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Identifying and Addressing Uncertainty in Architecture-Level Software Reliability Modeling

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Software Architecture-level Reliability Modeling

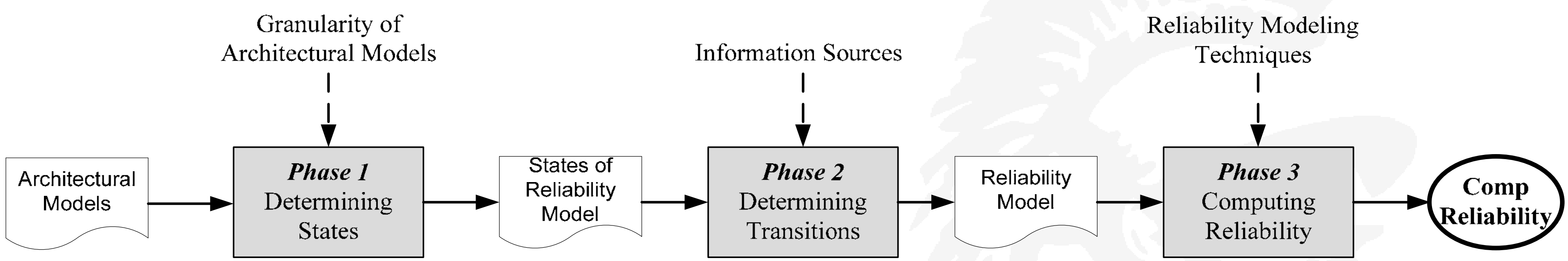
- Assessing reliability of software early is desirable
  - Fixing major problems discovered late in development is too costly
- Doing so at the level of software architecture would be preferable
  - Architecture is a linchpin of software system development
  - A set of abstractions, notations, techniques, and tools for developing large, complex software-intensive systems
- Challenge: Uncertainty
  - e.g., How do you know the runtime behavior of the system *before* it is implemented?
  - Needed information includes
    - Operational profile
    - Failure characteristics

Sources of Uncertainty

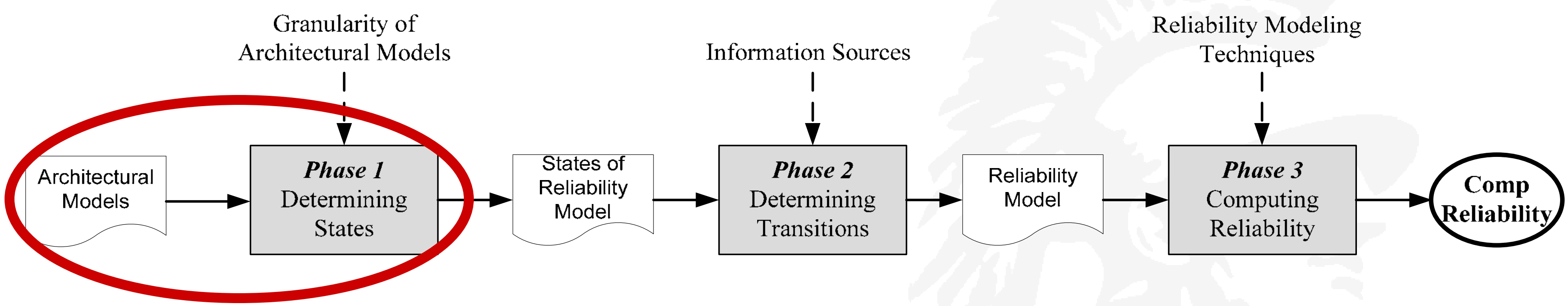
- Components' reliabilities
  - Existing approaches assume these are known
- Development scenario
  - Develop a system from scratch vs. from existing components
- Needed information about a system
  - Domain expertise
  - Software system requirements
  - Simulated architectural model
  - Functionally similar system
- Granularity of architectural models
  - Coarse-gained vs. detailed models of components
- Reliability modeling techniques
  - Different techniques are effective in different situations

Architecture-Level Reliability Prediction Framework

- Specifically targeted at the level of individual components

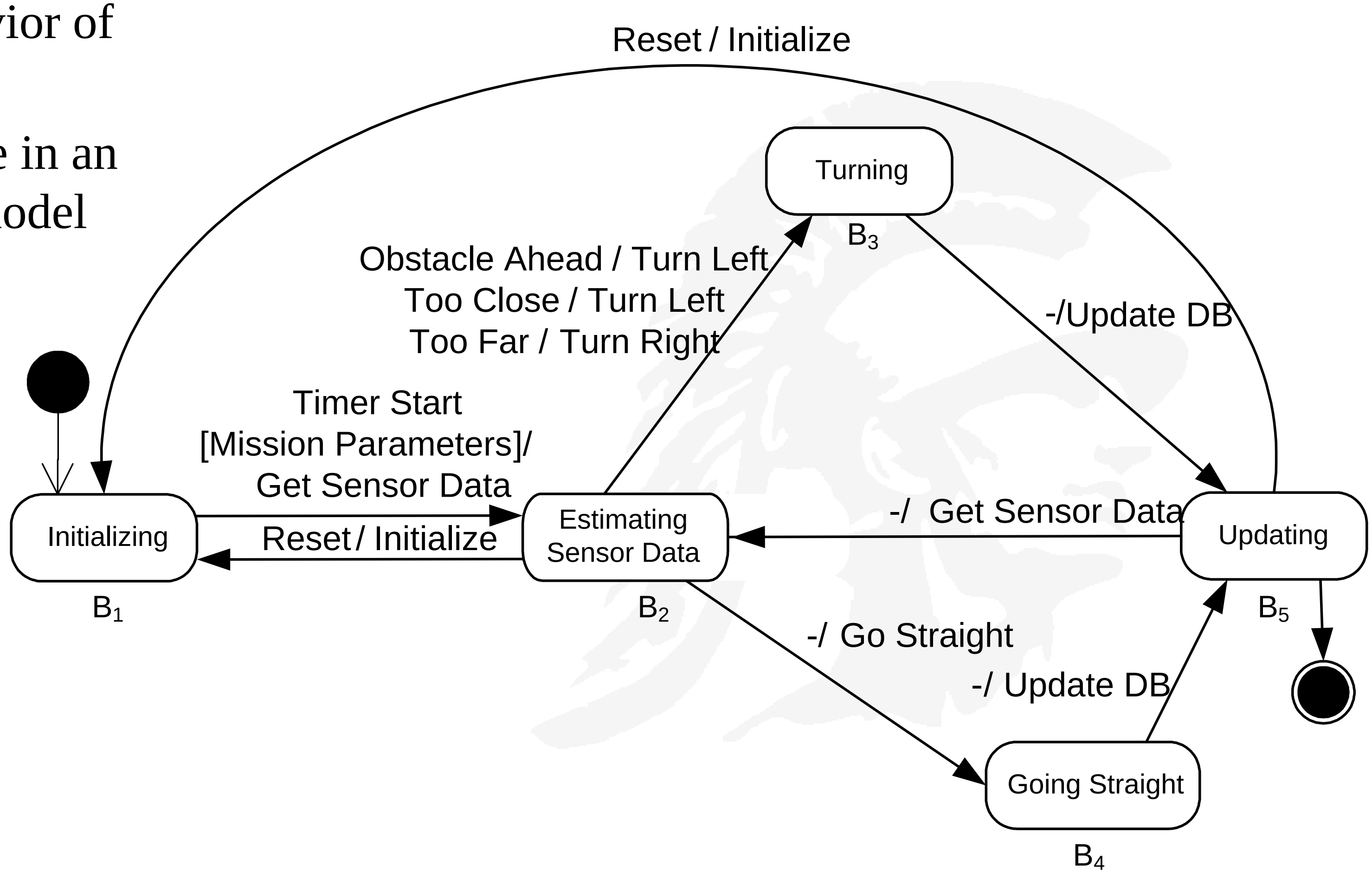


Architecture-Level Reliability Prediction Framework



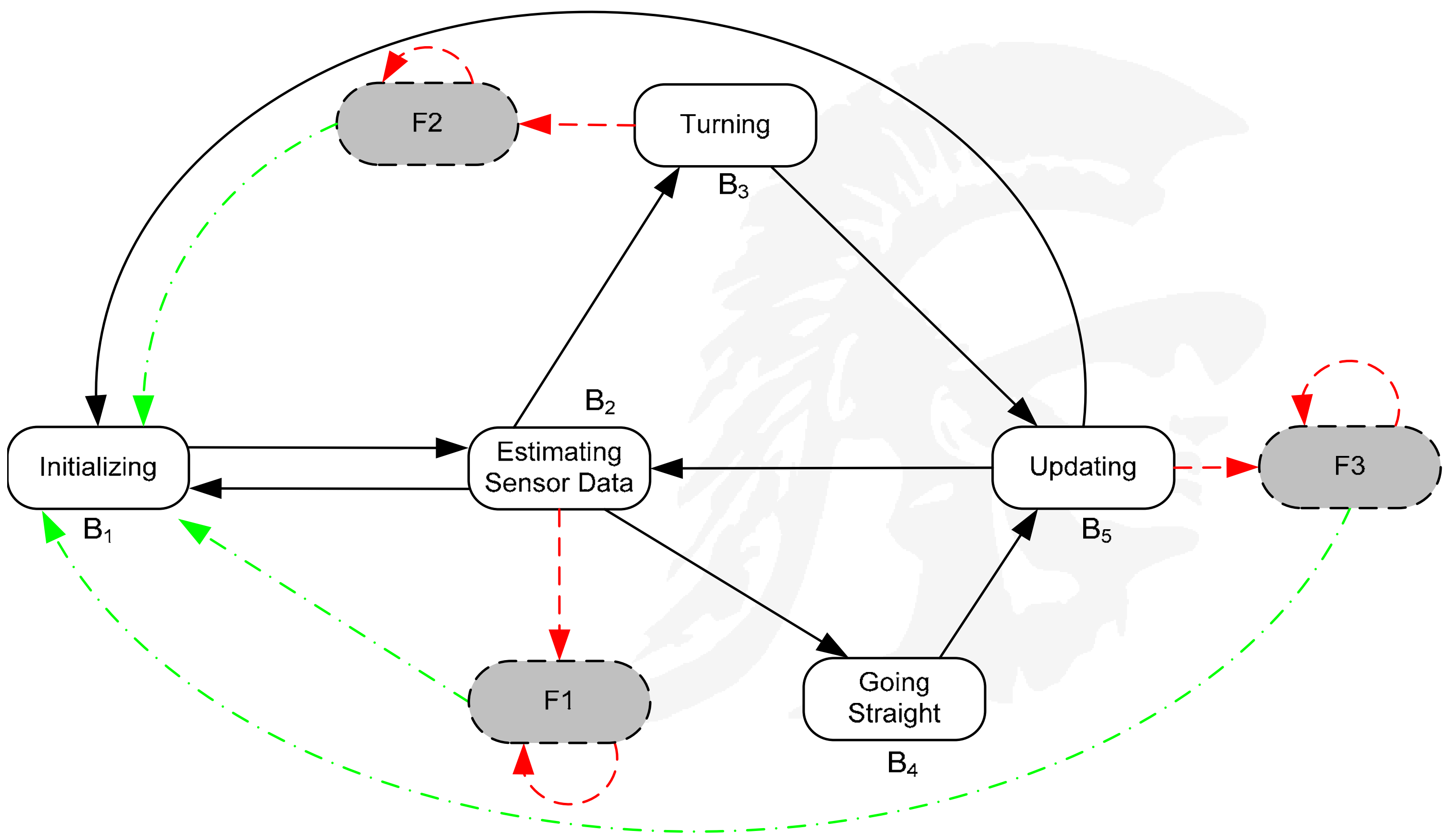
Framework in Action

- Goal: Leverage dynamic behavior of a component
- Often available in an architectural model

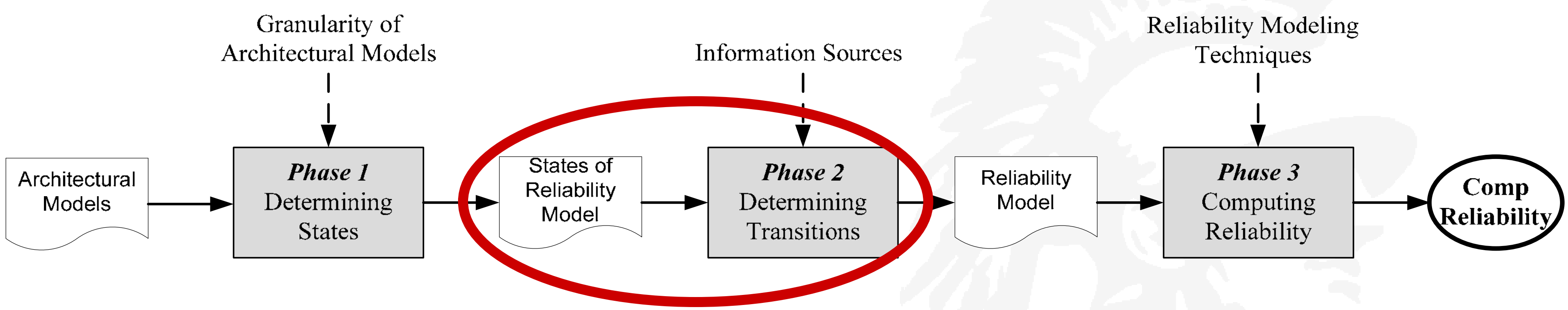


Framework in Action

- And build a stochastic reliability model



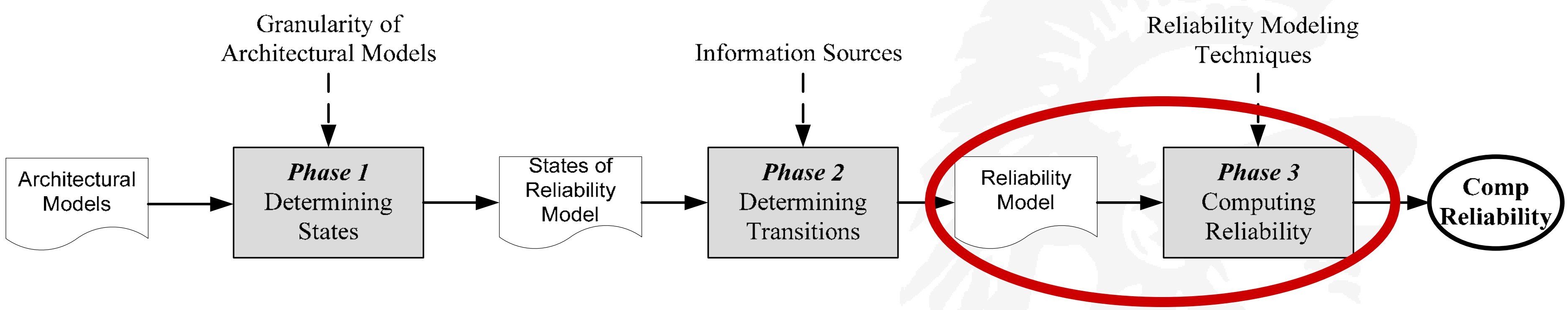
Architecture-Level Reliability Prediction Framework



Leveraging the Information Sources

- Little or no information
  - Explore the design space
- Domain knowledge
  - Use operational profiles suggested by expert(s)
  - Beware of expert inaccuracies (or worse)!
- Requirements documents
  - Contain typical use cases of a component
- Simulation of architectural models
  - Capable of handling complex state spaces
- Functionally similar component
  - Runtime behavior *might* be similar to the component of interest
  - Similarities may be misleading

Architecture-Level Reliability Prediction Framework



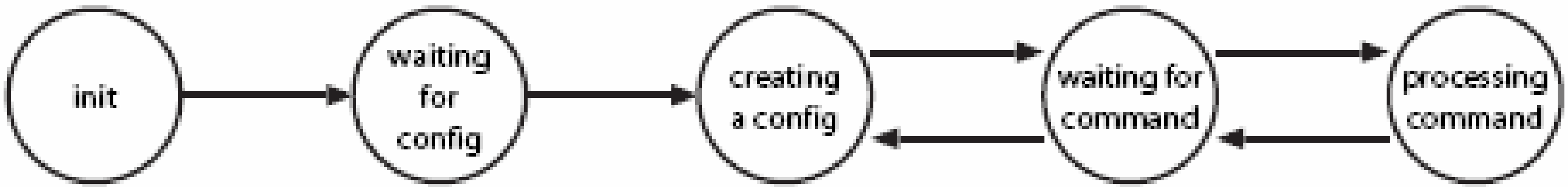
Techniques for Modeling Reliability

- **Discrete-Time Markov Chains**
- **Hidden Markov Models**
  - **Input:** Operational and failure profile from above sources
    Process: Standard approaches to solve the model
    Output: Transition probabilities
- **Bayesian Networks**
  - We have been exploring them for system-level reliability prediction
- …

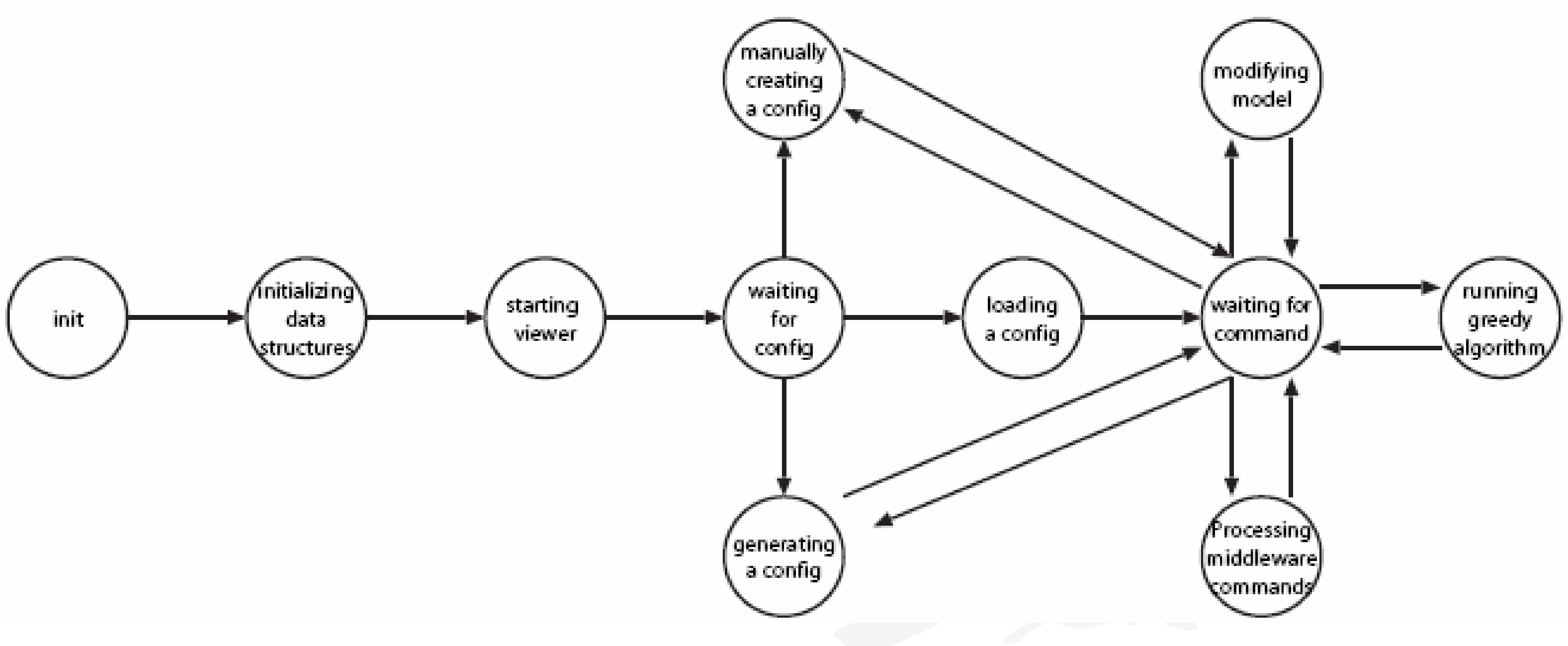
Evaluation Strategy

- Study the framework in many representative scenarios
- Establish the framework's predictive power vs. implementation-level reliability estimation techniques
- Evaluate the framework's sensitivity to changes in different parameters
  - Architectural model and its granularity
  - Source of operational profile and failure characteristics
  - Reliability modeling technique

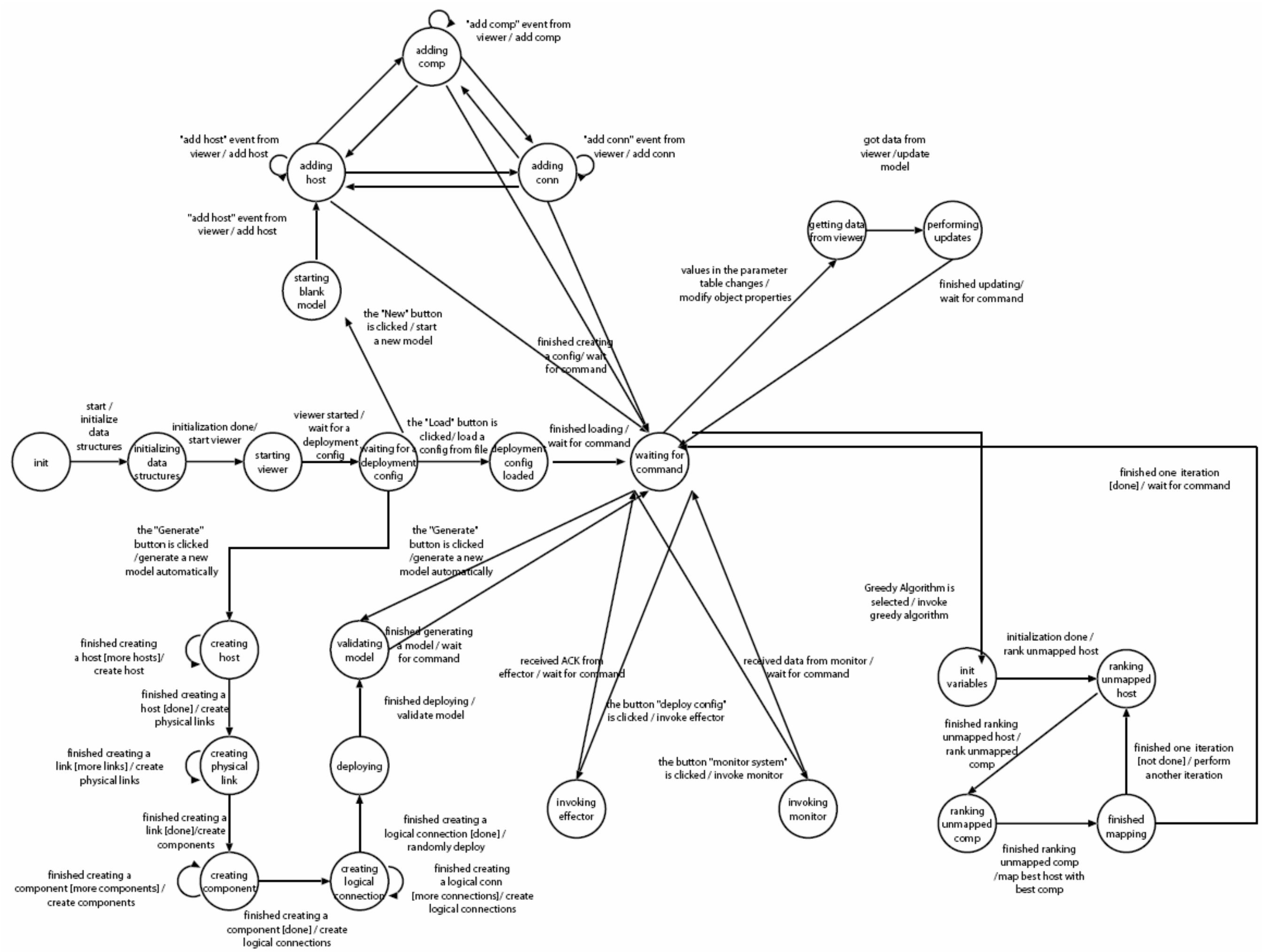
Example Software Component at Multiple Granularities



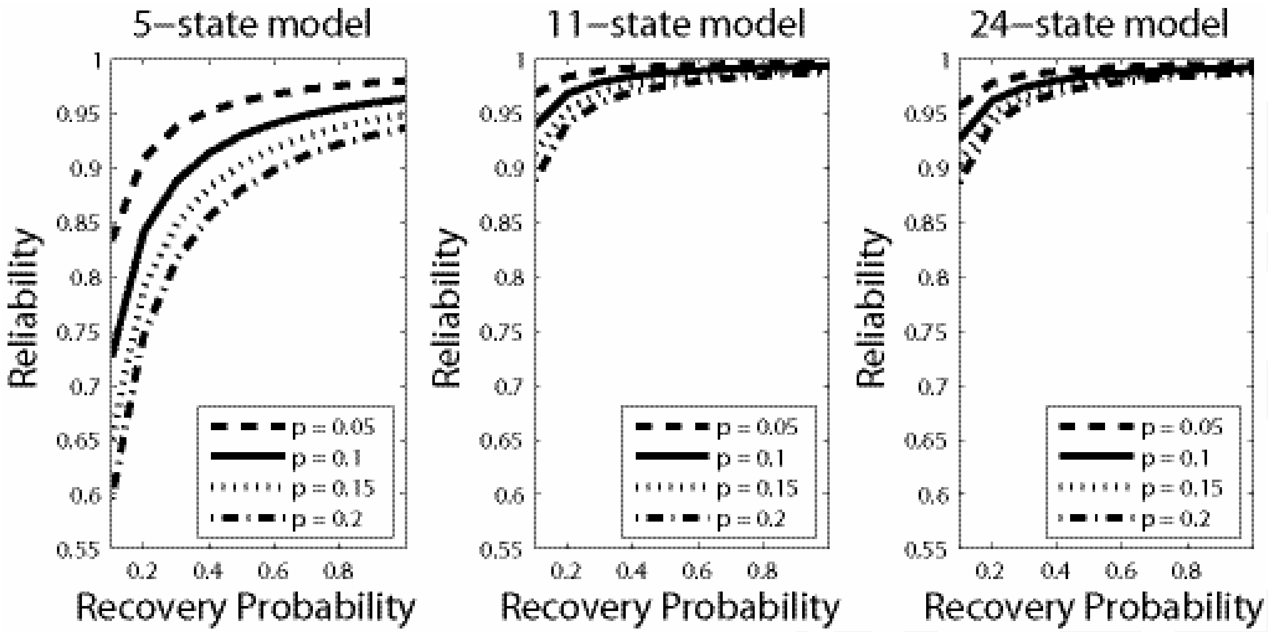
Example Software Component at Multiple Granularities



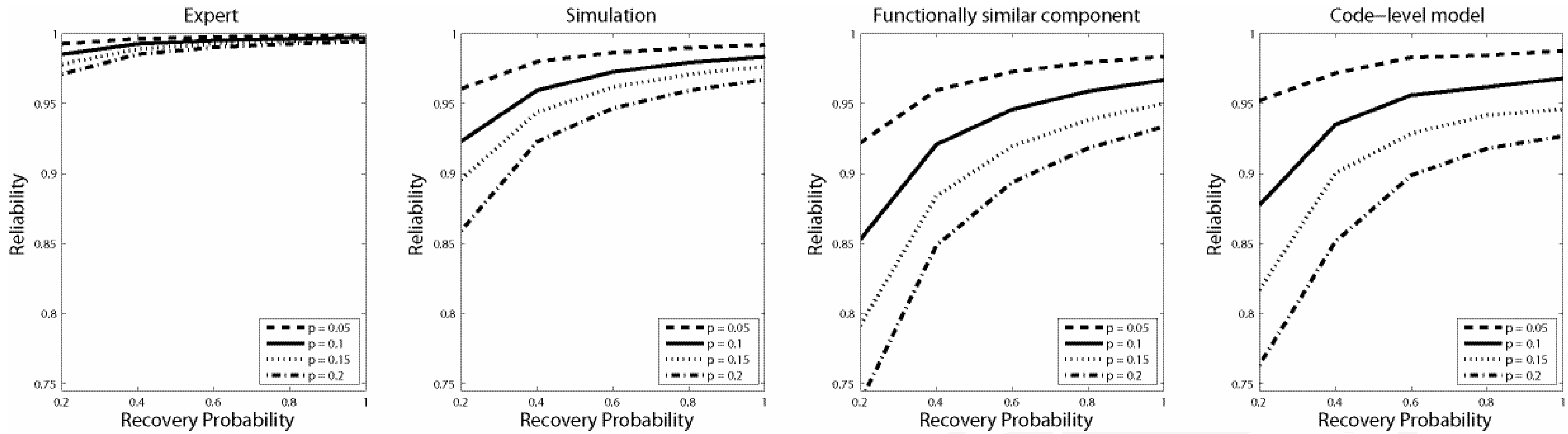
Example Software Component at Multiple Granularities



Sensitivity to Architectural Model Granularity – DeSi

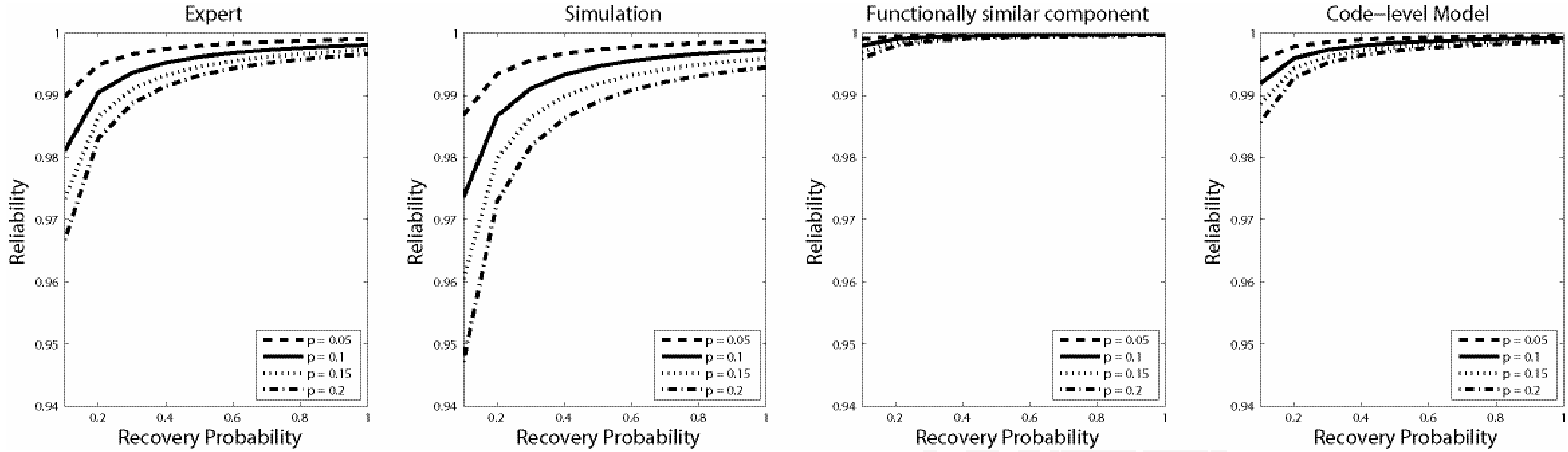


Sensitivity to Failure Probabilities – SCRover



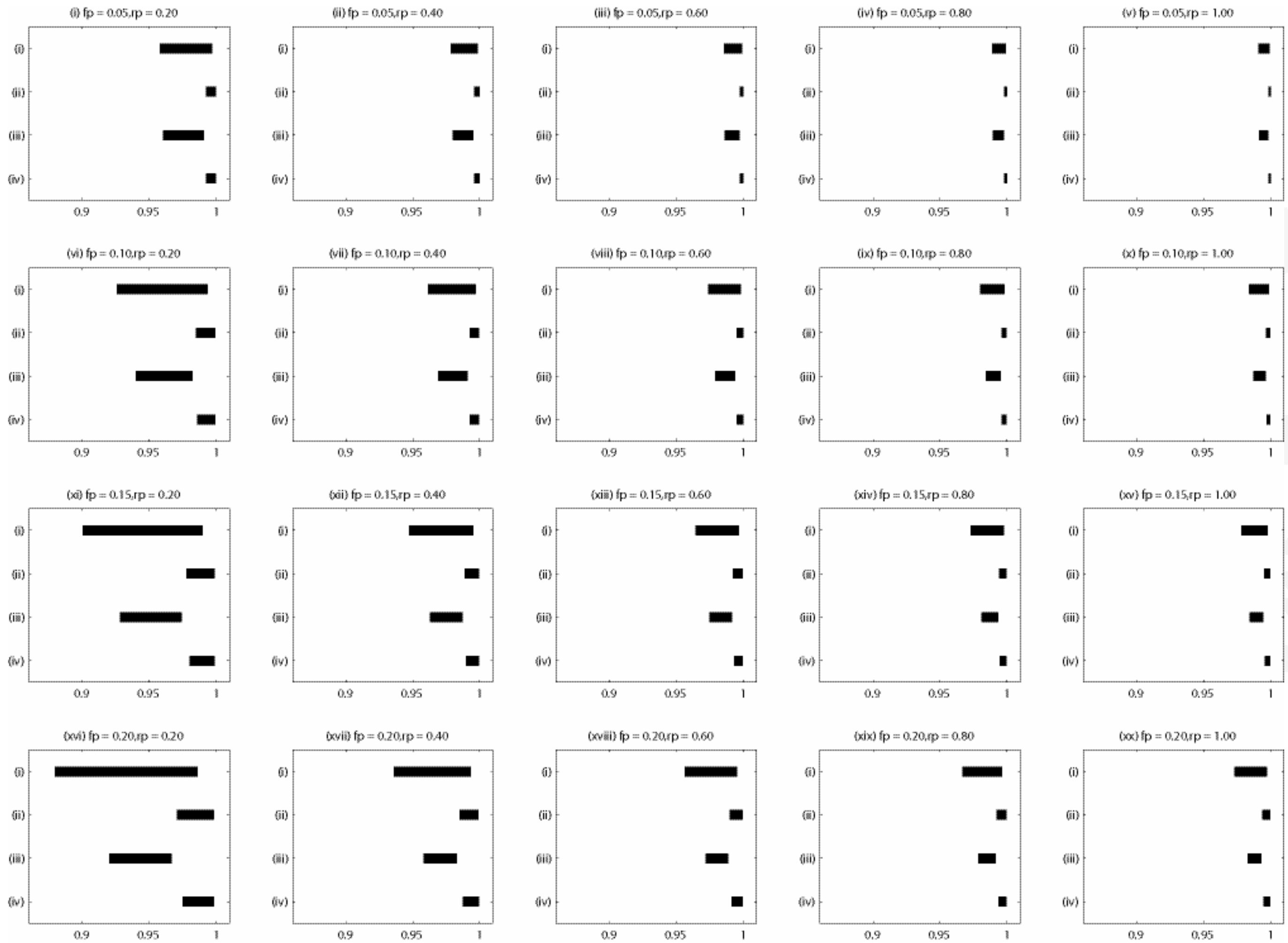
- **Only one defect is present (*Turn* defect)**
- **Each curve corresponds to different failure probabilities**
- **Vary recovery probabilities from 0.2 to 1 (at 0.2 intervals)**
- **Expert can be wrong!**

Sensitivity to Failure Probabilities – DeSi



- **Considering *Missing Model Validation Rules* defect**
- **Again, each curve corresponds to different failure probabilities**
- **Vary recovery probabilities from 0.2 to 1 (at 0.2 intervals)**
- **Expert was relatively close, but functionally similar component was not (close or similar)!**
- **Simulated model was imprecise**

Sensitivity to Operational Profile Estimation – DeSi



Conclusions and Current Directions

- One focus to date has been component reliability prediction at the architectural level
  - Uncertainty is a major challenge
- We explored different *information sources* available at the architectural level
- Current Directions
  - Predicting system reliability at the architectural level
    - Scalability – how to model a system with many components in a scalable way?
  - Firmware modeling
    - Operating system, device drivers, middleware, etc. also impact a software system's reliability