Experimental Facilities at UCLA

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**Background**

- Much of our current capability comes from our formation flight programs.
  - UCLA developed flight control computer for investigations of aircraft formation flight for drag reduction.
  - Currently developing formation flight instrumentation system for use on test flights with F-18 research aircraft, in partnership with Boeing and NASA DFRC.
  - Facilities have expanded to include extensive bench testing and hardware in the loop testing.
  - Vehicle testing facilities on automobiles and in UAVs.

- Currently attempting coordinated autonomous flight of a pair of UAVs.
  - Vehicles are the “Mule” at UCLA and the “Frog” from Naval Postgraduate School.
Formation Flight Instrumentation System

- Designed to provide highly accurate relative position, velocity, and attitude between aircraft.

- Primary purpose is formation flight for drag reduction.
  * Requires very accurate relative information, with less emphasis on inertial information.

- Uses integrated GPS/IMU system.
  * GPS provides common inertial and timing reference for all vehicles
  * IMU provides measurements of high frequency motion and angular motion.
  * Differential Carrier Phase GPS provides extremely accurate relative range measurements.
FFIS Functional Description

- The radio modem provides communication with the second aircraft
  * Can also provide communication with external equipment.

- The basic functioning of the FFIS is independent of the airframe interface.
**FFCC Hardware Architecture**

- FFCC is FFIS with control capability included.
  - Control for Mule is done through pulse-width-modulation output to standard R/C (hobby) actuators.
  - Control law is implemented in main CPU.

- The GPS requires a serial connection. A single-board computer allows communication without complicated software additions to main CPU.

Shown is current architecture; the dashed box includes additions for F-18 flight and upgrades to new IMU.
Hardware-in-Loop Simulation Facility

- Currently configured for F-18 simulations.
  * Aerodynamic simulation will be replaced with Mule simulation.
- For Mule simulation will be extended to include actuator hardware, rather than simulated actuators.
- Can (easily?) be extended to other aircraft and other vehicle dynamics.
Satellite Constellation Simulator

- 24 channels, divided between two RF outputs.
  - Configured to provide $L_1$ and $L_2$ signals from six satellites on each RF port.
  - RF ports feed directly to antenna ports on GPS receivers.

- Position, orientation, and rates of change delivered via ethernet from vehicle model workstations.

- SCS provides the 1 pulse-per-second signal to synchronize all parts of the simulation.
Aircraft Simulation Workstations

- Dual-processor Xeon workstations.

- Linux operating system.
  - Free, fast, flexible, runs in many flavors on a great deal of hardware.
  - Allows full control of background processes and direct access to hardware.
  - Sometimes difficult to get drivers for add-on cards.

- Synchronized every second to 1PPS signal from SCS.

- IMU signals simulated using D/A card in A/C workstations.
  - When IMU is upgraded to Litton LN-200, IMU simulation will be done using external device.
The Mule

- Remotely piloted aircraft, originally purchased for another program.
  * Aerodynamics designed to mimic ultra-light solar-powered aircraft.

- Physical characteristics
  * 17-foot wingspan, inverted V-tail.
  * Two-cylinder, 200-cc (approximately 13 hp) engine.
  * Current takeoff weight: 155 lb. (includes 10-lb payload)
  * Total payload: Greater than 30 lb.

- Used in flight tests on Formation Flight program since 1996.
  * Autonomous flight using previous flight control computer in 1997.
UAV Test Facilities

• Conducted at the Center for Interdisciplinary Remotely Piloted Aircraft Studies (CIR-PAS)
  * Center run by Naval Postgraduate School
  * Flights take place at McMillan Airfield on Camp Roberts, near Paso Robles, California

• Several very convenient features:
  * Airspace management
  * Frequency management
  * Physical infrastructure: power, hangar, paved runway.

• UAV’s operated by professional R/C pilots.
HYBRID TEST FACILITIES

• Essential tradeoff in a testbed is to include sufficient complexity to rigorously test algorithms without bringing in difficulty in analysing results.
  * A very simple hardware device may not provide sufficient flexibility.
  * A more complex hardware device introduces difficulties of modeling, construction, actuation, maintenance, et cetera.

• We desire vehicles of military interest – this is not feasible in a manageable testbed.

• Our major “hardware” restriction is likely to be communication.
  * Vehicle modeling can be done well, given sufficient time and incentive.
  * Communication is very environment dependent, and subject to bandwidth constraints, interference, power limitations, and other difficulties.

• We attempt to create a testbed that allows us to test our algorithms, rather than our mechanical abilities.
**Proposed Facility — “Pseudo-Vehicles”**

- Use computation to simulate vehicles; use hardware to implement communications.
  * Single-board computers are inexpensive and sufficiently powerful to model fairly complex vehicles.
  * Each “vehicle” will maintain its own state information, sensor models, and some local environment modeling.
  * SBCs will communicate with each other using wireless. Uncertainty can be allowed to arise naturally, and can be imposed through software or physically.

- Such an approach allows for complex, high-capability vehicles and includes necessary hardware uncertainty.
Proposed Facility – Environment

- One or more powerful coordinating computers will handle the environment and tell each machine if it has been damaged, what its sensors should see, et cetera.

- Coordinating machines will communicate with the SBCs via hardline ethernet. Given current network capacity, it is feasible to update environment variables within a reasonable control time frame.

- Existing hardware in the loop capability can be incorporated to create a “truth model” against which the performance of the pseudo-vehicles can be evaluated.