Role Of Health Awareness In Systems Of Multiple Autonomous Aerospace Vehicles

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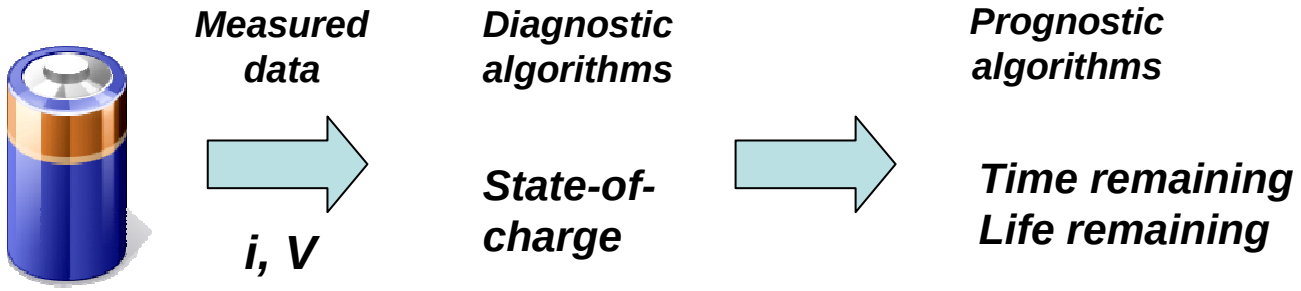
A few questions to explore …

- **What do we mean by health awareness?**
- **Why is it relevant and how is it being used for autonomous aerospace systems?**
- **What are the challenges and opportunities?**
- **What approaches are being used?**
- **What are the latest results and directions?**

What do we mean by health awareness?

- **Health management is widely used to understand the state of a system: diagnostics.**
- **Significant benefit is also derived from looking forward and evaluating capability: prognostics.**

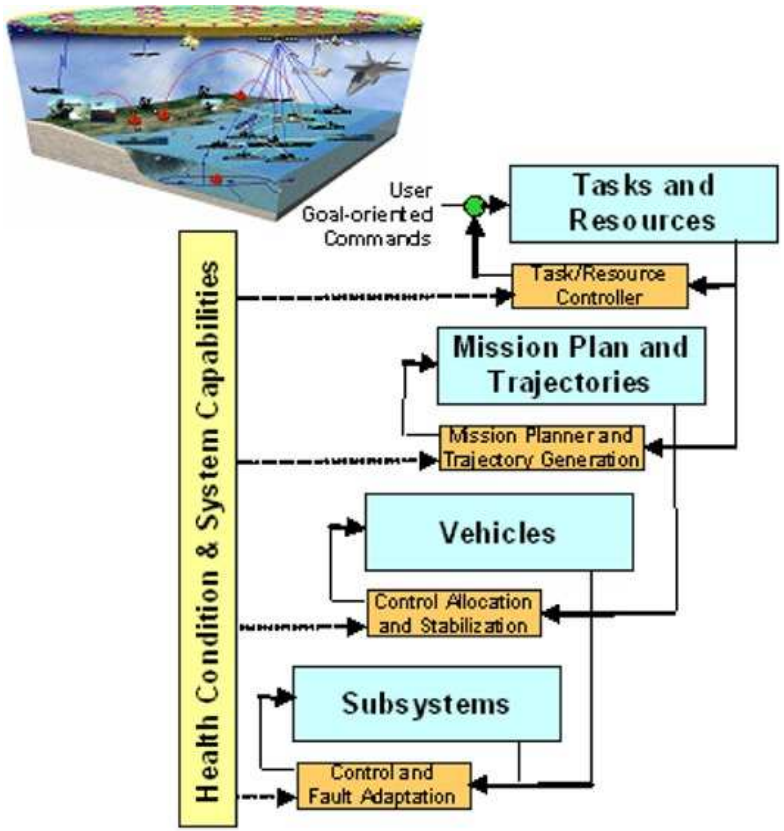


- **Related aspect is redundancy management such as in flight control systems.**

Why is it relevant? How might it be used?

Health-adaptive systems for mission assurance

- Prognostic health management technology advances are enabling real-time reconfiguration and mission adaptation.
- Goal is to achieve operational reliability as systems become more complex, highly coupled, and autonomous.
- Increase operator effectiveness by reducing need to manage individual vehicles.



Health-based adaptive control architecture for hybrid systems-of-systems.

What are the opportunities?

DARPA Fractionated Spacecraft (F6 Program)

Concept: DARPA

AFRL Foxhunt Demonstration
Multiple unmanned aircraft control from an airborne mothership

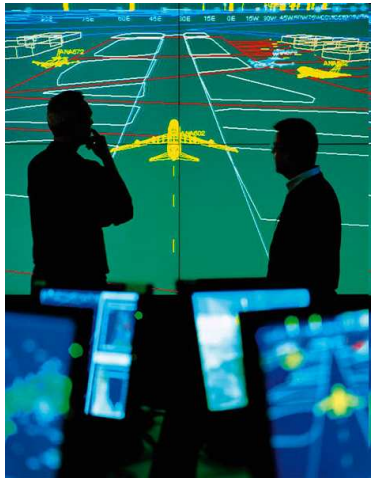
ScanEagle Compressed Carriage, (Photo:Boeing)

Unmanned Aircraft Systems Integration in the National Airspace System / UAS in the NAS

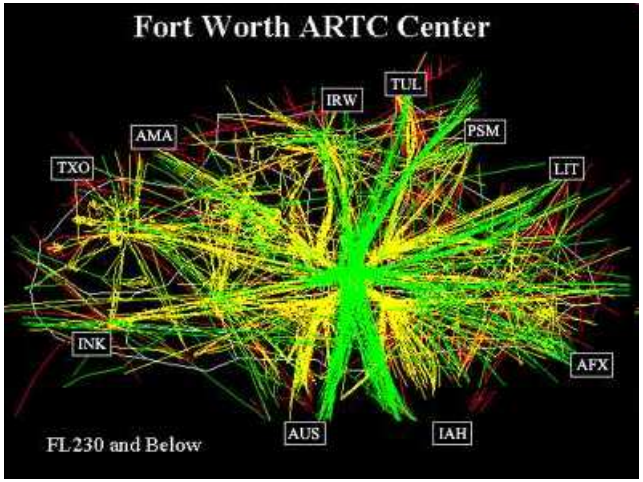
Concept: NASA

What are the challenges?

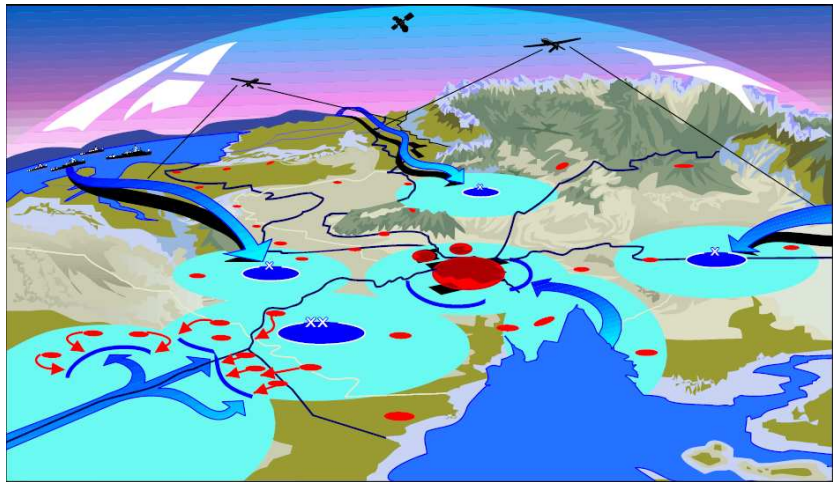
- **Systems are in development that involve complex interactions between vehicles and their environment.**
- **Challenge of developing technologies and evaluating them in terms of system performance.**
- **Need to understand common requirements across mission types and roles of various emerging technologies.**



Source: Boeing



Source: http://virtualskies.arc.nasa.gov/



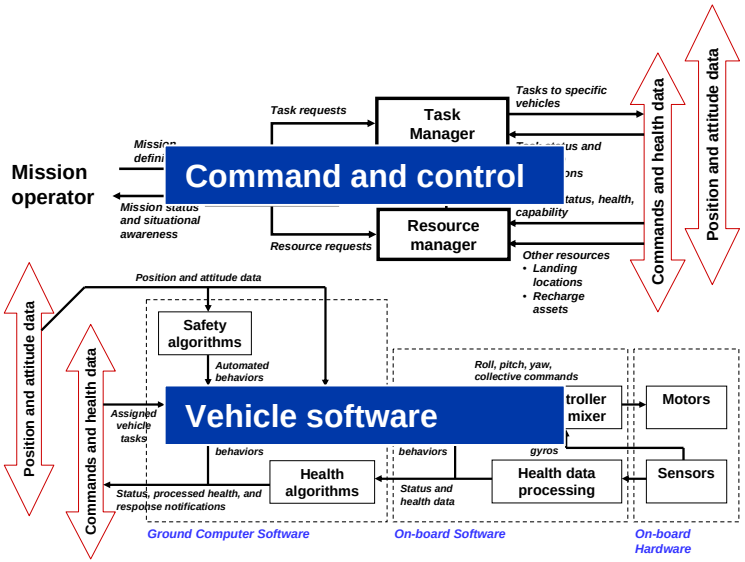
Source: "Future Combat Systems: Its Origin and Operational Concept," Major General Robert H. Scales, USA (Ret)

What approaches are being used?

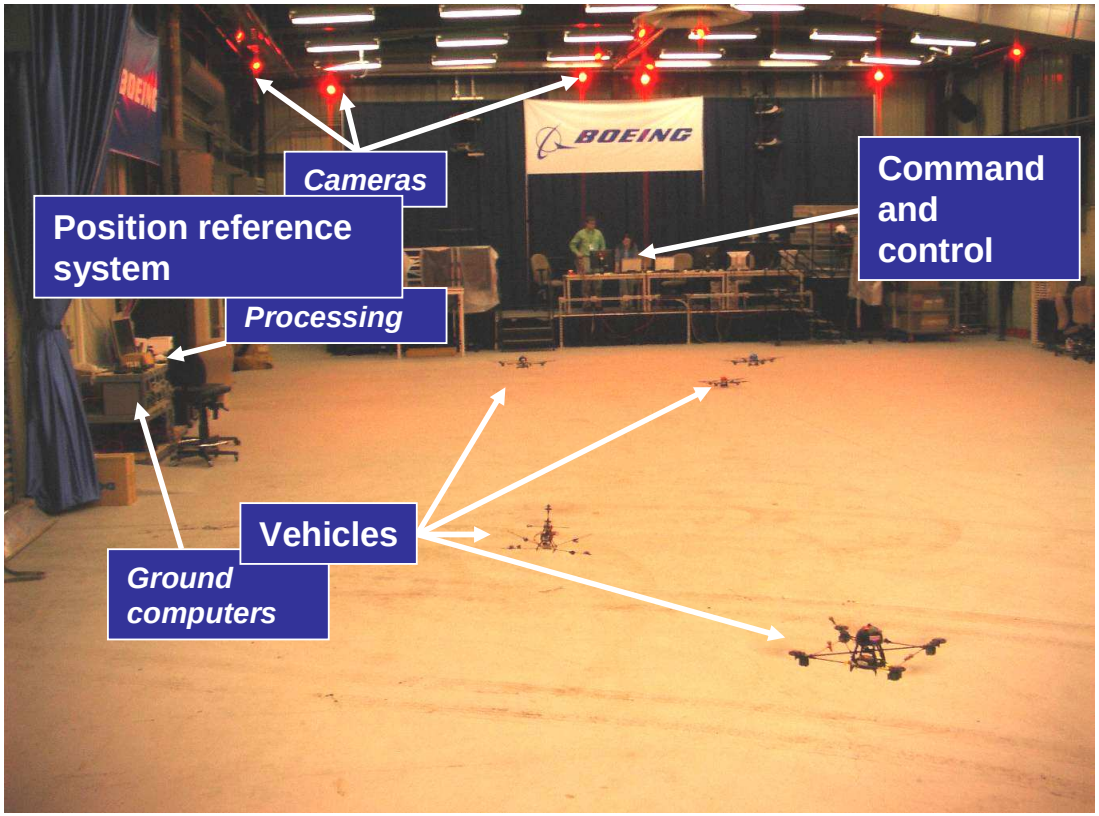
- **Utilize an indoor flight facility for rapid prototyping and evaluation of concepts and technologies.**
- **Exploit advances in motion capture and embedded electronics to minimize development time and cost.**
- **Focus on modular architecture and encourage cross pollination of technologies and researchers.**
- **Include health awareness and behaviors at all levels.**

What is our approach? Vehicle Swarm Technology Lab

- **Three primary elements include (i) position reference system, (ii) vehicles, and (iii) command and control.**
- **Result is increase in flight test hours, maturation, experience.**



Vehicle hardware



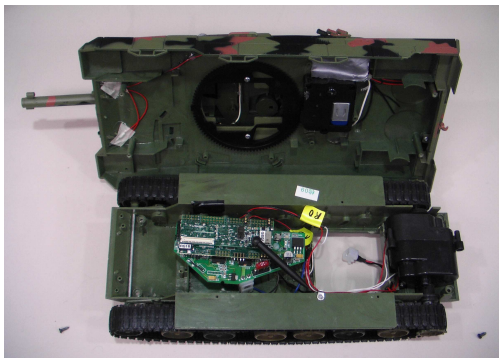
Vehicle Swarm Technology Lab - Vehicles

- **Lab supports a wide array of autonomous vehicles.**
- **All include health-based algorithm and behaviors.**

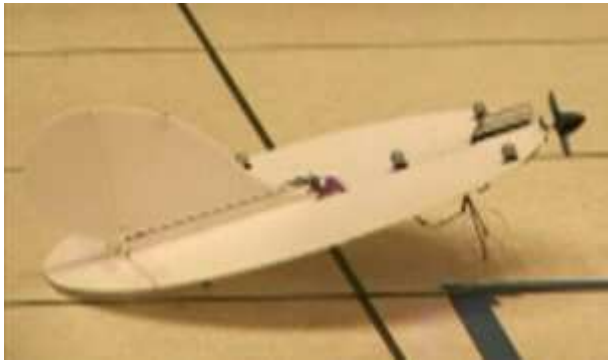
Conventional Helicopter

Quad-rotor Helicopter

Co-axial Helicopter



Ground vehicle

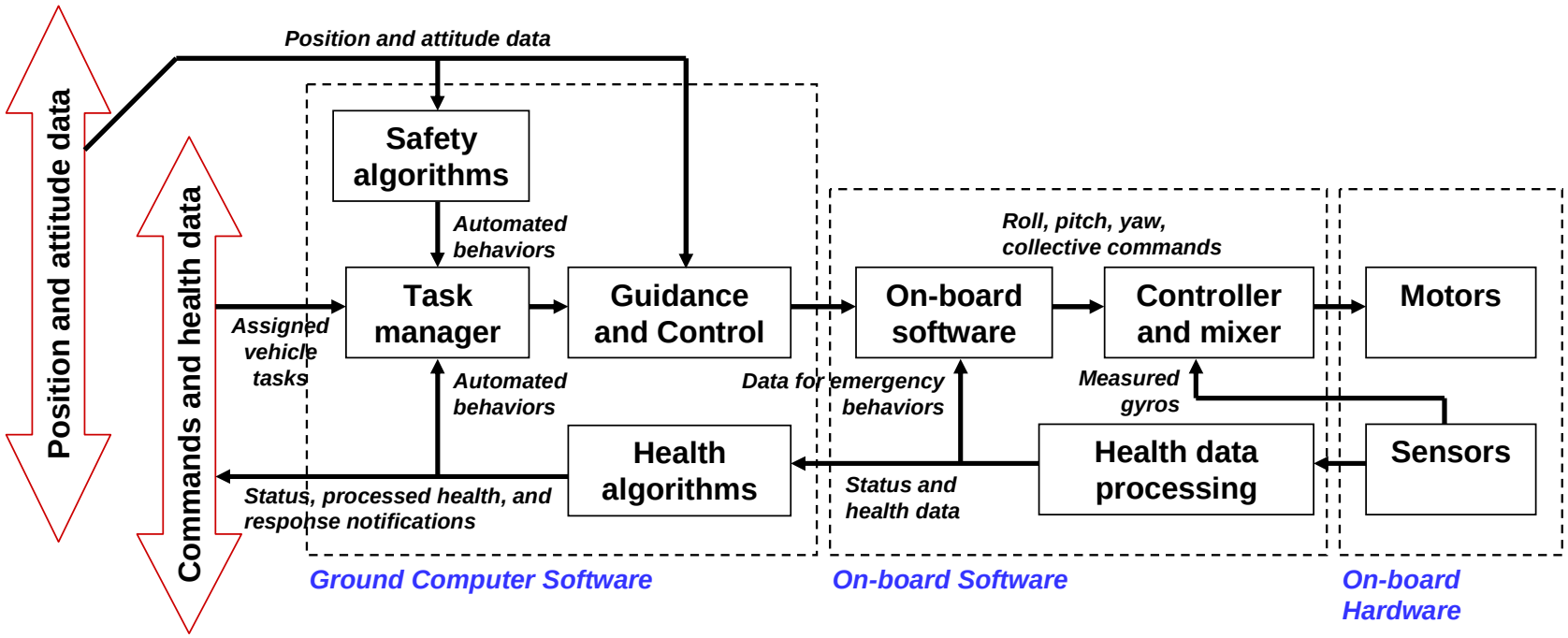


Flying disk

3-D Flyer

Vehicle Swarm Technology Lab – Vehicle Software

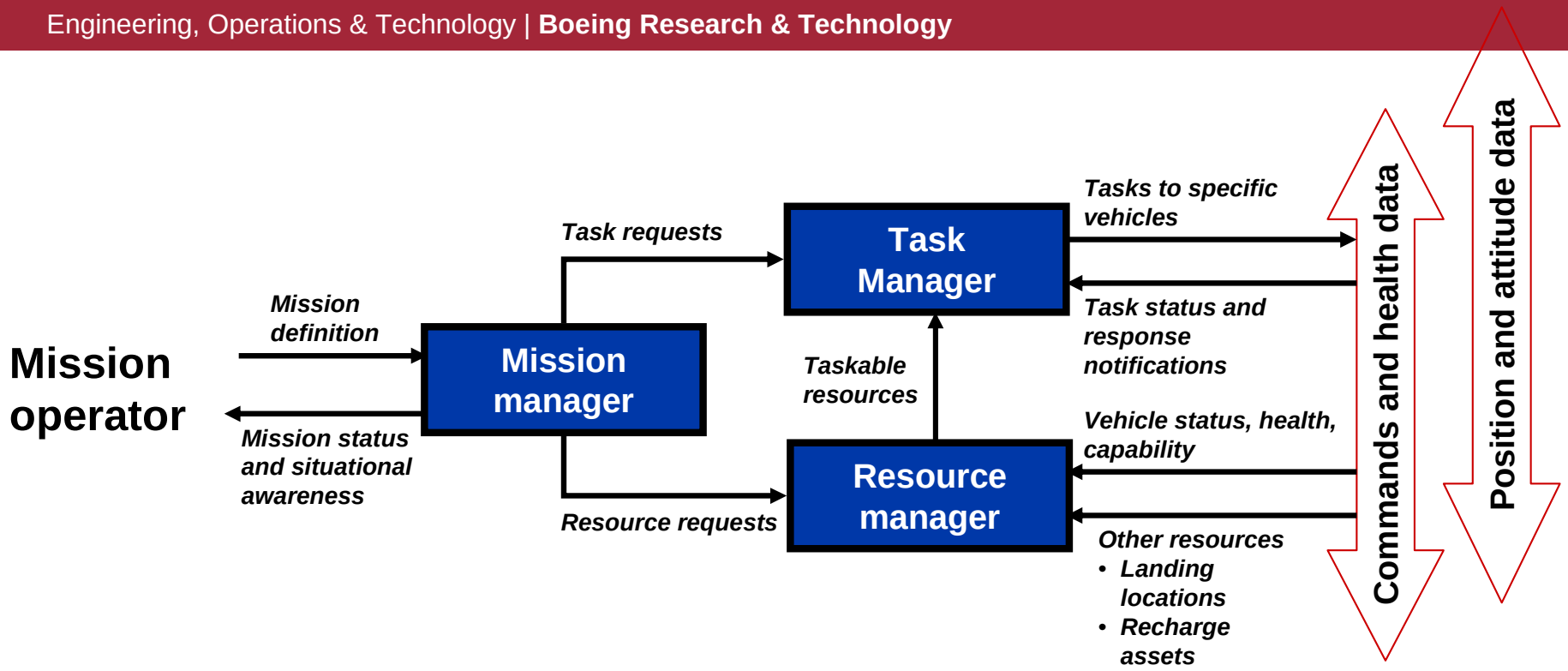
- **Vehicle software includes multiple health based algorithms running in parallel with standard functions.**
- **This "simple" system has sufficient complexity for evaluating tools and methods.**



Experimental Results

- **Numerous mission concepts have been developed and explored with the environment.**
- **Component technologies are implemented and evaluated in the context of multiple missions.**
- **Highlight two mission concepts here:**
  - **Non-collaborative mission with multiple, individually tasked vehicles.**
  - **Persistent search using distributed, scalable algorithm.**

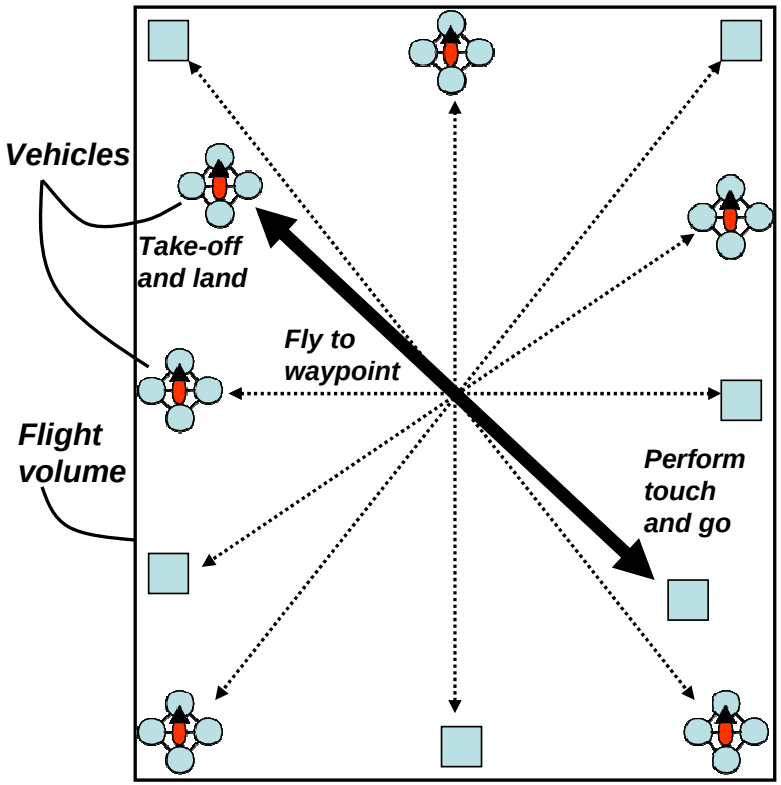
Mission Management Architecture

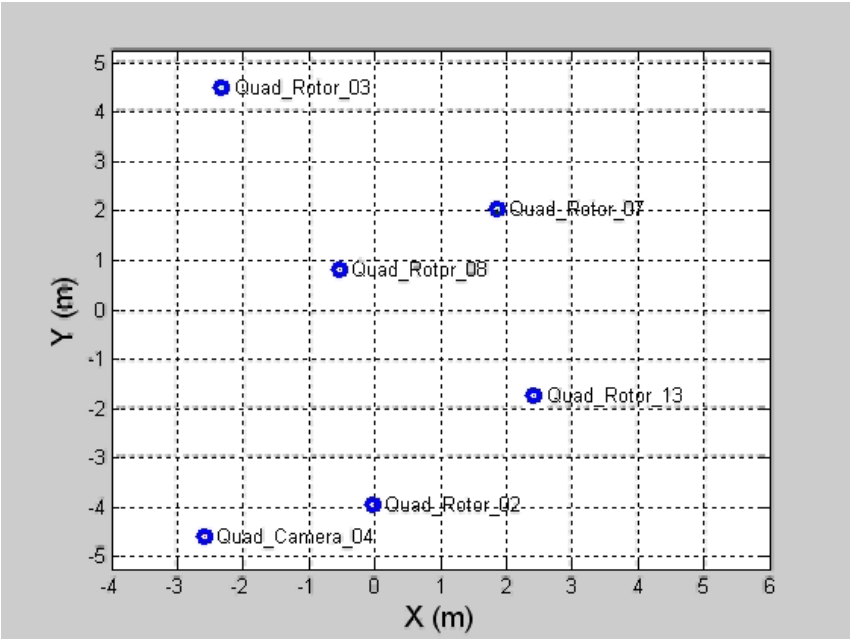


- **Flexible mission operator interface provides awareness and commanding capability.**
- **Architecture provides persistence for task and resource requests.**

Non-collaborative, multi-vehicle mission

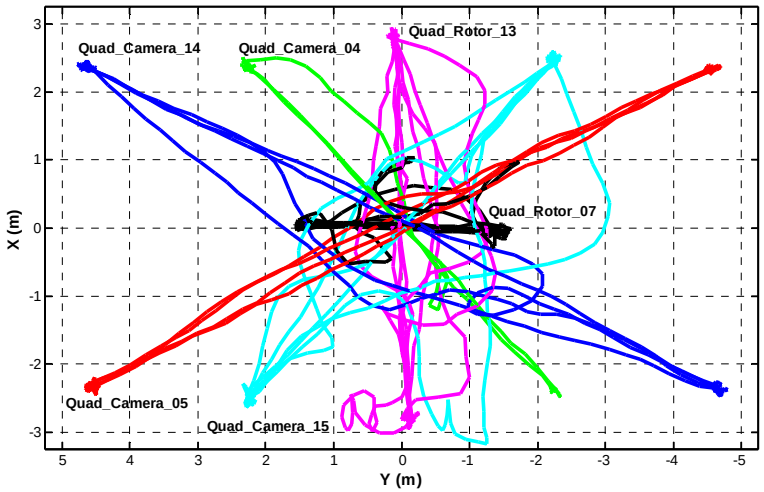
- **Vehicles individually tasked with flying point to point.**
- **Overall "mission" metric is safety assurance.**

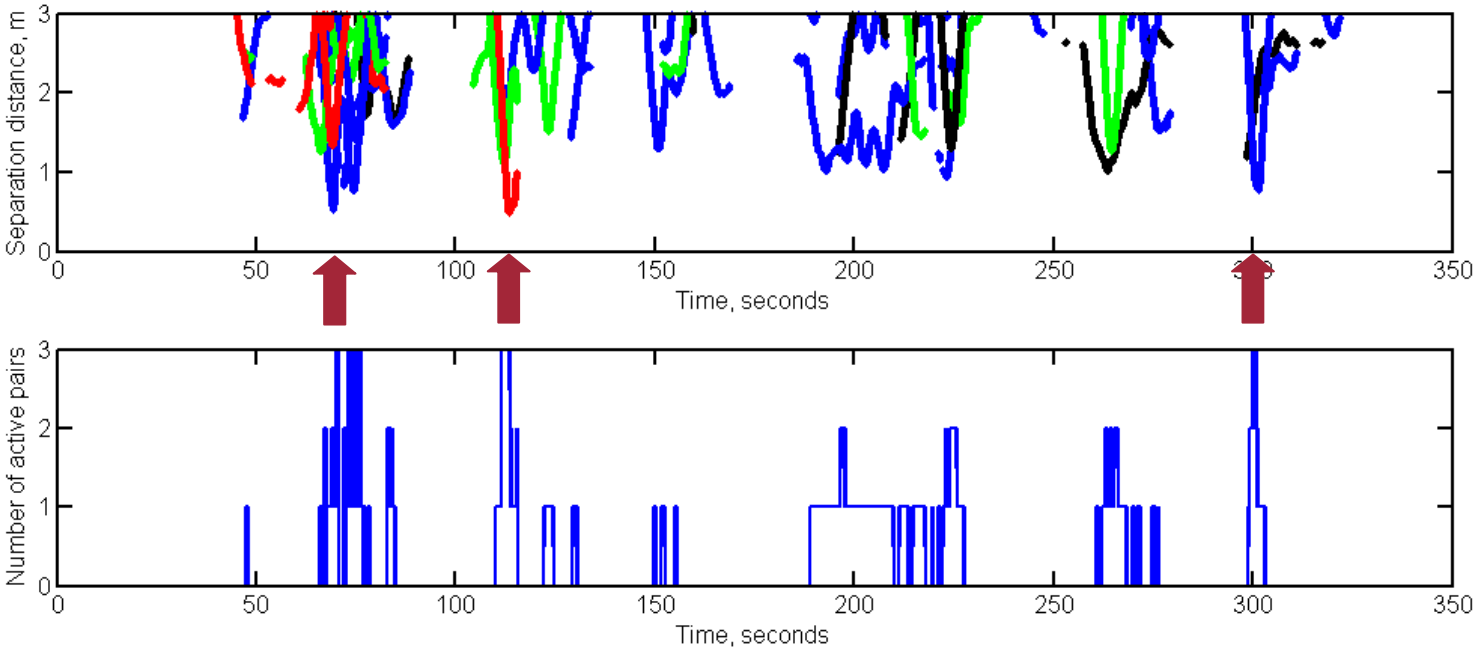




Non-collaborative, multi-vehicle mission

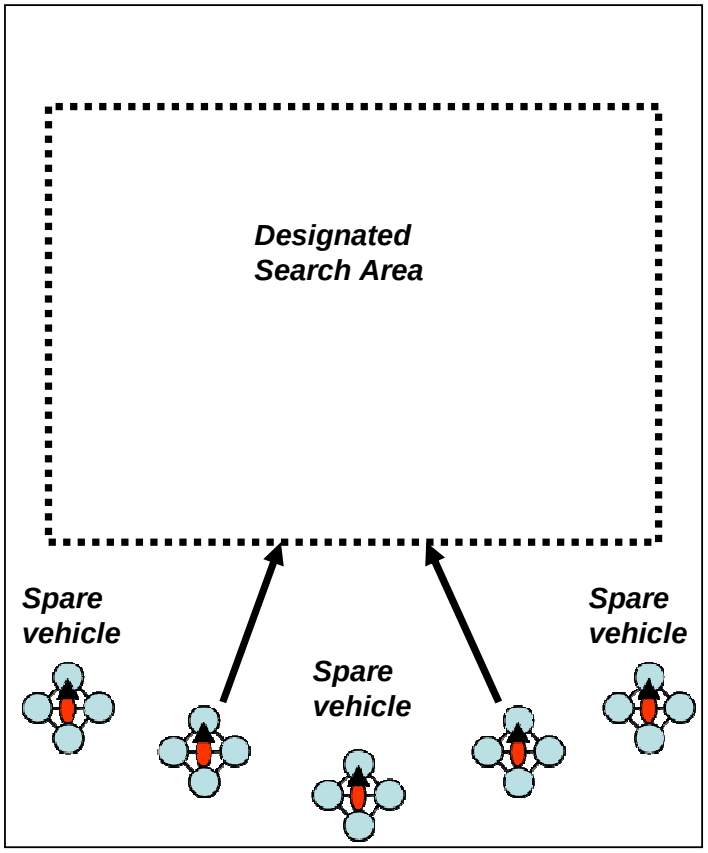
- **Mission metric is pairwise separation.**
- **Strong correlation between number of active pairs and times of minimum separation.**

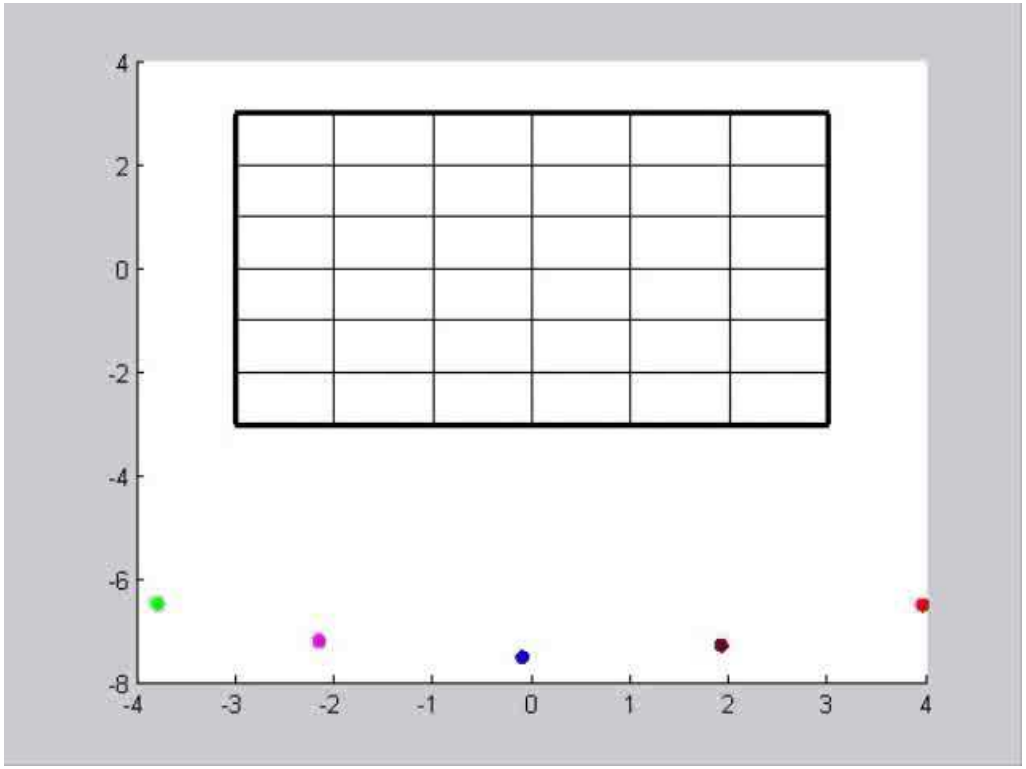




Collaborative, persistent search mission

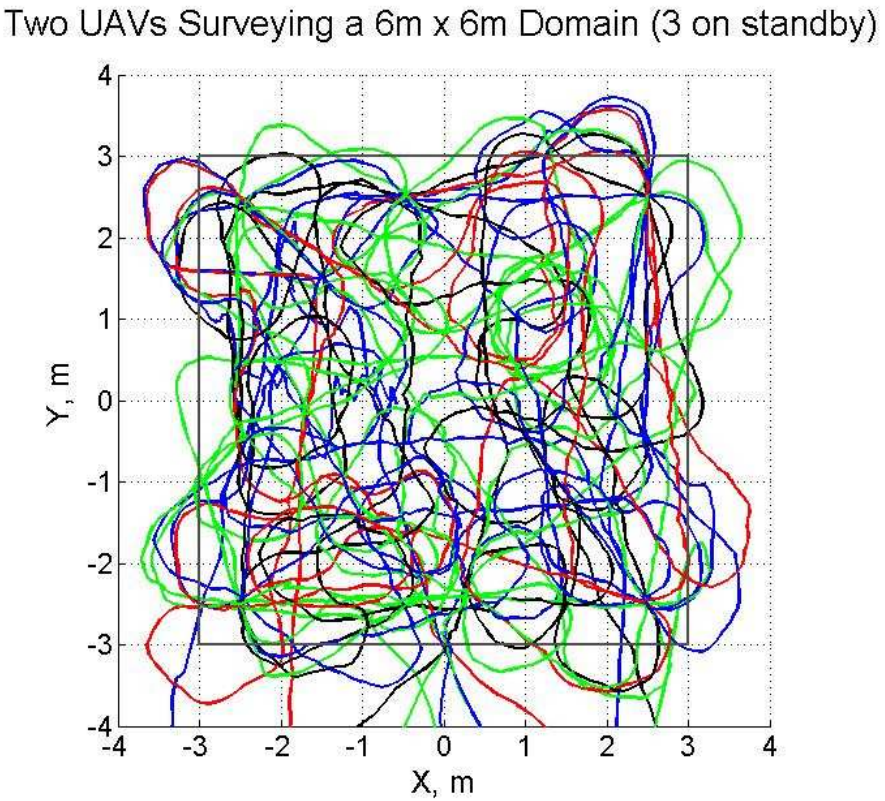
- **Vehicles jointly tasked to search designated area.**
- **Metric is time between repeated visits of points.**

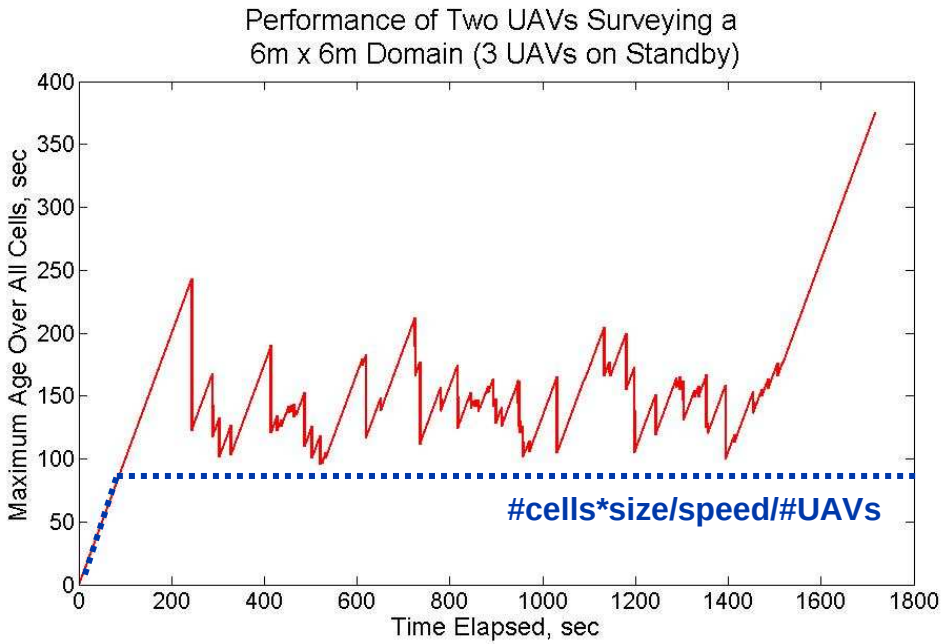




Collaborative, persistent search mission

- **Health, search, safety, and mission management features work in conjunction to achieve goal.**
- **Performance maintained even without sharing maps.**





Lessons – Validating the Approach

- **Experiments indicate the benefits of the approach for increased flight test hours and understanding of complex interactions.**
- **Health based behaviors played a key role in improving mission performance, system safety, and reliability.**
- **Several emergent behaviors are particularly important:**
  - **Interaction of safety functions (e.g. collision avoidance) and vehicle task management.**
  - **Communication links: their importance and fault tolerance.**
  - **Role of the operator (in-the-loop, on-the-loop, supervisory)**

Open Questions

- **How can we evaluate component technology benefits and impacts to help guide decisions on maturity?**

- **What are the appropriate roles and feedback mechanisms for inevitable human operators? How can their influence be included?**

Looking Forward

Trusted Highly-Autonomous Decision-Making Systems

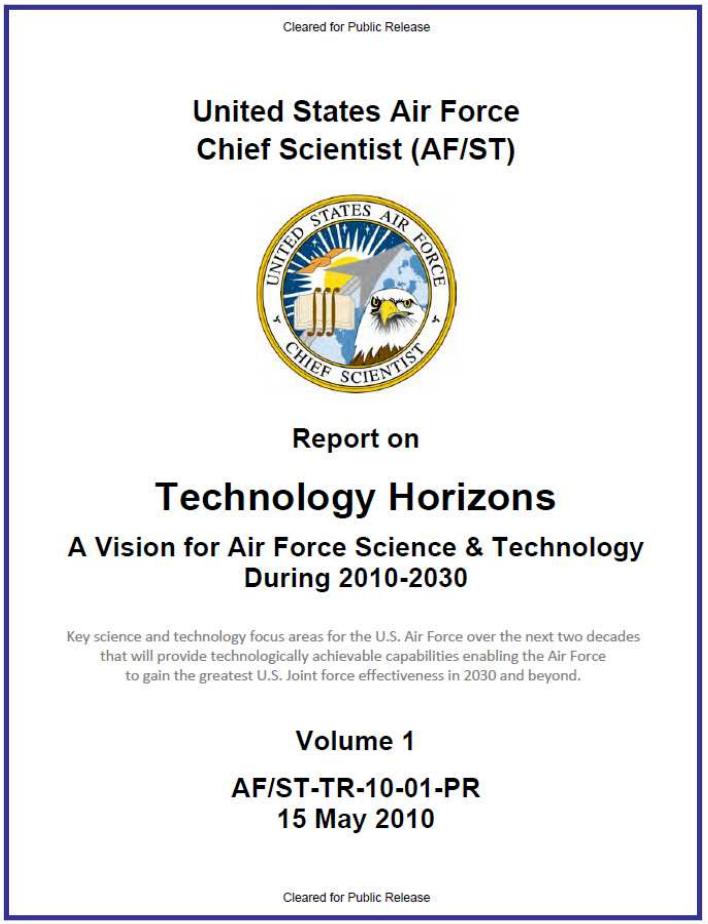
"… technologies that enable current human-intensive functions to be replaced … [and] that permit reliable verification and validation (V&V) to establish the needed trust…". p.100.

Target date for demonstration: 2017.

Fractionated, Composable, Survivable, Autonomous Systems

"Emphasis is on … fractionation and redundancy. Involves advancing methods for collaborative control and adaptive autonomous mission planning, and verification and validation (V&V) of highly adaptable, autonomous control systems." p.101.

Target date for demonstration: No later than 2018.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United States Air Force
Chief Scientist (AF/ST)

Report on

Technology Horizons

A Vision for Air Force Science & Technology During 2010-2030

Key science and technology focus areas for the U.S. Air Force over the next two decades that will provide technologically achievable capabilities enabling the Air Force to gain the greatest U.S. Joint force effectiveness in 2030 and beyond.

Volume 1

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THANK YOU.

QUESTIONS?