

RESEARCH REVIEW 2025

# Formalizing and Automating STPA with Robustness (FASR)

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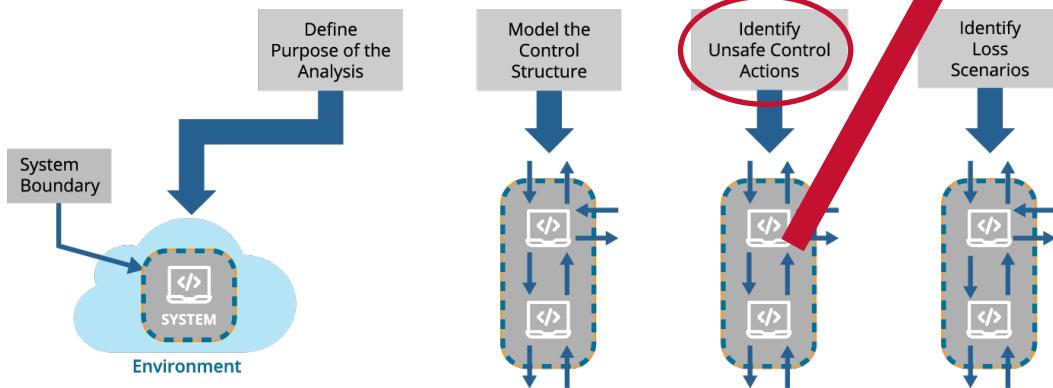
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DM25-1396

# 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.

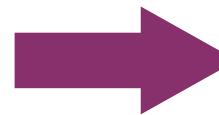
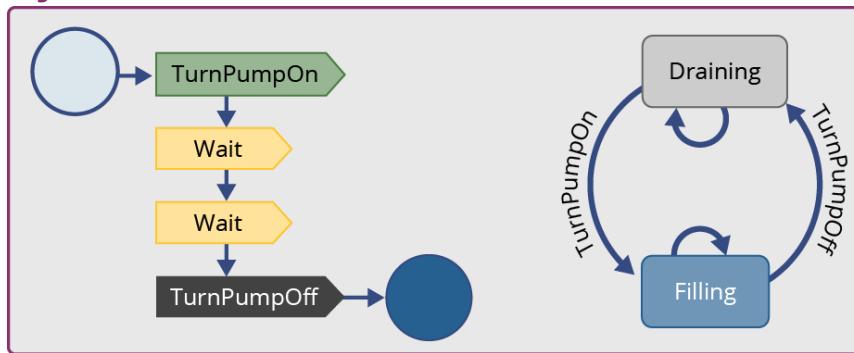
Control Action	Not Providing Causes Hazard	Providing Causes Hazard	Too Early, Too Late, Out of Order	Stopped Too Soon, Applied Too Long
Brake	UCA-1: Brake Does Not Engage	UCA-2: Brake Engages During Takeoff	UCA-3: Brake Engages Too Late After Touchdown	UCA-4: Brake Disengages Before Safe Taxi Speed is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



**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

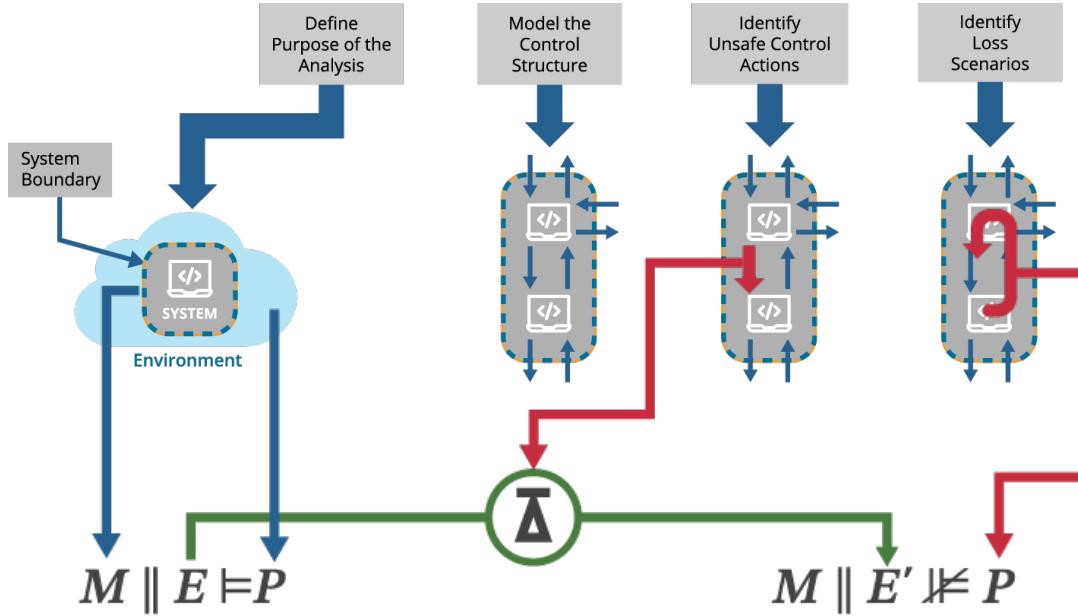
## SysML



## 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

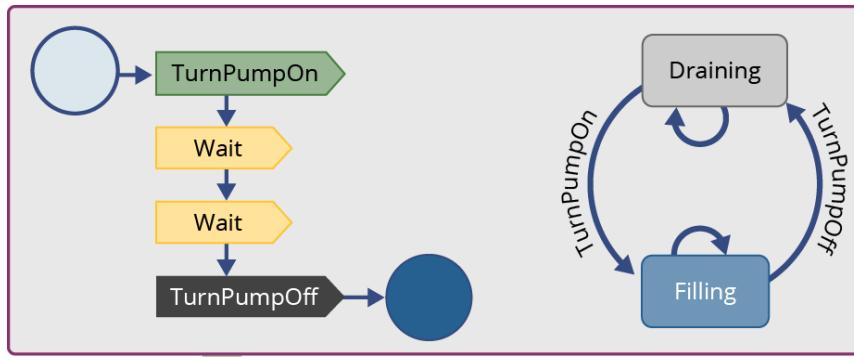


“... a system is *robust* with respect to a *property* and a particular set of *environmental deviations* if the system continues to satisfy the property even if the environment exhibits those deviations.”

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+

```

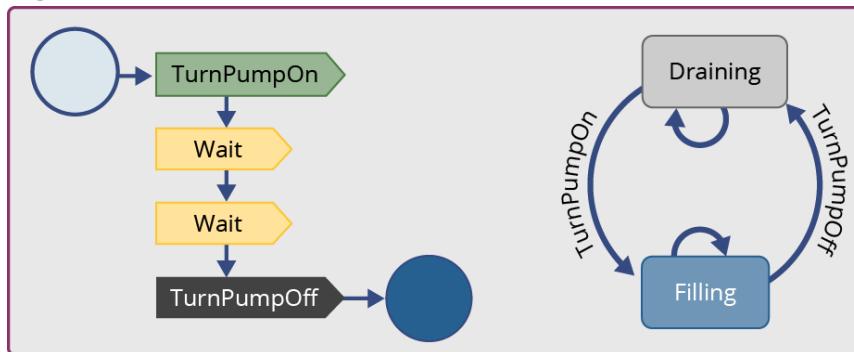
Module Tank
Extends Integers

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

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

# Method: Use CMU *Fortis* to Find Unsafe Behaviors

## 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 ==...
  
```

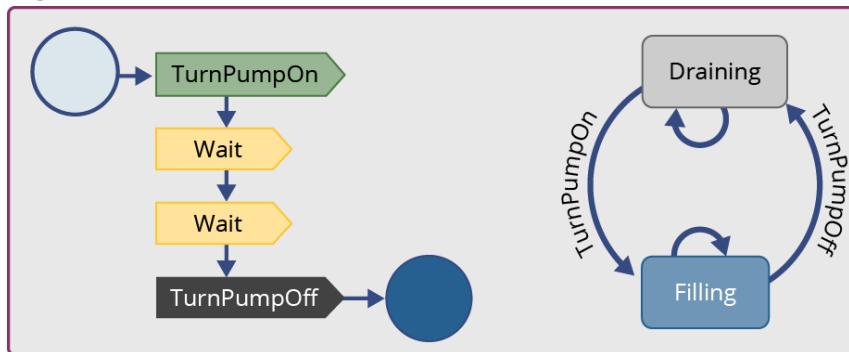
## JSON

```

[{"goodTrace": ["TurnPumpOn", "wait", "wait", "TurnPumpOff"], "badTrace": ["TurnPumpOn", "wait", "wait", "wait"], "vioComp": ["WaterTank"], "violInv": ["NoOverflow"]}, {"good Trace": ["TurnPumpOn", "wait", "wait", "TurnPumpOff"], "badTrace": ["TurnPumpOn", "wait", "wait", "TurnPumpOff", "TurnPumpOn", "wait"], "vioComp": ["WaterTank"], "violInv": ["NoOverflow"]}]
  
```

# Method: Categorize Behaviors with STPA Guidewords

## 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 ==...
  
```

## JSON

```

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

```

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

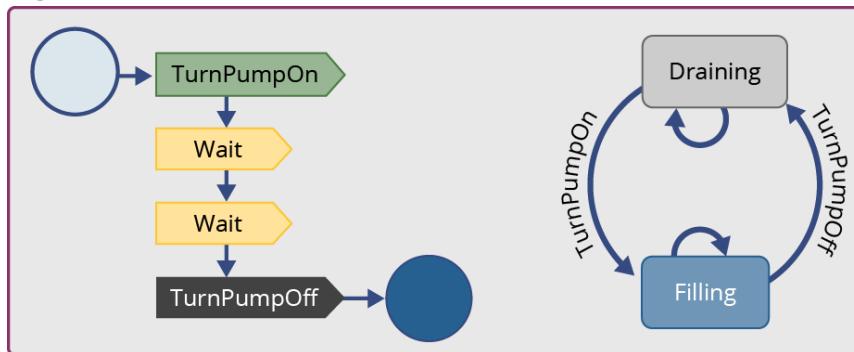
## JSON

```

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

# Method: Display STPA Output Using RAAML

## SysML



TLA+

```

Module Tank
Extends Integers
Variables WaterLevel, PumpOn
vars = <<waterLevel, pumpOn>>
Init ==
  ^ waterLevel = 0
  ^ pumpOn = False
TurnPumpOn ==...
  
```

JSON

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

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

## 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	



JSON

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

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