Application of Falsification Methods on the UxAS System

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Summer Of Innovation 2017

AFRL
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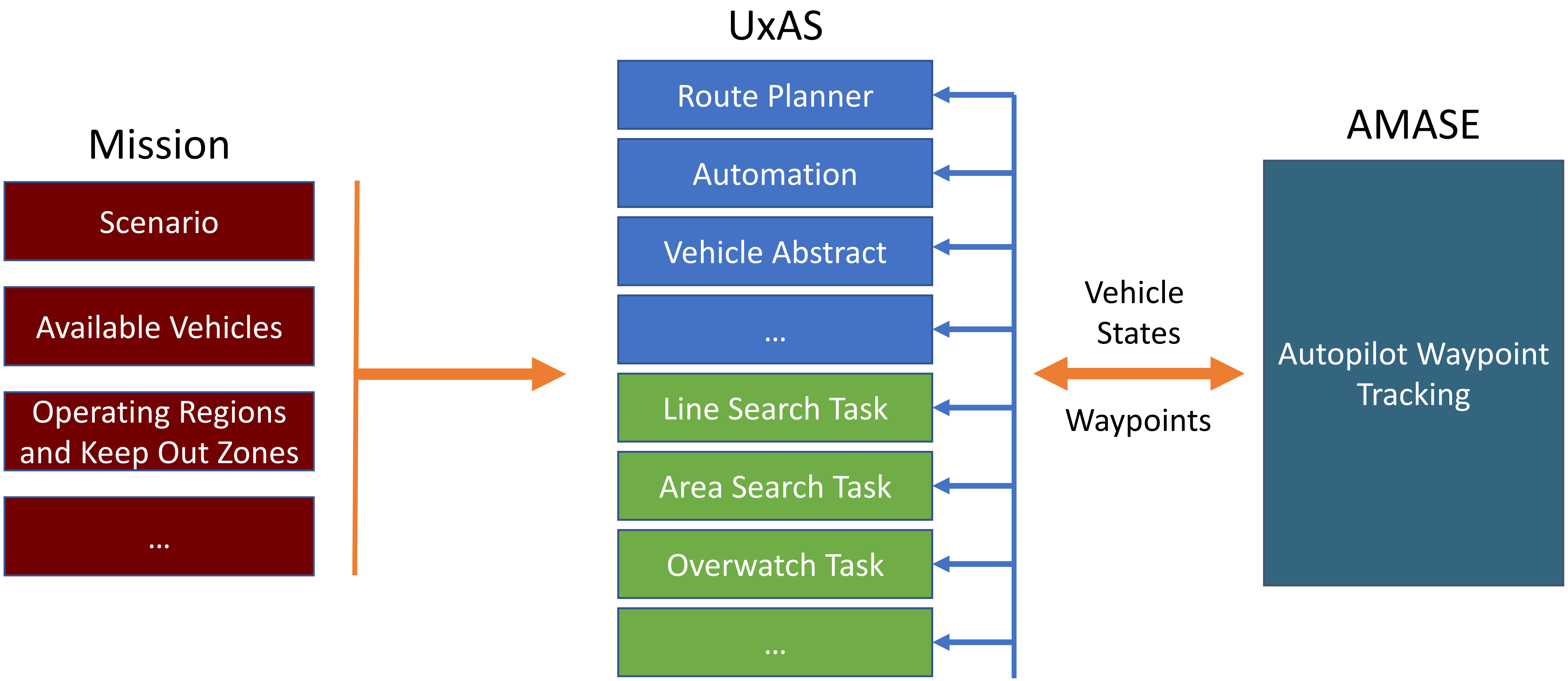
Participants from the industry, academia, and the government

Apply formal methods to the AFRLs UAV mission planning software UxAS

Requirement formalization • Formal architecture description • Methods for proving correct and safe behavior • Cyber-security considerations • Real-time scheduling/enforcement • Automated test generation • Argumentation and assurance cases • Run-time assurance • Hybrid systems analysis • Improvements in mission and task planning

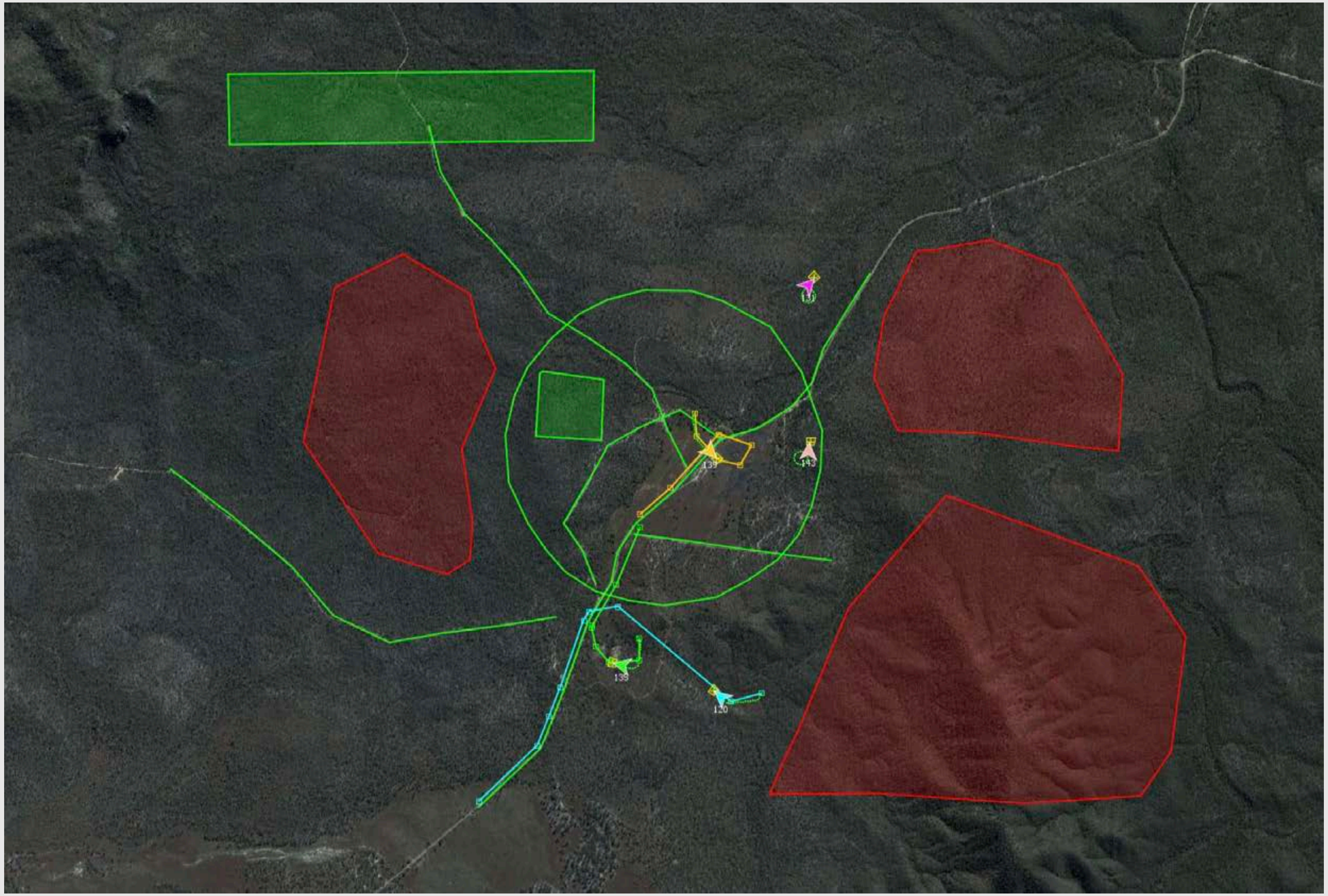
1. UxAS and AMASE

From Mission Scenarios to Simulation



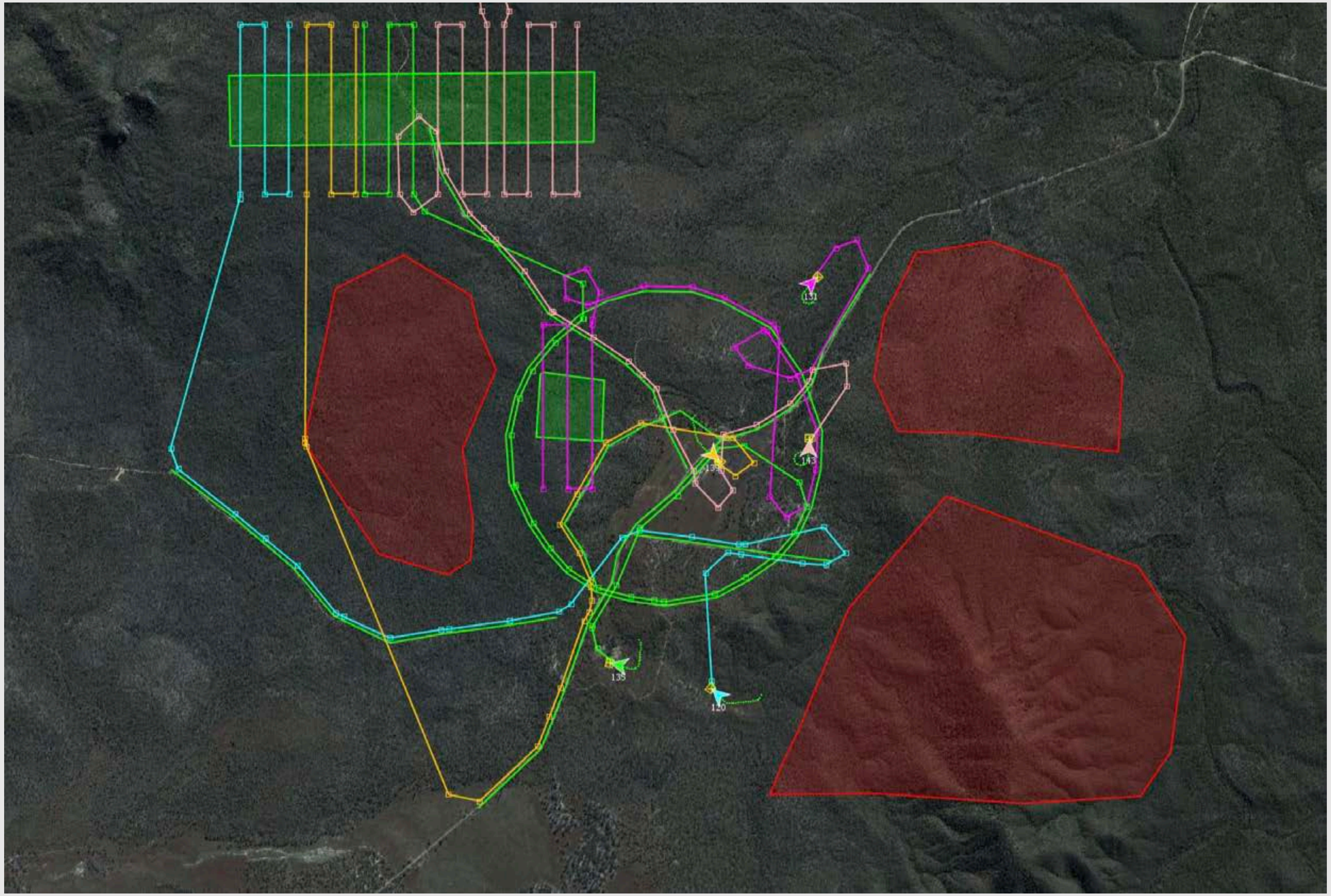
https://github.com/cmcghan/OpenUxAS
https://github.com/cmcghan/OpenAMASE

Tasks



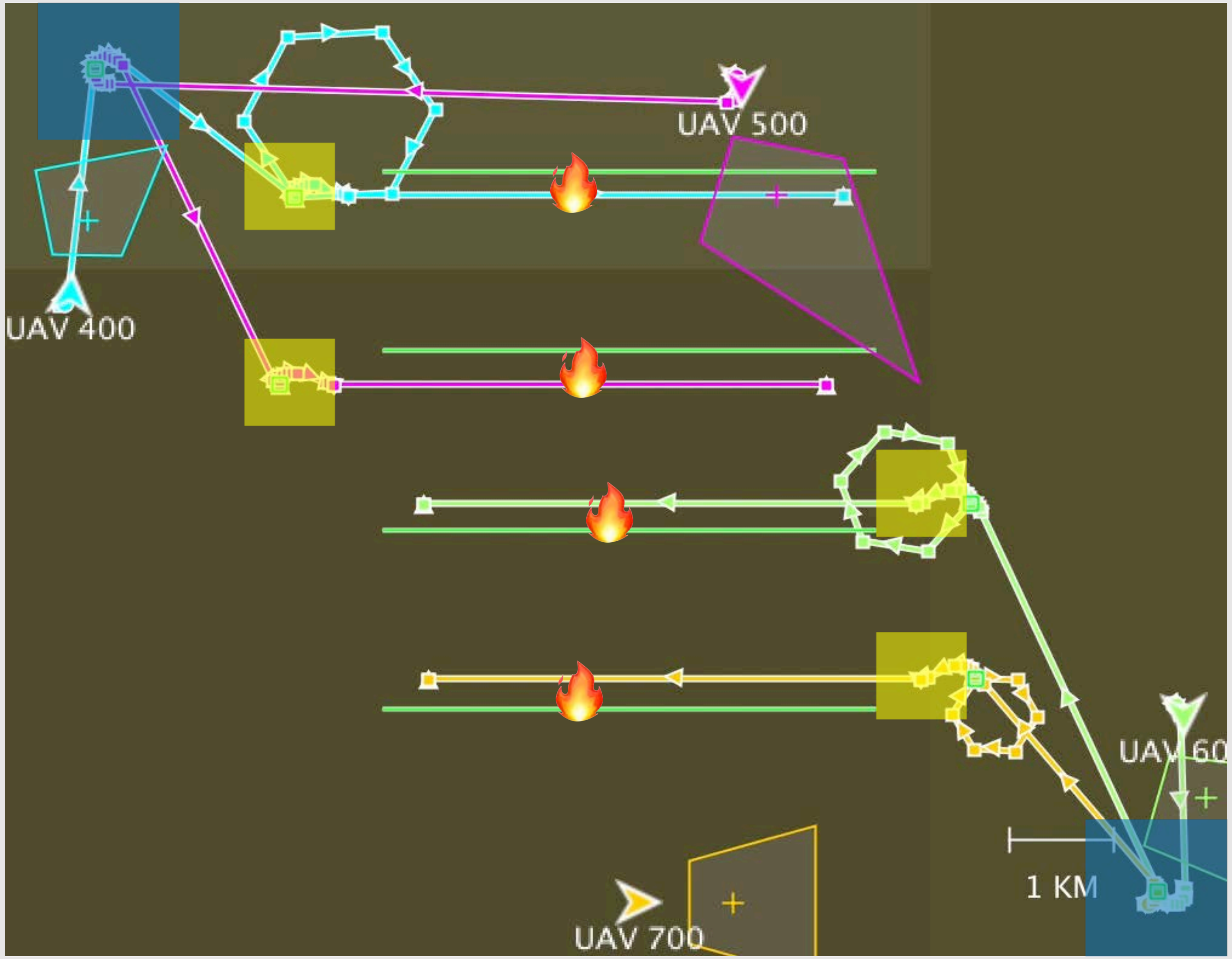
[Slide adopted/modified from D. Fisher, S5 2017]

Assignment



[Slide adopted/modified from D. Fisher, S5 2017]

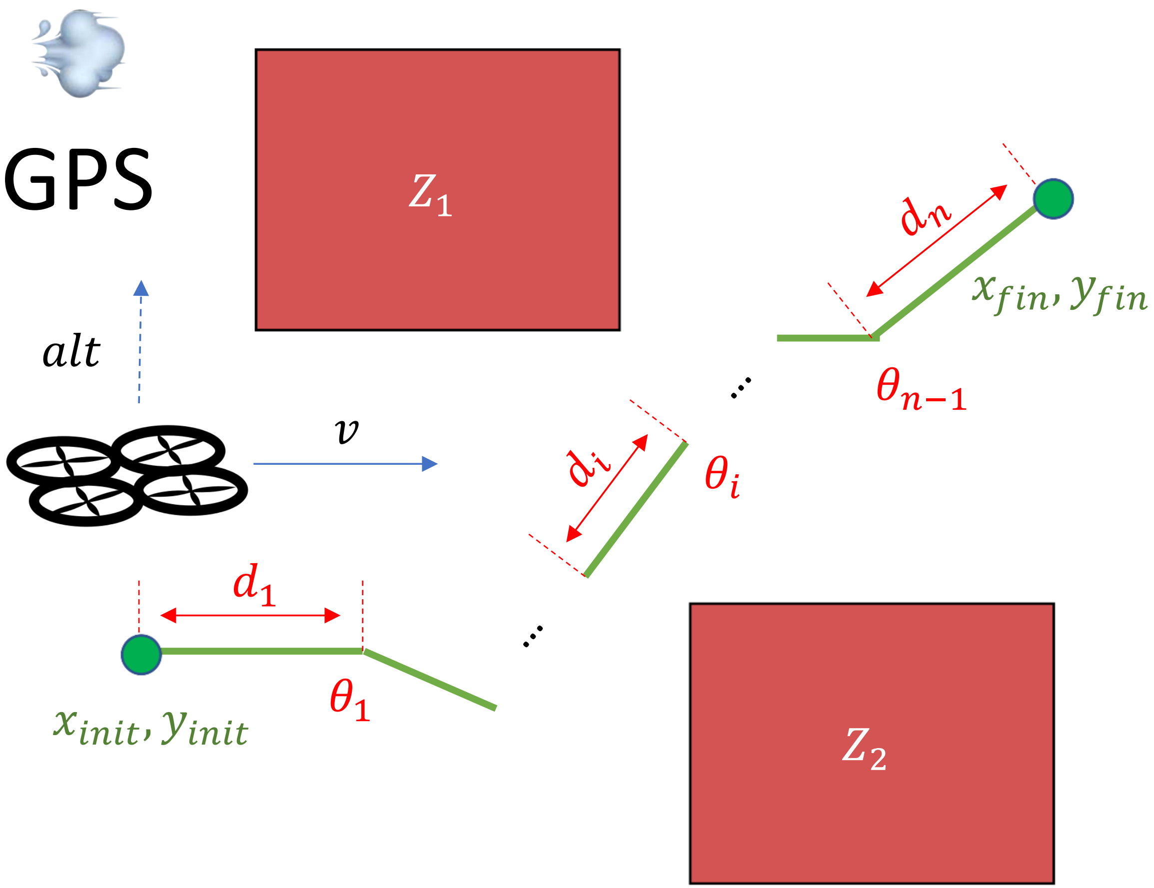
Synchronized Firefight



https://youtu.be/rgerTBylMsc

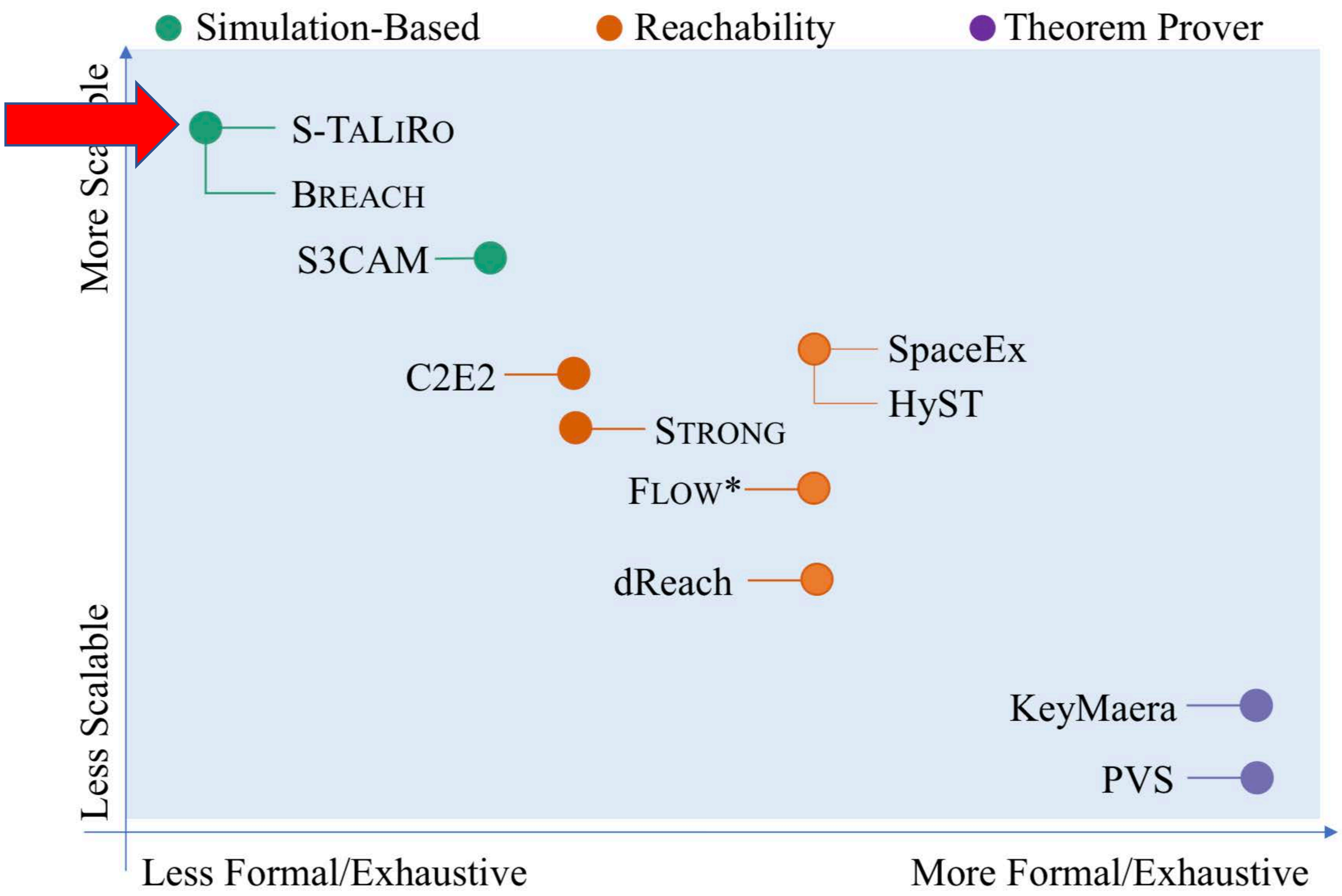
[ASU – SIU – VU] [ADHS2018]

Testing UxAS: Keep Out Zone Violations

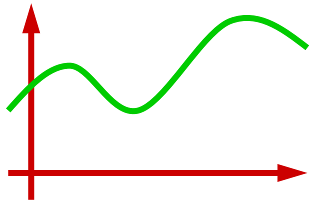


2. Robustness-Guided Testing

Methods and Tools

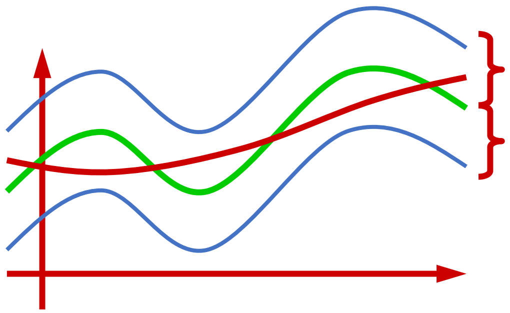


Falsification By Optimization



MTL ϕ

Robustness Metric
$\varepsilon \in \mathbb{R} \cup \{\pm\infty\}$



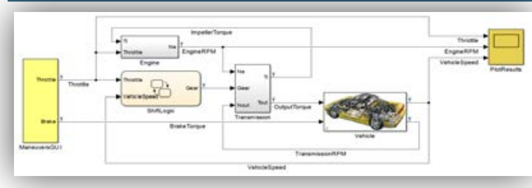
positive robustness → signal satisfies the formula

negative robustness → signal falsifies the formula

[Fainekos and Pappas, TCS]

System Σ

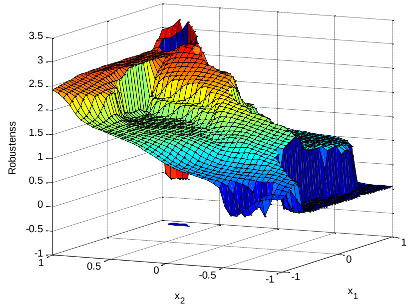
$y = \Delta(x_0, u)$ $\quad x_0 \in X_0$, $u \in U$



ϕ

Stochastic Optimizer

Next
$x_0 \in X_0$
$u \in U$



Minimum Robustness after termination condition met

[Abbas et al. TECS]

Metric Temporal Logic

- Propositional logic + Temporal Operators with timing intervals
- Interpreted over traces/trajectories
- Ex. $G_{[0,5]}p \wedge F_{[2.4]}b$:

"*always* from 0 to 5, p is true and *eventually* from 2 to 4, b is true"

Model

Simulink/Stateflow
User-defined functions

S-TALIRO

Stochastic Optimization Engine

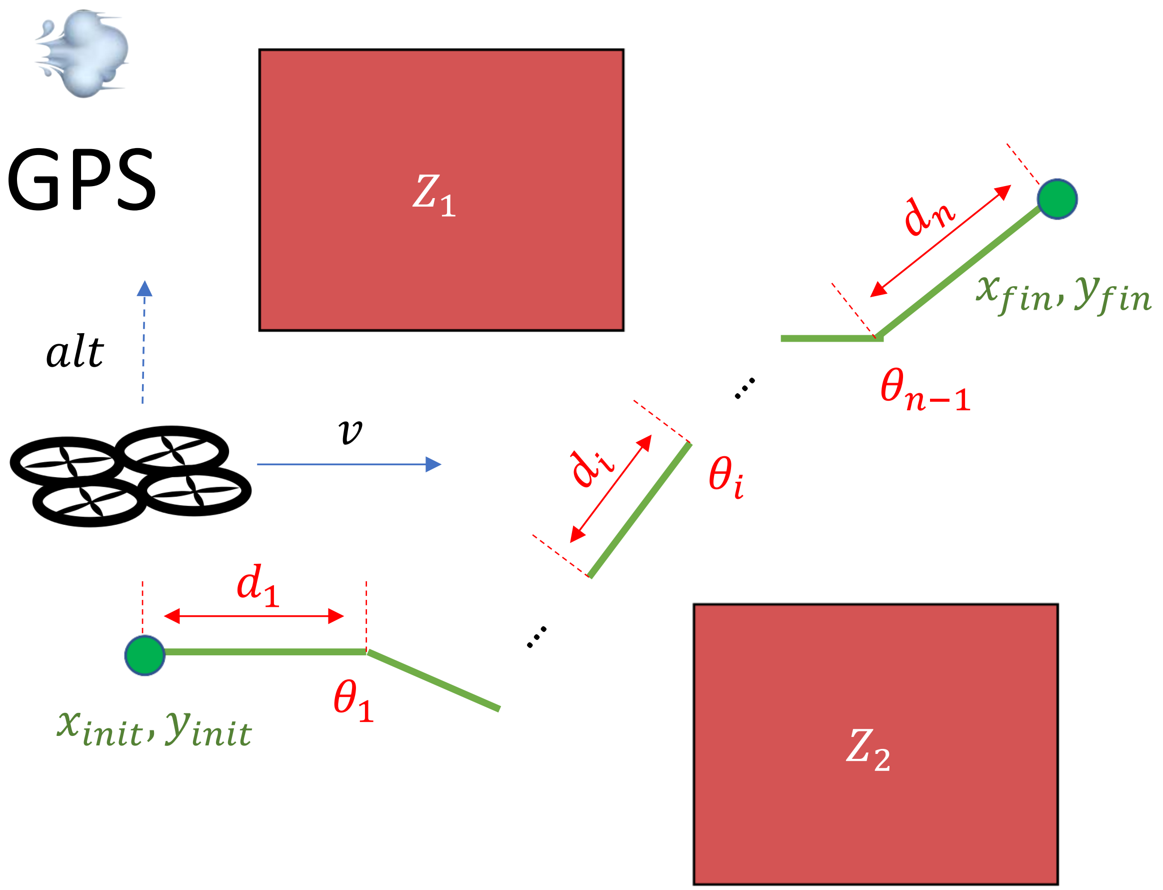
Simulated Annealing
Cross Entropy
Ant-colony
Gradient Descent
Flexible initial condition and input signal generation

Features

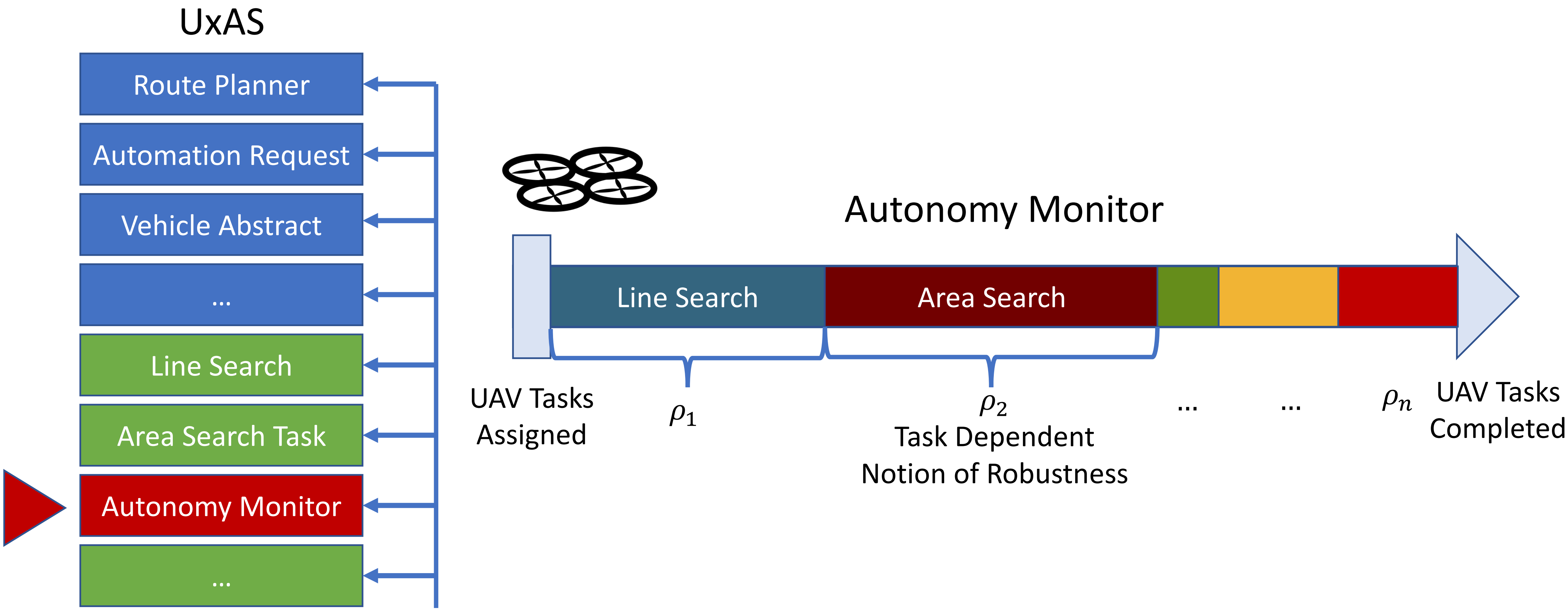
Falsification
Parameter Mining
Requirement Engineering with ViSpec
Runtime Verification
Conformance Testing
…

3. Testing UxAS

Keep Out Zones



Autonomy Monitors



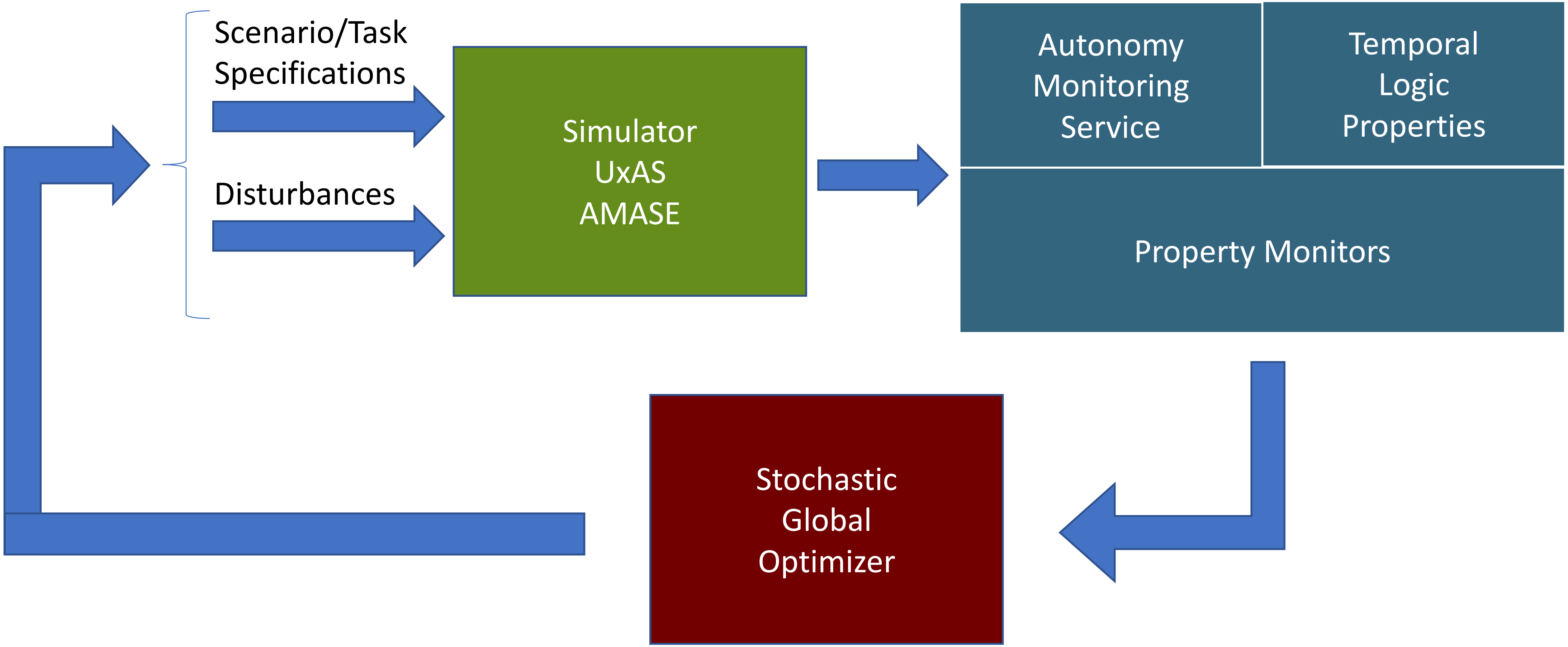
Testing UxAS with S-TaLiRo

Keep Out Zones: $$\phi_Z = \bigwedge_{i=1}^{n} G(r_i \rightarrow F_{[0,10]} \neg r_i)$$

Autonomy Monitors: $$\phi_M = \bigwedge_{i=1}^{k} M_k$$

Specification ϕ: $$\phi = \phi_Z \wedge \phi_M$$

Stochastic Optimization



Result: Falsification

https://youtu.be/tVB9TgwrCEc

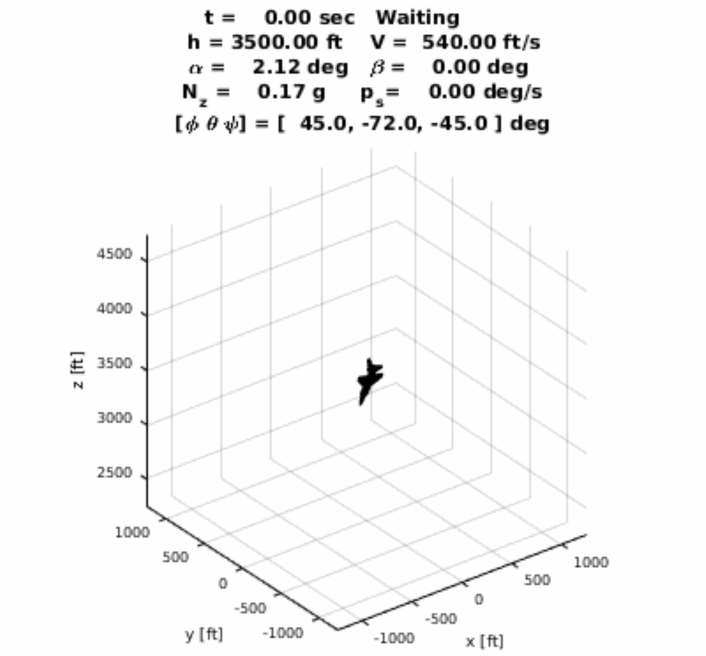
Future Work

1. Parameter Mining of MTL Specs [Hoxha et al. STTT]

What is the value of θ?

$$\phi_Z = \bigwedge_{i=1}^{n} G(r_i \rightarrow F_{[0,\theta]} \neg r_i)$$

2. More complex vehicle dynamics
Ex: F16 Aircraft Model
[Bak and Heidlauf]



github.com/pheidlauf/AeroBenchVV

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Acknowledgments

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- Shakiba Yaghoubi

Thank You
Questions?

MTL Survey

Test hypothesis that formal methods experts can write correct MTL specifications from NL

www.bit.ly/2HKsMQK