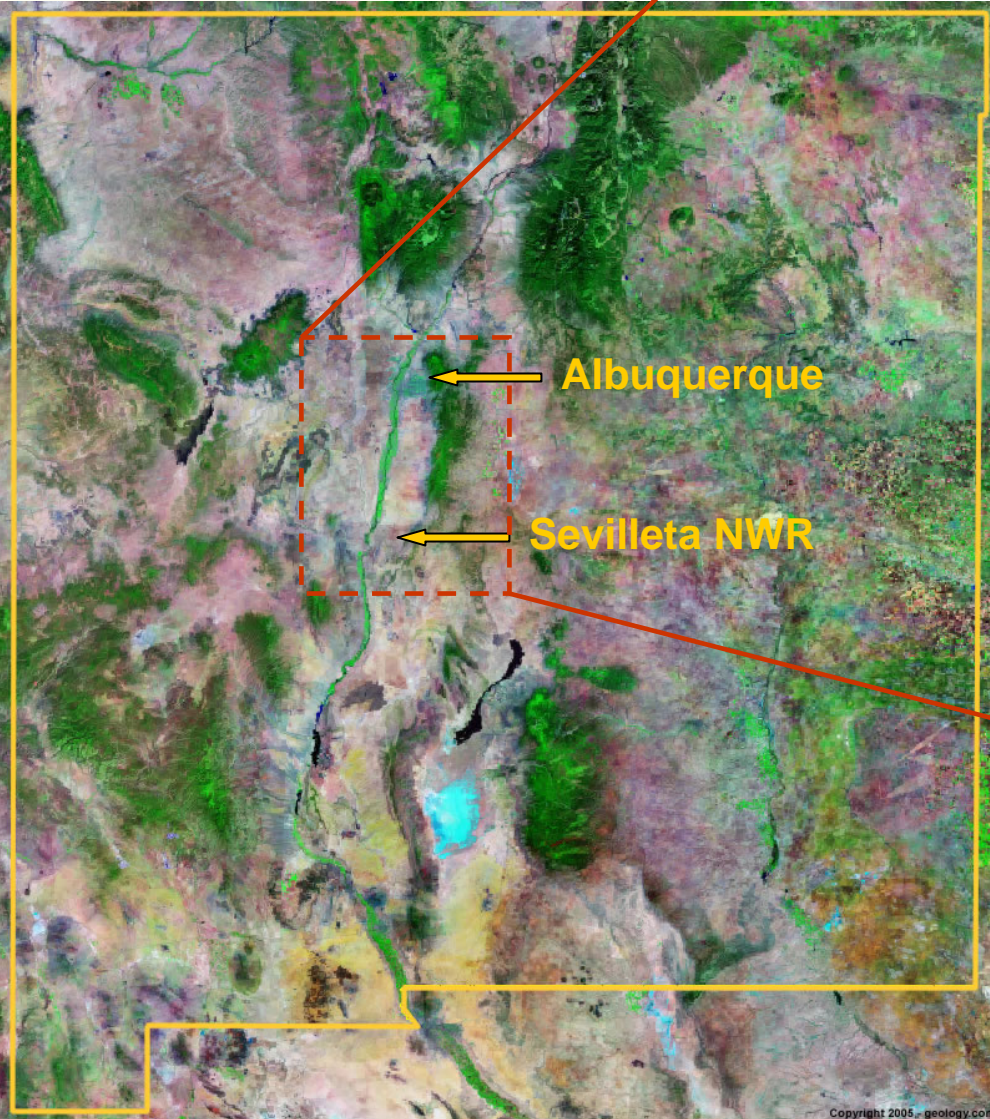
Sevilleta LTER Program & UNM Sevilleta Field Station

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SEEK Sevilleta



- ~50 mi S of Albuquerque
- ~220,000 acres
- Hosts Sevilleta LTER Program & UNM Sevilleta Field Station





What are sensors?

- A “sensor” is an electronic device used to measure a physical quantity.
- There are many different types of sensors used in ecology research today and measure things such as *wind speed and direction, solar radiation, temperature, relative humidity, precipitation, snow depth, barometric pressure, soil moisture, acoustic noise, air and water flows, and seismic vibrations.*
- Today’s sensors used primarily in conjunction with Campbell Scientific dataloggers.





Campbell
Scientific
Datalogger

Sensors

tipping bucket
rain gauge
(precipitation)

wind vane
(wind direction)

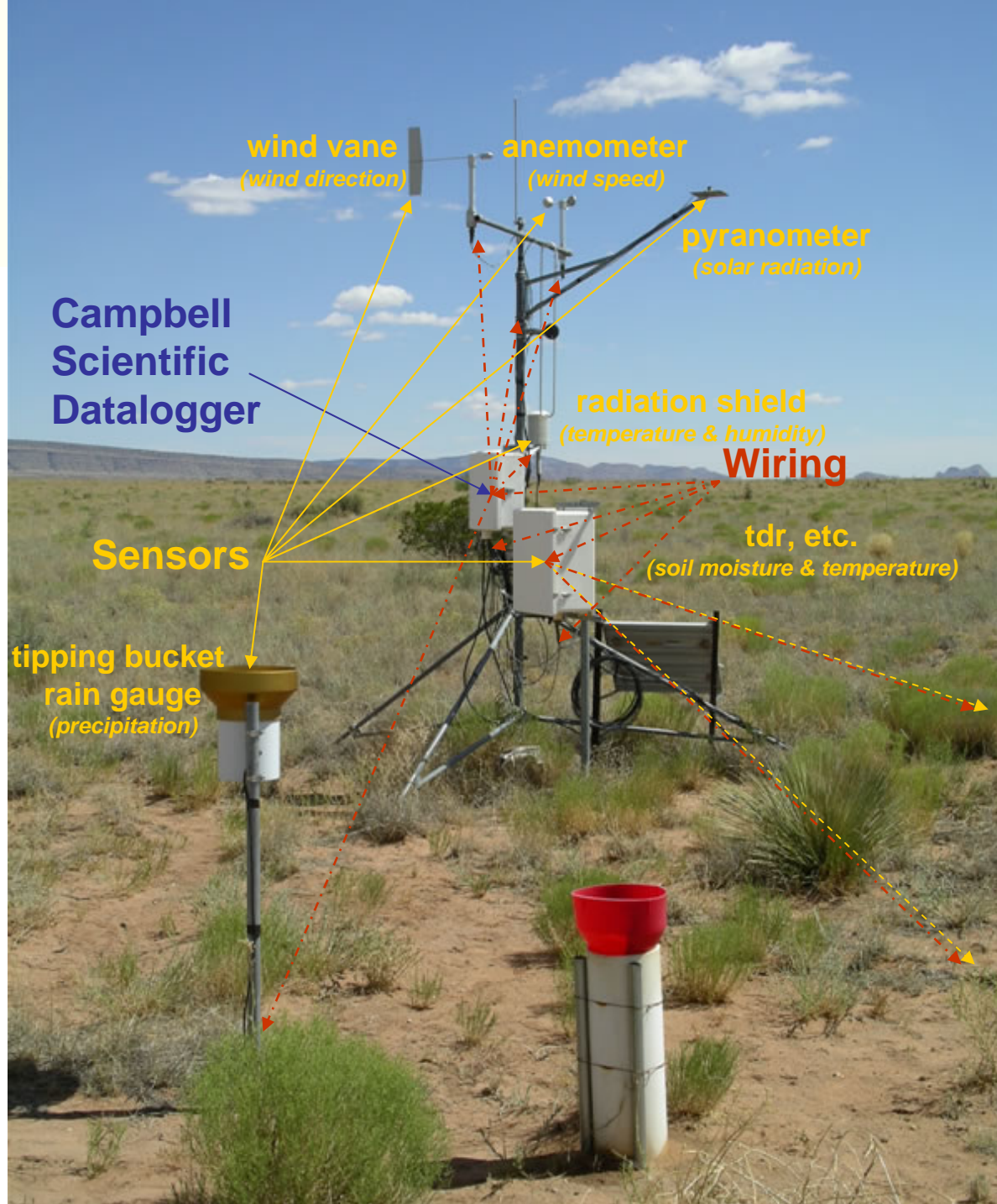
anemometer
(wind speed)

pyranometer
(solar radiation)

radiation shield
(temperature & humidity)

Wiring

tdr, etc.
(soil moisture & temperature)





Computer Networking 101

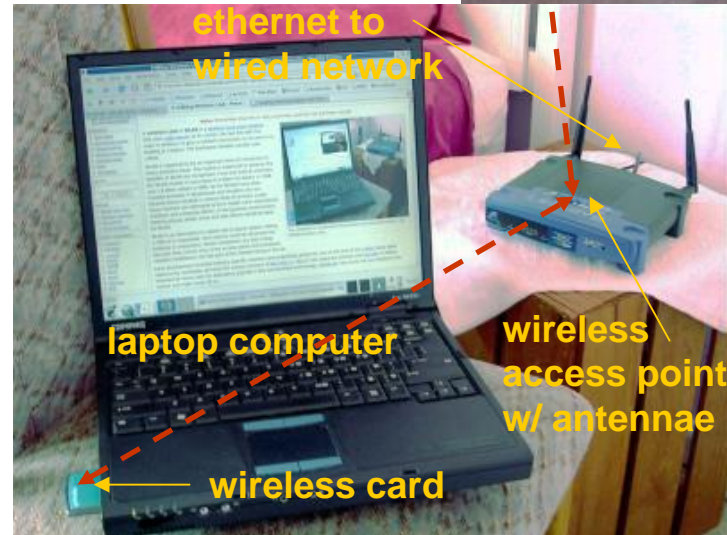
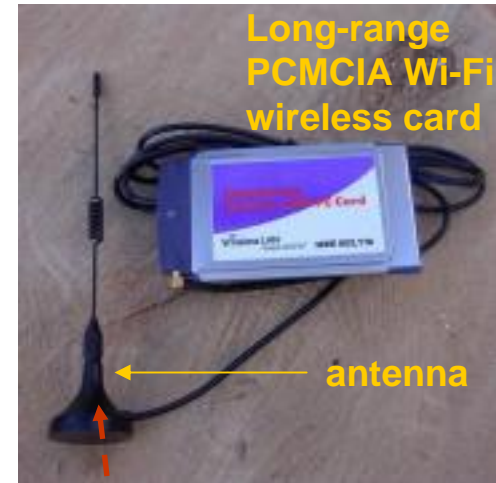
- A computer network allows for intercommunication, or the sharing of information, among users (*humans*) and devices (*computers*).
- Data is typically passed from one device to another according to standardized protocols, such as the internet protocol suite, or TCP/IP.
- Examples include computer labs, server connections (email), and the internet.
- This is accomplished using “wires” or wirelessly.





Wireless Networking

- Wireless devices communicate via radio waves, with access points interfacing with wired networks.
- Most familiar use of wireless is with laptops utilizing 802.11 a/b/g protocols.



↔
Wireless link





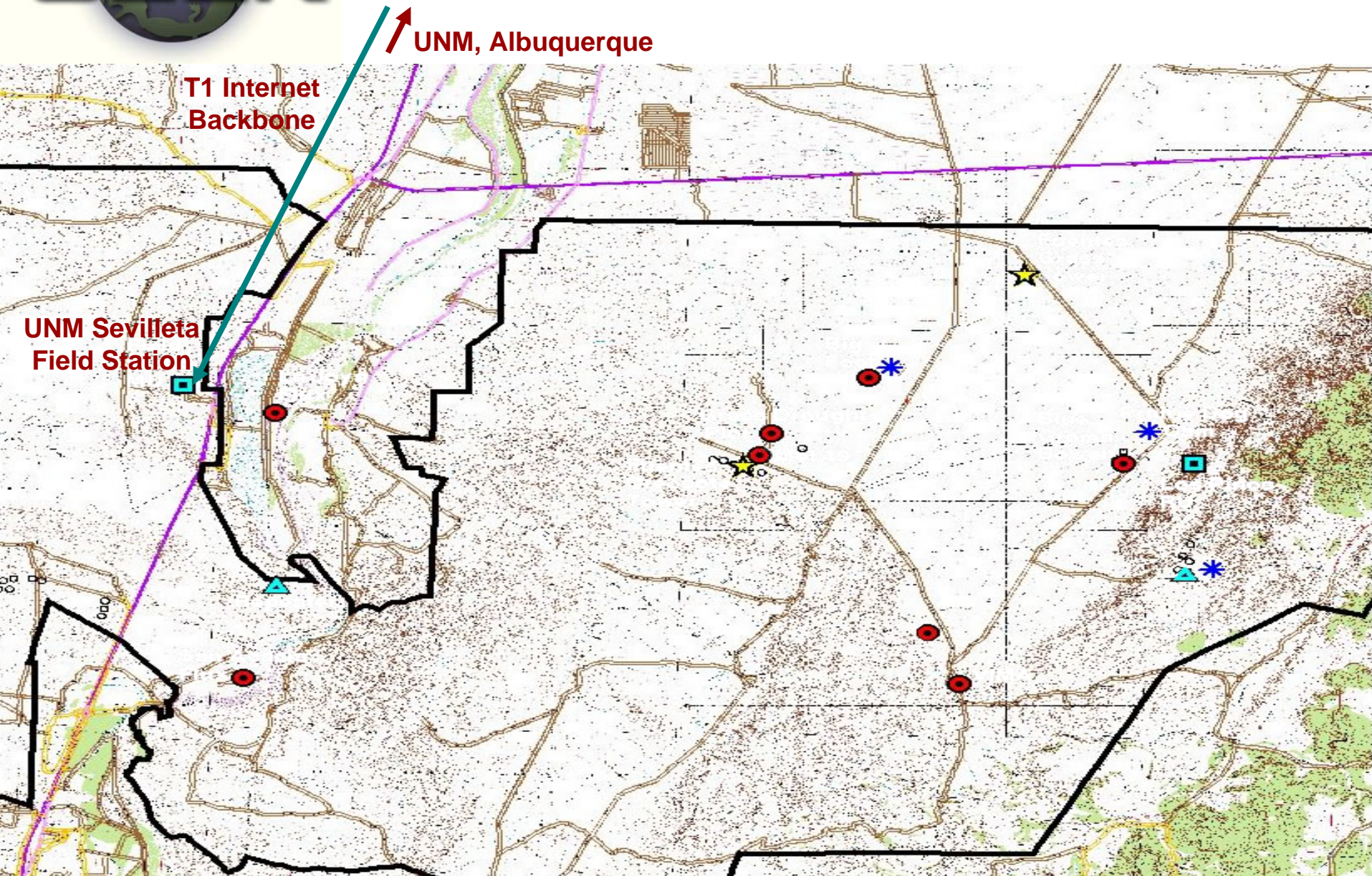
Advantages of Wireless

- Relatively inexpensive.
- Ease of implementation and use.
- No need for messy cable management.
- Can extend to remote areas (such as field sites), where wired network infrastructure is unavailable.
- Allows for real-time remote monitoring of data and problems at research sites.



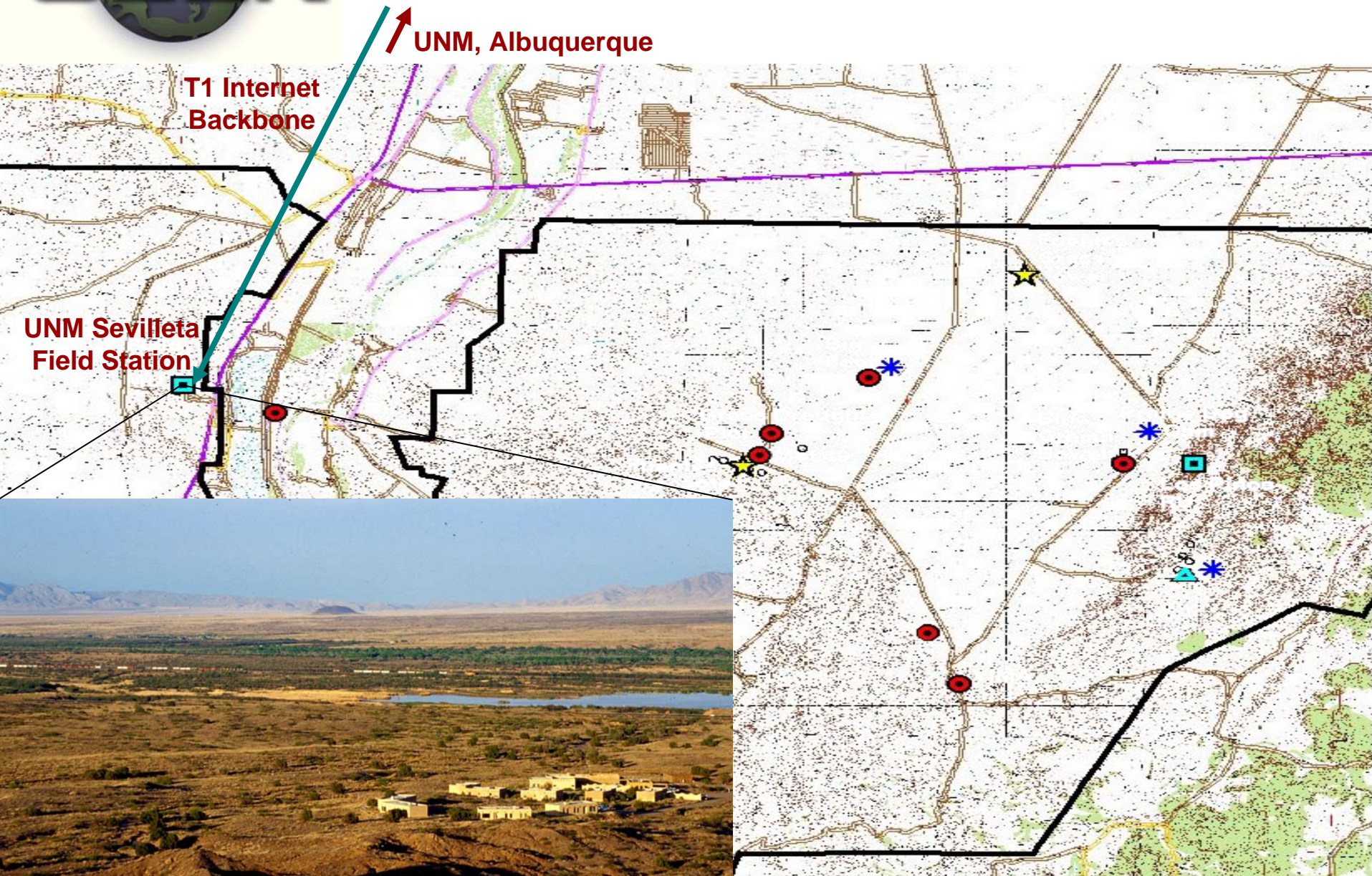


Sevilleta Wireless Network





Sevilleta Wireless Network



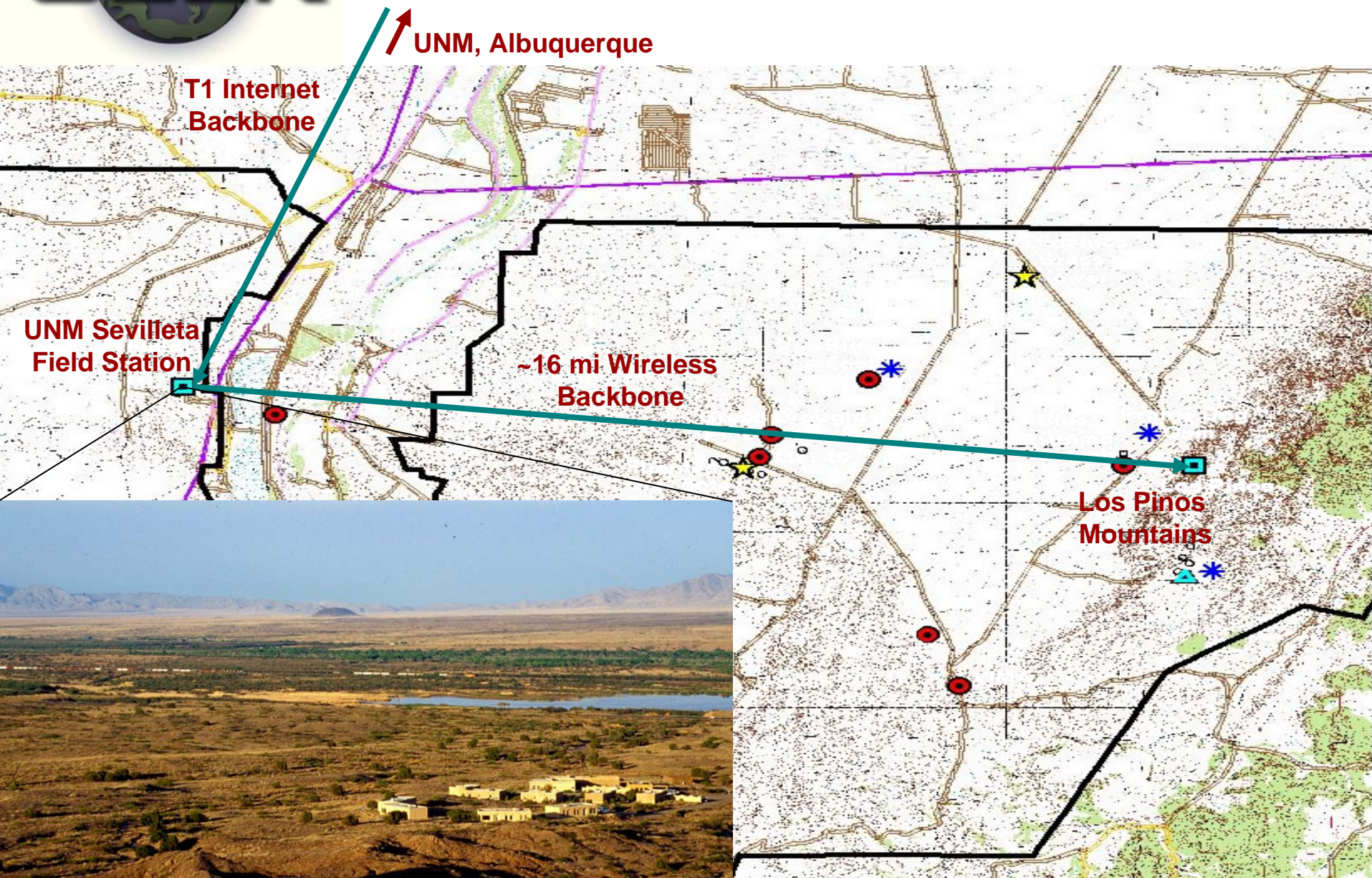
T1 Internet
Backbone

UNM, Albuquerque

UNM Sevilleta
Field Station

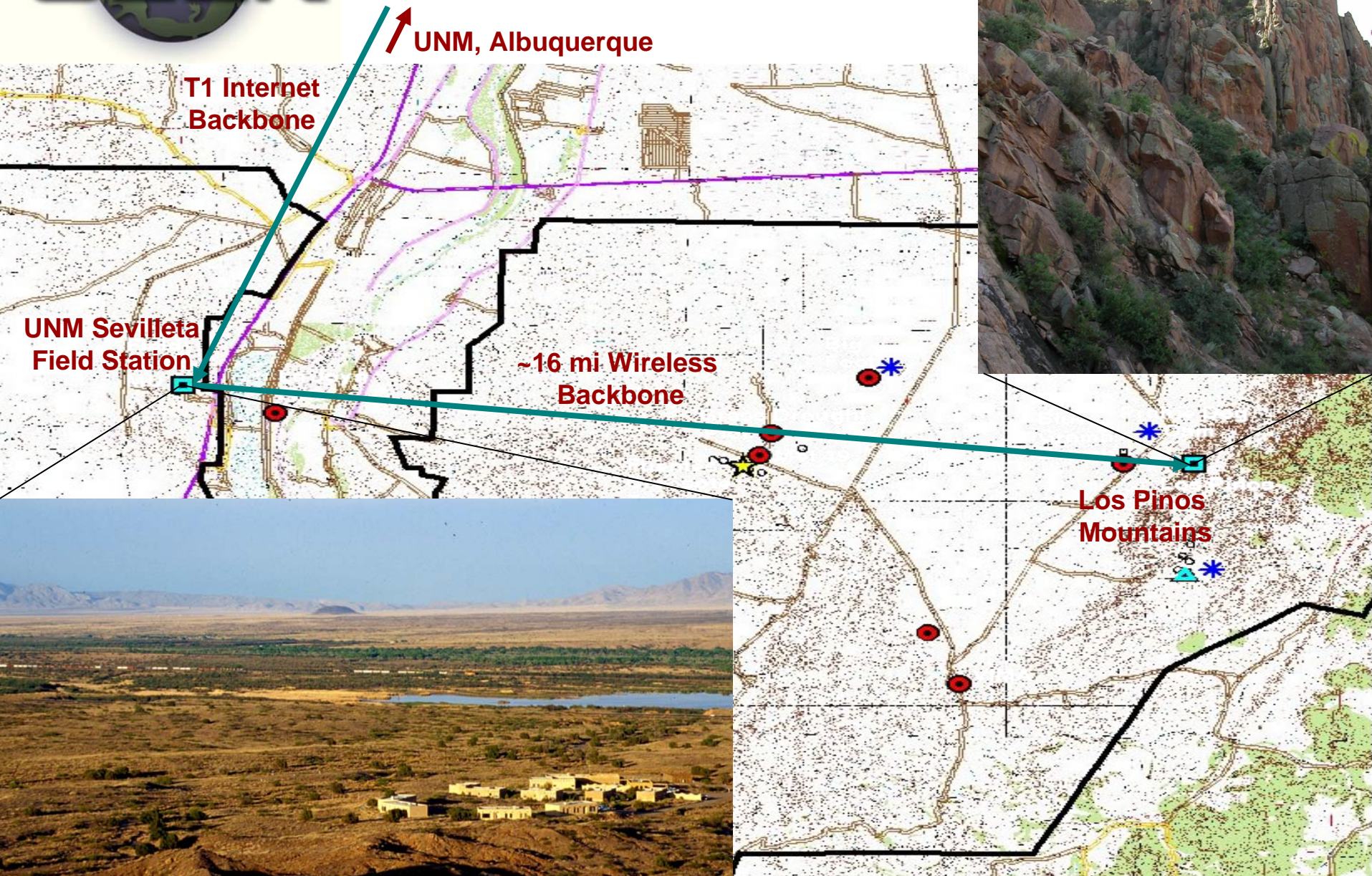


Sevilleta Wireless Network



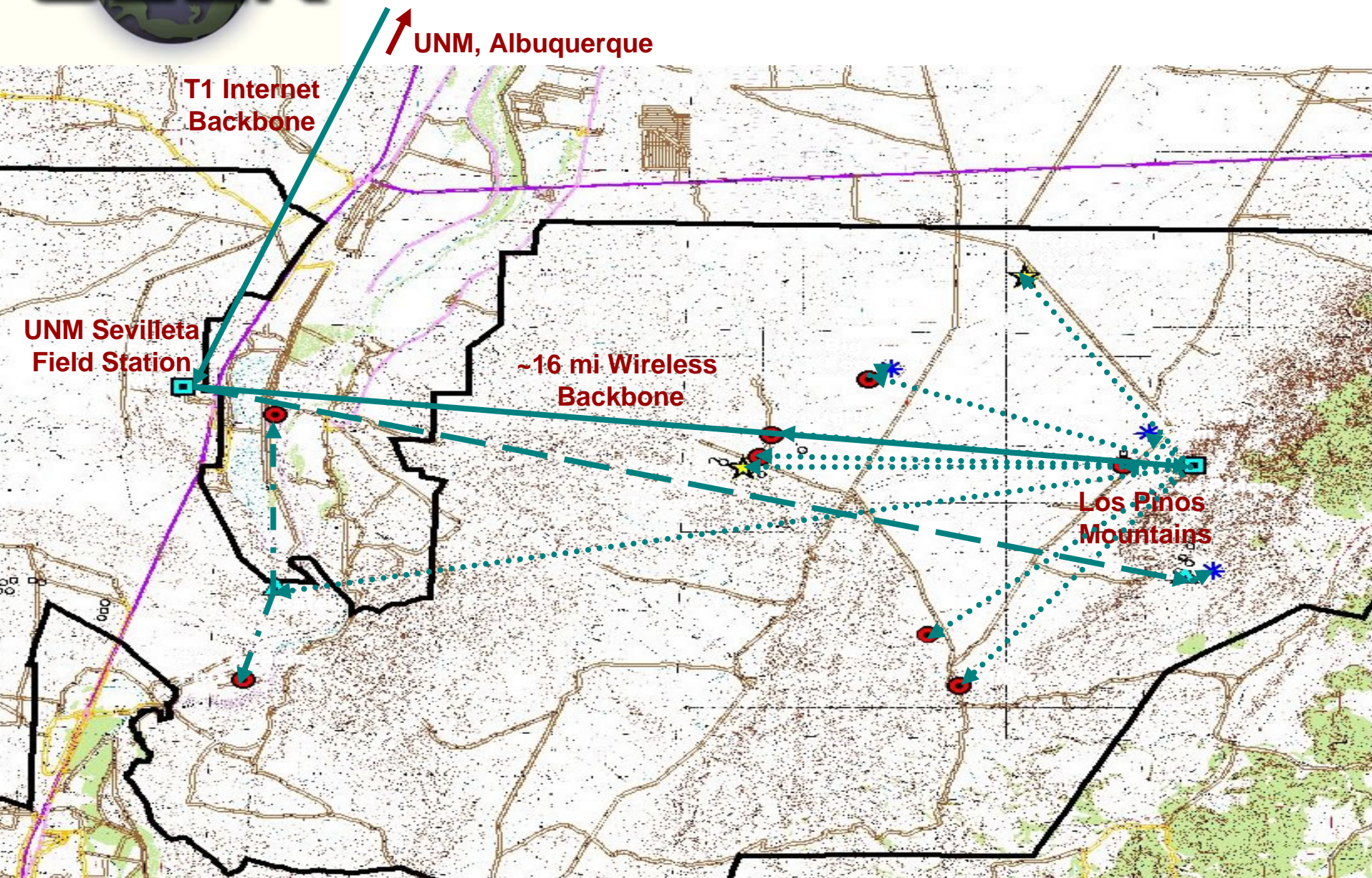


Sevilleta Wireless



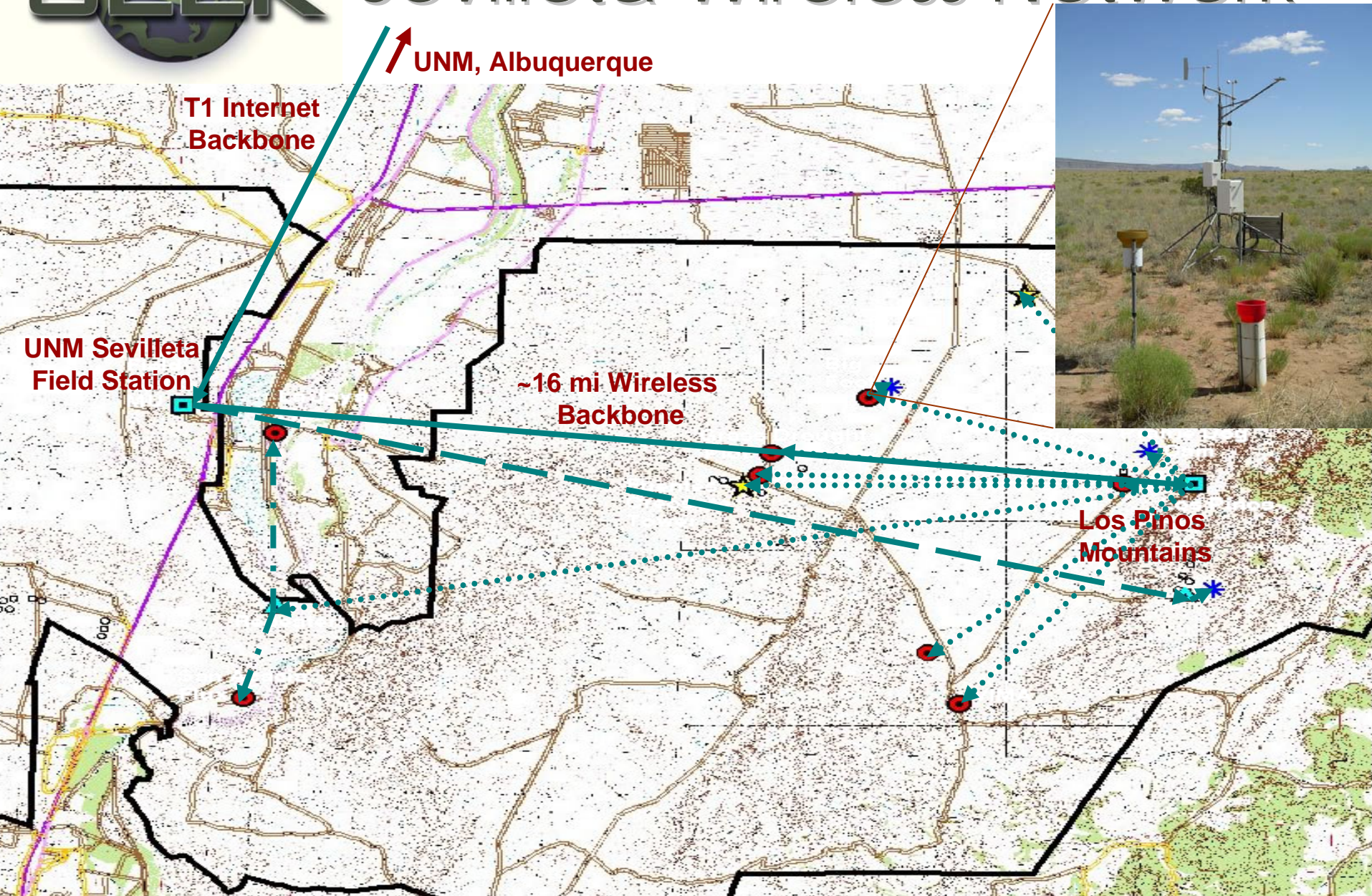


Sevilleta Wireless Network



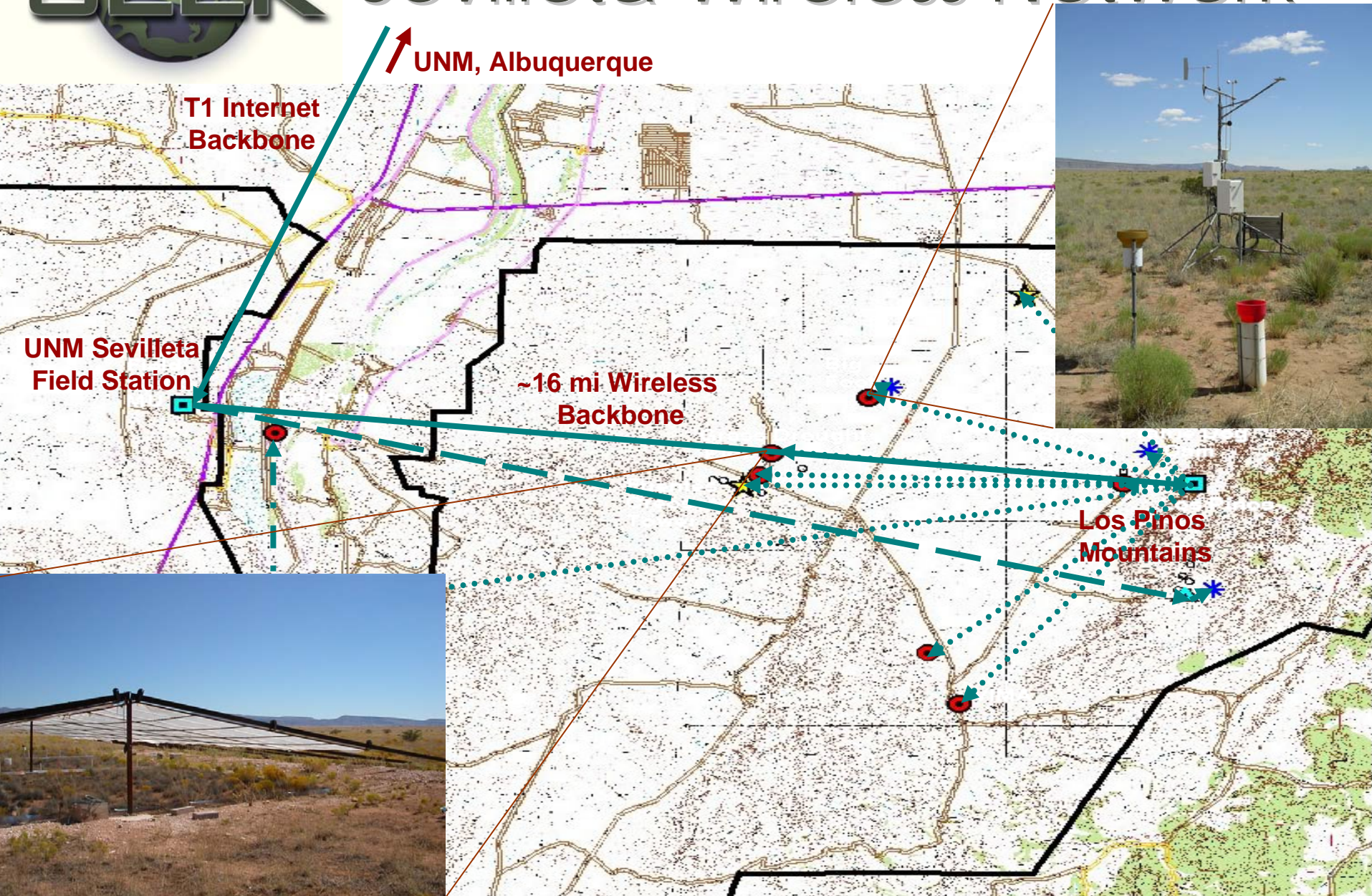


Sevilleta Wireless Network





Sevilleta Wireless Network



T1 Internet
Backbone

UNM, Albuquerque

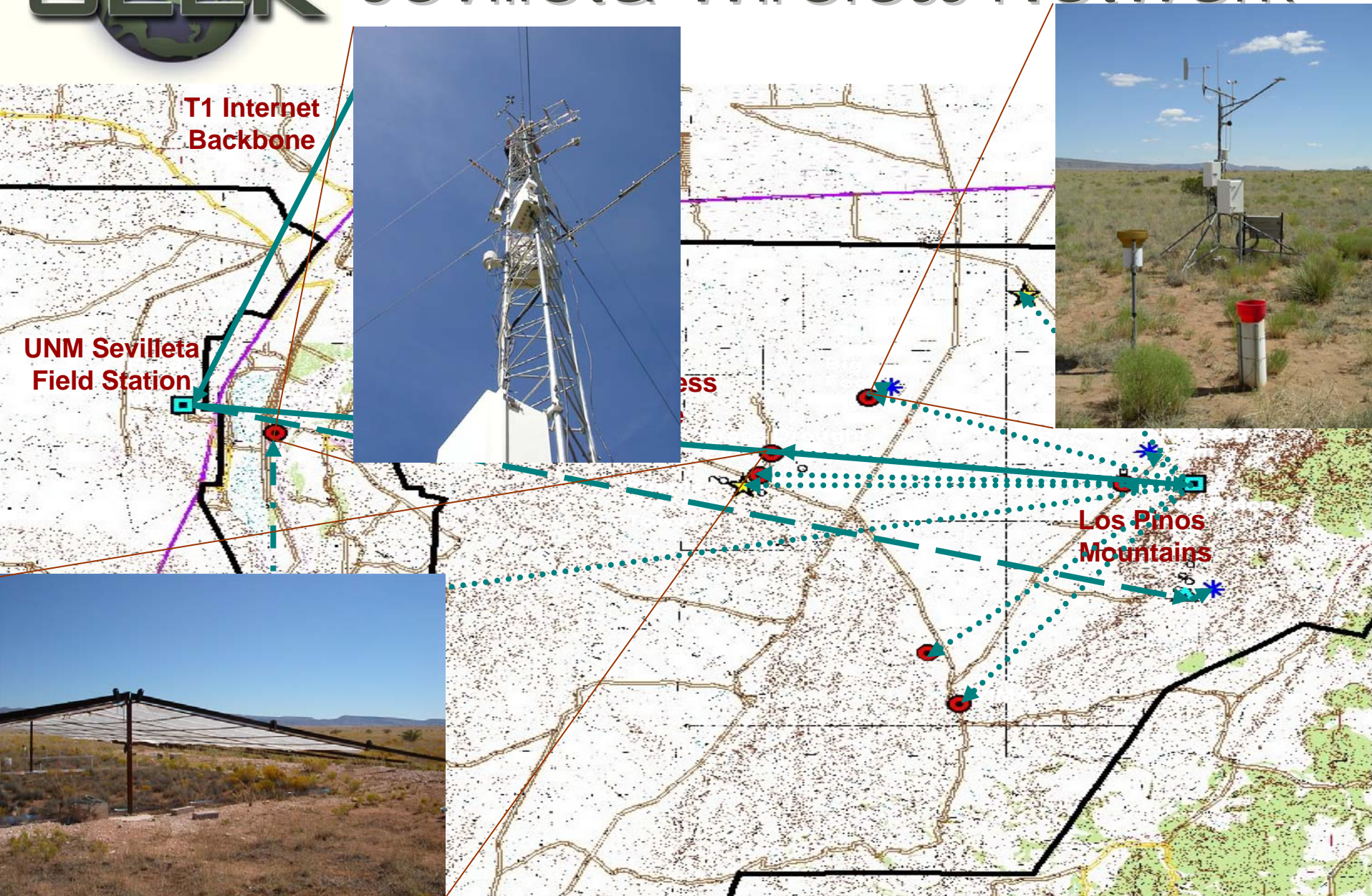
UNM Sevilleta
Field Station

~16 mi Wireless
Backbone

Los Pinos
Mountains

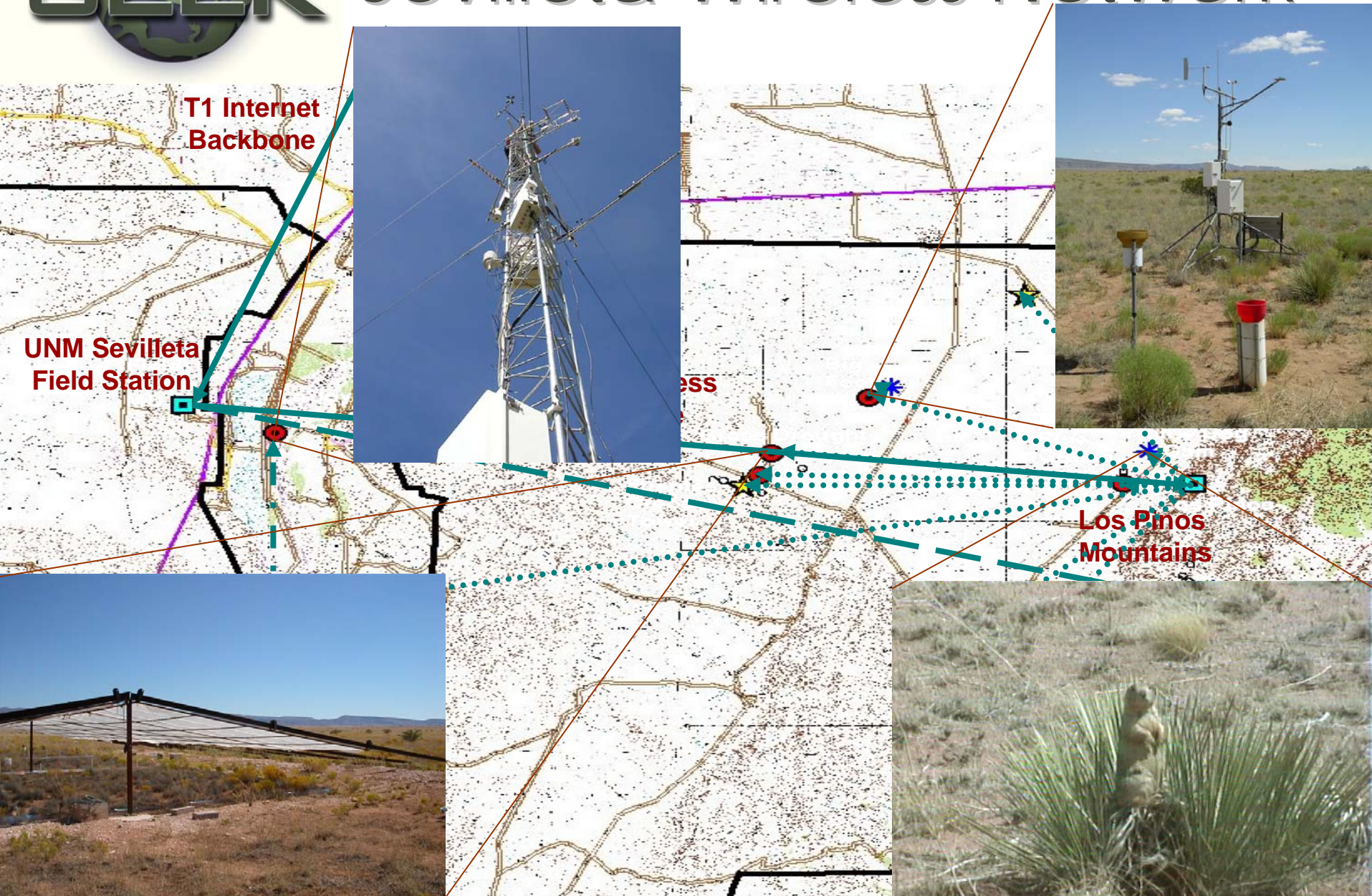


Sevilleta Wireless Network



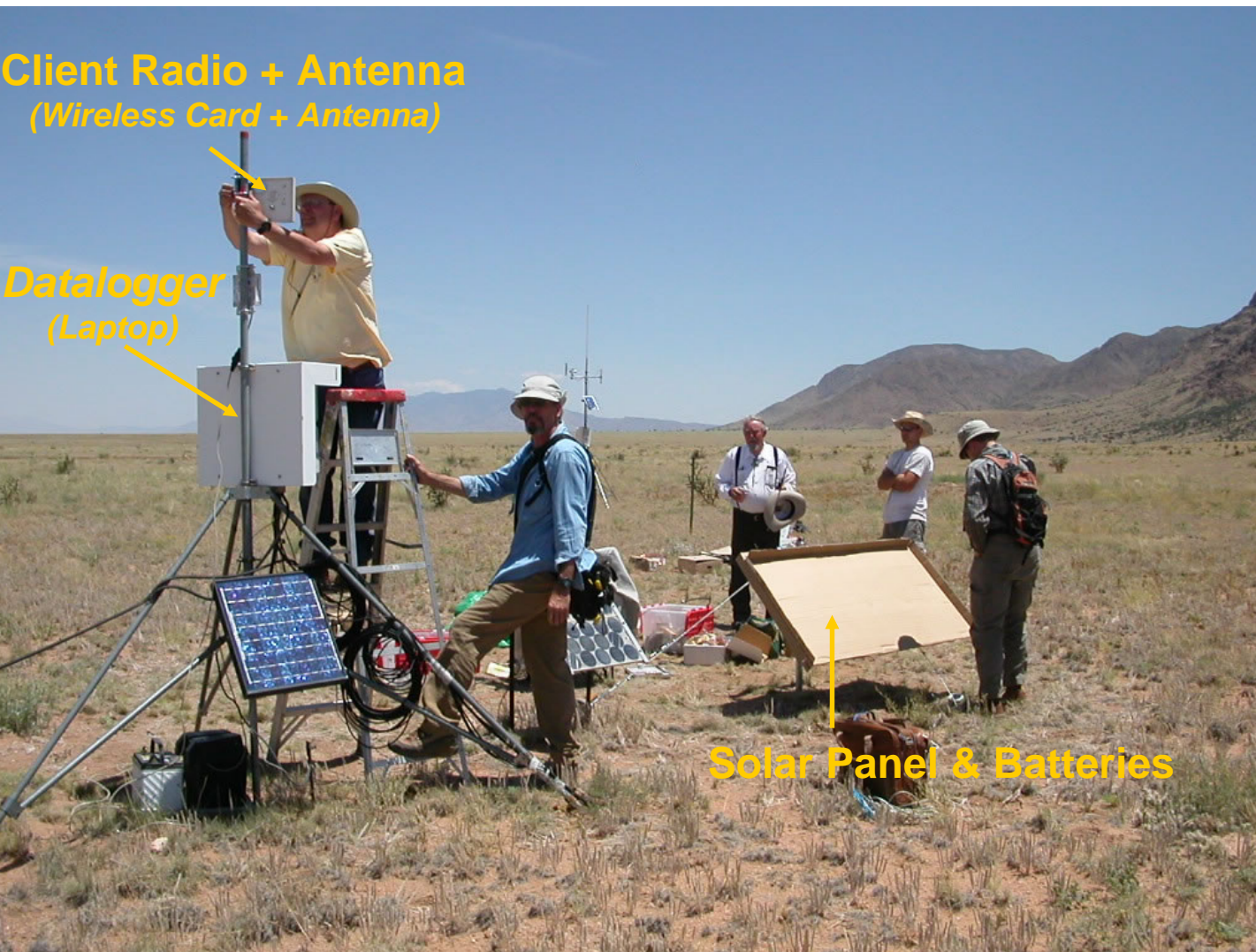


Sevilleta Wireless Network





Typical Field Client

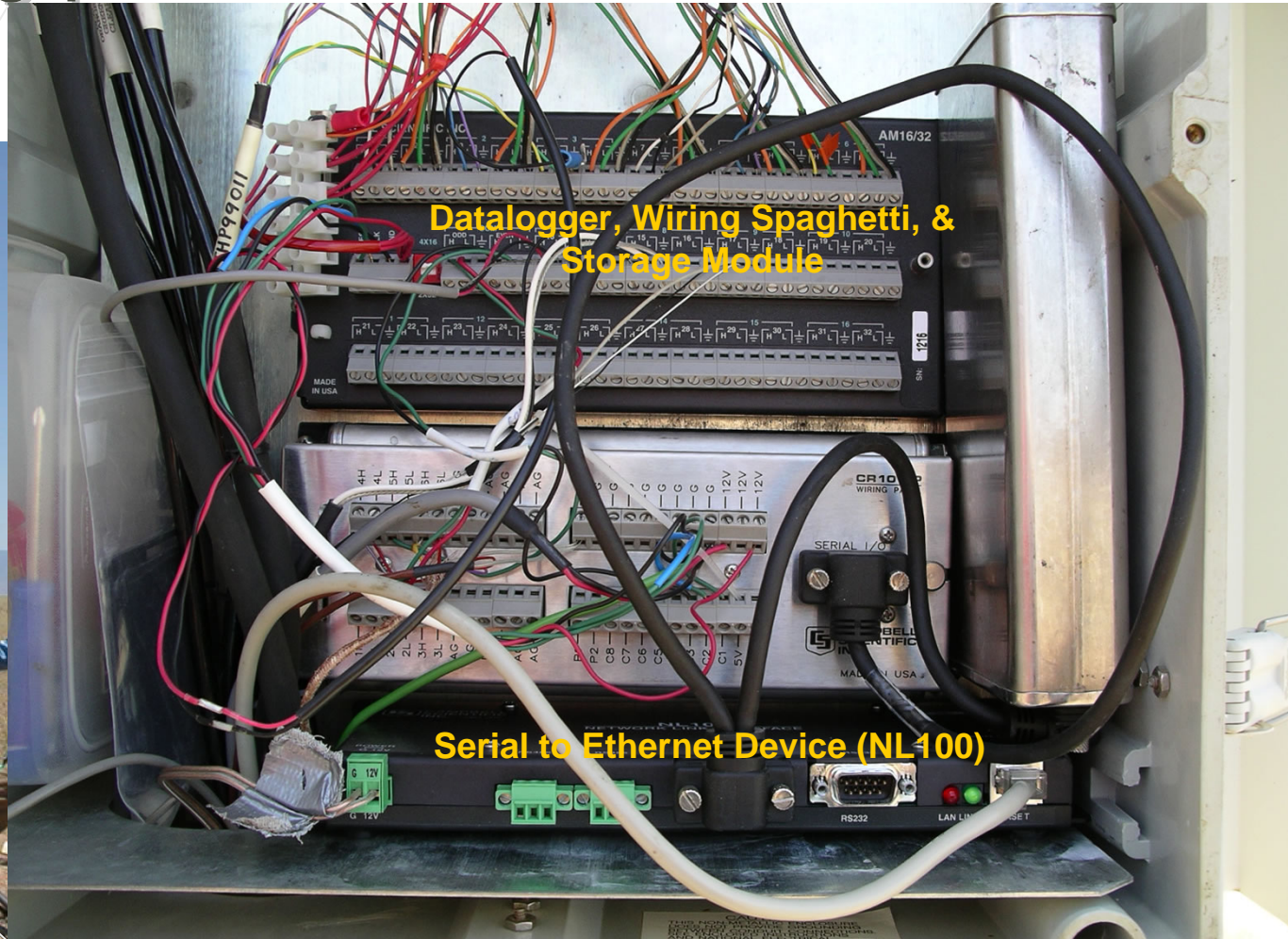
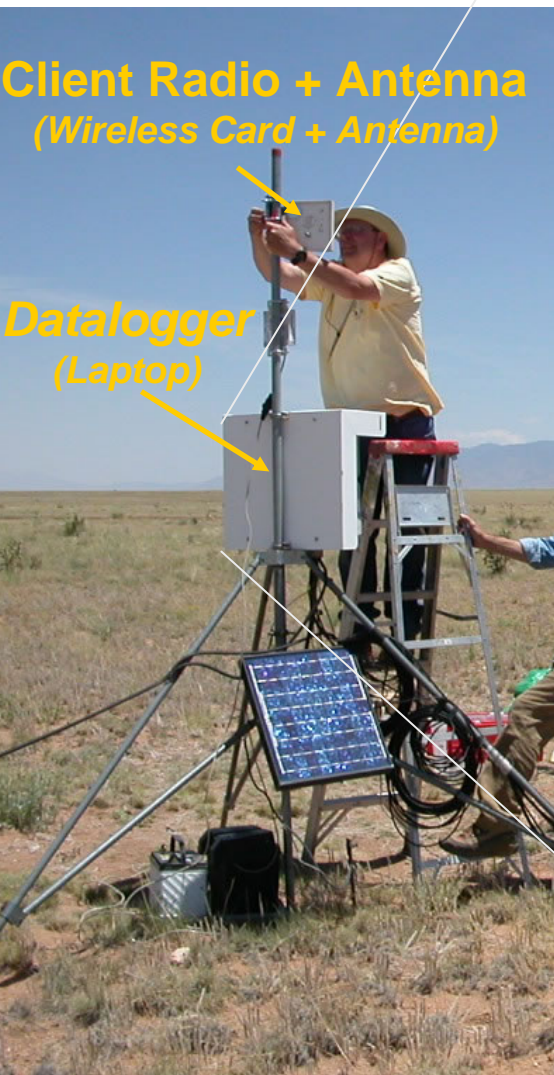




Typical Field Client

Client Radio + Antenna
(Wireless Card + Antenna)

Datalogger
(Laptop)



**Datalogger, Wiring Spaghetti, &
Storage Module**

Serial to Ethernet Device (NL100)

Solar Panel & Batteries





SEEK Sensor Networks

- Same basic network principle, using sensor “nodes” instead of computers or dataloggers.
- Often use different communication protocols to transmit/receive data.
- Sensor devices typically consist of a microcontroller, radio transceiver, energy source, and sensors.
- Requires a server machine to store and process data, connected to a primary sensor node or “base station”.





Embedded Sensor Networks

- “Embedded” inside the measured environment.
- Most embedded sensor networks today are wireless to utilize aforementioned advantages of wireless technology.
- Can integrate embedded sensor networks into larger scale wired or wireless networks--useful for real-time monitoring and data processing.





Ecological Research Benefits

- While specific benefits and challenges depend on the technologies used, sensor devices are generally *low cost*, *low power consumers*, *don't require extensive cabling*, and *are small in size*.
- Therefore..
 - Leads to easier, cheaper, & larger deployments.
 - Previously challenging projects can now be monitored effectively.





Ecology Applications

- Ecology specific environmental monitoring and wildlife tracking and monitoring.
- Can be utilized in innovative ways, providing new research opportunities in ecology.
- These include:
 - *Sampling over large spatial scales,*
 - *High-frequency sampling rates,*
 - *Observation of phenomena unobtrusively or under extreme conditions, and*
 - *Event-driven reactions.*





Sample SensorNet Application: Sap Flow Monitoring

- Want to be able to measure water use by many trees continuously.
- Sensor probes are inserted in many trees and connected by long cables to a single datalogger.
- It is often ideal to make these measurements over a large area to represent the variation over a landscape.





NASA/JPL Sensor Webs

[*http://sensorwebs.jpl.nasa.gov/*](http://sensorwebs.jpl.nasa.gov/)

- The Sensor Web is a spatially distributed, synchronous instrument that can react and adapt to changing environmental conditions.
- A *pod* is a sensor node in the Sensor Web.
- Each pod sends out collected data to every other pod in the network, via non-routable protocols (i.e., does not use TCP/IP).
- Customized sensor configuration per application.





SEEK JPL Sensor Pod

Sensor Pod 3.2 @ Sevilleta



Sensor Pod 5.0 @ Huntington

solar panel

internal battery

antenna/s

data/ext. sensor ports

air temperature/humidity

soil temperature

soil moisture

power “switch”





Sevilleta Sensor Web 3.2

<http://sev.lternet.edu/research/SWEETS/index.html>

- Investigation of the microclimate canopy effects of three desert shrub species (Juniper, Creosote, & Mesquite) and how these effects affect composition variation in plant communities.

- Real-time data:

<http://datura.unm.edu/>





Huntington Botanical Gardens Sensor Web 5.0

http://sensorwebs.jpl.nasa.gov/resources/huntington_sw5.shtml

- Investigating botanical conditions in an urban environment with strategic positioning of pods along building faces, hedges, and within dense flora will help illuminate the microclimate conditions seen by the plants.



- Real-time data:

<http://caupanga.huntington.org/webgui/>





Los Alamos National Laboratory

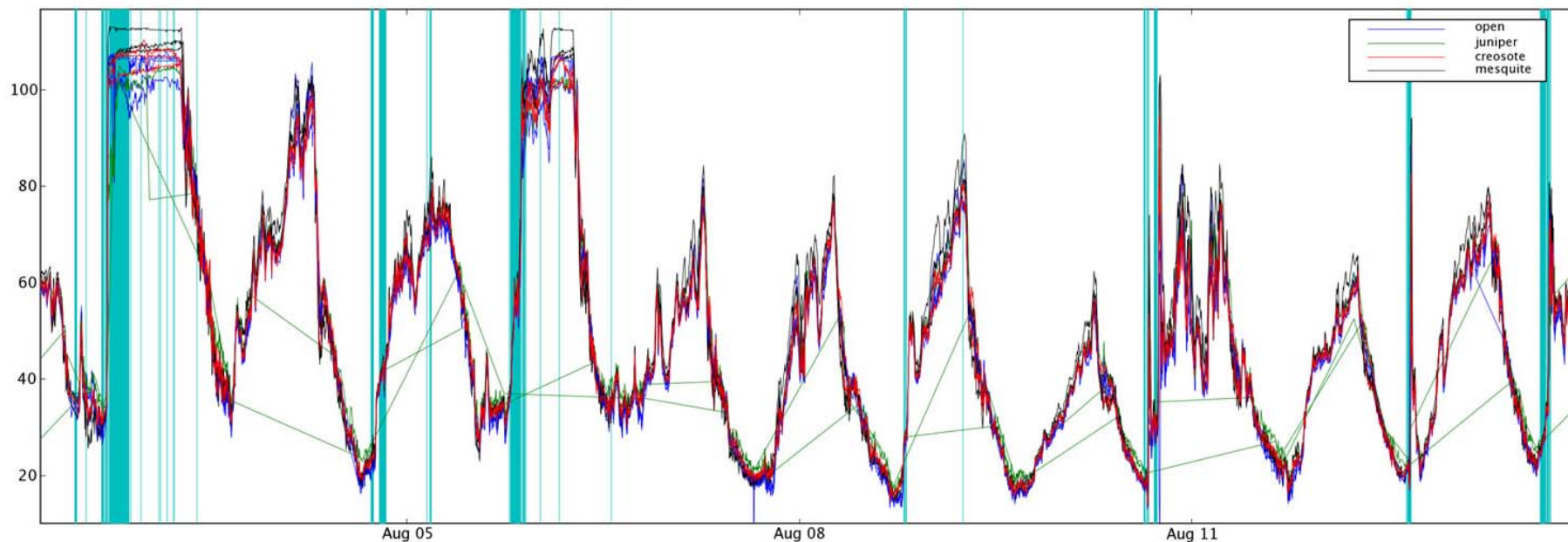
- Collaboration with the JPL Sensor Web Project and Sevilleta LTER Program.
- Sensor networks involve three areas: sensing, communications, and *computation--i.e., hardware, software, and algorithms*.
- Specifically interested in developing event-driven based algorithms, including prediction techniques.
- Also interested in development of on-the-fly QA/QC algorithms within sensor networks such as the Sensor Web.





Rain Events & Relative Humidity

Event-Driven Prediction & Response



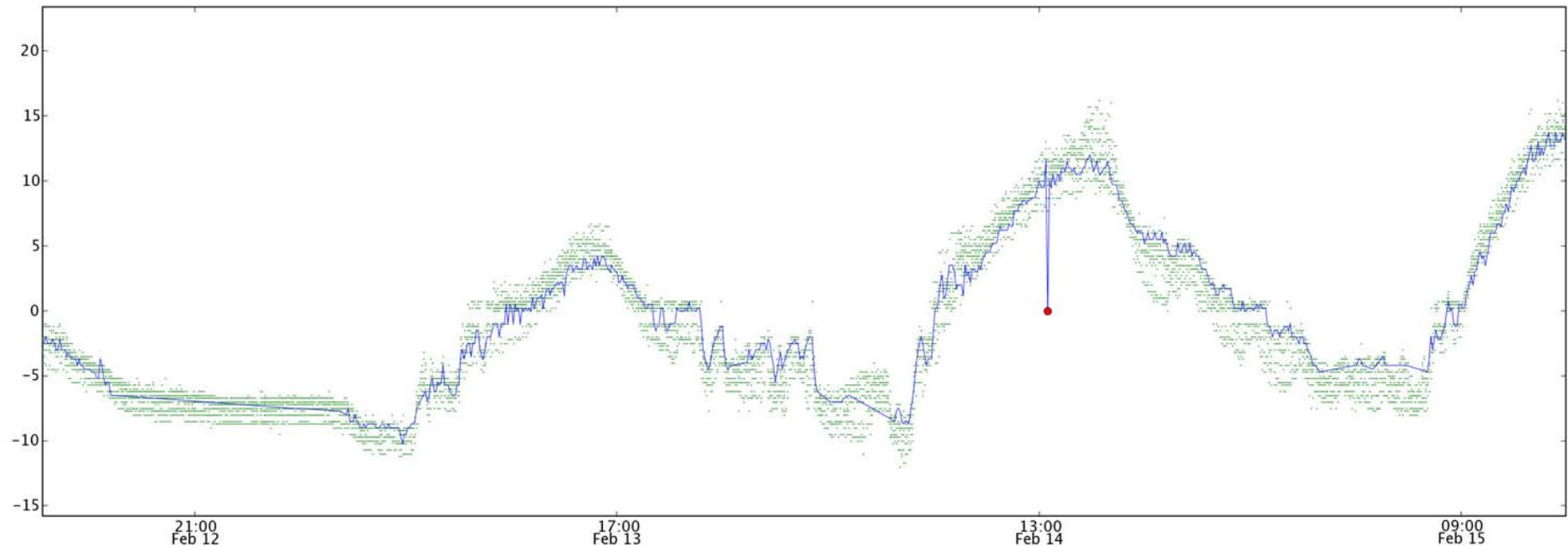
- Teal lines indicate rain events as given by Sevilleta tipping bucket data.
- Observe increase in humidity after it rains.
- Techniques employed are useful in sensor network prediction algorithms.





Finding Anomalies

QA/QC Algorithm Development



- The blue line is pod air temperature, the green dots are other pods' air temperatures, & the red dot is an anomalous measurement.
- Without the context of other pods, the measurement is perfectly reasonable (somewhere near the mean).
- Sensor Webs allow LANL to address issues of data quality in that isolated sensors don't support.





Crossbow Technology

<http://www.xbow.com/>

- A *mote* is a sensor node in crossbow sensor networks.
- Motes range in size and capability.
- Sensor options include: Light, Humidity, Temperature, Acceleration, Magnetic, Acoustic, GPS, & more..
- Motes run TinyOS operating system, which is open-source.
- Can reprogram motes in NesC, based on the C programming language.





Some Crossbow Products



MICA2 Series & Sensor Board

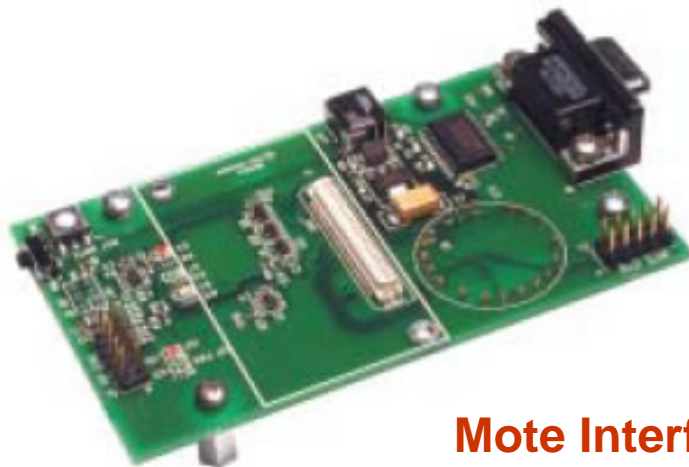


**MICA2Dot
Series**

&



Sensor Board



Mote Interface Board





Crossbow Promotional Video

Available from: <http://www.xbow.com/>





Center for Embedded Network Sensing (CENS)

<http://research.cens.ucla.edu/>

- CENS researchers investigating fundamental properties of Embedded Networked Systems, developing new enabling technologies, & exploring novel scientific and educational applications.
- CENS is one of six NSF Science & Technology Centers established in 2002, & projected to receive \$40 million in core funding from NSF over 10 years.
- Significant interdisciplinary collaboration among several California institutions including UCLA, USC, UCR, Caltech, UCM, & CSULA.
- Deborah Estrin is the Center director.

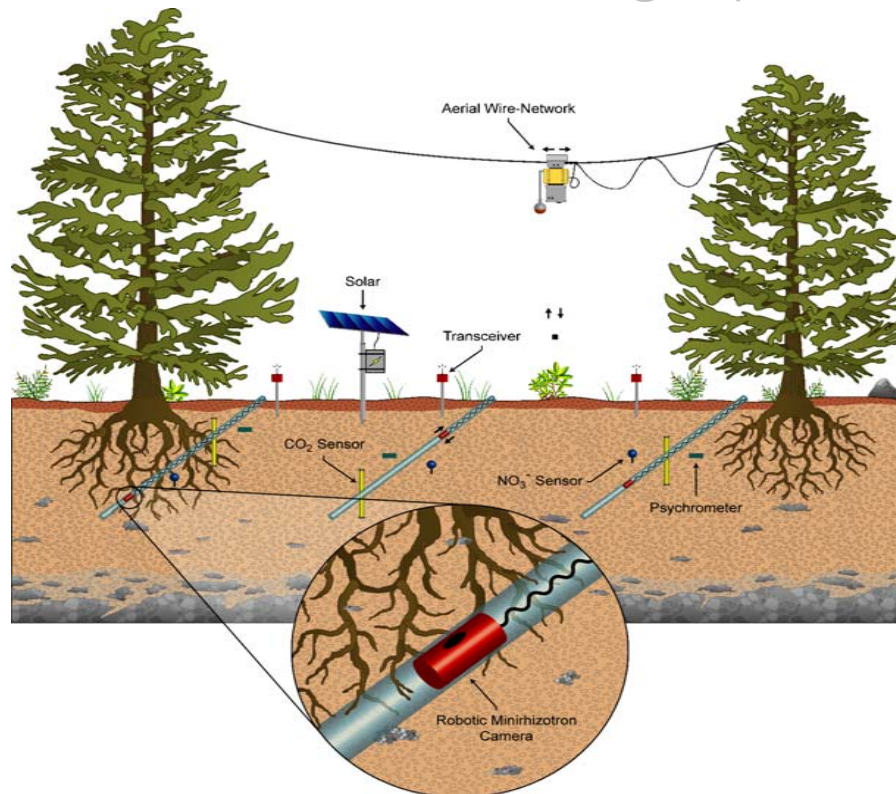
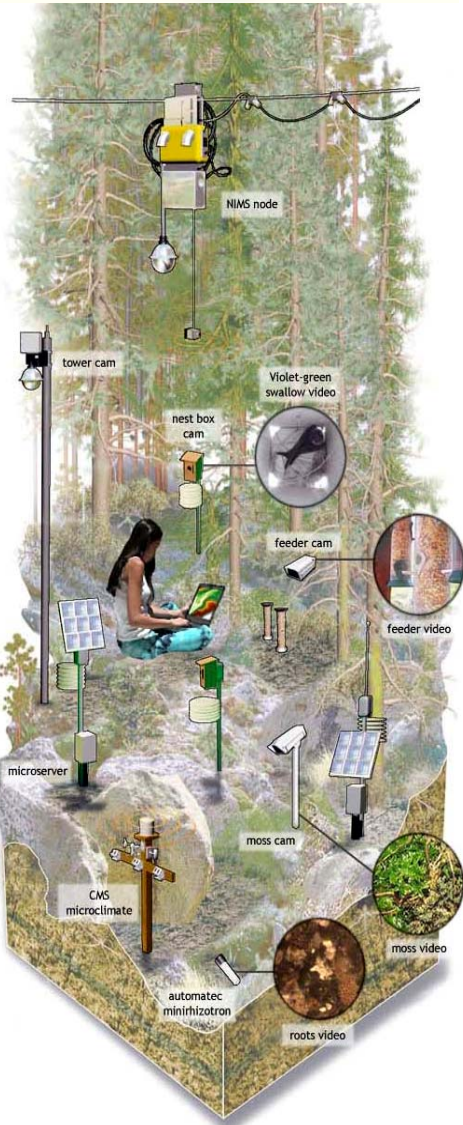




James Reserve

<http://www.jamesreserve.edu/>

- Affiliated with and test bed for CENS.
- Using crossbow mote technology.
- News story available at:
<http://californiaconnected.org/wp/archives/284>





BosqueNet

- Collaboration between University of New Mexico Computer Science & Biology Departments and Bosque School.
- Monitoring of porcupines living in bosque (riparian forest) of Rio Grande to determine previously unknown nocturnal behavior and dwelling locations.
- Using crossbow technology to implement and examine a real-world ecological application of sensor networks.





Other Ecology Sensor Net Experiments

- **Great Duck Island** – Measuring microclimates at nesting sites via sensors, allowing for non-intrusive monitoring of sensitive wildlife habitats.
- **ZebraNet** – Pose & answer long-standing questions regarding long-range migration, inter-species interactions, and nocturnal behavior by placing sensors on zebras.
- **Cane-toad Monitoring** – Uses acoustic sensors to monitor amphibian populations, specifically native frogs and the invasive Cane Toad.





Future of Sensor Nets in Ecology

- Innovative experiment designs.
- Event driven “smart” applications.
- Merging of ecology and technology – trend towards more collaborations among ecologists and “techies”.
- Stronger emphasis on development of sensors needed for ecology research.
- Improved data management algorithms.
- Improved power management.





Acknowledgements

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