CPS: Medium: Safety-Critical Cyber-Physical Systems: From Validation & Verification to Test & Evaluation

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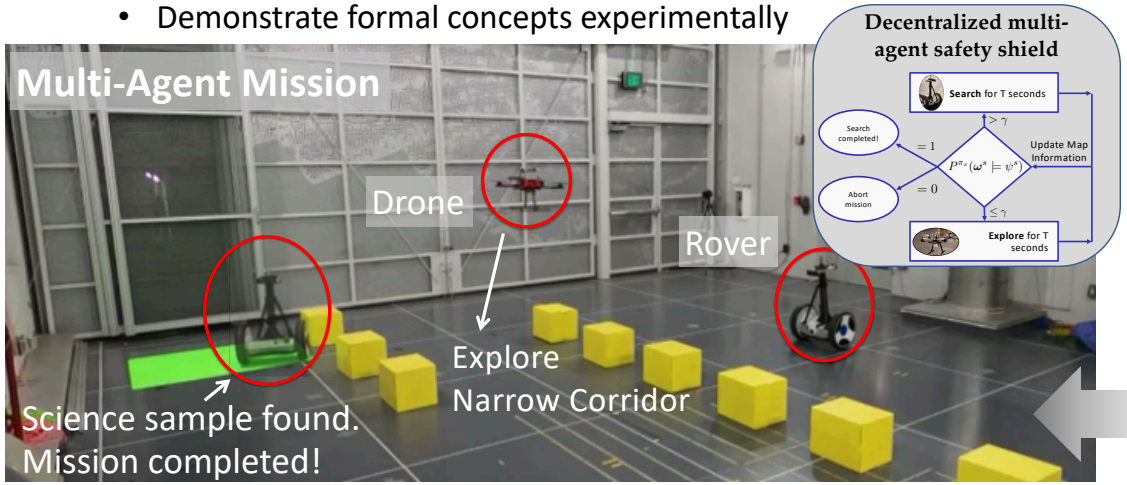
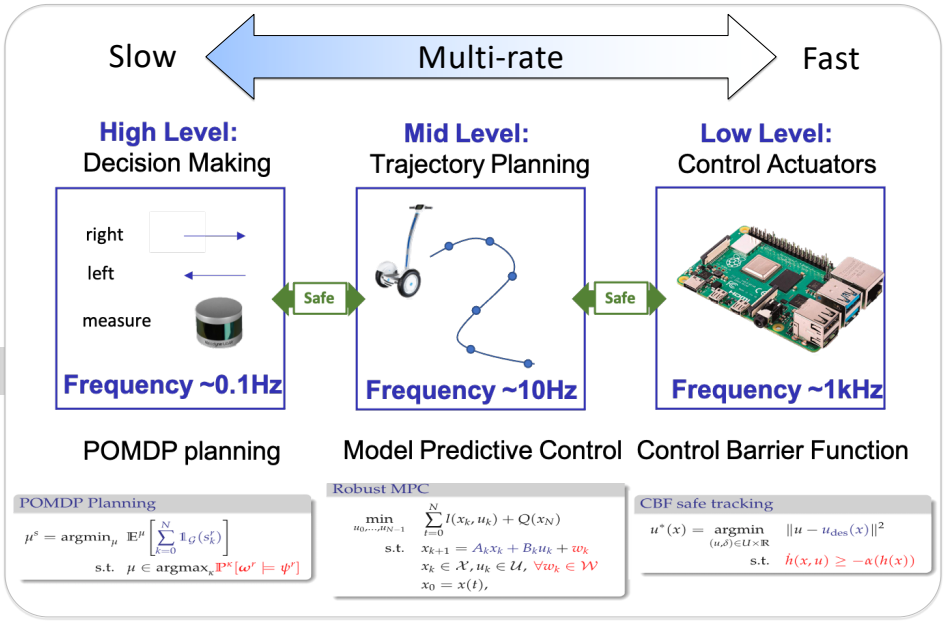
Challenge:

- *Goal:* Create a mathematical framework for T&E of safety-critical CPS, unifying formal methods and real-time constraint satisfaction
- Guarantee safety for highly dynamical systems operating in uncertain environments
- Demonstrate formal concepts experimentally



Solution:

- Developed *hierarchal multi-rate architecture* with different model abstractions at each layer
- Leverage recent advances in nonlinear control, robust predictive control, and MDPs to guarantee safety across layers
- Allows for both synthesis of provably safe controllers, and T&E of existing controllers across all layers



Broader Impact:

- Guarantee Safe behavior on complex CPS: from safe synthesis to T&E
- BPC plan: leveraging Caltech WAVE program to increase representation: 2 WAVE fellows this summer.

U. Rosolia, and A. D. Ames. "Multi-rate control design leveraging control barrier functions and model predictive control policies." IEEE Control Systems Letters 5, no. 3 (2020): 1007-1012.
M. Ahmadi, U. Rosolia, M. D. Ingham, R. M. Murray, and A. D. Ames. "Constrained Risk-Averse Markov Decision Processes." *AAAI Conference of Artificial Intelligence* (2020).
U. Rosolia, M. Ahmadi, R. M. Murray, and A. D. Ames. "Time-Optimal Navigation in Uncertain Environments with High-Level Specifications." *arXiv preprint arXiv:2103.01476* (2021).
P. Akella, U. Rosolia, and A. D. Ames "Learning Performance Bounds for Safety-Critical Systems" submitted to CDC (2021)

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