Multi-Vehicle Cooperative Control Research
NASA Dryden Flight Research Center
1998 - 2012

- 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
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

1. Initial propulsion charge = 12 minutes
2. All planes locate thermals within 10 minutes
3. Max altitude > 7,000 ft
4. End task due to low altitude
5. Min altitude = 1,600 ft after 80 minutes
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)
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