Panel Session #3

Scalable and Robust Distributed Collaboration

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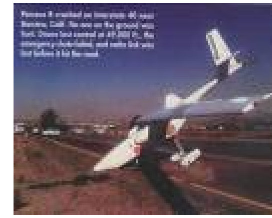
Marc Steinberg
Behzad Kamgar-Parsi
Mike Benjamin
Mitch Potter
Mike Traweek
Terri Paluszkiewicz
Bob Brizzolara

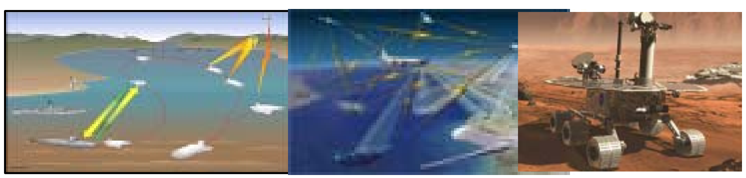
Limitations of Current Autonomous Systems


-Large unmanned systems require multiple highly skilled/dedicated operators
-Cannot easily share assets, collaborate, or get data to the tactical edge

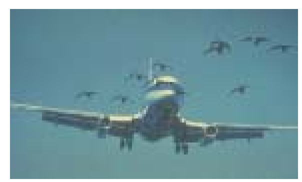

-Forward deployed units often have dedicated operators (require protection)
-Data from small systems often does not get disseminated to broader networks




-Poor robustness requiring substantial human intervention to maintain performance in unplanned or unexpected situations



-What autonomy exists is usually tailored only for specific missions, users, and environments
-Heavy reliance on pre-programmed plans & decision logic
-Cannot easily be adapted to the unexpected or to broader missions



-Not as smart as animals in some respects
- Major limitations in operating in challenging weather
-Cannot exploit environmental conditions (e.g., soar on thermals), perch, hide, take shelter, etc.
-Dependent on GPS & reliable maps
-Cannot collaborate in close proximity to others without collisions

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Scalable and Robust Distributed Collaboration

- Goal:
  - Manage large numbers of systems at a mission rather than vehicle level
  - Robust self-organization, adaptation, and collaboration among highly heterogeneous platforms and sensors in a dynamic battlespace
  - Decentralized control system that is flexible in its level of autonomy, with the ability to get the right information to the right user at the right time

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Scalable and Robust Distributed Collaboration

- Decentralized coordination and planning for safe navigation, sensing, and mission accomplishment with limited communications
- Scalable
  - 10’s, 100’s, 1000’s of elements
  - Operations up to large, complex areas (e.g., coastline, crowded port, sea base, convoy route, etc.)
  - Speed of Adaptation/Response from seconds (e.g., force protection) to days (e.g., env. monitoring)
- Supports Complex Mission tasks/Environments
  - Highly heterogeneous platforms, sensors, communications
  - Strong need for collaboration among elements
  - Need for survivability, covertness, time-critical execution, staying within complex constraints, etc.
  - Novel/unexpected situations, uncertain/partially known information
  - Safe operation in close proximity to other manned and unmanned systems and units
- Synthetic Perception from distributed taskable sensors
- Support of Human/Unmanned System Interaction
  - Enable humans to shape and redirect its plans/behaviors/capabilities in real time to meet the ever changing requirements of warfighters operating in a dynamic battlespace
  - Allow for flexible tasking, guidance, & human-directed learning of appropriate behaviors and tactics

State of the Art

- TRL 5-6 - Mission-Level Tasking of small numbers of heterogeneous unmanned systems
  - Experimental results from several programs support the viability of managing multiple heterogeneous unmanned systems on the basis of high level mission objectives, priorities, risks, constraints, etc.
  - Technical challenges remain in many areas including overconstrained tasking, robustness, increasing flexibility of tasking, allowing for very rapid ops tempo, etc.
  - Greater numbers of systems have been incorporated by simplifying the environment/mission tasking/ops tempo, operating in scripted/structured environments, or increasing the number/skills of human operators

- TRL 1-4 – Decentralized control of tens of systems
  - More scalable approaches have been demonstrated in several limited scope experiments
  - These approaches may be limited to simple mission tasking, homogenous vehicles/payloads
  - Not clear how to enable warfighters to interact with these complex systems of systems
  - Challenges in ensuring system will perform tasks either within a time-critical constraint or at all.
  - Many of these approaches were developed empirically and there is lack of analytic understanding

Solving the problem for either scalability/ops tempo or mission/environmental complexity is a huge challenge. Achieving both may require some radically new approaches

Currently Funded Research

- Multi-Disciplinary University Research Initiative
  - Biologically-Inspired Team & Coalition Formation of Heterogeneous Unmanned Systems for ISR of Large, Complex Areas
  - Highly Decentralized Autonomous Systems for Force Protection and Damage Control

- Several modest-sized ONR D&I and NRL Base Funding Efforts
  - Design & Prediction of Swarm Behaviors
    - Development of rigorous mathematical methods & design for specific tasks
  - Physicomimetics Approach for Swarm Behaviors
    - Decentralized behavior where autonomous agents react to artificial physical forces
  - Dynamic Co-Fields Approach for Control of Unmanned Sea Surface Vehicles
    - Emergent Approach applied to area search, track & trail, intercept with USVs

- Several FNC & INP efforts contain relevant technologies as parts of their efforts, focusing on specialized missions/operating environments
  - Large Tactical Sensor Network
    - Marine Corps/SOF small unit tactical intelligence requirements with small numbers of unmanned air systems and unattended ground sensors
  - Undersea Cooperative Cueing & Intervention
    - Search a large area for mine-like objects using undersea and surface vehicles
  - Adaptive Wide Area Cluster for Surveillance
    - Clusters of Underwater Unmanned Vehicles optimize ocean surveillance

Tough Problems: Panel Three

- Scalable, self-organizing, organizational structure/hierarchy appropriate to mission tasking
  - Robust to limited communications and uncertain or partially known information
  - Appropriate relationship between individual/team/coalition global intelligence
  - Deals with intelligent adversaries robustly
  - Trade-off numbers vs. capability

- Task allocation/assignment, planning, coordination & control for heterogeneous systems
  - Tasks have spatial/temporal dependencies w/ logical constraints
  - Structuring of the on-board autonomy to balance multiple competing and conflicting performance metrics, and individual platform vs. group objectives.

- Airspace/Waterspace management
  - Operation in close proximity to other manned and unmanned systems

- Rigorous mathematical methods and testing tools
  - Predicting behaviors of large numbers of systems under realistic assumptions
  - Field testing approaches to identify potential problems and prove capabilities
  - How should we define stability, robustness, performance, controllability, etc.?
  - Tools for software verifiability and certification of complex autonomous systems

Solving the problem for either scalability/ops tempo or mission/environmental complexity is a huge challenge. Achieving both may require some radically new multi-disciplinary approaches

Panel 3 Capabilities

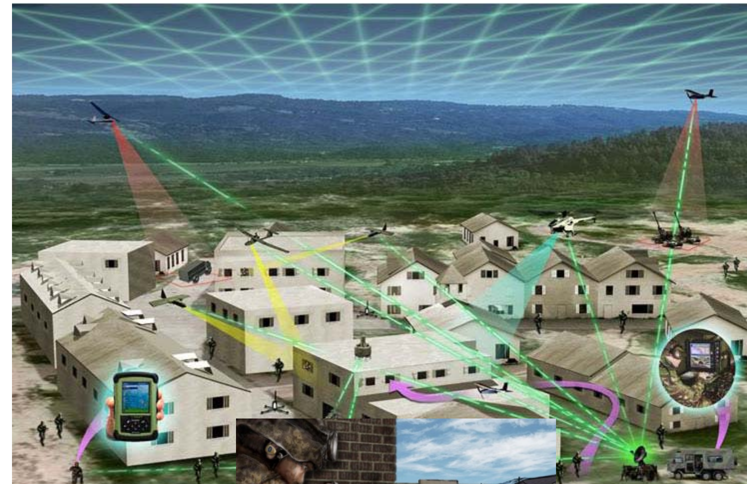
- Get automomous team services to the tactical edge
  - User requests the “what” and not the “how”
  - Helps find mobile, difficult to detect/ID targets in difficult terrain/environments
  - Provides tactical intelligence for unit self-protection
  - May act in way to minimize chance of enemy detection
  - Minimize chances of collateral damage/friendly fire through increased information

- Multi-UV Teams for Force protection in the littorals
  - Unmanned forces sent ahead of high-value manned assets
  - Detect, provoke, disrupt asymmetric threats
  - May act as decoy, absorb enemy resources, or limit enemy options
  - Decentralized with very fast adaptation/reaction when needed
  - Operates in close proximity to manned platforms safely
  - Limited manning on-board ships to operate

- Large, Adaptable, and Extendable Sensor Network
  - Limited network in place that can be extended/activated as required
  - Humans can interact at different levels with the system from a remote user to a human collaborating with unmanned systems directly
  - Mobile systems can operate around manned systems safely
  - Can provide data on threats that are difficult to detect/ID, but substantial need for human involvement.

Tactical Sensing Team - 2020

- Individual warfighters can directly get services from teams of up to 30 unmanned vehicles and up to 100 unattended sensors
- Increase in mission complexity
  - Perform multiple tasks simultaneously
  - Distributed search/surveillance of multiple locations
  - Track multiple targets moving in different directions
  - Tripwire for potential threats

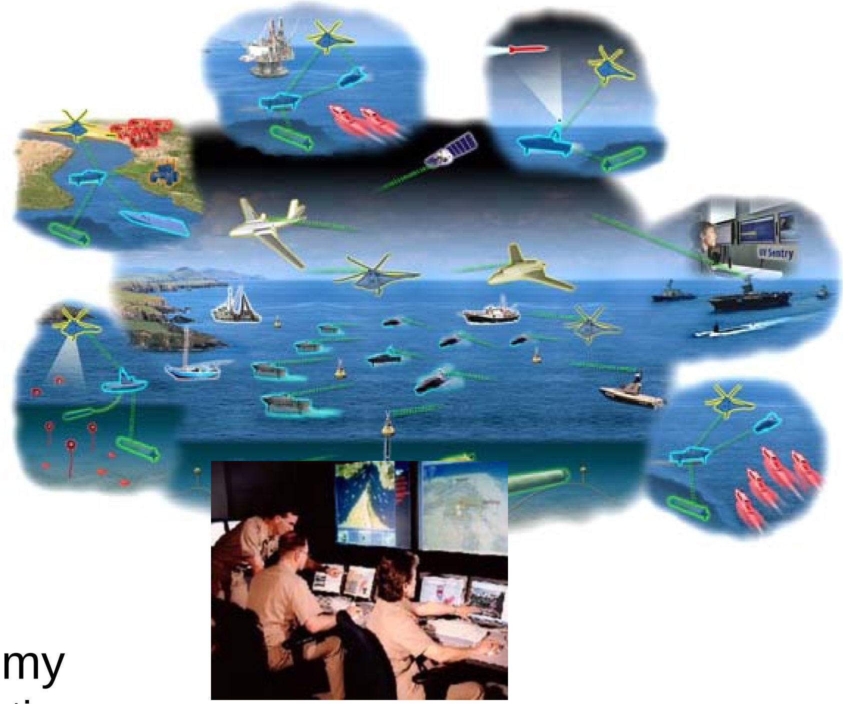


- Robustness, decentralized system
  - Vehicles dynamically redistribute tasks
  - Robust to loss of individual platforms/comms
- Low-Cost Dispensable Vehicles
  - Man-portable systems carried by the warfighter
  - Systems dispersed stealthily by larger unmanned vehicle or manned platform
- Larger, more capable unmanned vehicles may be made available to accept warfighter service requests within constraints set by operator

Warfighter tells the system what he wants to know & what the tactical considerations are. System figures out the how.

Autonomous Littoral Teams - 2020

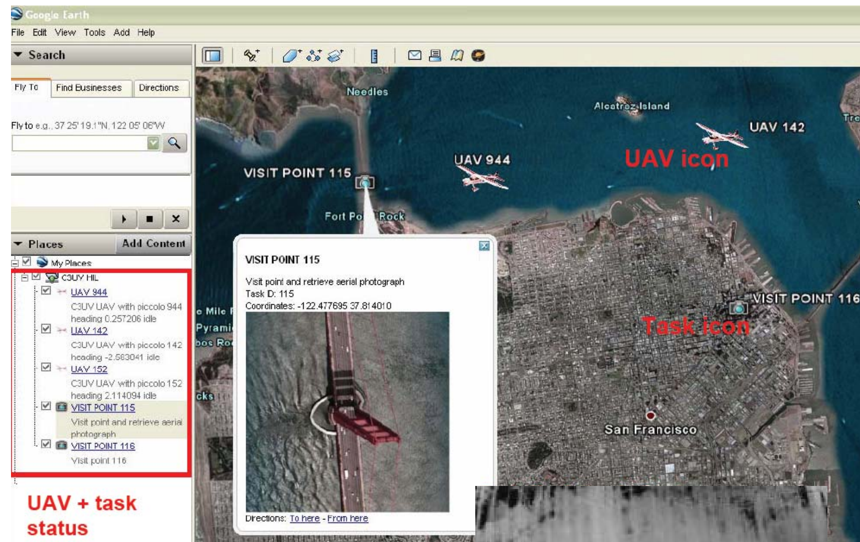
- Multiple watchstations control multiple teams of unmanned systems
  - 6 teams of 5-10 air/sea/undersea vehicles - MCM/ASW/ASuW/ISR/Expeditionary Ops
  - Can share resources/collaborate
  - Systems rapidly tasked at a mission level
- Improved situational awareness
  - Better, more timely information
  - Increased geographical coverage
  - Improved information for the user
  - Multiple sensing modalities
- Discern threats/provide alerts sooner
  - Unmanned vehicles and sensors in harms way instead of a manned platform
  - Provides sensor info not previously available
  - Early warning of an attack
  - Provoke/stimulate potential threats
- Survivable system with collaborative autonomy
  - Provides system redundancy and reconfiguration,
  - Mission accomplishment even if some unmanned platforms are lost.
- UVs may absorb enemy resources, hinder their effectiveness, act as decoys,
- Airspace/Waterspace management to allow operation in close proximity to manned assets in many cases



Mission-level tasking allows the operators to shape & redirect plans & behaviors at a high level, so that a given operator can handle more assets

Large, Adaptable Sensor Network - 2020

- Multiple operators/users task system with 100+ mobile & fixed sensors
  - Can remain in place for long time periods & be activated as needed
  - Improved information for the system users due to many sensing modalities and using synthetic perception
  - Faster retasking of sensors due to collaborative autonomy
  - Systems tasked at a mission level
- Work directly with human team-mates
  - Hybrid manned/unmanned teams
  - Complex tasks such as hull/pier search
  - Airspace/Waterspace management for greatly reduced separation
- Fusion of data into common operational picture while still allowing drill down to support specific user needs
- ID difficult threats using multiple sensor modalities/viewpoints
- New sensors/platforms can be added to the network as needed and become available to do tasks



Provides pervasive sensing and wide variety of ways for users to interact with network resources