Tool-Supported Dependability Evaluation of Redundant Architectures in Computer-Based Control Systems

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Motivation

- Architectural choices have profound influence on system dependability (reliability, availability)
  - Degree and type of redundancy (fault tolerance)
- Standards require a thorough evaluation of possible failures and protection mechanisms
  - Quantitative evaluation: Computation of system level measures using component-level reliability parameters
- Model-based dependability evaluation
  - (Formal) dependability model is constructed
    - Component failure and repair (recovery) behaviour is modelled
  - Allows „what-if" kind of analysis in early design phases
  - Optimization of architectural choices (decisons)

Dependability modelling approach*

- Formalisms for dependability models
  - Combinatorial models (e.g. fault trees)
  - Stochastic state space models (CTMC, GSPN) allow to capture dependencies between components
- Design models shall be supported
  - Construction of dependability models automatically
  - Assembling the state space of the model taking into account failure states and repair processes
  - Integrating the expert knowledge in a tool
- UML: formalism of the design model, GSPN: formalism of the dependability model

* I. Majzik, A. Pataricza and A. Bondavalli: Stochastic Dependability Analysis of System Architecture Based on UML Models. In „Architecting Dependable Systems”, LNCS 2677, Springer, 2003.

Dependability model construction

- Dependability model represents
  - Fault occurrences in components
  - Error propagations between components
  - Repair (maintenance) mechanisms
- Component types are assigned GSPN subnets that represent these processes
  - Hardware, software, stateful, stateless components are distinguished
  - Component types and related local dependability parameters can be identified in the design model (UML stereotypes and tagged values)

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  - – Hardware
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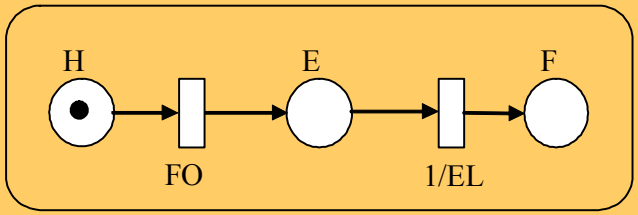
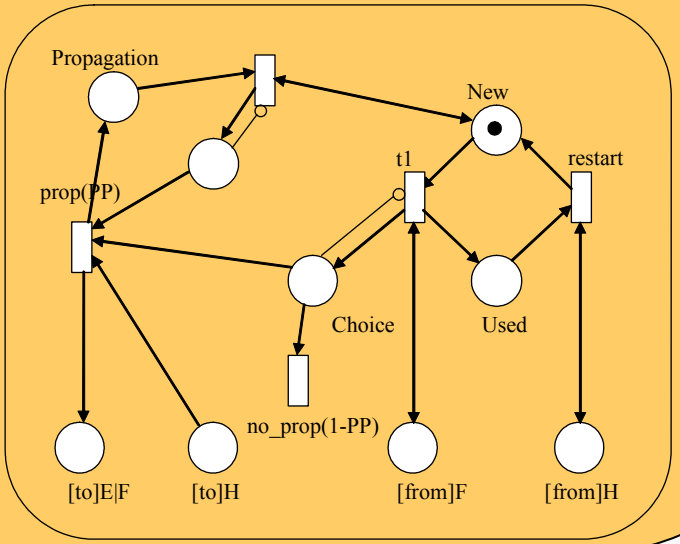
  - – Compone
    paramete
    (UML ste

Failure subnet of a stateful hardware

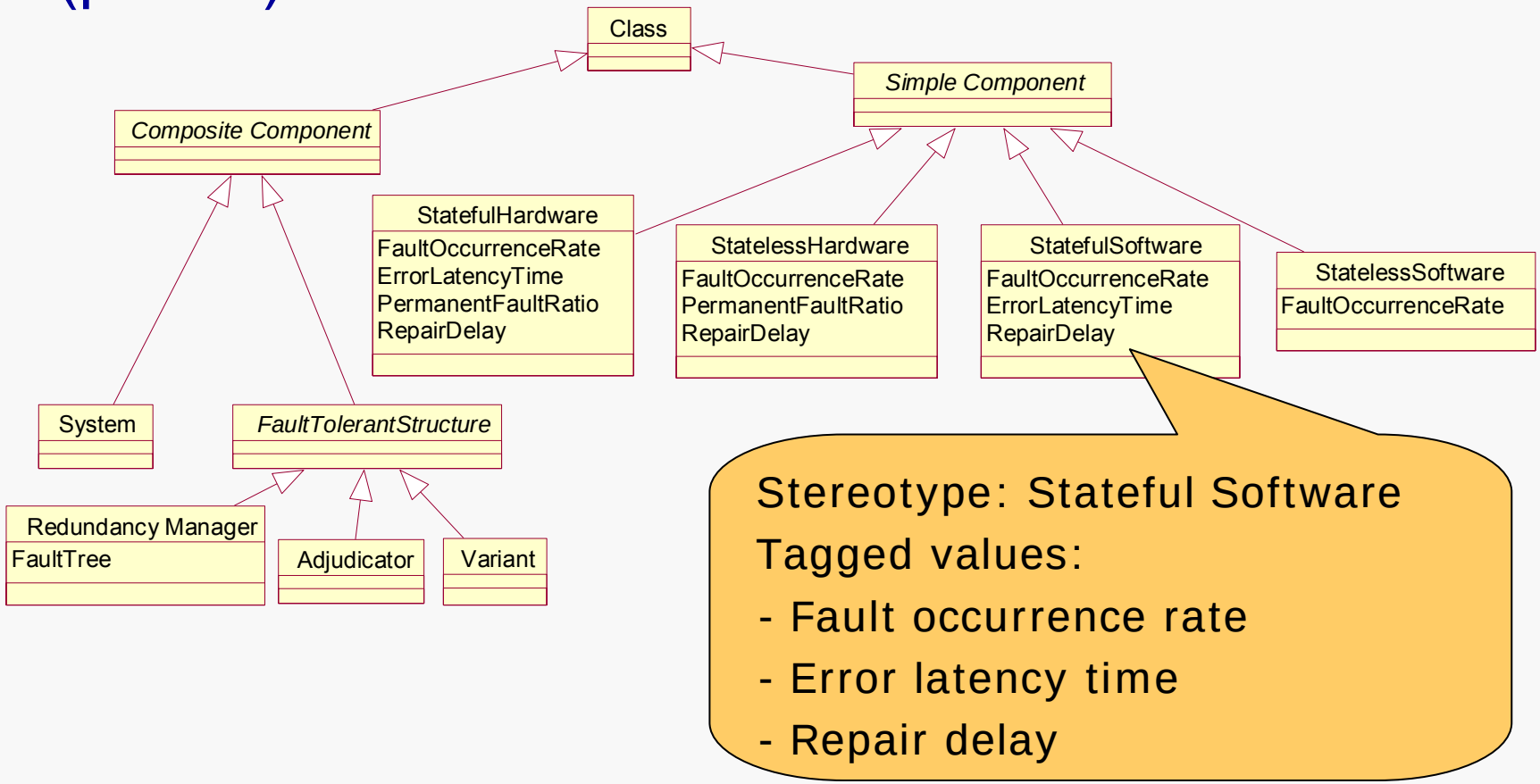


Generic error propagation subnet between components



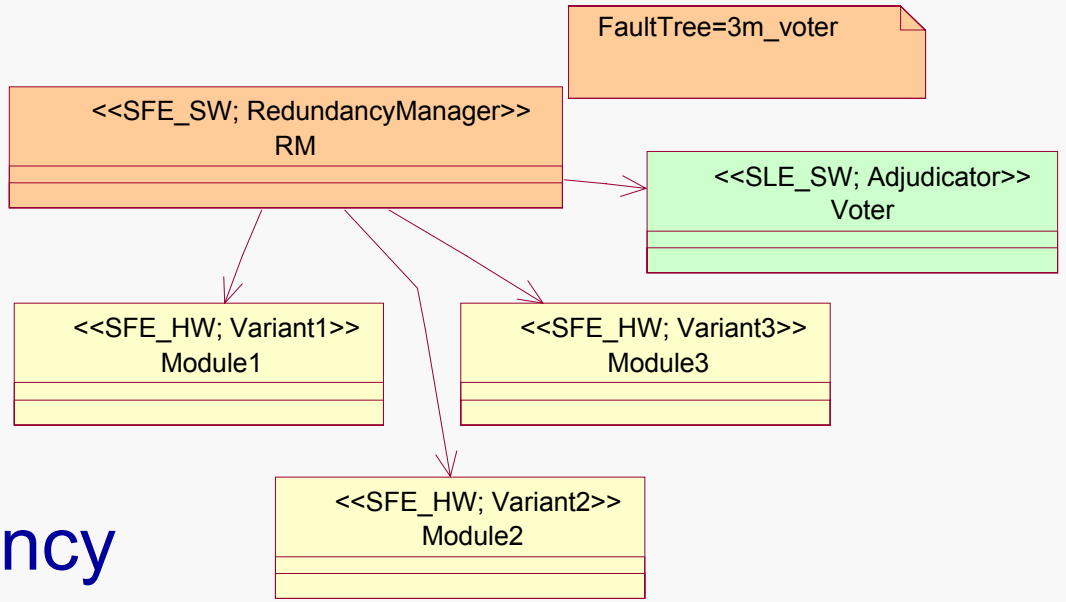
Extensions of the UML design model

- Identify component types and local parameters (profile)



Modelling redundancy

- Identification of roles
  - Redundancy manager
  - Variant
  - Adjudicator

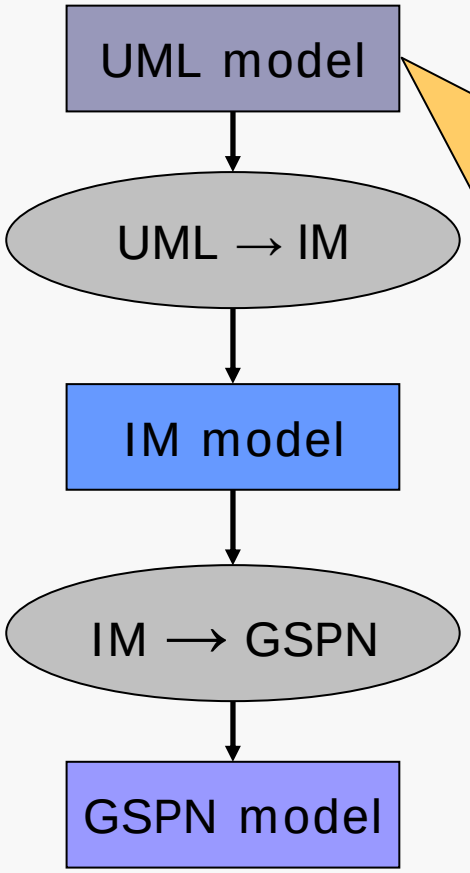


- „Logic” of redundancy (error propagation)
  - Fault tree
  - Specific GSPN subnet

Tool support for dependability modelling

- Integration of subnets assigned to components
  - Subnets are constructed by dependability experts
- Re-use of dependability subnets from a library
  - Assigned to common redundancy management (TMR, NMR, NVP, etc.)
  - Assigned to architectural design patterns (optionally handled as aspect models)
- Refinement of dependability subnets
  - Early phases of design: Generic subnets
  - Design refinements: Refined subnets
    They can be transformed from behavioural models:
    E.g. statechart of the redundancy manager → Fault tree

Tool architecture



System model

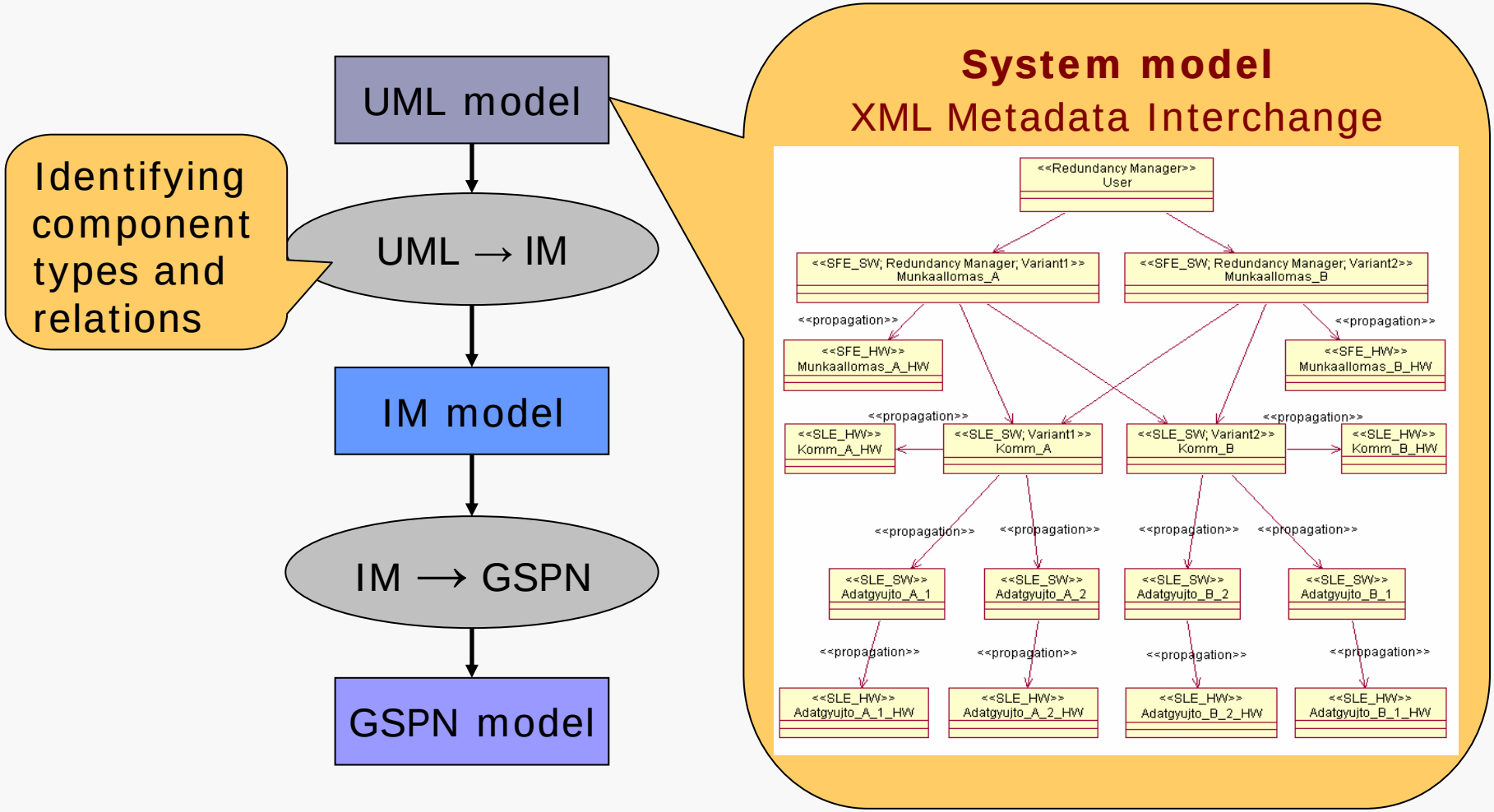
UML architecture diagrams:

- classes and objects
- associations / relations, deployment (sw on hw)
- packages (subsystems)

Extensions:

- Component type from dependability viewpoint (stateless, hardware etc.)
- Numerical attributes (local failure rate, repair rate, propagation probability etc.)

Tool architecture



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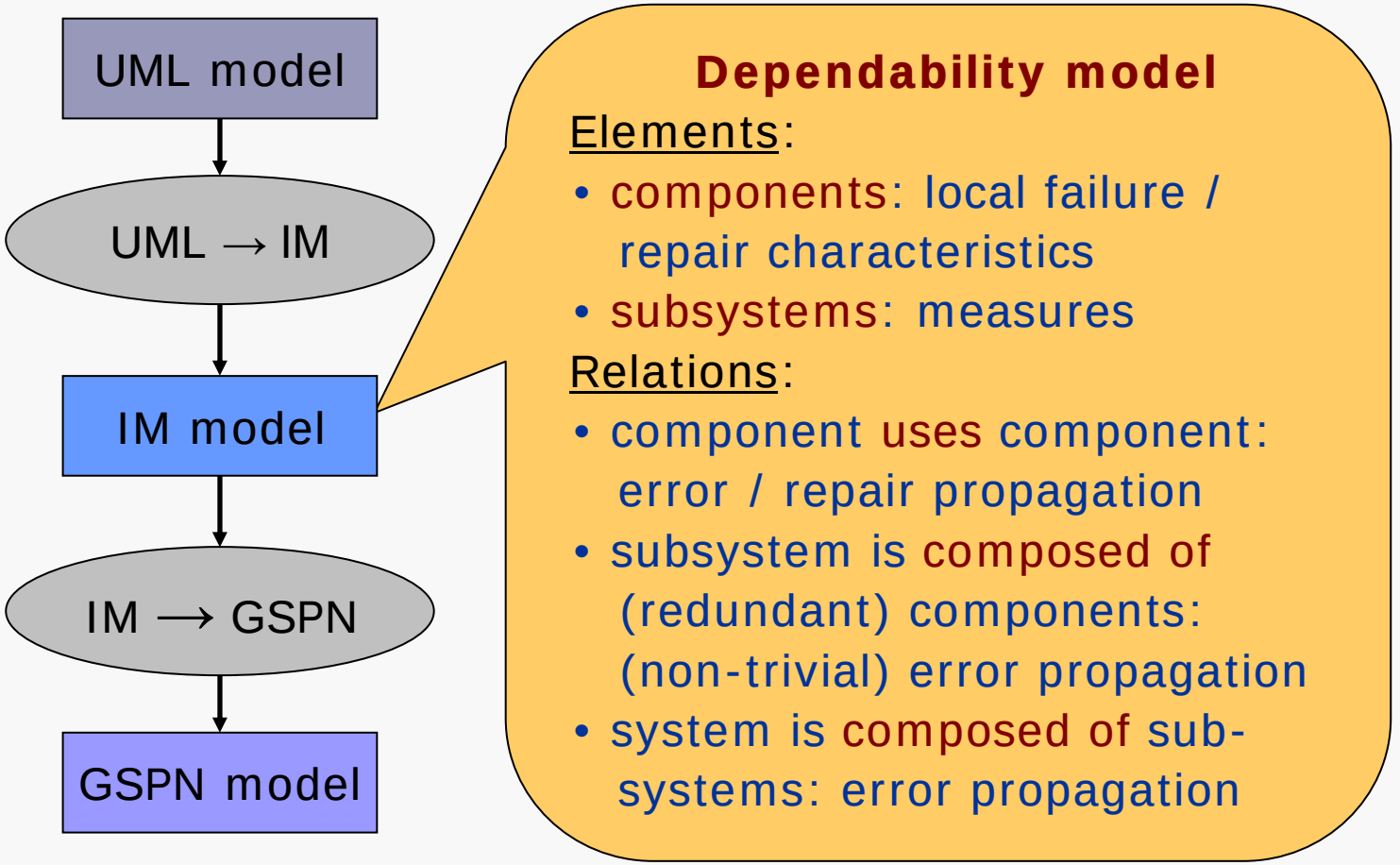

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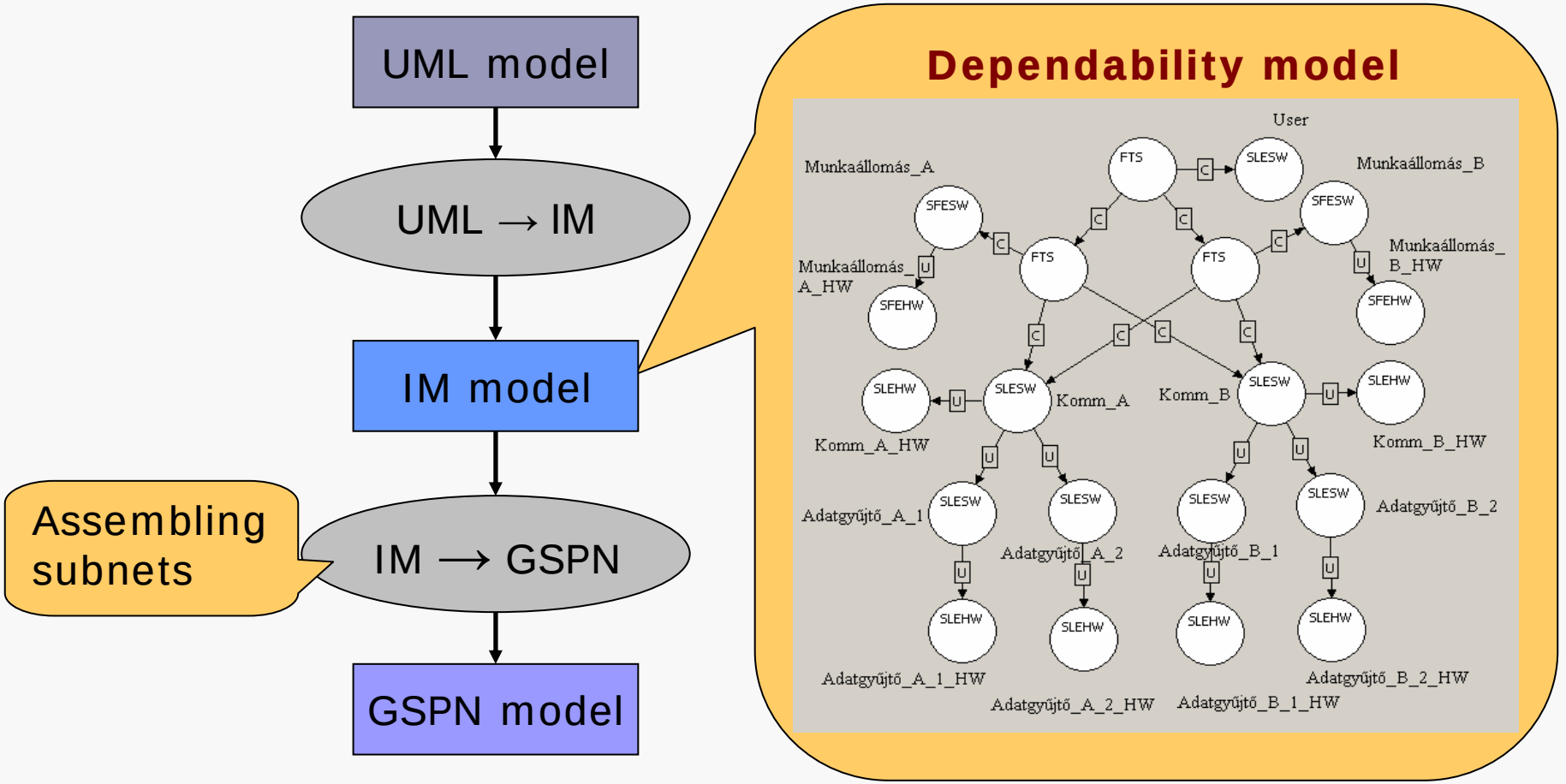

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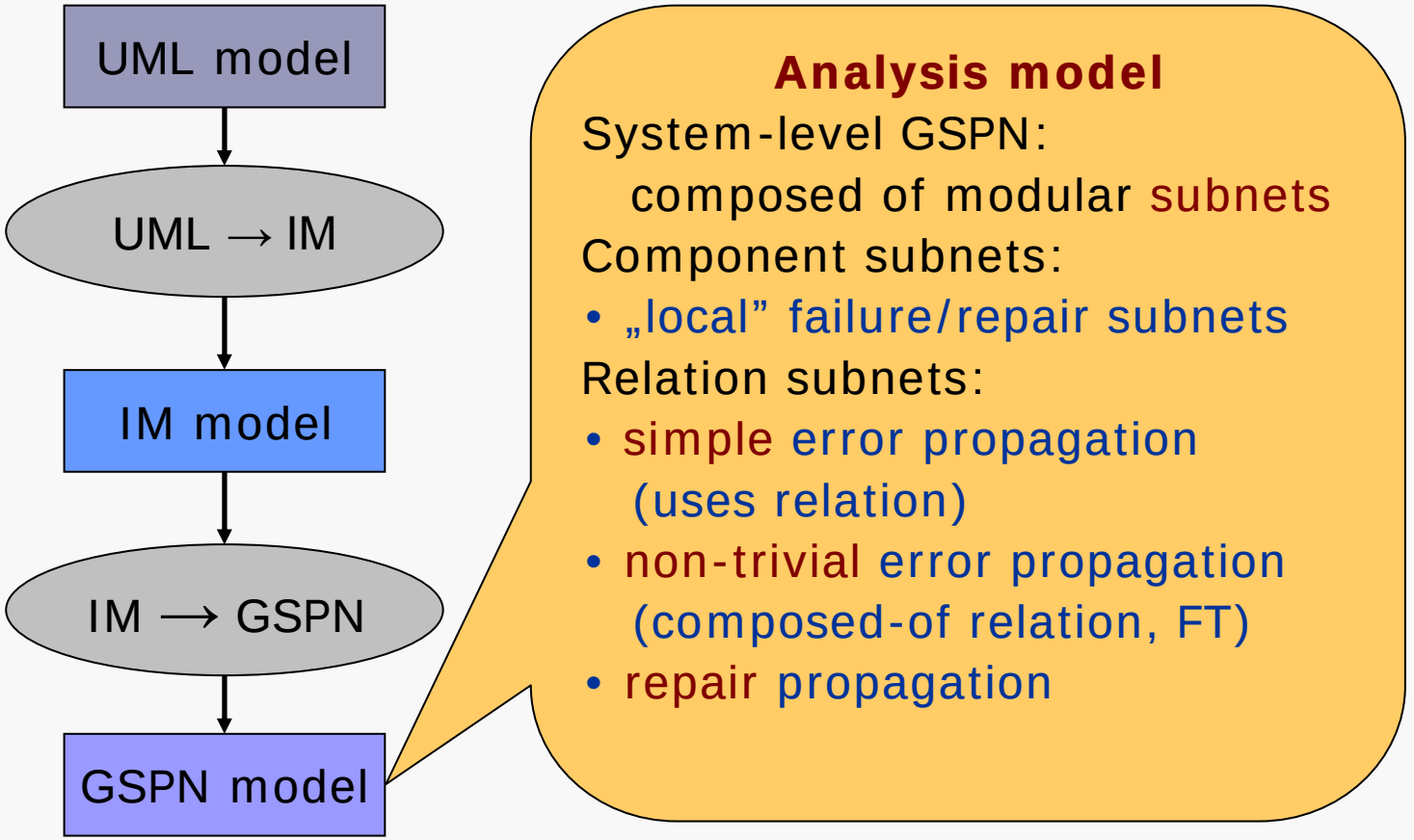

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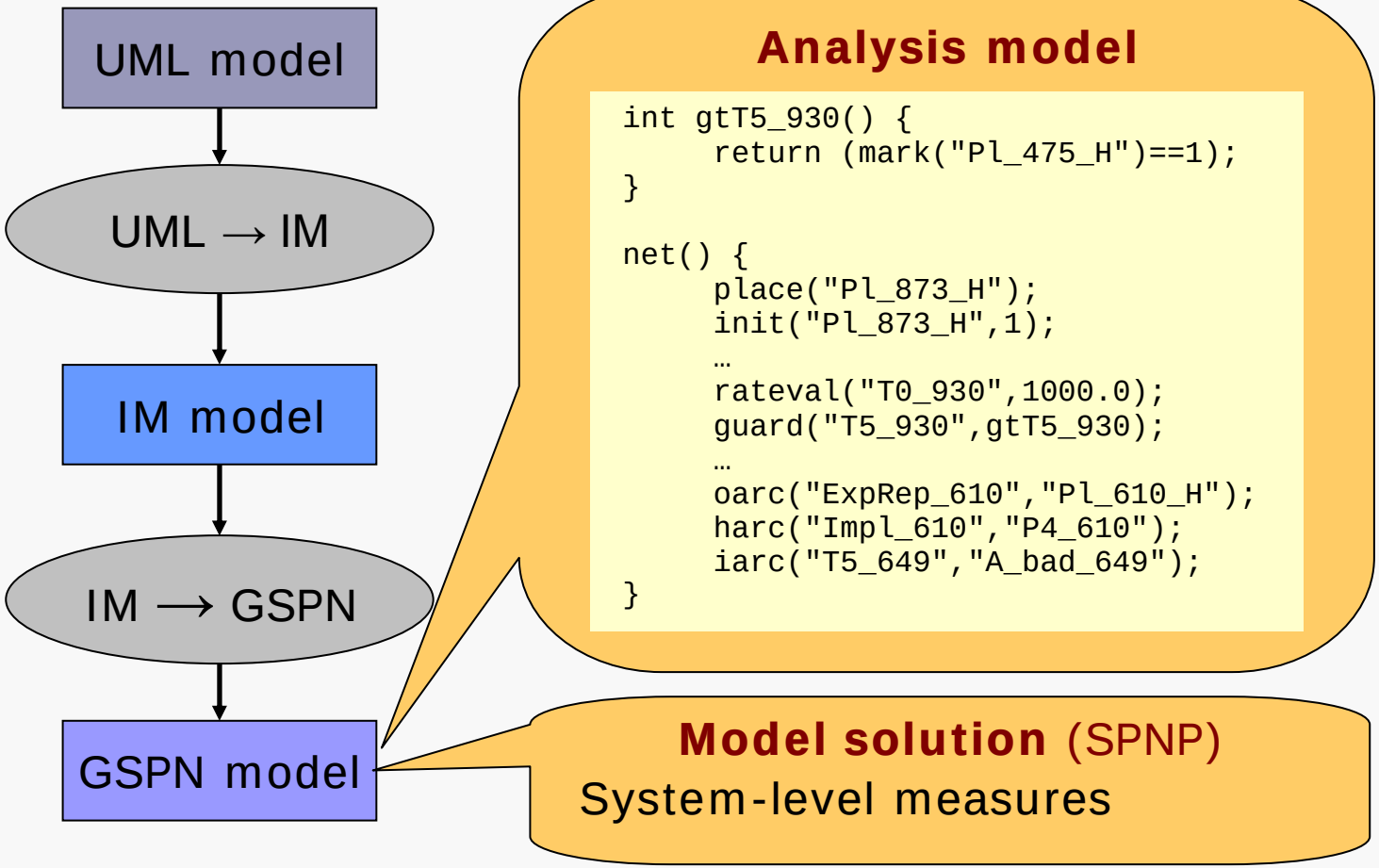

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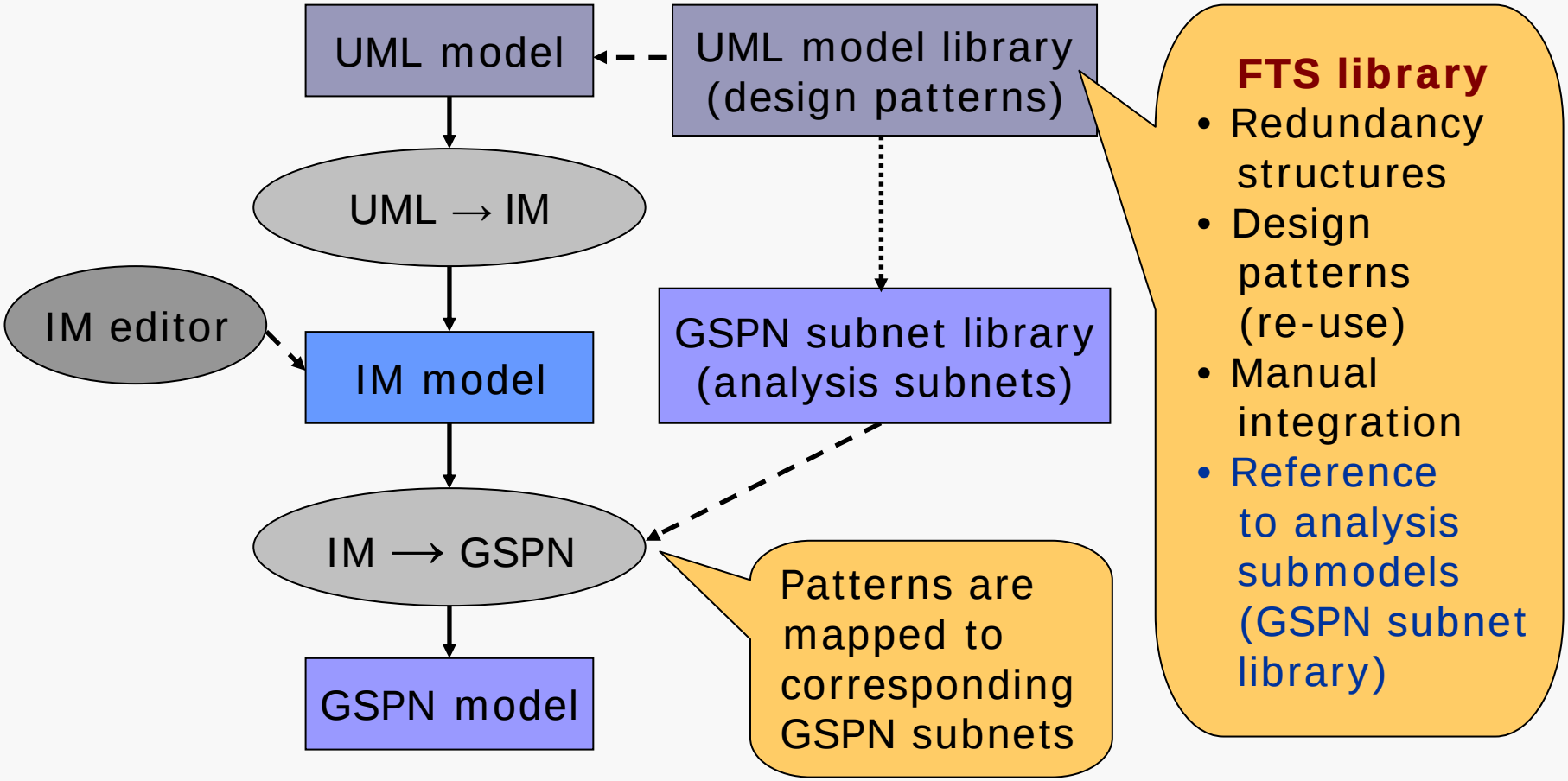

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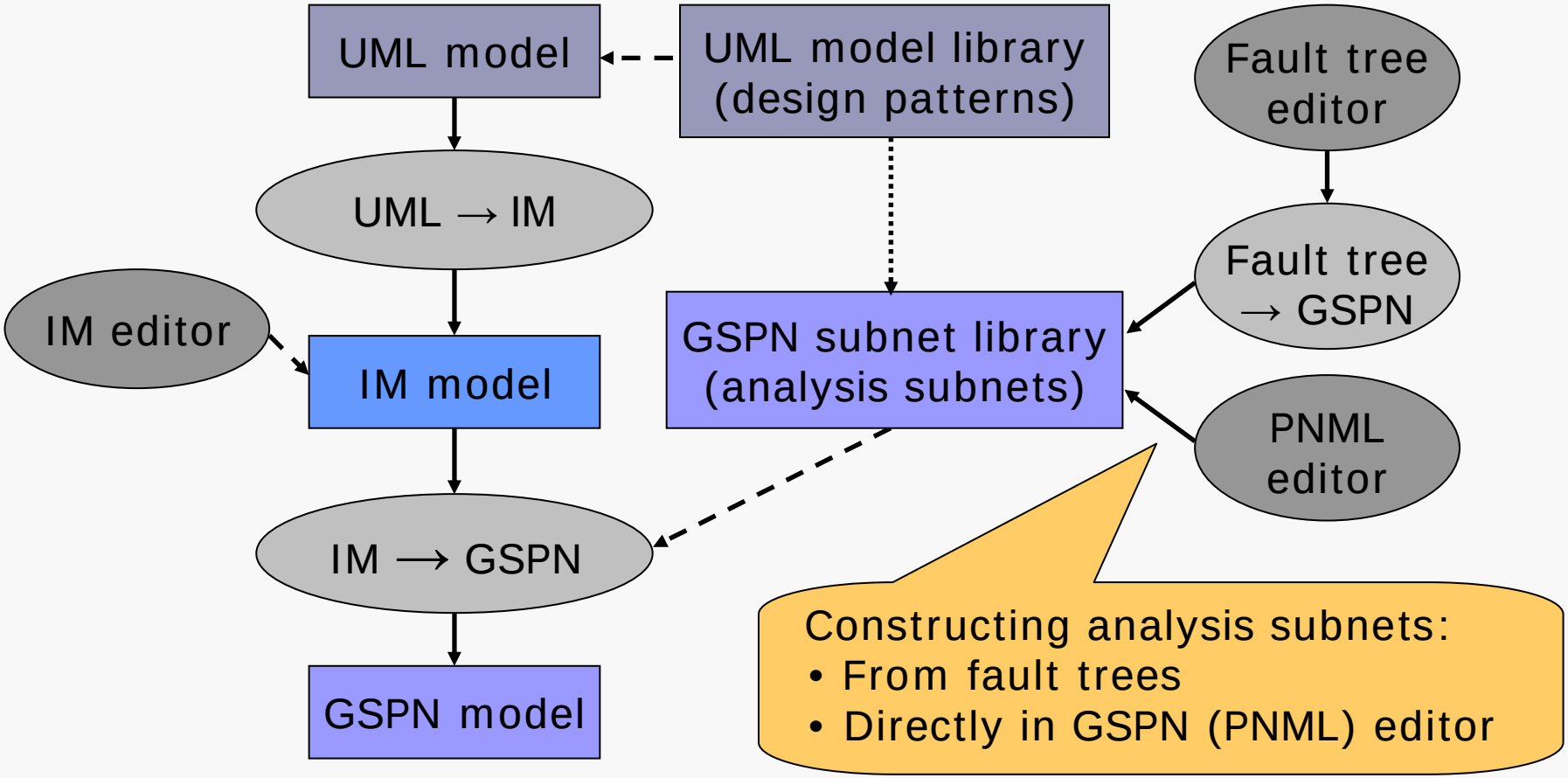

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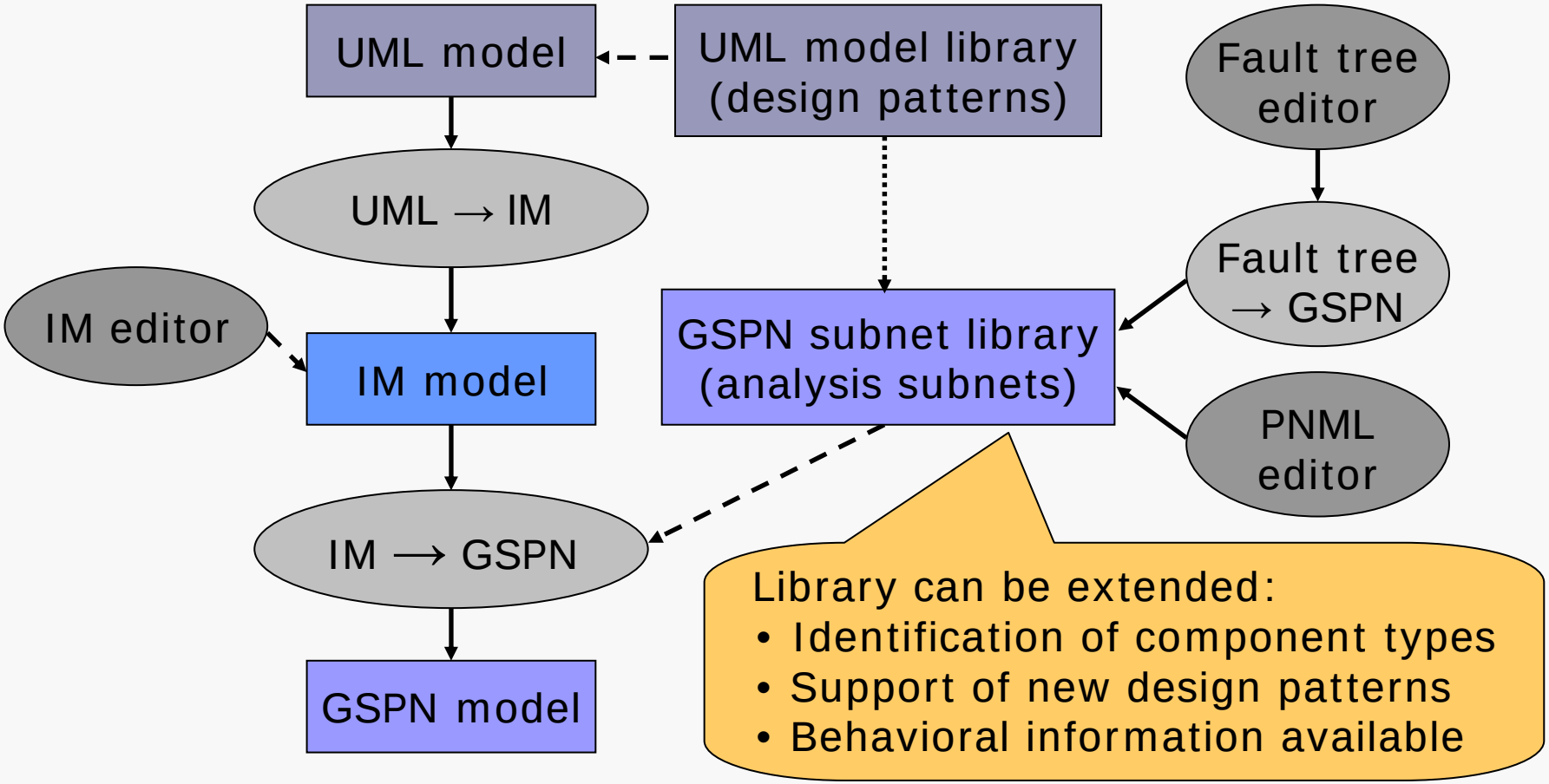
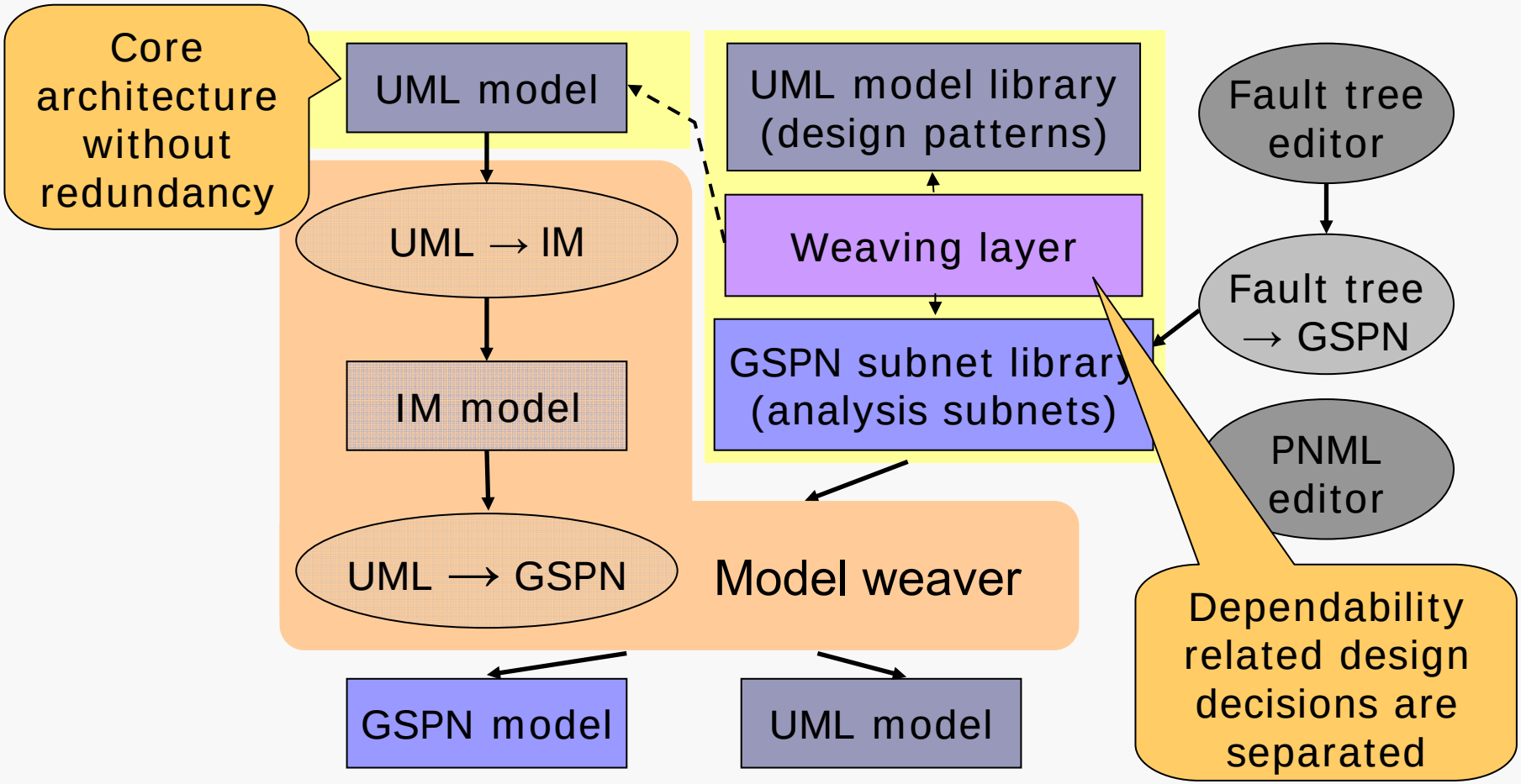


Aspect-oriented modelling approach



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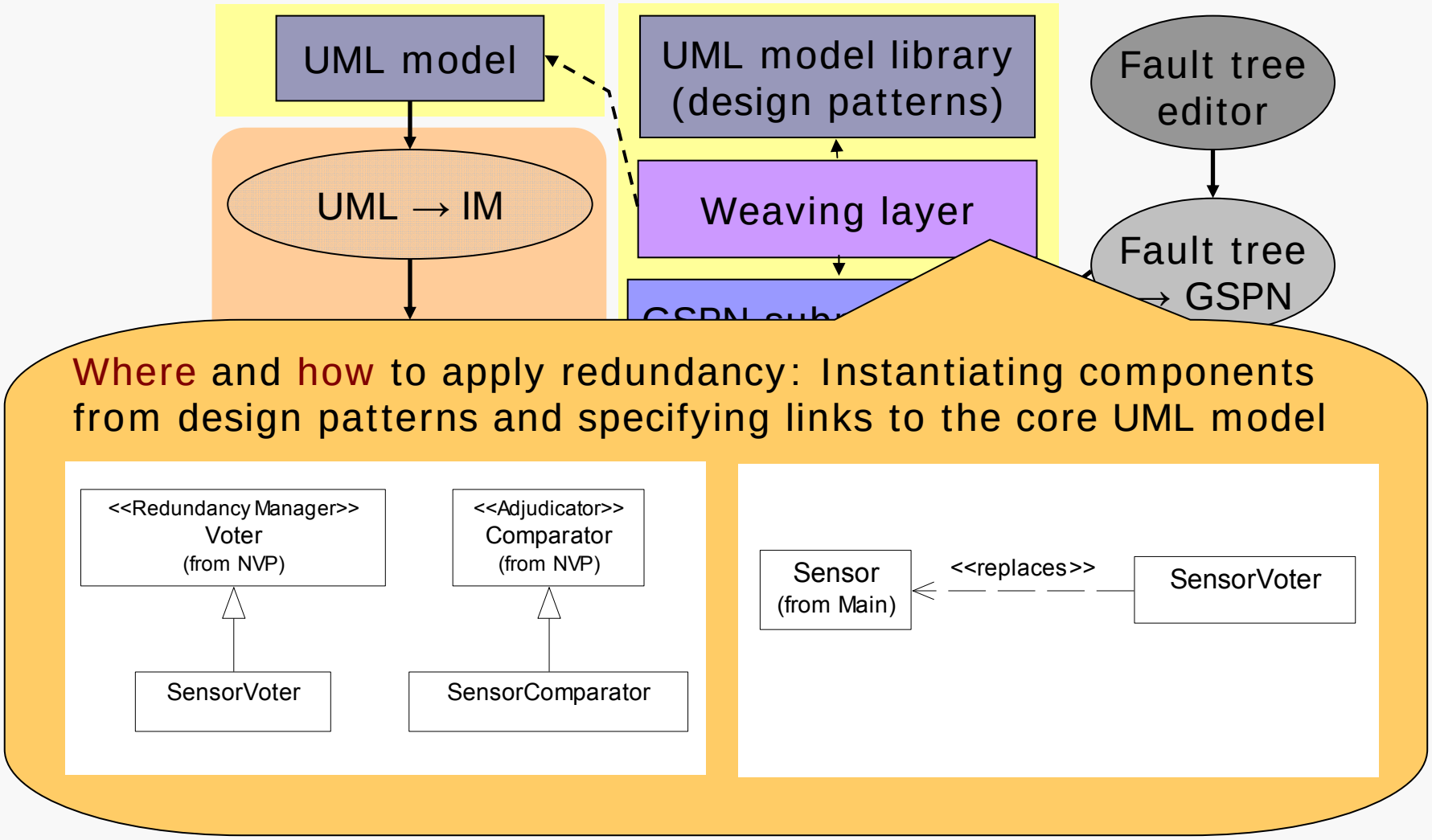

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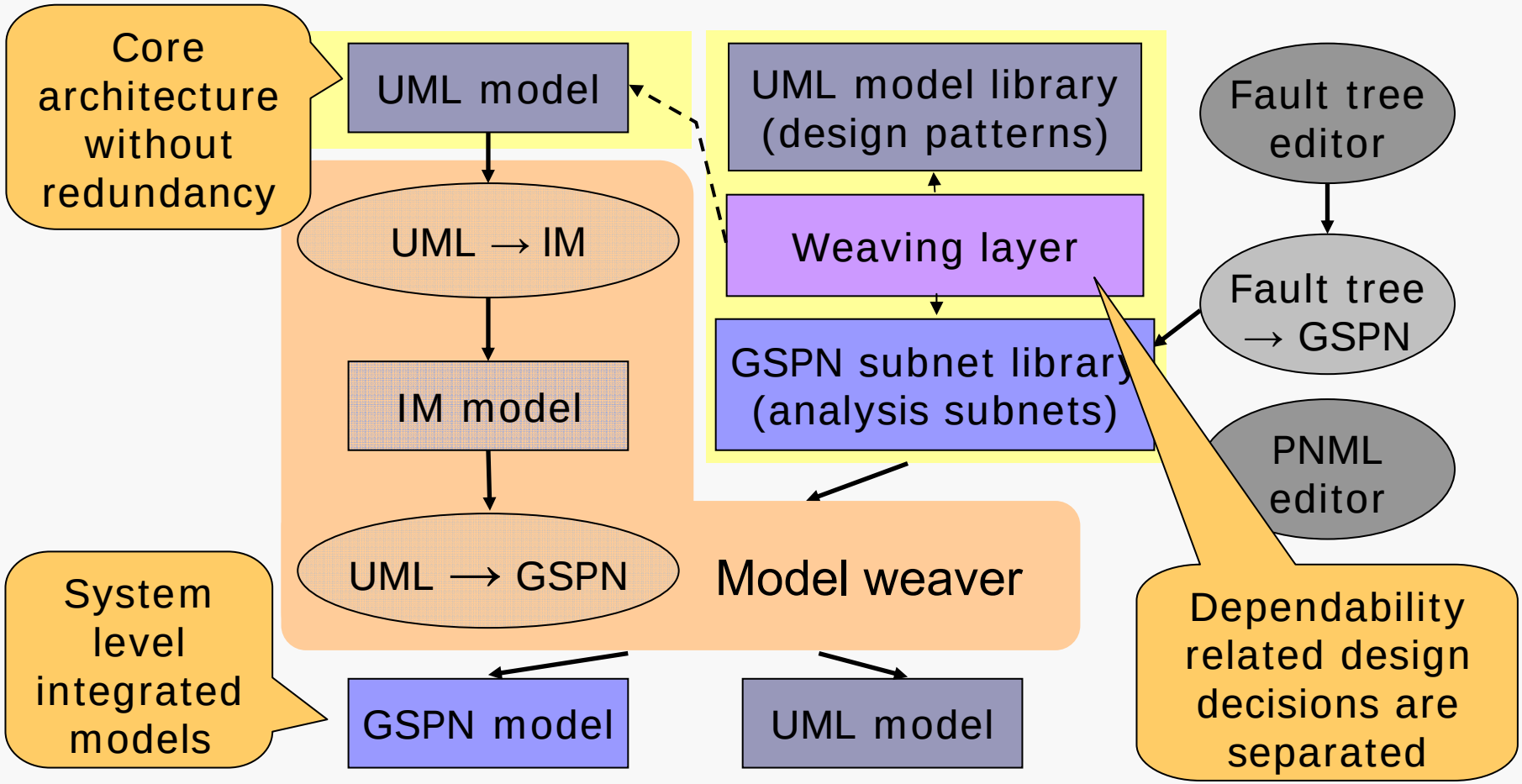

Summary

- Method to construct GSPN dependability models
  - External GSPN solver → System level availability
- Adaptability to different input models
  - UML, AADL (in progress)
  - IM is the core mathematical formalism
- Extensibility: Subnet library for components
  - Specialisation, design refinement
- Aspect-oriented modelling of redundancy
  - Separation of design decisions related to fault tolerance
  - Weaving of design and analysis models