BAE SYSTEMS

Next Generation Adaptable RF Seekers for Precision Munitions

40th Annual Guns-Ammunition-Rockets-Missiles Conference

Missiles & Rockets Session

April 27, 2005

Dr. Cory Myers
BAE Systems IEWS
cory.s.myers@baesystems.com

Mission Need

- Provide small unit of operations with organic Precision Strike capability against High Value Targets
- Accelerate Enemy Defeat
- Reduce Collateral Damage
- Improve Deployability & Logistics
- RF Guided Munition (RFGM)
  - Provide a low cost precision means for ground forces to engage C3 targets, enemy FOs, and some radars
  - Completes the sensor-to-shooter chain for IO targets operating from 30MHz to 3GHz

Current Mortar Munitions generally do not achieve first shot direct hit on target. RFGM guidance system capable of correcting trajectory improves first-shot hit on the target to 50%.

System Concept

- **Exploit dismounted, close-in attack scenario with small aperture, RF seeking weapon**
  - If the dismount (SOF) can be cued to the presence of the emitter then the dismount can attack the (soft target) emitter with an organic weapon (e.g. 81 mm mortar)
- **Create a passive, all-weather, and inexpensive precision RF seeker capability for multiple weapon types**
  - Enable a suite of precision and area suppression weapons (ground-to-ground, ground-to-air, and air-to-ground) that home on RF energy all using similar RF seeker and guidance technology
- **Deny enemy use of RF spectrum for military purposes**
  - Counter enemy radar/IR/acoustic signals Camouflage, Concealment and Deception (CCD) efforts

DARPA Hard Technical Challenge: Quick and Precise Geo-location of RF Emitters from a Single, High-Velocity, Small Weapon

Technical Challenges

BAE SYSTEMS

System Requirements:

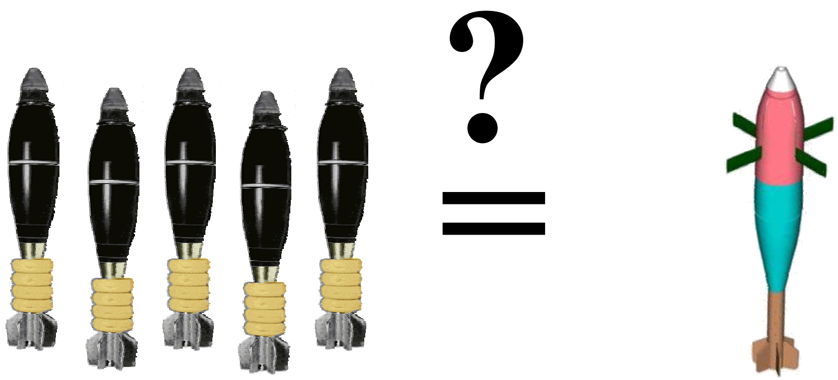
- *Quick:* Geo-location estimate must be fast enough (5 sec) to guide a mortar which has only 25-30 seconds of flight time
- *Precise:* Geo-location with an objective radius of an 81 mm mortar (20 m)
- *RF Emitters:* Target frequencies from 30 MHz to 3 GHz and multiple waveforms
- *Single:* Emissions received by only a single platform (passive technique)
- *High-Velocity:* Velocity of a mortar varies from 300 m/sec to 100 m/sec
- *Small:* e.g. 81 mm mortar form factor restricts antenna size and distance

Technology Enablers:

- Organic detection (cueing) capability
- Small, lightweight, wideband, and inexpensive RF receivers
- Inexpensive memory and processors
- Proliferation of guided weapons (IR, laser, GPS, etc.)

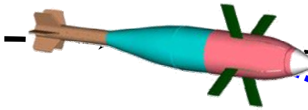
DARPA RFGM Program

- Replacement fuze/guidance package that effectively converts current, ballistic 81 mm mortar munitions into precision RF guided munitions
- Screw-on mod-kit
- Affordable, Easy to use
- Frequency range 30MHz to 3GHz
- Accuracy not dependent on visual observation
- Fire and Forget
- Passive, all-weather
- Technology that is scalable to other munitions



System Operation

BAE SYSTEMS



Launch Cue → **Geo-locate** → **Maneuver toward target** → **Detonation**

Initial detection, discrimination, and Geo-location to <1.5km radius circle

<20m accuracy (CEP) with << 0.3λ aperture

Maneuver capability and stable control

3m Airburst using GOTS proximity fuze

System Integration

- Miniaturize to a 81mm mortar round
- Cost effective
- Match maneuver, target, and munitions capability

Existing technology	Extension of existing technology	Seedling analysis indicates feasible

Design/Trade Space

BAE SYSTEMS

- Cueing:
  - The weapon receives cueing information from an external system such as Wolfpack, ACS, etc.
    - Utilize SIGINT standard emitter descriptors (carrier frequency, bandwidth, modulation, etc.) to future proof weapon versus template matching emitter waveforms
- Geo-location
  - Despite high SNR condition, classic DF techniques alone will not work well enough due to the limited aperture size/spacing and the (low) frequency range of interest
- Maneuver toward target
  - Guidance/control techniques are well known (e.g. ERGM, PGMM, etc.)
- Detonation
  - Utilize existing GOTS fuze technology to avoid re-qualification costs
- System Integration
  - Optimizing the relationship between geo-location accuracy and aerodynamic control authority while minimizing weight, volume, and cost and impact on weapon range and effects
    - Integrating the RF Guided Munition kit with the fuze is preferred
    - Volume/length will need to be added to the weapon (mortar) for antennas, RF electronics, signal processing, and control surfaces in a manner that minimizes range loss
    - Using GPS is possible but an IMU may be sufficiently capable while being cheaper than SASSM modules – both add a precise targeting capability

RF Guided Munitions Program

BAE SYSTEMS

FY05 | FY06 | FY07

Phase 1:
Task 1
Core Geo-location Technologies

Design
- *Antenna*
- *RF Hardware*
- *Geo-location Signal Processing Software*

Demo
- *Captive Carry*

Task 2
Phase 2 Risk Reduction
- *Emitter Discrimination*
- *Miniaturization*
- *Maneuverability*

Phase 2:
Refine Technologies Harden Components
- *Discriminate Target*
- *81 mm Form Factor*
- *GNC*

Demo
- *Soft Launch*

Phase 3:
Refine & Harden All Components for Operational Launch
- *Antennas*
- *Electronics*
- *Control Surfaces*
- *Objective weapon (e.g. 81mm mortar) Form Factor*

Demo
- *Operational Launch*

Alternate weapon platforms to the 81mm mortar will also be considered for funding if a transition sponsor has been identified

Contract Award/ Kickoff Sep/Oct 04

Phase 1 Go/No-Go

50% geo-location estimates w/in 20m of actual emitter

Phase 2 Go/No-Go

50% rounds impact w/in 20m of target emitter

Phase 3 Go/No-Go

50% Rounds impact w/in 20m of target emitter

Go/No-Go

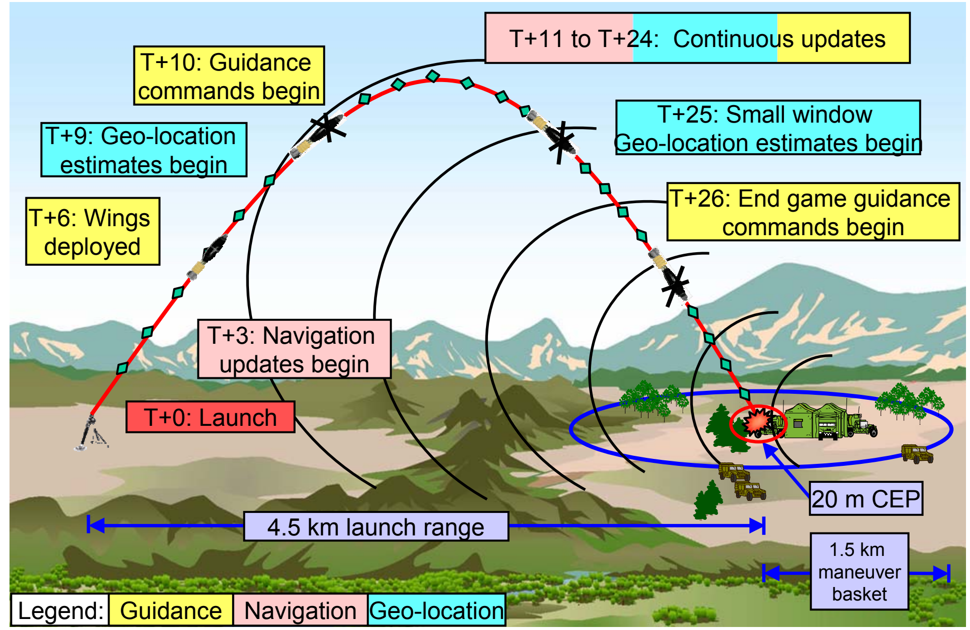
1 2 3

Final Demo and Transition

Geo-location Challenge

BAE SYSTEMS

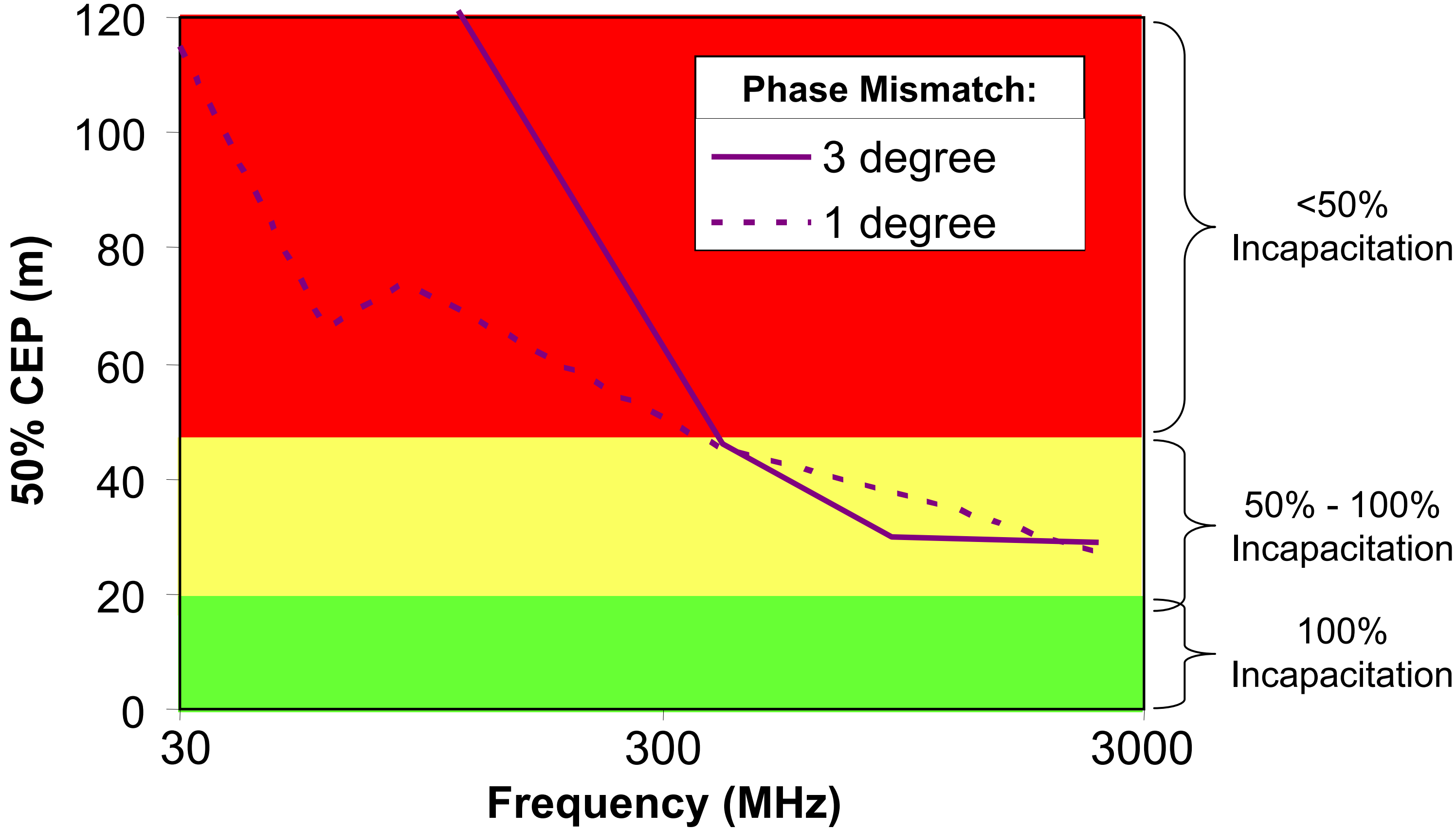
- **Geo-location Error Sources:**
  - Thermal noise
  - Quantization noise
  - Phase noise
  - Receiver spurs, intermods and harmonics
  - Man-made noise and atmospheric noise at HF
  - Navigation errors from position and roll sensors
  - Channel mismatch errors
  - Calibration errors
  - Multi-path signal corruption
  - Co-channel signal interference
  - Platform motion induced modulation



- **Geo-location Requirements:**
  - Provide guidance commands well before apogee to support maneuver basket.
  - Deal with multi-emitter environment. Guide to one emitter, not the centroid of emitters.
  - Provide resiliency to multi-path and polarization.

Geo-location Challenge

Angular precision of classic DF techniques is limited by λ/D, SNR, and channel mismatch which is unacceptable for low frequency emitters



Lower Frequency

- **Dominated by channel mismatch which causes a biasing error**

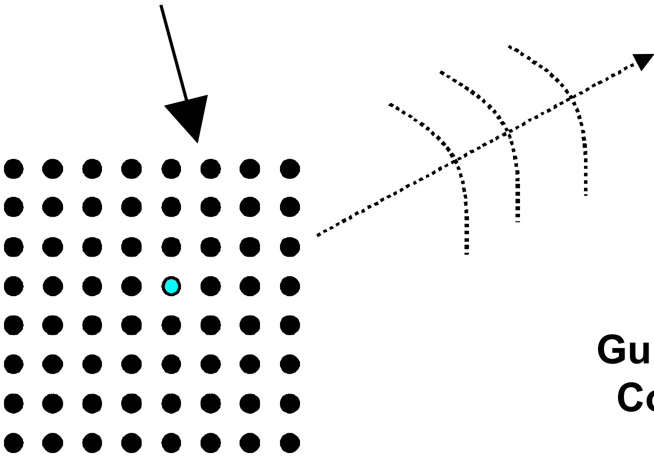
Higher Frequency

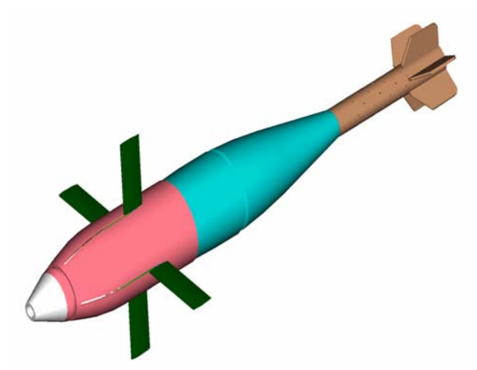
- **Dominated by imprecision in guidance (GPS/IMU error)**

Geo-location Processing

BAE SYSTEMS

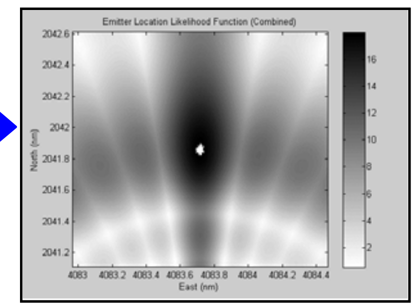
Grid of hypothesized target positions on the ground





- Collected IQ data and navigation data
- Cued emitter frequency data
- Pre-flight calibration data

Signal Separation and Geo-location



Guidance Control

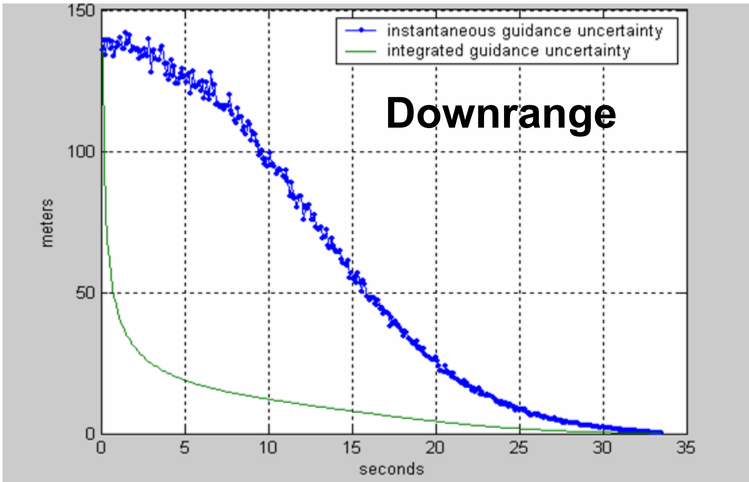
Likelihood function

Geo-location method uses temporal, phase and amplitude information from all the antenna elements, separates signals of interest and then determines emitter geo-location metric by computing the probability likelihood surface of the potential emitter location as a function of its hypothesized location.

BAE SYSTEMS

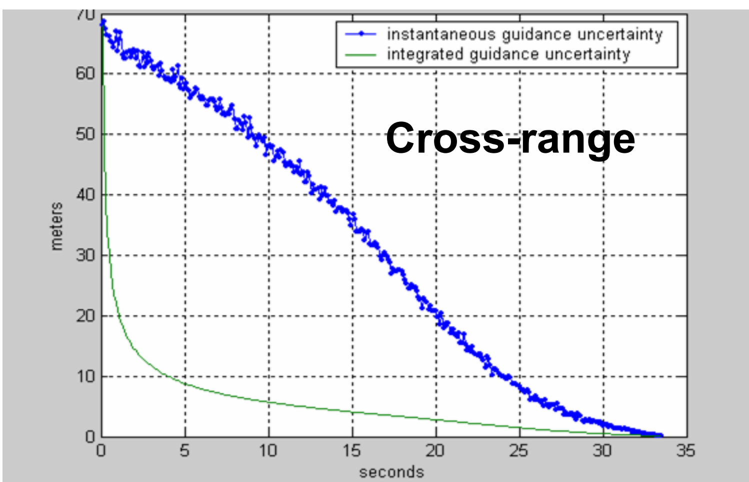
Geo-location and Guidance Performance

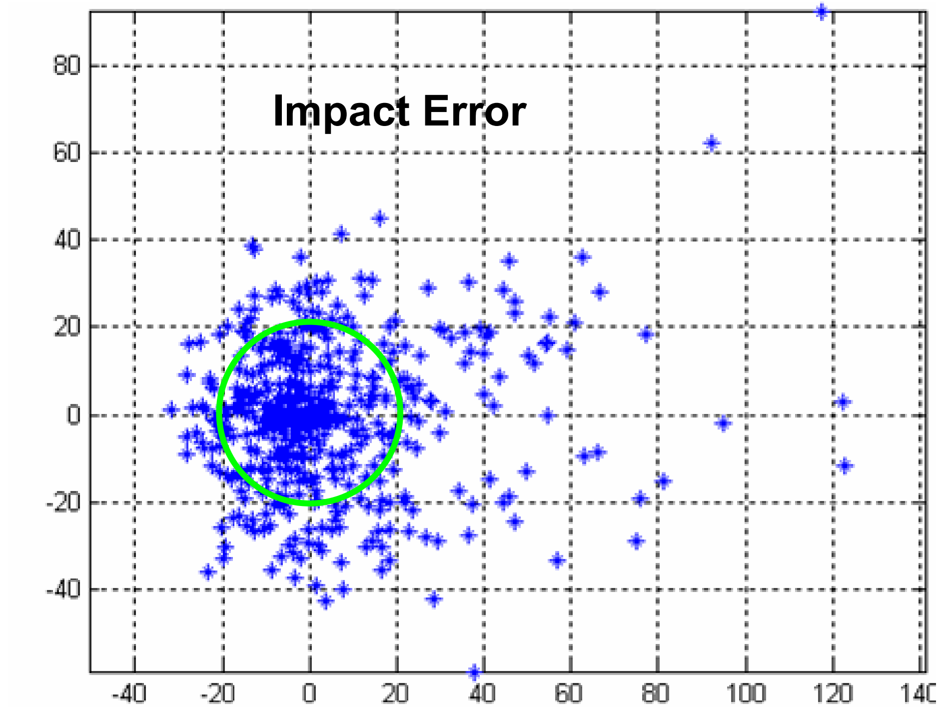
Error



Flight Time

Error





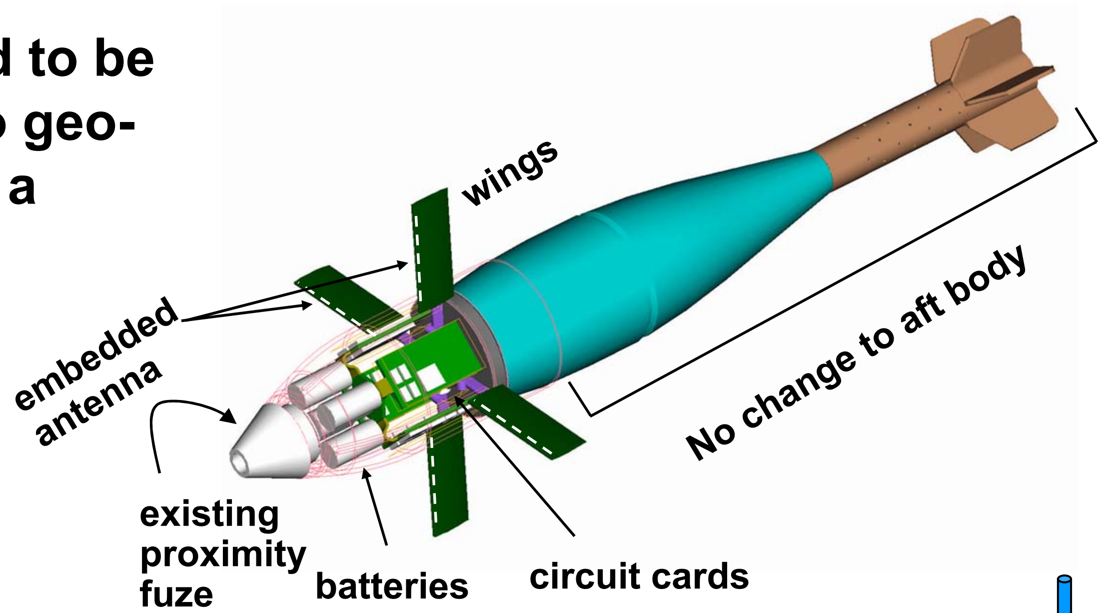
Model of combined geo-location and guidance shows better performance than the specified 20m CEP goal with a maneuver basket of 1.5km in radius.

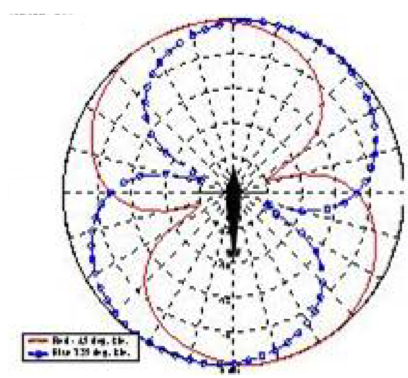
System Integration

BAE SYSTEMS

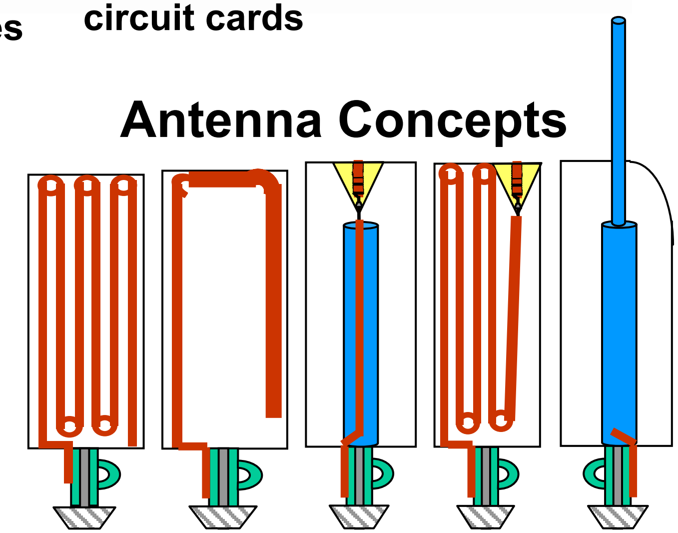
Multiple subsystems need to be integrated, in addition to geo-location, to make RFGM a reality:

- Antennas
- Receivers
- Actuators
- Wings
- Navigation
- Guidance
- Control
- Signal Processing
- Power
- Cueing
- Fuze





Antenna Concepts



Questions?

Points of Contact

BAE SYSTEMS

DARPA/ATO Program Manager

Dr. John Allen

jallen@darpa.mil

BAE Systems Program Manager

Ms. Marianne Tenore

marianne.tenore@baesystems.com

Phone: 603-885-8470

BAE Systems Management

Dr. Cory Myers

cory.s.myers@baesystems.com

Phone: 603-885-6845

BAE Systems Business Development

Mr. Daniel Bradford

daniel.bradford@baesystems.com

Phone: 603-885-5937