RT-166: Formal Methods in Resilient Systems Design using a Flexible Contract Approach

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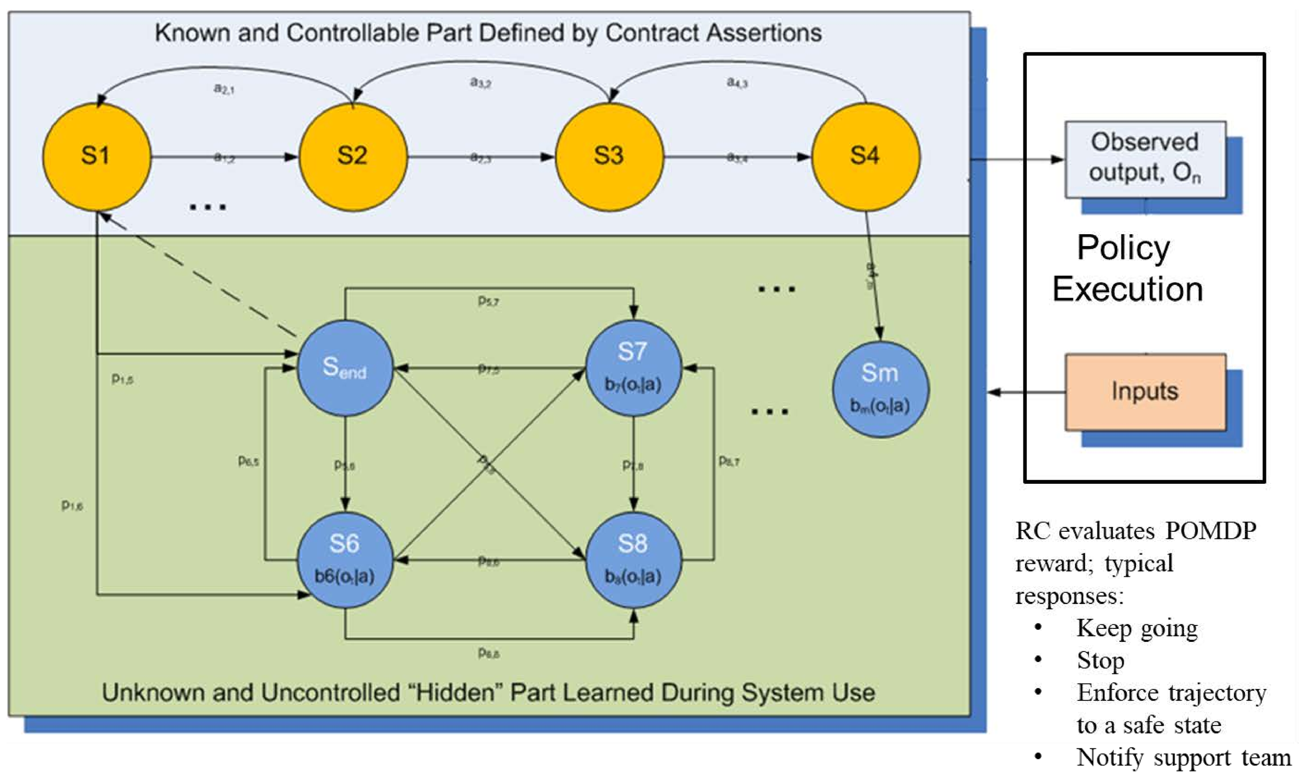
Research Task / Overview

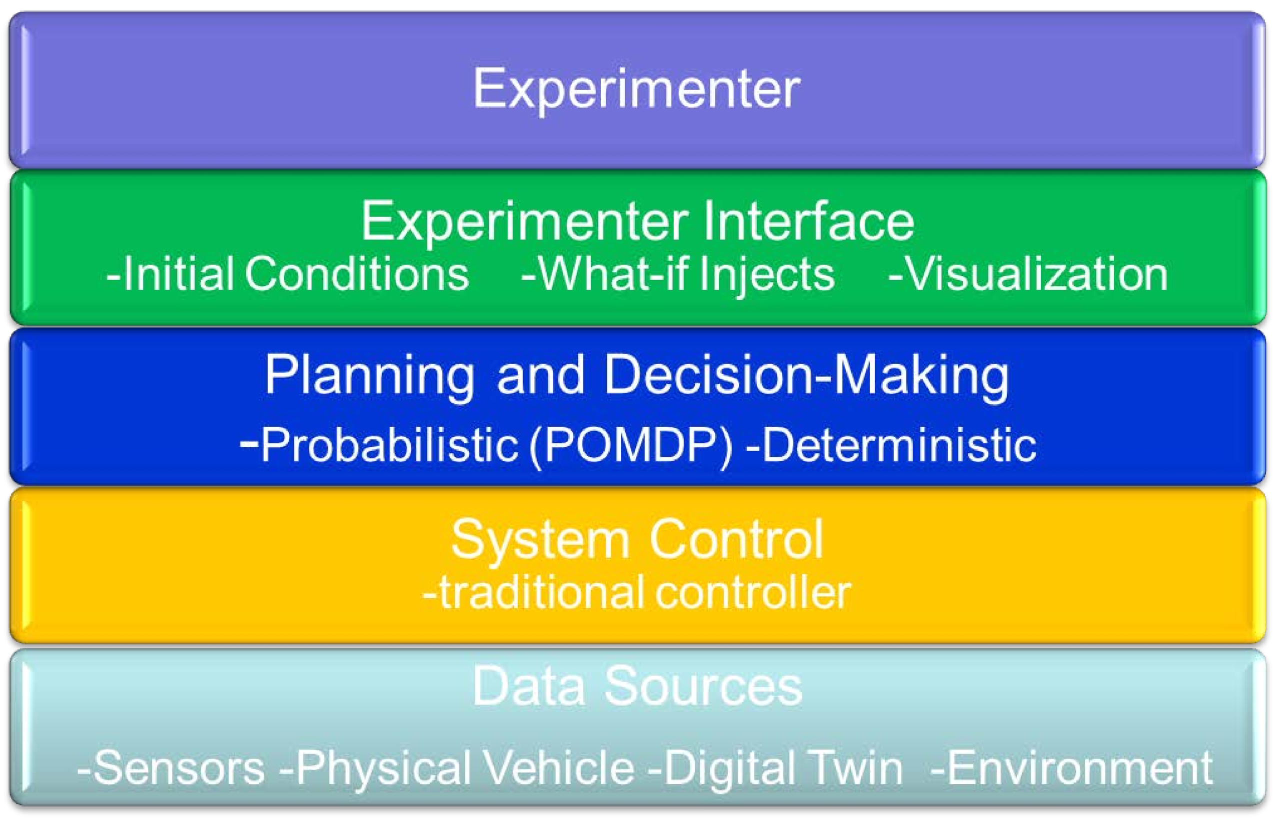
- Develop formal methods-based approach for resilient system and SoS design
- Support SERC's Systems Engineering and System Management Transformation Research Area

Data & Analysis

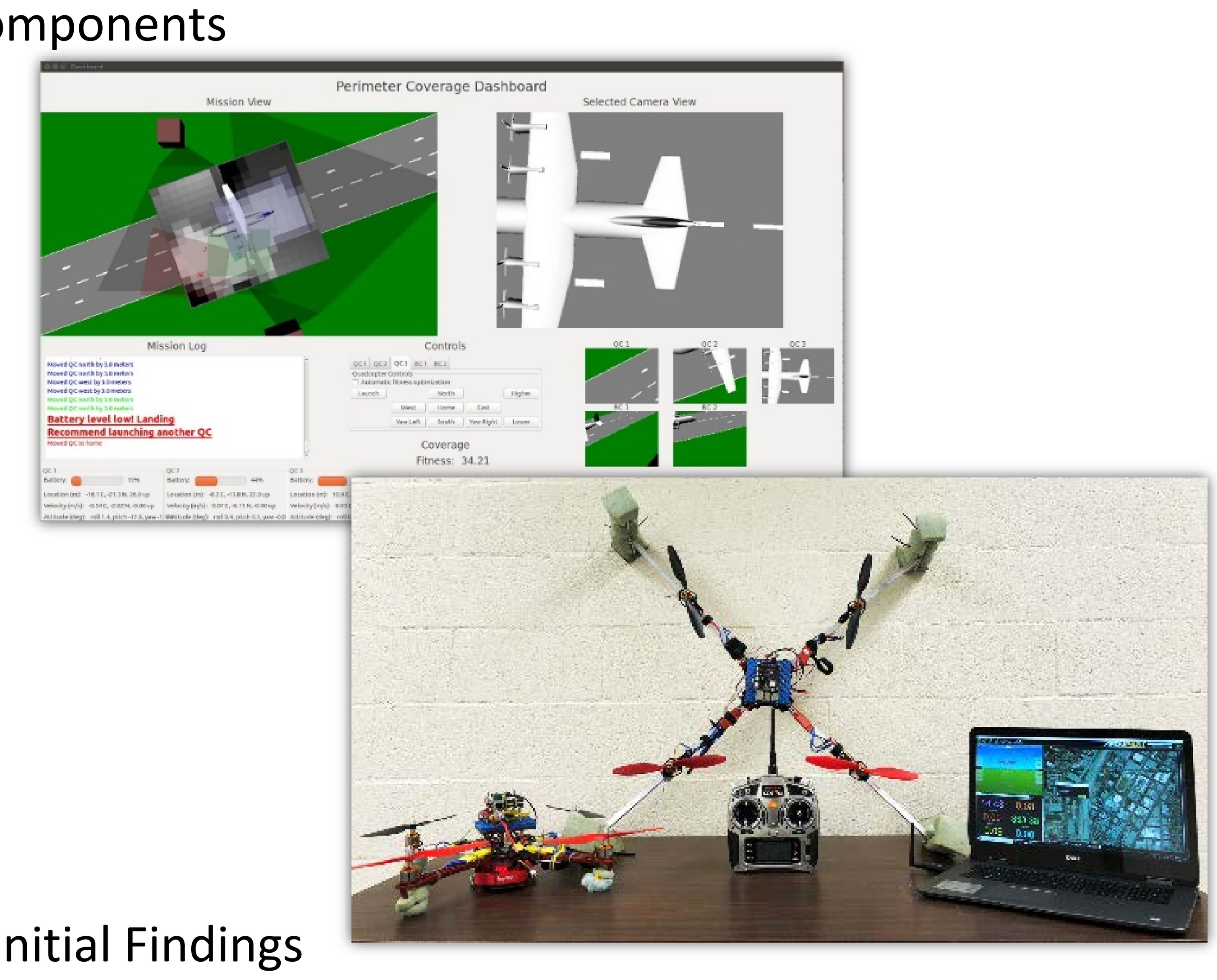
- Data Sources
  - Representative Multi-UAV mission
  - Exemplar scenarios
- Resilience Contract Formalism



- Experimentation Testbed Architecture



- Execution Monitoring Dashboard and Hardware Testbed Components



- Initial Findings
  - Key problem: resolving mismatch between decision-making layer & vehicle control layer
  - POMDP and vehicle controller execute on different time scales
  - Concurrent creation of experimentation testbed facilitates experimentation and data collection
  - Monitoring and execution dashboard facilitated both understanding and debugging of vehicle behaviors

Goals & Objectives

- Enable a capability for verifiable and flexible complex system behaviors
- Exemplar Application: multi-UAV mission
- Exploit Formal and Flexible System Representation
  - deterministic + probabilistic modeling
  - patterns of disruptions
  - pattern-driven responses

Methodology

- Combines formal and probabilistic modeling with heuristics
- Architecture Characteristics:
  - Layered: planning and decision making; control
  - Decisions and information flow from planning and decision making (top layer) to control (bottom layer)
  - Execution constraints flow from control layer to planning and decision making layer
  - In case of conflicts, global swarm objectives have priority over local AV goals
- Defined Resilience Contract formalism to balance system verifiability and system flexibility requirements
  - Relaxes assertions in traditional contract to introduce flexibility ("belief-reward")
  - Partially Observable Markow Decision Process (uncertainty handling)
  - In-use reinforcement learning (hidden states, transitions, emissions)
  - Heuristics/patterns (complexity reduction)

Future Research

- Develop multi-UAV high-level probabilistic decision-making using POMDP
- Expand capability of experimentation testbed
- Collect and analyze data for more complex scenarios
- Transition capability to designated site(s)
- Develop measurable utility function (i.e., Reward Function) to evaluate candidate options
- Refine reward value assignment method
- Employ experimental testbed to refine transition probabilities among vehicle states

References

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