UT-BATTELLE

Oak Ridge National Laboratory

"Technologies to Help Wage the Long War"

Presented to the
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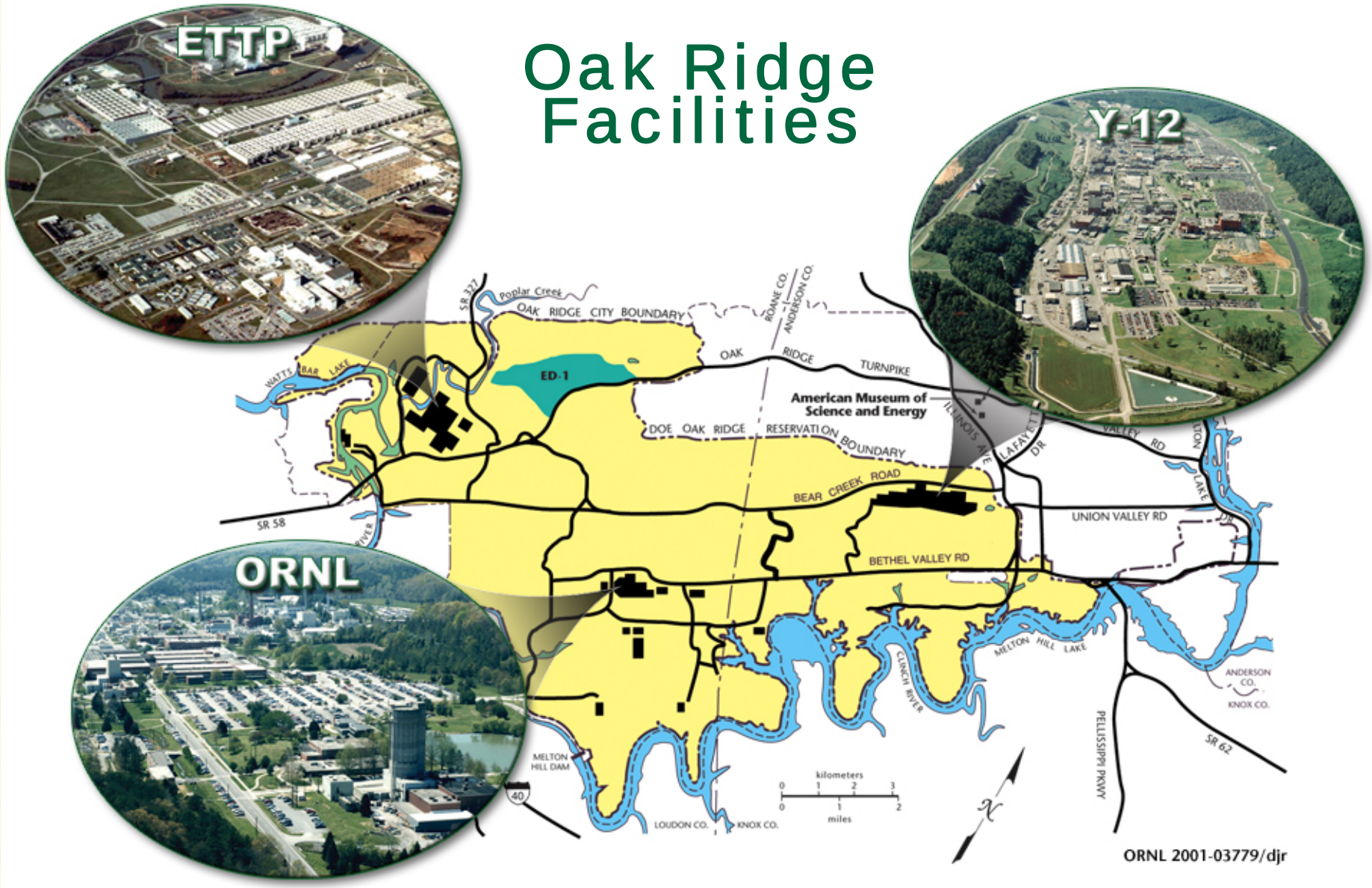
ORNL Cognitive Radio Program Mission:
"to integrate software radio, sensors and computational intelligence capabilities to realize the art-of-the-possible in cognitive computing and communications to address both government and commercial problems, in a manner that enhances US National Security."

Chameleon
...the power of change...

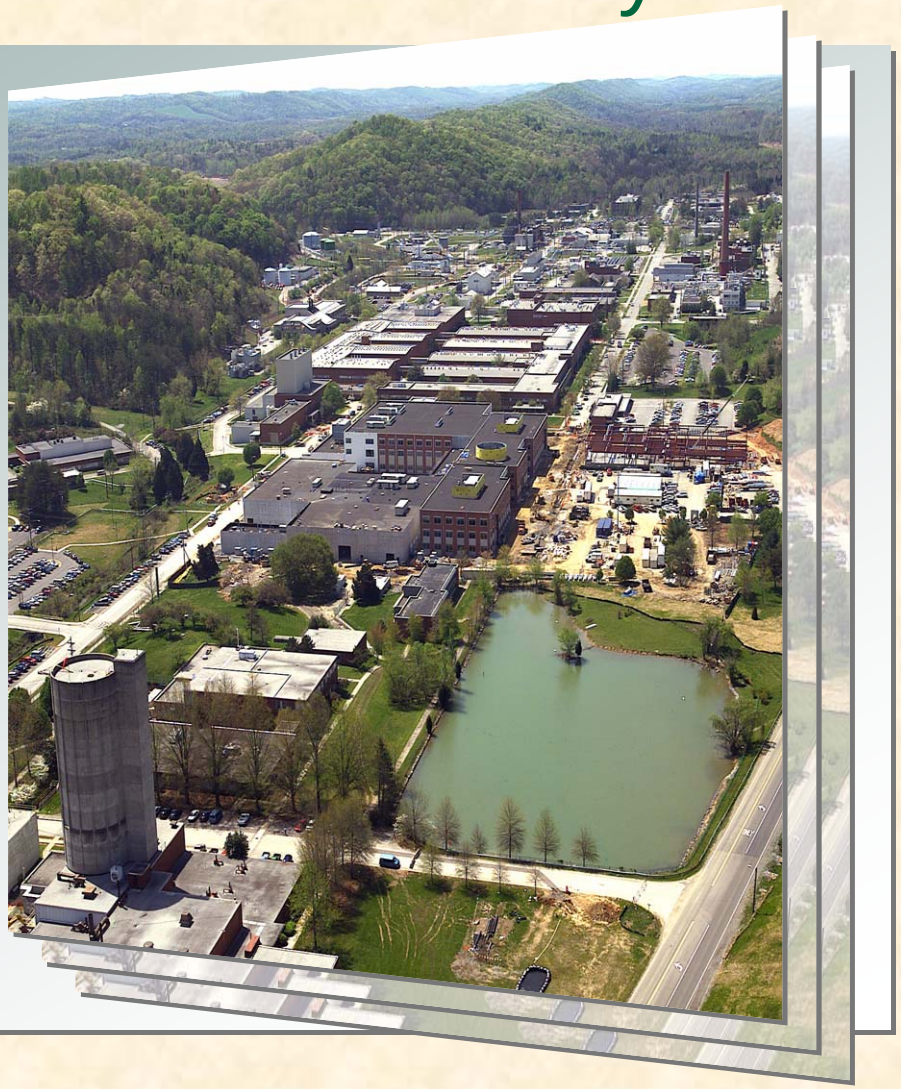
OAK RIDGE NATIONAL LABORATORY
U. S. DEPARTMENT OF ENERGY

Oak Ridge Facilities

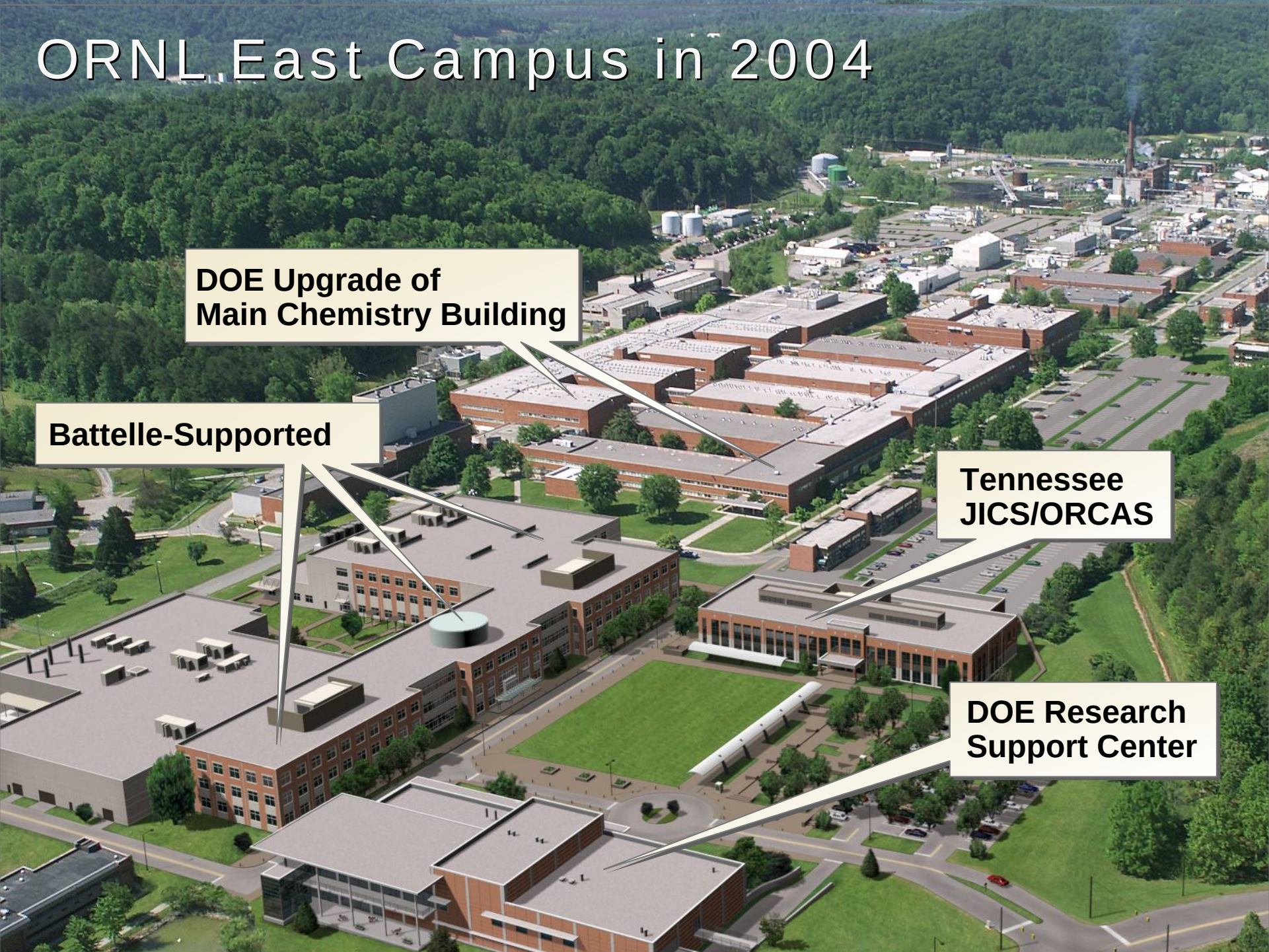


ORNL is DOE's Largest Multi-Purpose Science Laboratory

- **$1 billion budget**
- **3800 employees**
- **3000 research guests annually**
- **Nation's largest energy R&D laboratory**
- **World class computing facilities**
- **Nation's largest concentration of unclassified materials research**
- **$1.4 billion Spallation Neutron Source under construction**
- **$300 million modernization program in progress**



ORNL East Campus in 2004



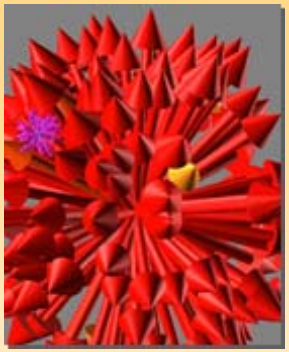
Multiprogram Research Facility

Capable of handling the full range of national and homeland security work

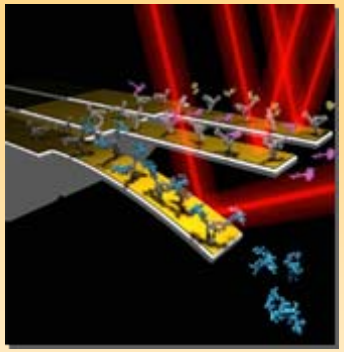
ORNL Science and Technology Agenda Has Six Priorities

Energy

Homeland/ National Security



Neutron Science



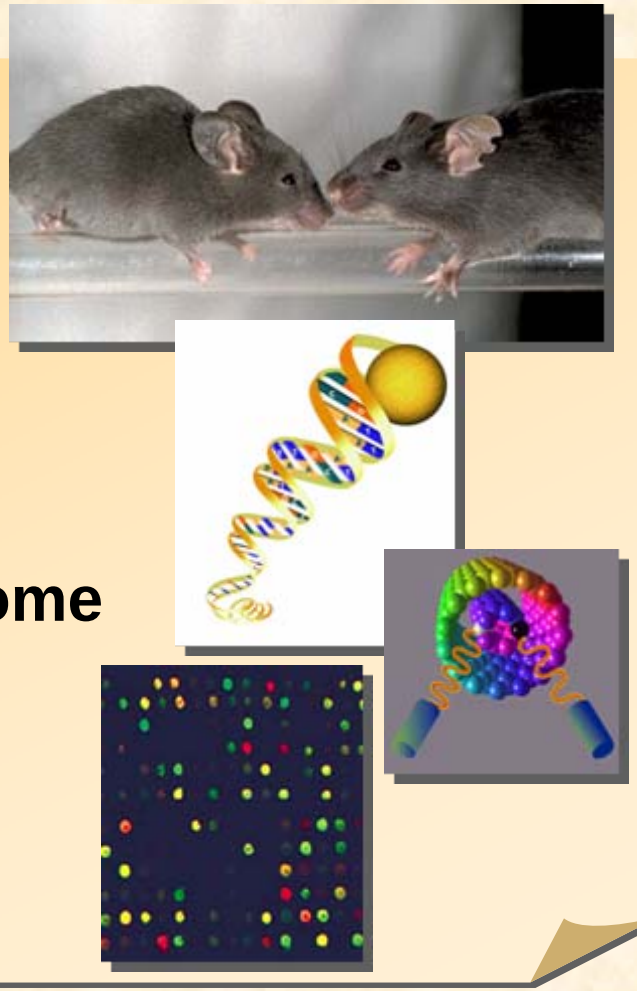
Materials

Biology

Computing

A Center Of Excellence For Understanding Complex Biological Systems

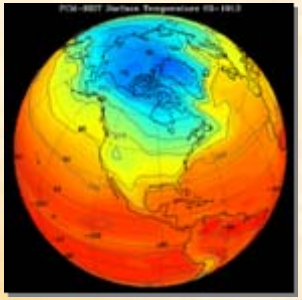
- **Moving into a new Laboratory for Comparative and Functional Genomics**
- **Designing a state-funded facility for the Joint Institute for Biological Sciences**
- **Sequencing the hybrid poplar genome**
- **Exploring microbial genomes for bioremediation**
- **Applying life sciences capabilities to needs in homeland security**

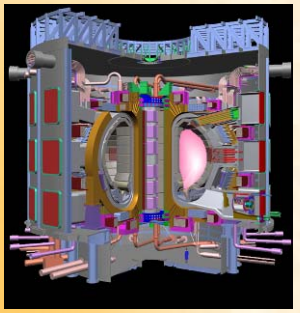


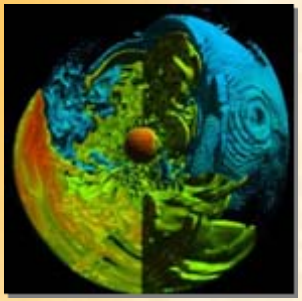
We are at the forefront in computing and simulation

- **Leading the partnership to develop the National Leadership Computing Facility**
  - **World's best scientific computing capability**
  - **100 teraflops in 2006; 250 teraflops by 2007**
- **Attacking key computational challenges**
  - **Climate change**
  - **Fusion**
  - **Nuclear astrophysics**
  - **Materials sciences**
  - **Biology**

- **Providing access to our computational resources through high-speed networking**







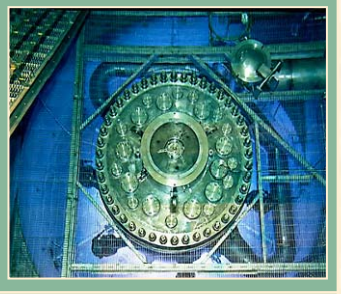
We are developing and deploying world-class tools for nanoscale R&D

Spallation Neutron Source

- High-intensity neutrons for materials research at the nanoscale
- 1.4 MW of beam power on target
- 16 instruments

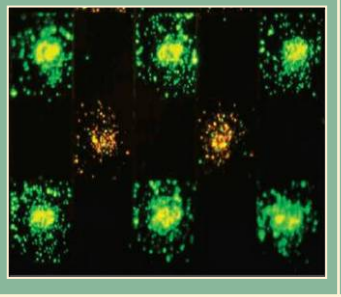
High Flux Isotope Reactor

- The nation's leading research reactor
- World-class for neutron scattering



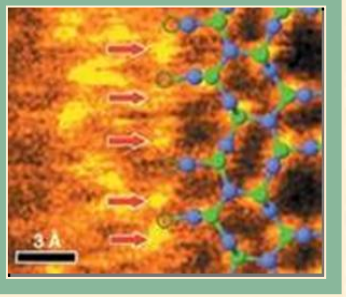
Center for Nanophase Materials Sciences

- $65M facility now in operation
- 75 user projects already under way
- DOE's first nanoscience research center



Ultrahigh-resolution microscopy

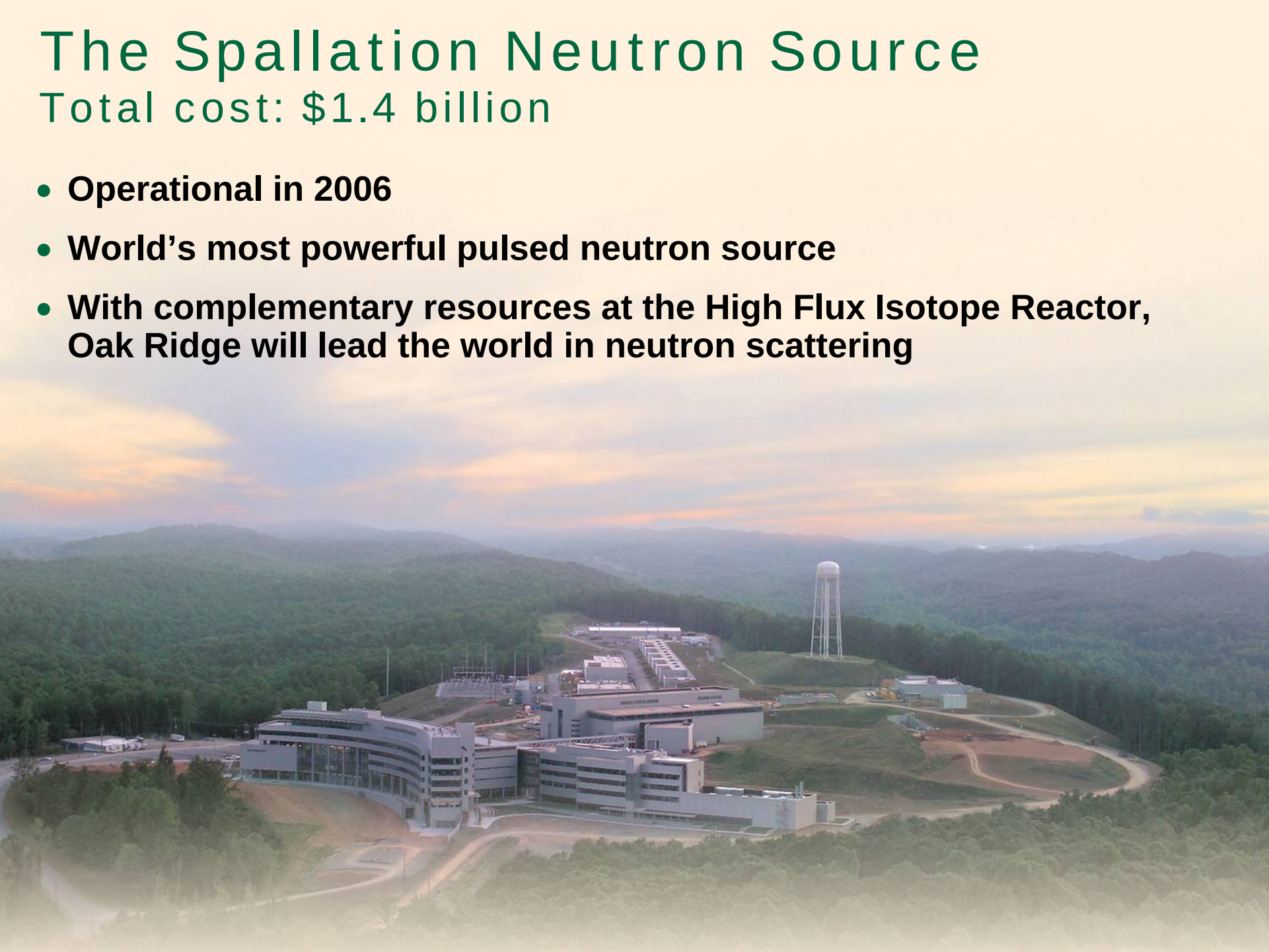
- Advanced Microscopy Laboratory
- Aberration-corrected electron microscope
- World-record resolution: 0.6 Å



The Spallation Neutron Source

Total cost: $1.4 billion

- **Operational in 2006**
- **World's most powerful pulsed neutron source**
- **With complementary resources at the High Flux Isotope Reactor, Oak Ridge will lead the world in neutron scattering**



We have significant strengths in key areas

Radiological and nuclear weapons countermeasures

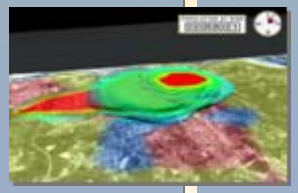
- **RDD attribution studies, forensics program development, and decontamination of the aftermath**
- **Active interrogation technologies**
- **Radiation detection technologies and new materials**

Chemical and biological

- **Mass spectrometry**
- **Bioinformatics**
- **Host-pathogen interactions**

Threat vulnerability testing and assessment

- **Geospatial science**
- **Plume/effect modeling**
- **Cybersecurity technology**



Infrastructure protection

- **Vulnerability assessment and mitigation**

Crosscutting

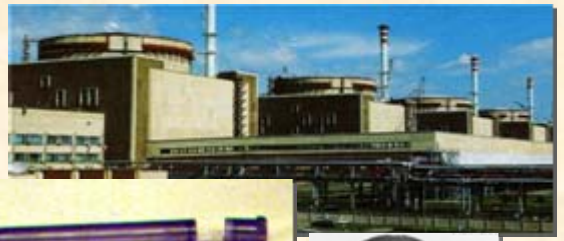
- **Sensor technologies**
- **Knowledge discovery**

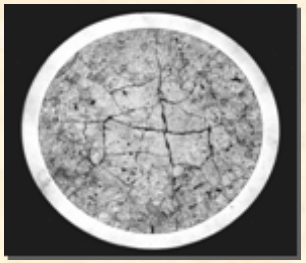
Program areas

- **Defense Nuclear Nonproliferation**
- **Homeland Security**
- **Department of Defense**
- **Other Government Agencies**

Nuclear Nonproliferation Programs

- **Material Protection Control and Accounting**
- **Fissile Materials Disposition**
- **International Safeguards**
- **HEU Transparency**
- **Export Controls**
- **Radiological Dispersal Devices**
- **Nuclear Material Detection & Identification**



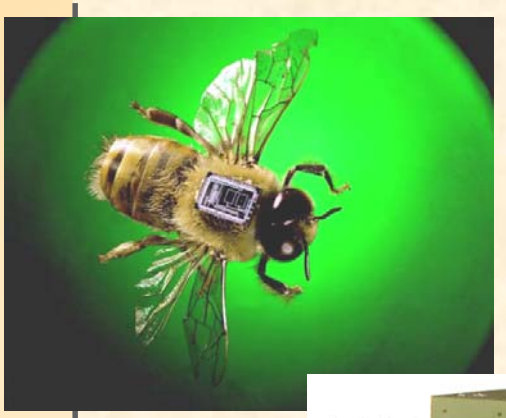


Homeland Security Programs

- **Radiological/nuclear countermeasures**
- **Threat and vulnerability testing and assessment**
- **Biological and chemical countermeasures**
- **Standards development**
- **Countermeasures Testbed**
- **Regional Technology Integration**
- **Protective Security Analysis Center**
- **Transportation analysis**
- **Highway weigh station radiation portal monitors**
- **FEMA support activities**

Department of Defense

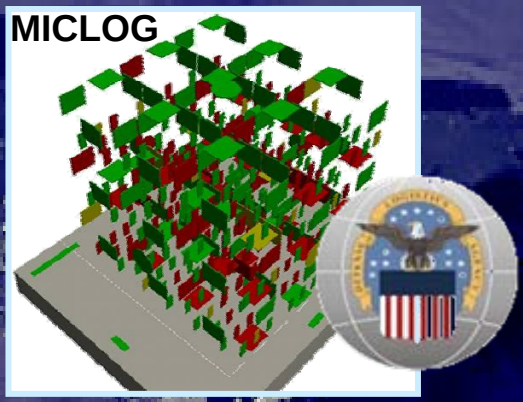
- **Military transformation**
- **Chem/Bio defense and early warning**
- **Logistics and transportation management**
- **Defense materials**
- **Sensor miniaturization and communication**
- **Information management, synthesis and analysis**



SensorNet

Marine Asset Security & Tracking System (MAST)

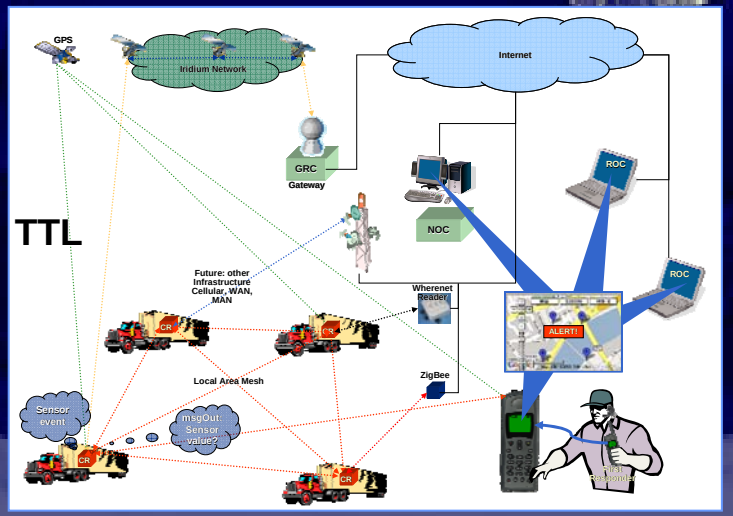
MICLOG



Small Contingency Theater Positioning System (SCTPS)

IC

TTL



NGA Evacuation Management & Accountability System (NEMAS)

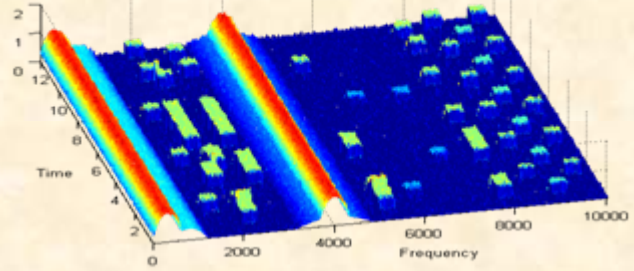
ORNL Tracking System

Cognitive Radio: What is it?

"a disruptive, but unobtrusive technology" [Haykin05]

Cognition/Intelligence?

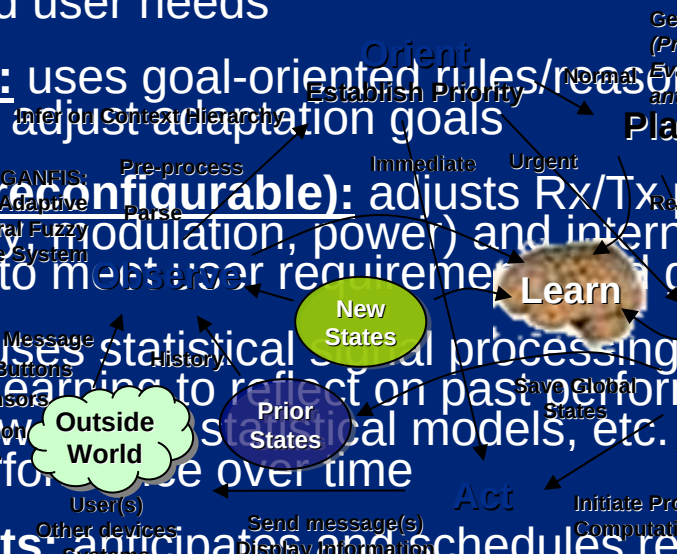
- "**knowing**, **perceiving**, or **conceiving** as an act…" [Oxford English Dictionary]
- "**interdisciplinary study** … concerned with exploring general principles of intelligence through a synthetic methodology termed learning by understanding." [Pfeifer & Scheier99]
- Intelligence: "The capacity to **acquire** and **apply** knowledge, especially toward a purposeful **goal**." [American Heritage_00]



Future Cognitive Systems:
"will converse with the user, anticipate their needs and adapt to meet them … "

Cognitive Radio is an intelligent wireless communication systems that:

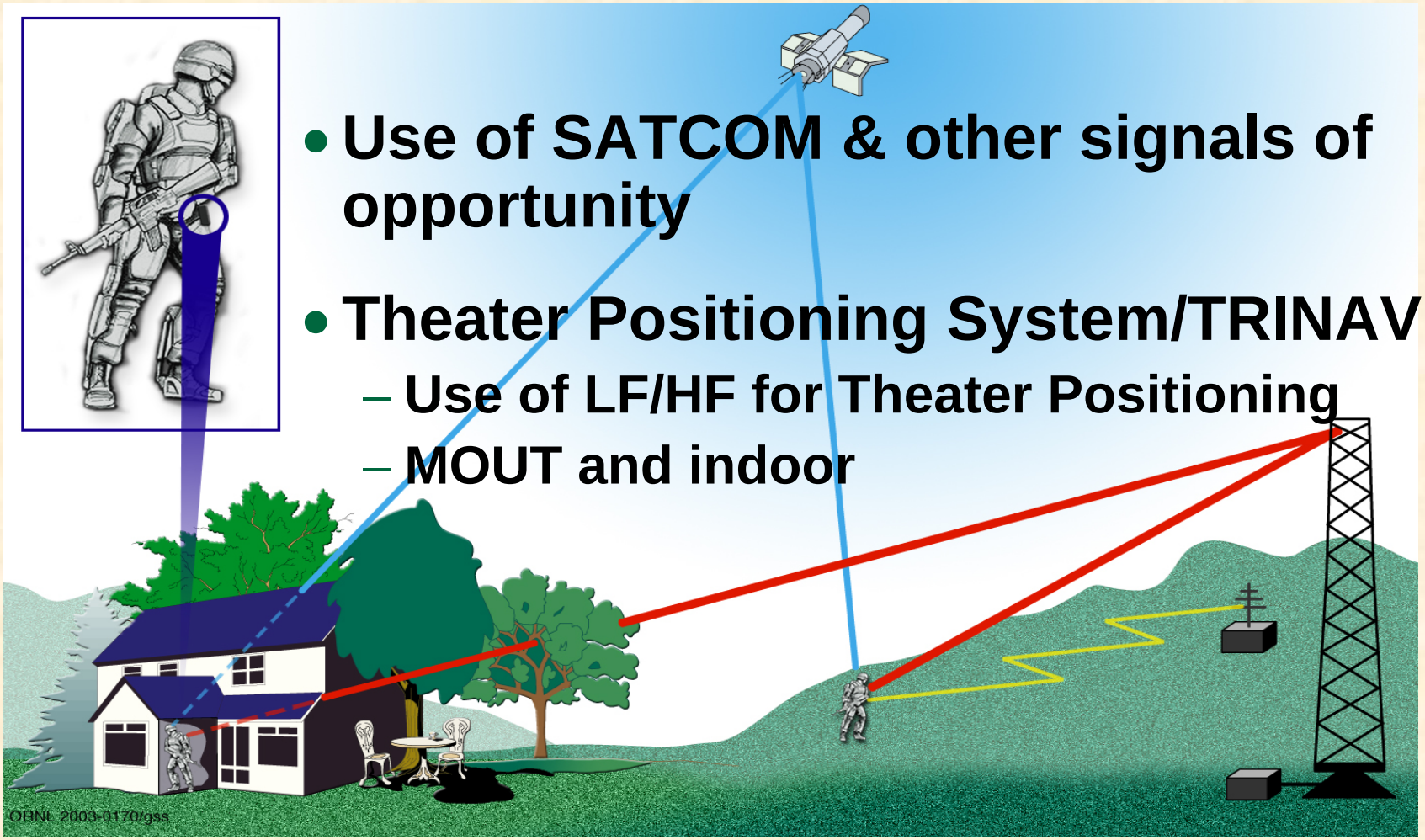
- **Senses (Awareness):** acquires and maintains knowledge of its environment, internal capabilities/ states and user needs
- **Reasons:** uses goal-oriented rules/reasoning (model-based) to adjust adaptation goals
- **Adapts (reconfigurable):** adjusts Rx/Tx parameters (frequency, modulation, power) and internal states in real-time to meet user requirements/goals
- **Learns:** uses statistical signal processing and machine learning to reflect on past performance and create new statistical models, etc. to achieve better performance over time
- **Plans/Acts:** anticipates and schedules required future actions based on current and past conditions
- **Collaborates:** leverage experience/capabilities of other CRs to attain goals
- **For the primary purpose of providing:**
  - Highly reliable communications w/ assured QoS
  - Robust performance
  - Efficient spectrum utilization



Overview of SD/CR-related Capabilities

- **Multi-Waveform Prototypes**
  - One effort combined wideband RFID waveform (30 Mcps DSSS) with narrow band RFID and Satcom.
  - Another effort combined Satcom waveform with sensor signal processing.
  - Started an effort to combine Satcom, specialized comms, conventional terrestrial communications, sensor signal processing and cognitive control engine into a single prototype by end of FY08.
- **Rapid Prototyping**
  - Use of MATLAB/Simulink/Sys Gen Model-Based Design Approach.
  - Prototype SDR system was tested OCONUS within 60 days of receipt of funds.
- **Reduced SWAP**
  - Working on rapid method to port SDR designs to ASIC
  - Working with DOD to develop improved power source

Geolocation Gap-Fillers



Waveform Development Progress

- Zigbee
- IEEE 802.11b
- Bluetooth
- Wi-Max
- UWB
- SATCOM
- FastHSS
- LPI/LPD Waveforms
- LF Navigation (TPS)
- Legacy Sensor

RFID/Tagging Waveforms
- WhereNet
- SAVI

- Channel Sounder Waveforms

Internal R&D TTL Project FY07-08