Reliable
Micro and Nano System Design
Using Multi Level Process Verification

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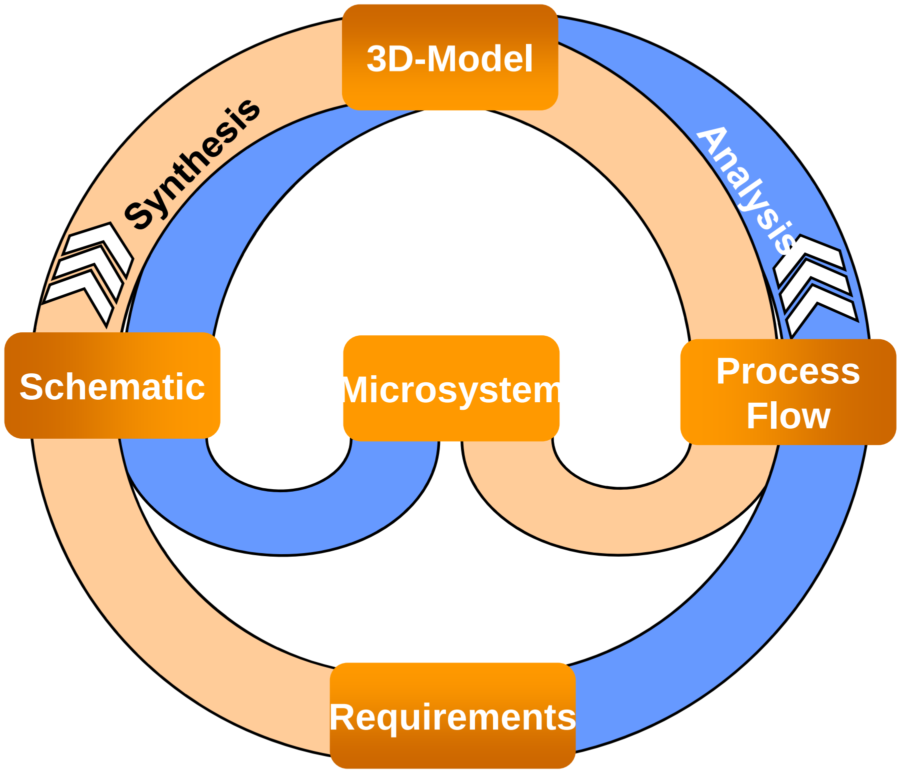
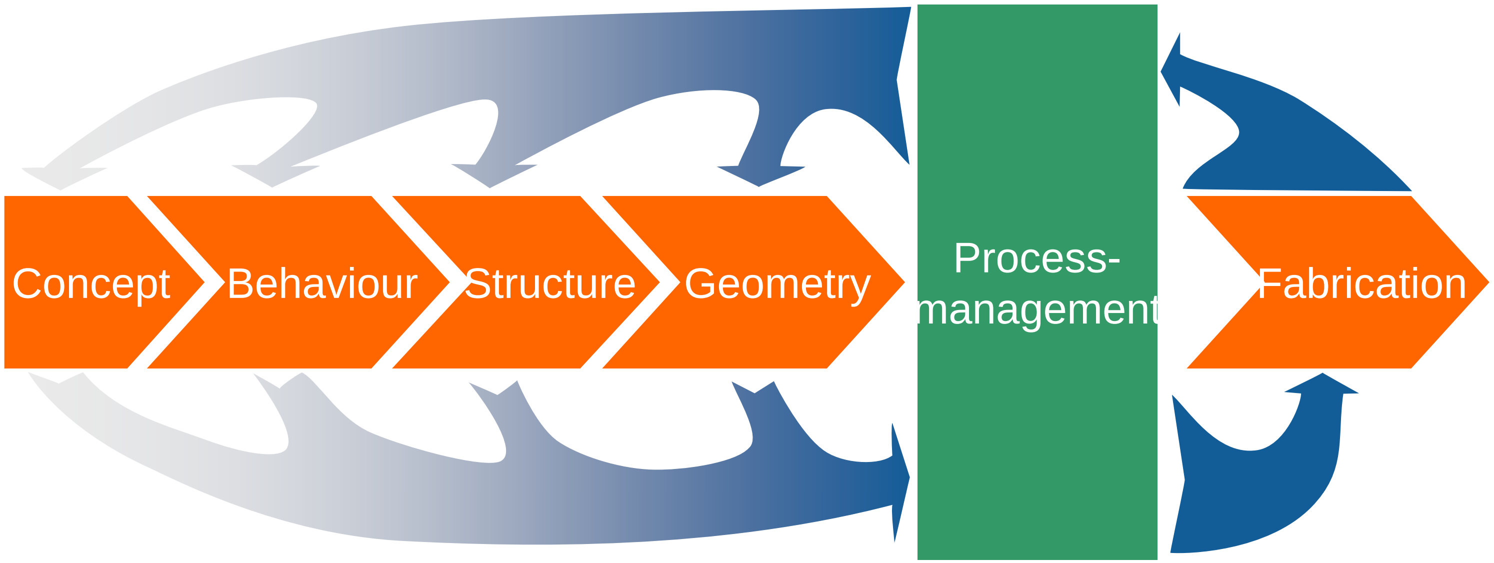
Outline

- Processes and Reliability
- Process Design Flow
- Levels of Process Verification
- Process Verification Environment
- Conclusions

- **Generic design flow for micro and nano systems**
  - Top-down behavioral design
    - Synthesizing a schematic representation and a 3d model of the intended micro/nano structure from a given set of requirements defining
      - *the intended functionality*
      - *all constraints from the intended application environment*
  - Bottom-up fabrication-oriented design
    - Creating a process flow matching the 3d model and assuring
      - *manufacturability*
      - *compliance with the intended fab machinery*
      - *optimum yield*
  - Top-down and bottom-up flows are strongly interwoven

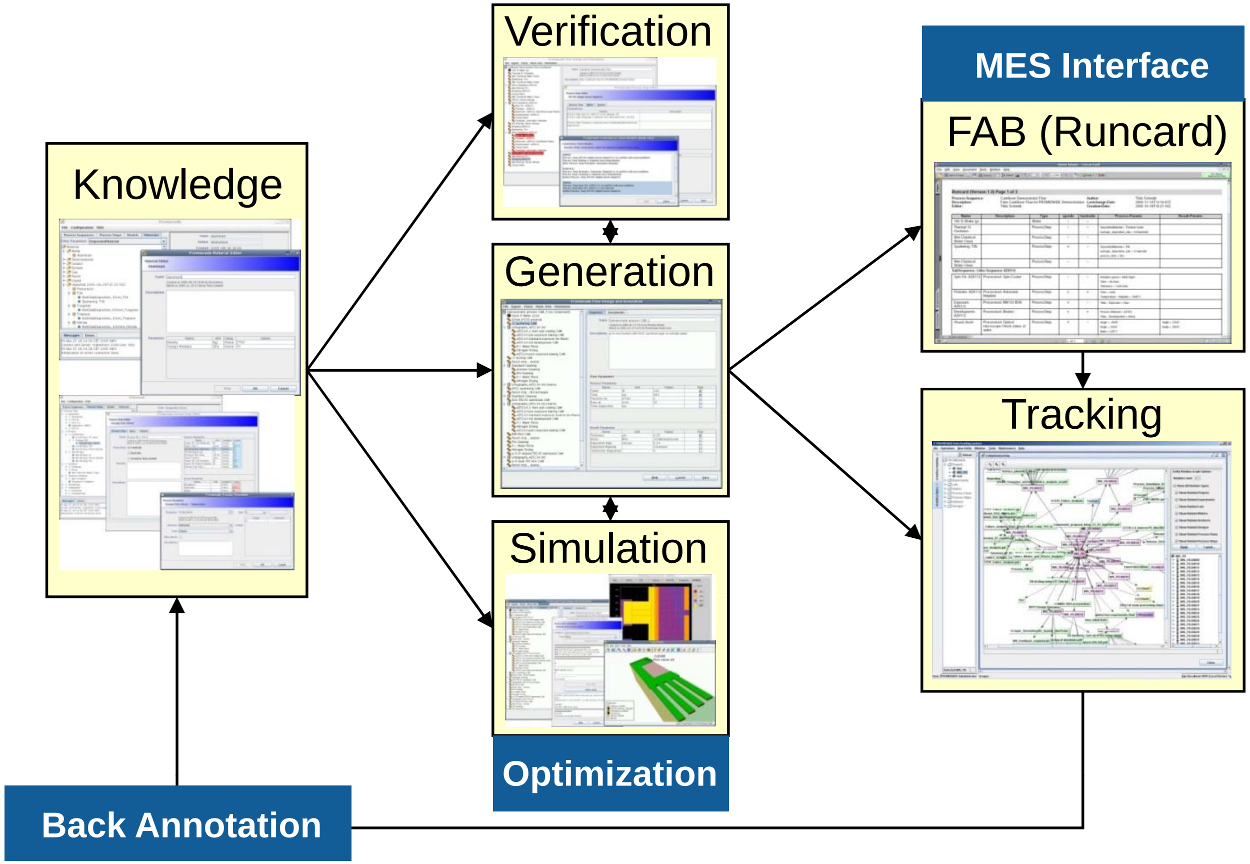


- **Design flows and reliability**
  - In micro/nano system design all design stages are strongly influenced by process knowledge
  - Reliable system design requires reliable process design!
    - on all levels of abstraction
    - in a continuously increasing level of process definition detail
    - with acceptable additional effort (design time) for process flow generation and verification



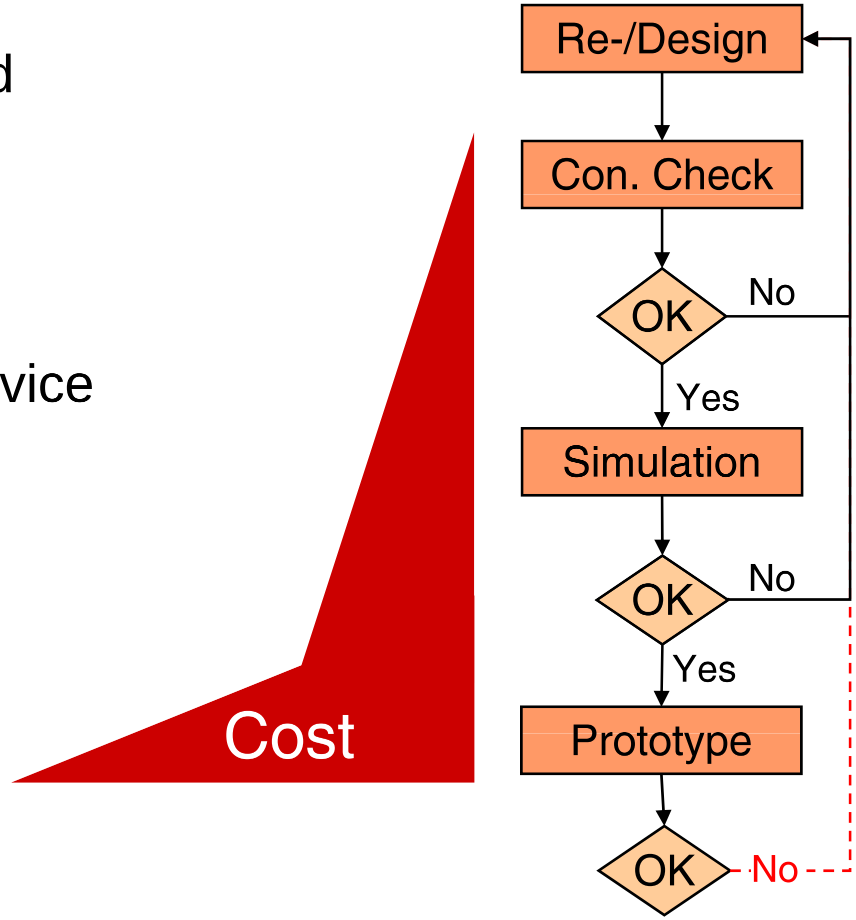
Process Design Flow

- **Reliable process management makes use of**
  - a comprehensive process knowledge base
  - process optimization with multi-level verification capabilities
  - intelligent interfacing of process design and fab environment



Stages of Process Flow Verification

- **Consistency checking**
  - to ensure manufacturability and feasibility
- **Process simulation**
  - to allows the assessment of device structures and functionality
- **Experimental verification**
  - to validate process flows in production environment



Stages of Process Verification

- **LEVEL 1: Consistency Checking**
  - Requirements
    - A knowledge-base of process steps, materials, process step parameters, effects, etc.
    - A process flow editor allowing the construction of process flows and configuration of parameters from process related objects in the knowledge base
  - Verification step
    - Checking compatibility rules associated with the process related objects used to construct the process flow
  - Verification result
    - Assessment of the principle viability of the assembled process flow

Qualitative process flow viability assessment

Stages of Process Verification

- **LEVEL 1: Consistency Checking**
  - Re
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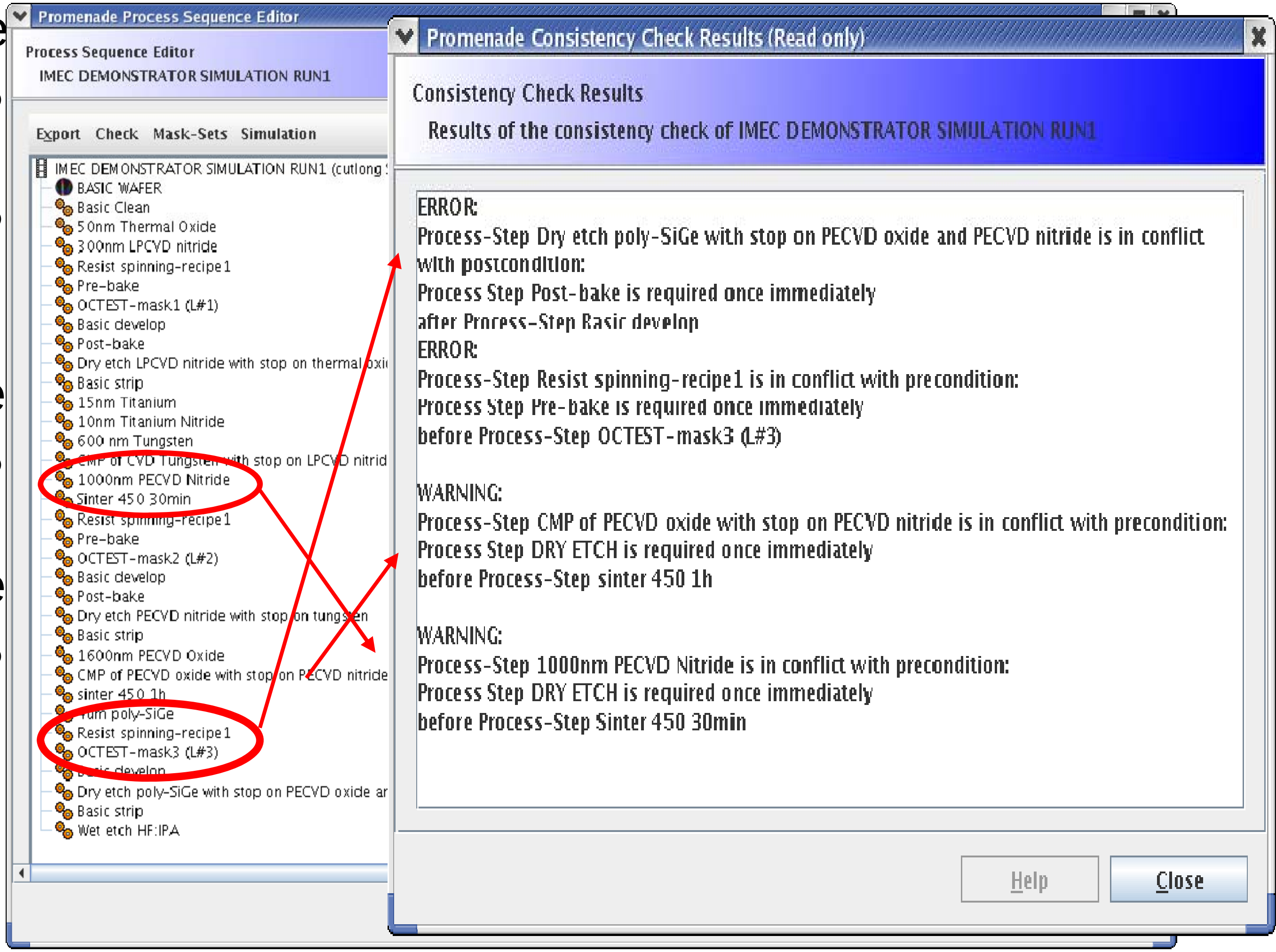
    - flow



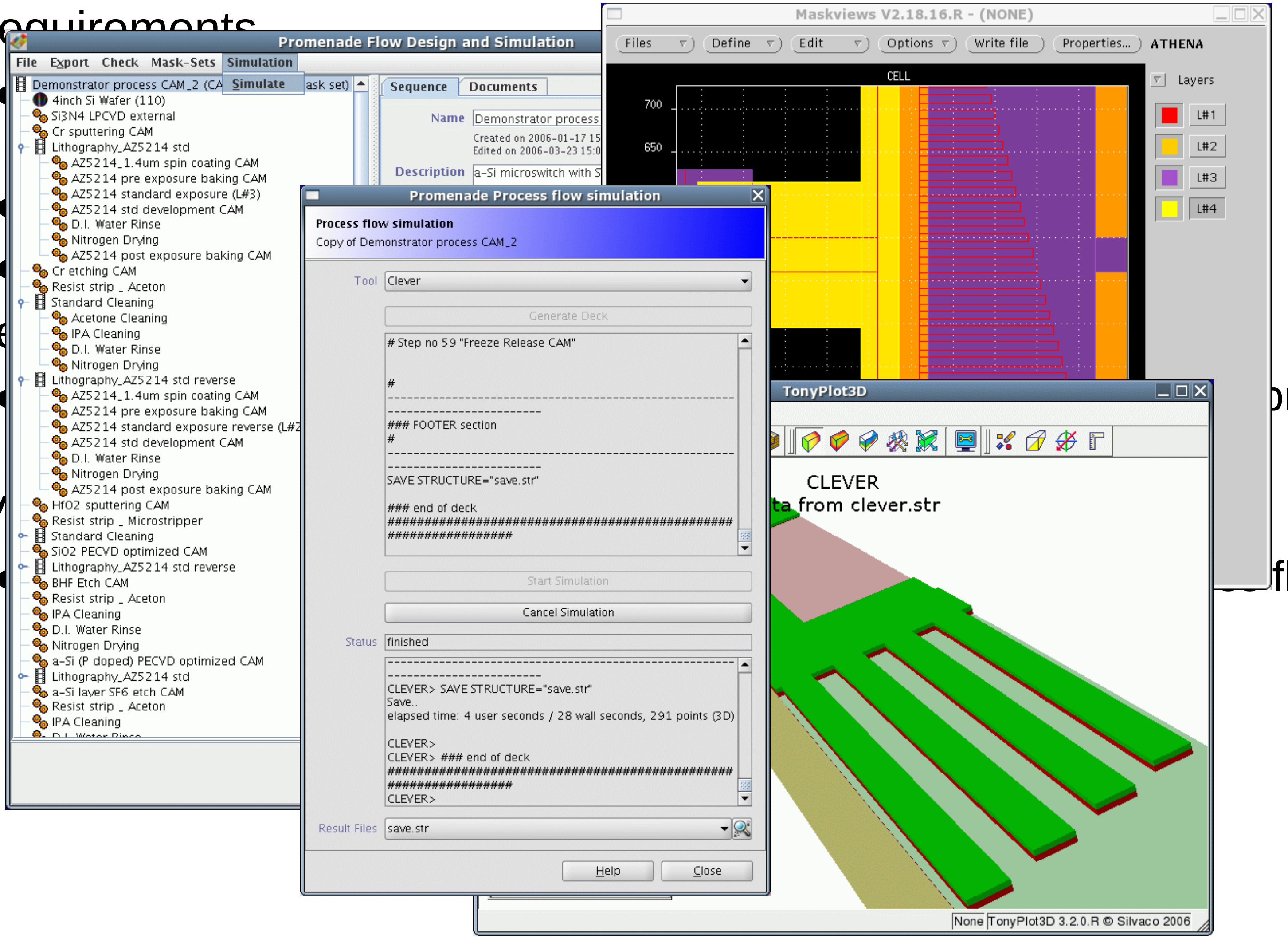
Stages of Process Verification

- **LEVEL 2: Process simulation**
  - Requirements
    - A knowledge-base containing simulation models assigned to all process-related entities, esp. process steps
    - An interface to process step and device simulators
    - A simulation setup and driver engine
  - Verification step
    - Performing complete process flow simulations by selecting appropriate simulations models and setting up sequences of simulator calls
  - Verification result
    - Simulated 3d-visualization of the effects of executing the process flow

Quantitative process flow viability assessment

Stages of Process Verification

- **LEVEL 2: Process simulation**
  - Requirements
  - Ve
  - V



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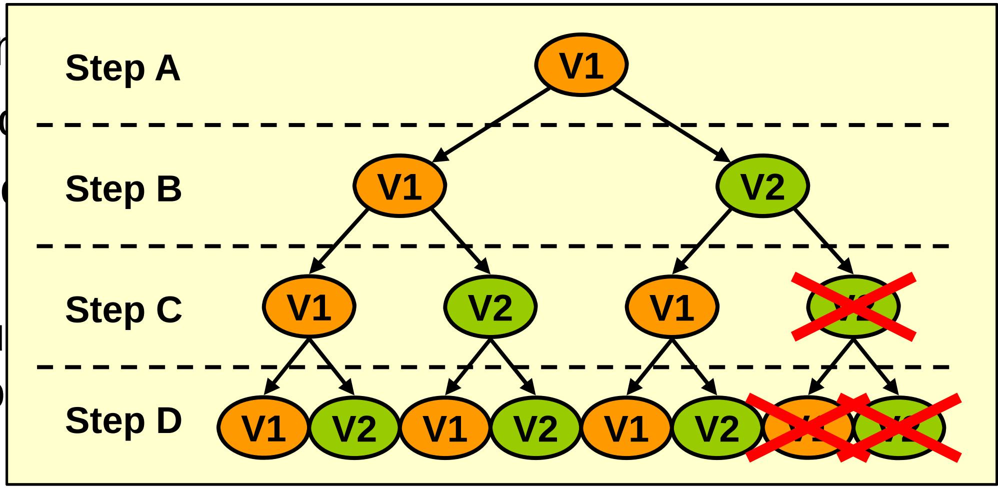
flow

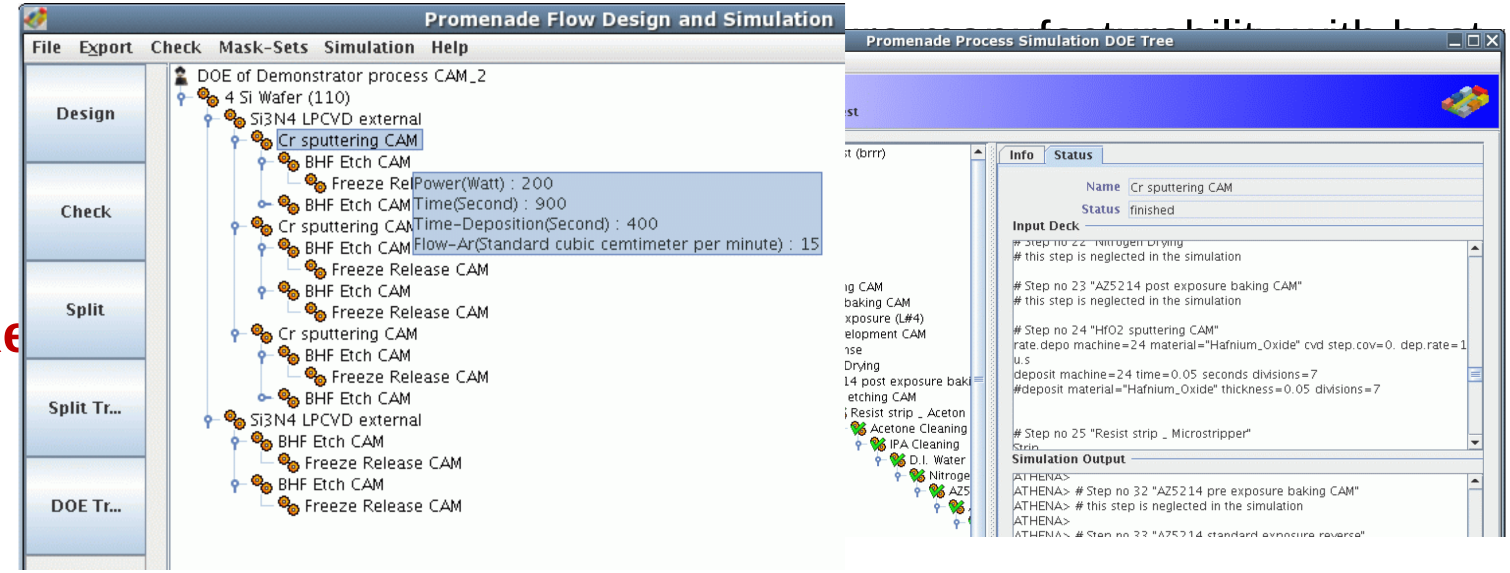
Stages of Process Verification

- **LEVEL 3: Experimental verification**
  - Requirements
    - Access to real-fab data for process parameter values and distributions
    - Fast concurrent simulation capabilities
  - Verification Step
    - Setting up an experimentation tree and performing process flow simulations with varying process step settings
  - Verification Result
    - Process parameter settings that assure manufacturability with best possible results

Real-life (fab-data-related) process flow viability assessment

- **LEVEL 3: Experimental verification**
  - Requiremen
    - Access t … nd distributions
    - Fast con
  - Verification
    - Setting u … ess flow simulatio
  - Verification





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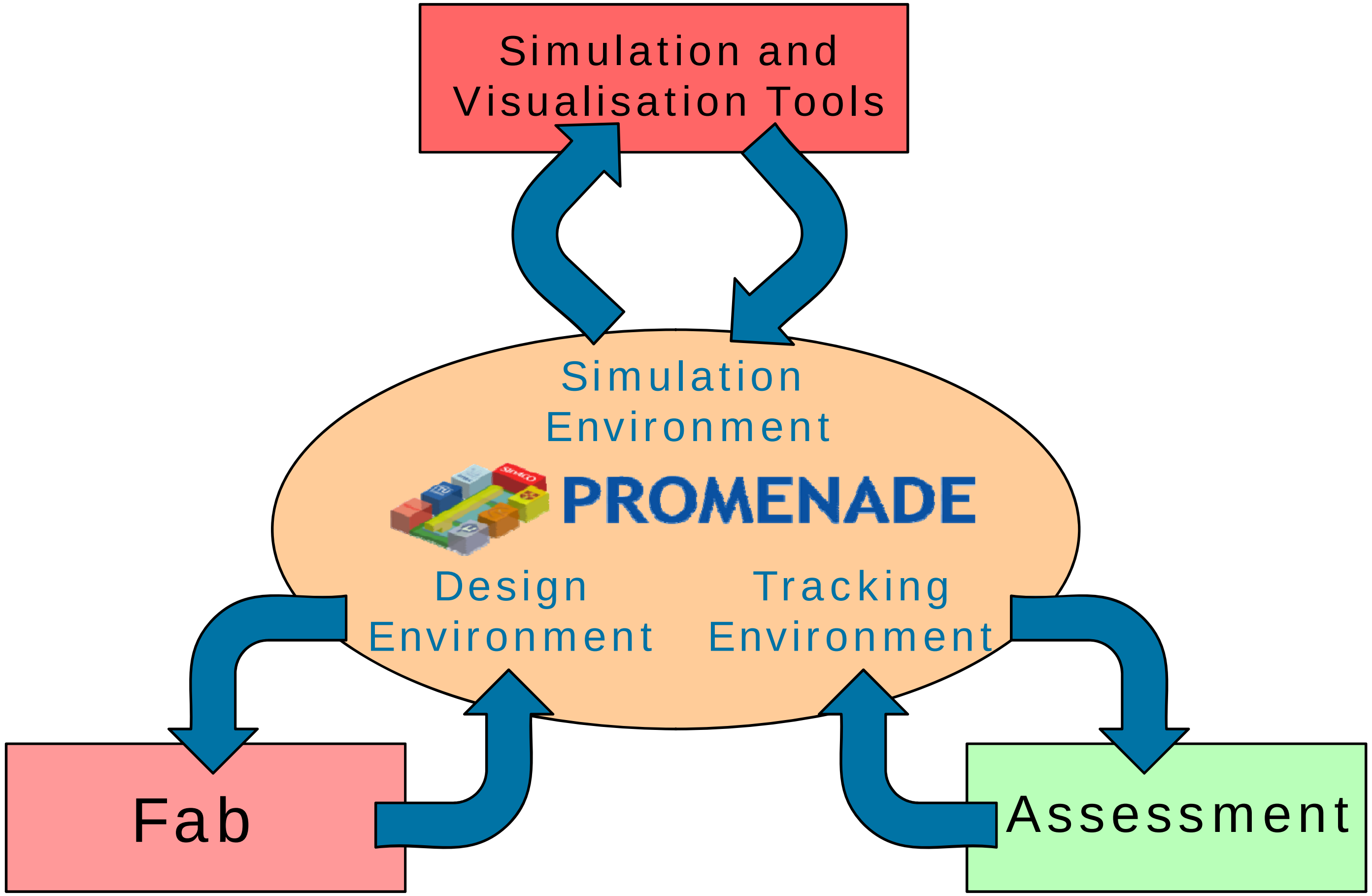
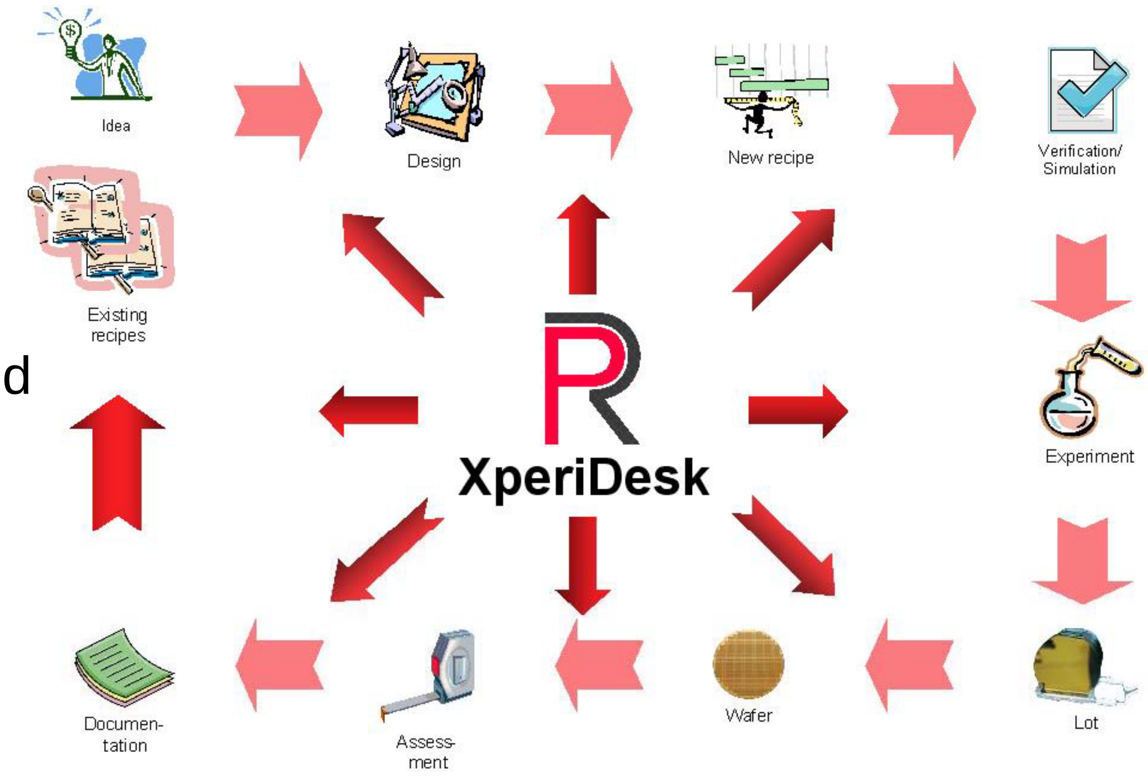
Process Verification Environment

- **Process design and tracking** PROMENADE



Developed in EU-FP6-project IST-1-507965

- **XperiDesk**
  - Complete round-trip support for process management flow
  - Supporting experiment based development and optimization of silicon thin film manufacturing sequences
  - Process design and verification
  - Interfacing simulation and MES
  - Complete document management and intra-project communication capabilities



Conclusions

- **Reliable micro/nano systems require reliable fabrication processes**
- **Reliable process design can be assisted by process management and design tools covering**
  - High-level process verification by consistency checking of abstract process flow models
  - Medium-level process verification by extended process flow simulations
  - Low-level process verification by active experimentation
- **Tool support available: XperiDesk (PROMENADE)**
- **Future research topics**
  - Integrating bottom-up (process design) and top down (behavioral) flows and design frameworks
  - Supporting concurrent, integrated design of mask layout and process flow
  - Providing tools for knowledge-based fab data exploration