CPS: Synergy: Collaborative Research: Managing Uncertainty in the Design of Safety-Critical Aviation Systems

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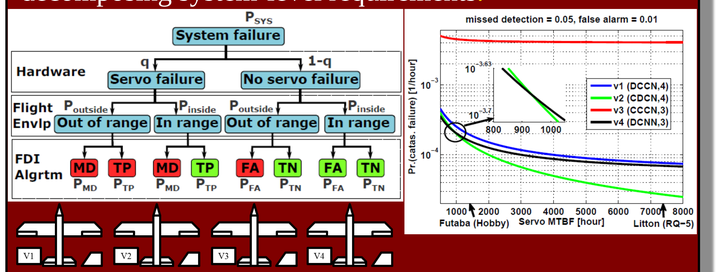
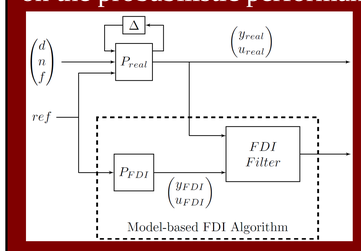
Aim 1: Convert system requirements to component-level requirements using a probability density function approach.

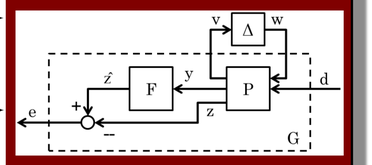
Task 1.A - Derive density-function methodology for decomposing system-level requirements.



Density-based fault trees are used to assess the reliability of actuator architectures for unmanned aircraft.

Task 1.B - Investigate techniques for computing bounds on the probabilistic performance of a system.





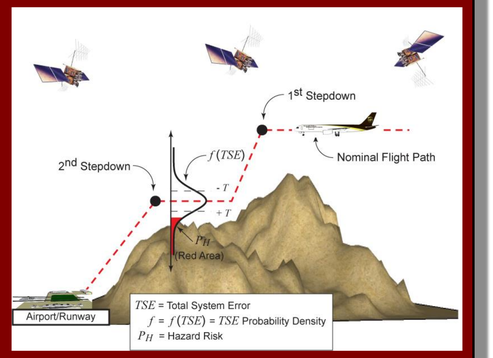
Integral quadratic constraints provide a method to analyze the probabilistic performance of uncertain systems.

[1] R. Venkataraman and P. Seiler, "Model-Based Detection and Isolation of Rudder Faults for a Small UAS," AIAA Science and Technology Forum, AIAA 2015-0857, 2015.
[2] R. Venkataraman, M. Lukátsi, B. Vanek, and P. Seiler, "Reliability Assessment of Actuator Architectures for Unmanned Aircraft," 9th IFAC SafeProcess, 2015.

Overview

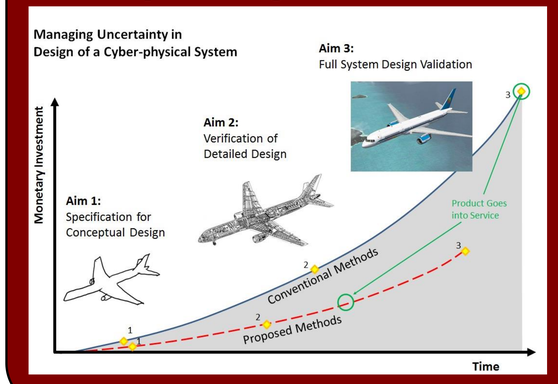
Issue: Aviation systems require hardware (physical) and software (cyber) components designed by many engineering teams to be safely integrated.

Objective: Create tools to manage uncertainty in the design and certification process of safety-critical aviation systems, e.g. NextGen.



Typical Profile for a Precision Landing

Development Costs for Conventional and Proposed Design Methods



Impacts:

Significant reduction in the costs and time required for fielding new aviation systems.

Applications to other complex systems including smart power grids and automated highways.

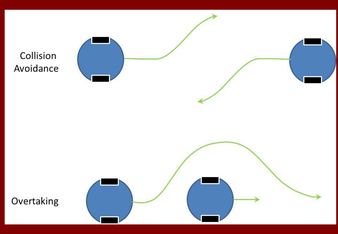
Outreach and Education: Engage engineering students in hands-on, CPS-centric projects.

Robotic Snowplow Competition

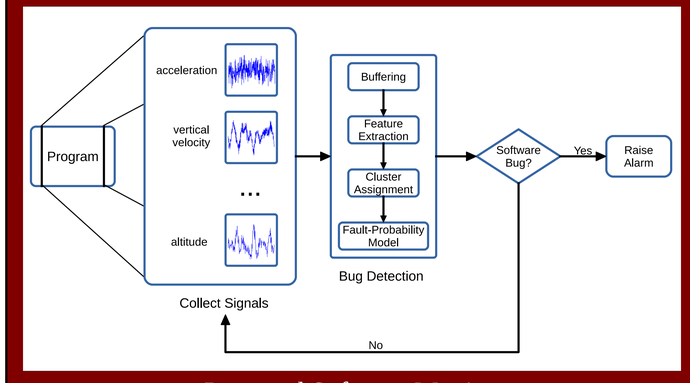
Student competition to design, build and operate an autonomous snow plow. Competition rules are now being modified to incorporate a CPS-challenge starting with the 2015 competition cycle.

CPS Curriculum Development

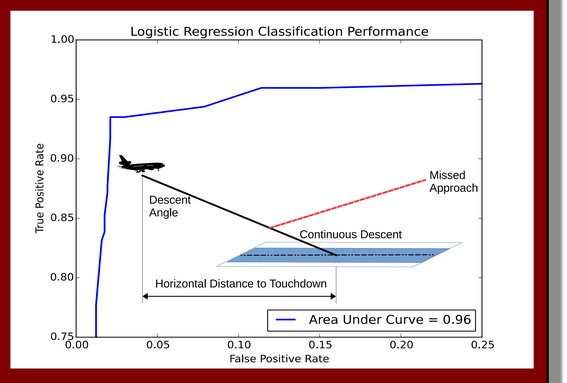
Use sim. and hardware experiments in intro. control course to explore hybrid controls (as example CPS application).



Aim 2: Develop a framework for software design and verification that incorporates probabilistic software failure models.

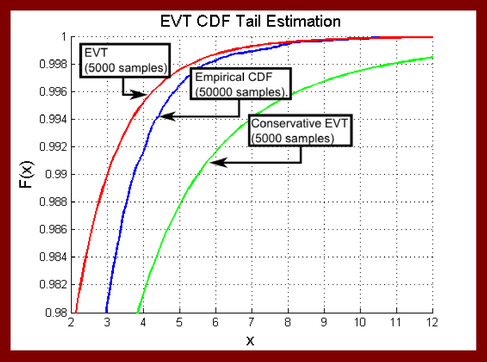


Proposed Software Monitor



Results

Aim 3: Apply techniques from Extreme Value Theory (EVT) to develop adaptive verification and validation procedures that shorten the time required for certification of complex cyber-physical systems.



Task 3.A - Probability-Weighted Moment estimators provide an adaptive approach

- Conservative CDF overbounds are generated using EVT techniques
- EVT requires 90% less data than empirical CDF reconstruction

Tasks 3.B&C – Design a hybrid particle filter with EVT estimation to eliminate impoverishment. Apply techniques to the certification process of a synthetic air data system