Self Healing (Antitank) Minefield (SHM) SAIC Team Program

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The SAIC SHM Team

Program management, system architecture, integration, command and control (CPU programming, healing algorithm, multilateration algorithm, system controller/diagnostic device, and power).

Network, communication unit core hardware, acoustic ranging subsystem.

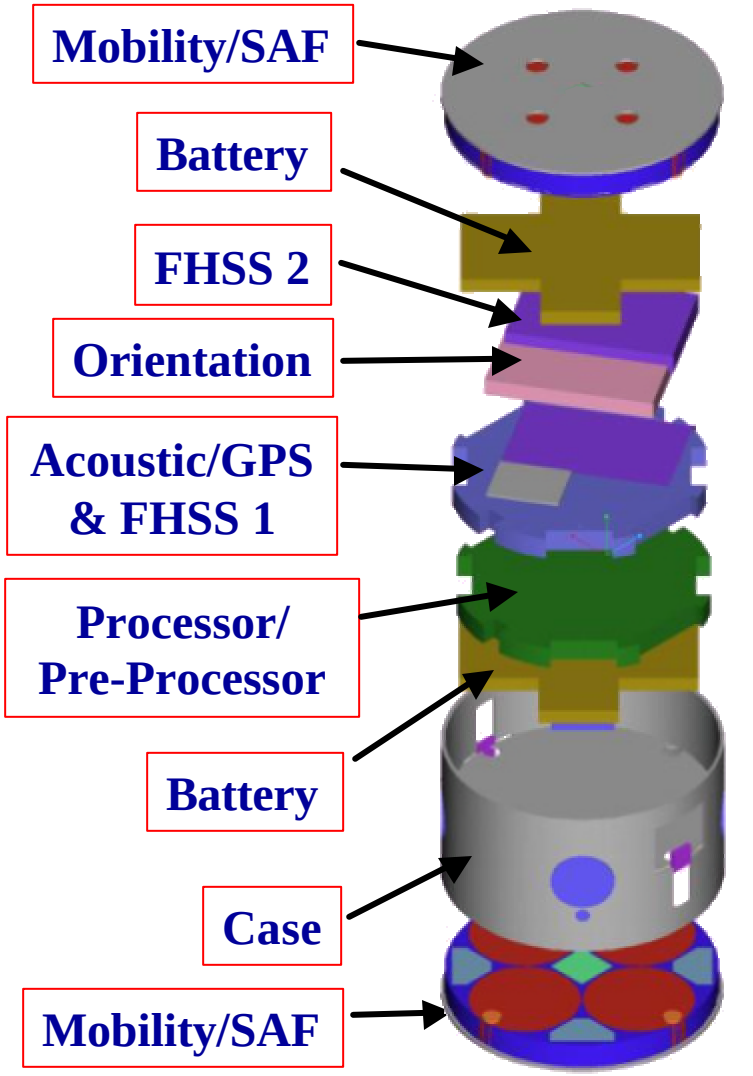
Rocket motor development and testing.

Safe, arm, and firing (SAF) unit, mobility unit housing design and integration.

Innovative trajectory and landing control

Team philosophy – Test early and test often.

SHM Hardware Design and System Architecture



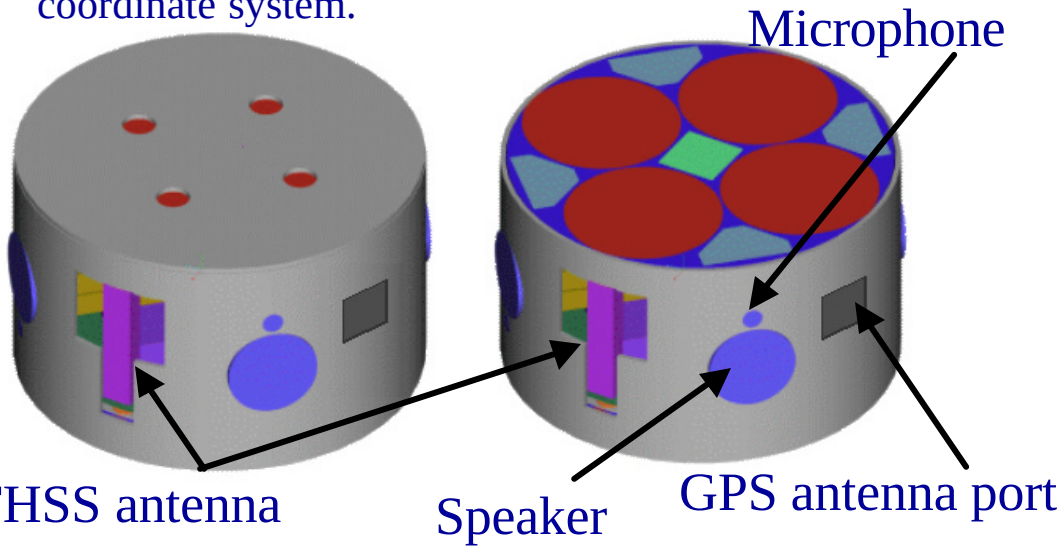
(1) **Mobility/SAF:** 8 independent thrusters (4 on each side) --hop distance > 7.5 m, height > 2.5 m, action < 100 ms.

(2) **Communications**: full duplex, dual FHSS on each node, --acoustic TOA for position.

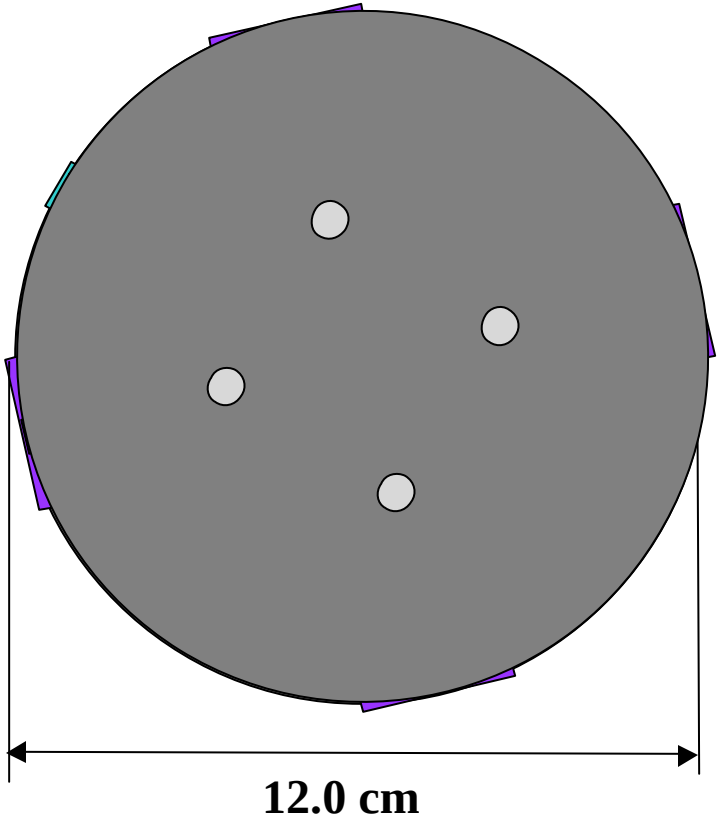
(3) **Network:** totally ad hoc (energy efficient architecture), multi-cluster-multi-hop, dual channel, TDMA.

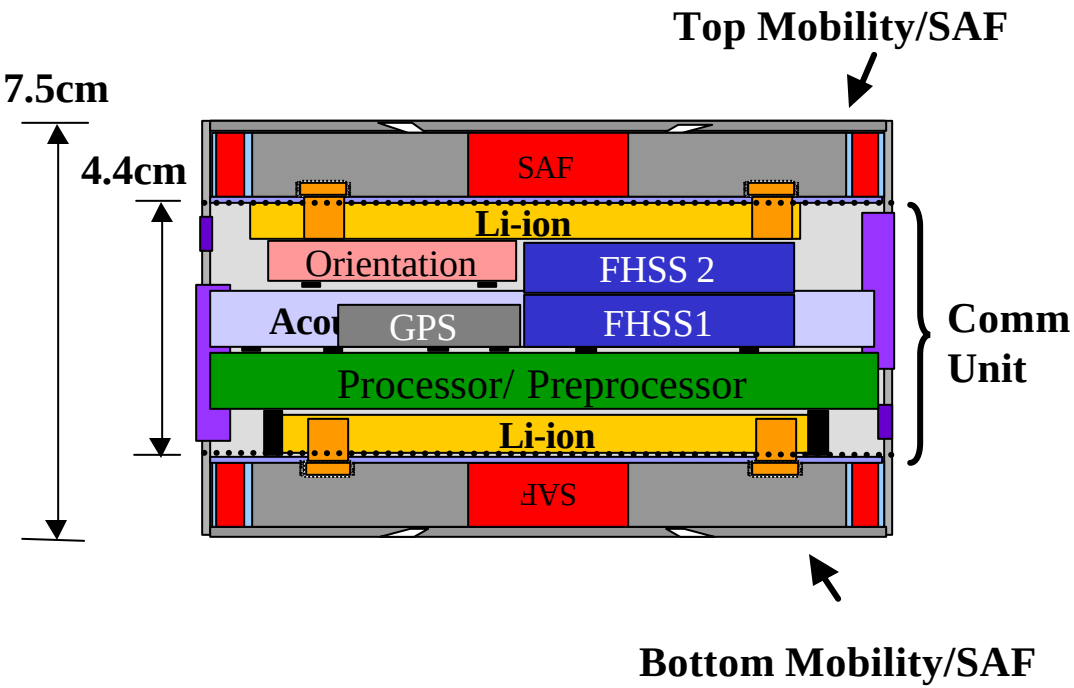
(4) **Healing Algorithm:** local decision on each node, multi-mode based on info available.

(5) **Acoustic ranging and angle for geolocation:** Use angle and range data to calculate a least-squares local coordinate system.



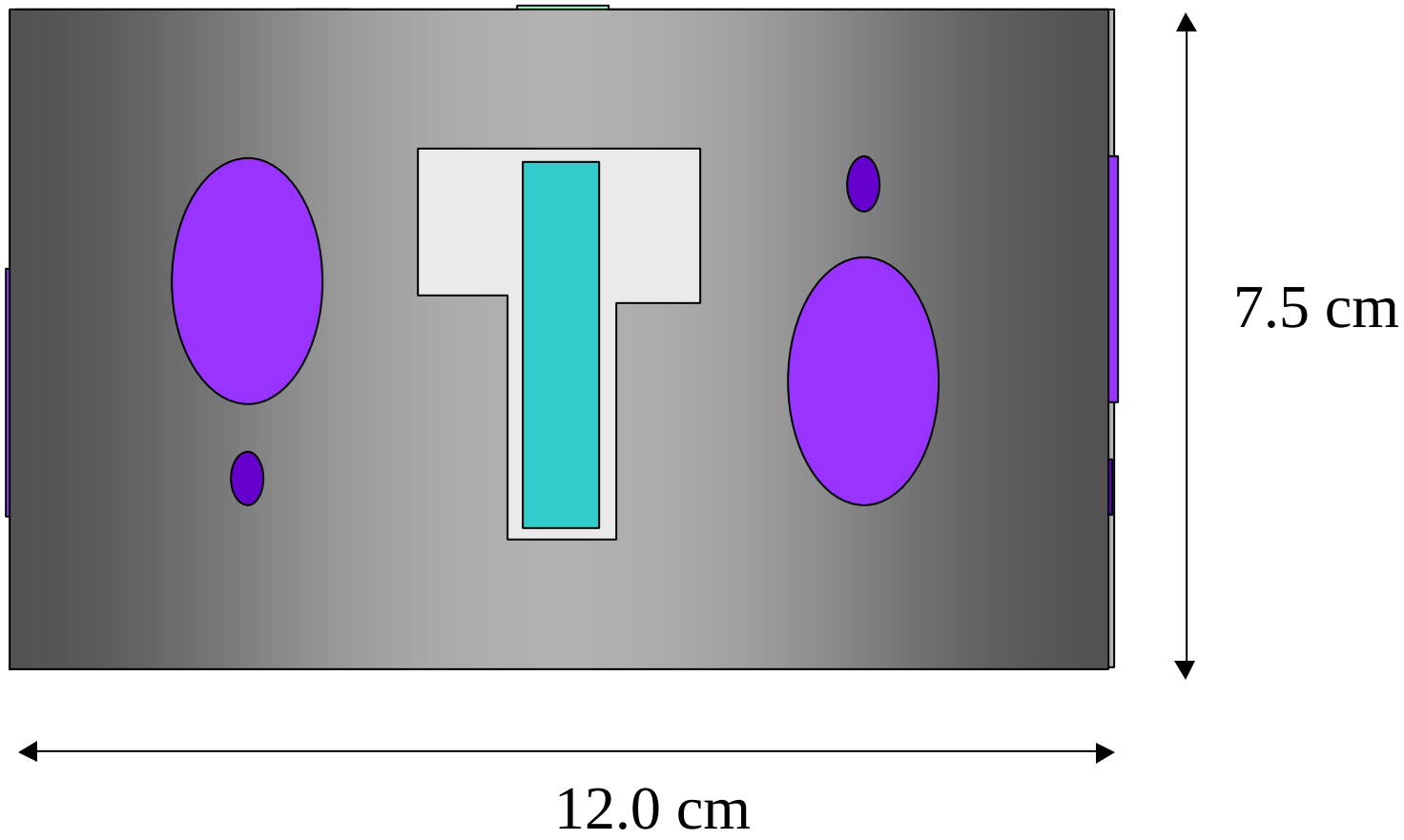
Demonstration Hardware Design
Top View/Assembly Procedure





Demonstration Hardware Design

Side View



Program Accomplishments
June 2000 – March 2002

(1) Mobility

- Developed and demonstrated small rocket thrusters to move desired distance
- Integrated 8 rockets into a single mobility unit, and are able to selectively fire desired thruster

(2) Safe, Arm, and Fire (SAF) System

- Developed and demonstrated a distributed system that can safely control all eight rockets (redundant safety including a remote SAF)

(3) Communications

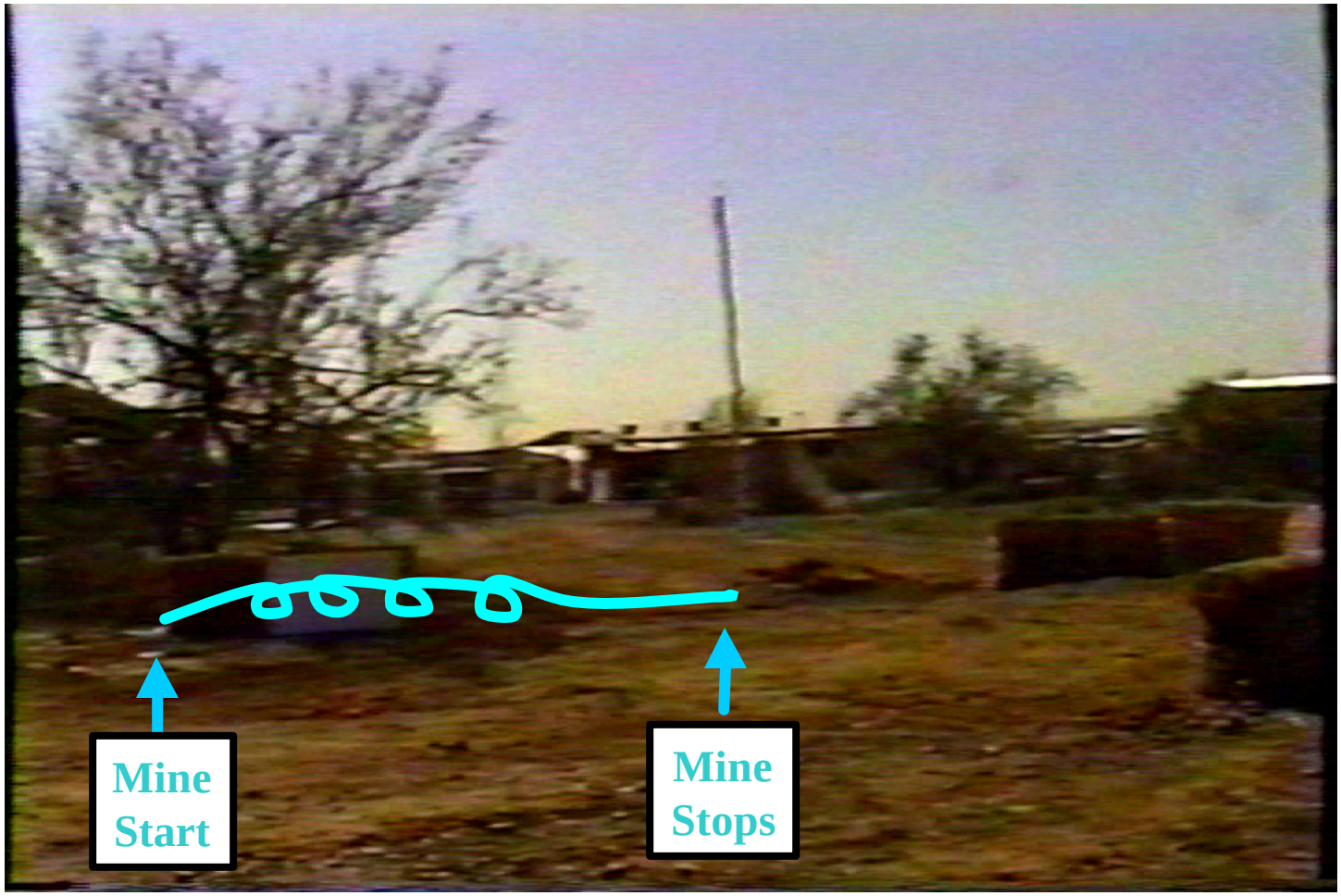
- Developed and demonstrated a totally ad hoc network and local geolocation system.
- Demonstrated ability to control and/or monitor network activity or allow network to operate autonomously.

(4) Command and control

- Demonstrated nodes ability to autonomously monitor and report changes to the system followed by autonomous determination and execution of an appropriate response.

Mobility Subsystem
Where We Started (Shot #1)

Max height < 0.4m
Flight distance= 1m
Final distance= 8m



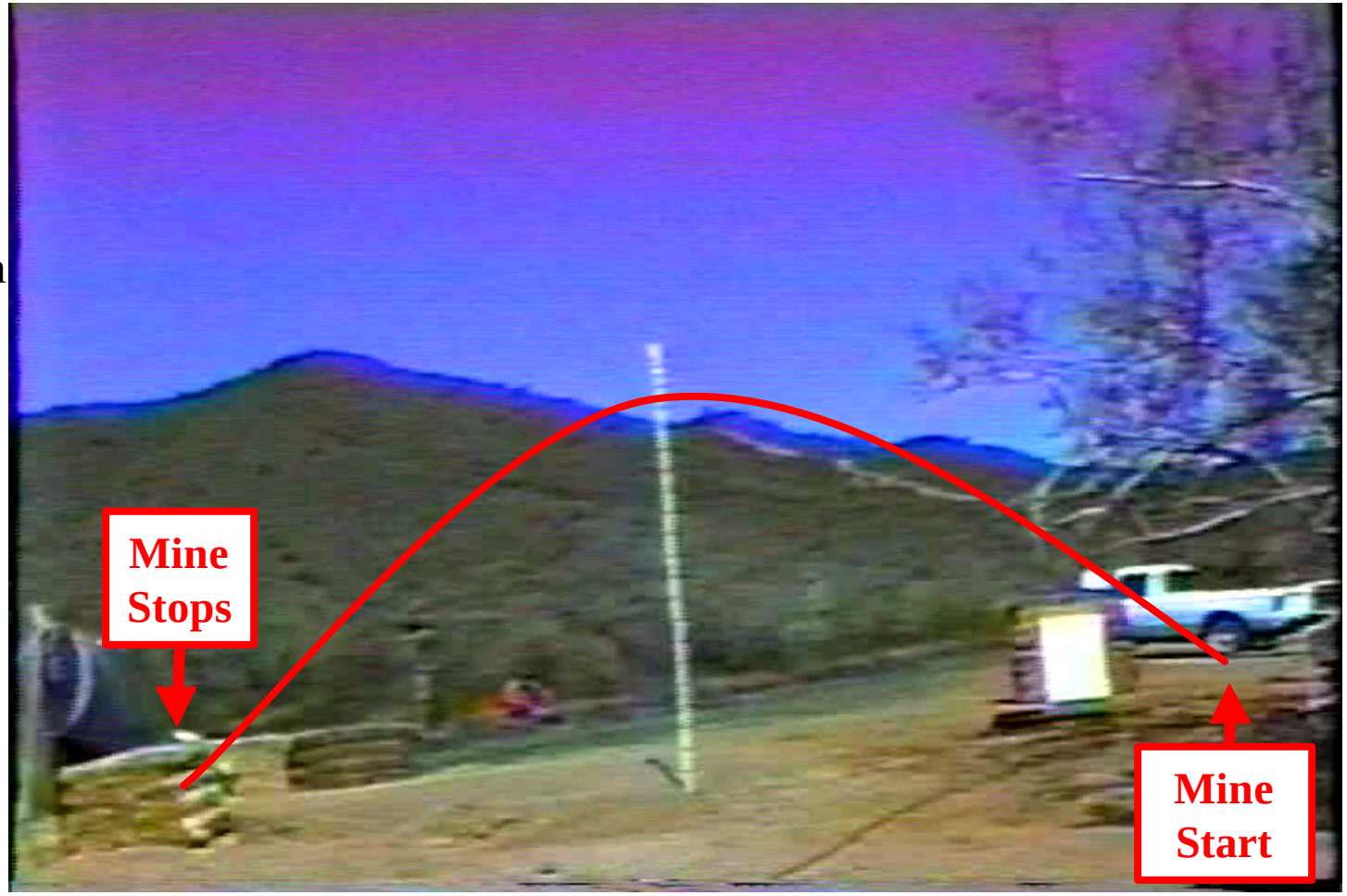
- **Learned importance of the ground plane and developed mitigation approaches.**

Mobility Subsystem
Where We Are (Shot #9)

Max height = 3.1m
Flight distance= 8.8m
Final distance= 10m

Baseline design:

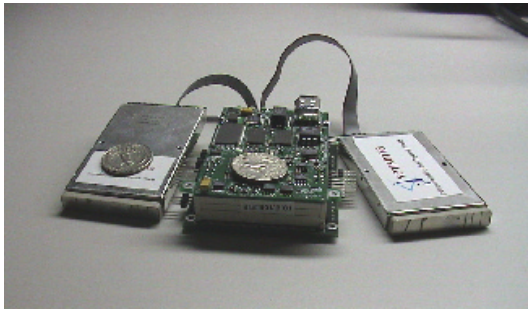
-Fire below CG.
-Robust for all ground plane conditions

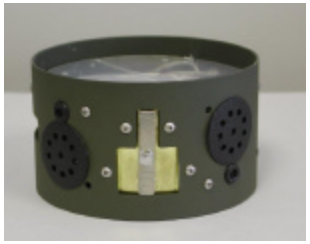


- **Accepted some performance degradation to ensure robustness.**
- **Potentially use a simple design to slightly elevate mine off ground.**

Comm Unit Development/Evolution

New Generation Every 6 Months





First Generation (6/1/00-12/31/00) – Proof-Of-Principle

- Processor/Pre-processor, Radios
- Early hardware for parallel software development
- Limited network capability **(dual radio network)**
- Bench-top development/operation/de-bugging

Second Generation (1/1/01-6/30/01) – Software Development

- Comm Unit prototype
- Processor/Pre-processor, Radios, **Orientation, GPS**
- Basic **network assembly, messaging and heartbeat**
- Early interface and software development

Third Generation (7/1/01-12/31/01) – Demonstration System

- Processor/Pre-processor, Radios, Orientation, GPS, and Acoustic Ranging
- **Custom and COTS Hardware**
- **Full network functions and geo-location, and form-fit**
- Field Operation with Primary Li-ion Battery

Healing Algorithm

- **Multi-mode healing algorithm:** Each node utilizes the maximum amount of network information available to execute an optimum "local" response.

Breach Specific	Nearest Neighbor	Random
Breach Specific Healing Mode	Nearest Neighbor Healing Mode	Random Healing Mode
Network fully operational: • 40-50 mines in table	Network partially operational: • 5-10 mines in table	Network not operational: • 0 mines in table

Summary

All Phase 1 Objectives Accomplished on Schedule

- Develop and demonstrate an energy efficient ad hoc network
- Develop and demonstrate a viable mobility approach
- Develop and demonstration SAF
- 10 communication unit demonstration -- (12/01)
- 8-hop mobility demonstration -- (1/02)
- Final 10-unit demonstration at Fort Leonard Wood -- (3/02)

- **Very successful Phase 1, but equally challenging Phase 2.**

10-Unit Test at Fort Leonard Wood

Five mobile and five communications-only nodes

- Performed a series of network/geolocation tests
  - Successfully predicted movement of mines from control room

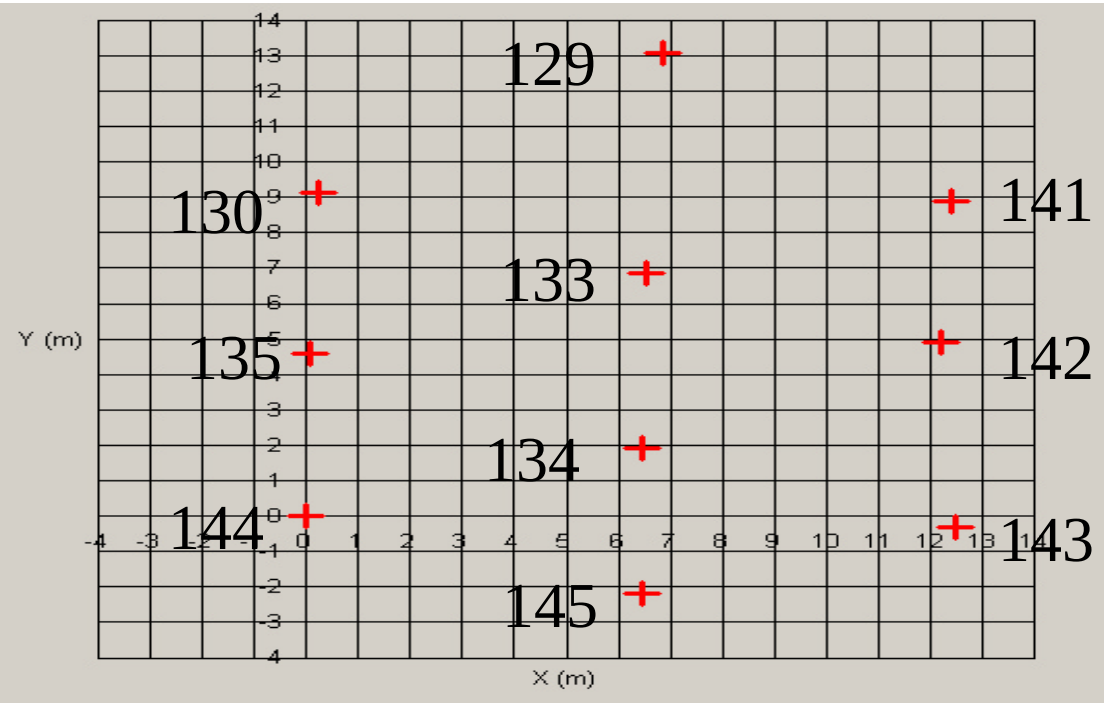
- Then we performed a series of “hopping” tests
  - **Complete end-to-end demonstration**
  - To simulate a breach, we “turned off” mines through the network
  - The other mines would then
    - recognize node disappearance,
    - calculate a response, and if desirable,
    - select and fire appropriate thruster to “heal” the breach.

  - Performed five tests where a node was removed over the RF network, where multiple nodes hopped to heal. (four times 3 hopped, and one time 4 hopped)
    - Desired response every time

  - Demonstrated ability to hop out of a ditch, off the side, and out from under a board.

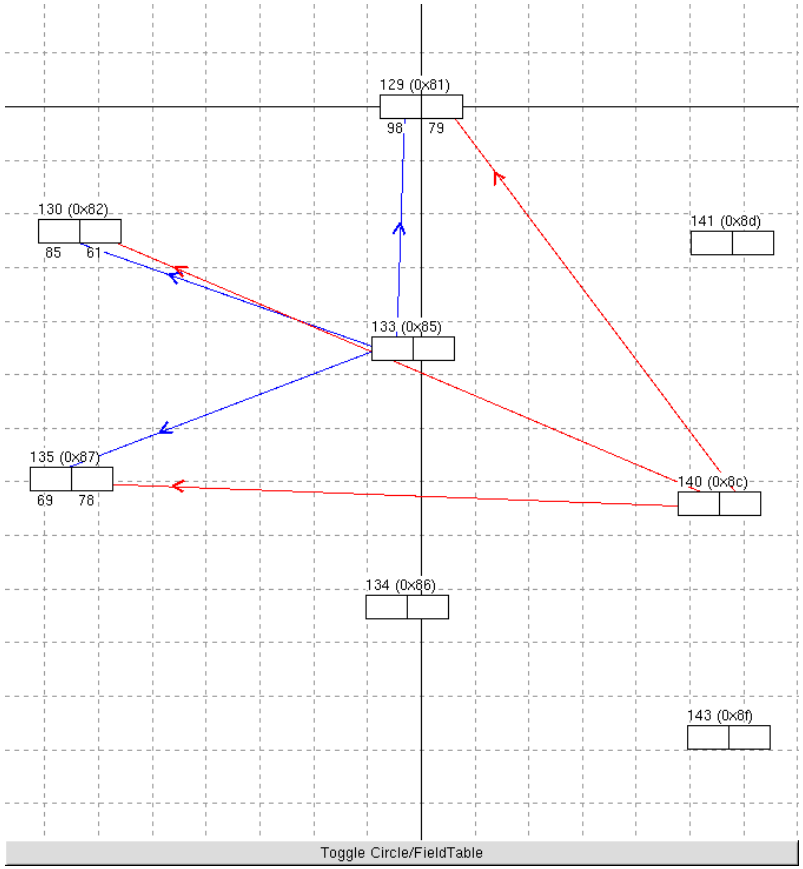
- **In all, we successfully fired 27 rockets.**

System Testing Setup



Geolocation GUI

Network connectivity GUI

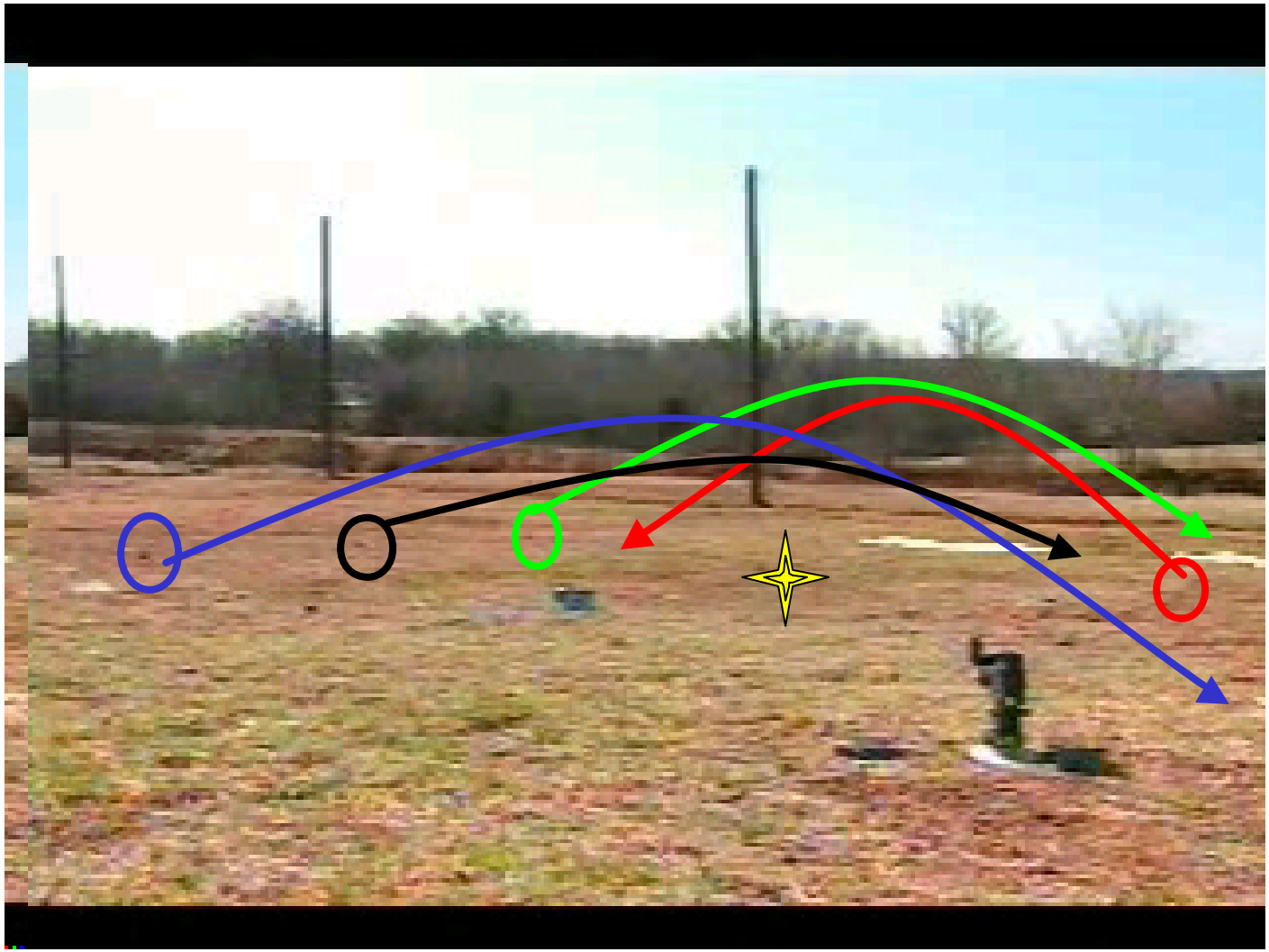


SHM Field Testing, March 2002

Video #1: Simulated breech. Three mines hop to heal

Video #2: Close up of mine hopping

SHM Field Testing, March 2002



Video #3: Simulated breech. Four mines hop to heal

Summary

- Program to-date has been a big success
- All major subsystems have been demonstrated working together
- Within a year, scaling to 50 nodes will be demonstrated
- Program is on-track to potentially be a key system for the U.S. Army
- Spin-off applications are tremendous
- **Success is a result of hard work by an integrated government and industry team**