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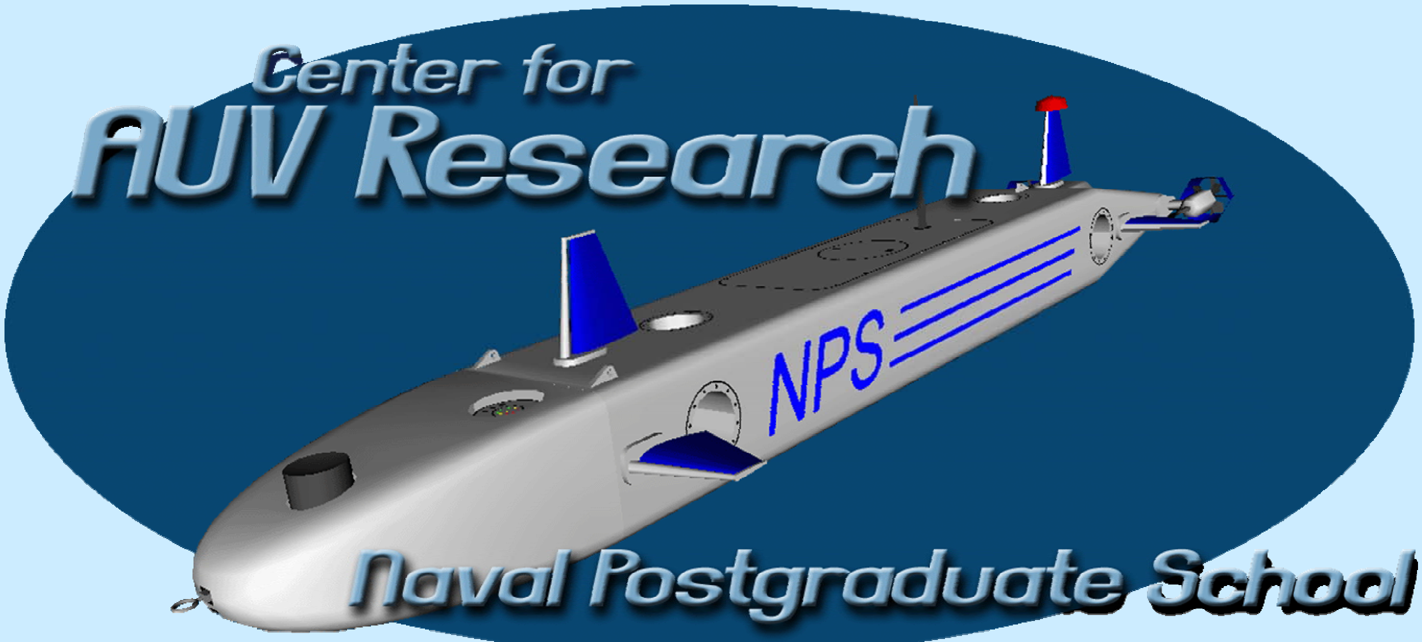
High Bandwidth Wireless Networks for Unmanned Maritime Vehicle Communications



by
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Need Statement

- Unmanned Maritime Vehicles (UMVs) can collect environmental data quickly and economically
- Tactical applications (ISR, OMCM) can benefit from simultaneous deployment of multiple UMV systems
- Data must be collected, distributed, and assimilated into meaningful information quickly
- Volume of data can overwhelm existing comms systems
- **Higher bandwidth communications can significantly improve collaborative UMV missions**

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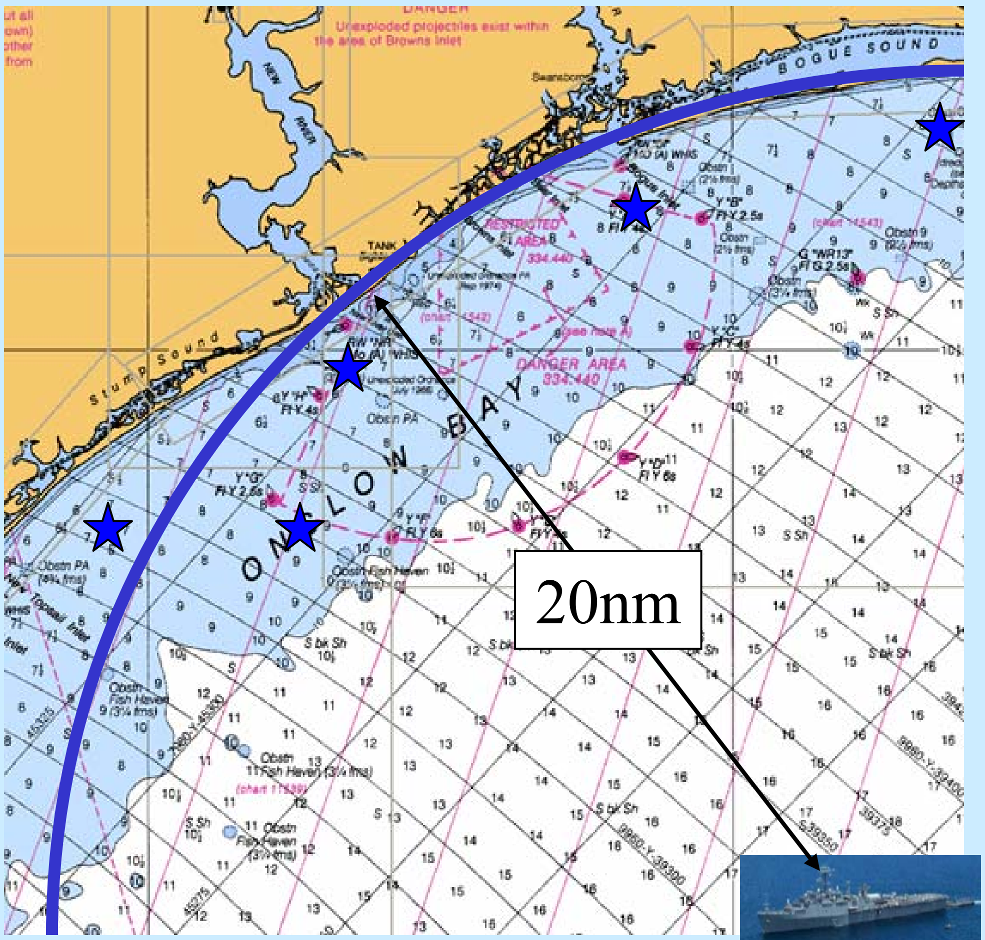
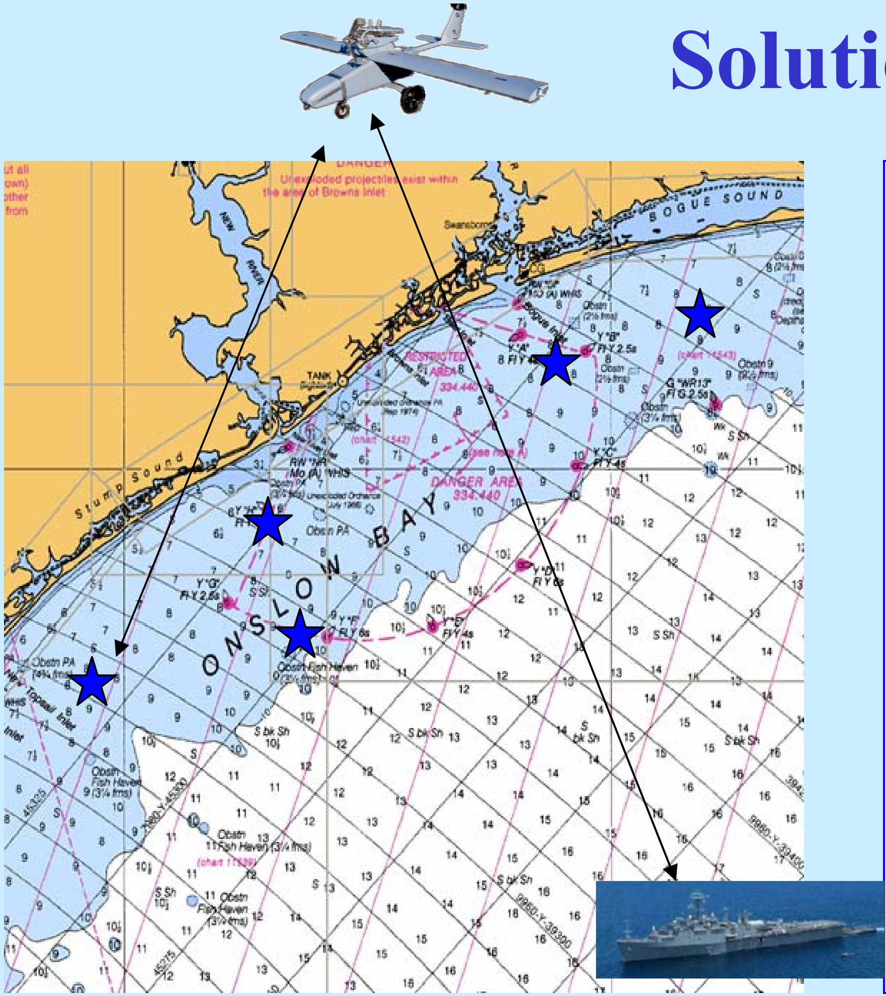
Operational Concept



★ UMV (AUV, USV or Crawler)

- Blue Force tasked with finding the best beach landing site
- Teams of UMVs deployed for wide area reconnaissance & VSWMCM
- Challenges and considerations:
  - –**Interoperability of different UMVs**
  - –**Sonar, video, and bathymetry data is voluminous**
  - –**Data must be passed back for rapid assimilation, assessment & planning**
  - –**Not always feasible (or desirable) for vehicles to return from missions**

Solution



- Enable UMVs with high bandwidth data links (currently 802.11b)
- Employ UAVs to extend comms to C2 ship in international waters

BENEFITS

- Common WLAN architecture
- Overcome comms range limitations
- Increased UMV time on station
- Data transfer: no more “snippets”
- C2: facilitates coordinated behavior

★ UMV (AUV, USV or Crawler)

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NPS ARIES

(Acoustic Radio Interactive Exploratory Server)

FEATURES:

- 802.11B Wireless LAN antenna
- GPS, DGPS receivers, Kearfott INS
- 900MHz Freewave modem
- APL:UW Blazed Array Forward Look Sonar
- Benthos Telesonar Acoustic Modem
- RDI 600KHz ADCP
- Video Camera
- Digital Video Recorder

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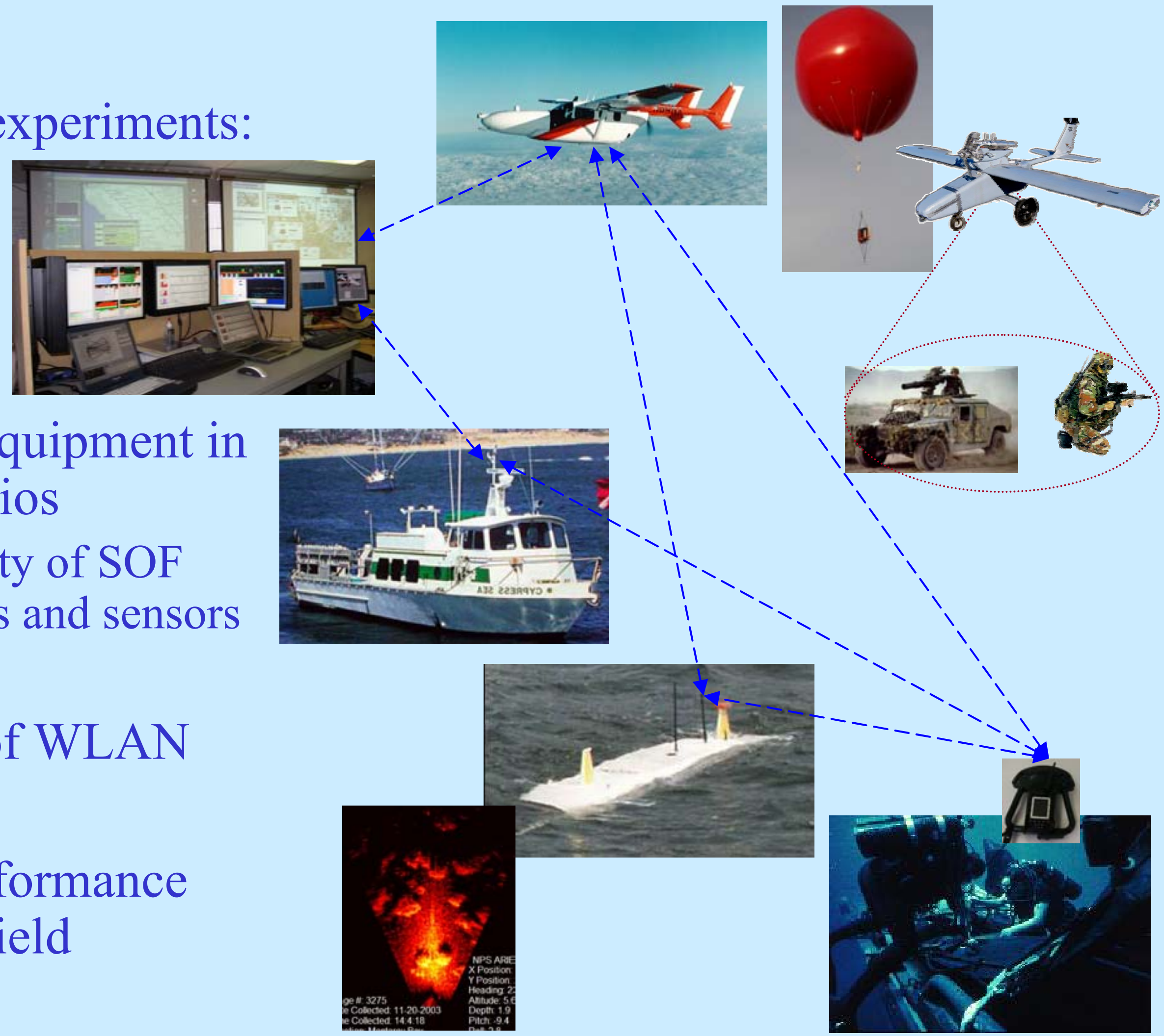
NPS Wireless Network Experiments

- Quarterly USSOCOM field experiments:
  - 2003-04: STAN
  - 2005: TNT
- Employ COTS networking equipment in operationally relevant scenarios
  - Enhance warfighting capability of SOF with wireless links to vehicles and sensors
- Demonstrate tactical utility of WLAN
- Test & evaluate network performance and robustness on the battlefield



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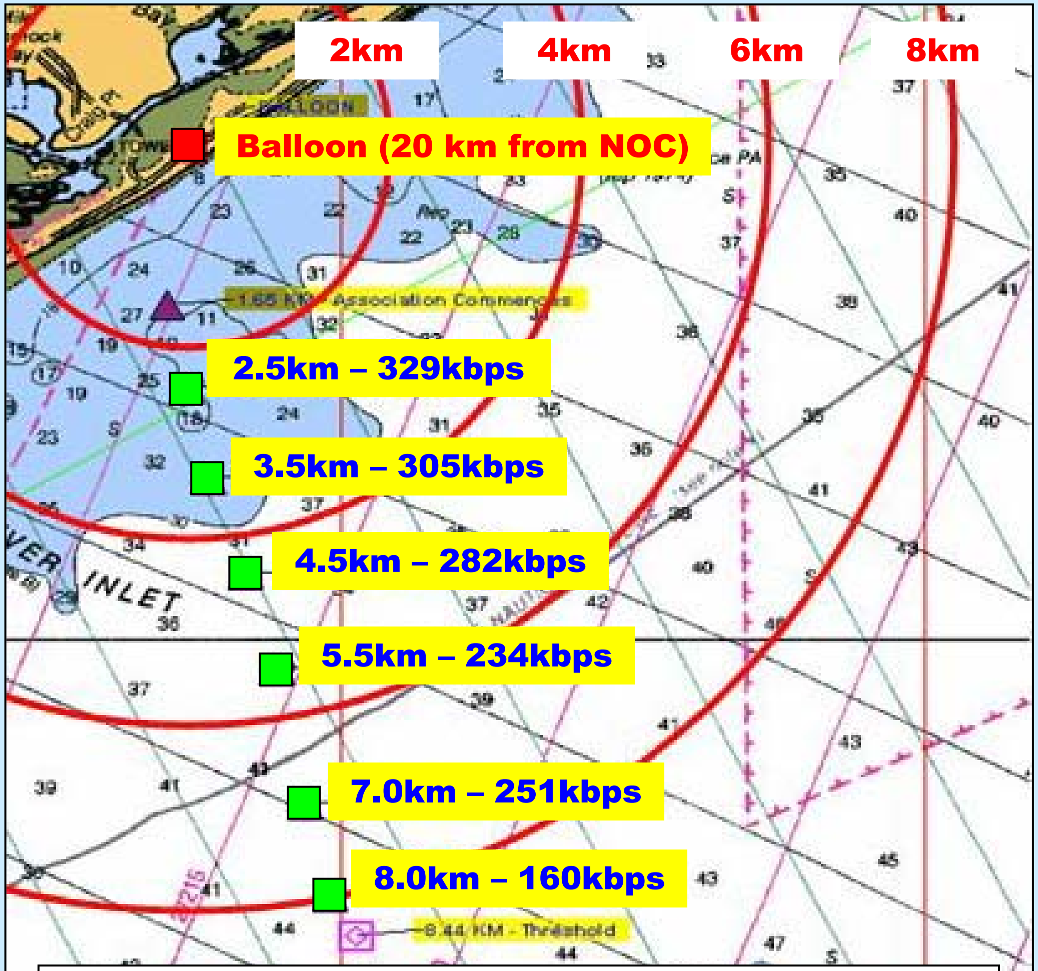
Experiment Results



CJTFEX 04-2 Data Rates vs. Range

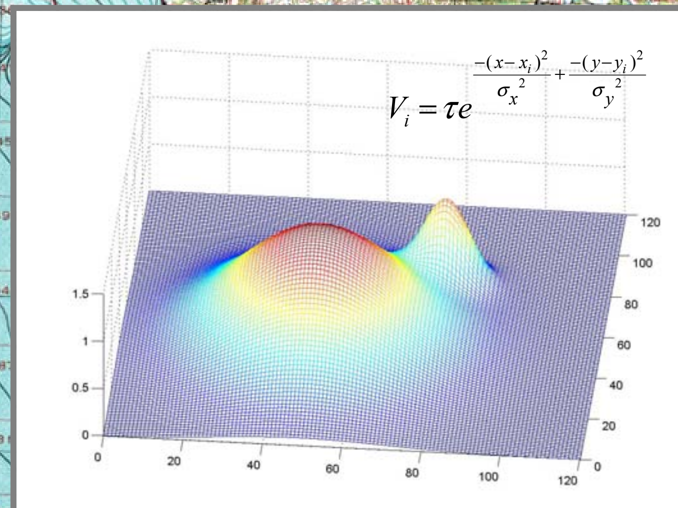
IEEE 802.11b

- Provided a reliable TCP/IP compliant data link
- Total link length of 3 nodes with ranges out to 28 km
- File transfer rate vs. range:
  - 2 Mbps under 1 km
  - 500 kbps from 3 km to 22 km
  - 200 kbps at 28 km

IEEE 802.16 (OFDM)

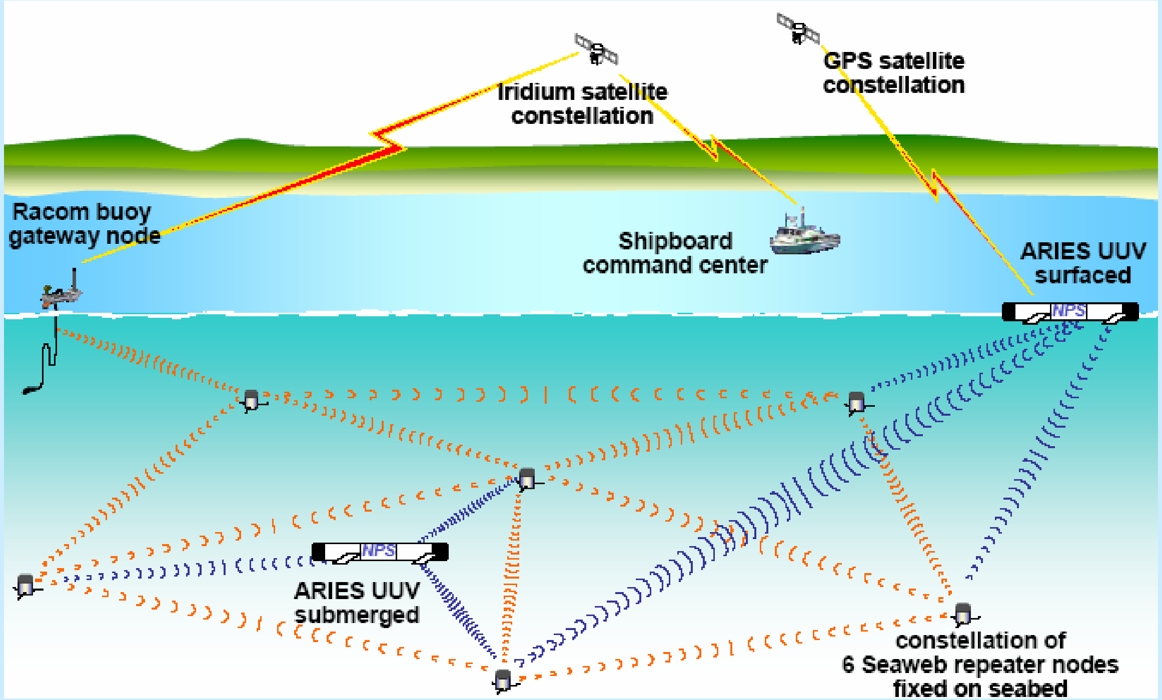
- Max range (LOS) of 13 km
- Used for wireless backbone from NPS to CR (>150 km)
- Data rates up to 6 Mbps

Optimal UAV Positioning



- UAV positioning is critical to maximize data throughput
- Signal strengths of surface nodes can be measured by spectrum analyzer
- Use sensory-based navigation to autonomously position the UAV for optimal throughput
- As surface vehicles enter/exit the network topology, UAV automatically repositions

Seaweb Underwater Comms Network



- Extend command and control comms range (node-node distances of 2500 m)
- Ad Hoc underwater tracking and navigation aid
- Mobile nodes can function as data trucks or communications gateways

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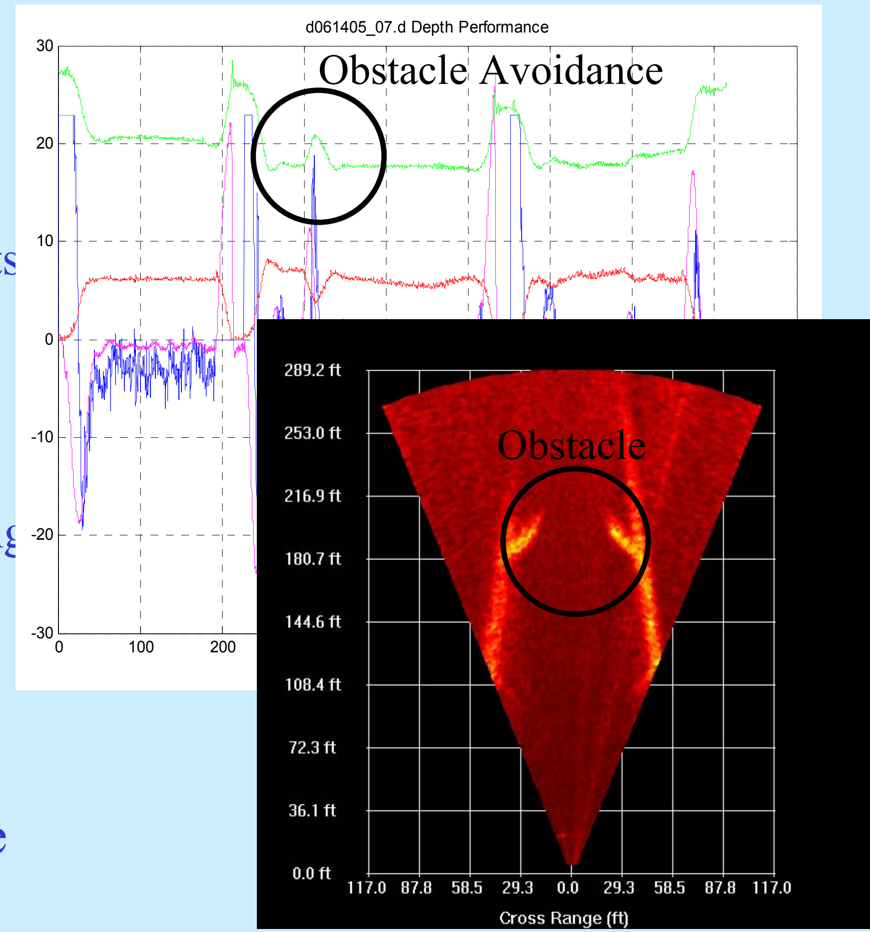
UMV Testing & Data Acquisition

High Bandwidth WLAN

- UMV-recorded data is available instantly
  - –Vehicle recovery not necessary
  - –Wireless download to operators and analysts
- More tests and data per range time
  - –Onsite mission review (i.e. navigation data or sonar imagery)
  - –Permits vehicle re-tasking or reprogramming

Seaweb Underwater Comms Network

- Ad Hoc underwater tracking range
- Extend command & control comms range



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Conclusion

- Benefits of COTS Wireless Networks for UMV T&E:
  - –Low cost
  - –Reliable
  - –Readily available
  - –Easy to administer
  - –Industry standard protocols
  - –Promote interoperability

- Issues requiring attention:
  - –Easy to jam
  - –Security considerations for sending classified data

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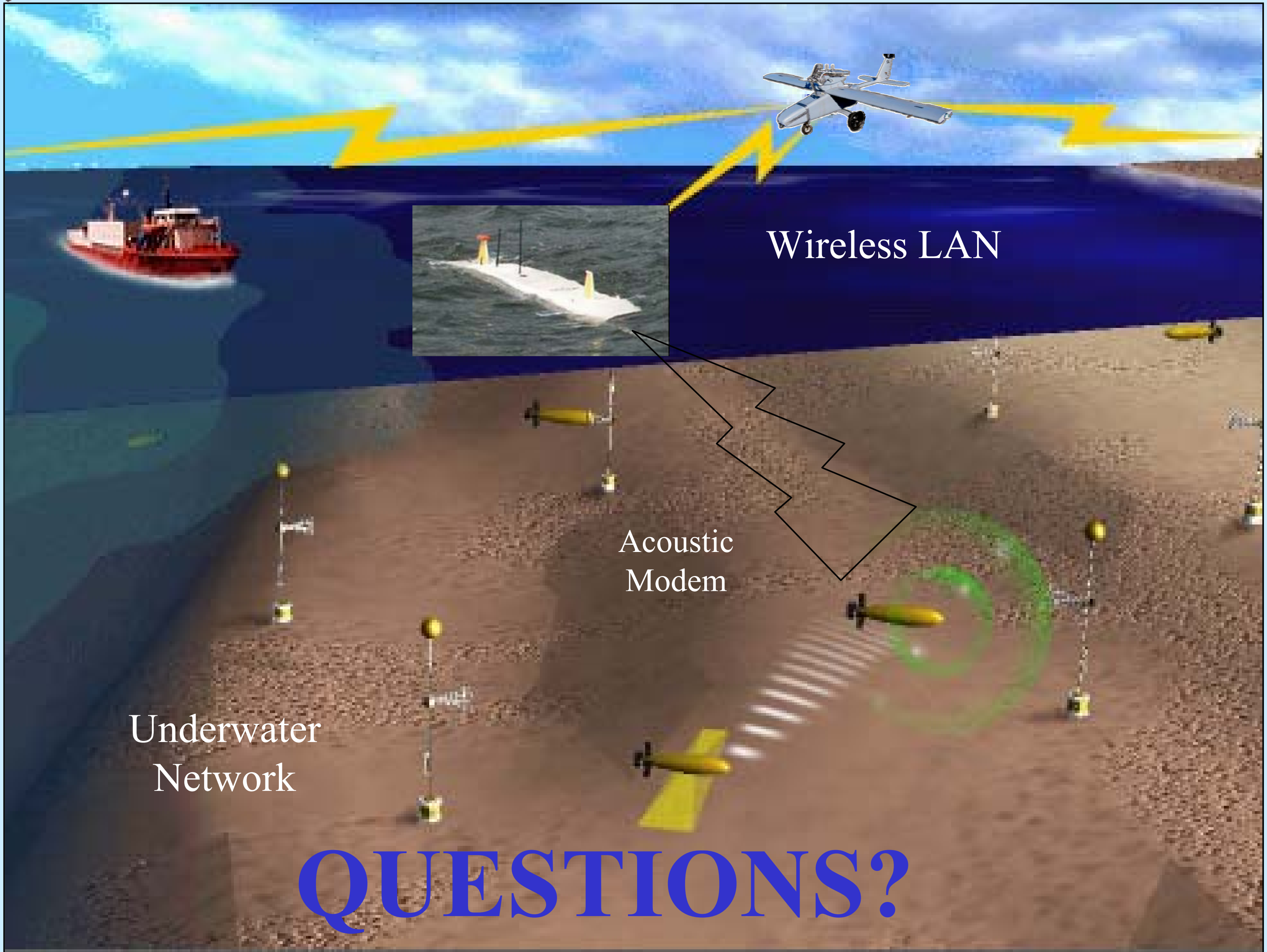


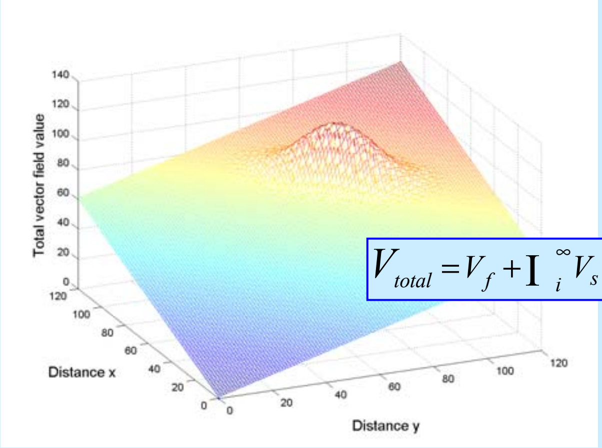
QUESTIONS?

Backup

General Methodology

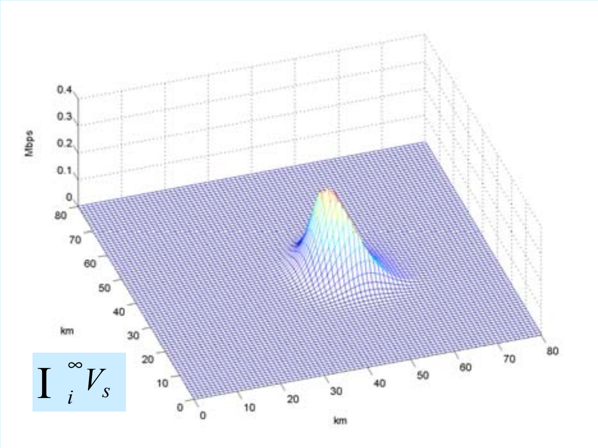
- Model signal strengths with representative Gaussian distributions
- Estimate the intersection of the distributions as another Gaussian fct.
- Use Artificial Potential Fields together with a Sliding Mode Controller to enable autonomous UAV navigation
- Using the intersection of signal strengths from the surface network nodes ensures that there exists at most one global maximum

Total Vector Field



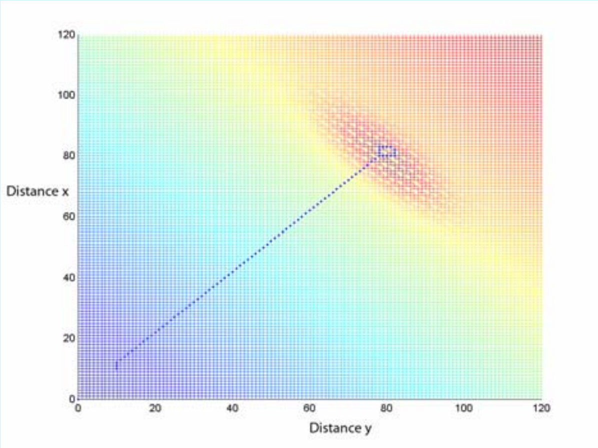
$$V_{total} = V_f + \bigcap_i^{\infty} V_s \qquad for\ i = 1..\infty$$

Intersection of Gauss Functions



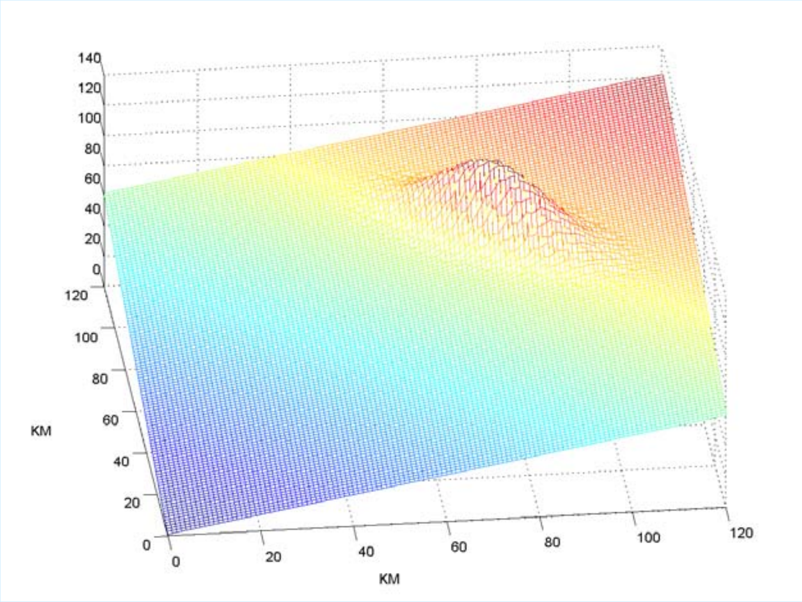
$$\bigcap_i^{\infty} V_s$$

Simulated UAV Nav



Sensory-Based Navigation

- The measured signal strength can be used for UAV navigation
- The intersection of multiple surface nodes signal strength is where the maximum data transfer rate should be.
- Artificial Potential Fields is a technique which can be applied for an autopilot algorithm for UAV navigation



Artificial Potential Fields

- Draws from Potential Field Theory in Physics
- APF traditionally thought of for Obstacle Avoidance
- Basic idea
  - A vector field is constructed consisting of a preferred path and obstacles
  - Desired path has an attractive force (gradient is steep)
  - Obstacles have a repellant force (gradient is shallow)
  - At each navigation step the field gradient is calculated and the vehicle navigations toward the steepest gradient

Artificial Potential Fields

- Limitations
  - –You need to be able to identify the obstacles in advance
  - –Trap situations can occur due to local minima
  - –Difficulties in passage between closely spaced obstacles
  - –Oscillations in the presence of obstacles
  - –Oscillations in narrow passages
- Good News
  - –For this particular application none of these present difficult issues for UAV navigation
  - –The Vector field is an intersection of signal strength vs an additive field so that calculation of the additional attractive object is straightforward.

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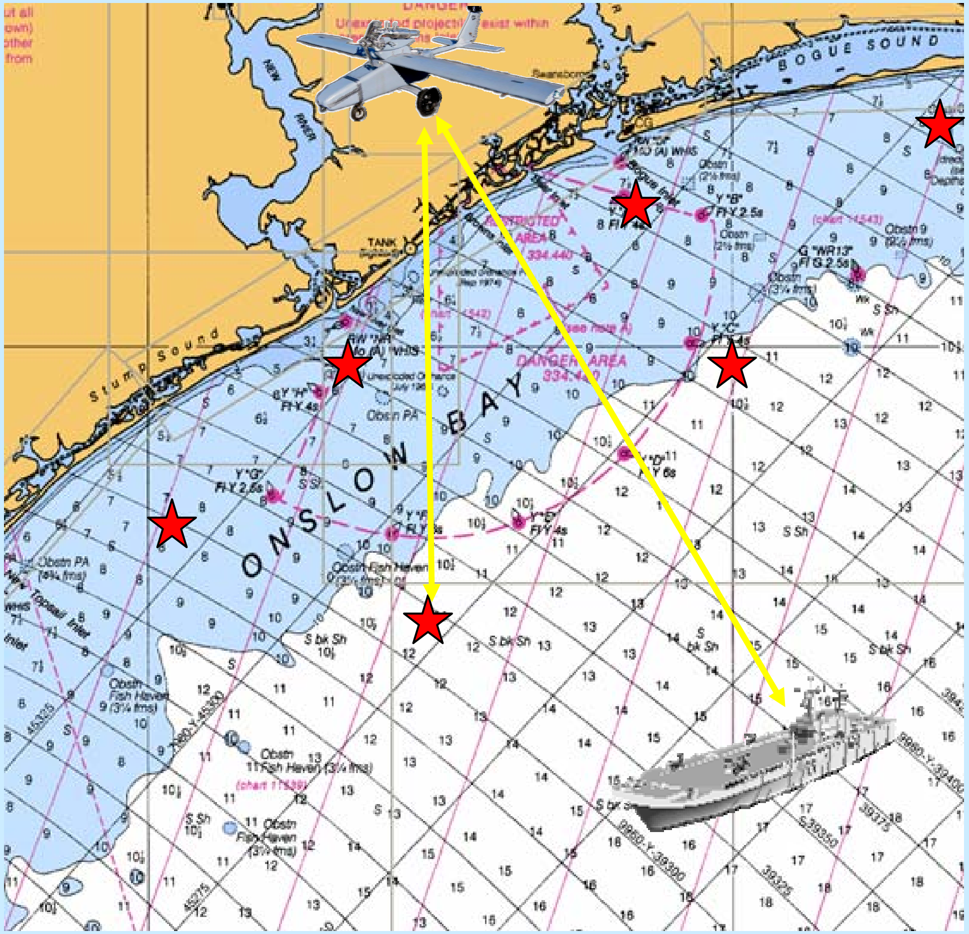
UAV APF Algorithm

(Conceptual Overview)

- Support vessel at sea
- AUV operations are underway
- UAV launches from the ship
- Through prior knowledge and over-flights UAV characterizes signal strength of sea nodes
- UAV start/defaults to waypoint nav
- When AUV surfaces Freewave msg (900MHz) sent to UAV giving position
- UAV calculates the Total vector field and reverts to APF Navigation
- When in vicinity UAV uses onboard sensors for fine tuning positioning



★ AUVs, Crawlers

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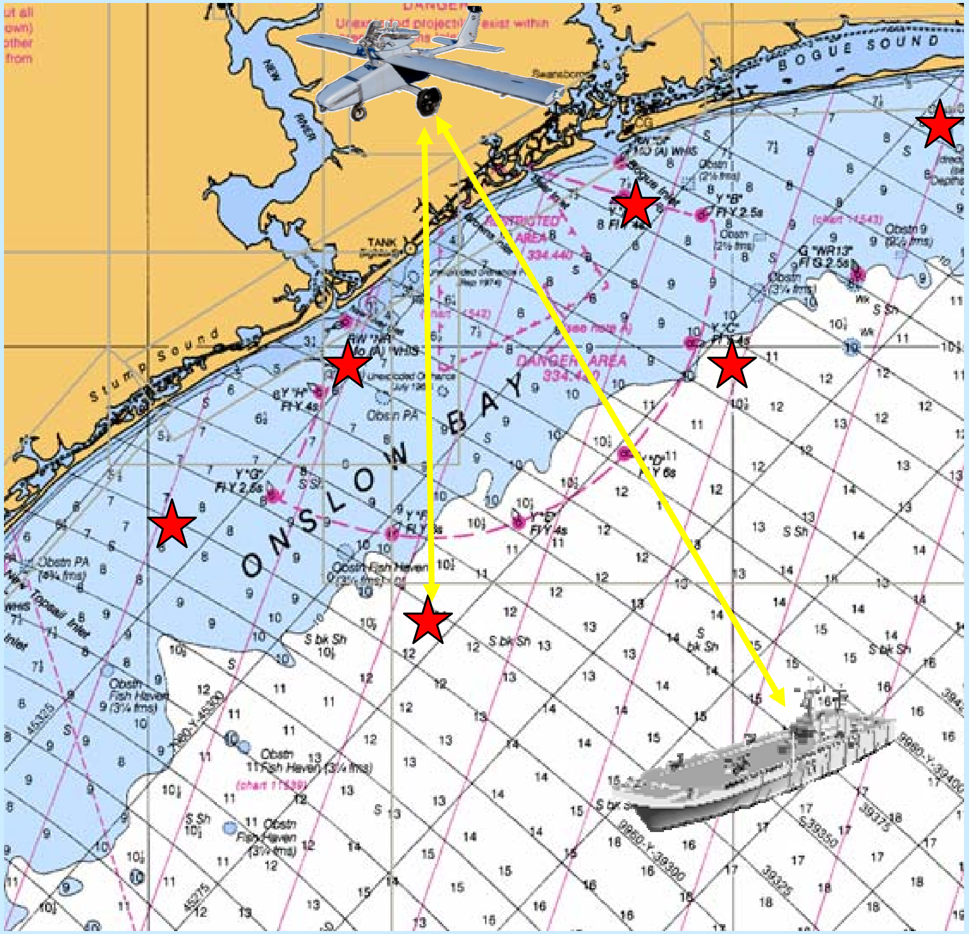
APF Algorithm

(Conceptual Overview - continued)

- As vehicles become available the intersecting calculations determine if there is an optimal position
- If no optimal position is available UAV continues with present loitering position until data transfer is complete
- AUV waiting to transfer data either waits for the UAV to reposition or continue on its mission
- Many other variants possible
  - –UAV collects from one node and acts as a data bus



★ AUVs, Crawlers

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APF UAV Navigation

(Mathematical Steps)

- Initially using a Gaussian equation to model the SNR ratios of the surface vehicles.
- Construct the intersecting volume – again modeled as Gaussian volume using the max/mins to determine σ_x σ_y
- Orient the volume to the vector field through Euler azimuth tranformation
- Bearing calculated based on the highest gradient in the vector field