

Multi-Vehicle Cooperative Control Research

NASA Dryden Flight Research Center

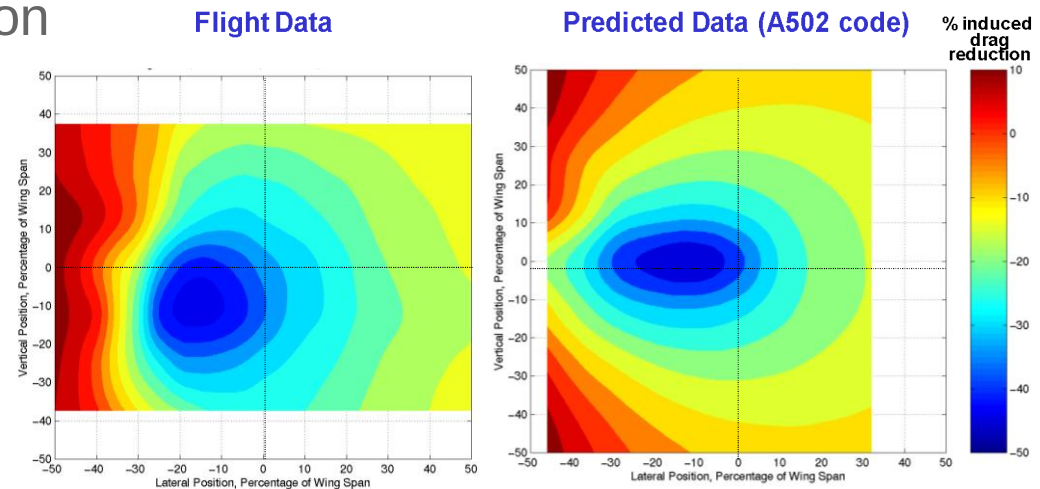
1998 - 2012

Curt Hanson
Controls and Dynamics Branch
NASA Dryden Flight Research Center

Autonomous Formation Flight (AFF)

1998-2001

- ❑ 14% reduction in drag due to wingtip upwash of the lead airplane
 - Initial tests flown manually
 - Pilots reported extended-duration formation flight to be reasonable physically but mentally exhausting
- ❑ Autonomous Formation Control
 - Enables performance optimization
 - Alleviates pilot fatigue
 - INS/GPS Relative Navigation
 - Large formations (4 or more aircraft) require cooperative control for string stability



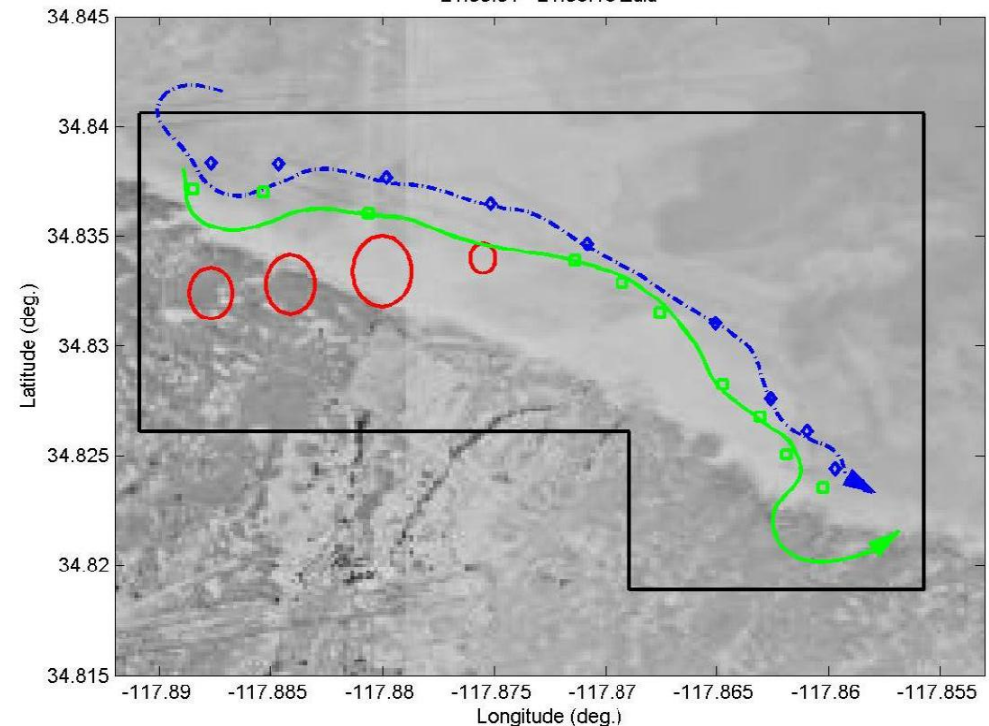
Networked UAV Teams (NUAVT)

2004-2005

- ❑ Algorithms for Forest Fire Monitoring
- ❑ Bird Android (BOID) Path Planning
 - Flocking
 - Velocity Matching
 - Collision Avoidance
 - Obstacle Avoidance
 - Target Seeking
- ❑ Cooperative Search and Real-Time Task Replanning
- ❑ 4D Navigation



Boids Test 6, 01/20/2005
21:35:51 - 21:38:18 Zulu



Energy Efficient Flocking of Small UAVs

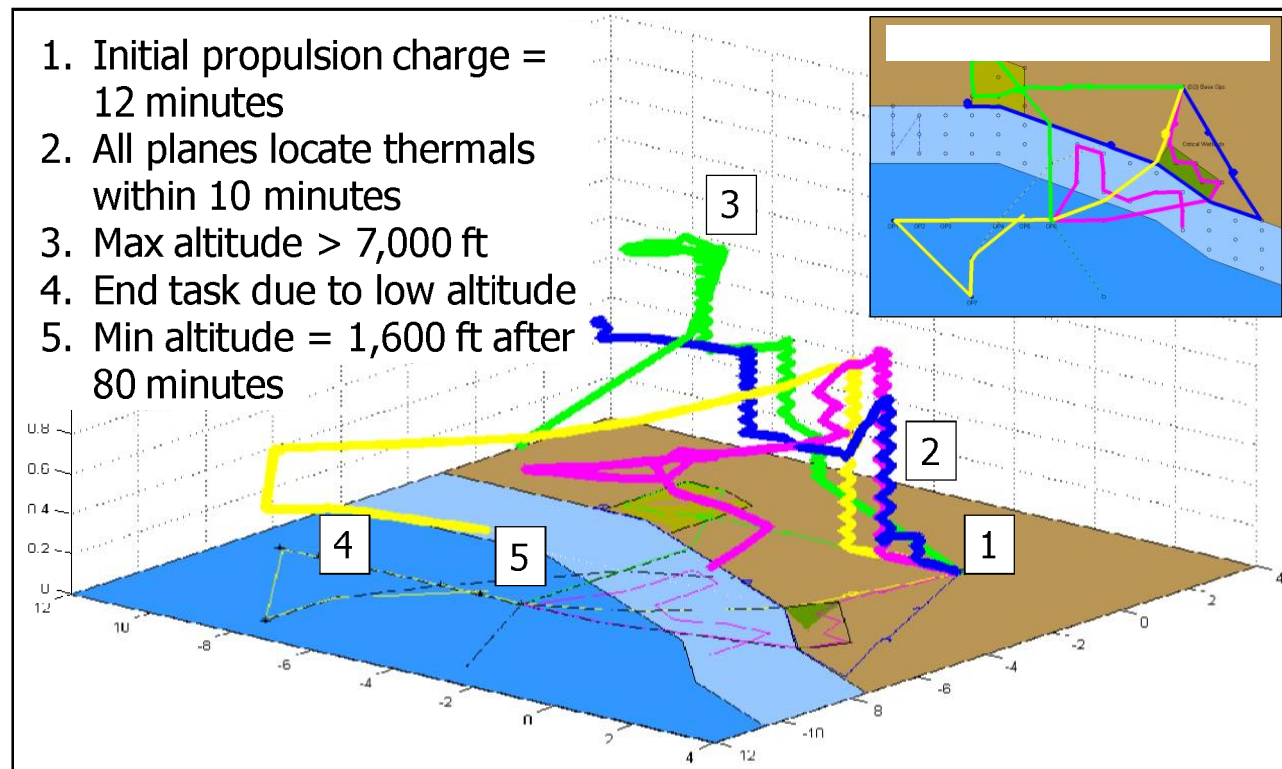
2005

❑ Dynamic Mission Planning for a Cooperative Multi-Vehicle Coastal Patrol Mission (Simulation Study)

- Offshore pipeline leak detection
- Marine wildlife observation
- Wetlands monitoring
- Wildfire detection

❑ Integrated Concepts for Energy Efficiency

- Cooperative thermal soaring
- Formation flight for drag reduction



Autonomous Aerial Refueling Demo (AARD)

2005-2007

- ❑ First ever autonomous hose-and-drogue style aerial refueling
 - DAPRA / Sierra Nevada Corporation / NASA
 - Boeing 707-300 tanker with unmodified, production refueling system (32-inch dia. basket)
 - NASA F/A-18B surrogate UAV
 - autonomous modes: rendezvous, plug, hold, unplug, miss / re-attempt
 - safety pilot on-board for takeoffs, landings and emergencies
 - GPS-based relative navigation combined with optical tracking of the basket



Cooperative Autonomous Thermal Soaring

2007-2008

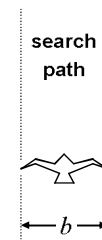
- ❑ Implemented BOID-like rules to mimic three cooperative behaviors observed in migratory hawks (Kerlinger, 1985):

1. Random Encounter
2. Local Enhancement
3. Climb Rate Feedback

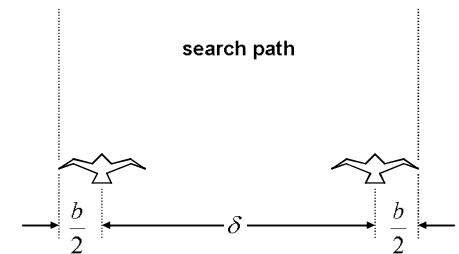
- ❑ Paper study

- Followed 2004 NASA flight experiments into single-aircraft autonomous soaring (Allen, 2005)

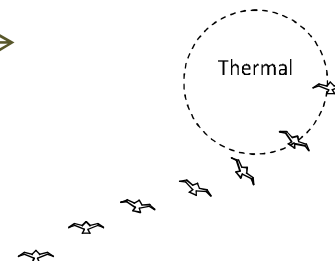
Single



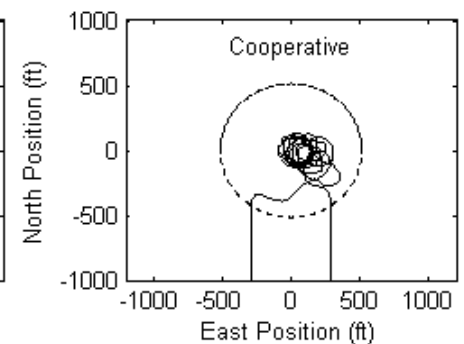
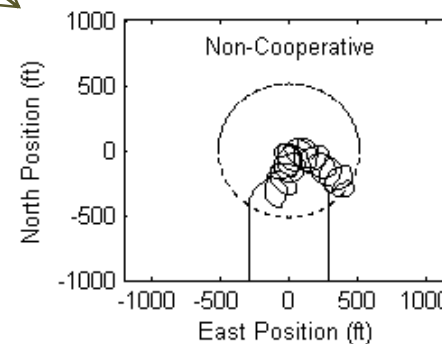
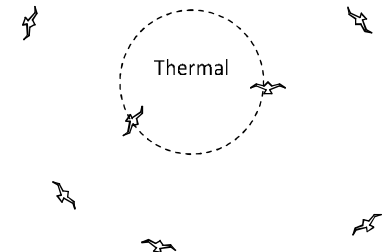
Flock of Two



Formation



Dispersed



Optimized Formation Flight

2003, 2008-Present

- ❑ Vortex-Induced Navigation Experiment (VINE)
 - estimation of relative position between aircraft based upon sensed aerodynamic disturbances
- ❑ Peak-Seeking Relative Position Optimization
 - estimate gradient and curvature of fuel savings vs. position
- ❑ Peak-Seeking Optimization of Spanwise Lift Distribution in Asymmetric Upwash Fields
 - optimize the roll trim solution

