UAV Cooperative Control – Motivation & Introduction

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Dr. Corey Schumacher

AFRL/VACA

Air Vehicles Directorate

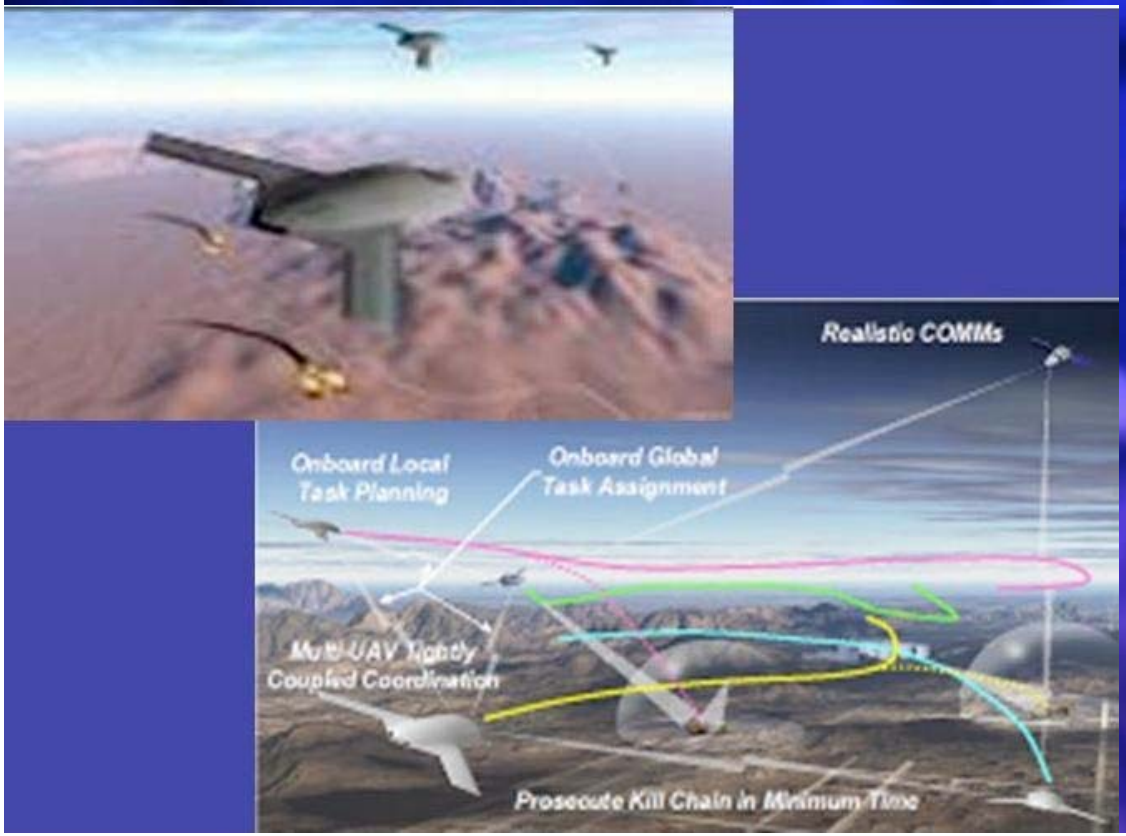
Air Force Research Laboratory

Outline

- Introduction
  - USAF and AFRL Technology Goals
  - CSCoE and MACCCS Topics
- AF Scenarios
  - Recent Work
  - Future Scenario Directions
- Collaboration Plan
- Summary

AFRL Collaborative System Control Strategic Technology Thrust

Collaborative System Control: Develop the insights, technology, and tools required to enable verifiable safe and effective collaborative control of networked air, space & cyber systems by considering integrated assets across physical domains (air and space), information assets in cyber domain (networks, databases, infrastructure), and human interaction.



Technology areas:

- control algorithm development across multiple domains
- validation & verification methodologies for system of systems
- robust & secure networked control techniques
- trust worthy next generation control design methodologies

AFRL/VA - Cooperative Airspace Operations

Air Domain - Time Phased Attributes

Operations in Manned/Unmanned Teams

Near Term (07)

- Single coordinated UCAV package
- Adaptive to continue the mission
- Human as Operator

Mid Term (10)

- Cooperative/Collaborative control of unmanned assets in complex and urban environments
- Human as Supervisor

Far Term (15)

- Distributed/Cooperative Control of multiple packages and ISR assets
- Adaptive for max effectiveness in dynamic environment
- Human as Teammate

Safe Operations From Airbases and In Airspace

Near Term (07)

- Min ATC Op's – "See & Avoid" (1 v 1) – Equivalent performance to man

Mid Term (10)

- Flexible ATC & Ground Op's – Equivalent performance to man, "File & Fly"
  - n v m
  - GATM compliance
- Ability to operate w/o GPS

Far Term (15)

- Equivalent ATC & Ground Op's – "Same Time, Same Base, Same Tempo"

Operations in Manned/Unmanned Teams

Near Term (07)

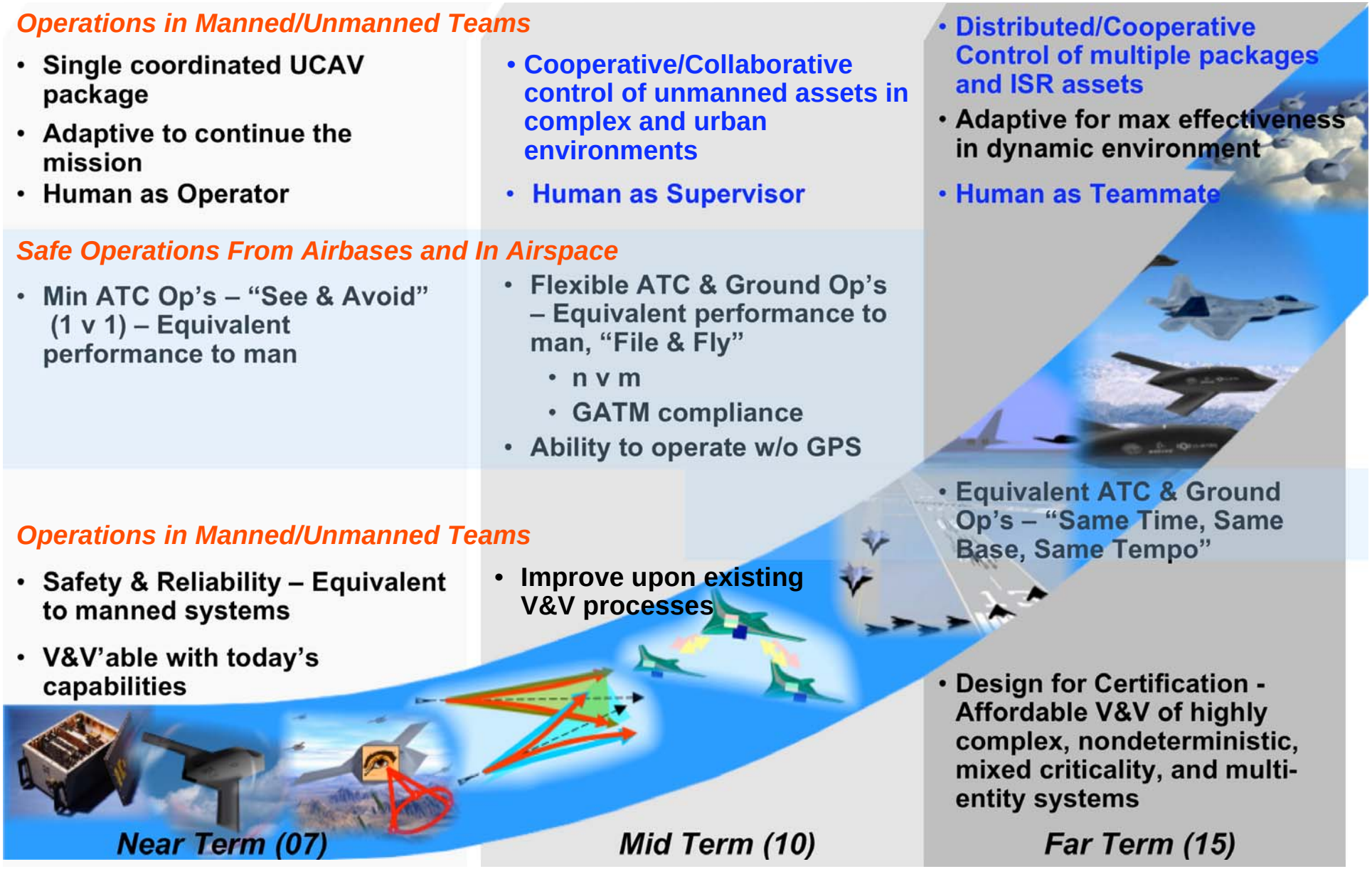
- Safety & Reliability – Equivalent to manned systems
- V&V'able with today's capabilities

Mid Term (10)

- Improve upon existing V&V processes

Far Term (15)

- Design for Certification - Affordable V&V of highly complex, nondeterministic, mixed criticality, and multi-entity systems



UAV Cooperative Control Research Directions in AFRL/ VACA

- Major Topics:
  - Operator-on-the-loop cooperative planning
  - Cooperative Control in a Heterogeneous System of Systems environment
- Desired Traits:
  - Provably good performance of planning algorithms
  - Computationally feasible, scalable
  - Targeted to VA 6.2/6.3 program scenarios
    - Implemented, tested in AFRL mission simulations
  - Connected over a limited communication network
  - Flexible to changing mission requirements, dynamic adversaries
- Multiple levels of human involvement
  - High level supervision, imagery analysis, task prioritization
- AF-relevant Missions

MACCCS Topic – from the BAA

- **A few quotes:**
  - **"…design an interconnected decision and control system that allows a variety of assets to act as a coordinated system of systems."**
  - **"…allow human operators to flexibly interact with the system on multiple levels."**
  - **"…achieve desirable group behavior in a resource-limited environment."**
  - **"challenges to be addressed may include… multi-objective ad hoc collaboration, heterogeneous systems, mixed initiative control, scalability in a system-of-systems architecture… and system robustness"**
- **Can be summarized as: Mixed initiative control of heterogeneous systems of systems**
- **Tightly Integrated with AFRL/VACA research effort**

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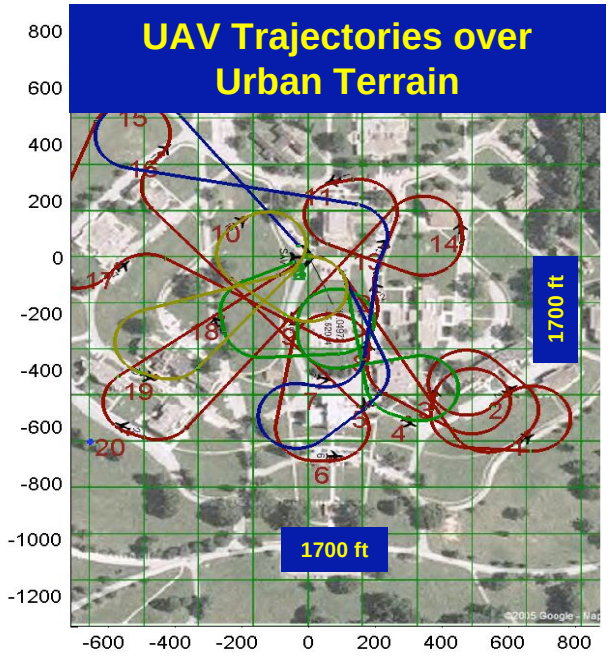
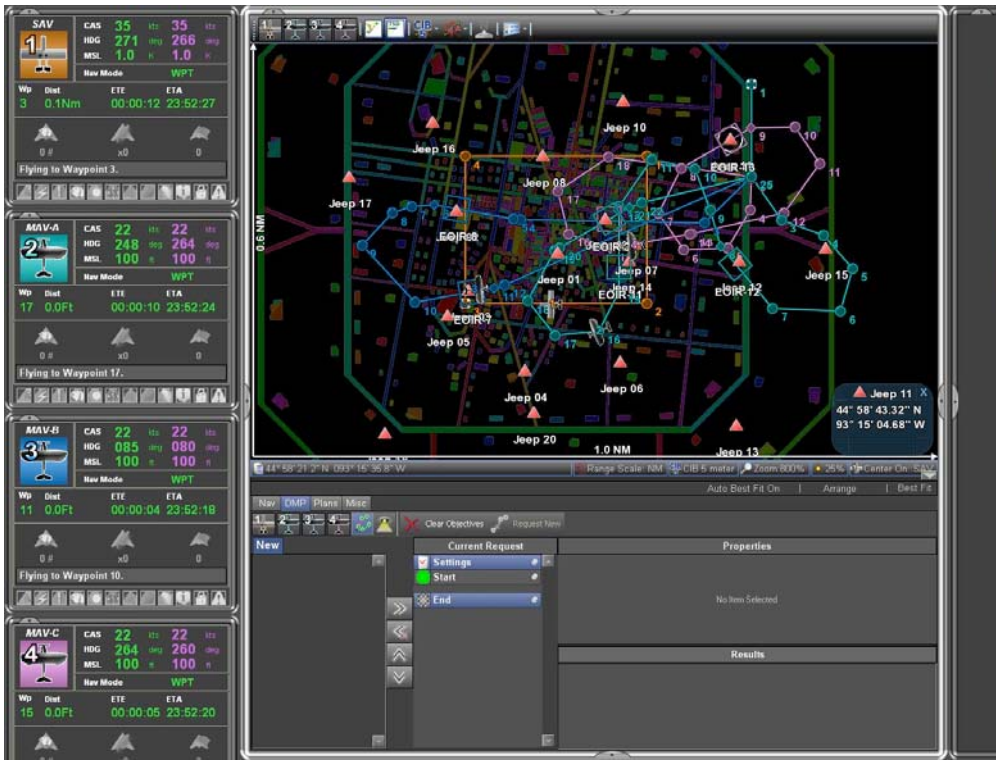
Recent Work

- **COUNTER 6.2 program – transition target for much of VACA's recent 6.1 research**
  - **Cooperative ISR in an urban environment – flight testing**
  - **Heterogeneous team of UAVs – Operator oversight**
  - **Using Vigilant Spirit Ground Station developed by AFRL/HE**





“Operational” Scenarios for future research

Persistent ISR by UAV team

- Urban terrain likely
- Heterogeneous UAV assets
- Varied Task list
  - Search
  - Target imaging, ID
  - Tracking (vehicles, dismounts)
  - Continuous area surveillance
  - Patrol
  - Laser designation of targets
  - “Safe Path” determination
  - Attack

Additional Scenario Characteristics

- ***Multiple levels of human interaction***
  - UAV Operators
  - Mission Commander
  - Ground forces, other air assets
- Substantial range of UAV and manned assets involved
- ***Dynamic Environment***
- Identify potentially or actively hostile personnel

Varied scenarios:

- Perimeter defense, convoy escort, combat search & rescue, ground forces support

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Collaboration Plan

- Substantial MAX Center participation in VA visitor programs
- Frequent collaboration visits (in both directions)
- Extensive involvement with MAX by AFRL researchers
- Joint research projects
- Webmeetings “difficult” due to WPAFB restrictions
- Common simulation environment
  - Algorithms applicable to AFRL/VA scenarios
  - SW/code for use in VA simulations
- We should be able to point at concrete transitions into AFRL/VACA’s research program
  - Transitions should flow in both directions

UAV Cooperative Control Team

Dr Corey Schumacher

Mr Phil Chandler (Branch Tech Advisor)
Dr Mark Mears
Dr Raymond Holsapple
Capt Nidal Jodeh
Dr Derek Kingston
Mr Steve Rasmussen (GD)
Dr Dave Gross (GD)
Dr Nicola Ceccarelli (NRC)
Prof Meir Pachter (AFIT)

Visiting Researchers in 2007:

Prof Anouk Girard (UM - MAX Center)
Prof Maruthi Akella (UT-Austin)
Prof Guoxiang Gu (LSU)
Prof Emilio Frazzoli (MIT – MAX Center)
Mr John Baker (UM – MAX Center)
Mr Jeff Saunders (BYU)
Mr Tyler Summers (LSU)
Mr Karl Obermeyer (UCSB)
Prof Randy Beard - BYU

Vigilant Spirit Control Station
(Developed by AFRL/HE)

- **Presently used for COUNTER, VACA in-house work**
- **Will be released for use by MAX Center also**
- **Common simulation environment to foster collaboration, transitions**

Left Screen Sample

Right Screen Sample

Summary

- **Mixed Initiative Cooperative Control of Heterogeneous Systems of Systems**
  - **UAV Focus, but not solely UAVs**
  - **Critical technology for the future Air Force**
- **Combination of theoretical and applied research**
  - **Scenario details dependent on future VA directions**
  - **Fundamental theoretical issues independent of scenario**
- **Close collaboration between AFRL/VACA and UM, MIT teams**
  - **One team!**
  - **Extended visits in both directions**
  - **Common scenarios, challenges**
  - **Common simulation environment**

Questions?