Sixth Annual Cyber-Physical Systems Principal Investigators' Meeting
Arlington, VA – November 16-17, 2015

Engineering Safety-Critical Cyber-Physical-Human (CPH) Systems

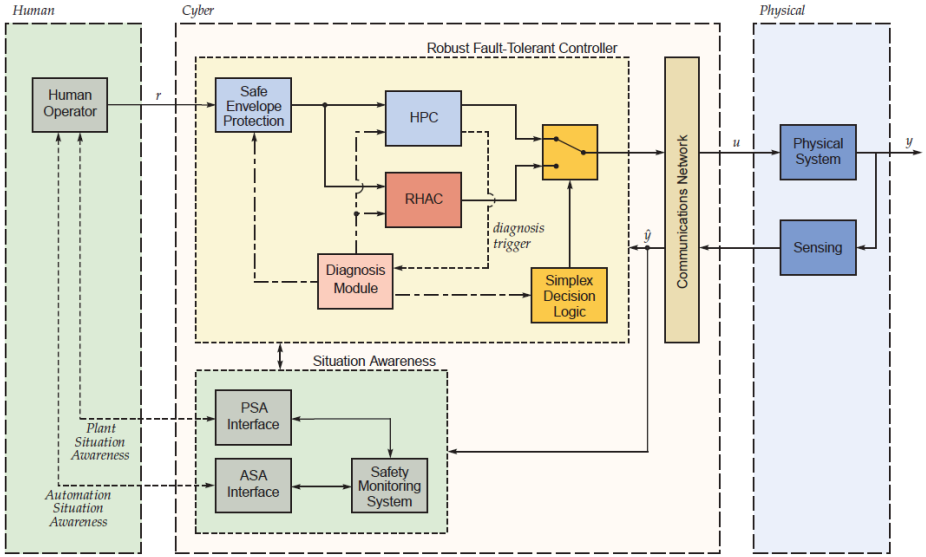
Alex Kirlik, Computer Science & Beckman Institute, UIUC

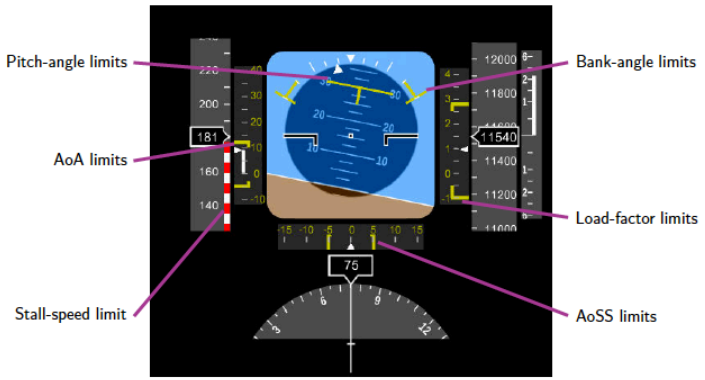
Challenge:

Standard methods for automating control systems drive the human out of the loop, resulting in loss of situation awareness, skill degradation, inability to jump into the control loop when needed, etc.

Solution:

Repurpose control automation to create novel interface designs visualizing envelopes of safe operation, keeping the human in the loop. Automation can also be engaged to provide control compensation to ensure safe envelope protection in cooperation with human control input.





Scientific Impact:

Approach should generalize to CPH systems where safety envelopes can be quantified, control laws or best practices are known and system state can be visualized in the context of these envelopes: Humans and automation share responsibility for safe system operation.

Broader Impact:

Aviation (airplanes), highways (intelligent vehicles), medicine (robotic surgery), etc.

NSF Project #1330077. Co-PIs: N. Hovakimyan, L. Sha, C. Beck, (UIUC), X. Wang, (U. S. Carolina)

BUSINESS *October 2014*

The Human Factor

Airline pilots were once the heroes of the skies. Today, in the quest for safety, airplanes are meant to largely fly themselves. Which is why the 2009 crash of Air France Flight 447, which killed 228 people, remains so perplexing and significant. William Langewiesche explores how a series of small errors turned a state-of-the-art cockpit into a death trap.

By William Langewiesche • Photo Illustration by Sean McCabe

THE NEW YORKER

SEPTEMBER 4, 2014

THE HAZARDS OF GOING ON AUTOPILOT

BY MARIA KONNIKOVA

Google's Next Phase in Driverless Cars: No Steering Wheel or Brake Pedals

By JOHN MARKOFF MAY 27, 2014

MOUNTAIN VIEW, Calif. — Humans might be the one problem Google can't solve.

For the past four years, Google has been working on self-driving cars with a mechanism to return control of the steering wheel to the driver in case of emergency. But Google's brightest minds now say they can't make that handoff work anytime soon.

Their answer? Take the driver completely out of the driving.

TECHNOLOGY | NYT NOW

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We agree that the "handoff" problem has no good practical solution.

We are exploring alternative paradigms (to the handoff, to Google).

Reversing Figure and Ground

Instead of asking the human to look over automation's shoulder and intervene when necessary, let's ask automation to look over the human's shoulder, and:

1. Provide continuous information on the relationship between current performance and safety barriers (or safety "envelopes").

2. And possibly also intervene to ensure performance stays within these envelopes. Yet the human can still override automation by deactivating it, and automation's role in providing control compensation is fully transparent to the human.

Flight Envelope Information-Augmented Display for Enhanced Pilot Situation Awareness

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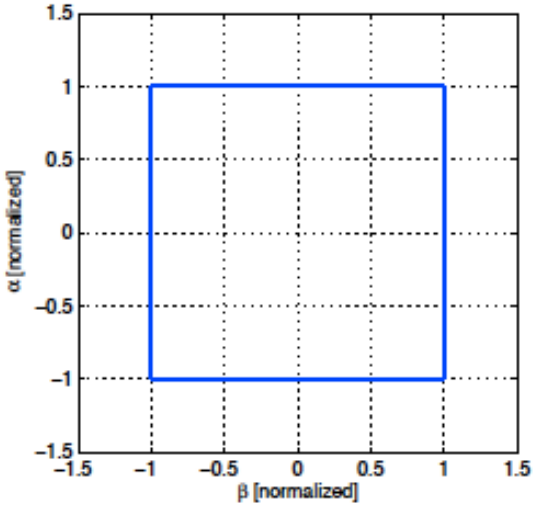
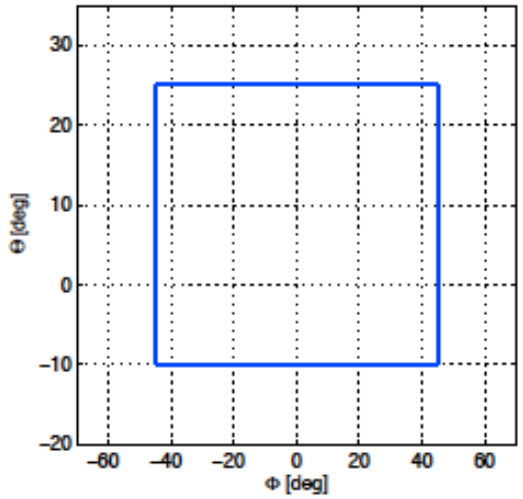
AIAA Guidance, Navigation and Control Conference, Jan. 2015.

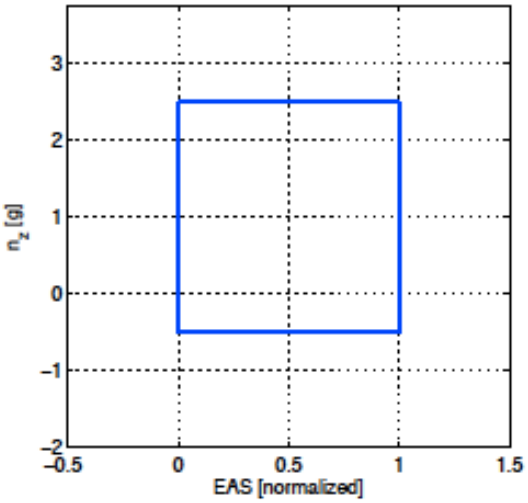
Quantifying “Loss-of-Control” (Safety) Envelopes



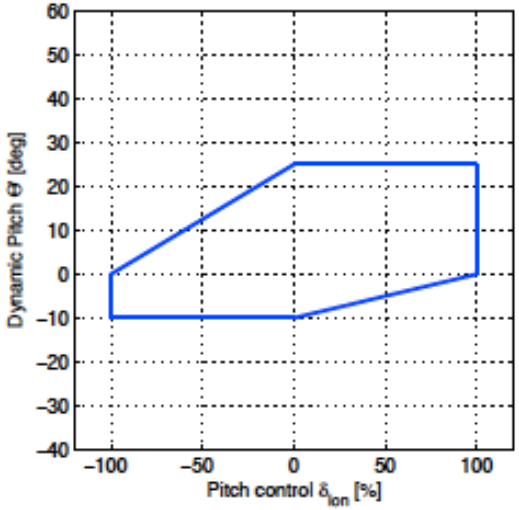
(a) Adverse Aerodynamics



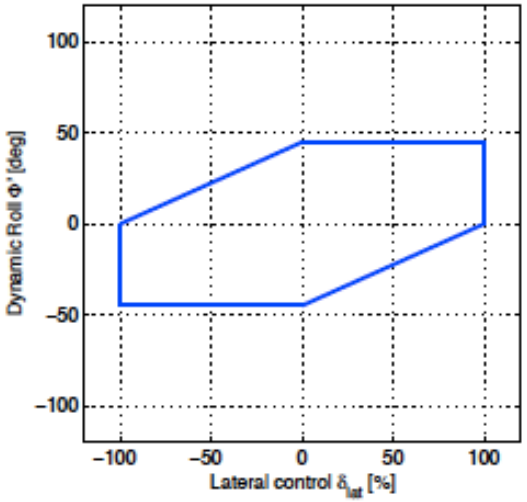
(b) Unusual Attitude



(c) Structural Integrity



(d) Dynamic Pitch Control



(e) Dynamic Roll Control

Figure 1: Loss-of-control envelopes, as defined in [2].

Cockpit Interface Design Enhancements

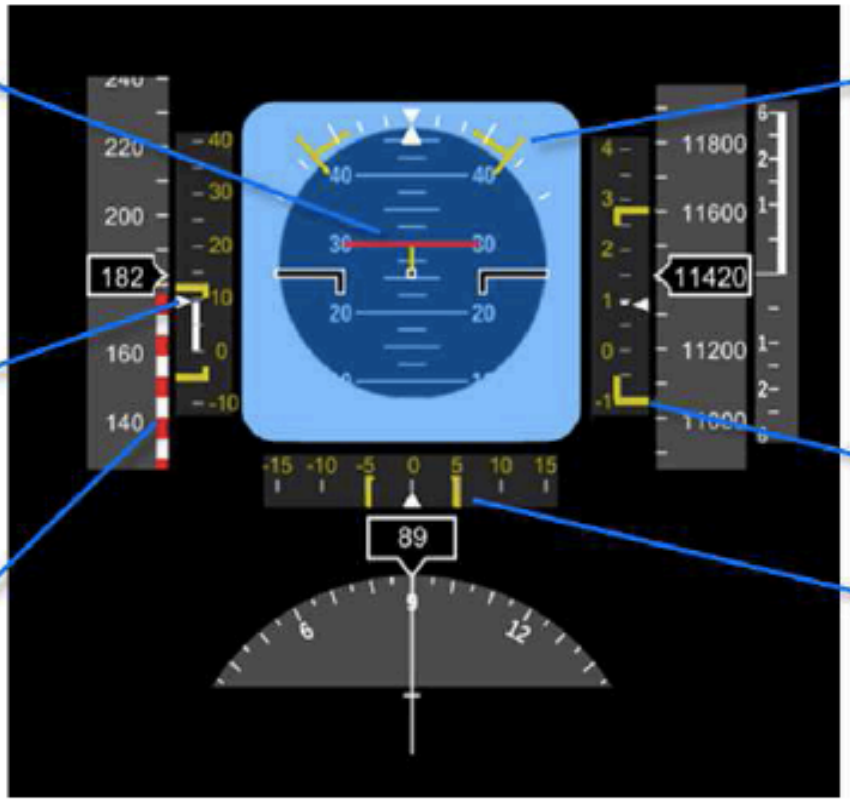


Figure 4: Augmented Primary Flight Display.

Cockpit Interface Design Enhancements

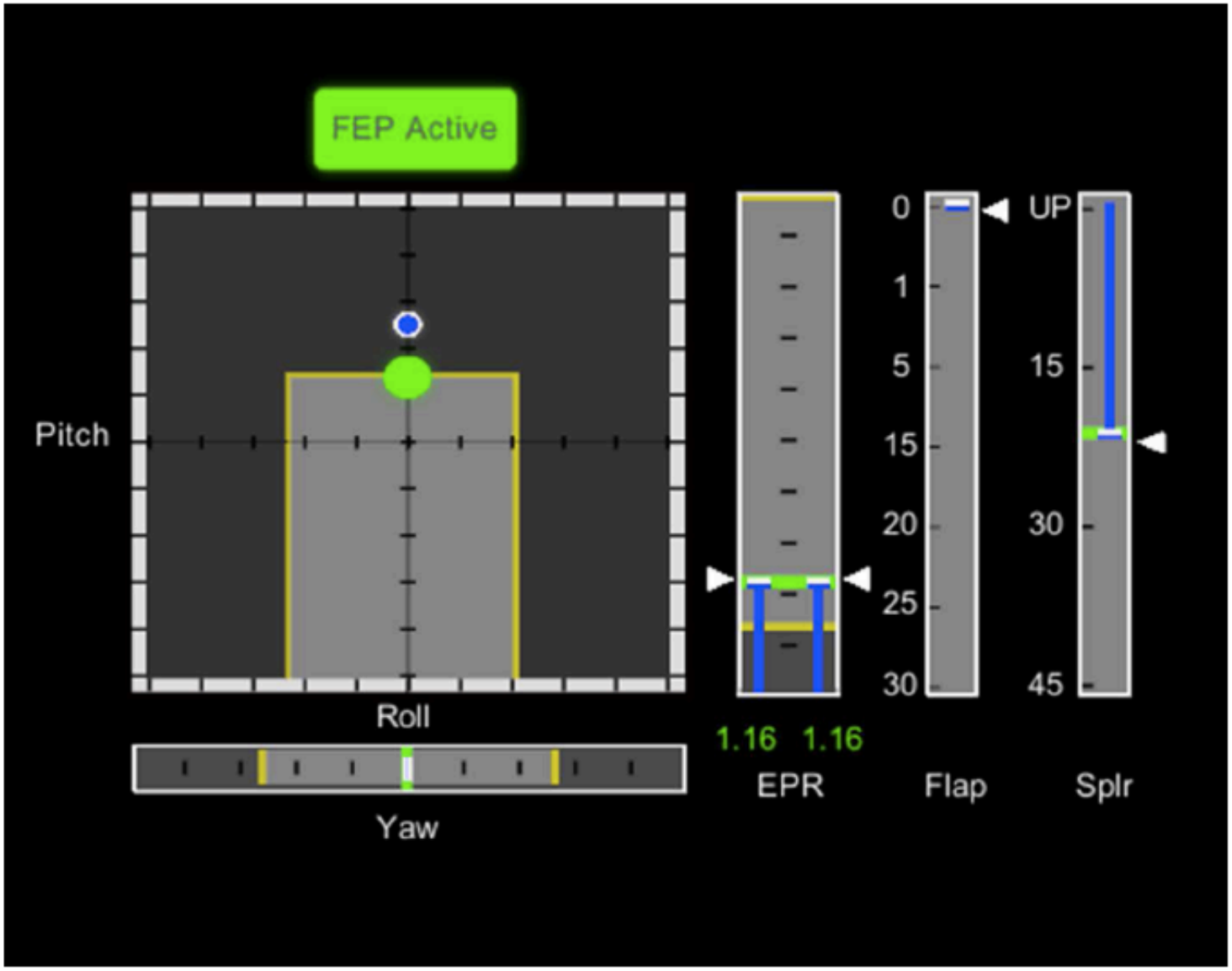
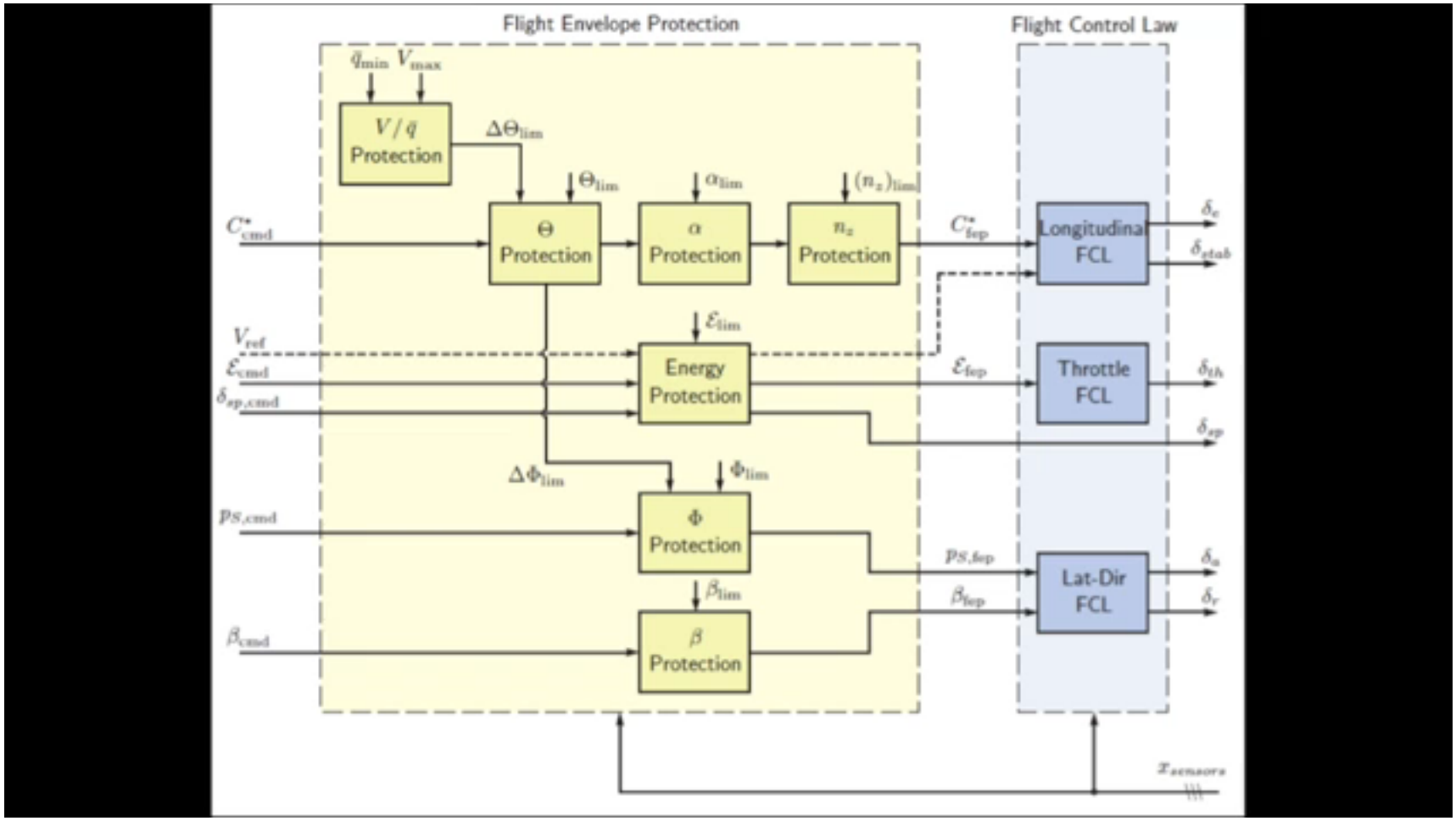


Figure 5: FEP/Input Display.

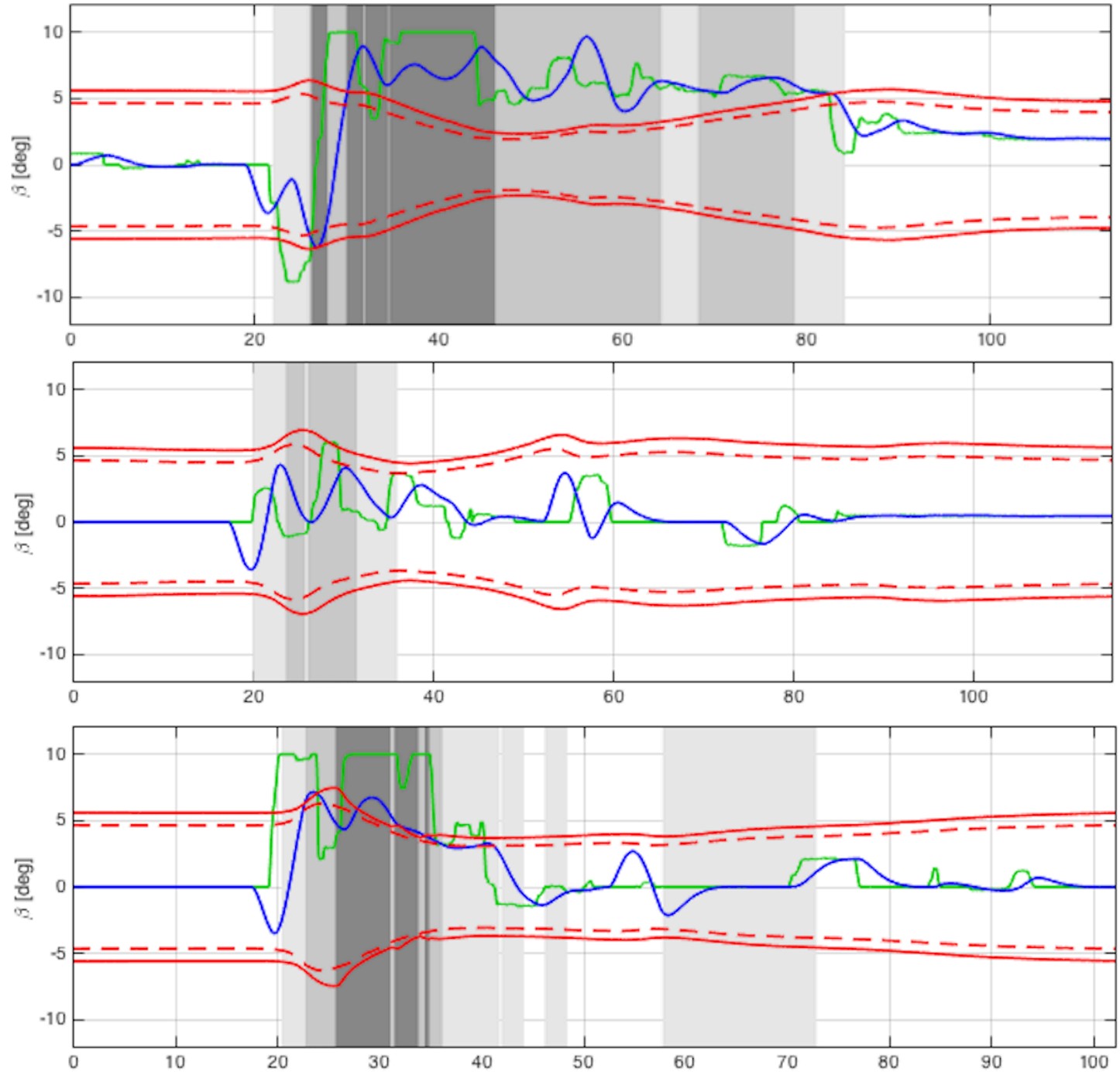
Reversing Figure and Ground in HAI



Experimental Evaluation in Process

Figure 8: Pilot-in-the-loop flight simulator at the Illinois Simulator Laboratory.

- 3 Conditions: 1. Control 2. Display Aids 3. Display Aids + FEP Compensation
- N= 12 per condition (pilots with varying expertise – co-factor)
- Condition order counterbalanced
- All subjects get accommodation training in Condition 1, pre-experiment
- Scenarios: Wind sheer onsets (randomized) at 19 seconds
- Scenario termination: When subjects restore level flight at specified altitude



1 env. exceeded

2 env. exceeded

>2 env. exceeded

Red – Envelopes (hard and soft)

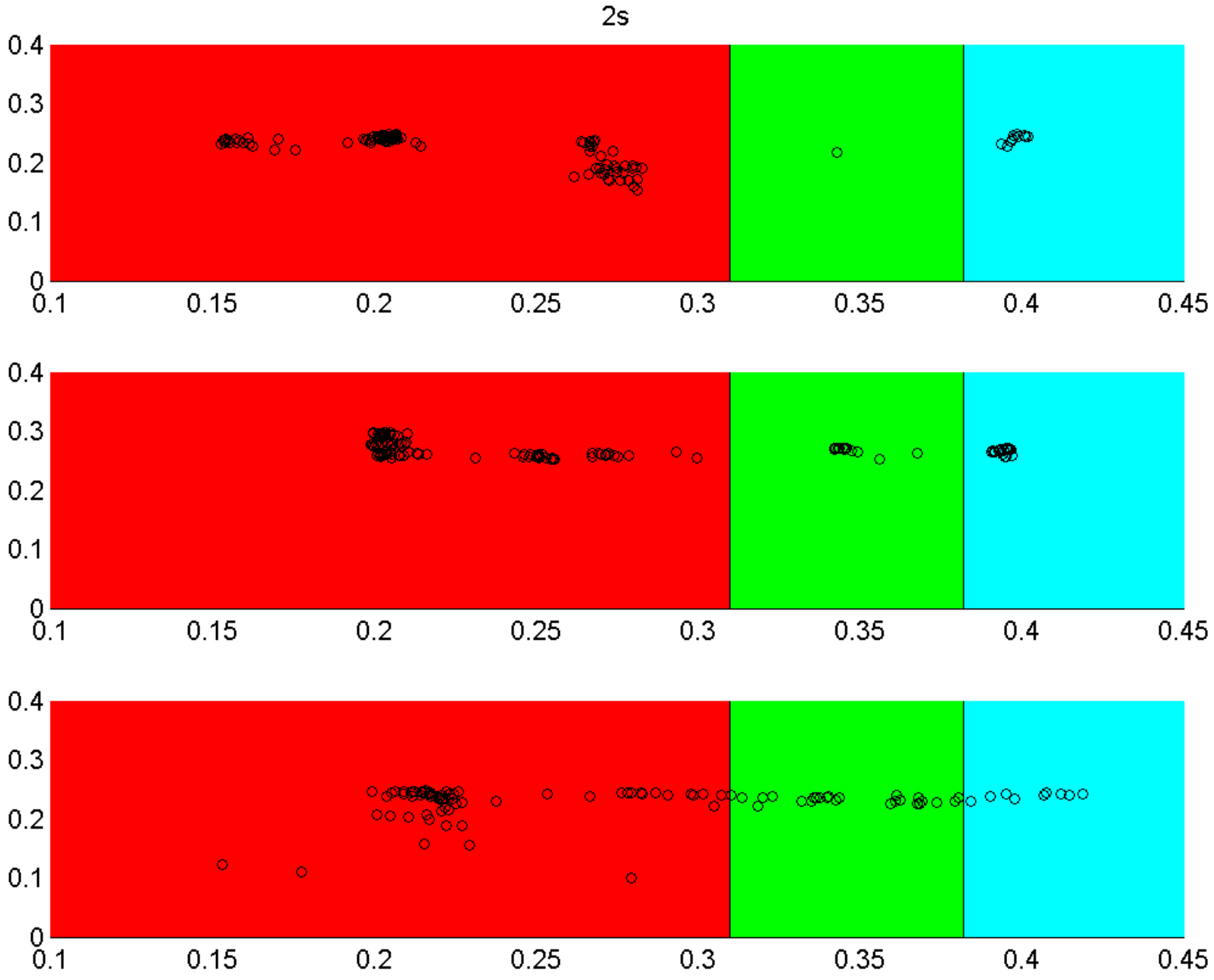
Green – Pilot command

Blue – Aircraft state

Variable: SIDESLIP

ONE SUBJECT

ORDER: 3,1,2


2s
0.4
0.3
0.2
0.1
0
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45

Thank you for your attention

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