RESEARCH REVIEW 2025

Carnegie Mellon University Software Engineering Institute

Formalizing and Automating STPA with Robustness (FASR)

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ADVANCING SOFTWARE for NATIONAL SECURITY
40 years
SOFTWARE ENGINEERING INSTITUTE

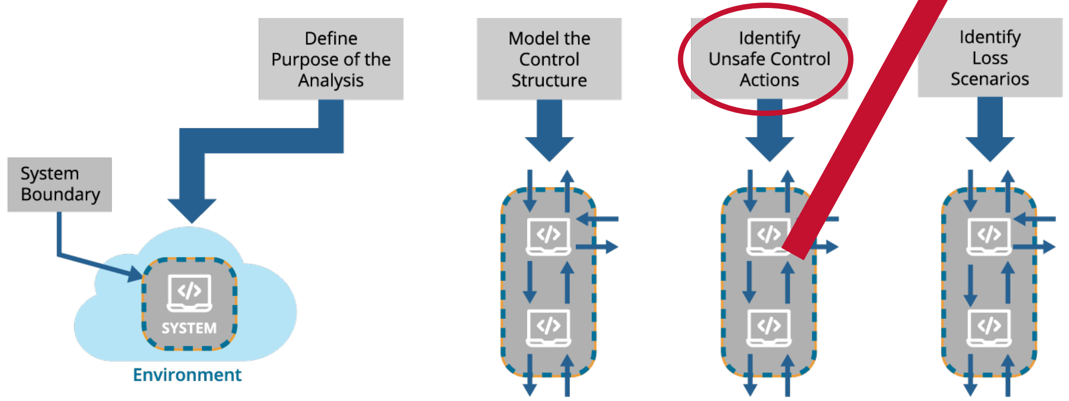
Innovation in Action

Document Markings

Background: Safety Analysis Is Slow, Hard, and You Don’t Know When You’re Done

Most critical systems are evaluated for safety before use, often using *hazard analysis* techniques.

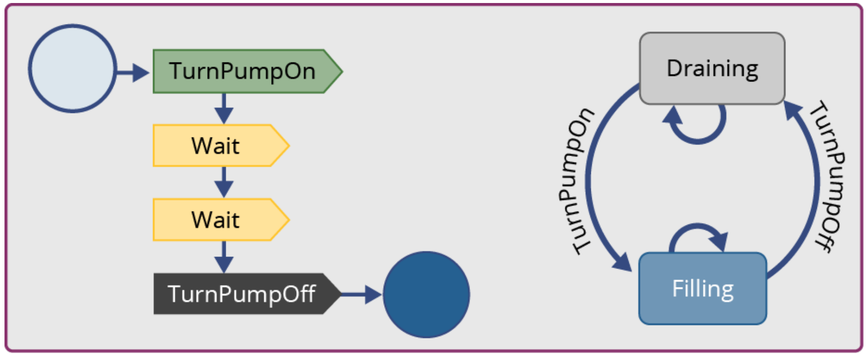
Control Action	Not Providing Causes Hazard	Providing Causes Hazard	Too Early, Too Late, Out of Order	Stopped Too Soon, Applied Too Long
Brake	UCA-1: Brake Does Not Engage	UCA-2: Brake Engages During Takeoff	UCA-3: Brake Engages Too Late After Touchdown	UCA-4: Brake Disengages Before Safe Taxi Speed is Attained


Define Purpose of the Analysis
Model the Control Structure
Identify Unsafe Control Actions
Identify Loss Scenarios
System Boundary
SYSTEM
Environment

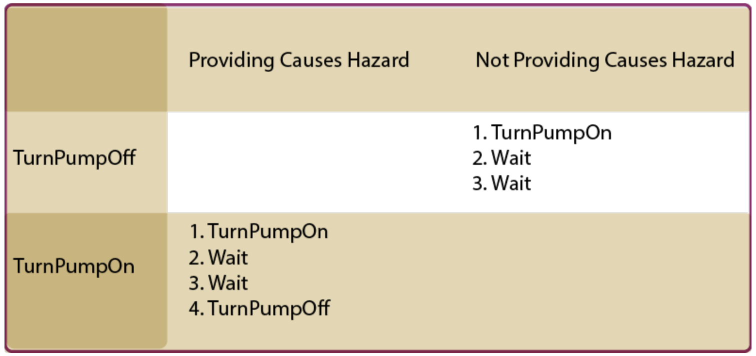
Research question: Can we use *formal methods* to improve analysis **speed** and **accuracy** while providing a **measure of completeness**?

Goal: Automatically Calculate Unsafe Control Actions from System Models

SysML

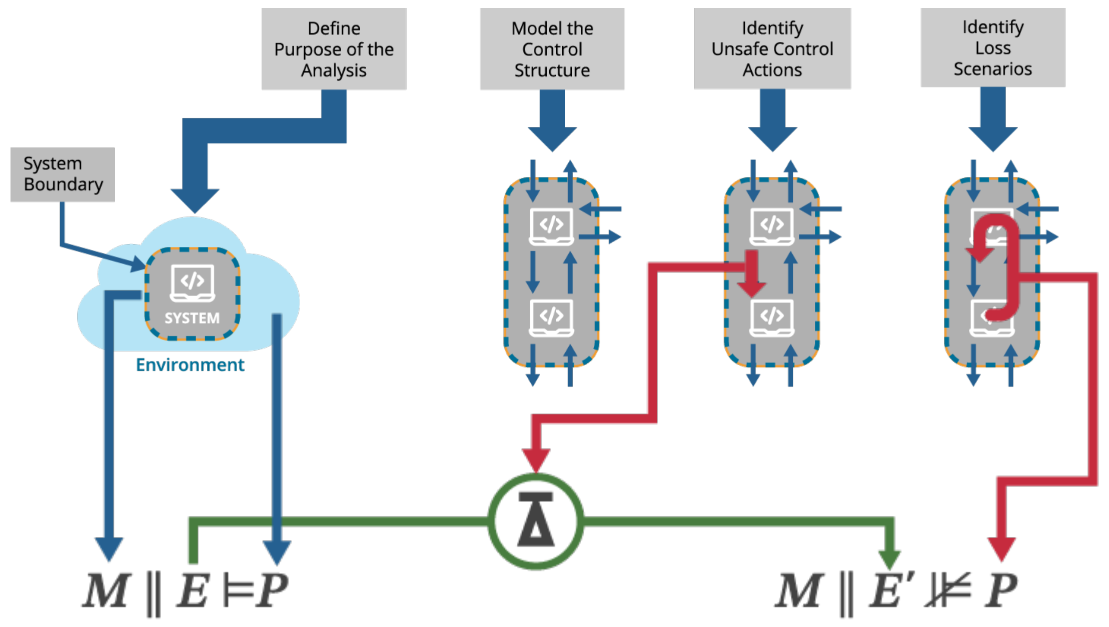


RAAML/STPA



	Providing Causes Hazard	Not Providing Causes Hazard
TurnPumpOff		1. TurnPumpOn 2. Wait 3. Wait
TurnPumpOn	1. TurnPumpOn 2. Wait 3. Wait 4. TurnPumpOff	

Robustness: Safety in the Presence of Environmental Deviations


Define Purpose of the Analysis
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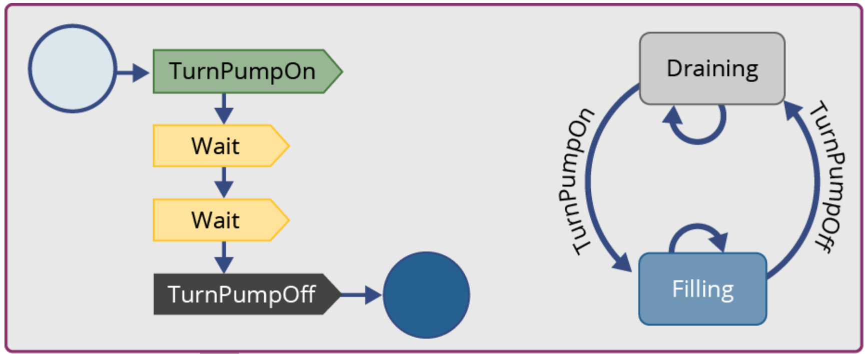
$M \parallel E \models P$
$M \parallel E' \not\models P$

"… a system is *robust* with respect to a *property* and a particular set of *environmental deviations* if the system continues to satisfy the property even if the environment exhibits those deviations."

Zhang, Changjian, David Garlan, and Eunsuk Kang. 2020. "A Behavioral Notion of Robustness for Software Systems." *ESEC/FSE 2020 - Proceedings of the 28th ACM Joint Meeting European Software Engineering Conference and Symposium on the Foundations of Software Engineering* (New York, NY, USA), November 8, 111–22. https://doi.org/10.1145/3368089.3409753.

Method: Translate SysML into Precise Specification

SysML



RAAML/STPA

	Providing Causes Hazard	Not Providing Causes Hazard
TurnPumpOff		1. TurnPumpOn 2. Wait 3. Wait
TurnPumpOn	1. TurnPumpOn 2. Wait 3. Wait 4. TurnPumpOff	

TLA+

```
Module Tank

Extends Integers

Variables WaterLevel, PumpOn
vars = <<waterLevel,
pumpOn>>

Init ==
   ∧ waterLevel = 0
   ∧ pumpOn = False
TurnPumpOn ==...
```

Method: Use CMU *Fortis* to Find Unsafe Behaviors

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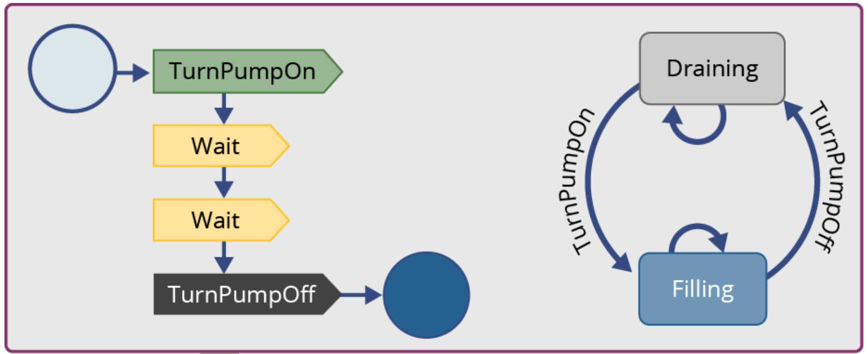
SysML



RAAML/STPA

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TLA+

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```

JSON

```
[
  {
    "goodTrace":   ["TurnPumpOn", "wait", "wait", "TurnPumpOff"]
    "badTrace":    ["TurnPumpOn", "wait", "wait", "wait"]
    "vioComp":     ["WaterTank"]
    "violnv":      ["NoOverflow"]
```

```
    "good Trace":  ["TurnPumpOn", "wait", "wait", "TurnPumpOff"]
    "badTrace":    ["TurnPumpOn", "wait", "wait", "TurnPumpOff", "TurnPumpOn", "wait"]
    "vioComp":     ["WaterTank"]
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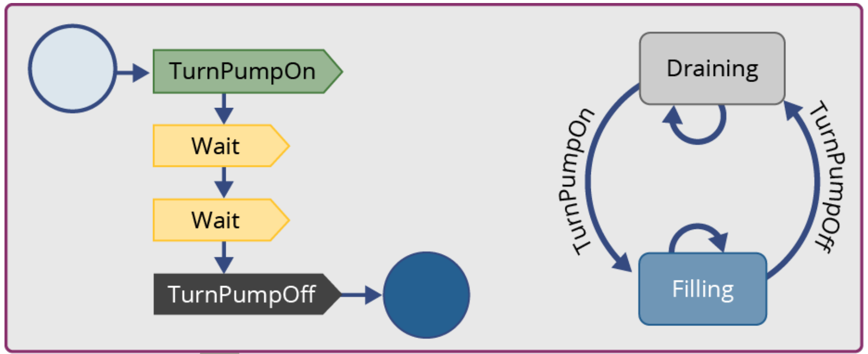
  }
]
```

Method: Categorize Behaviors with STPA Guidewords

SysML



RAAML/STPA

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TLA+

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    "good Trace":   ["TurnPumpOn", "wait", "wait", "TurnPumpOff"]
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    "vioComp":      ["WaterTank"]
    "violnv":       ["NoOverflow"]
  }
]
```

JSON

```
[
  {
    "source": "WaterTank"
    "guideword": "NOT_PROVIDING"
    "controlAction": "TurnPumpOff"
    "context": ["TurnPumpOn", "wait", "wait"]
    "violatedConstraint": "NoOverflow"
  }
]
```

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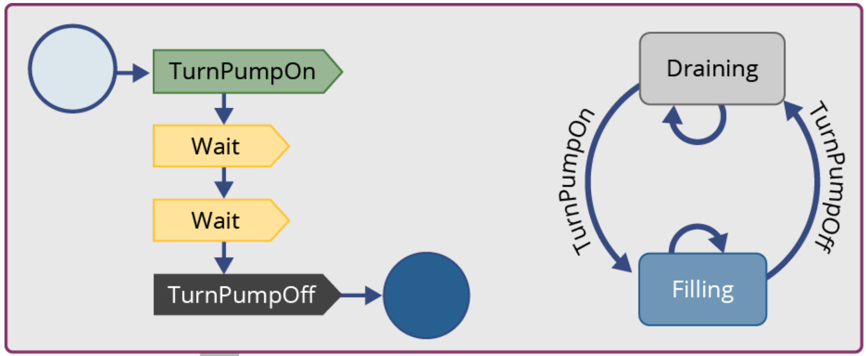
Method: Display STPA Output Using RAAML

SysML



RAAML/STPA

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For more information, follow this QR code to
https://cmu-soda.github.io/projects/project_fasr.html