Formal validation of TASTE designs with the BIP framework

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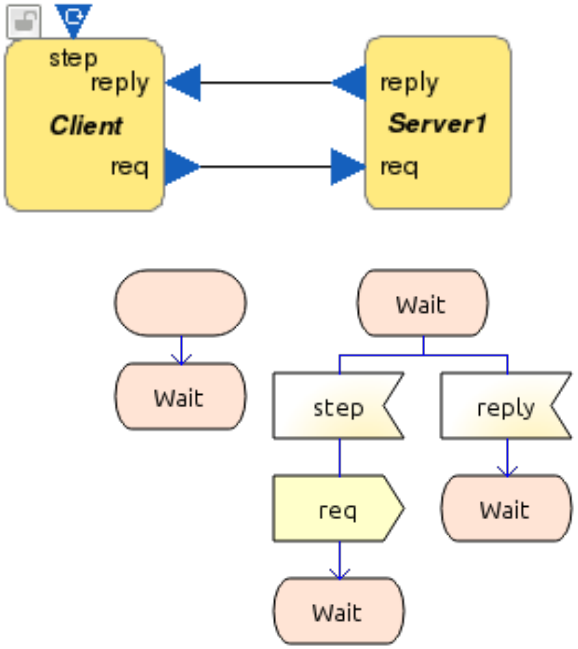
Shortcomings of system design in practice

- Requirements in natural language, therefore ambiguous or incomplete
- Large, reactive, component-based designs in graphical semi-formal languages
  → ambiguous or unspecified operational semantics
  → erroneous implementations due to different possible interpretations
- A posteriori validation of the implementation
  → testing is incomplete (e.g., autonomous systems operating in unknown environment)
- Increased development effort, costs, resources

ESROCOS project: TASTE language and tool

- Targets the model-based development of heterogeneous, reactive, discrete embedded systems
- The language is based on several modeling formalisms (ASN.1, AADL , SDL, Simulink, etc.) or programming languages (C, Ada)
- A TASTE design consists of:
  - Data view
  - Hierarchical interface views (software architecture and behavior)
  - Deployment view
  - Concurrency view computed from the above
- The tool-chain allows for:
  - Well-formedness and typing analysis of a design wrt the used modeling formalisms
  - Real-time scheduling analysis (e.g., Cheddar)
  - Code generation and deployment (in C/C++, Ada) wrt an execution platform
  - Simulation, debugging and testing



Rigourous system design

- High-level formal modeling frameworks encompassing heterogeneous computation models
  $\rightarrow$ model- and component-based
- Scalable validation and verification methods and tools
- Performance analysis and resource optimization
- Correct-by-construction transformations towards implementations (code)

The BIP framework offers support for rigourous system design.

Outline

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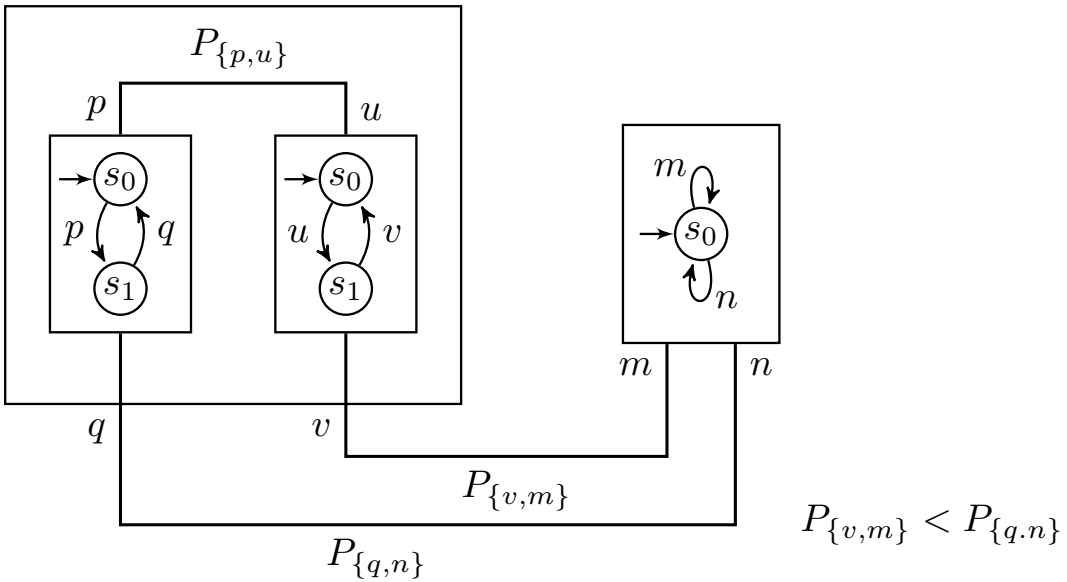
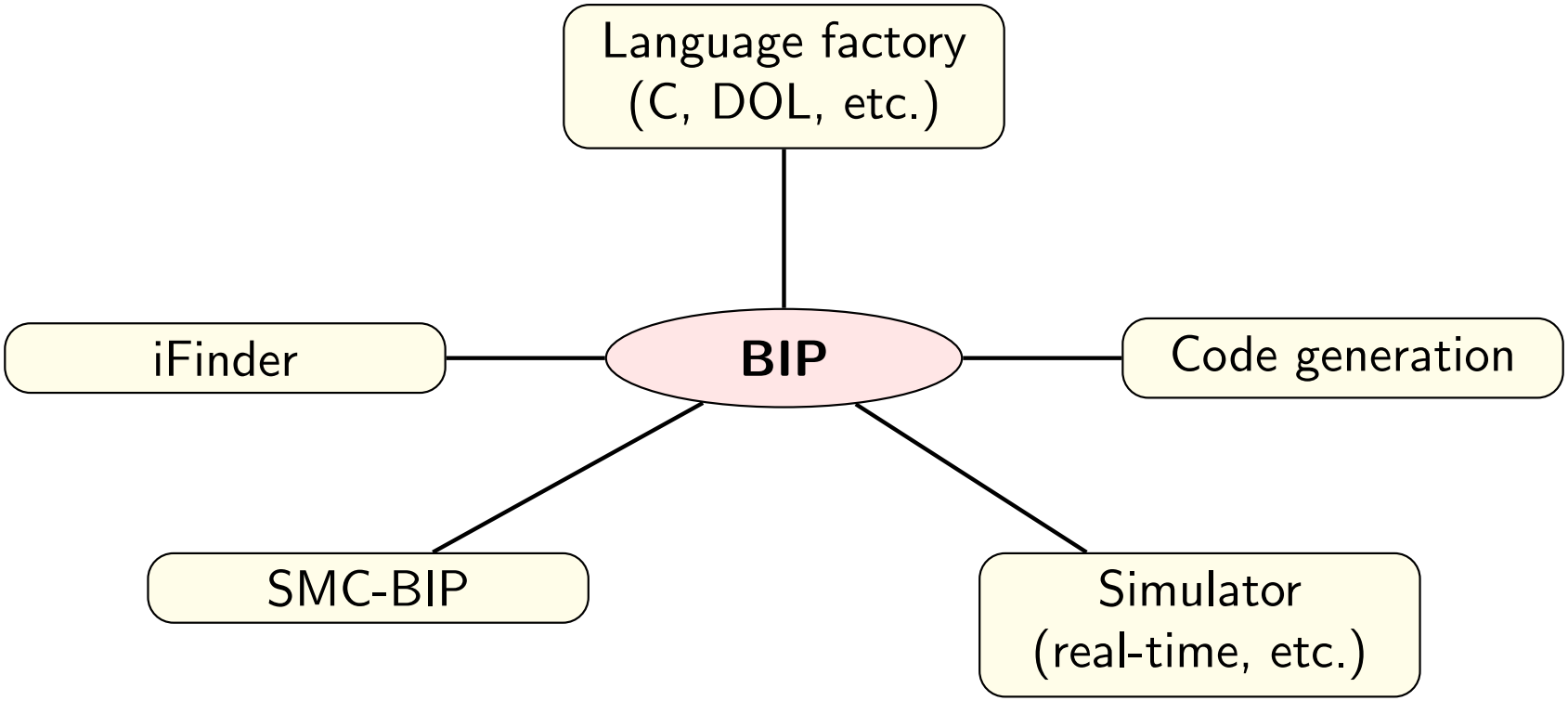
The BIP framework

- Component-based design:
  - Behavior: atomic functional units (automata, code, etc.)
  - Interactions: cooperation and coordination between actions of behavior
  - Prorities: scheduling between interactions



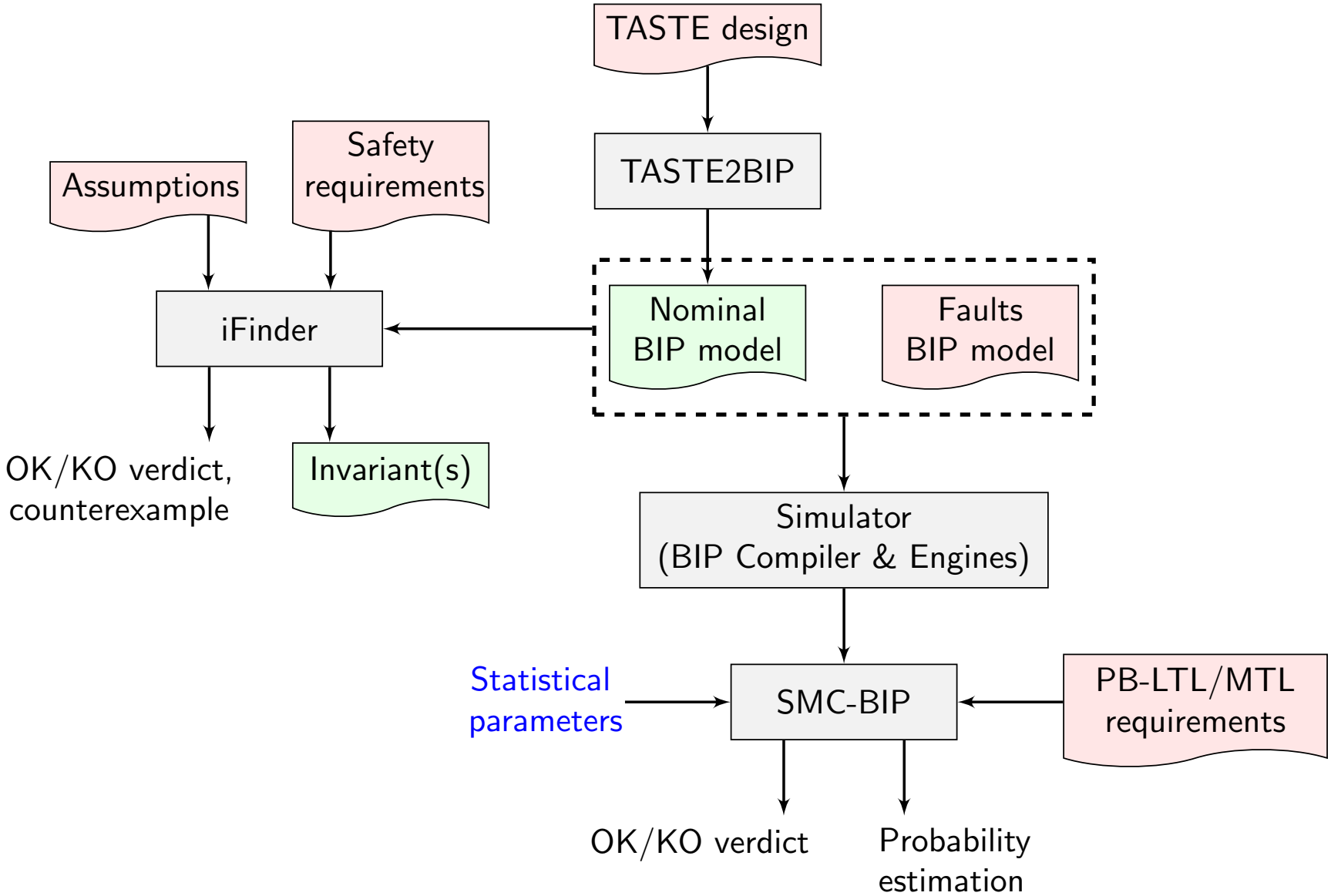
- Model-based design:
  - Heterogeneity: execution, interaction, abstraction, etc.
  - Minimal set of constructs and principles
  - Automated validation, verification and performance analysis
  - Automated code generation for given platforms

The BIP tools



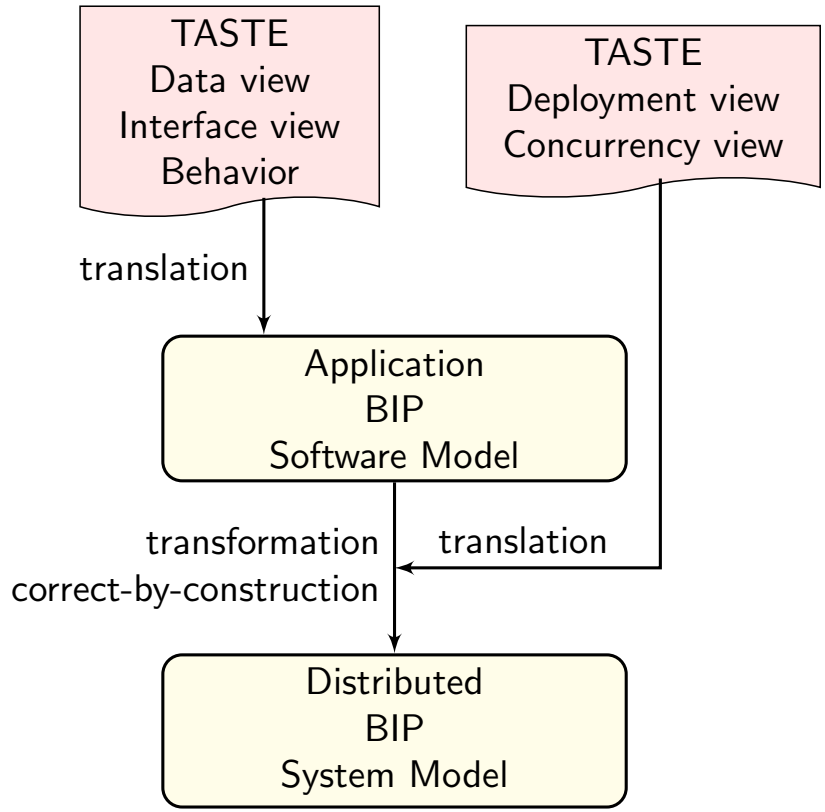
Outline

The formal validation workflow with BIP



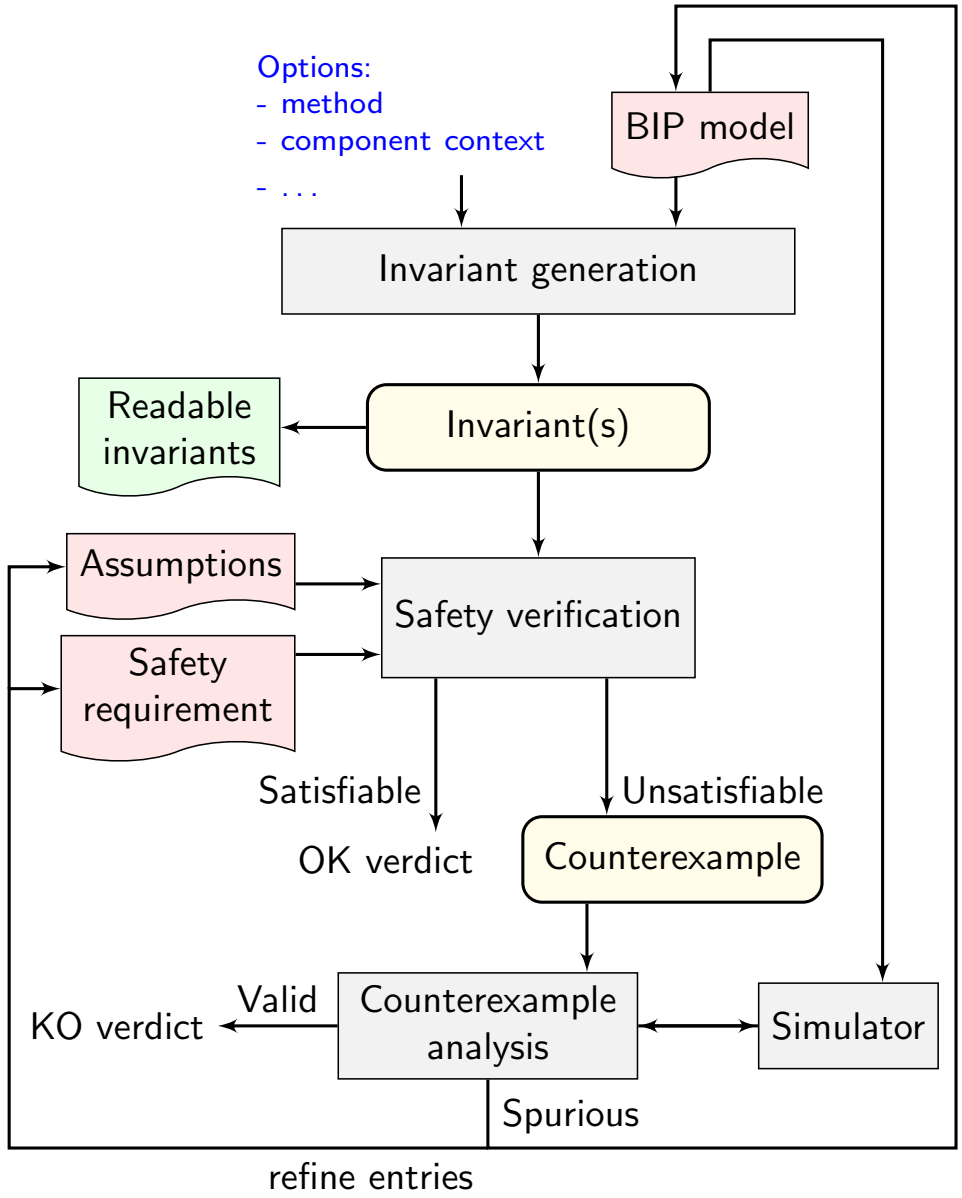
TASTE2BIP model translator

- New tool generating BIP models from full TASTE designs
- Tool input: data / interface / deployment / concurrency views, SDL state machines
- Tool output: nominal BIP model, possibly including FDIR components
- Principles of translation:
  - Data view, interface view and SDL state machines give a timed automata network
  - Deployment and concurrency views refine the timed automata network into a HW/SW BIP model
  - Enforcement of timing constraints, e.g., period, wcet



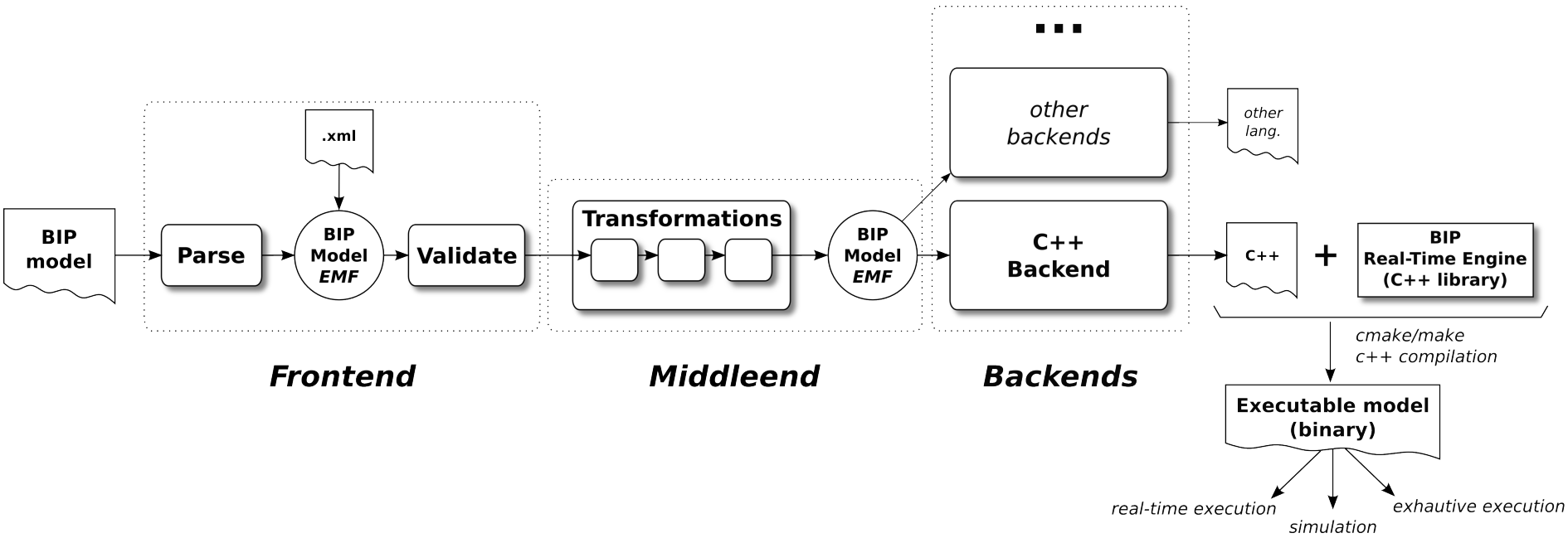
iFinder verification tool

- Check safety properties of a system by separate analysis of components and their composition – compositional invariant-based method
  - component invariants
  - interaction invariants
  - history clocks constraints
- Current black-box tool to be redesigned
- New tool features:
  - User-given invariants for property verification (assumptions)
  - Modularity of invariant computation and generation
  - Interaction with different SAT solvers (e.g., Yices)



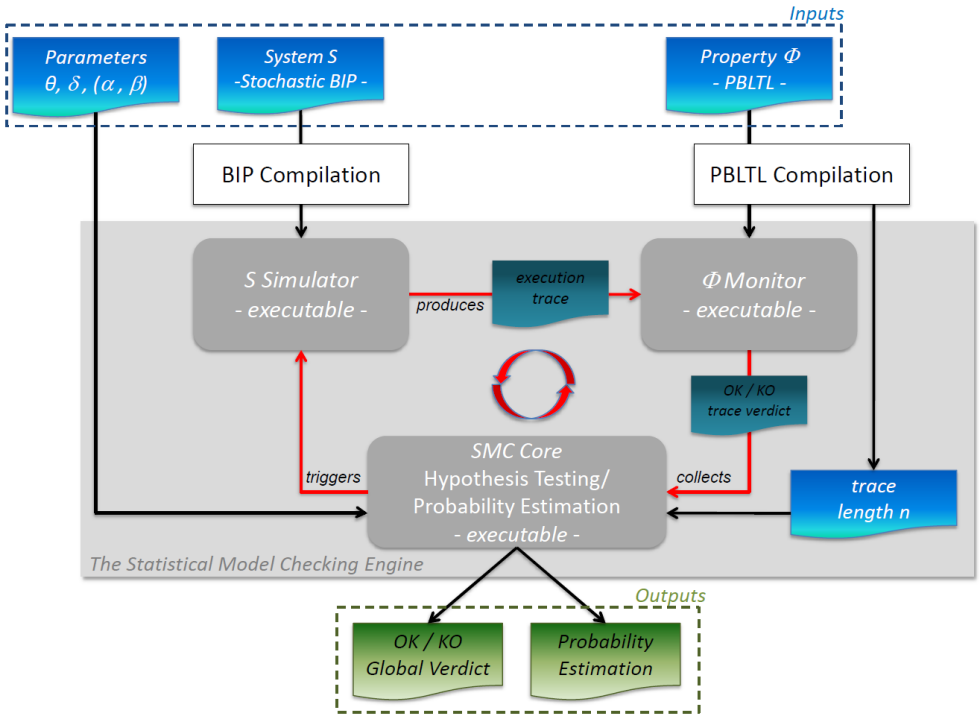
BIP compiler and engines

- (C++) Code generation and simulation engines
- Extensions:
  - Timing constraints: real-time executions
  - Stochastic transitions: probability to fire a transition depending on a user-given probability law λ
  - Faults model: identification of faults, timed fault, probability of faults to occur, etc.



SMC-BIP analysis module

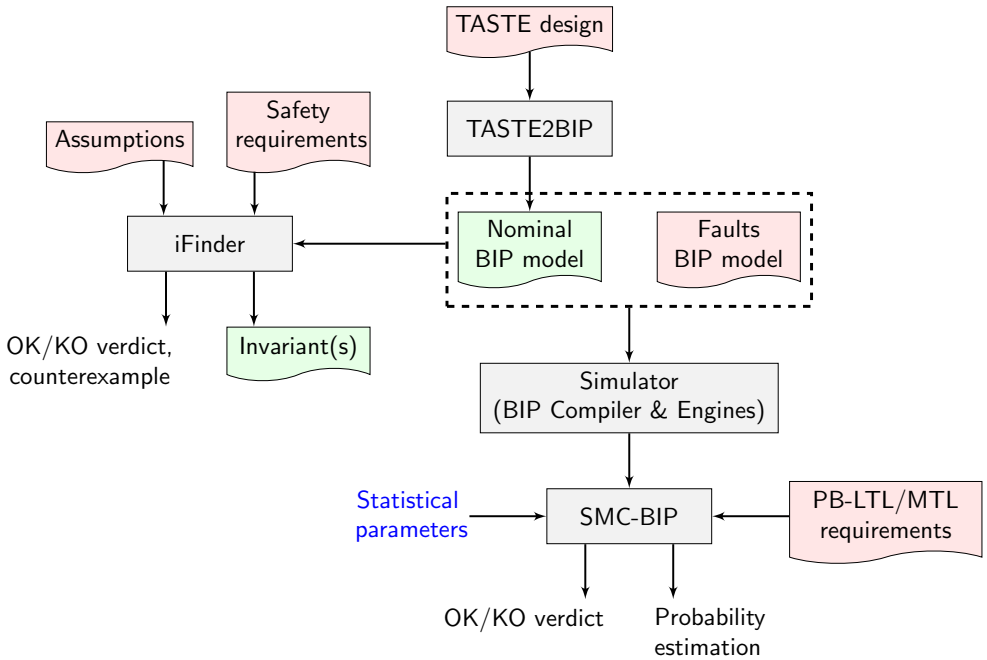
- Statistical model-checking of a stochastic system S and a requirement φ:
  - Qualitative question: $S \models_{P \geq \theta} \varphi$
    $\rightarrow$ *yes* or *no* answer with a *confidence bound*
  - Quantitative question: $P(S \models \varphi)$
    $\rightarrow$ the estimation can be bounded, susceptible to mistakes
- Extensions:
  - Real-time, stochastic behavior
  - Richer property logic for formalizing requirements, e.g., MTL



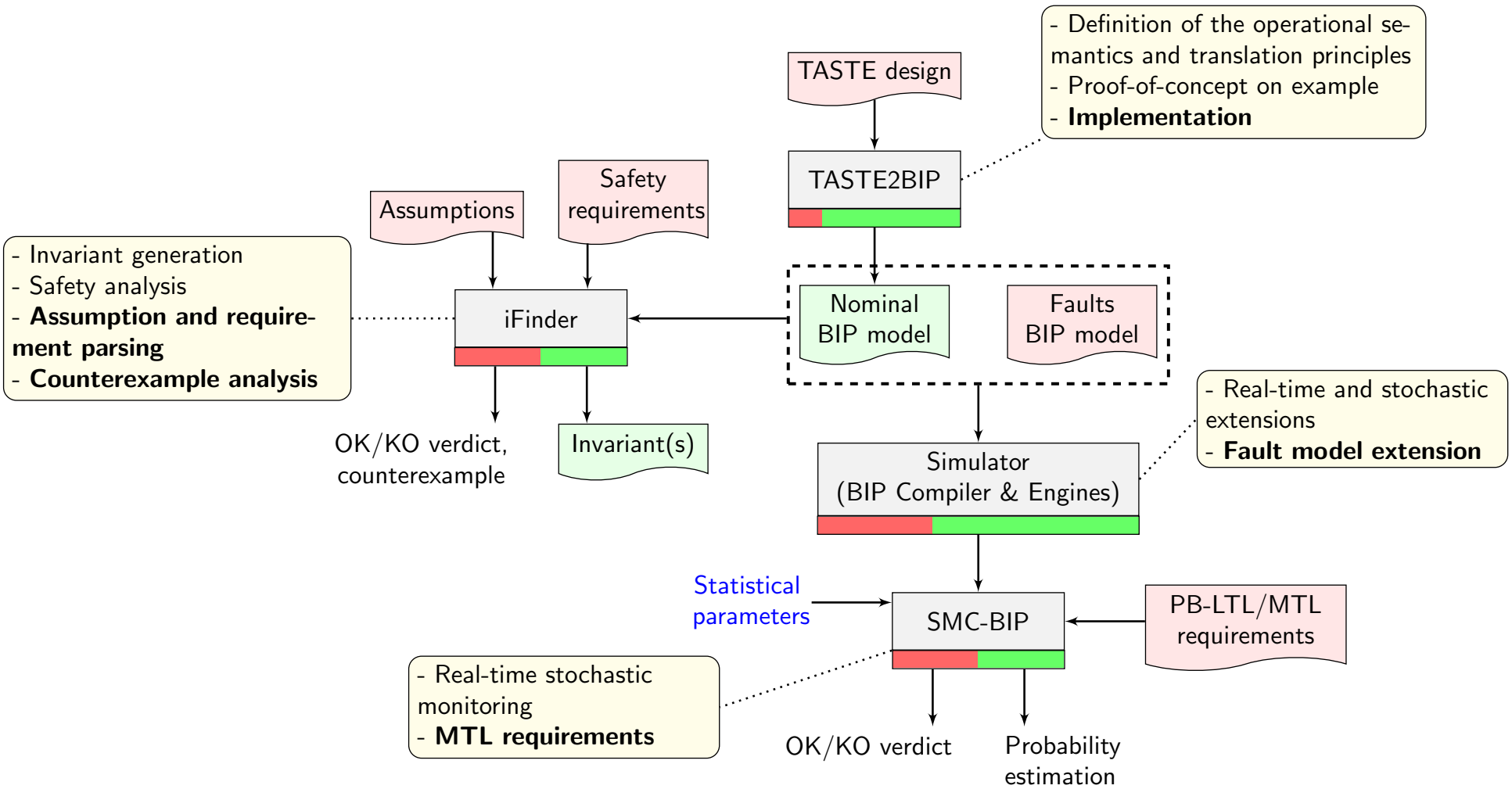
Outline

Contribution to ESROCOS

- BIP: a framework formalizing robotic systems designed in TASTE
- TASTE2BIP: an automated tool to generate BIP models from TASTE
- A set of tools to verify and validate TASTE designs via BIP
  - BIP compiler for C++ code generation
  - BIP engines for simulation
  - iFinder for safety requirements verification
  - SMC-BIP for statistical model-checking of performance requirements

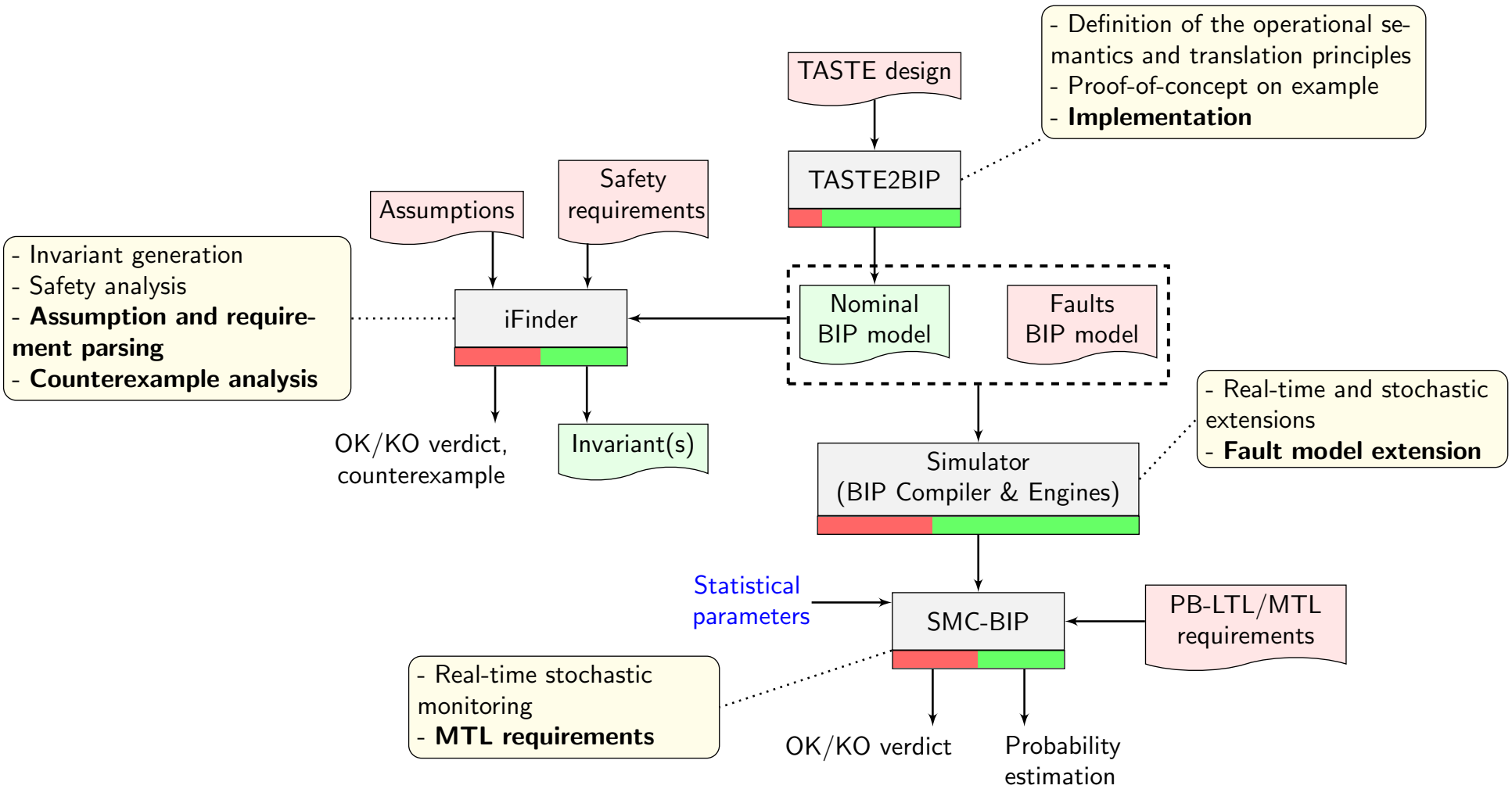


Ongoing work



Thank you!
Questions?

Ongoing work



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