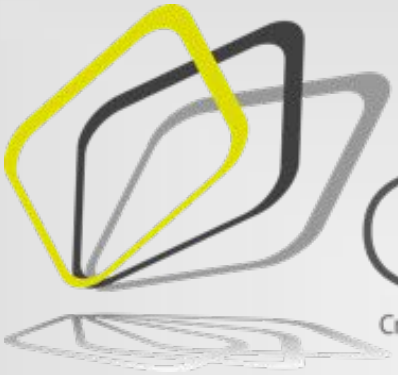

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FP7 projects HARPA CLERECO and EXCESS

Convergence, Perspectives and Joint Vision (S. Di Carlo – POLITO)

HiPEAC CSW - May 5th 2015 Oslo

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WHO WE ARE

POLITECNICO DI TORINO 1859 1906

Laboratoire d'Informatique de Robotique et de Microélectronique de Montpellier
LIRMM

THALES

UPC

ABB

YOGITECH

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RELIABILITY IN DIGITAL SYSTEMS

- Many existing and new digital applications aim at implementing the **Computing Continuum**
- From a **reliability** and **dependability** perspective, the end-user or end-application can declare precise requirements
  - Reliability constraints and requirements are highly variable according to the application areas and the criticality of the considered system or component
- Reliability directly drives technology, HW and SW design decisions

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RELIABLE SYSTEMS DESING

How do we design reliable systems today?

Error management solutions at all design/ implementation levels are feasible: **technology**, **hardware**, **software**, etc.

What's the best combination?

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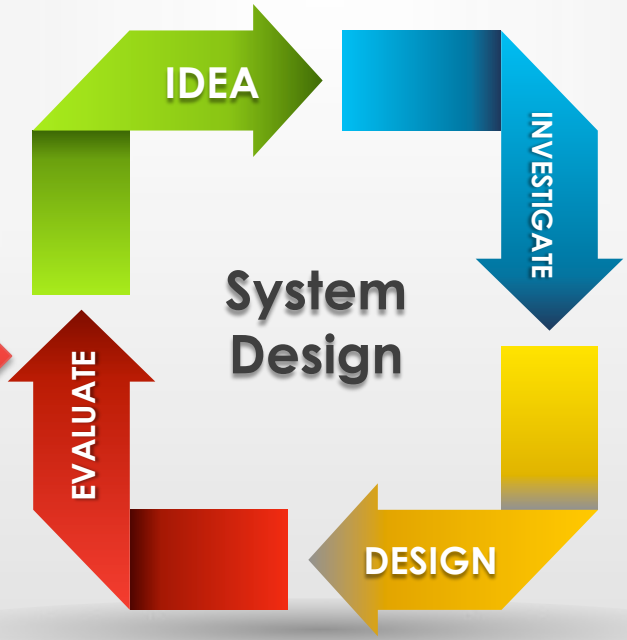
OVER DESIGN OF RELIABLE SYSTEMS

Reliability engineers and system architects are required to fulfill demanding safety requirements to budget and allocate reliability targets per system component while depending on incomplete or missing reliability data

RTL/Gate level fault injection

Physical stress test



A safe approach: OVERDESIGN

Large margins

Massive redundancy

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THE **COSTS** OF RELIABILITY

Products failing to reach the reliability objectives may be penalized with commercial failure, decreased brand name reputation and financial penalties

Reliability costs

Many design and implementation choices, decisions or compromises can be traced back to cost criteria

Overdesign

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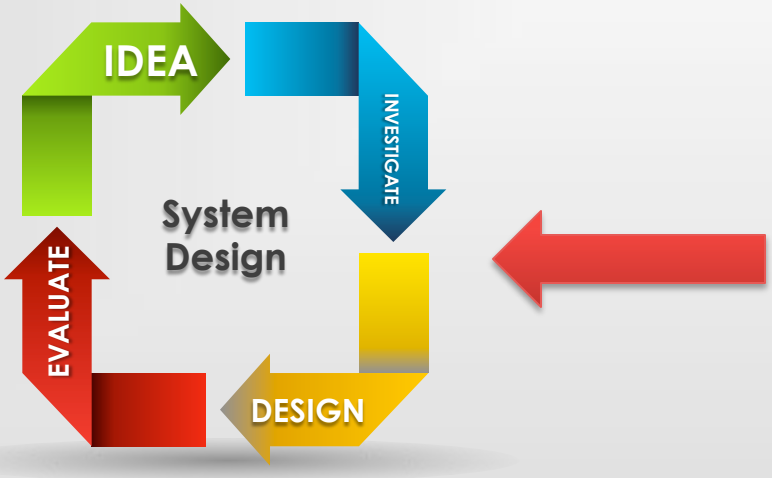
OBJECTIVE OF THE PROJECT

Overdesign

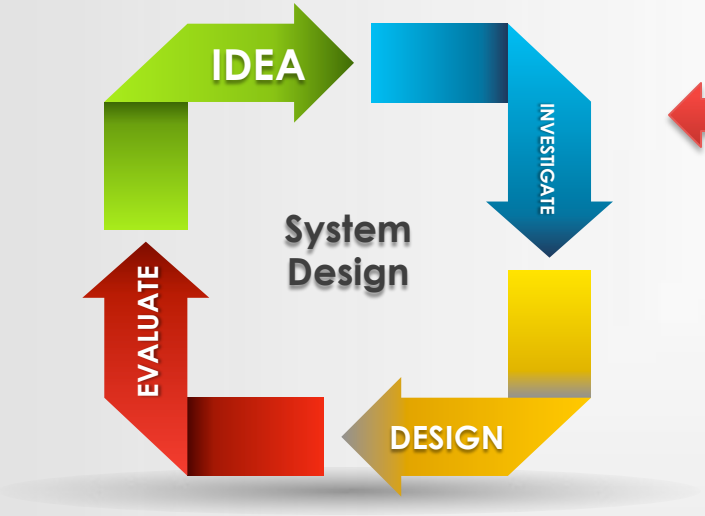
- Is over-design really required?
  - Errors are often masked by several layers of hardware and software
  - The way HW and SW components are interconnected plays a crucial role in these masking effects

IF WE PROVIDE DESIGNERS WITH TOOLS TO EVALUATE SYSTEM RELIABILITY EARLY IN THE DESIGN CYCLE CAN WE HELP THEM DESIGNING MORE EFFICIENT SYSTEMS?



OBJECTIVE OF THE PROJECT

If we provide designers with tools to evaluate reliability early in the design can we help them designing more efficient systems?



WE BELIEVE THE ANSWER IS "YES" AND NEXT SLIDES WILL OVERVIEW CLERECO APPROACH TO REACH THIS GOAL

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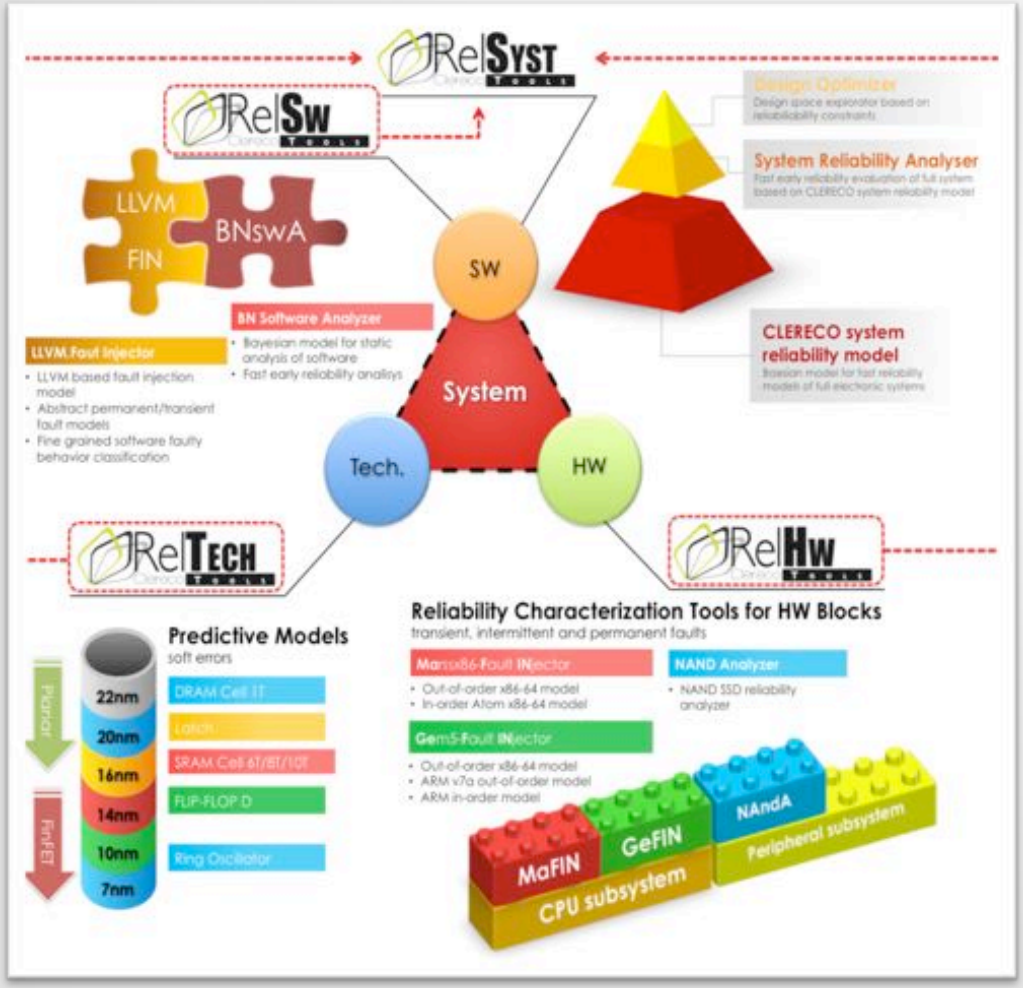
WHAT WE PROVIDE



CLERECO provides a **reliability analysis and management framework** consisting of libraries, tools and formats able to model, evaluate and optimize the reliability of complex systems.

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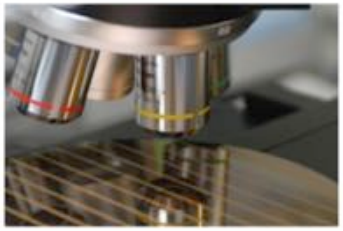
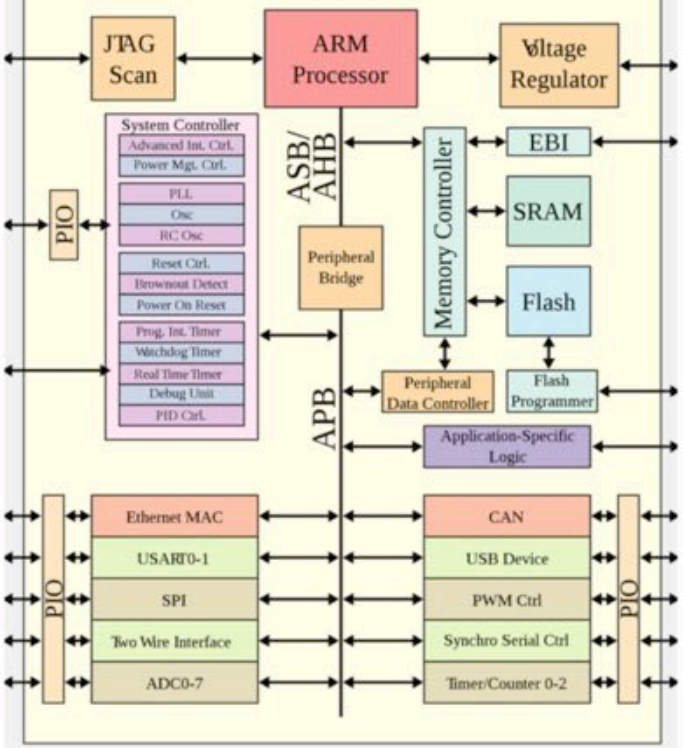
SYSTEM MODELING FOR RELIABILITY ANALYSIS

Technology



Hardware architecture



Software

SYSTEM

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SYSTEM MODELING FOR RELIABILITY ANALYSIS

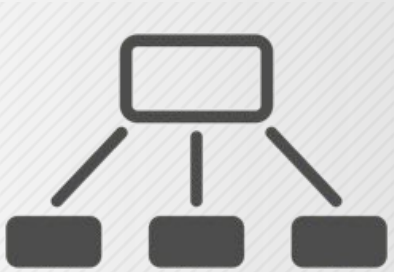
Component based

Modeling system's components and reliability characteristics (technologies, hardware, software)

System architecture

Modeling system's architecture (components interconnection)

Hierarchical



Hierarchical analysis to manage complexity

Statistical reasoning

Enable statistical reasoning on system level reliability

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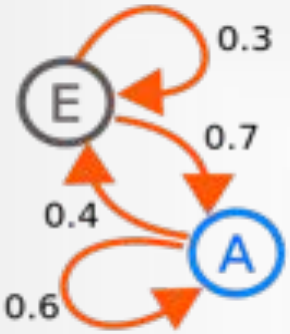
STATISTICAL MODELS OPTIONS

FAULT TREE ANALYSIS

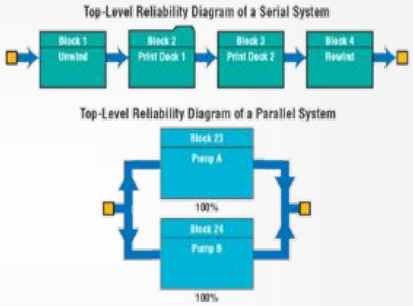
Top-down deductive failure analysis in which an undesired state of a system is analyzed using Boolean logic to combine a series of lower level events

MARKOV CHAINS



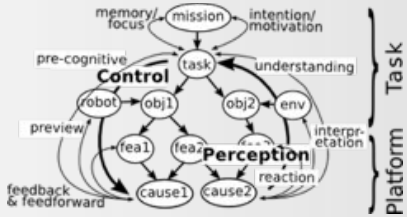
A random process that undergoes transitions from one state to another (correct state, failure state).
Probability distribution of next state only depends on the current state

RELIABILITY BLOCK DIAGRAMS



Very similar to fault tree analysis. The most fundamental difference between FTDs and RBDs is that an RBD works in the "success space", and thus looks at system successes combinations

BAYESIAN NETS



A statistical model representing multivariate statistical distributions. They model relations among random variables

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STATISTICAL MODELS OPTIONS

	Fault Tree Analysis	Reliability Block Diag.	Markov Chains	Bayesian Networks
Top DOWN	✔	✔	✔	✔
Bottom UP	✖	✖	✔ limited	✔
Full propagation of events	✖	✖	✖	✔
Multiple output	✖	✖	✖	✔
Continuous values	✔	✔	✔	✔
Cycles definition	✖	✔	✔	✔
Dynamic modeling	✖	✖	✔	✔
Component based	✔	✔	✖	✔

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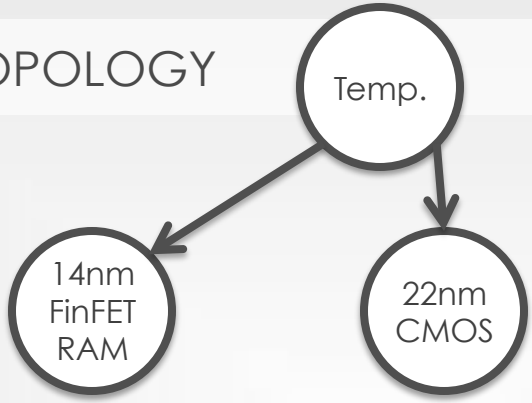
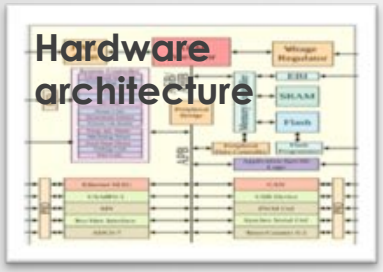
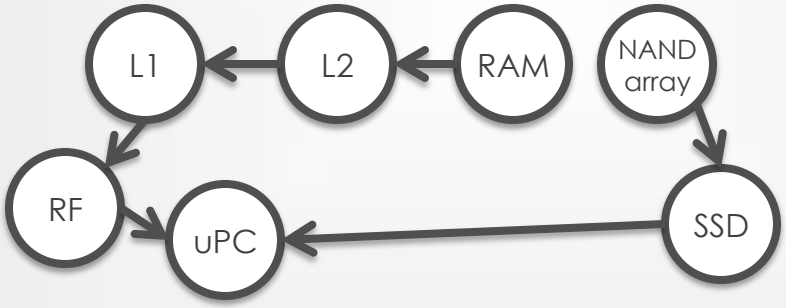
SYSTEM MODELING TOPOLOGY

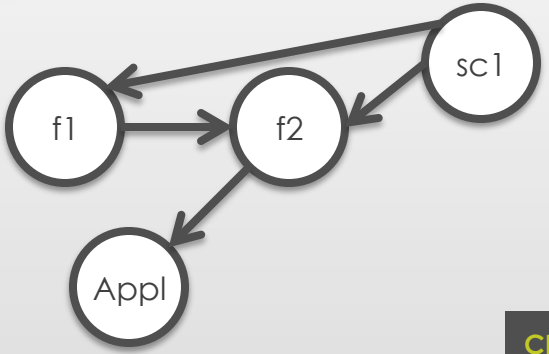


Technology nodes model raw error rates, environmental conditions, etc.





HW blocks are nodes of the network. Complex blocks can be split into sub blocks (e.g., uPC). Arcs are candidate error propagation paths.



SW blocks (e.g., functions or portions of a function) are nodes of the network. Arcs are candidate error propagation paths. Also concepts such as concurrency can be easily expressed.

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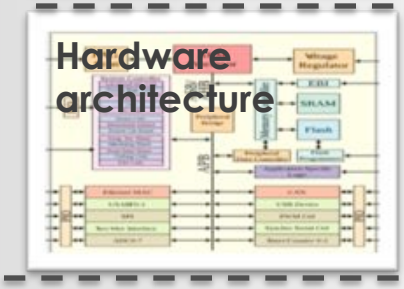
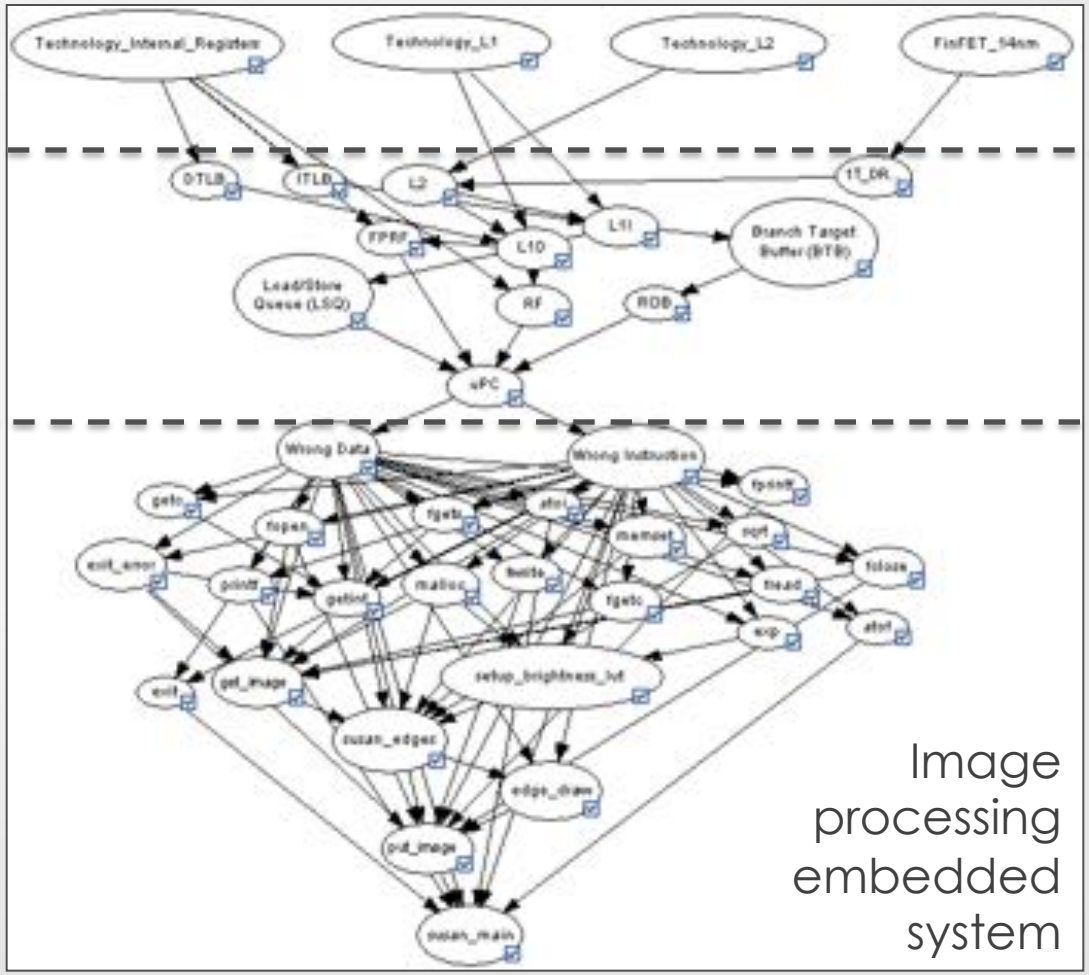
ING TOPOLOGY





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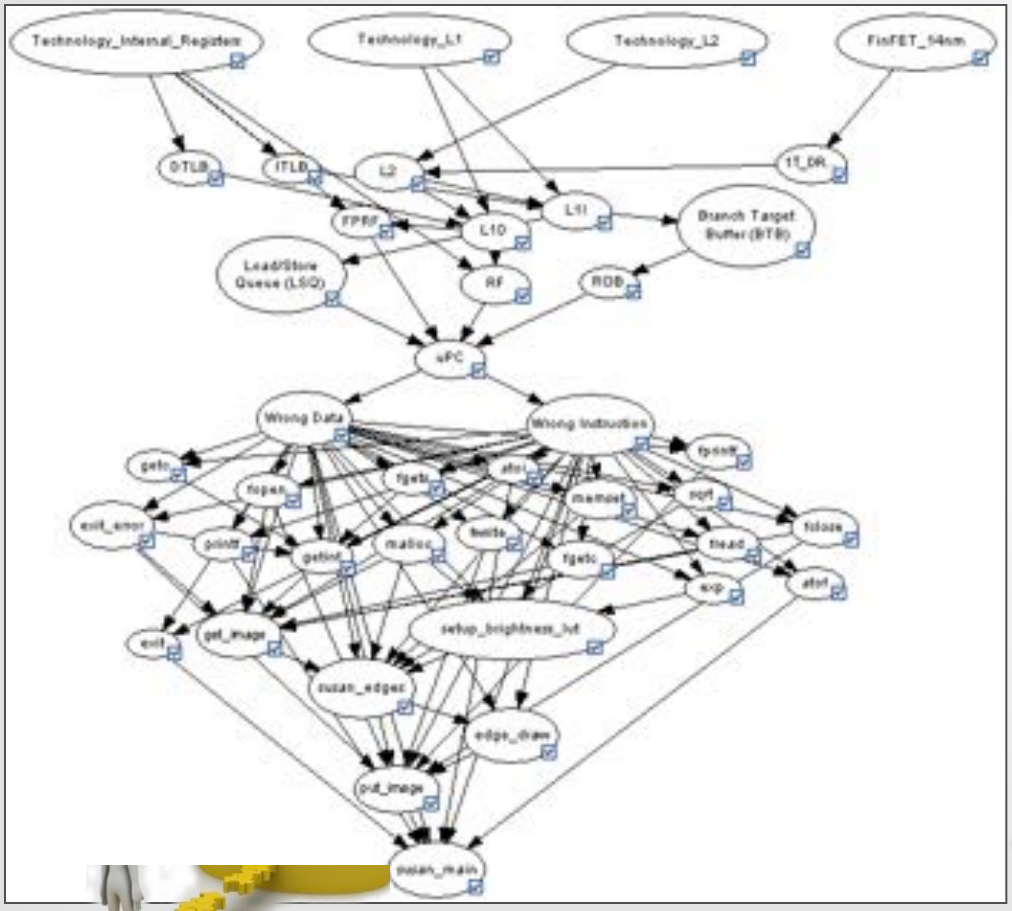
REASONING AND RELIABILITY ANALYSIS



1 **Global rel. analysis**

System level reliability inference (e.g., MTBF, MTTF, FIT, etc.) taking into account raw errors and propagation/masking of raw-errors

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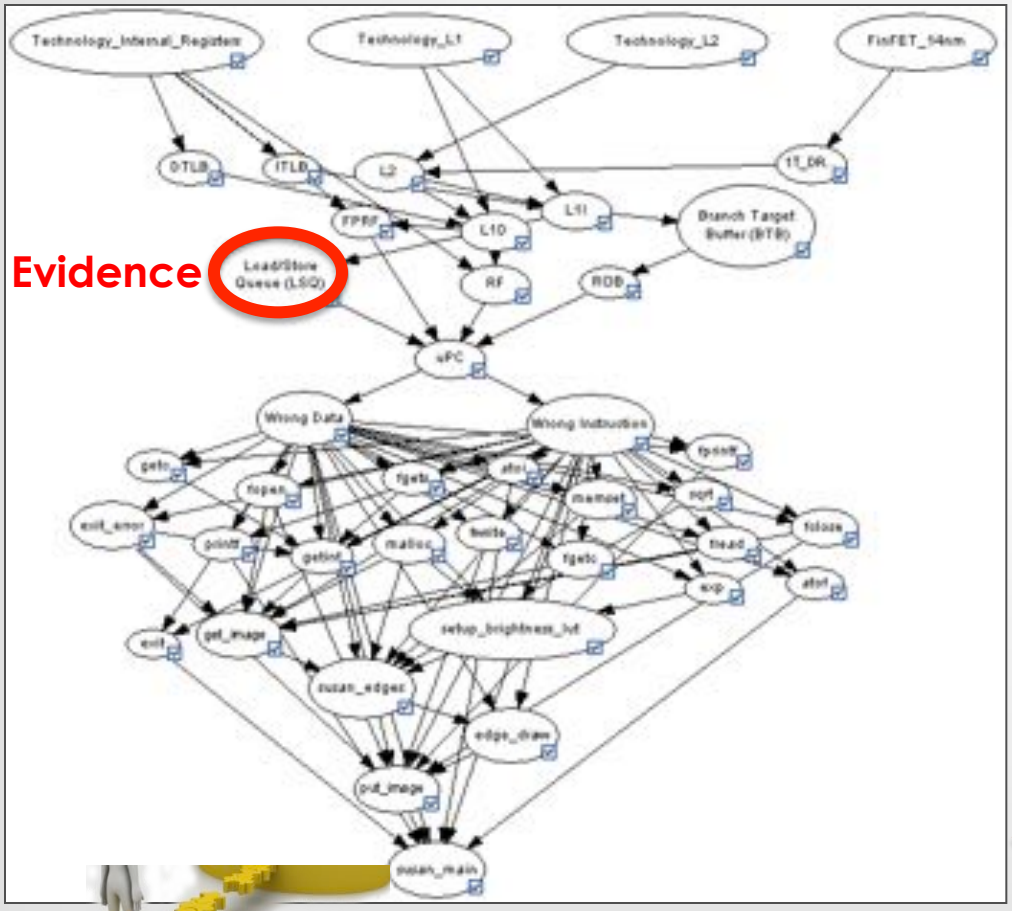
REASONING AND RELIABILITY ANALYSIS



2 **Forward inspection**

Given the evidence that a node is in a given state (i.e., failure) which is the probability of correctness/ failure observed at the application layer?

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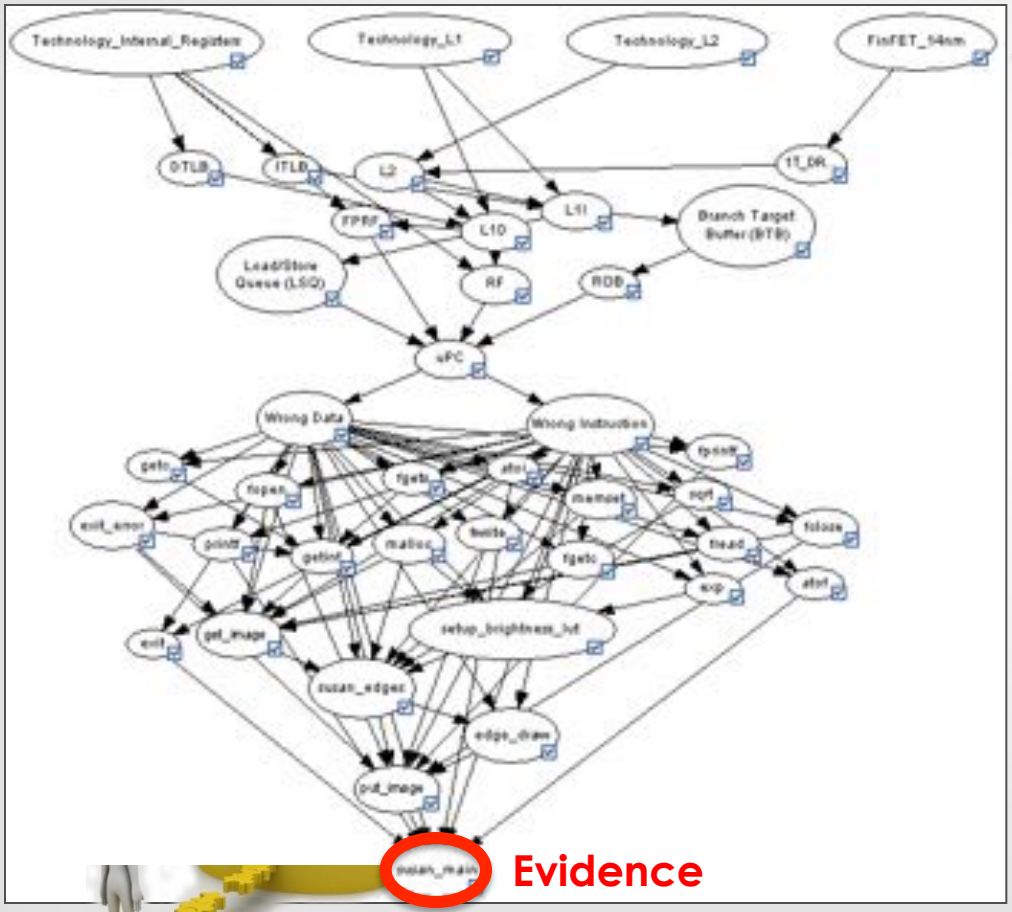
REASONING AND RELIABILITY ANALYSIS



3 **Backward inspection**

Given the evidence that the application fails, which are the most probable roots of failure?

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REASONING AND RELIABILITY ANALYSIS

CREATING THE MODEL FOR A SYSTEM, COMPUTING ITS PARAMETERS (I.E. CONDITIONAL PROBABILITIES) IS A COMPLEX AND CHALLENGING TASKS

Is CLERECO reliability framework another SPREADSHEET based system reliability analyzer?

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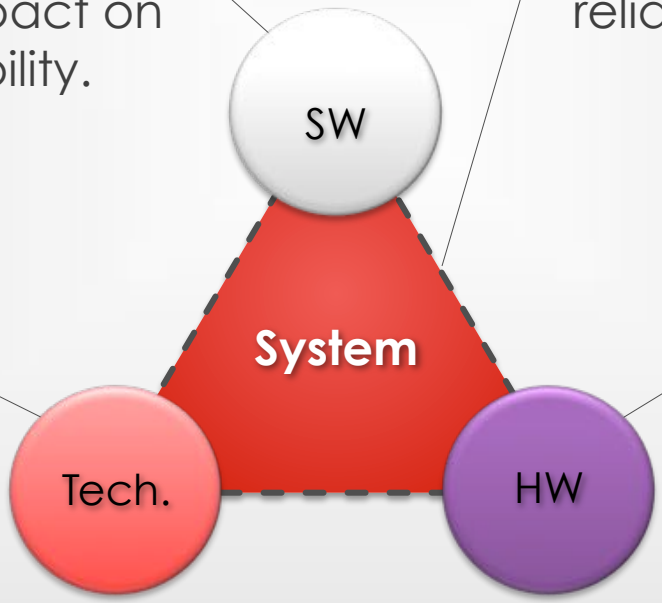
TOOLS FOR RELIABILITY ANALYSIS

RelSw Clereco Tools

Tools for analysis of software impact on system reliability.

RelSyst Clereco Tools

Tools for system level reliability analysis.



RelTech Clereco Tools

Tools for analysis of technology impact on system reliability.

RelHw Clereco Tools

Tools for analysis of hardware architecture impact on system reliability.

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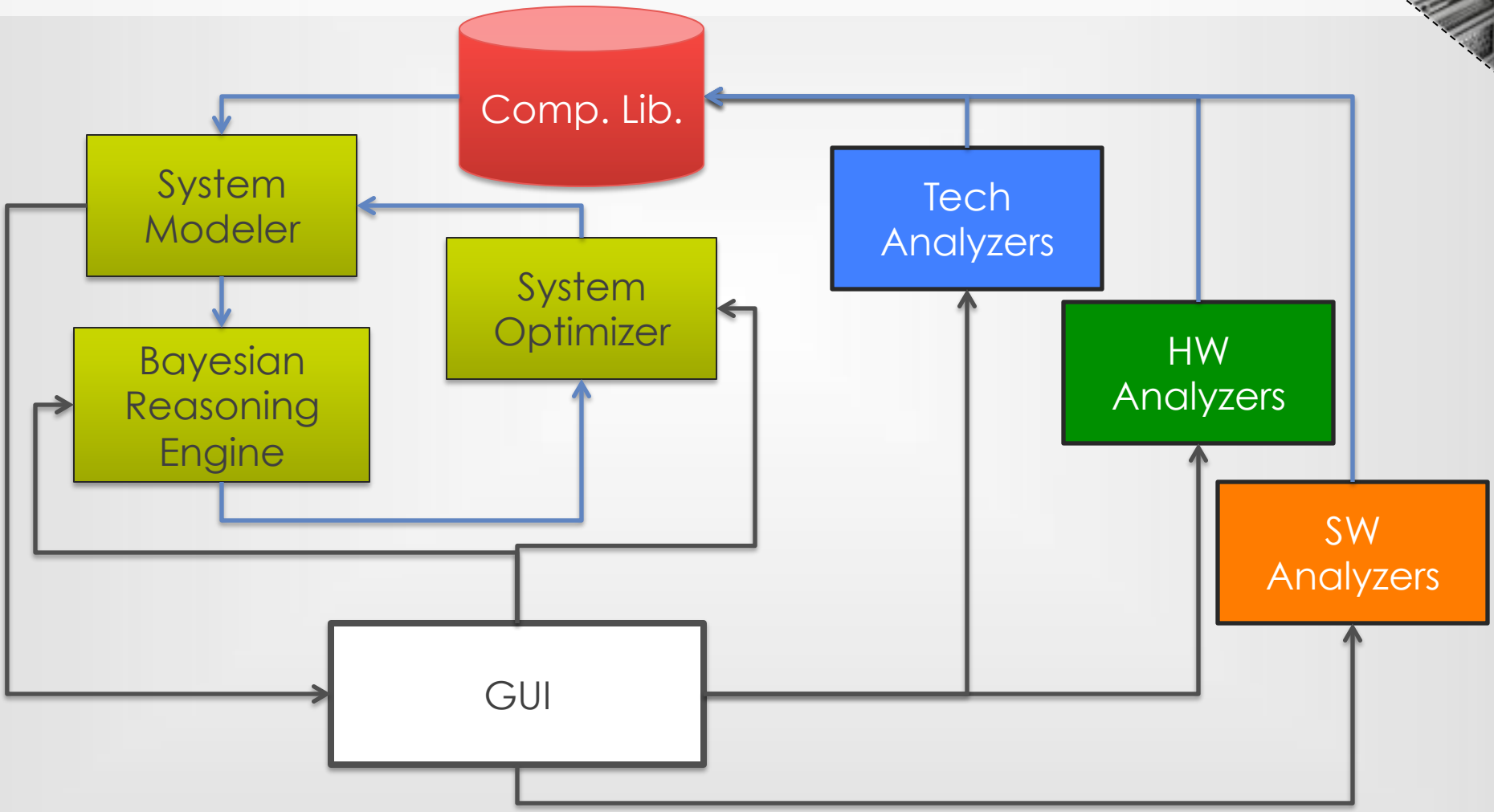
TOOLS FOR RELIABILITY ANALYSIS



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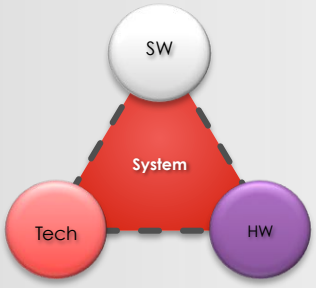
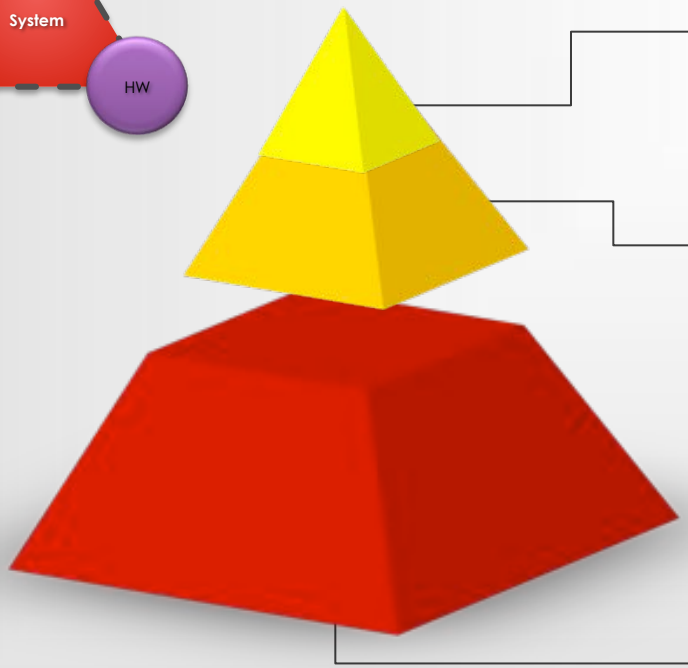
TOOLS FOR RELIABILITY ANALYSIS

RelSyst Clereco Tools

- The **core** of the CLERECO design methodology
- Integrates information from the other toolsets into a **high-level system model**
- Provides tools to perform **early system level reliability analysis**





Design Optimizer

Design space explorator based on reliabiliability constraints

System Reliability Analyser

Fast early reliability evaluation of full system based on CLERECO system reliability model

CLERECO system reliability model

Bayesian model for fast reliability models of full electronic systems

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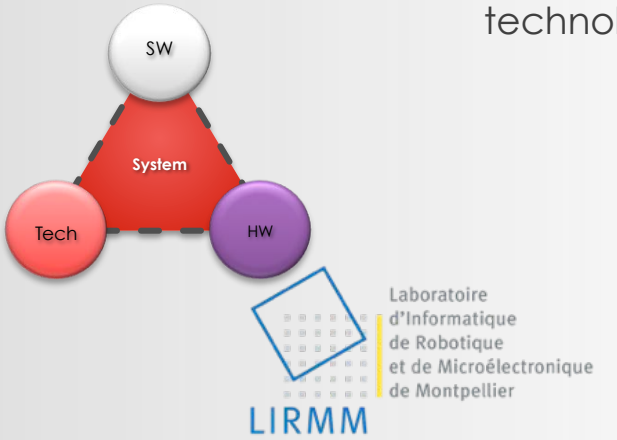
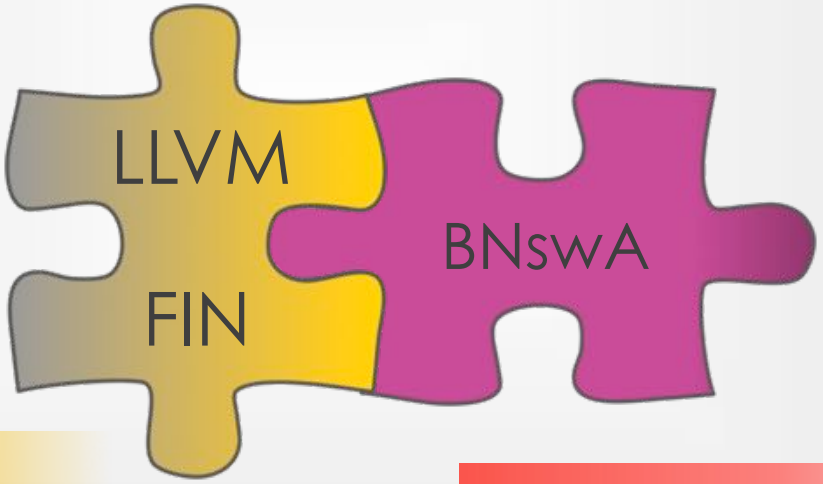
TOOLS FOR RELIABILITY ANALYSIS

RelSw
Clereco TOOLS

- Offers capability to analyze **software fault masking** in isolation from the hardware architecture
- Both **static** and **dynamic analysis** of the software is supported by our technology



Laboratoire d'Informatique de Robotique et de Microélectronique de Montpellier
LIRMM



POLITECNICO DI TORINO 1859 1906

LLVM Fault Injector

- LLVM based fault injection model
- Abstract permanent/transient fault models
- Fine grained software faulty behavior classification

BN Software Analyzer

- Bayesian model for static analysis of software
- Fast early reliability analysis

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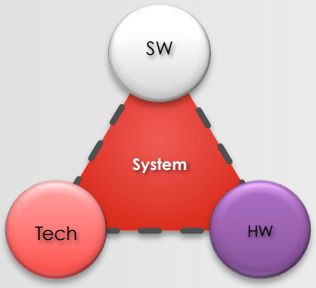
TOOLS FOR RELIABILITY ANALYSIS

RelHw
Clereco TOOLS

- Reliability characterization tools for HW Blocks considering transient, intermittent and permanent faults
- The core of these tools focuses on the analysis of fault masking effects in microprocessor blocks that represent the core of modern digital systems



Marssx86-**F**ault **IN**jector

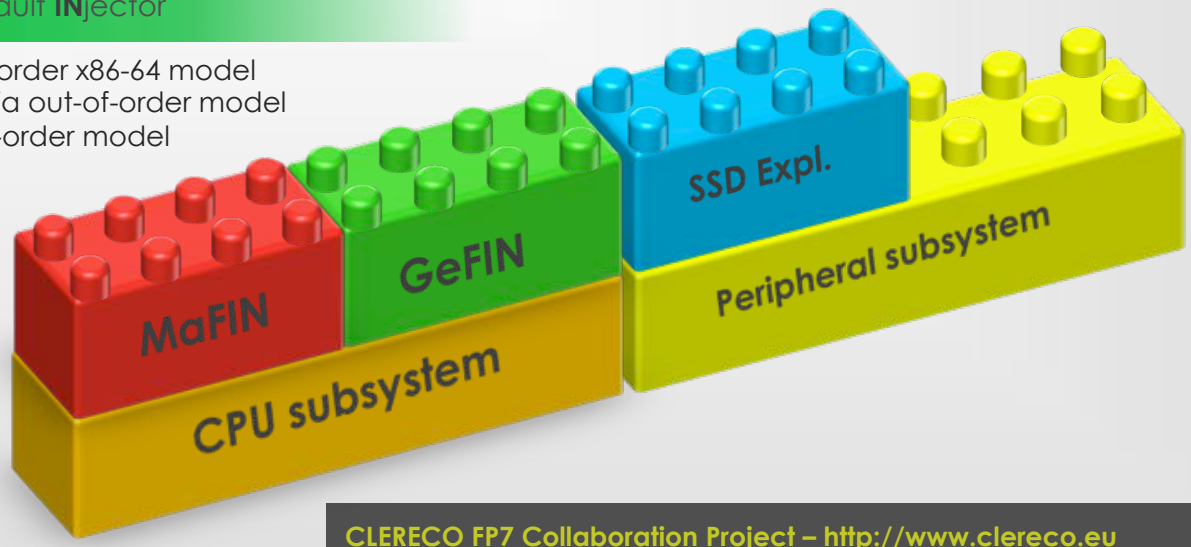
- Out-of-order x86-64 model
- In-order Atom x86-64 model

Gem5-**F**ault **IN**jector

- Out-of-order x86-64 model
- ARM v7a out-of-order model
- ARM in-order model

SSD Explorer

- SSD reliability analyzer
- NAND flash and STT-MRAM models



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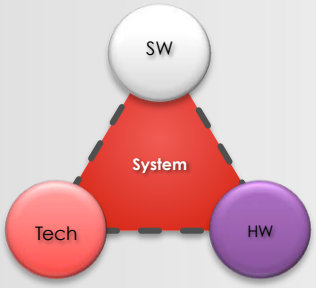
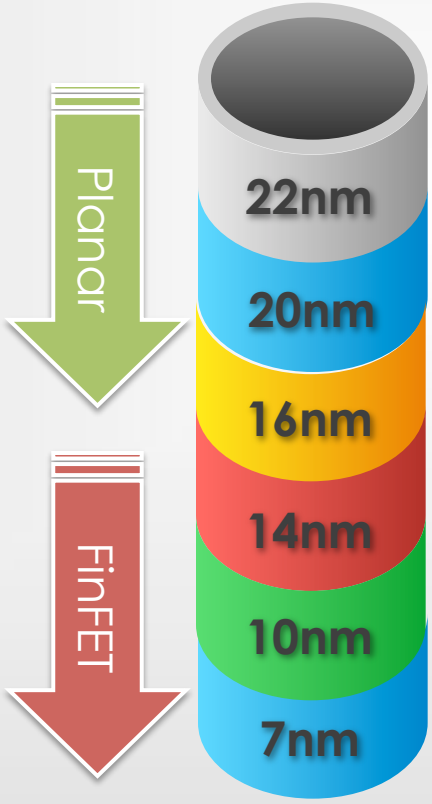
TOOLS FOR RELIABILITY ANALYSIS

RelTECH
Clereco TOOLS

- Offers a set of predictive models to analyze the impact of future technology nodes on specific basic design blocks.



UPC



Predictive Models

soft errors

- DRAM Cell 1T
- Latch
- SRAM Cell 6T/8T/10T
- FLIP-FLOP D
- Ring Oscillator

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TOOLS FOR RELIABILITY ANALYSIS

COMPONENTS LIBRARY

Characterization of components is complex. Characterized components must be stored in a library for easy reuse in different design.

HOW DO WE REPRESENT COMPONENT LEVEL INFORMATION?

CE-RIIF

CLERECO EXTENDED RELIABILITY INFORMATION INTERCHANGE FORMAT

Extends the RIIF reliability language:

- Hierarchy
- Uniform HW/SW description

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SCALABILITY AND COMPLEXITY

System engineers reason with probabilities rather than complex HW, SW simulation results

Any reliability metric that can be expressed in terms of conditional probabilities can be easily computed

Networks with up to several thousands of nodes can be analyzed in few seconds

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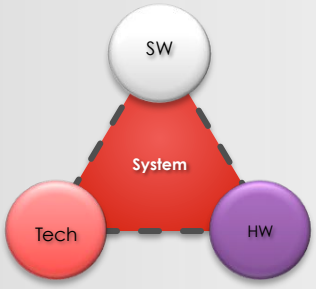
CONCLUSIONS



Several tools are still under development to cover an additional set of components and technologies (e.g., HW accelerators, system software).

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