From Augmentation to Automation to Autonomy in Aircraft Flight Control

Sarta HiTEC

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Ronald A. Hess

Dept. of Mechanical and Aerospace Engineering

University of California

Davis, CA

Autonomy in Flight Control…Are We There?

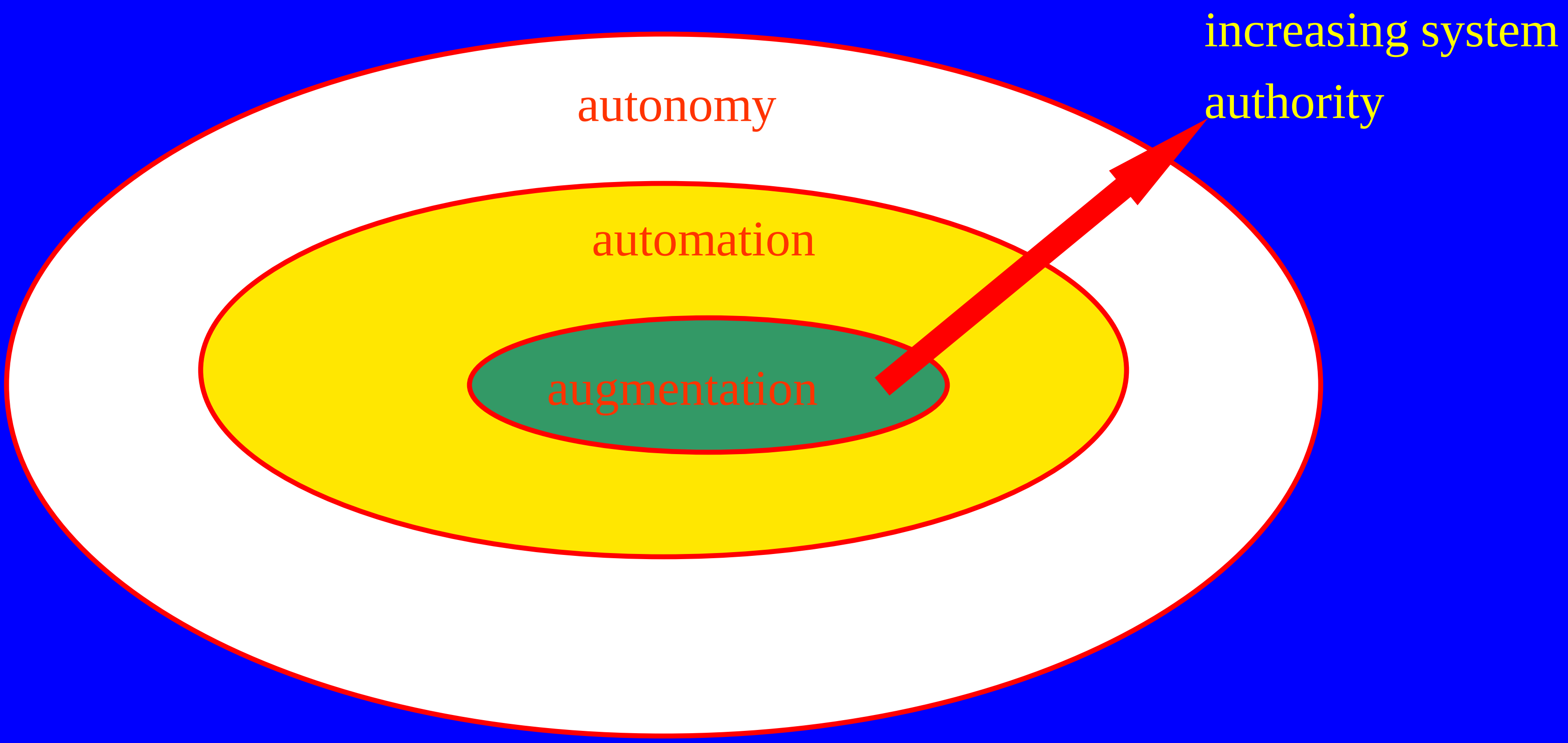
- Autonomous System: A system that is able to make its own decisions without intervention or pre-programming.

- "The author is not aware of any fully autonomous system existing outside of science fiction (shades of computer HAL in Arthur C. Clark/Stanley Kubrick's '2001 A Space Odyssey'). It is conceivable that this may yet come about, but would it be desirable?"
  - Reg Austin, *Unmanned Aircraft Systems: UAVS Design, Development and Deployment*, Wiley, March 2010

Verification & Validation of Autonomous Systems

- verification is checking whether the correct product has been built
- validation is checking whether the product has been built correctly.
- Can a truly autonomous system be validated?

Augmentation to Automation to Autonomy in Aircraft Flight Control



Benefits of Increased Automation in Flight Control

- Safety
- Performance
- Economics
  - As compared to systems under continuous manual control

Safety

Human error is a significant contributing factor in a very high proportion of civil transport, general aviation and rotorcraft accidents...

"A Theory for Human Error," McRuer, Clement and Allen, NAS2- 10400, 1980

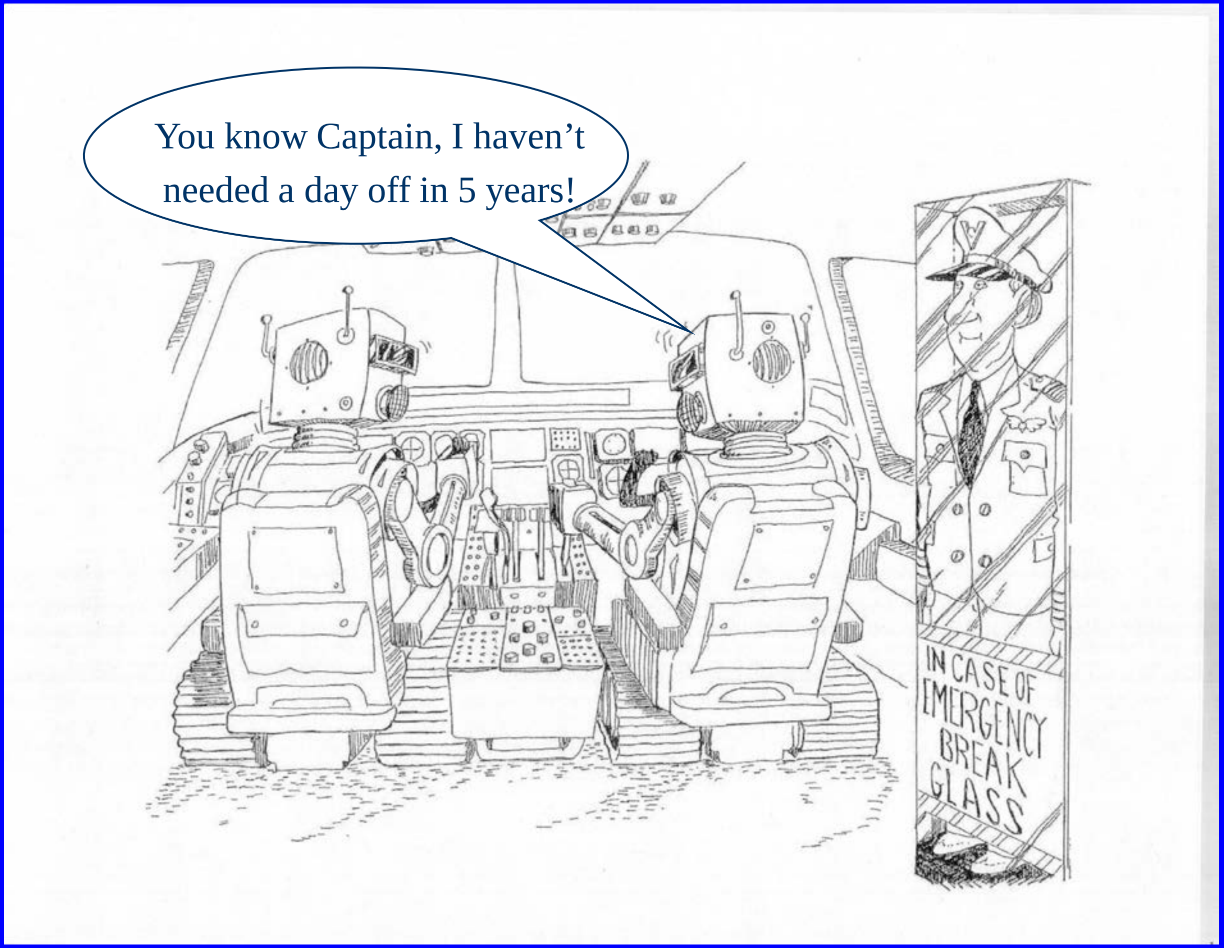
Performance

Honeywell Flight Management System

For Boeing 777

With computer management, the heading, altitude and airspeed whereby the aircraft can travel at the most ideal efficiency, can be instantly retrieved.

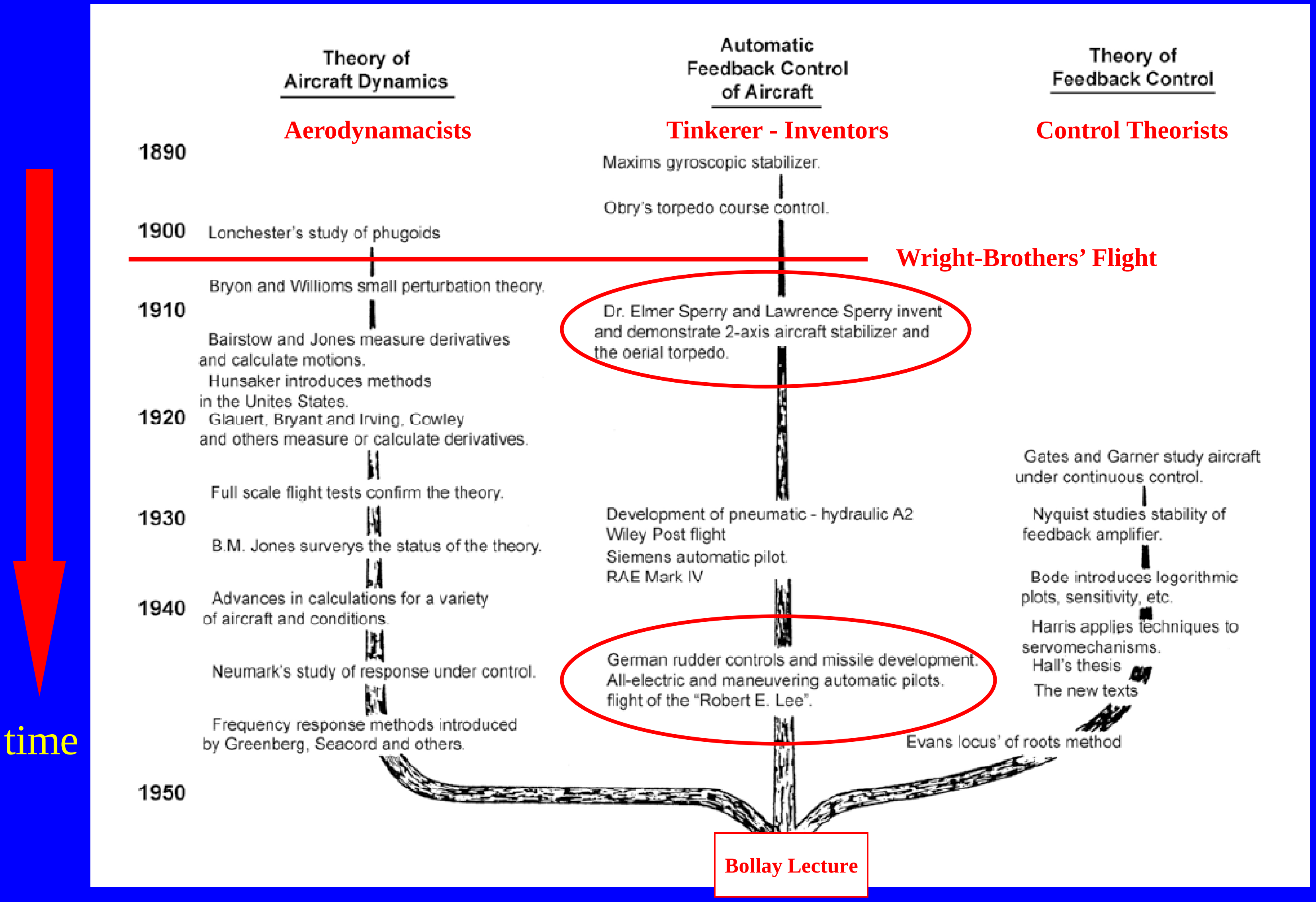
Economics


You know Captain, I haven't needed a day off in 5 years!
IN CASE OF EMERGENCY BREAK GLASS

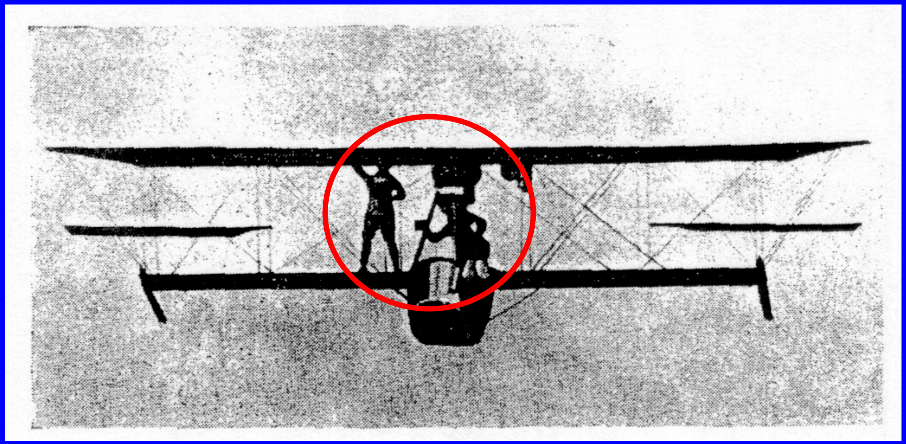
Drawbacks of Increased Automation in Flight Control

- Overdependence on automation…complacency
- Adverse impact on airmanship…degradation of basic flying skills
- Increased mental workload…developing working “mental models” of automation systems
  - As compared to systems under continuous manual control that possess limited automation

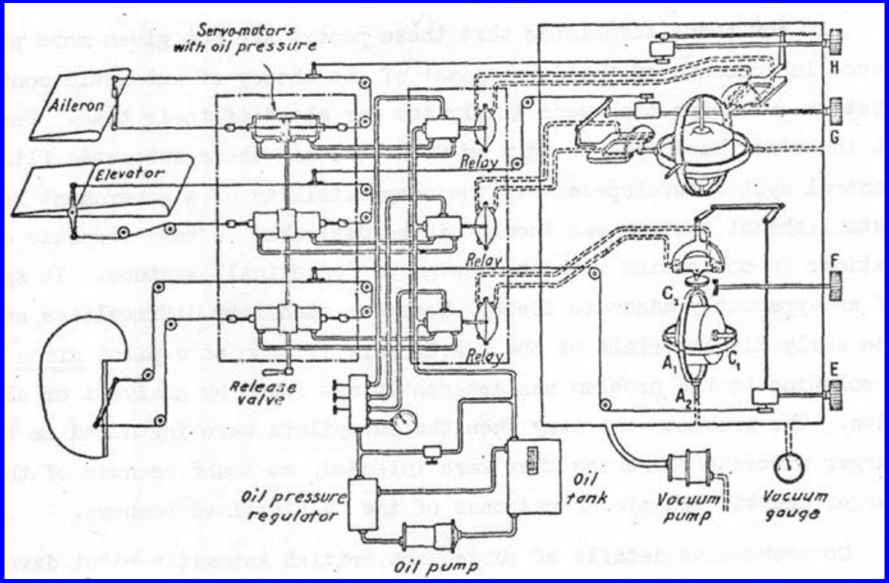
History of Flight Control Augmentation/Automation



The Sperry Demonstration



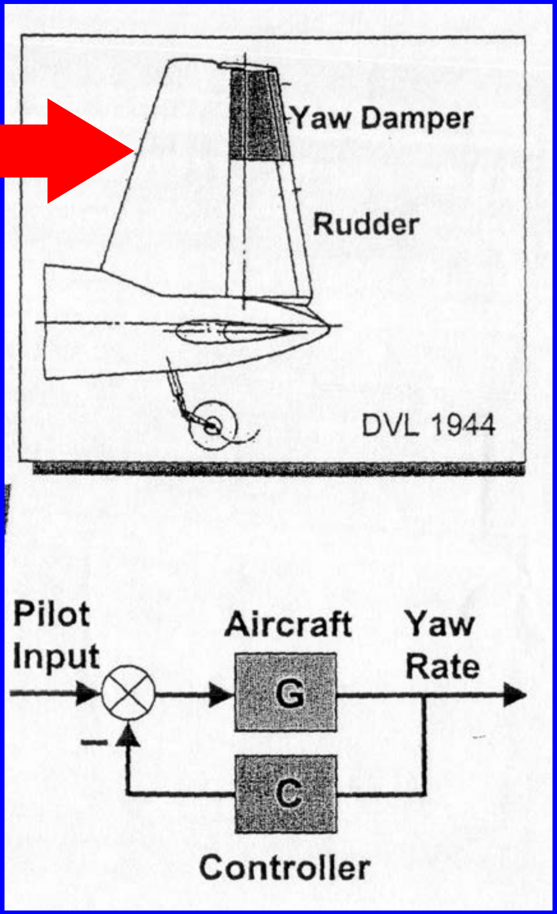
Lawrence Sperry and mechanic Demonstrating the Sperry Autopilot over the Seine river, Paris 1914



Assembly sketch of Sperry Autopilot

The Henschel Stability Augmentor

Henschel HS-129, 1944



<u>Problem</u>: Heavily armored fuselage led to lateral "snaking" tendancy in flight

<u>Solution</u>: Separate rudder surfaces:

- one controlled by pilot
- second controlled by stability augmentor

Flight of the Robert E. Lee C-54

Robot-Piloted Plane Makes Safe Crossing of Atlantic

No Hand on Controls From Newfoundland to Oxfordshire—Take-Off, Flight and Landing Are Fully Automatic

By ANTHONY LEVIERO

Special to THE NEW YORK TIMES.

WASHINGTON, Sept. 22 — A Douglas C-54 Skymaster with a mechanical brain landed without human aid near London today after a robot directed hop from Newfoundland.

The revolutionary flight across the Atlantic, effected by the push of the button, was hailed by Air Force leaders as a feat with vast new possibilities for war and peace.

The robot Skymaster, only one of its kind in the world, lifted itself off the field at Stephenville, Newfoundland, at 5 P. M. Eastern standard time, yesterday. This morning, 10 hours and 15 minutes later, the Skymaster eased itself onto the field at Brise Norton, forty miles west of London. The ship had flown 2,400 miles.

Fourteen crew men and observers were aboard the unique plane, but not once was it necessary for any of them to take a control or to intervene in any way with the mechanically prescribed course.

Delicate instruments, which did not falter, guided the ship, Air Force spokesmen said. Two ships somewhere in the Atlantic furnished bearings to the Skymaster's brain. She had 3,700 gallons of fuel aboard.

Great Britain several weeks ago had asked as a favor that the Air Force send the Skymaster there to make demonstration flights for Royal Air Force technicians. Thereupon, according to an official announcement, the Air Force decided to make the transatlantic flight itself without human control, if possible.

The plane was rolled out at Stephenville. The pilot, Col. James M. Gillespie of Wilmington, Ohio, chief of the All-Weather Flying Division, and the other passengers climbed aboard. The Skymaster was pointed to its distant goal. Its brain was adjusted for the task. On the field someone pushed a button.

The plane taxied down the field at maximum power, became airborne, and at 800 feet the brain

Continued on Page 2, Column 3

New York Times Sept. 23, 1947

- September 23, 1947 C-54
- Sperry A-12 autopilot
- Bendix automatic throttle control
- IBM punch card equipment for course
- No human touched the controls from start until landing
- Automatic selection of radio station, course, speed, flap setting, landing gear, final application of wheel brakes.

Military Flight Control Automation/Autonomy

Northrop-Grumman Global Hawk in Air Force and Navy Livery

Global Hawk is the only unmanned aerial system (UAS) to meet the military and the Federal Administration Aviation's airworthiness standards and have approval to fly regular flights within U.S. airspace.

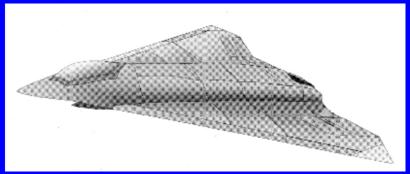
Functions of an Automatic/Augmented Control System – the Core of an Autonomous System

- Provide vehicle stability and controllability
- Provide specified command-response relationships
- Reduce effects of unwanted inputs/disturbances
- Suppress effects of vehicle & component variations due to damage

Of increasing interest to automation community

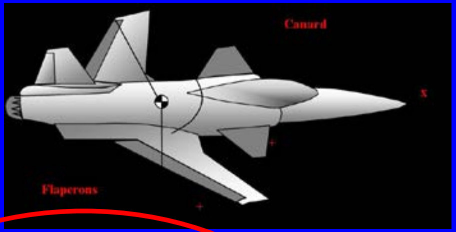
Vehicles Studied for Design of Robust Automatic/Augmented Flight Control Systems

Flexible B-1



Innovative Contol Effector Vehicle

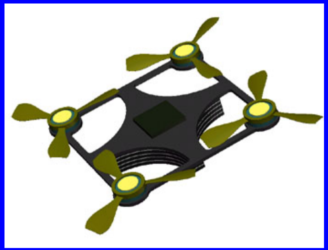
F-18 HARV



Forward Swept Wing Fighter

29-Inch Ducted Fan UAV

"Micro" 9-Inch Ducted Fan UAV

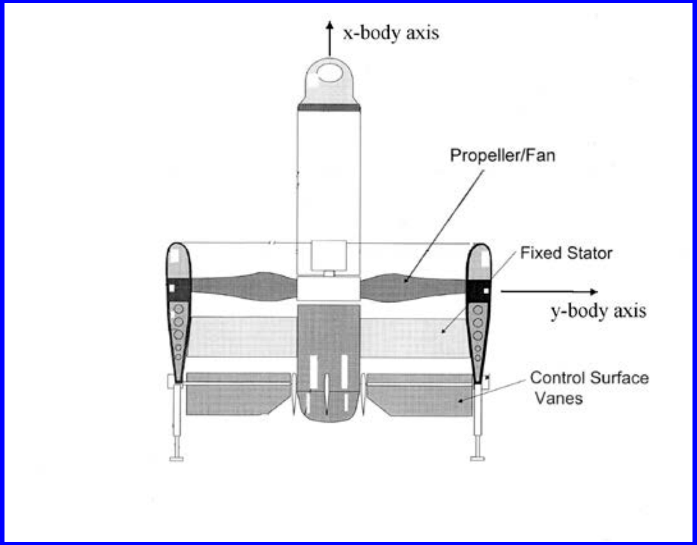


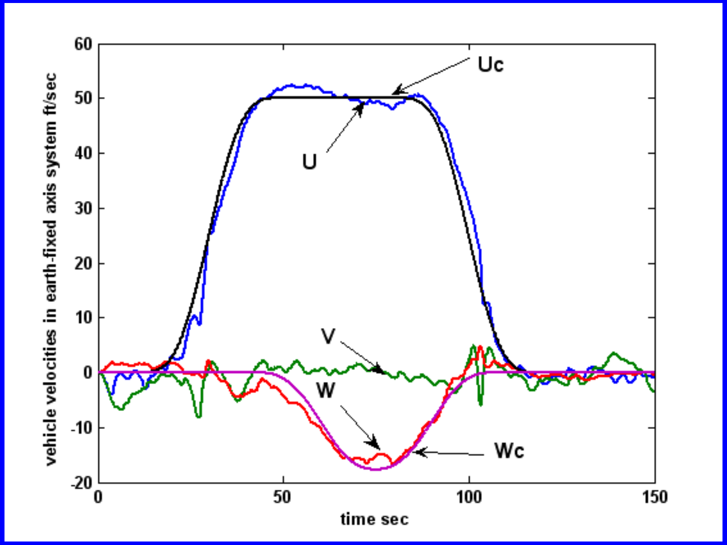
"Nano" Mesicopter UAV

UH-60

Each vehicle model subjected to simulated "damage"

Automatic, Robust, Flight Control Design for a 29-Inch Ducted-Fan UAV





MS Thesis, Mary am Bakhtiari-Nejad

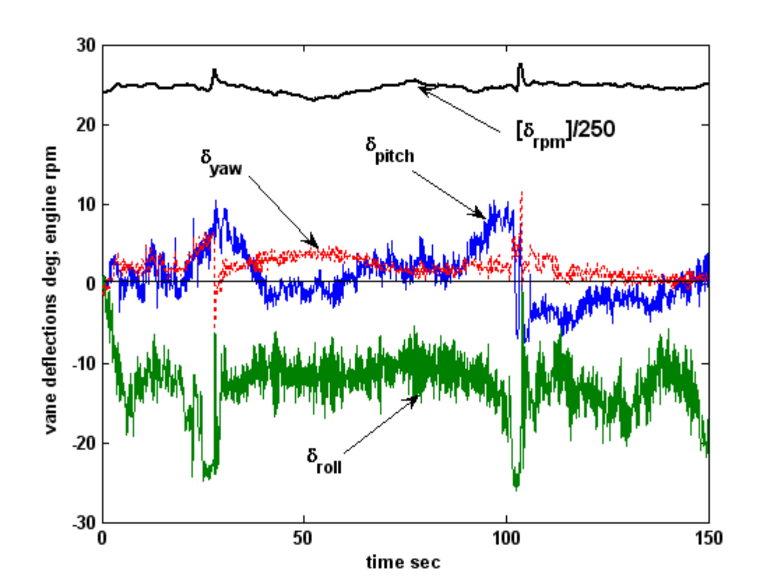
Dept. Mech. & Aero. Eng.

UC Davis, June 2007

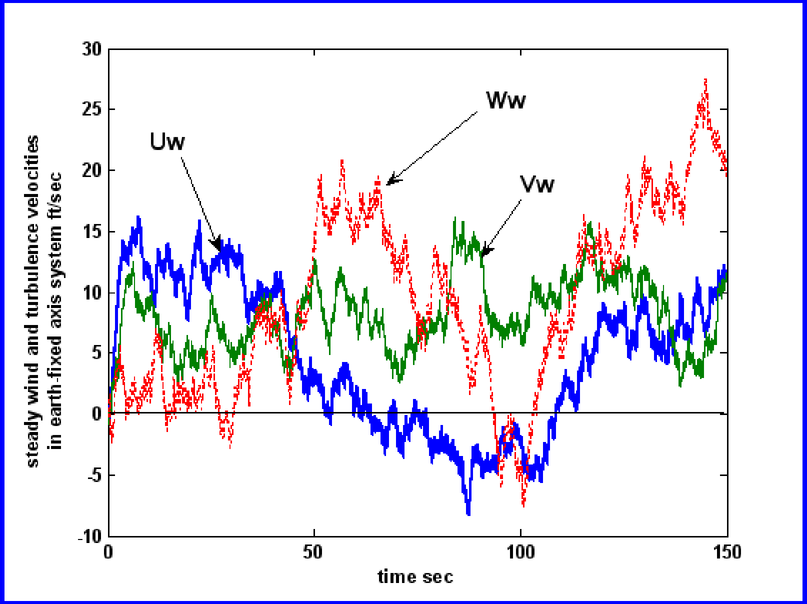
Vehicle velocity responses; turbulence and 10 ft/sec steady wind

20% unmodeled decrease in principal moments of inertia

Automatic, Robust, Flight Control Design for a 29-Inch Ducted-Fan UAV

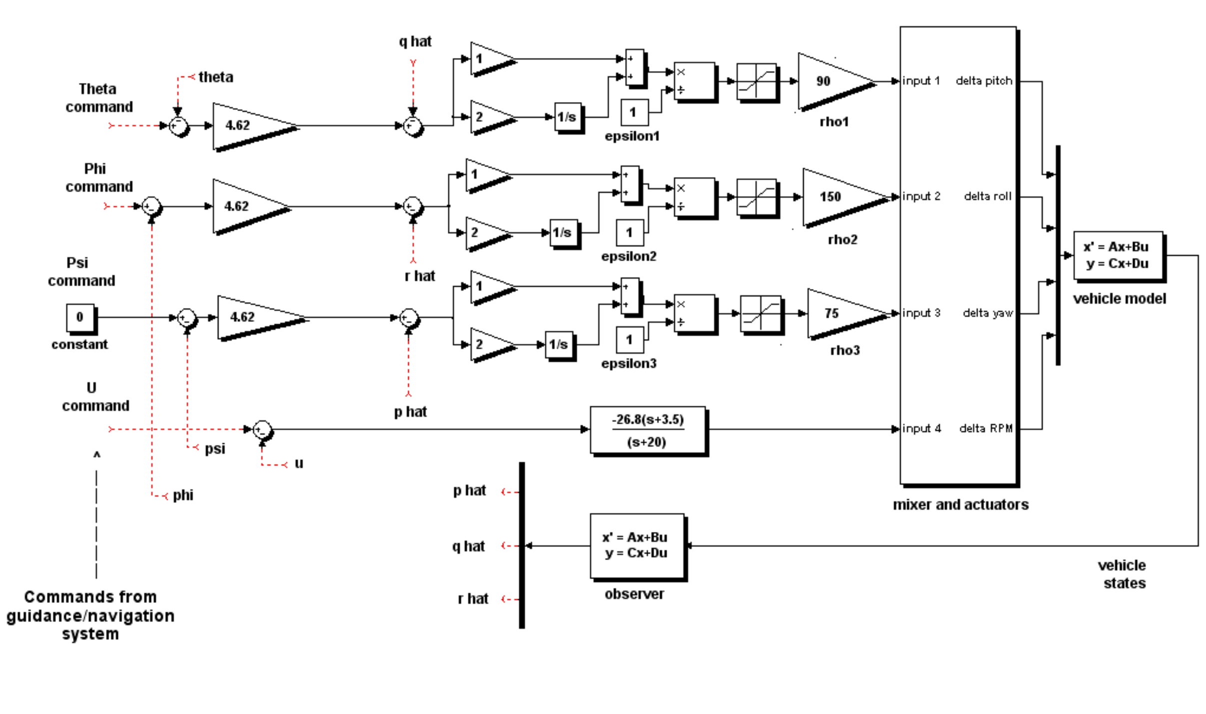


Control inputs



Winds and turbulence

Automatic, Robust, Flight Control Design for a 29-Inch Ducted-Fan UAV

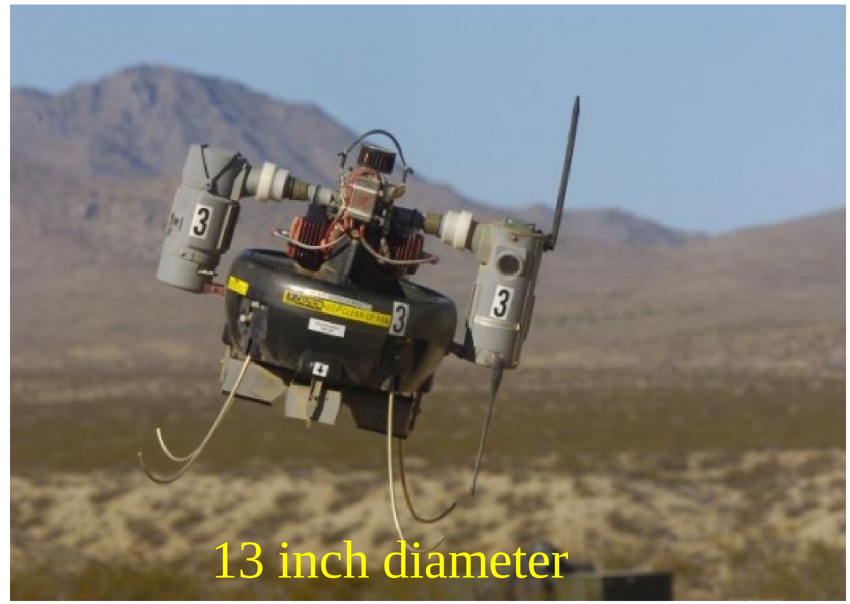


Sliding-Mode Flight Control System Architecture

Operational Ducted Fans

37 inch diameter

BAE Ducted-Fan UAV
in autonomous tests
Aug 2005



13 inch diameter

Honewell Ducted-Fan deployed
in Iraq

Current Research

Autonomous Landing at Unprepared Sites for a Cargo Unmanned Air System

– Office of Naval Research (ONR), Phase I STTR

Lockheed Martin/Kaman

K-MAX manned/unmanned rotorcraft

Autonomy technology for an intelligent VTOL unmanned aircraft system (UAS) to provide air cargo services in support of Marine Corps Expeditionary Warfare without excessive complexity or cost

Current Research

Overall Task Challenges

(ONR Input)

- Night/degraded visual environment
- GPS denied
- Known/possible threats in area
- Winds near aircraft limits
- Sloping landing zone terrain
- Manmade and natural obstacles
- Uncertain surface hardness
- Requirement to minimize exposure of landing zone

- UC Davis Contribution – Sliding Mode Control System Design