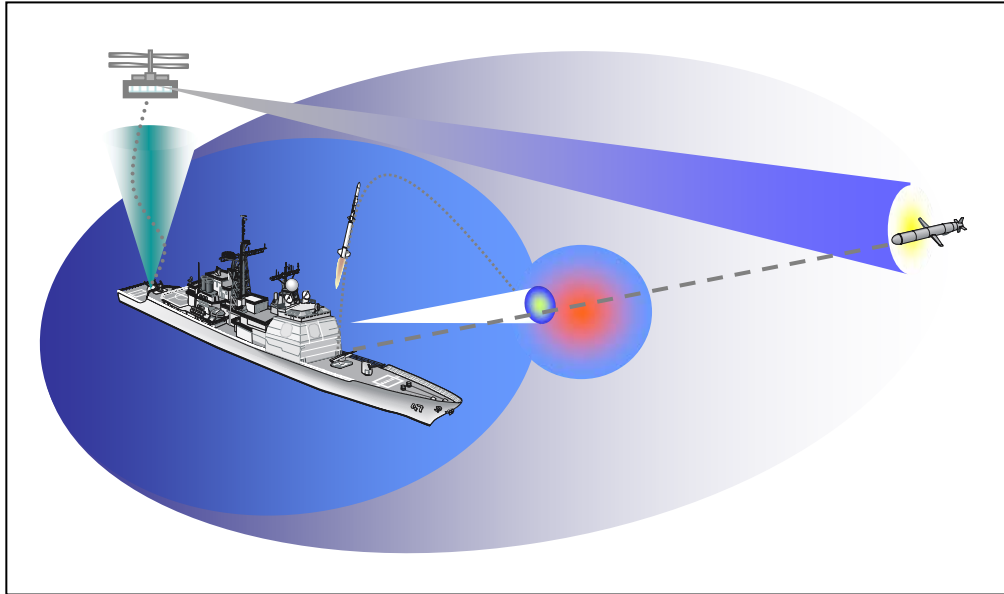


# Command Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance (C4ISR)

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***Future Naval Capability:  
FORCEnet  
Hard S&T Problems We Are Addressing***



*Relevant Research and Results . . .Yesterday, Today, and Tomorrow*

**Bobby Junker  
Head, C4ISR Department  
703-696-4212  
junkerb@onr.navy.mil**

# Definition of FORCEnet

*FORCEnet is the operational construct and architectural framework for Naval Warfare in the Information Age, integrating warriors, sensors, command and control, platforms, and weapons into a networked, distributed combat force.*

# Rapid, Accurate Decision-Making

- Joint Service Oriented Architectures for rapid, interoperable, Secure, sharing and discovery of mission relevant sensor data and information and joint command and control
- ▶ – *Automated signal and image understanding*
- ▶ – *Automated integration of disparate sensors and sources of information including metadata (e.g., information source, quality, validity, integrity, priority, degradation) to produce actionable knowledge*
- *Automated Courses Of Action with insight into uncertainty and risk particularly for specific scenarios such as urban, guerilla, and Cyber activities and port / force / base protection and application to automated generation of alternative courses of action in the future*
- *Highly flexible means of presenting complex information including uncertainty, geo-spatial, Net Topologies, etc from multiple relevant data sources for aiding in assessing intent as well as situation awareness while performing mission (31/34)*
- Means to rapidly assemble/re-configure real-time software systems for survivability to ensure security, quality of service and information for decision-making
- Certification of software-intensive systems for functional correctness and security

*Italicized, red font indicates particularly difficult issues*

# Dynamic, Efficient, Mission-Focused Communications and Networks

- Where necessary, develop protocols and architectures for dynamic, mobile naval forces
- *Within this architecture, develop mission-driven, quality of service and secure capabilities*
- Develop tools for network automation which account for battle-space situation, battle-space environment, and commander's intent
- ▶ – *Enable robust over-the-horizon connectivity*
- ▶ – *Develop necessary aperture technology to ensure continuous platform participation in the network*
- ▶ – *Investigate concepts for enhancing underwater communications and for rapidly moving underwater sensor information and data into overall common picture database*
- *Develop software technologies to support seamless multilevel secure real-time access to and processing of network information across domain boundaries*
- Develop Software Compliant Architecture (SCA) enabled highly adaptive tactical communications (throughput, anti-jam and LPI/LPD)

# Pervasive and Persistent Sensing

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- ▶ • *Advanced light-weight, small, efficient sensors for variety of platforms (video, IR, SAR, chem/bio, etc)*
  - *Flexibility in search / ID*
  - *Multi-modal*
- ▶ • *Automated processing at sensors and sensor networks (triage, assessment, and control)*
  - Integrated modules including on-board processing and control
  - Automated self-control and self-tasking of sensors and sensor networks including optimization of resources and COTP development
- ▶ • *Four-dimensional navigation data with and without GPS*
  - *Jam-Resistant GPS navigation*
  - *Non-GPS navigation*
- ▶ • *CONOPS and TTPs*

# High Impact Technologies

- Increased speed and precision of decision making – Simply making more information available to decision-makers / warfighters doesn't help if they cannot assimilate and use that information. This requires advances in a number of technologies
  - Automated integration of disparate sensors and sources of information including metadata (eg information source, quality, validity, integrity, priority, degradation) to produce actionable knowledge and COAs with insight into uncertainty and risk
  - Integration and presentation of information to humans for maximum rate of comprehension and optimal utilization taking into account the variation in human perception . Must enable human to understand attributes of the information such as nature of source, timeliness, quality of source, rate of degradation of information, etc.
  - Automated Image Understanding – necessity to automate / speed analysis of larger amounts of image and video information which is an increasing larger component of information being made available for decisions making. Would also produce major reduction in throughput requirements as image analysis could be accomplished at sensor site and only ID and coordinate (space and velocity) need to be transmitted. Quantum jump in effective information transmission, but may require advances in nano/bio-electronics to enable sufficient, low-power computation at remote sensors. Elements of this are already spiraling into applications in the form of image compression, image deblurring, contrast enhancement, and image repair.

# High Impact Technologies

- Multifunction/multiband/multibeam digital RF apertures – enables robust, multi-routing capability that ensures robustness of all nodes of the network and consequently inclusiveness of all resources. Could significantly enhance the functionality and thus the capability of smaller platforms.
- Low-power, high capability computer/communications technology - Nano/bio-electronics would enhance the level of capability for the small unit / Marine user, enable massive sensor nets, and significantly enhance level of computational and information storage capability for remote users/sensors/platforms. Potential for a quantum jump in information availability
- Information Assurance -- provides capability to ensure the security, integrity, trustedness, and confidentiality of shared data and information across and within coalition security enclaves, at multiple security levels, with diverse computing platforms. Technologies that will maintain security integrity across multiple servers, or in peer-to-peer collaboration, are needed.
- Flexible command structure – enables optimum (metrics: speed and precision of decision making), dynamic siting of decision making authorities based on local and non-local battle-space situation and trends and on tempo of the battle.
- Mission-focused network Quality of Service – enables automated, optimum utilization of network resources to accomplish multiple, simultaneous missions. Sets priorities based on mission(s) accomplishment as opposed to who pays the most as in commercial technology.
- Underwater communications and networks – enables the sensors, C2, and weapons systems to be tightly coupled as in the above surface case and is essential for overcoming access denial.

# QUESTIONS

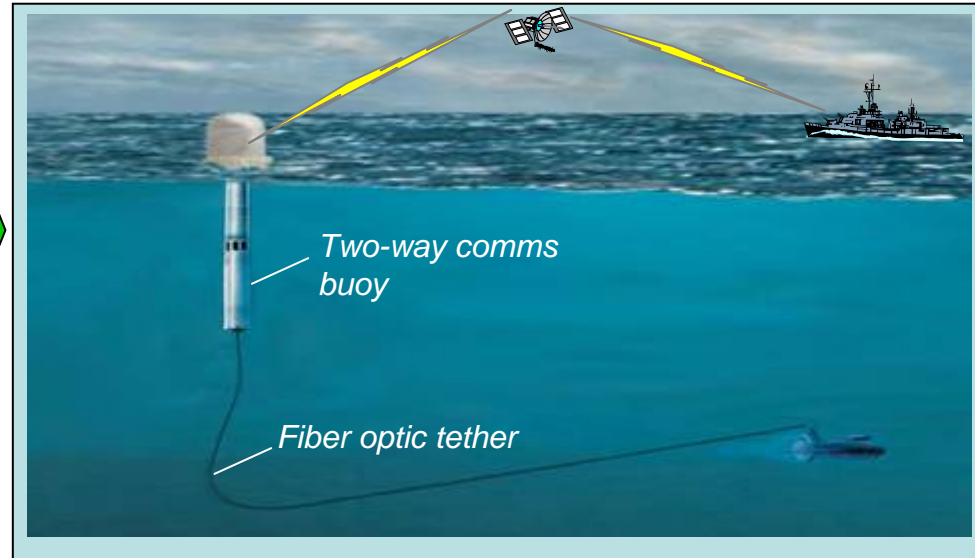


# Next Generation Sub Comms at Speed and Depth

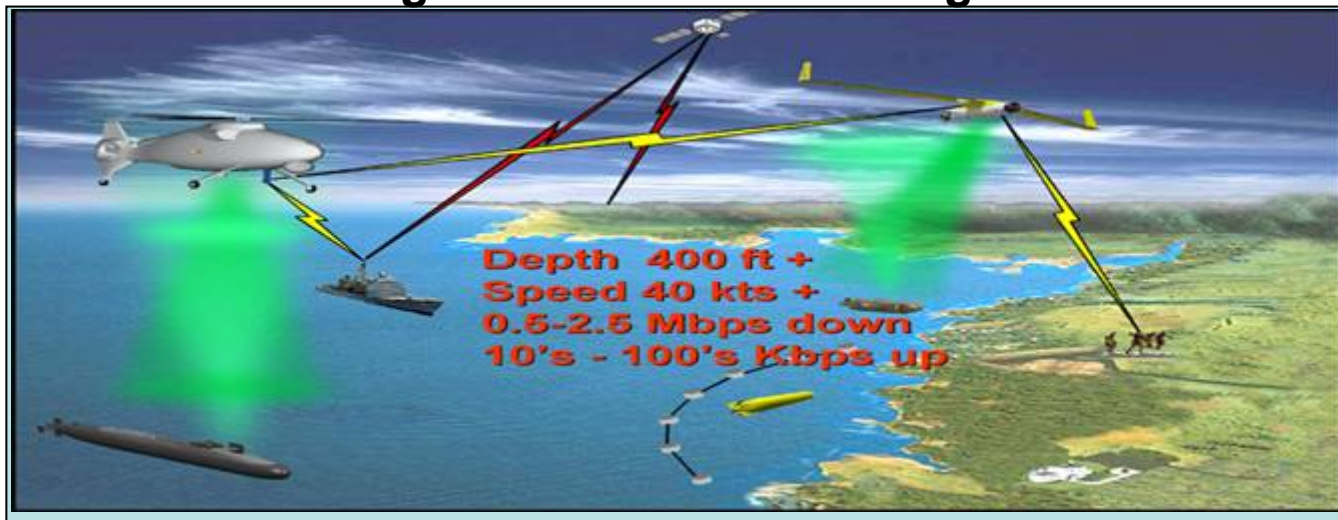
## Next Generation Submarine Buoyant Cable Antenna (NGBCA)



## The Expendable Communication Buoy



## Submarine-Enabling Airborne Data Exchange & Enhancement Program



# Automated Fusion Algorithms to Address Combat ID

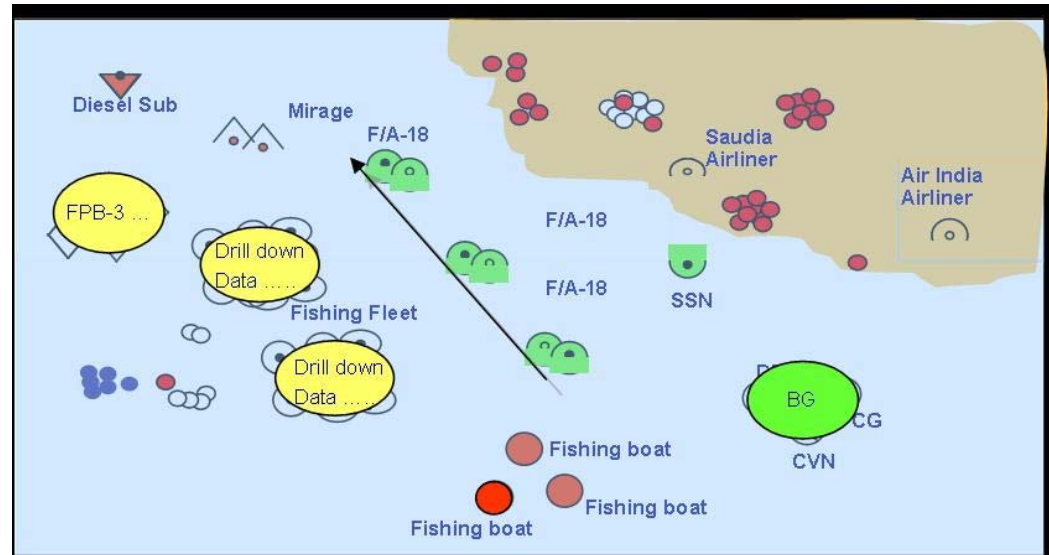
## Implications of Groupings of Entities and Events

### Current Capability

- Lots of data from many sources
- Little understanding about how entities and events relate
- Manual capability to manage multiple hypotheses about the meaning of
  - Groups of entities
  - Events that may potentially be related

### ONR's Product Produces

- Data from many sources automatically exploited
- Warfighter-relevant understanding about how entities and events relate
- Automated capability to manage hundreds of multiple hypotheses about the meaning of
  - Groups of entities
  - Events that may potentially be related



***Relationships established; Intent predicted action;  
Can be taken with high confidence in a timely fashion***

# Missile Defense S&T

## Sea Shield Future Naval Capability Program

Applied Research to develop advanced algorithms for use in Navy combat systems for combat identification and sensor fusion, and supporting a common tactical air picture



★ Multi-Source Integration (MSI): Develop advanced data fusion algorithms for E-2C Mission Computer

- Integrate multiple organic sensors (Radar, CEC, IFF, ES) with off-board sources (Satellite comms and tactical data links) to support Theater Air and Missile Defense (TAMD) requirements



★ Advanced Sensor Netting Technology (ASNT): Develop advanced algorithms for combat ID in netted sensor systems

- Integrate electronic support (ESM) data fusion with real time tracks in the future joint / Navy track manager
- Append ID attributes to real time netted sensor air tracks



★ Composite Combat Identification (CCID): Develop advanced algorithms for building high confidence ID from real time and non-real time sources & sensors

- Real time netted sensor -SIGINT integration, aircraft & surface combatants
- Common reasoning algorithm for all naval TAMD units in theater



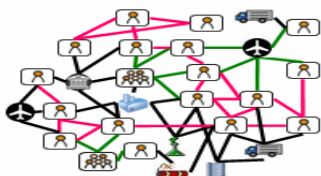


# PALADIN- An Application of Bayesian Networks on Naval Information

DATE	BOL_NBR	CONTAINER	FPORT	USPORT	SLINE	VESSEL
40601	2154053365	TTNU4567496	SHANGHAI	LONG BEACH	CSCO	TENG YUN HE
40612	HKGRJ5021	MSKU3231647	HONG KONG	LOS ANGELES	MLSL	CLIFFORD MAERSK
40612	826120540	KKFU1180754	YANTIAN	LOS ANGELES	KLIN	YM WEALTH
40612	826120544A	KKFU7285990	YANTIAN	LOS ANGELES	KLIN	YM WEALTH

## PALADIN Innovative Technologies

### Link Extraction



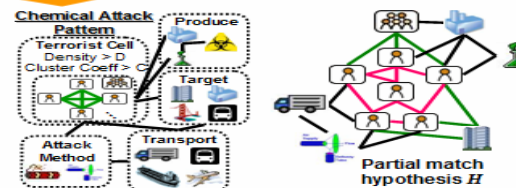
- Extract entities and links with attributes from data sources
- Use group detection to focus attention, reduce search space

### Network Anomaly Detection



- Detect graphical anomalies to identify potential threat networks
- Use as starting points for pattern matching searches

### Pattern Matcher



- Subgraph matching to find signatures
- Connect related signatures to infer organized activities

### Network Visualization



### Hypothesis Scorer

$$\Lambda(H) = \frac{\Pr(\text{evidence in support of } H \mid \text{threat})}{\Pr(\text{evidence in support of } H \mid \text{clutter + noise})}$$

- Compute likelihood ratio for each hypothesis
- Filter and rank hypotheses

**METRON**

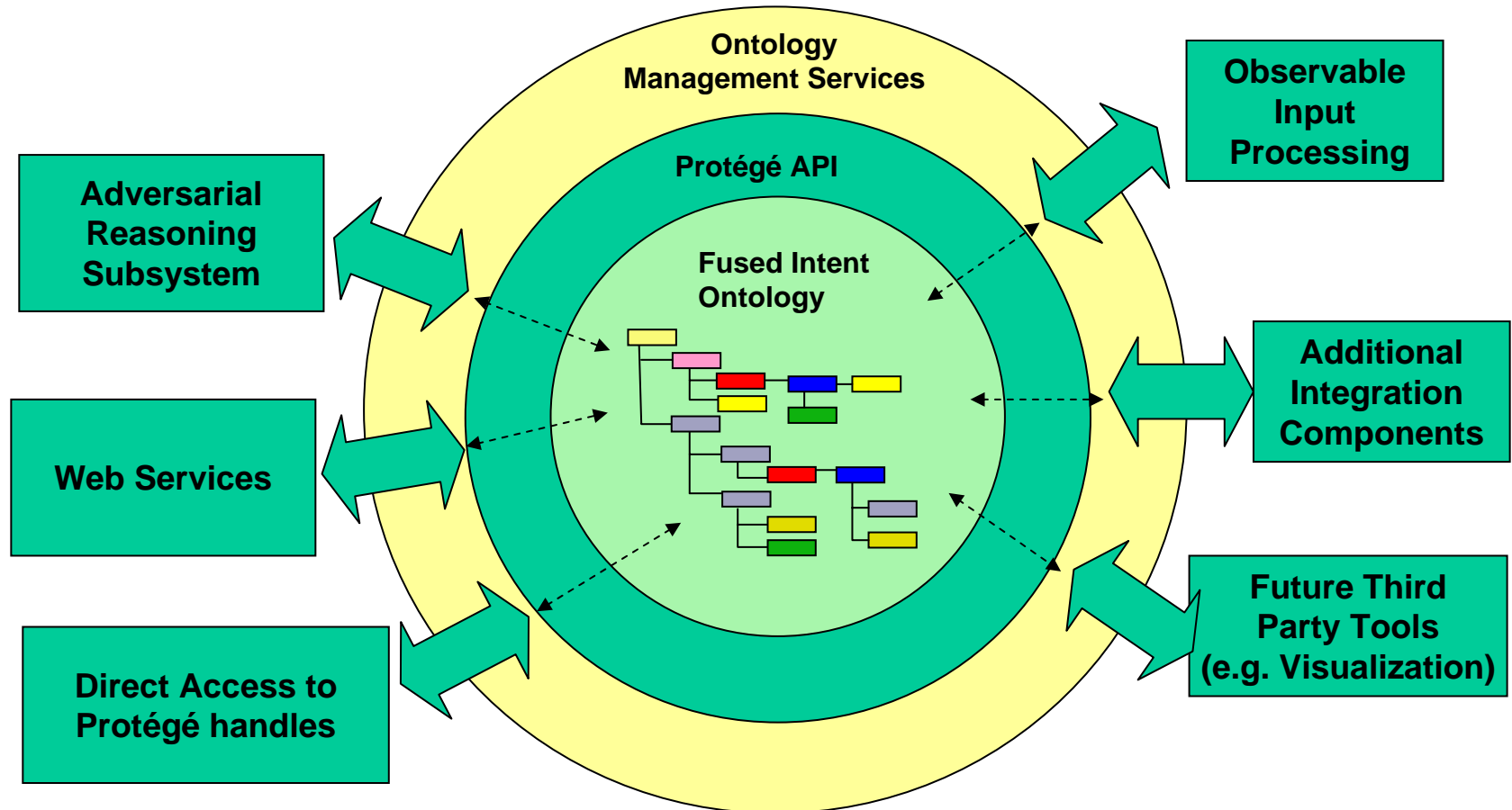
UNCLAS

**Theorem [Lo, Ferry]:** For  $m, n \rightarrow \infty$  with constant  $\mu$ , the expected number of subgraphs of  $\mathcal{B}^*(n, m, \mu)$  isomorphic to  $H$  is given by

$$\frac{E[X_H(\mathcal{B}^*)]}{X_H(K_n)} = \frac{\mu^{V(H)}}{m^{E(H)}} \prod_{i=1}^q \sum_{s=1}^q \binom{b_i}{s} \mu^{s-1} + O\left(\frac{1}{m^{E(H)+1}}\right)$$

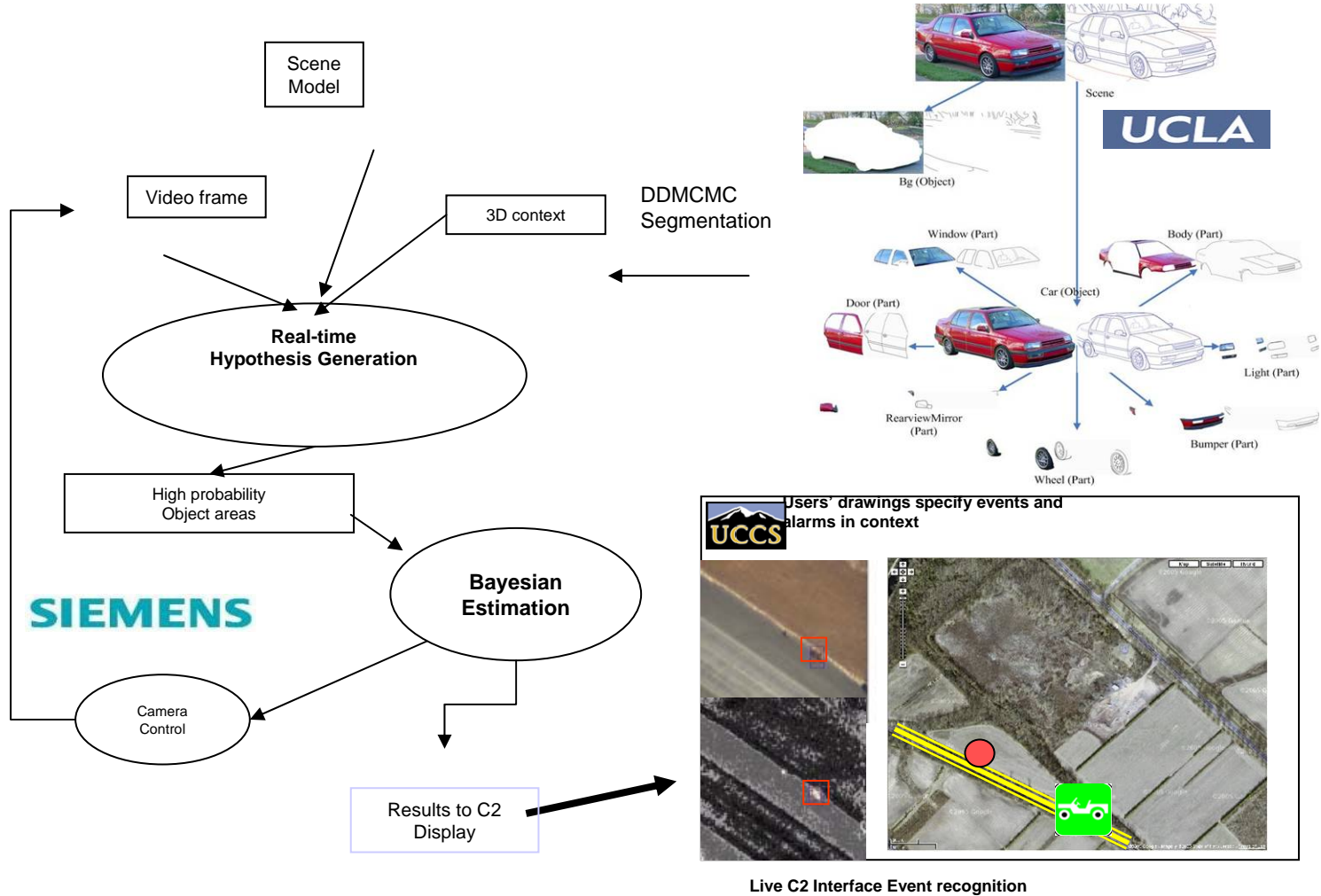
- $H$  represents a threat activity obscured by noise model  $\mathcal{B}^*$
- Formula used to detect whether  $H$  arises by chance or by design

# Ontology Management Services



**The bottom line: if the ontology isn't right, the integration cannot supported.**

# C2Fuse: Supporting UAV-based Change Detection and IED



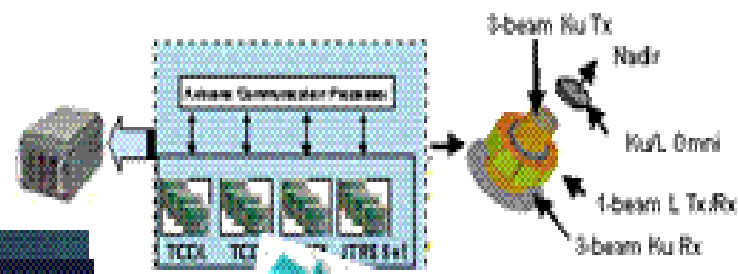
**Developed novel methods for segmenting images into meaningful regions**

# Automated Object Recognition





# High Altitude Airborne Relay and Router Package

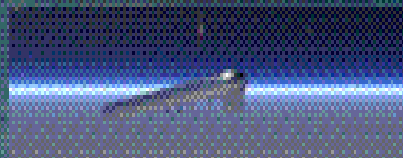


Three basic types of near-space platforms:

- Free-Floaters
- Steered-Floaters
- Maneuvering Vehicles



JP Aerospace's Near Space Maneuvering Vehicle



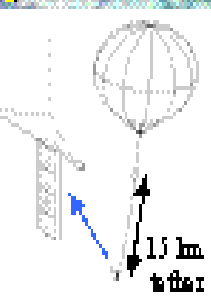
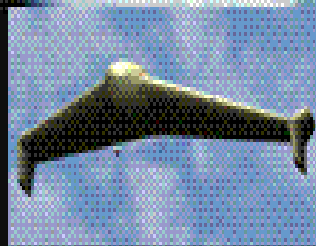
AeroEnvironment's Helios



SpaceData Corp's Sloysite



US Army's High Altitude Airship

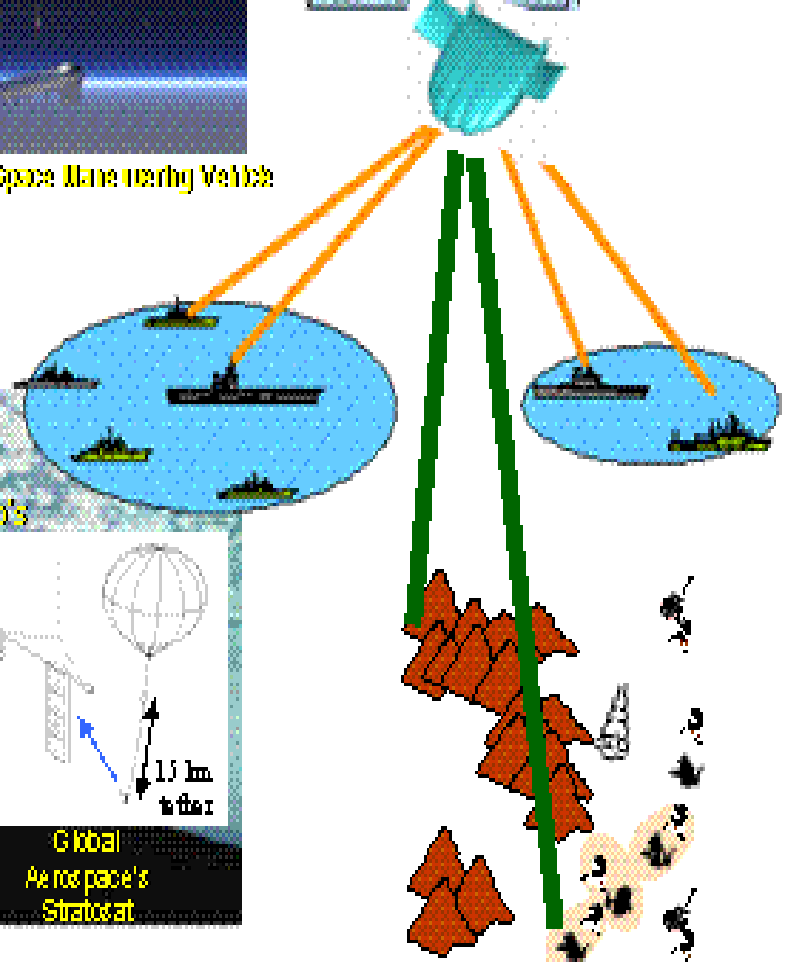


Global Aerospace's Stratocat

Platforms are designed independent of payload

- Mass and power requirements are all that platform cares about
- Inherent flexibility with plug-and-play payloads

New Mexico State University Physical Science Lab's AHAB





# Integrated Digital Apertures and Array Radars Foundation (CY)



◆ Demonstrated multiple simultaneous beams doing multiple comms, EW, and radar functions



▲ Delivered and demoed three simultaneous beam S-Band receive aperture on Lake Erie

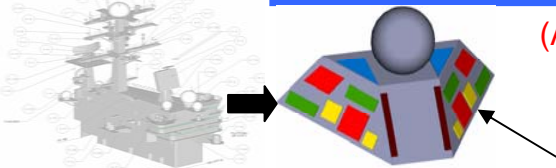
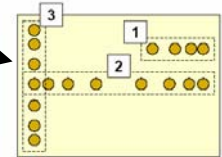


▲ Demonstrated multi-beam X-band and Ku-band TCDL apertures and delivered Ku TCDL to DDX for EMI topside testing and subsequent selection for DDX

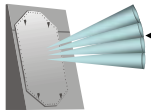
▲ MDA taking delivery of multi-beam C-band transmit and receive apertures based on S-band architecture

Deliver OA Multi-function (HPOI, PDF, SEI) ESM Interferometer to DDX

(Analysis this year lead DDX to remove the top-hat from the topside)



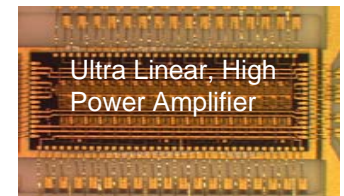
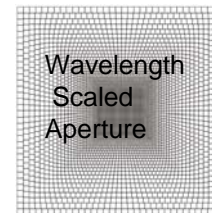
Deliver multifunction UHF / L – Band Line of Sight and SATCOM Aperture suitable for CVN21 or DDX



Open Architecture Digital Array Radar

Cost Avoidance Aperture Architectures and Electronics

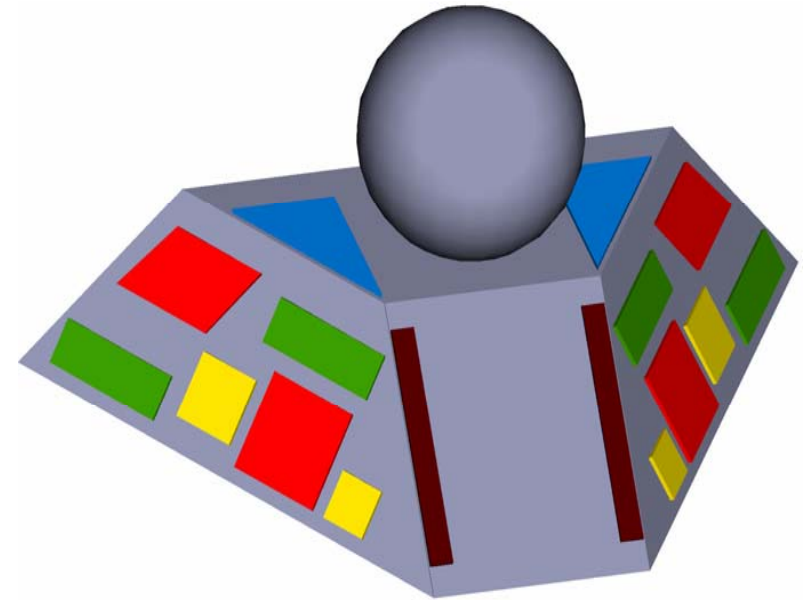
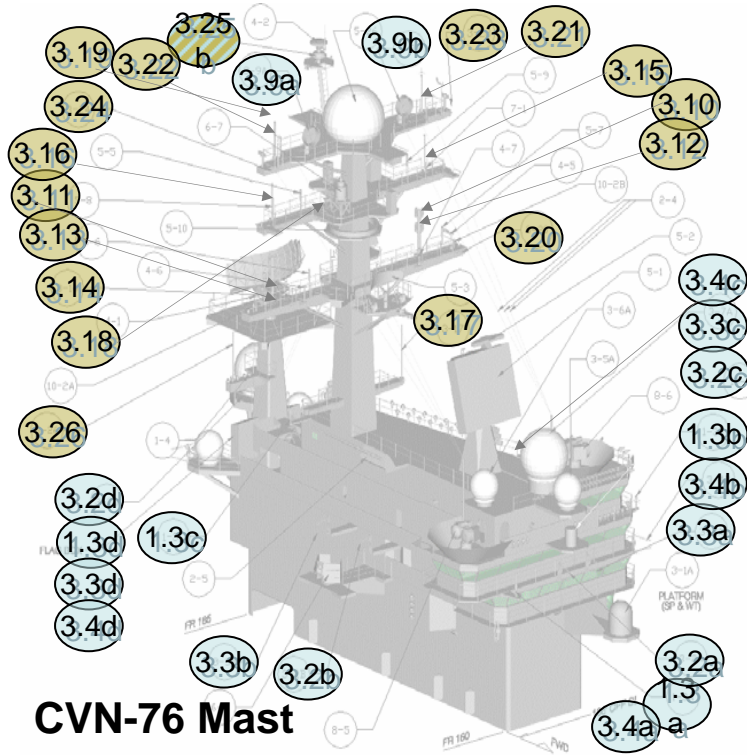
- Motivated \$225M DARPA High Power Amplifier Program
- Motivated \$40M DARPA High Speed Electronics Program



Industry-Navy Partnership on RF Open Architecture Definition

**Significant Experience Base and Transitioned Products**

# UHF/L SATCOM/LOS Aperture



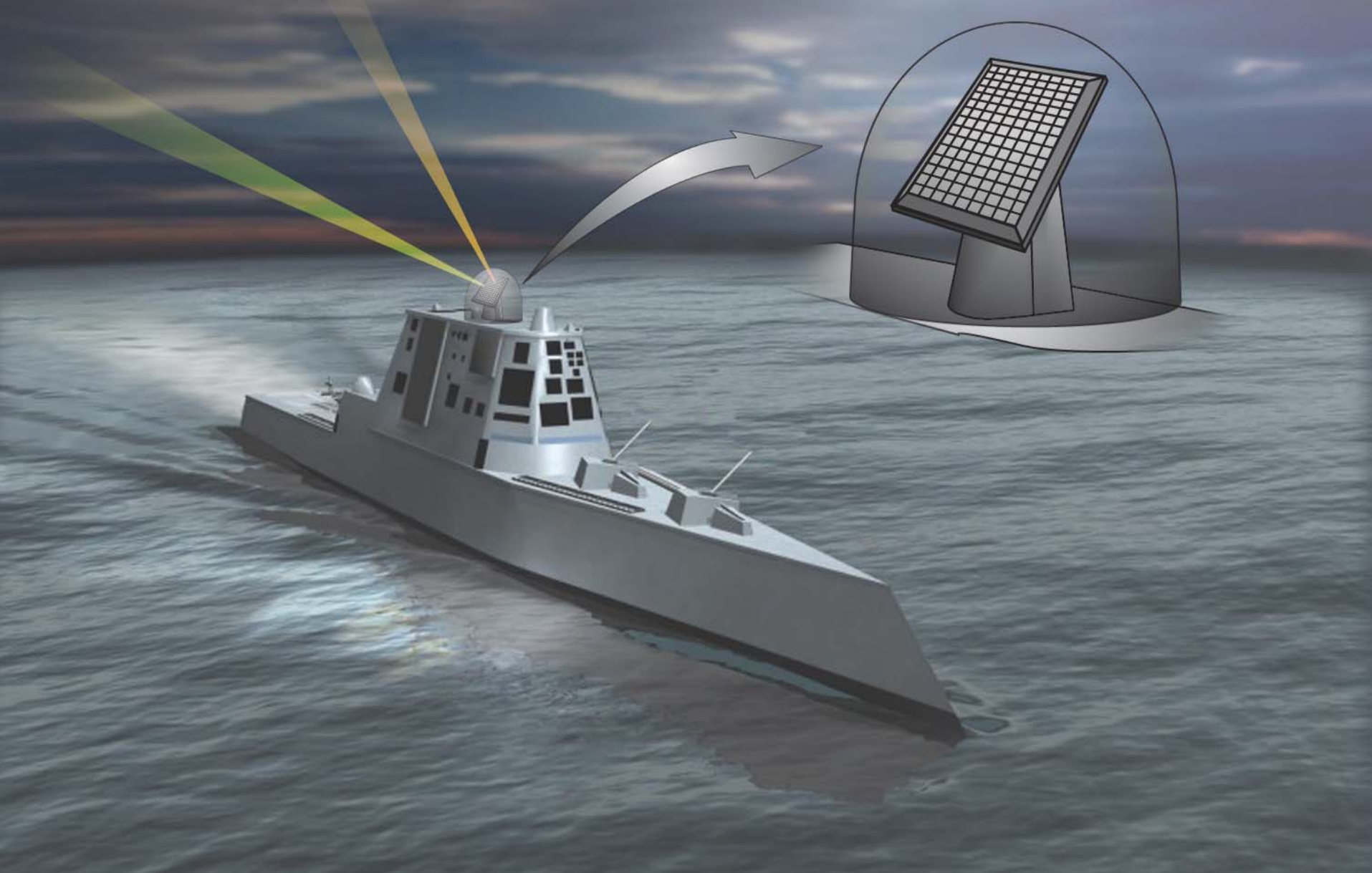
46 to 51 antennas

> 3500 pounds (Ant. Only)



4 panels , 20 meters <sup>2</sup>

< 1800 pounds



Multi-beam, Multi-SATCOM, Trainable Array  
(Replaces five apertures with one)





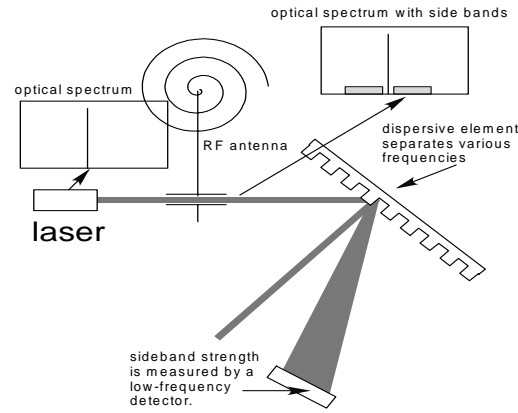


# Miniaturized UAV Sensors

Silver Fox fielded In Operation Iraqi Freedom with 1MEF and Navy SPECOPS in 60 Days



## Passive Millimeter Wave Imager



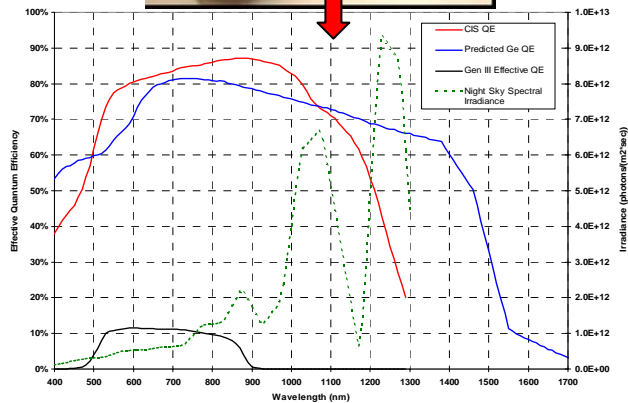
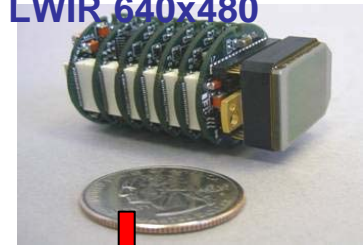
Quad HDTV 1920x1080  
Electronic Zoom + JPG2000



Color 640x480  
120 dB Dynamic Range



LWIR 640x480



# Specific Emitter Identification Capabilities Extension

## Specific Emitter Identification Extended Multi-processor

### Develop, evaluate and test algorithms to address known shortfalls

- Cross Mode Radar Matching - Sample window independent (SWI)
- Low SNR operation - Tree Structure Representation (TSR)
- Align effort with Specific Emitter Identification Program Office (SEIPO) at the National Security Agency
- Address database design

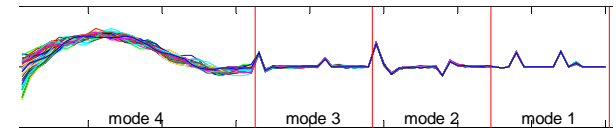
### Implement algorithms in WinSEI Software and SEI Field Programmable Gate Array hardware

- Algorithms will be hardware independent
- Available for community use

### Transition to fielded SEI systems



Received Radar Pulse



SWI Pulse Representation



IFD-120 Next Generation SEI  
Processor mounted on  
VME Pentium card

# Missile Defense S&T

## Sea Shield Future Naval Capability Program

Advanced Technology to test and demonstrate advanced algorithms developed in PE 0602235N for use in Navy combat systems for combat ID and sensor fusion, and supporting a common tactical air picture

★ **Multi-Source Integration (MSI):** Test & demonstrate data fusion algorithms for E-2C Mission Computer

- Integrate multiple organic sensors (Radar, CEC, IFF, ES) with off-board sources (Satellite comms and tactical data links) to support Theater Air and Missile Defense (TAMD) requirements



★ **Advanced Sensor Netting Technology (ASNT):** Test & demonstrate algorithms for combat ID in netted sensor systems

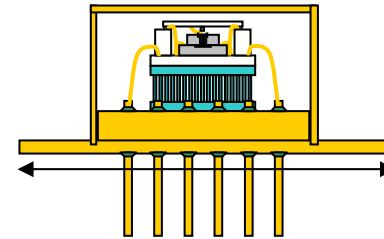
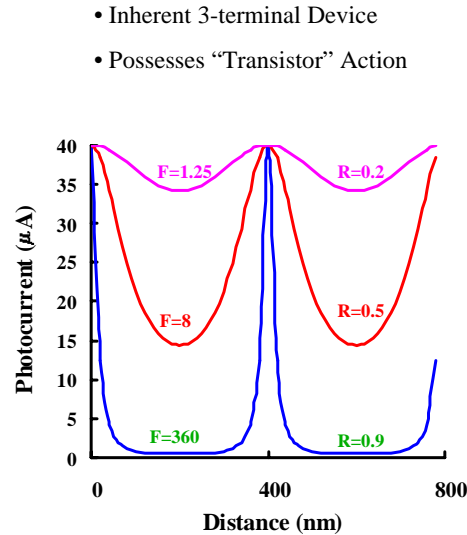
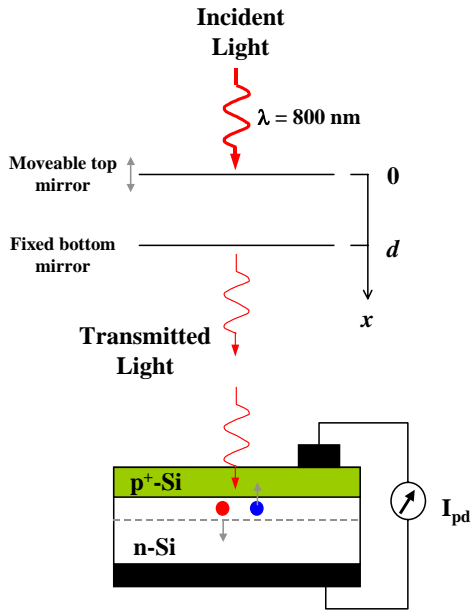
- Integrate electronic support (ESM) data fusion with real time tracks in the future joint/Navy track manager
- Append ID attributes to real time netted sensor air tracks



★ **Composite Combat Identification (CCID):** Test & demonstrate advanced algorithms to build high confidence ID from real time and non-real time sources & sensors

- Real time netted sensor -SIGINT integration, aircraft & surface combatants
- Common reasoning algorithm for all TAMD units in theater

# Electro-Optic Accelerometer



Design and Fabricate Small, Lightweight MEMS Ultra Sensitive Accelerometers for Navigation Systems.

PI: Dr. T. Jones (SSC-SD)



# CONOPS

- An IR camera with a narrow field of view is scanned through 360°, down-looking approx. 4.5° into an annular footprint that covers from within 5 miles of the ship out to 30 statute miles.
- Four UAVs each flying at 70 mph update the inner perimeter in approx. 10 minutes, and update the outermost perimeter in approx. 20 minutes. Points in-between have a graduated update rate.

