National Aeronautics and Space Administration

Advanced Technologies for Artificial Intelligence in Flight Applications

Vahram Stepanyan
ASRA
NASA Ames Research Center

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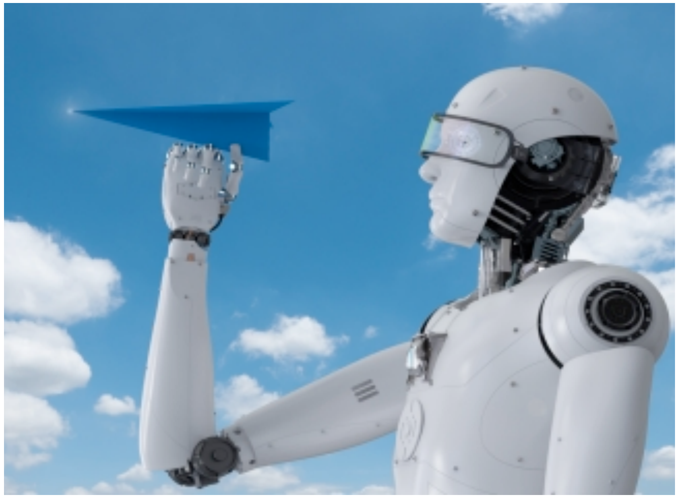
Flight Intelligence

Human pilot
controlled flying machines

Artificial intelligence
controlled flying machines



Same Performance

- Safety
- Predictability
- Society acceptance
- ……………………………..

And same quality

Passenger comfort, noise, emission, …

Picture ref. https://www.healthytravelblog.com/2013/08/29/safety-tips-for-kids-flying-alone/
http://www.connectivity4ir.co.uk/article/159844/Innovators-challenged-to-use-AI-to-boost-aircraft-performance.aspx

Human Controlled Flight

Pilot is the authority

- Monitoring
- Communication
- Negotiation
- Decision making

- Reasoning
- Training
- Memory
- Creativity
- Etc.

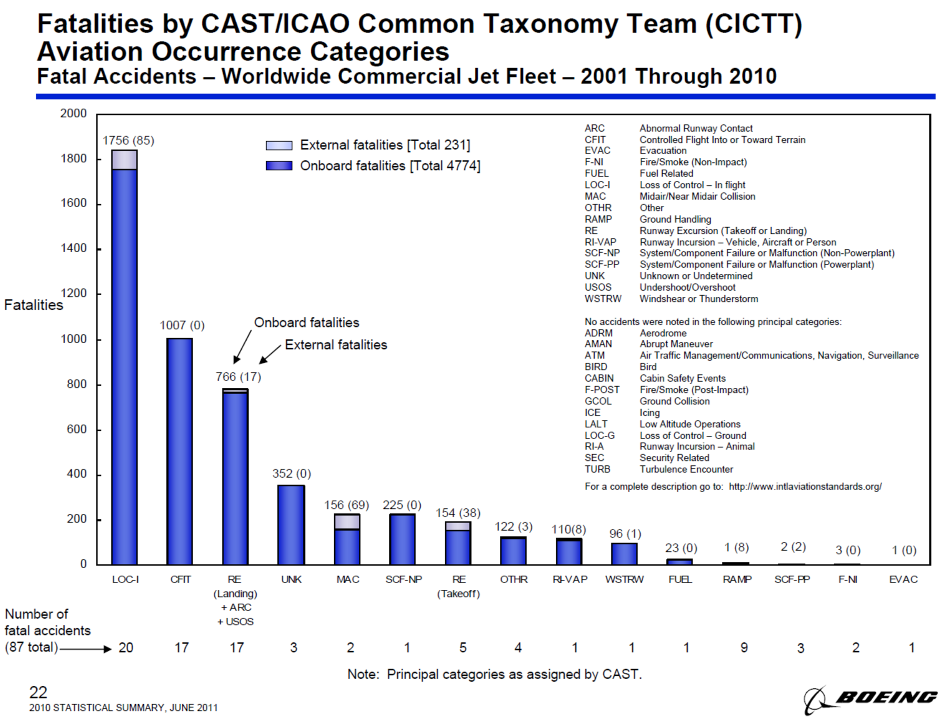
- Fatigue
- Distraction
- Stress
- Panic
- Etc.

How can we do better ?

Picture ref. https://www.flightsafetyaustralia.com/2017/07/getting-smart-artificial-intelligence-and-aviation/
https://itunes.apple.com/us/app/f-sim-space-shuttle/id352670055?mt=8
https://alis.alberta.ca/occinfo/occupations-in-alberta/occupation-profiles/helicopter-pilot/

Intelligent Pilot Assistance

Accidents happen



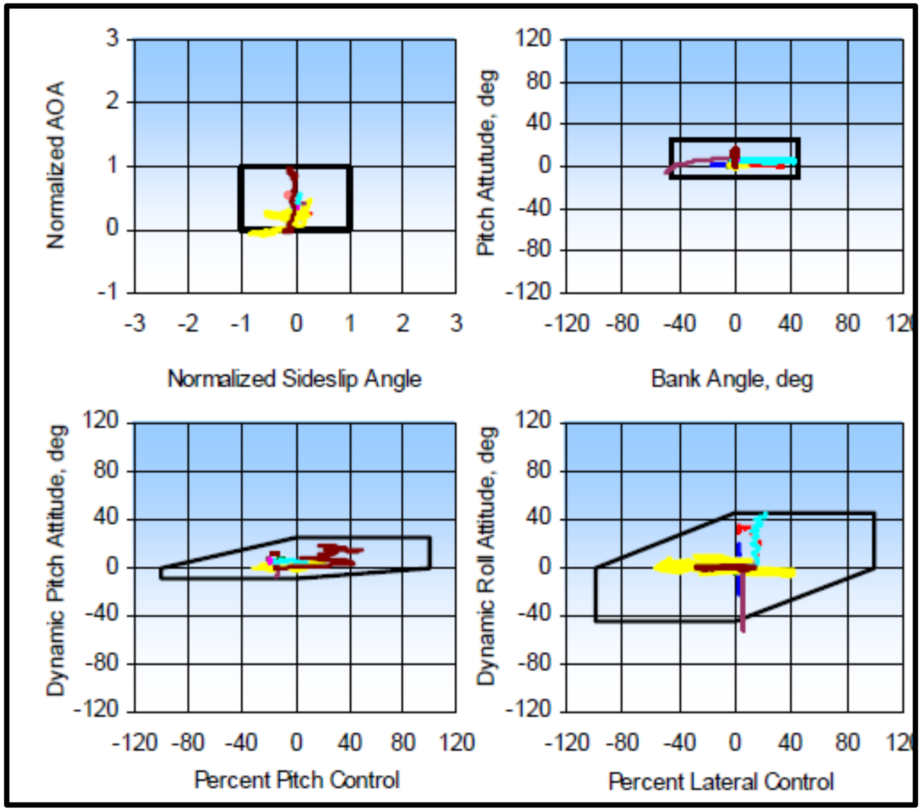
How to prevent?
Design onboard AI to assist the pilot

Technology requirements

- Reliable state estimation
- Maneuverability margin predictions
- Real-time pilot cueing

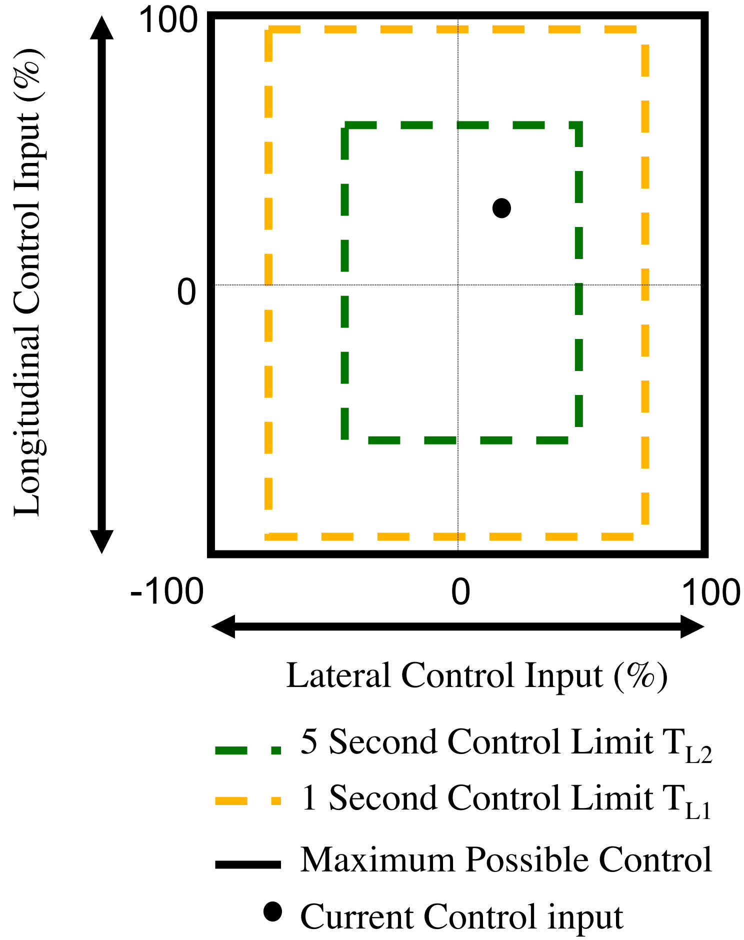
Margins From Piloting Perspective

Los-of-control Criteria

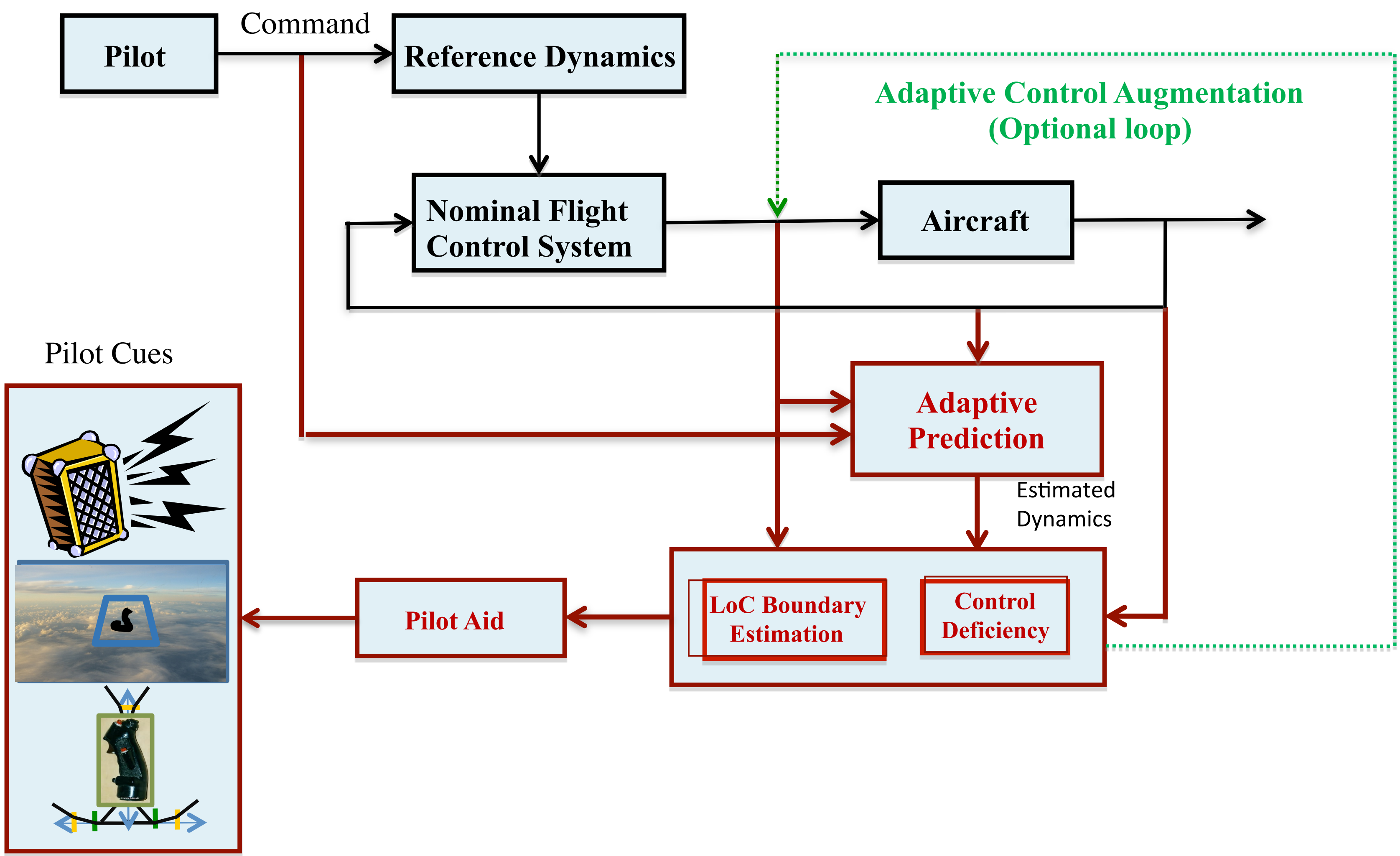


Reference: AIAA 2004-4811; Authors: Wilborn and Foster

Intelligent computations



The Predictive Architecture



LOC Example Without Cueing

Pilot Cue (amber box) on left not displayed to pilot

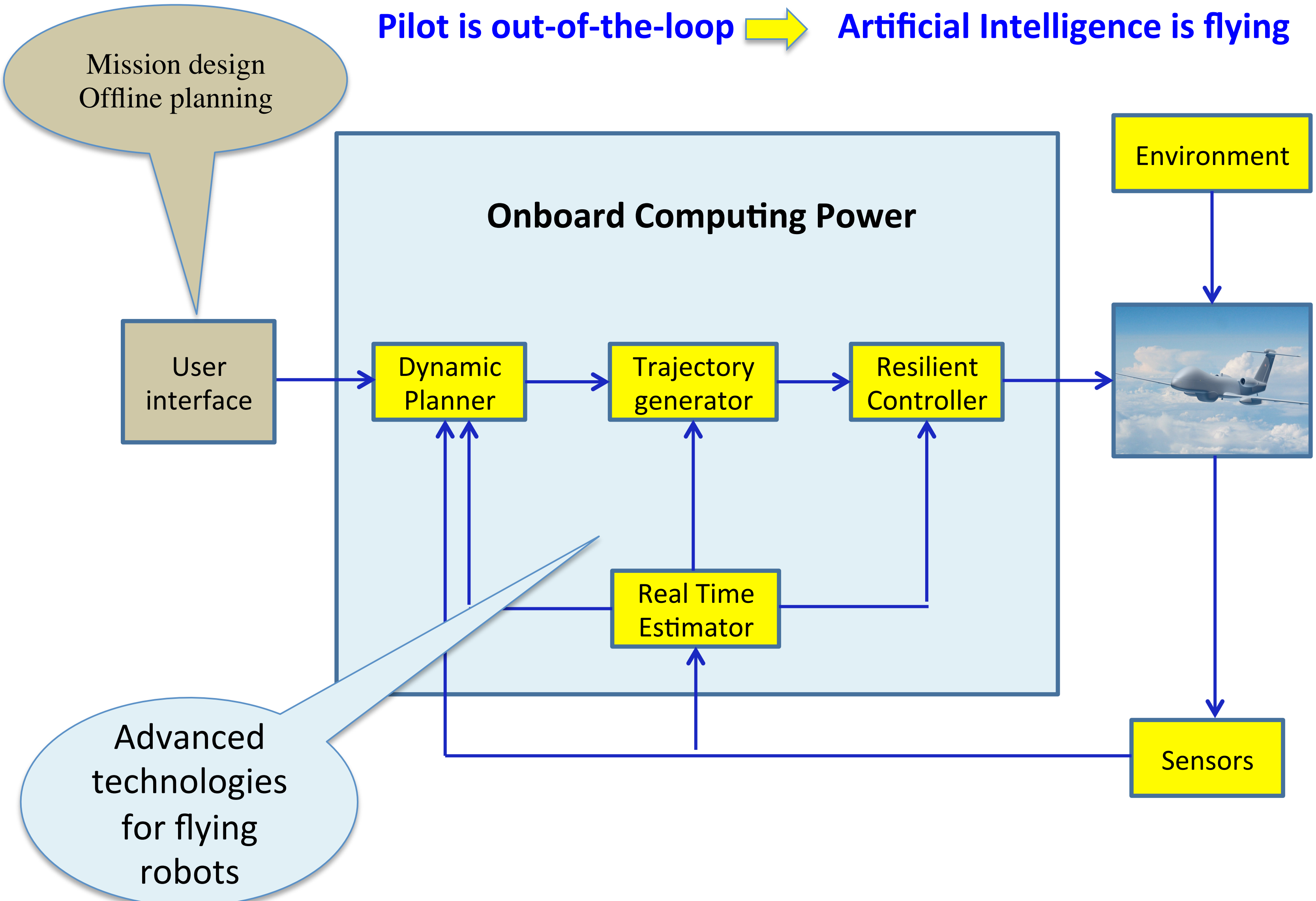
Left wing damage with no pilot visual cue

LOC Example With Cueing

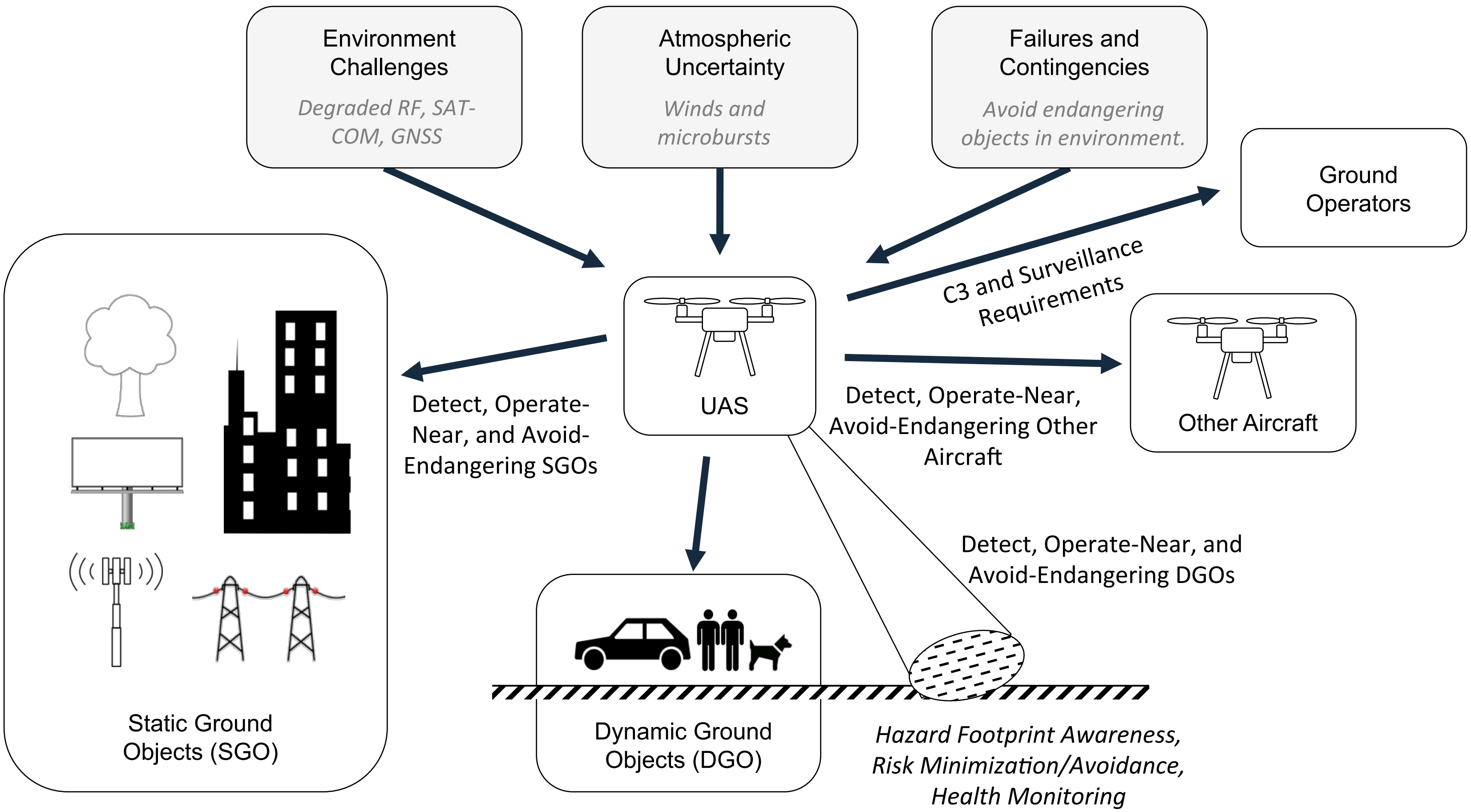
Left wing damage with pilot visual cue

Flying Robot's Architecture

Pilot is out-of-the-loop ⇨ Artificial Intelligence is flying



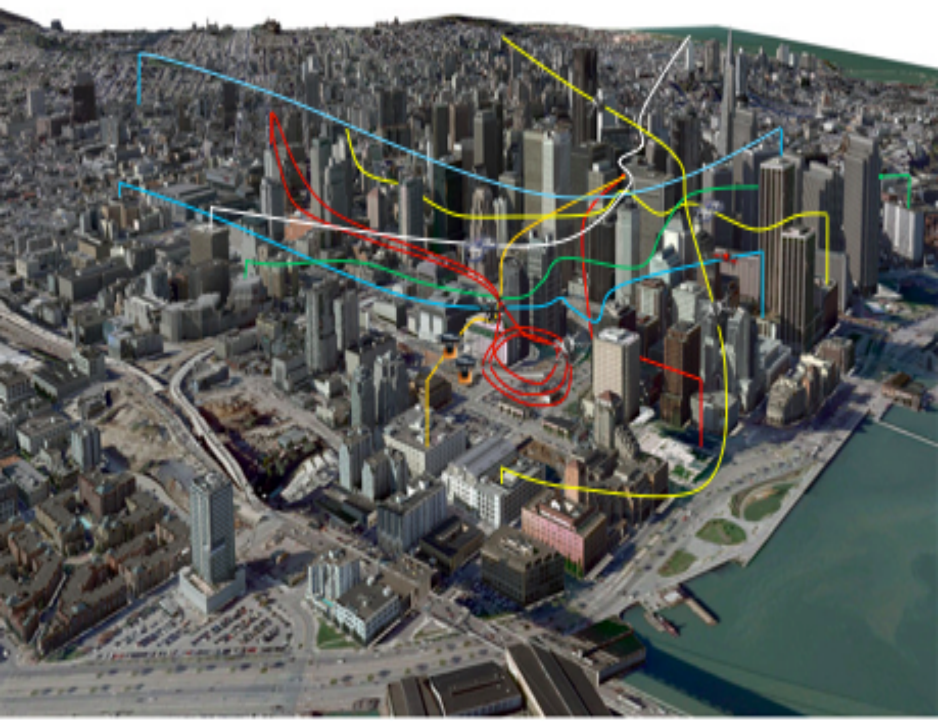
Challenges of Robotic Flight



Courtesy of C. Ippolito

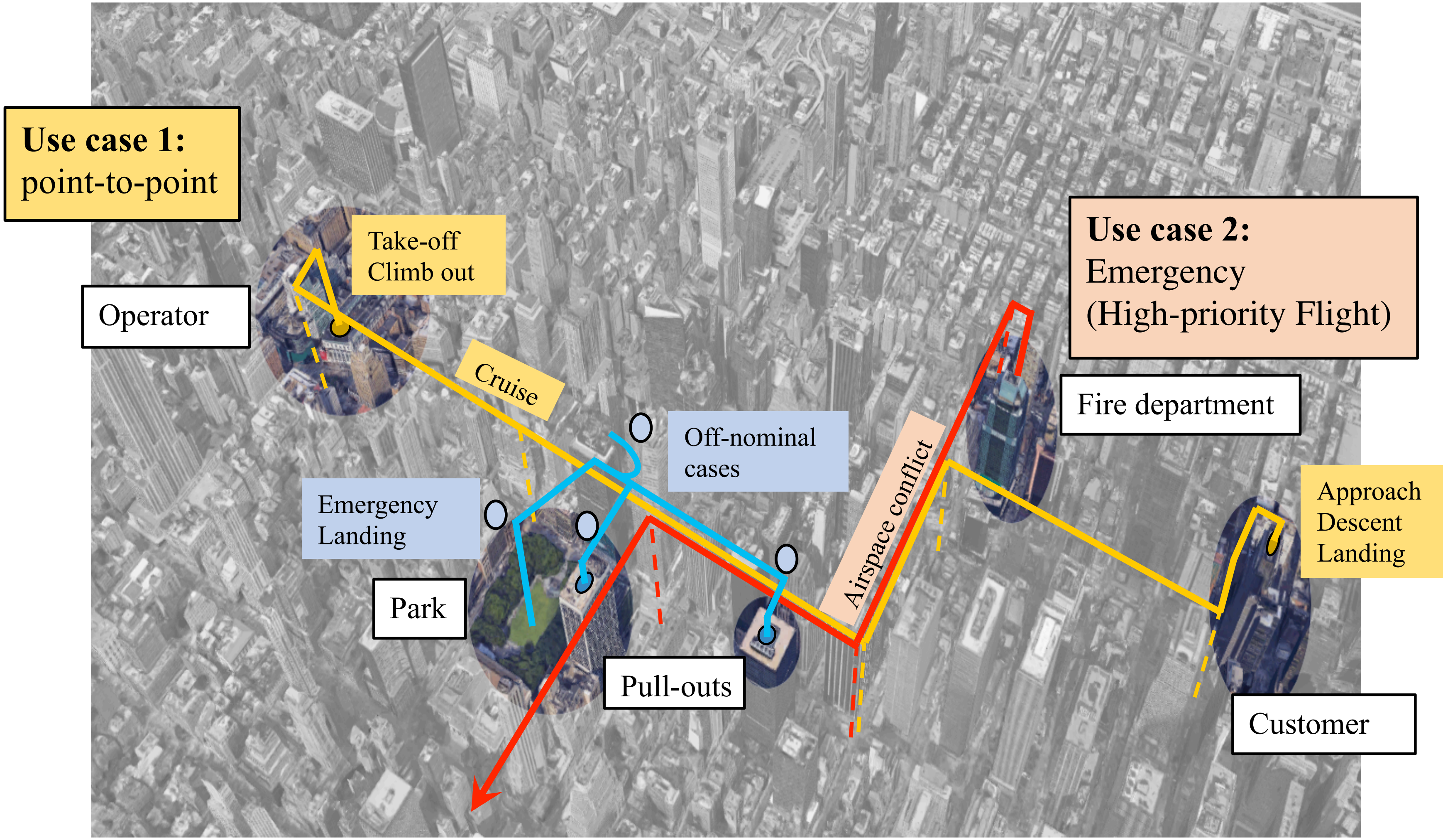
Technology Requirements of Robotic Flight

How can we safely operate in high density urban environment?



- Estimator shall provide in real tome
  - Vehicle state and location in the environment
  - Obstacles locations and motion
  - Atmospheric disturbance
  - Detect and identify component failures
- Dynamic planner shall plan/replan in real time providing
  - Man maid strictures and terrain avoidance
  - Static and dynamic ground obstacle avoidance
  - Cooperative dynamic air obstacle avoidance
  - Acceptable air and ground risk.
- Trajectory generator shall provide
  - Feasible trajectories in real time
  - Power required to traverse the trajectory
  - Minimum endurance and maximum vehicle range
  - Acceptable time time of flight
- Resilient controller shall provide
  - Stability of the vehicle
  - Acceptable tracking performance and flight envelop
  - Compensate for failures and disturbances
  - Flight within approved 4D volume in all phases

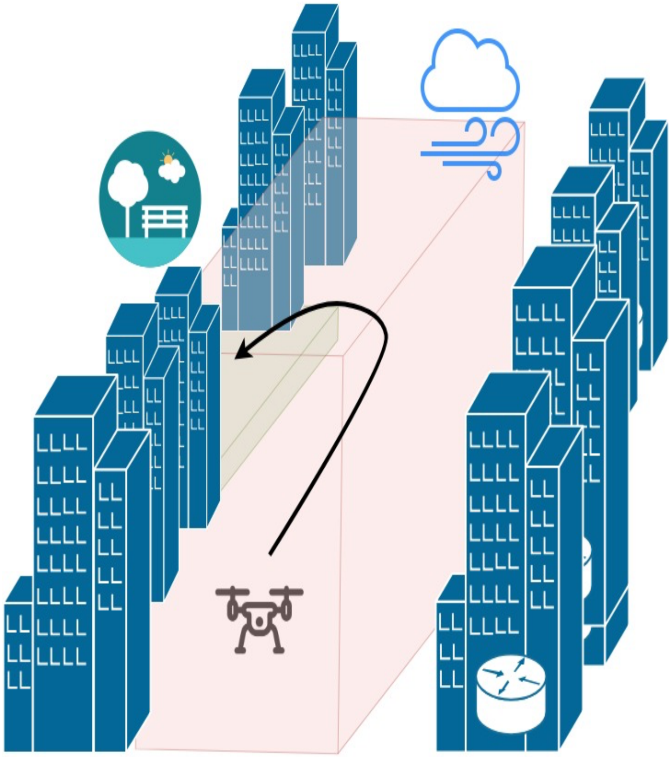
Use case: Point-to-Point Operation



Contingency Example: Wind

Objective

Autonomously fly the UAV in the uncertain wind field using onboard sensors and estimation algorithms.



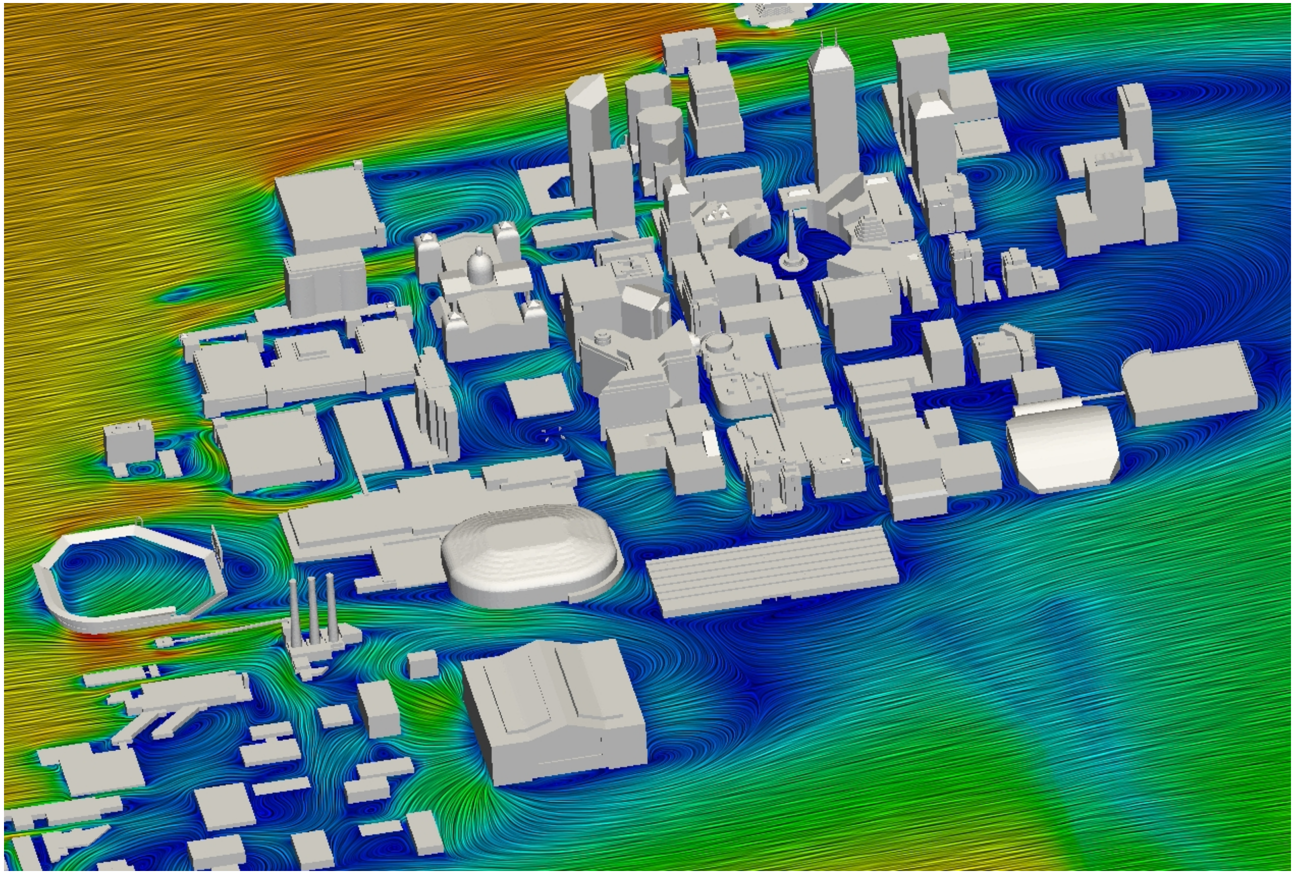
Challenges

- Real-time wind estimation
- Real time re-planning to accommodate the wind
- Required power estimation for the new plan
- Decision making: continue or abort
- Find alternate landing site to abort
- Fly UAV though approved volume and change plan to land to alternate landing site taking into account wind and battery constraint.

- How reliable is the wind estimation?
- Is the mission still possible?
- Is the flight safe for the vehicle and environment?
- Are the predicted performance bounds acceptable?

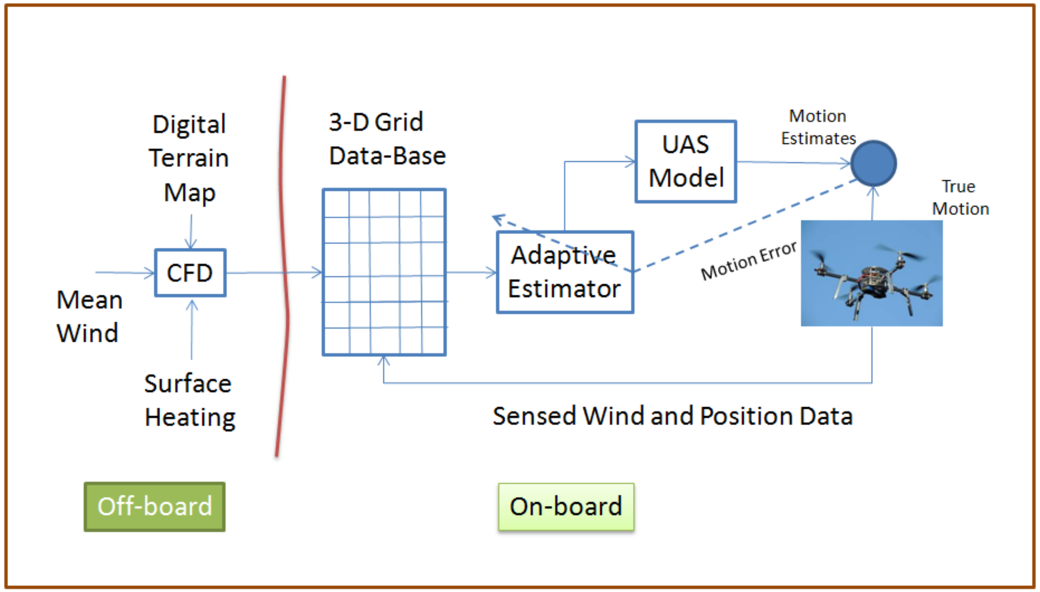
Urban wind Field Specifics

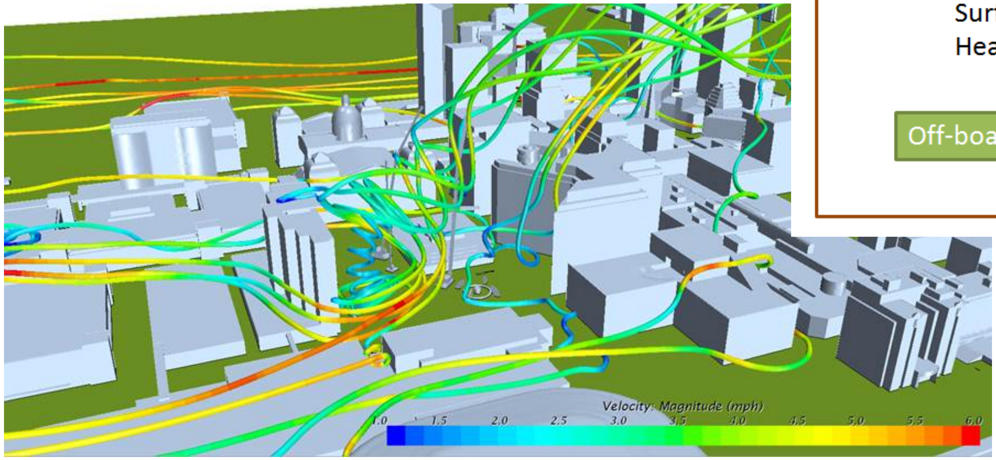
- Wind characteristics
  - Turbulent air flow
  - Isolated roughness
  - Wake interference
  - Skimming flow
  - Hard to predict
- Local Measurement
  - Isolated roughness
  - No infrastructure
  - Too expensive
- Wind field modeling
  - Digital 3D mapping
  - Heavy computations
  - Large memory
- Not feasible onboard
- Expensive transmission



Wind Information

Can on-board sensors and compact CFD models provide sufficiently accurate and robust wind estimates?

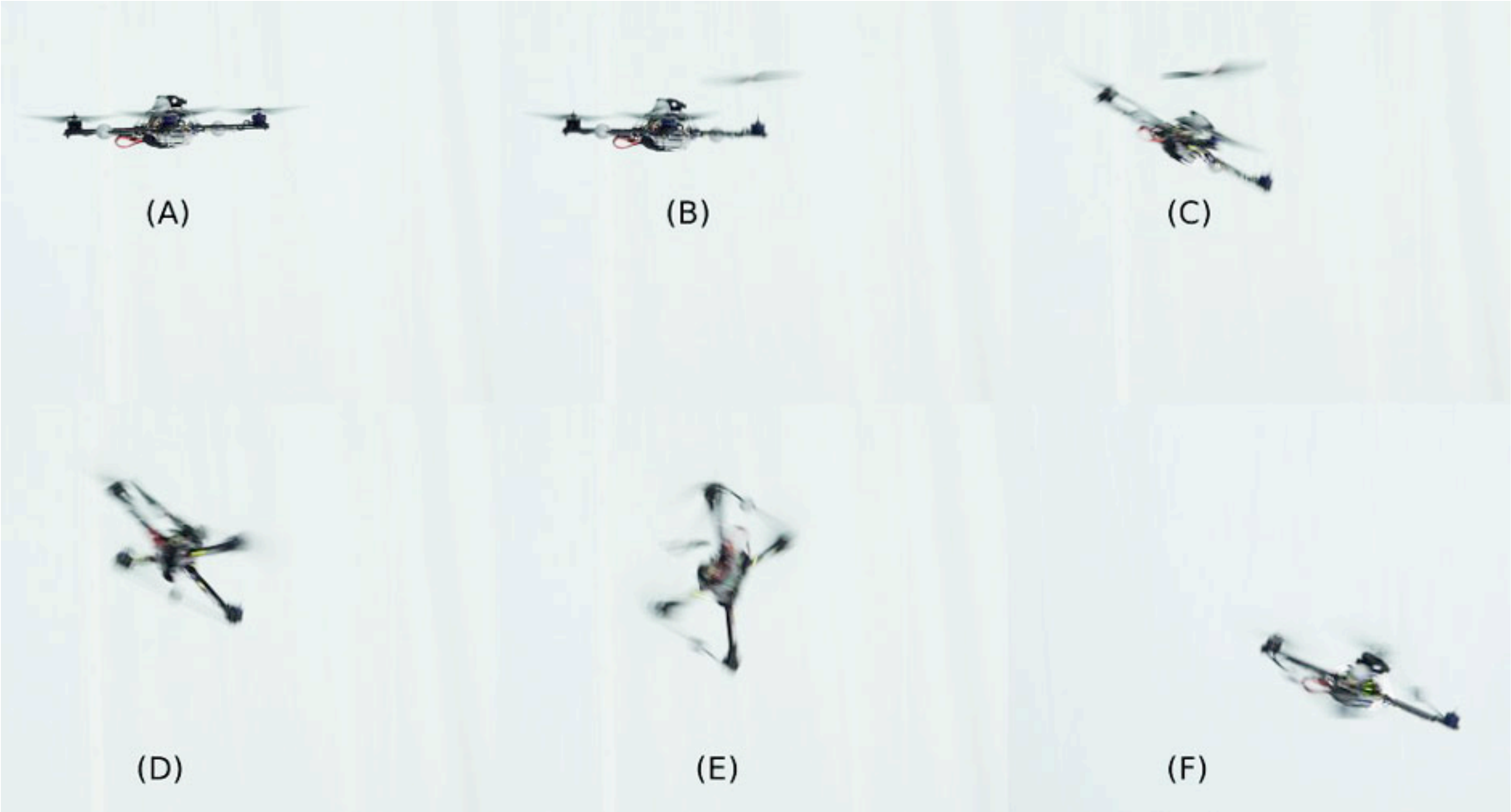




Wind Estimation in Reflection

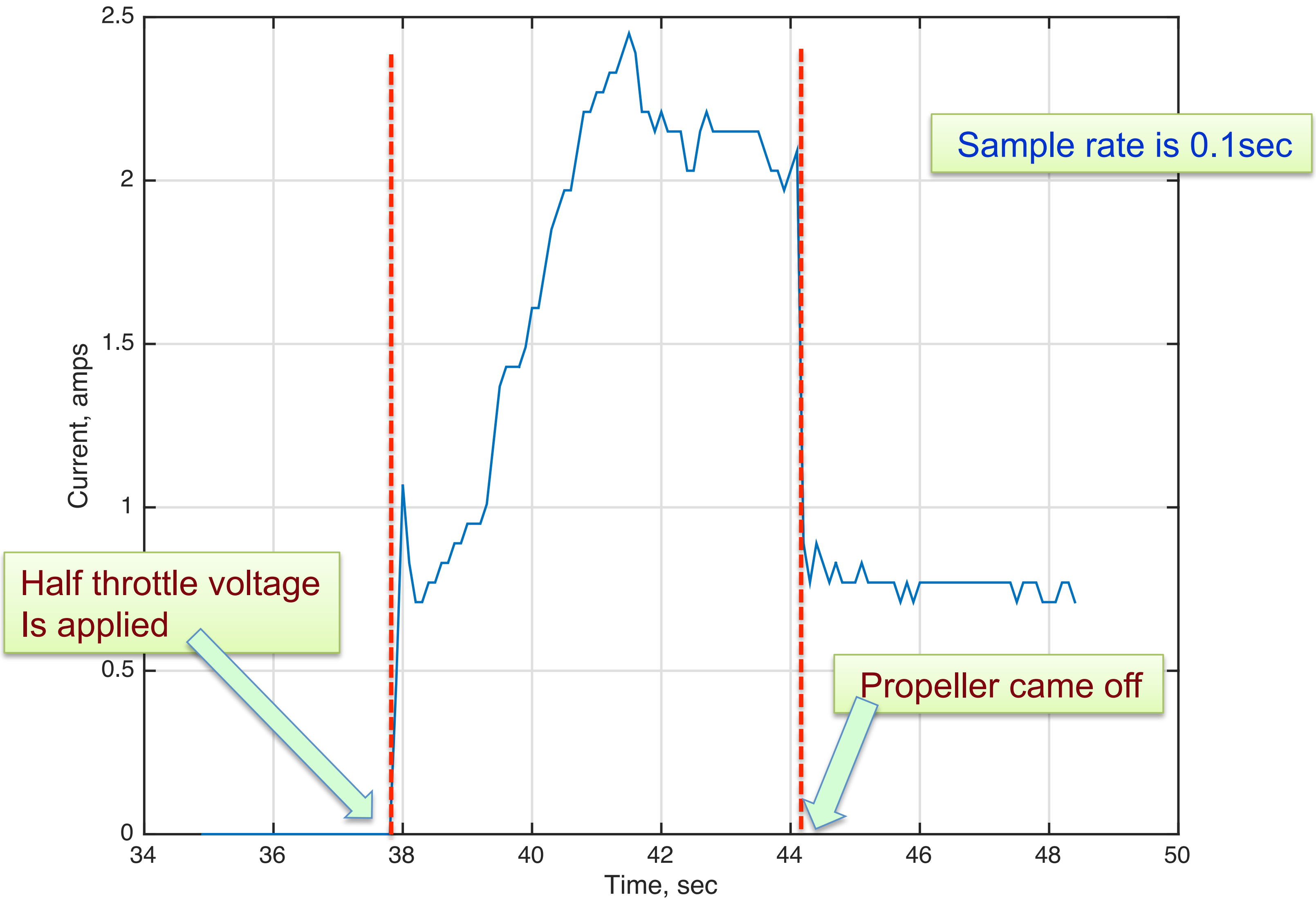
Wind field is generated using CFD and city digital map

Typical Component Failure



Is it still possible to safely fly this vehicle?

Failure Identification Test



Resilient Control Application

- Motor 2 fails at t=8 sec
- Vehicle switches to safe mode
  - Find nearby emergence landing site
  - Land

Failure identification and intelligent control reconfiguration stabilizes the vehicle