A case study in formal system engineering with SysML

Iulia Dragomir[1], Iulian Ober[1] and David Lesens[2]

[1]IRIT - University of Toulouse

[2]Astrium Space Transportation

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Outline

1. Full Model Driven Engineering development process
2. OMEGA SysML Profile & Toolset
3. The Automated Transfer Vehicle (ATV) case study
4. Validation results
5. Conclusions

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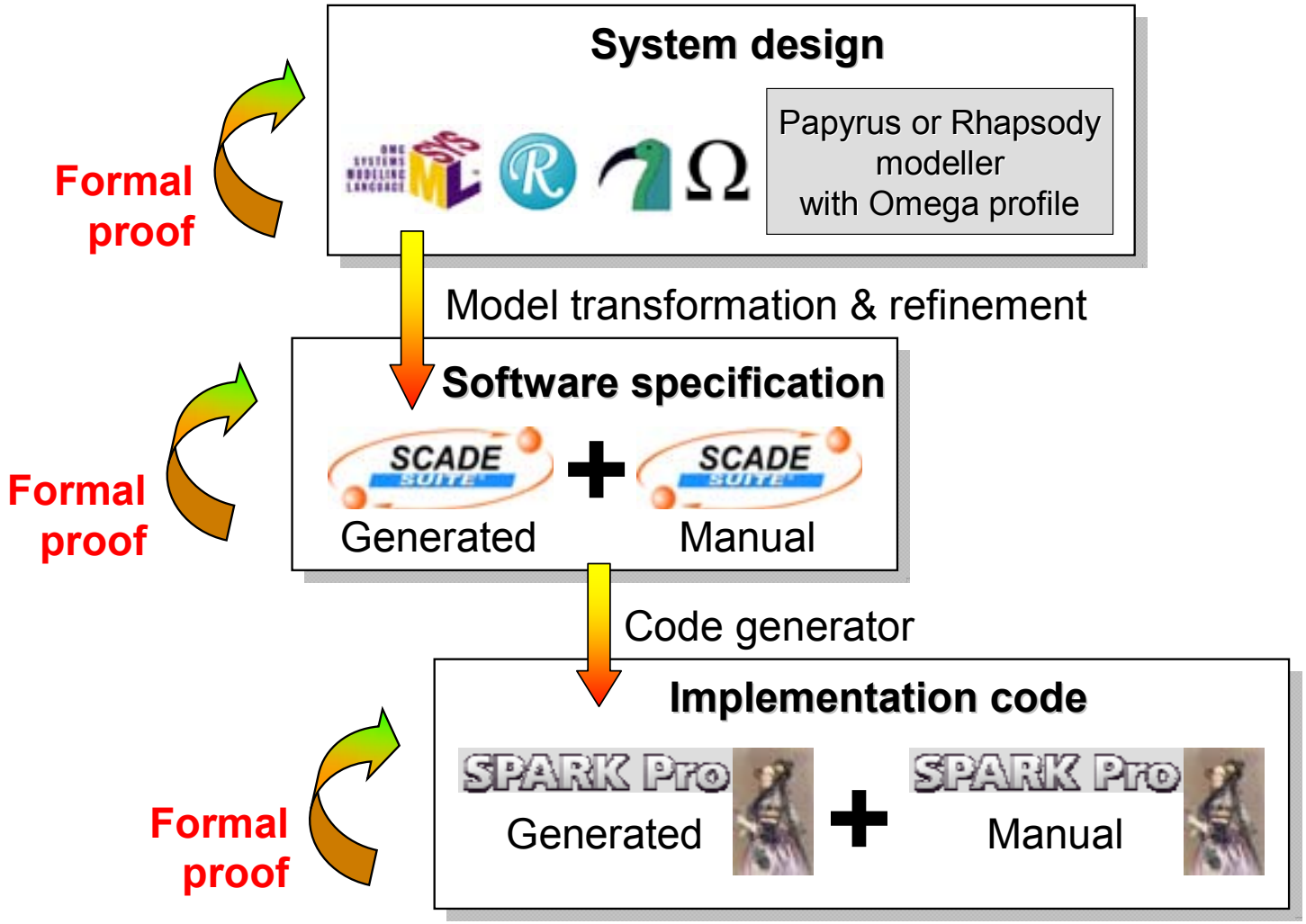
1. Full Model Driven Engineering development process

Full Model Driven Engineering Process



This project has been partially funded by the European Space Agency.

Outline

2. OMEGA SysML Profile & Toolset

The OMEGA Language

- SysML Profile for the specification and verification of real-time embedded systems
- Consists of:

A large subset of SysML

+

Model coherence constraints

+

A formal operational semantics

+

Real-time & verification extensions

The OMEGA Profile

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  - SysML Block Definition Diagrams & Internal Block Diagrams
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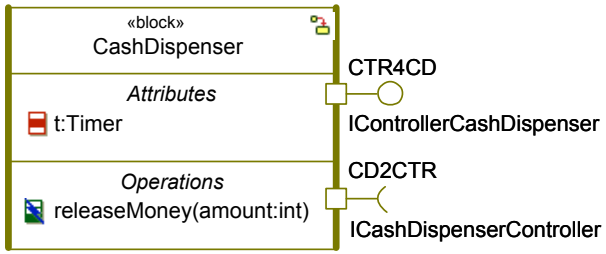
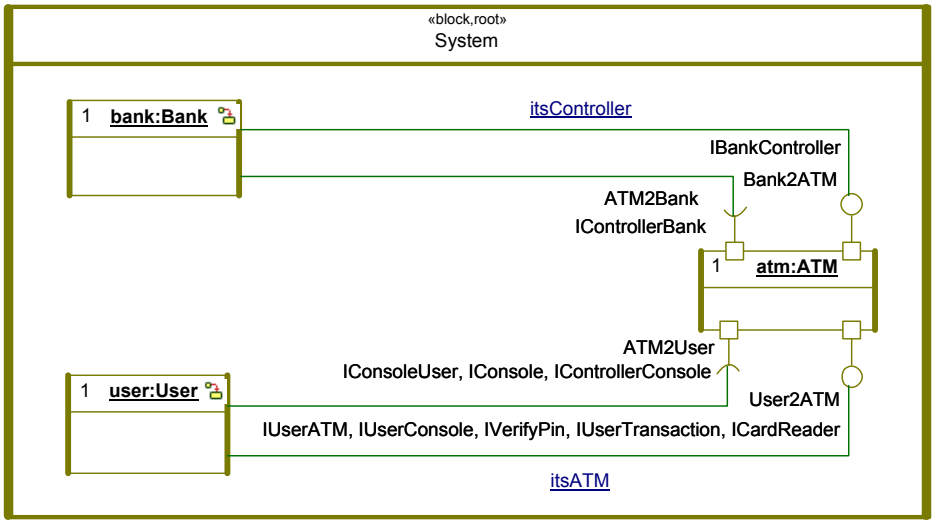
  - Structured data types and signals





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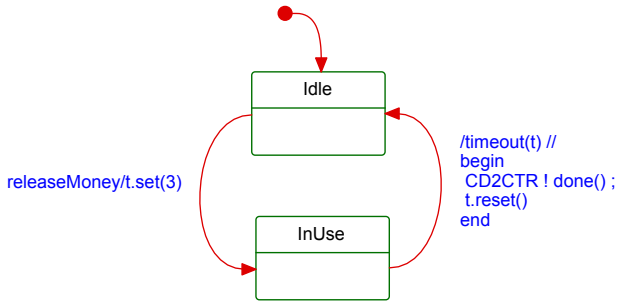

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- Real time
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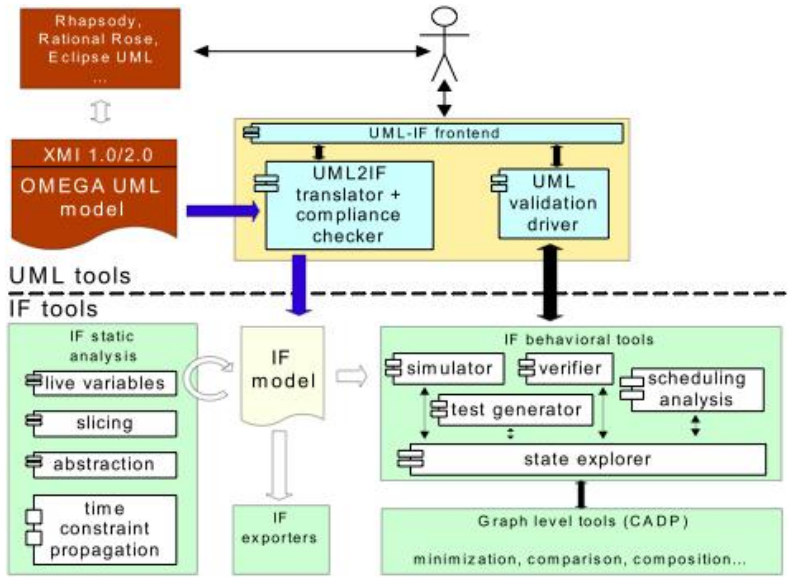
- Observers
  - Objects monitoring the system (state and events) and giving verdicts about a safety property

The IFx Toolset

- Goal: Early model validation and debugging
- Principle: Transforming to communicating extended timed automata (IF Language)

- Functionalities
  - Simulation
  - Static analysis: dead code/variable elimination, slicing, ...
  - Model-checking: observers, state graph minimization, μ-calculus, ...



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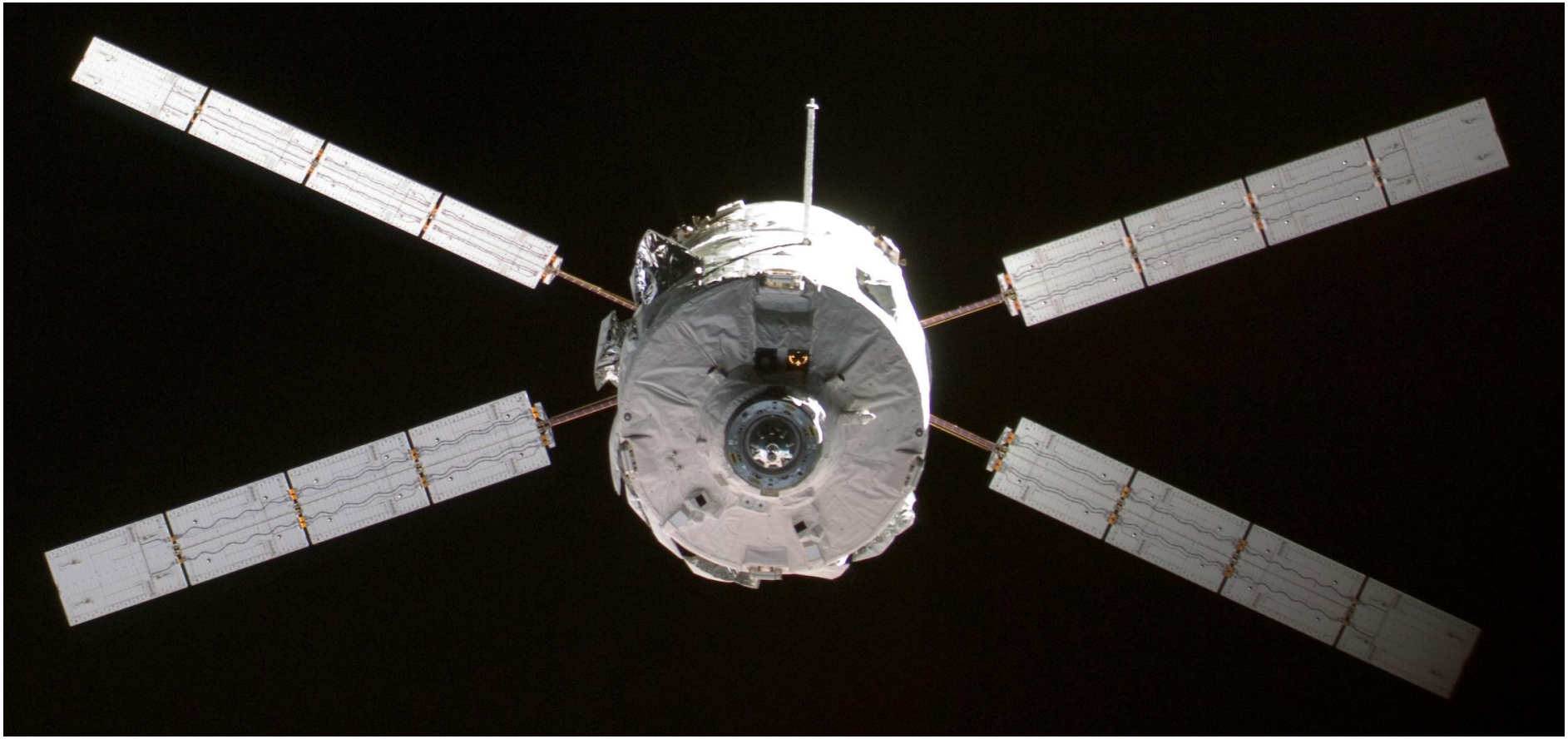
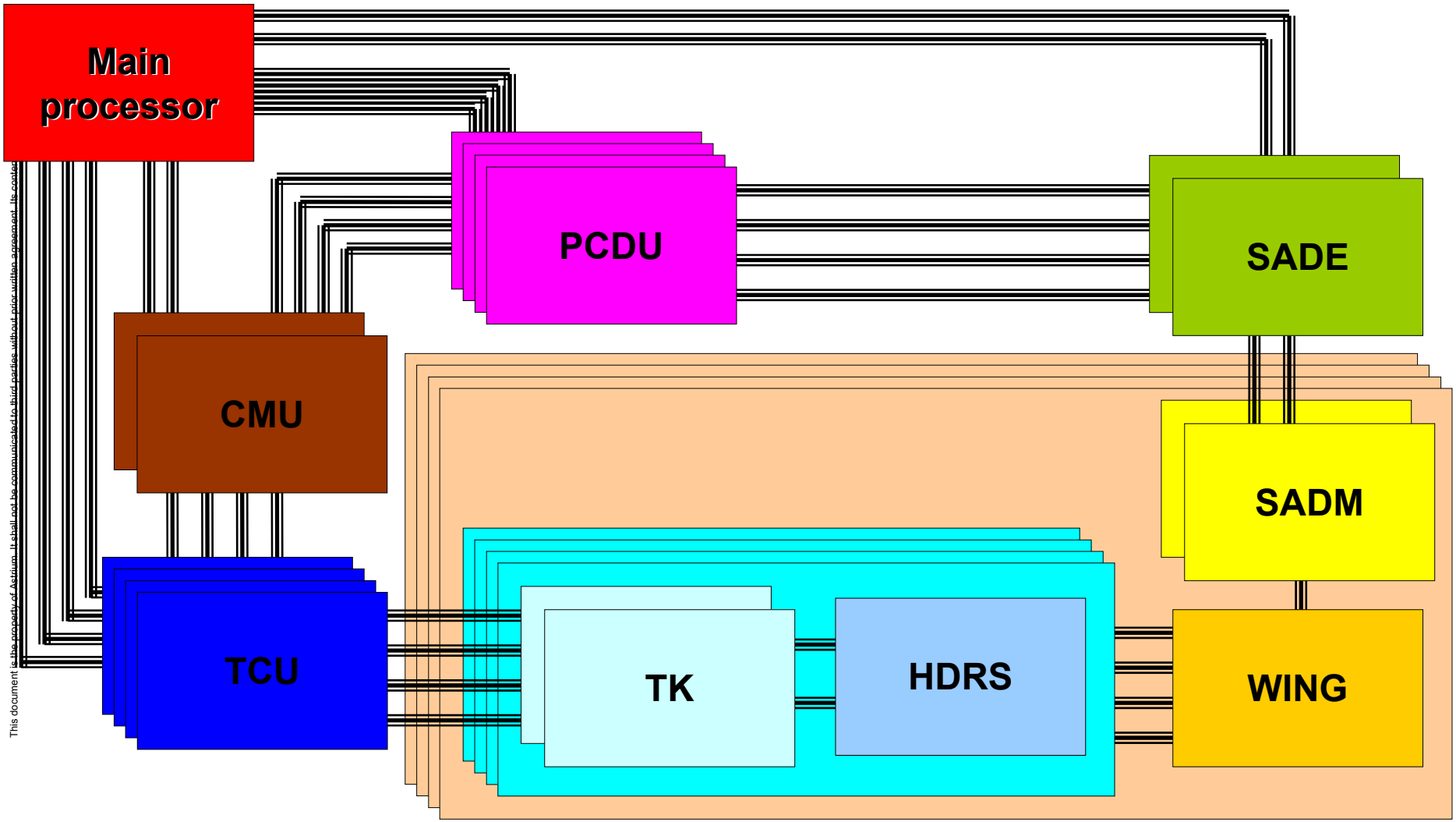
3. The Automated Transfer Vehicle (ATV) case study

The ATV Solar Generation System



The ATV has been developed by Astrium Space Transportation for ESA.

The Solar Generation System Architecture



The system model

- Reverse engineered from the actual system for the purpose of FullMDE
- 4-layer architecture
- 20 block types - HW, SW, MM - and 95 block instances
- 348 (661) ports (instances) and 372 (504) connectors (instances)

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- 1-fault tolerant
- 62 possible hardware failures

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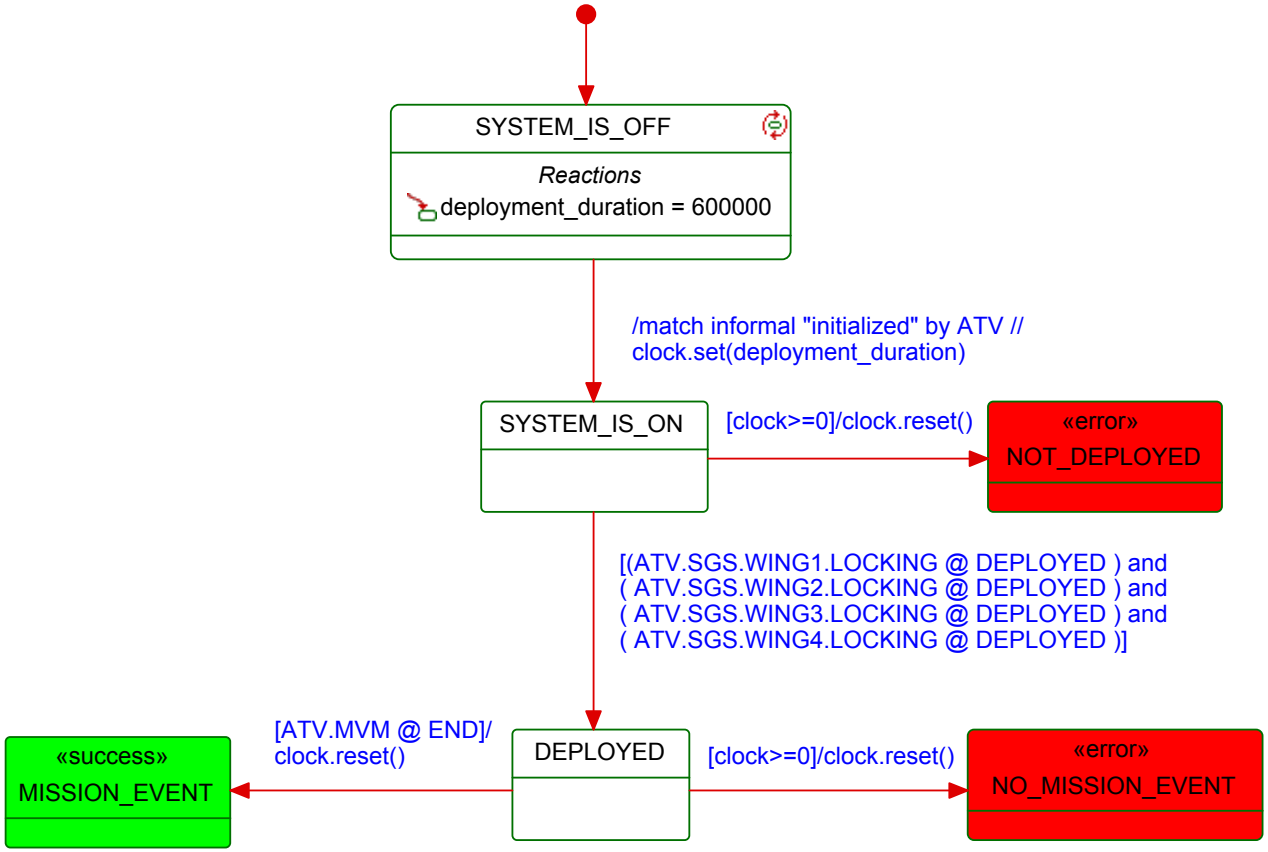

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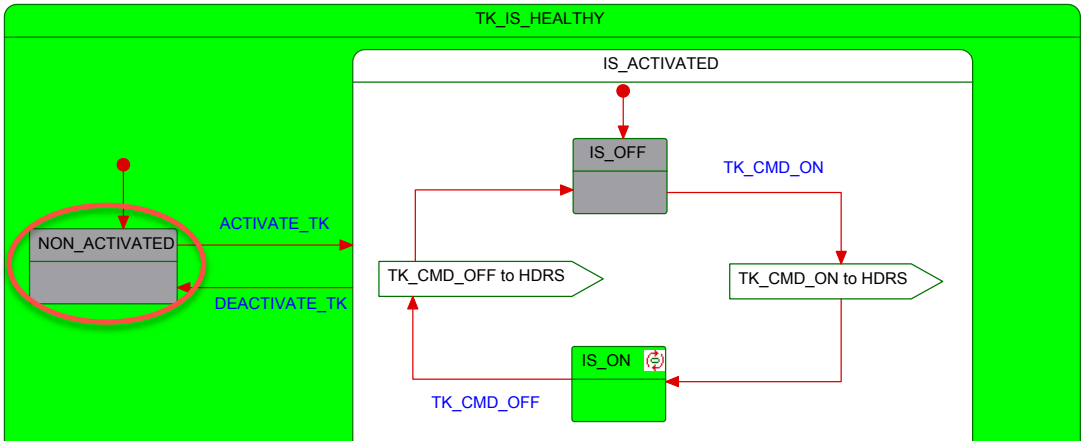

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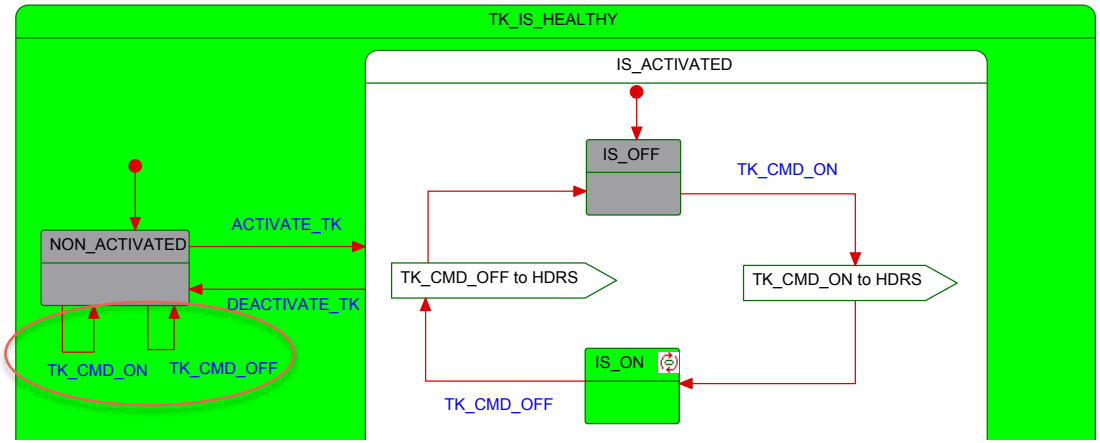

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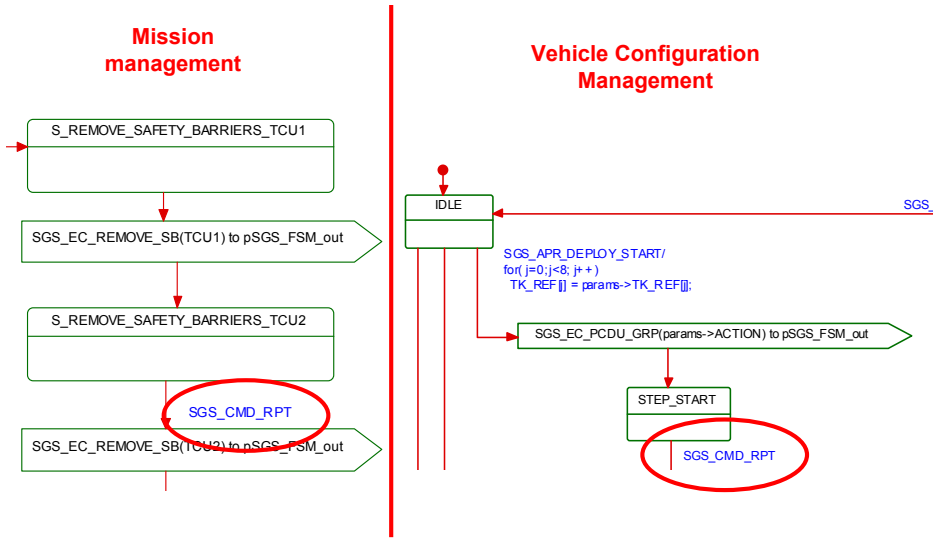

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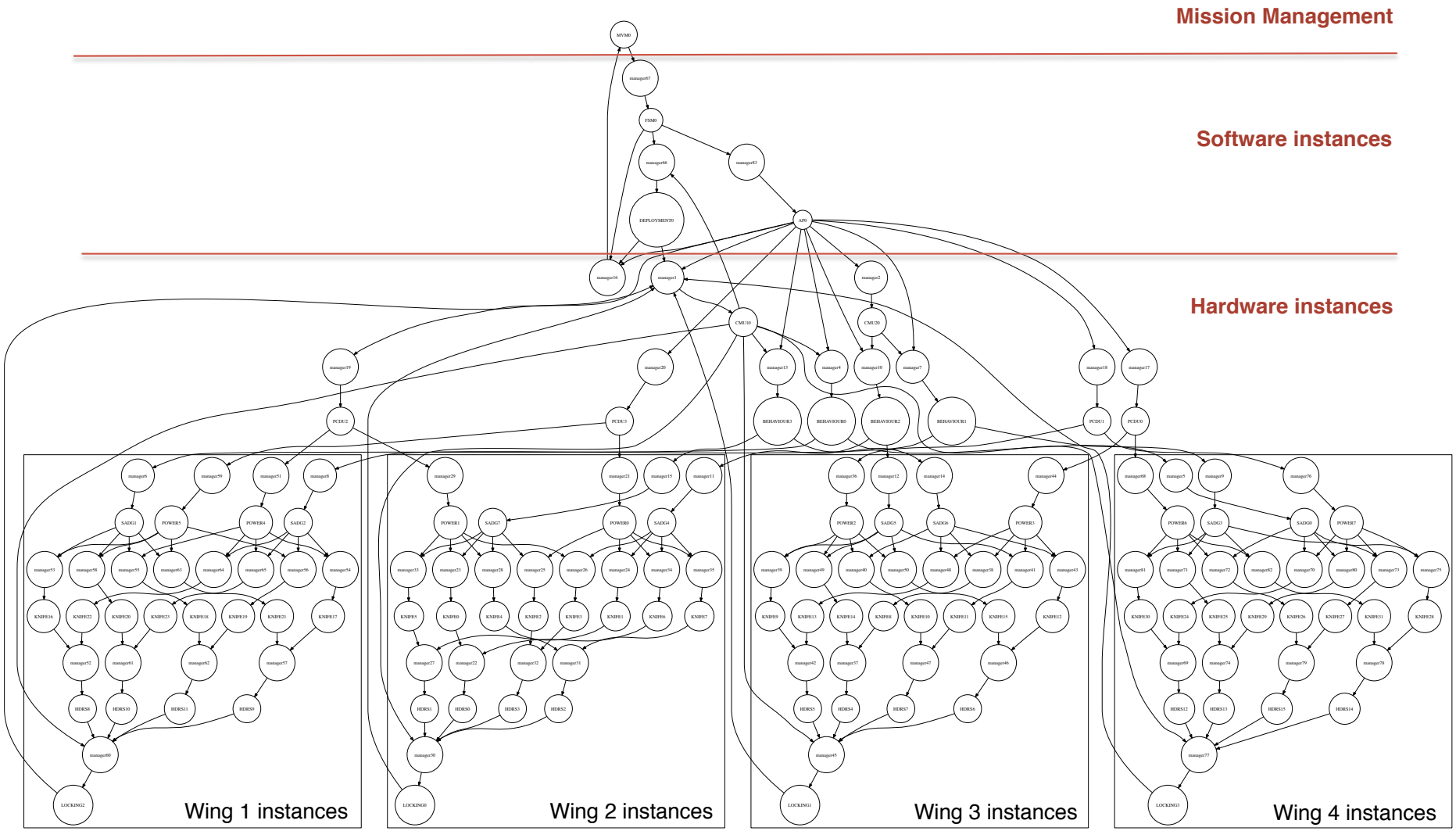
  - Incorrect (sequences of) requests that result in deadlocks; e.g. SADE receives deactivation before disable

State space explosion and its cause



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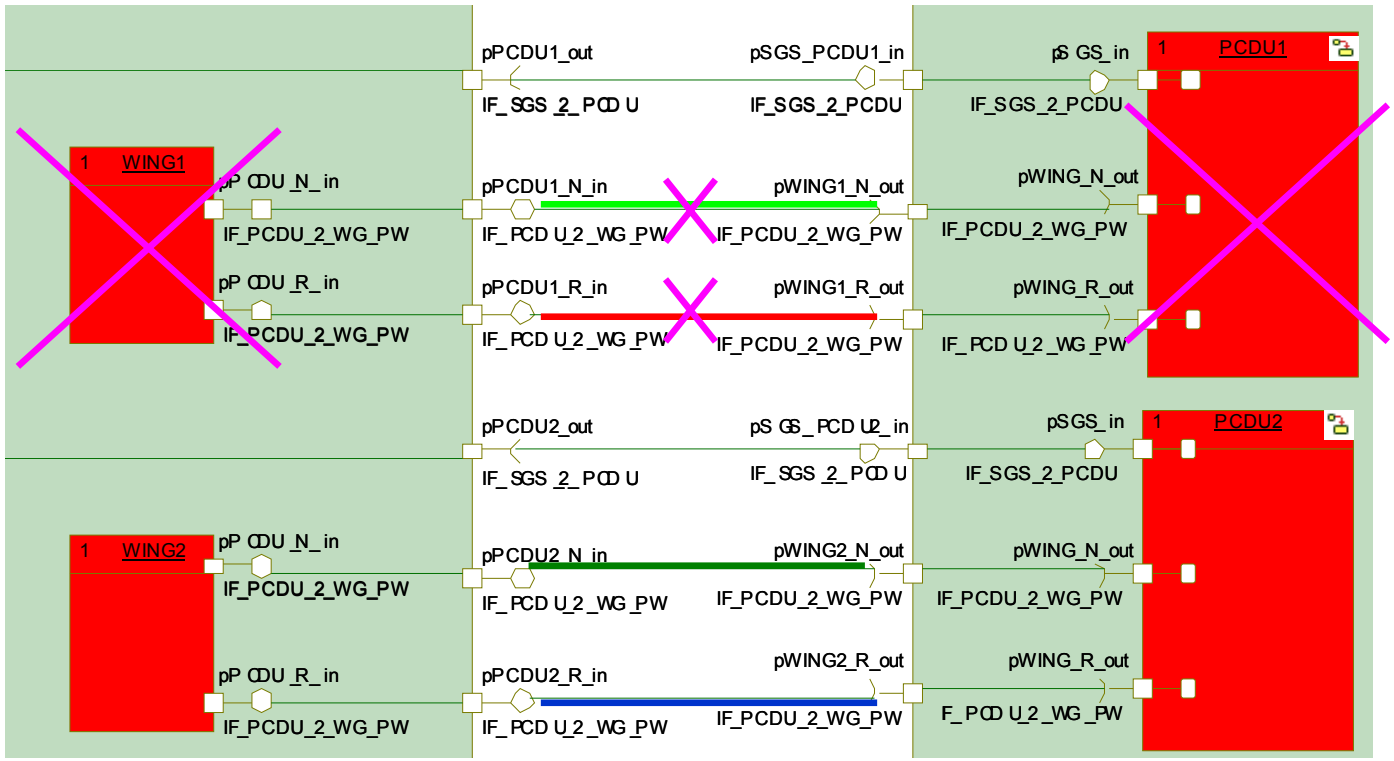

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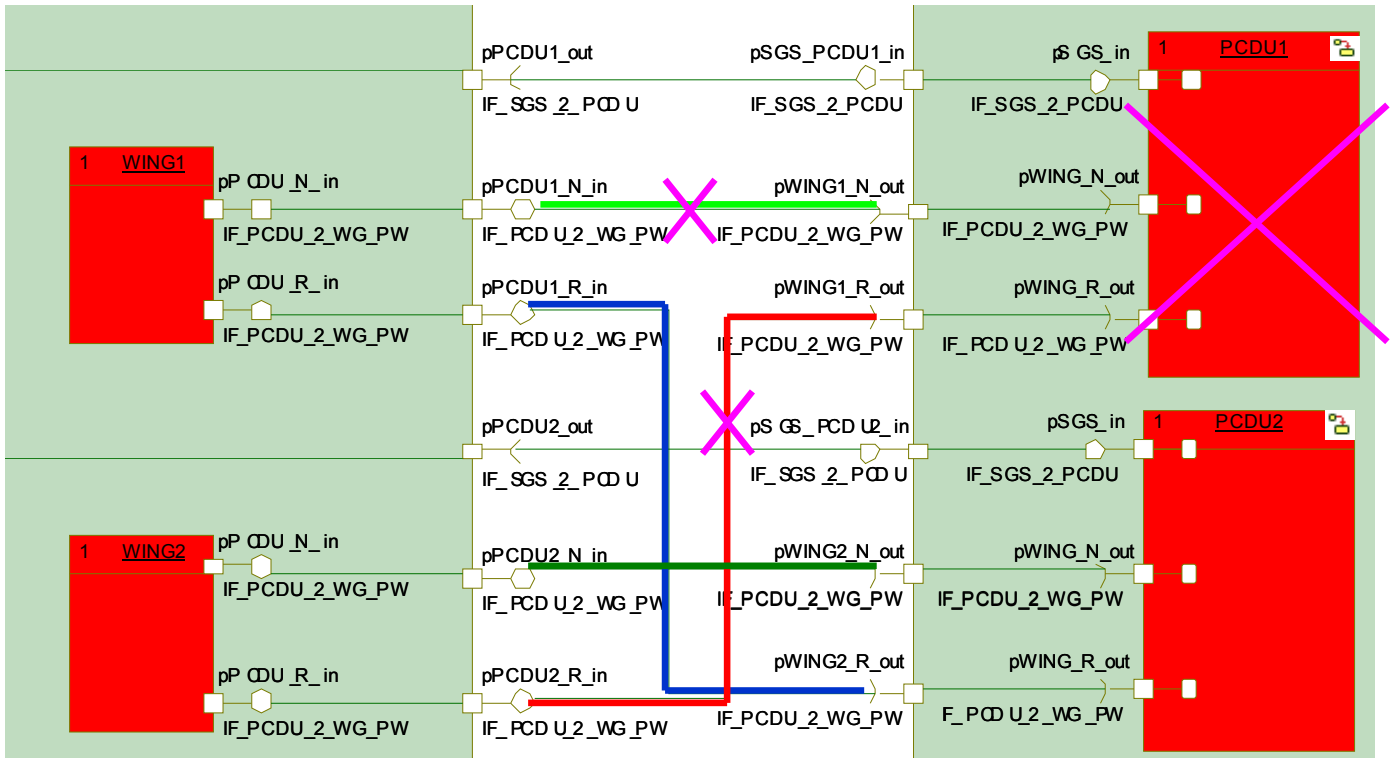

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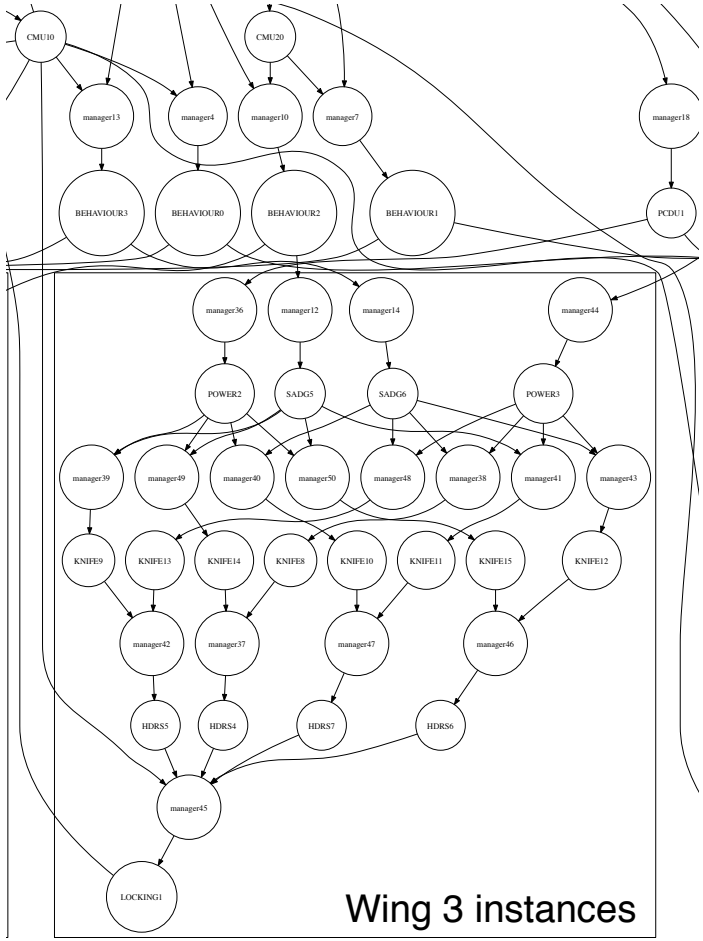
  - Incorrect connections between the power units and the wings
  - Unhandled received requests by the hold-down and release systems
  - Control and monitoring unit is already 1-fault tolerant, which makes this type of failure incorrect and removed from the set of verifiable errors

Verification using abstractions

Abstraction

One wing structure that does not experience any hardware fault is replaced by a block with a simpler behaviour: it ends up by being deployed.



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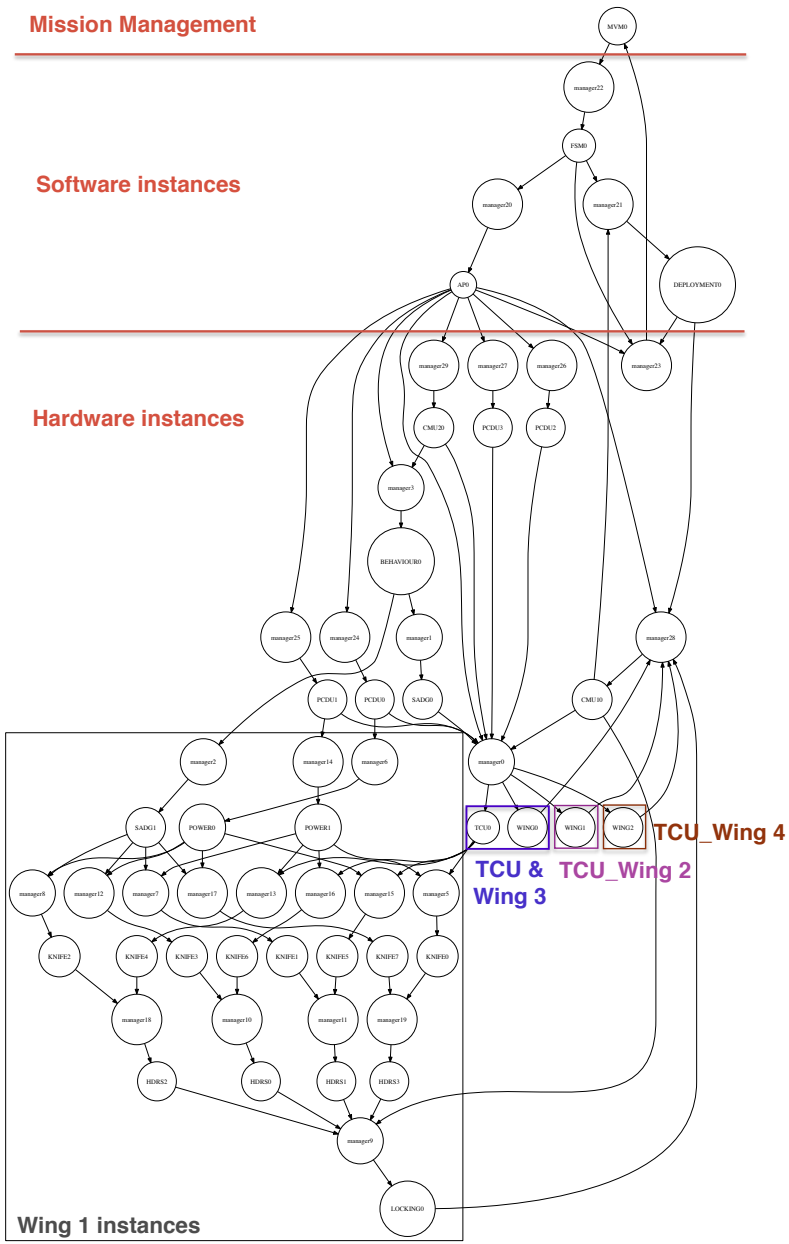
- System configuration: 1 extended wing and 3 abstract ones

Abstract communication graph



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- The total number of instances is reduced by 55%
- Separate verification for each 60 possible failures for each configuration
- Error detected: failure of the redundant thermal knife while the nominal one is enabled leads to a not deployed wing

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→ Both steps have been formally verified within OMEGA-IFx

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Conclusions

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- Use of abstractions & Contract-based Reasoning

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- Verification & Validation by simulation and model-checking
- Use of abstractions & Contract-based Reasoning
- User feedback
  - More formal approach than the classical SysML
  - Early detections of errors in the model
  - Complexity in usage of the tool chain OMEGA-IFx
  - Proof limitations

Future Work

- Formal definition of contracts within OMEGA-IFx
- Proof automation based on circular reasoning
- Automated assumption generation