Interconnected safe and secure systems

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RiTICS Spring Showcase 2019

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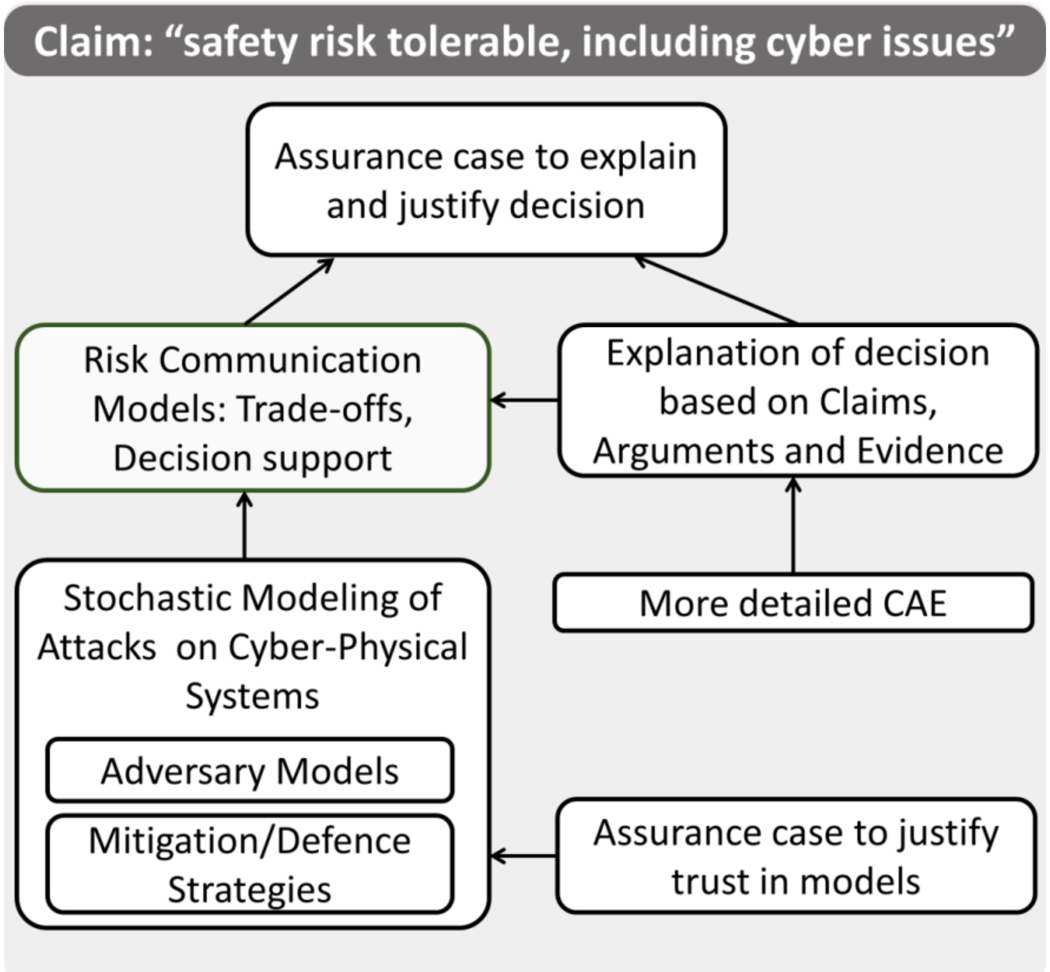
Overview of CERDICS (RITICS - 1)

Stochastic models of systems and adversaries



Decision analysis and communication based on Claims, Arguments, Evidence

Outline

- What we promised in IS3
  - WP 1 “Consultation and outreach”
    - Safety and Security – Workshop with CINEF
    - Interdependency modelling – Workshop with ResilShift and a report on the state-of-the art and ways forward.
  - WP2: Model based analysis
    - Review of SoA in modelling “Resilient Operator of a CNI operator” and identify research issues
    - Examples of models useful in “co-engineering” for safety and security
  - WP3: Safety and Security Decision Making
    - Change of tempo in safety-case lifecycle to account for security (e.g. how to make safety cases robust to software patching)
    - Trade-offs and synergies.

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Progress made to date

- Engagement with stakeholders – ongoing. Workshops planned for mid-May/early-June
- Models of safety and security (examples)
  - Examples of models of embedded systems (details will be presented today)
  - Examples of models of critical infrastructures (e.g. to help with “optimal allocation of defence in depth”)
    - Ongoing work with Nordic-32 simulator (used by City in RITICS - 1).
- Models of analysis from SysML models
  - not in the proposal, but approved by sponsors (will give a presentation on the progress)

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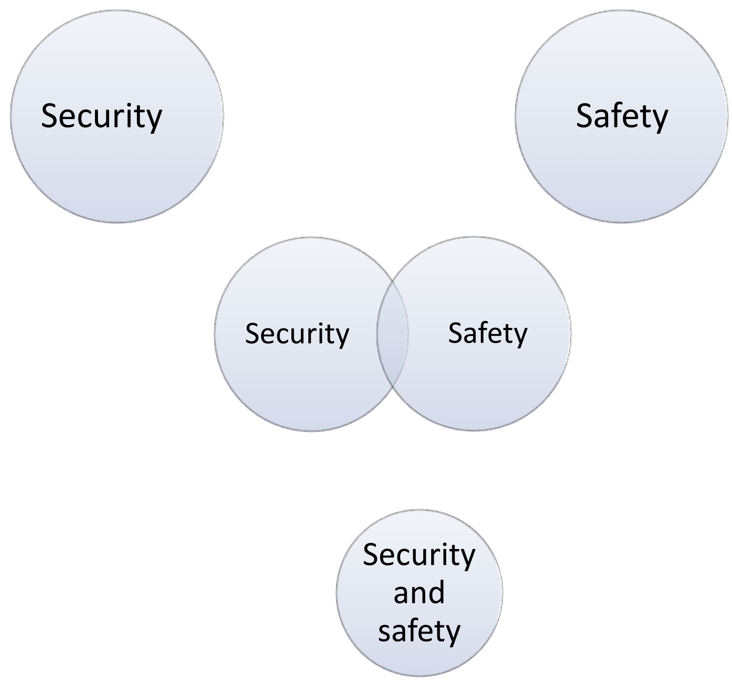
Models for combined analysis of safety and security



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Maybe???

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Combined safety and security analysis ≠ S + S

- Combined analysis is not just ***safety-only*** + ***security-only*** analyses.
- A truly ***combined SSP analysis*** *requires* an explicit and credible ***model of dependencies*** between the properties of interest, e.g.:
  - Conflicting Safety and Security requirements lead to the need for trade-off analysis:
  - successful attacks may ***impair safety*** against accidental faults, e.g. by eliminating the ***safe state*** (real attacks on safety are well documented)
    - “If it is not secure it is not safe”
  - strengthening security controls typically affects performance (e.g. response time)
    - and increases the likelihood of missing a hard real-time deadline

Credible trade-off analysis is impossible without a credible combined analysis

Quantitative Combined SS analysis (2)

- Hazard analysis to identify security threats that may impact safety (or performance) is complemented by:
  - Judgement about the *likelihood* of various events
    - Attack occurrence
    - Attack success probability
  - An explicit ***model of how successful attacks*** affect reliability/performance of components. Some examples include:
    - the functionality of a *safe state* is blocked (eliminated), or
    - the *rate of failure* of compromised software components increases, thus increasing the likelihood of *unsafe system failures*.

Quantitative Combined SS analysis (3)

- Common mistakes in constructing models for combined SS analysis:
  - Safety is demonstrated in "trusted" environment
  - Security controls are added (e.g. to meet security requirements), but their impact is limited to checking if the additional overhead due to these security controls is tolerable.
- The questions that we should address in constructing models suitable for SS analysis are:
  - Security controls *are not perfect*. They may have flaws, they may be also compromised.
  - Anticipate compromises everywhere and study the implication of each compromise.
  - The answers related to likelihood of attacks and their effect are subject to *uncertainty*. Can we quantify credibly this uncertainty, or at least establish *bounds* on it?

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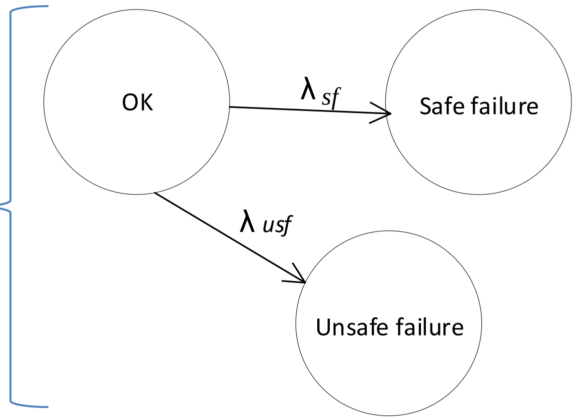
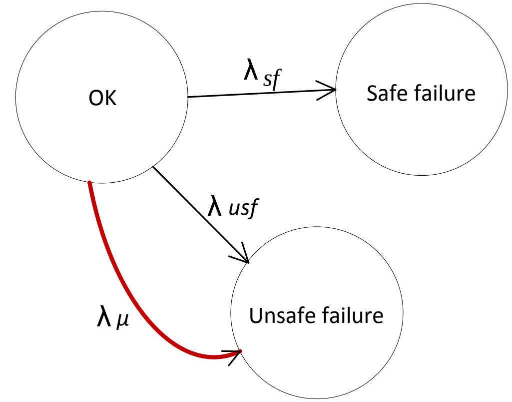
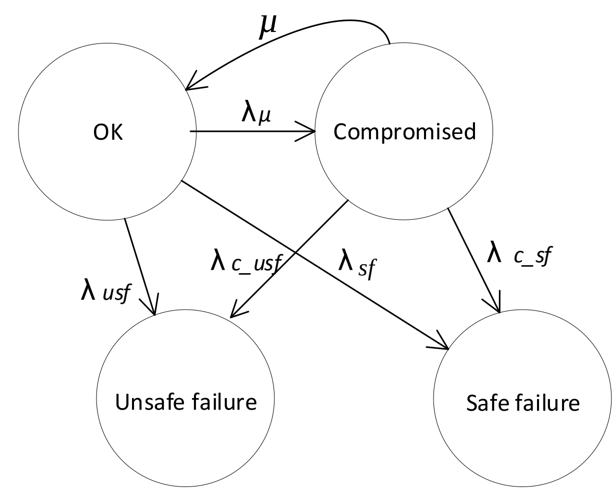
Model of Dependence: Example 1

- Model of system safety in *"trusted environment"*







- How much worse is system safety in adverse environment?
  - It depends on how we model the adverse environment?
    - *Model 1:* All successful attacks lead to ***unsafe state***.
    - *Model 2*: Attacks lead to a ***compromised state***, from which transitions are possible to safe/unsafe state or to OK (e.g. if we deploy "proactive recovery").
  - The outcomes of trade-off analysis will be affected significantly by the choice of dependency model (1 or 2 above).

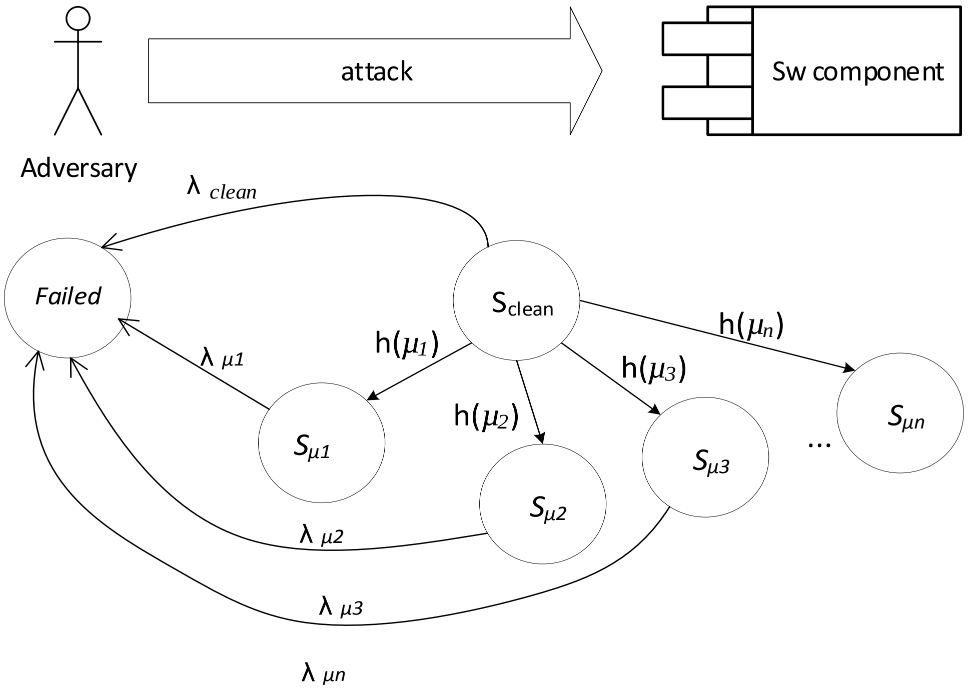
- Models of system safety in "*adverse environment*"

Model of Dependence: Example 2

- Consider the case when ***reliability*** of a software component ***is reduced*** by a successful attack which compromises software integrity.
  - An example: alteration of a threshold value of a software-based ***protection device*** (e.g. of a power line)

Model the effect of a successful attack on software reliability:

  - $\lambda_{clean} \leq \lambda_{\mu1}, \lambda_{\mu2}, \ldots, \lambda_{\mu n}$,
    - Successful attacks increase the rate of software failure.
  - Validating a ***safety goal*** would be dependent on:
    - ***security goal*** set for attacks.
    - ***attack effect*** on software reliability.
  - Parameterisation becomes harder.



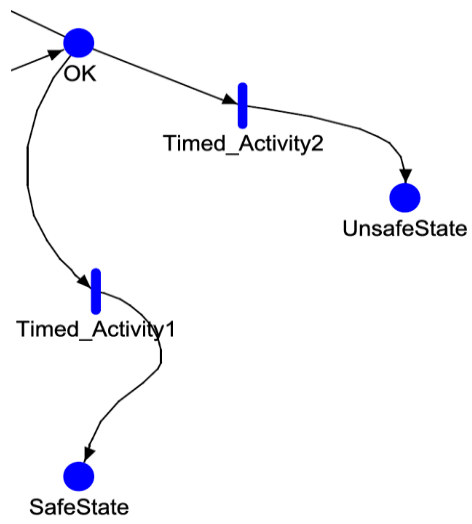
- A similar model of dependence on security, applies to performance, too
  - Successful attacks may increase the response time of a s/w component

Popov, P.T., Models of reliability of fault-tolerant software under cyber-attacks, (ISSRE 2017).
Model of attacks validated recently on NORDIC-32.

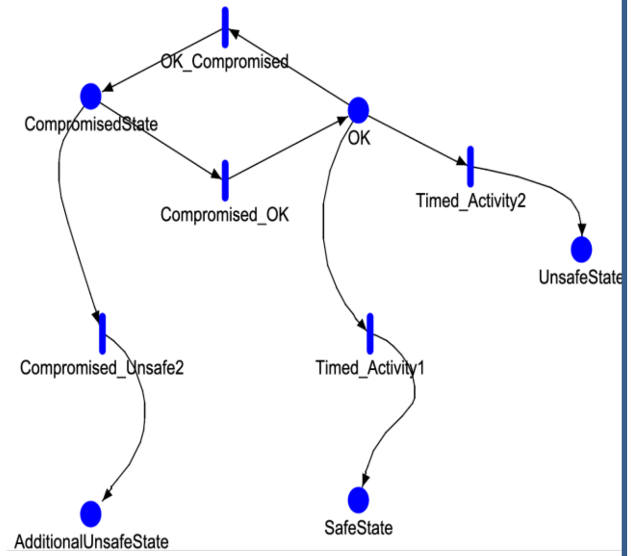
Model of Dependence: Example 3

- The ***safe state may be eliminated*** as a result of a cyber attack.
- λ_{UF} | NonC SS ≤ λ_{UF} | Com SS
- UF – unsafe failure.
- NonC SS - non-compromised safe state
- Com SS – compromised safe state.
- Clearly, the effect of removing the safe state is an *increased rate of unsafe failure*.
- Setting a ***safety goal*** for unsafe failure is simple, but its validation is dependent on the ***security goal*** set for the security event *"compromising the safe state"*.
- This particular problem is *recognised in IAEA guidelines*.

A safety model in ***trusted*** environment



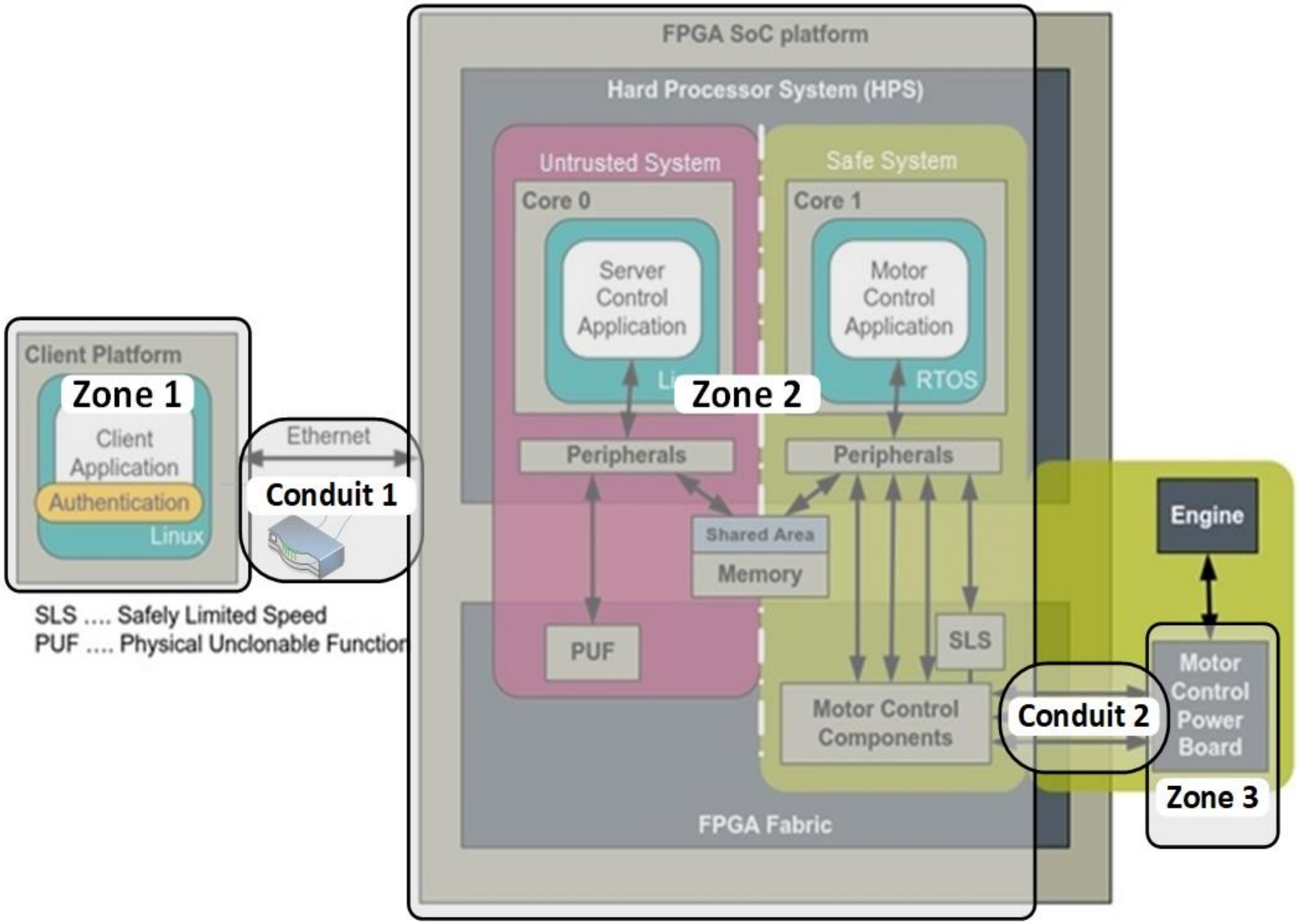
A safety model in ***adverse*** environment



Popov, P.T., Stochastic Modeling of Safety and Security of the e-Motor, an ASIL-D Device., (SAFECOMP 2015).

Models for SS analysis in practice

- An AQUAS (an EU ECSEL JU project) case study: A virtual prototype of an Industrial Drive.



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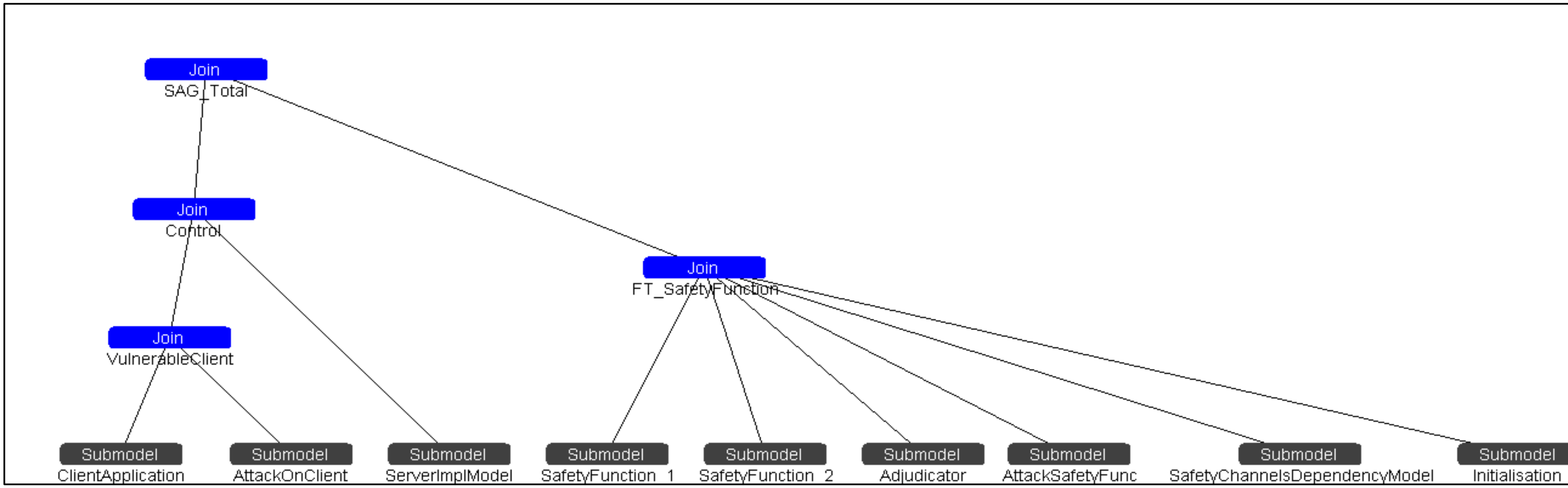
A SAN (stochastic activity networks) model



- Modelled all zones (with some simplifications)
- Modelled 2 attacks:
  - Attack on the client application: when client compromised, the failure rate increases.
  - Attack on the safety function (bringing the device to a safe state, i.e. stop the motor). Safety function is implemented as a 2-channel sub-system:
    - A successful attack on a channel of the safety function may affect either the ***coverage*** (i.e. the probability of detecting a failure provided there is a failure) or the probability of ***false alarm***.
    - Attacks may be on a ***single channel*** or ***simultaneously on both channels*** (with small interval between attacks of the channels).
- ***Sensitivity analysis*** (rate of attacks, probability of success of attacks) completed. Looked at the effect of “cleansing” to mitigate the consequences of successful attacks.
  - Numbers suggests that cleansing is quite effective! The “owner” of the prototype convinced that the client application should be designed with cleansing.

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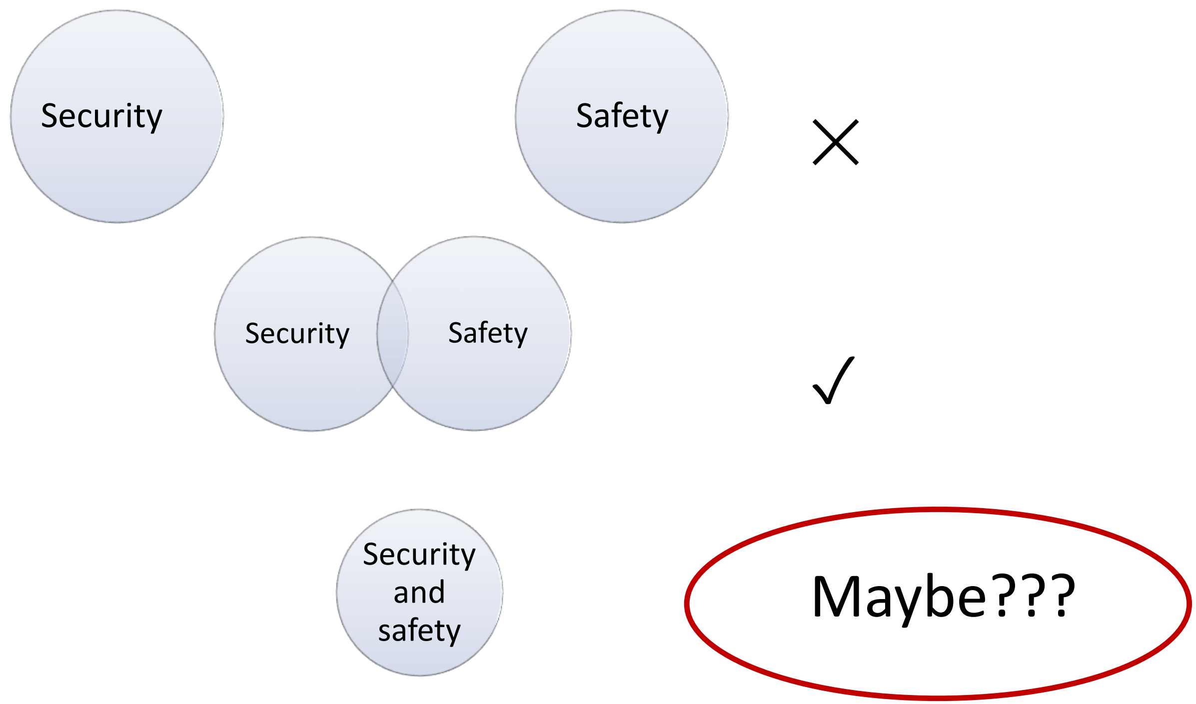
Models of Combined analysis (Safety and Security)



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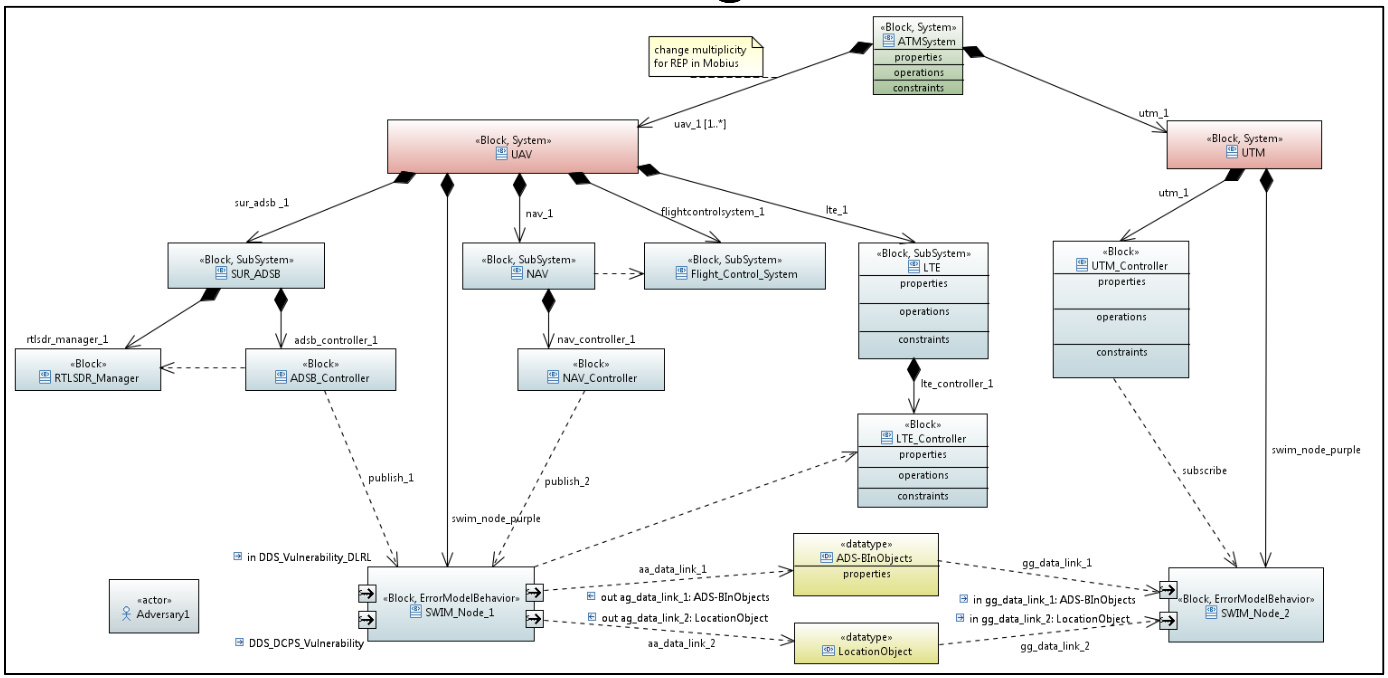
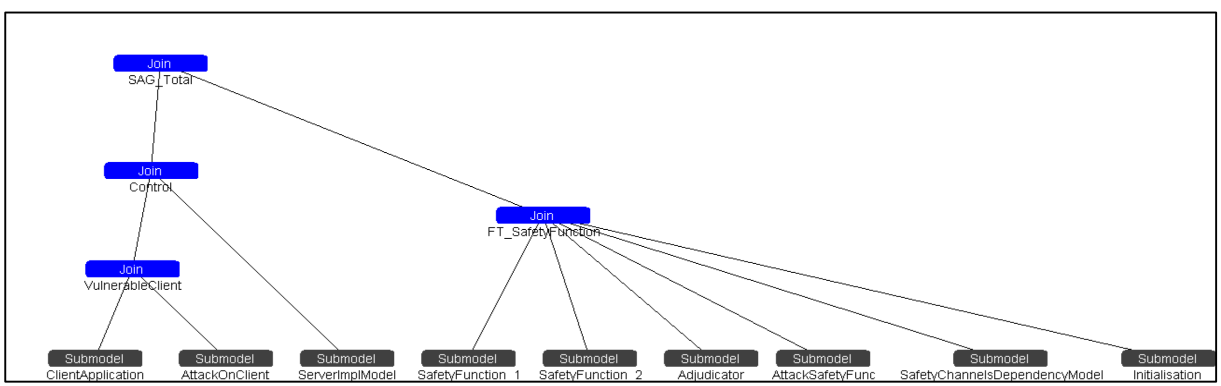
System development and SS analysis: Deriving SAN models from SysML model



- Model transformation: from CHESS (SysML) -> SAN



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Questions