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# **Application of Jini technology to a Swarm of Autonomous Vehicles**

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# Applied Physics Laboratory

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- **University-Based Applied Research and Development Laboratory**
- **Focus on National Security**
- **Major Effort in Space Science and Technology**
- **Partner in Johns Hopkins Commitment to Education and Medicine**
- **~3,350 Staff**
- **~\$590M Annual Revenues**

## Swarm of Heterogeneous Robots



## Autonomous Surveillance Application



- Jini Lookup-Service used to discover new platforms at run-time
- Allows for a fault-tolerant, self-healing network of sensors and robots
- Jini used for knowledge propagation between agents in swarm



# Autonomous Sensor Networks



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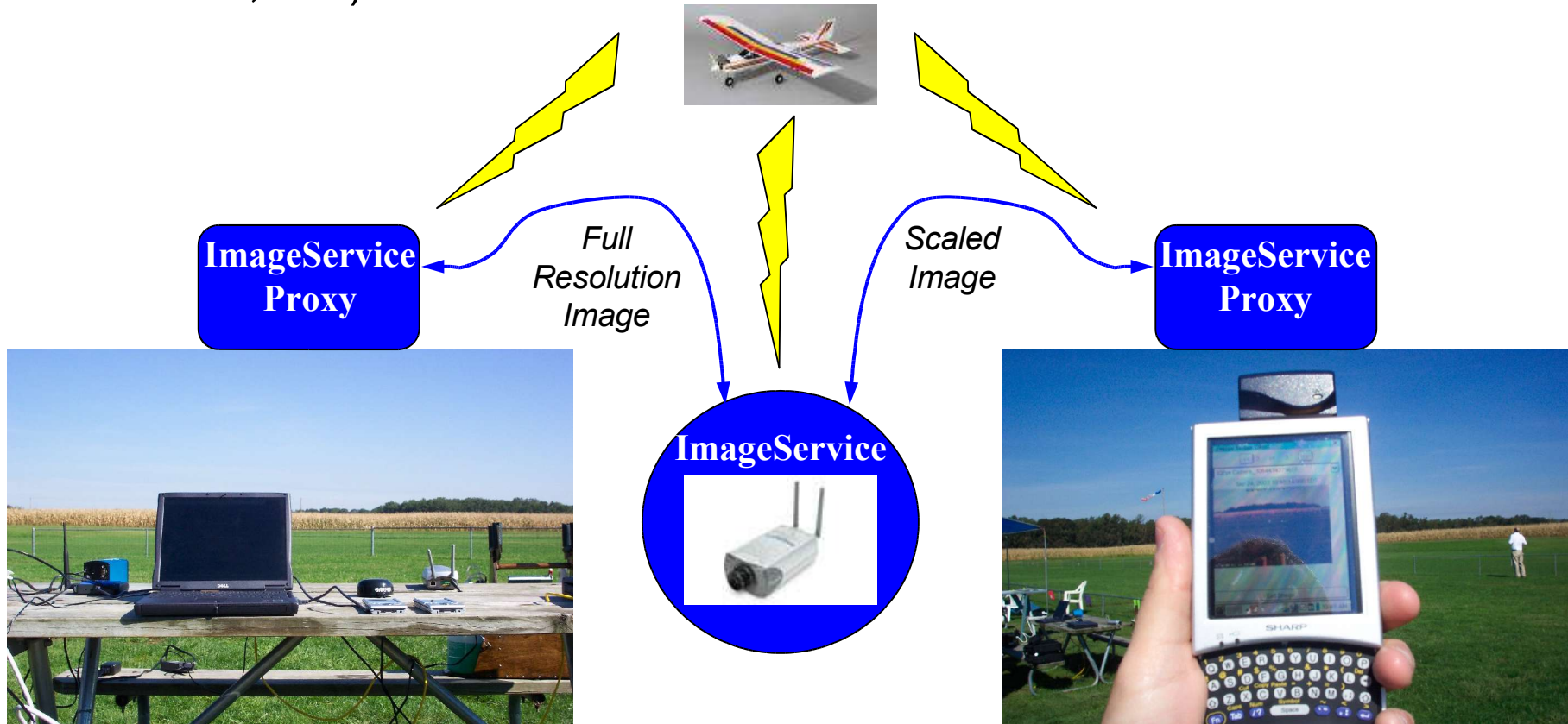
- Allow sensor networks to truly operate autonomously
  - Long-term, unmanned surveillance
- In this domain, Jini can provide:
  - Introduction of sensor upgrades and new capability to deployed systems
  - Intelligent fault-tolerance and re-distribution of resources
- Prototype Services:
  - ImageService interface
    - Provides images from camera-like devices
  - AcousticService interface
    - Provides acoustic data from microphone/geophone devices



# Sensor Network Prototype

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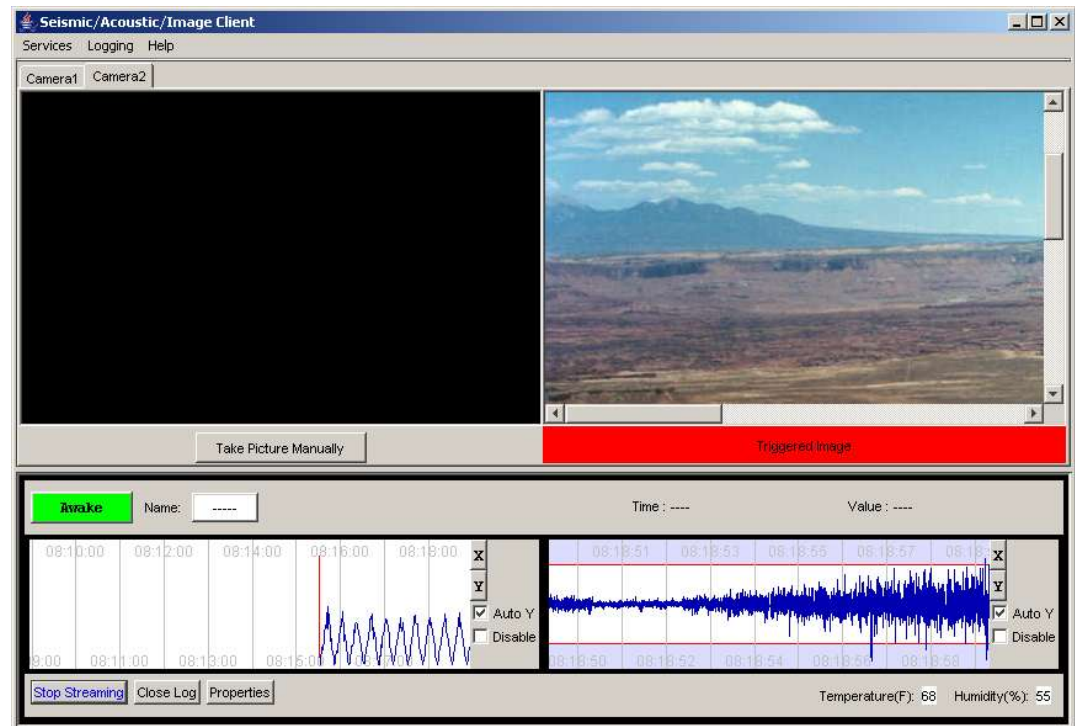
- Wireless network provided to distributed sensors via air vehicle
- ImageService proxy scales image query to conserve network bandwidth and client resources based on platform it lands within (e.g. laptop, handheld, etc.)



# Sensor Network Prototype

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- Client surveillance application reconfigures based on current services available
  - ImageServices allow for manual image retrieval
  - AcousticServices report acoustic activity
  - If both available, AcousticServices automatically trigger ImageServices when activity is detected

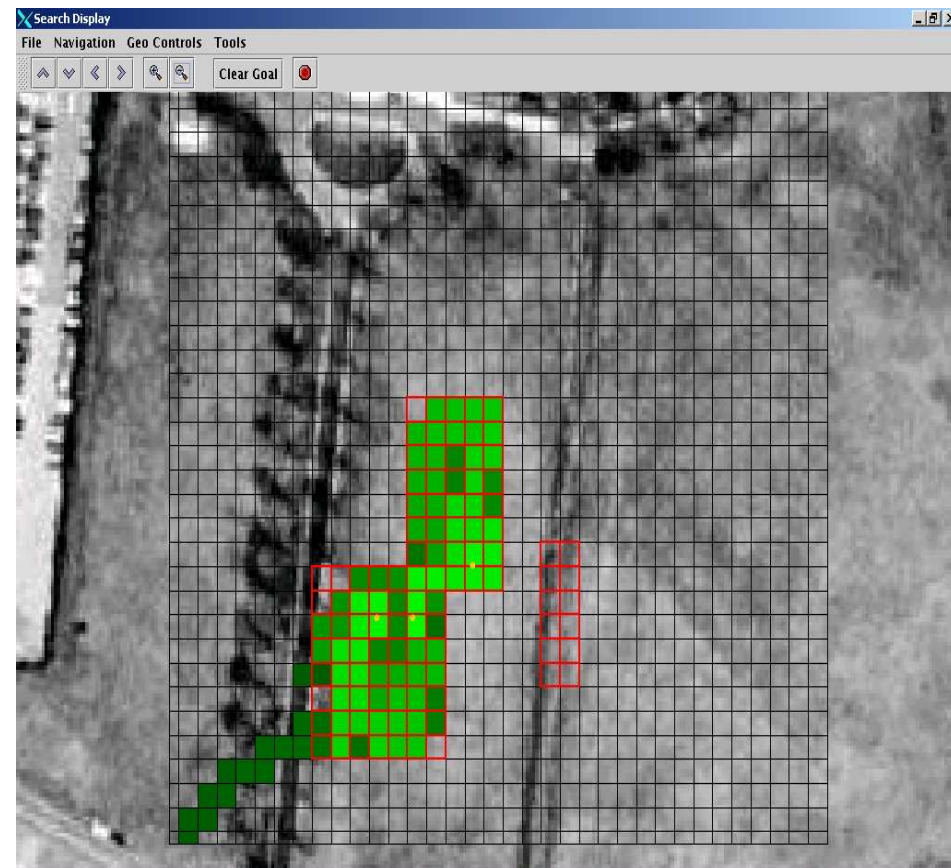


# Swarming

- Modeled after insect behavior
  - Knowledge about the world is translated into beliefs (pheromones)
  - Shared beliefs between agents dictate behavior
- Heterogeneous Swarm of Vehicles
  - Emergent behavior
  - Self-organizing, Self-regulating
- Communication is critical
  - Jini is an excellent solution for application layer communications
  - Discovery of agents at run-time
  - Propagation of new knowledge types and behavior



- Problem: Area Search
  - Robots are attracted to goal areas
    - Attracted-ness decreases as area becomes searched
  - Repelled from obstacles and each other
- Agents share and propagate beliefs (pheromones).
  - Beliefs are searchedness, search goal, robot location(s).







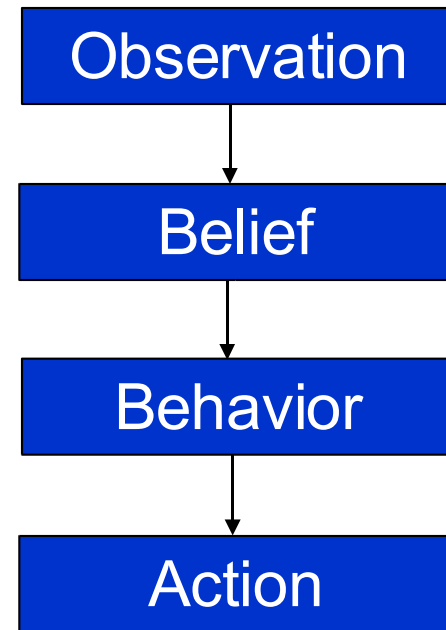
# Robot Specs



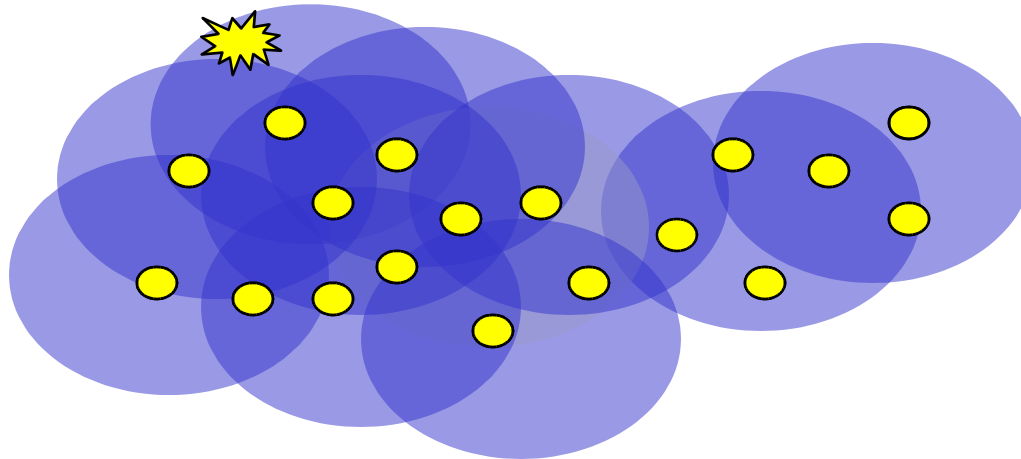
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- Robot Processor
  - Pentium II
  - 20 GB hard disk drive
  - video frame grabber
  - Serial Port board
  - iRobot Mobility software
- Sensors:
  - Multi-element Sonar array
  - V TC Camera
  - Laser Range Finder
  - GPS receiver
  - Compass / tilt module

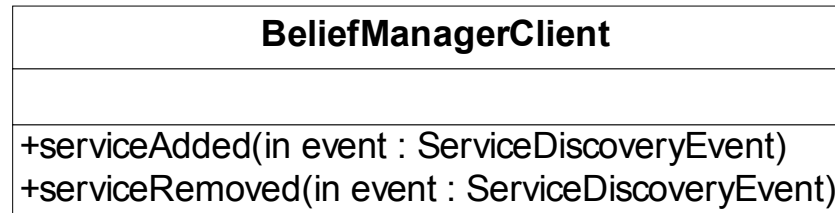
- Variation on classic AI paradigm of: Sense, Plan, Act
  - Sensor-based Observations are used to generate...
  - Belief about the current state of the world which in turn is used to devise an appropriate...
  - Behaviors to satisfy group goals and objectives. Behaviors are then used to generate...
  - Actions which translate into real world movements of the robot.
- Jini currently being used for transmission of beliefs between agents.



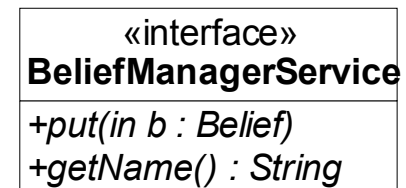
- Java ideal platform for heterogeneous swarm.
  - UGV, UAV, Windows Laptop, Handheld
  - Future embedded devices....
- Deployment
  - Run-time discovery of new platforms, beliefs, behaviors
- Robust in an unreliable network



- New beliefs (pheromones) can be discovered and propagated.
  - Robot does not need to use new belief, can merely propagate it.
- Proxy provides a simple “put” interface.
- New classes are loaded with a custom ClasspathServer
- Beliefs shared using RMI

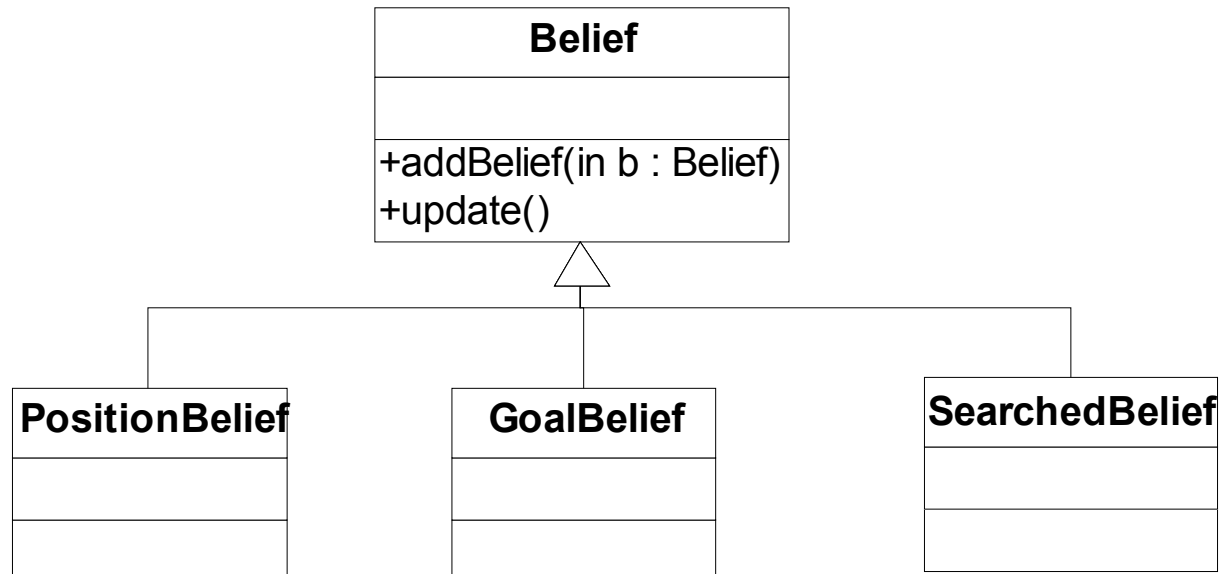


```
public void run(){
    while(proxyIterator.hasNext()){
        BeliefManagerService service =
            (BeliefManagerService)managerIterator.next();
        service.put(belief);
    }
}
```

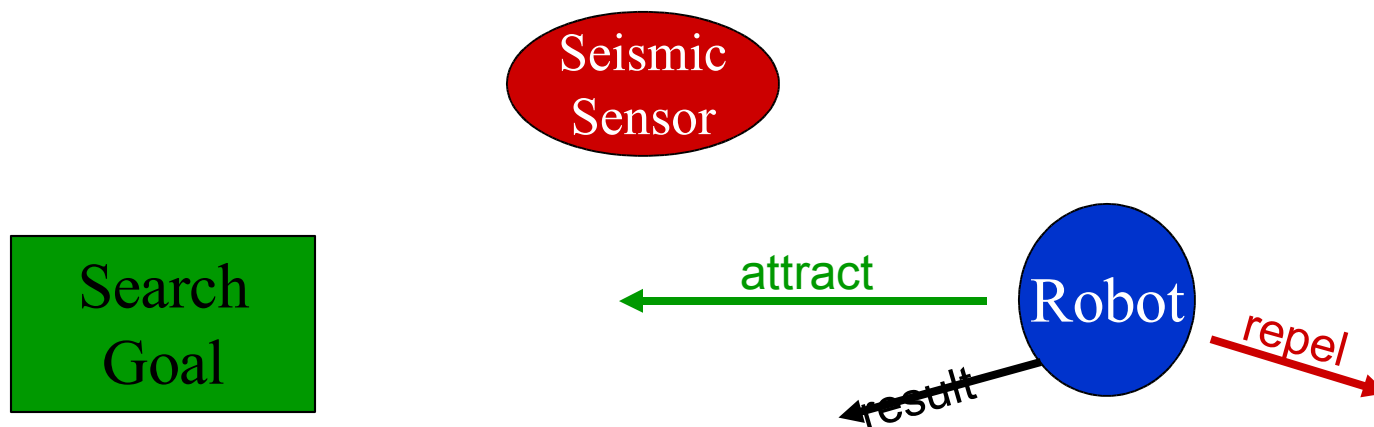




- Beliefs have behavior associated with their state
  - Know how to perform “add” operation. May differ depending on belief type.
  - Can degrade quality based on elapsed time and belief type.



- Beliefs are useless without a behavior
  - Ant pheromone for food-source useless without ability to gather food
- Each platform should have both a belief and associated behavior
  - Seismic sensor can send belief of its location
  - Behavior will keep noisy ground vehicles away





# Implementation Challenges

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- Network is unreliable
  - Can experience flood of TCP/IP rebroadcasts at edge of communication range
    - RMI communication breaks down at edge of wireless range
  - UDP multicast is more desirable for belief transmission
- Modifications required for UDP based communications
  - Implement a UDP based lookup-service
  - Implement a UDP based class-loader
  - Re-implement Proxy without RMI interface



# Future work



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- Jini-based behaviors
- Merge Jini-based sensors with robots
- Interface standardization
- Scalability
- Integrate connectionless class-loader