ZealCore Embedded Solutions

WE MAKE IT VISIBLE

ZealCore
Embedded Solutions

Accelerated Troubleshooting

Record Play

Henrik Thane, Ph.D.,
Founder
SVP Market Development

ZealCore Embedded Solutions

ZealCore Focus

Monitoring,
Debugging,
Testing of:

- *Embedded*
- *Multi-tasking*
- *Real-Time*
- *Multi-Core*
- *Distributed Systems…*

- *Used in*
  - *The Field / Deployed*
  - *The Lab / Pre-deployment*

About ZealCore

- Spin-off from the pioneering research work performed at the Mälardalen Real-Time Research Centre in Västerås, and the Royal Institute of Technology in Stockholm, Sweden
- Recognized by Gartner as Cool Vendor:

Gartner COOL VENDORS 2005 Emerging Trends and Technologies

- Award by MIS, 2005
  - "One of top 10 risings stars in the world".

Our Research and Technology

Tackles the difficulty of understanding the behavior of complex embedded systems

We provide solutions for

- Observability
- Reproducibility

Questions we try to answer

- What information is of interest?
- How to extract the information?
- How to analyze the information?
- How to manage the information?

Fact: The Inadequacy of Verification

Incorrect specifications cause over 50% of all failures

[N. G. Leveson. Safeware System, Safety and Computers. Addison Wesley 1995.]

'The radar system of HMS Sheffield identified an incoming Exocet missile as non-Soviet and thus friendly. No alarm sounded. The Ship sunk with substantial losses of life.'

[ACM Software Engineering Notes , Vol.8, No. 3.]

- All wrong despite V&V

We need means to see what happens out there…

Fact: Debugging

Difficult to understand the behavior of complex embedded systems

- Difficult to observe behavior
- Difficult to reproduce behavior

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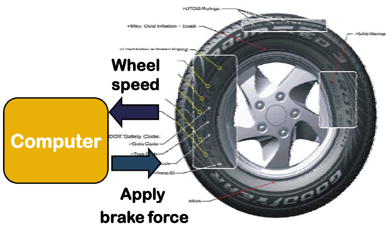
Fact: Debugging



Software controlled ABS

Fault Identification

(Debugging)

- Non Stop
  - System keeps running even if software stops
- Indeterminism
  - Rerunning a program gives different results
  - Hard to reproduce failures
- Probe-effect (Heisenbugs)
  - Instrumentation to record behavior changes behavior
  - Bugs hide when we are looking for them

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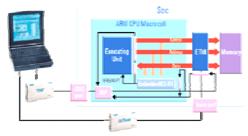
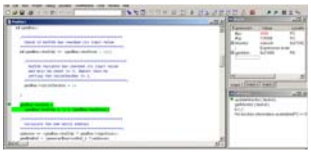
Common Solutions

ZealCore Embedded Solutions — Observation & Reproducibility Techniques



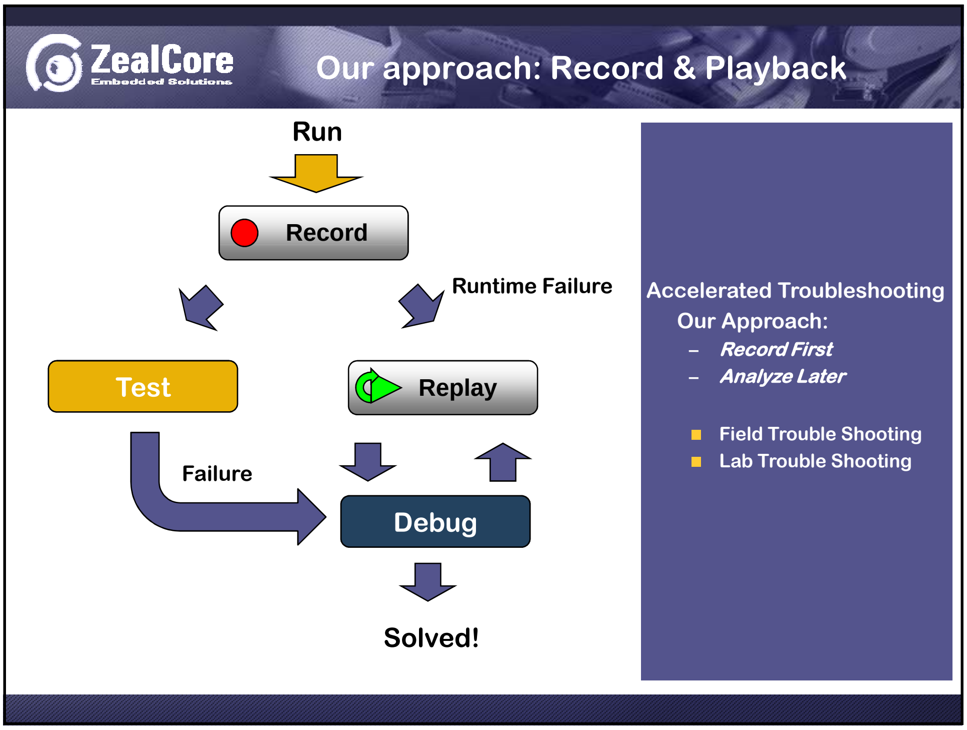


TRACE_1("ROUTE", "gps_ROUTE_R4_Link")

- Hardware features
  - In-circuit emulators, BDM, ETM, JTAG ports, logic analyzers
  - Usually do not scale to deployed systems. Expensive to "Insure" target with hardware recorders.
- Using a symbolic source code debugger
  - Watches
  - Problem: Non stop debugging
  - Problem: Indeterminism
    - How to reproduce inputs from the field
  - Problem: Probe-effects
- Virtualization/simulators
  - Non intrusive
  - Problem: typically only virtualization of computer HW, not environment, e.g., Dynamics of a Robot
  - No input from deployed systems.
  - In some cases lock step simulation – but 50% of failures come from incorrect specifications.
- Software instrumentation
  - The most common means by which the programmer can increase the observability and reproducibility
  - auxiliary outputs, typically in terms of classic "printf()" statements and storage in logs.

ZealCore Embedded Solutions — Software Instrumentation Techniques

- For Languages with Pre Processors (C/C++) or Using Aspects
  - Textual substitution by parser
  - Textual substitution with macros of the C-preprocessor
- Inclusion/replacement additional library
- Trace functions/methods
  - Log4J (logging package for Java)
- Binary wrapping of object code
- Dynamic instrumentation of executable/executing code
  - ATOM,EEL Etch (Need restart)
  - DynInst (no restart, no real-time considerations)
  - Dynamic Patch/Relink (no restart, real-time considerations)
  - WindRiver Sensorpoints


ZealCore
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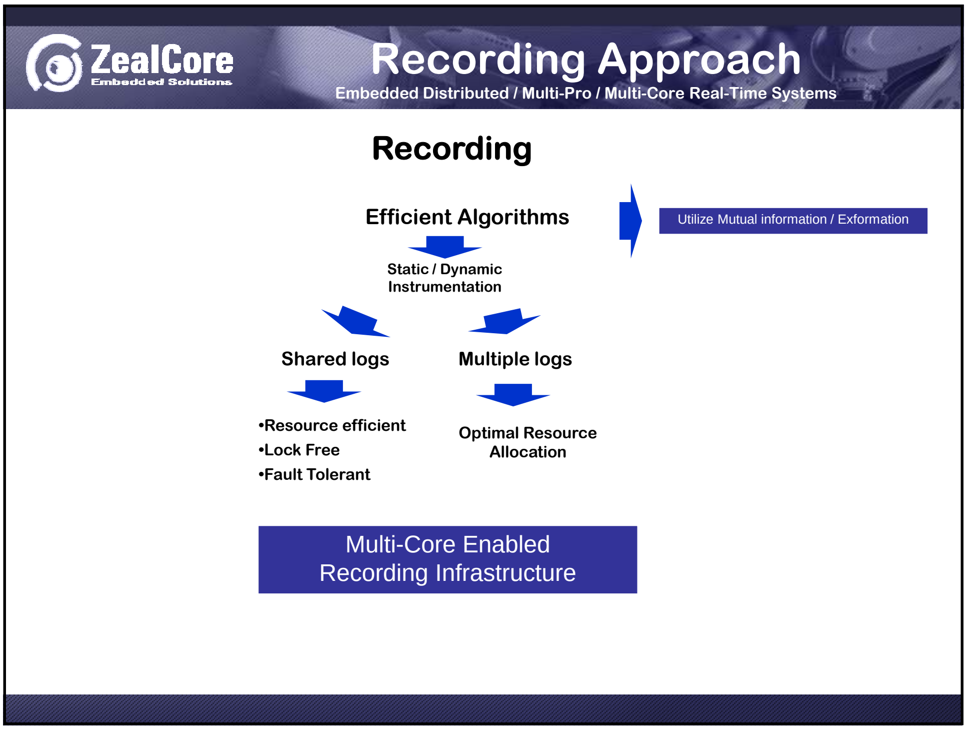
Our approach: Record & Playback
Run
Record
Runtime Failure
Test
Replay
Failure
Debug
Solved!
Accelerated Troubleshooting
Our Approach:
– Record First
– Analyze Later
Field Trouble Shooting
Lab Trouble Shooting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Recording Approach
Embedded Distributed / Multi-Pro / Multi-Core Real-Time Systems
Recording
Efficient Algorithms
Utilize Mutual information / Exformation
Static / Dynamic Instrumentation
Shared logs
Multiple logs
•Resource efficient
•Lock Free
•Fault Tolerant
Optimal Resource Allocation
Multi-Core Enabled Recording Infrastructure

System Debugging

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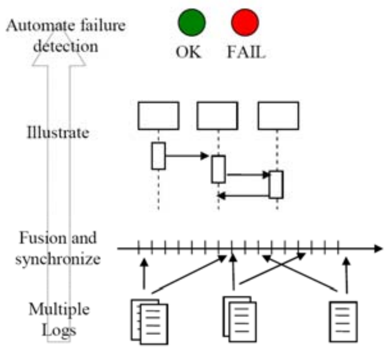
System Debugging =
Software Monitoring + System Event Processing



A necessary evolution Of traditional debugging methods
- To find and understand complex bugs
- Need to fuse & synchronize logs
- Need to automate the process
- Need to raise the abstraction level

Computer aided bug analysis
- Automatic import of several logs and synchronization
- Use graphics/abstractions
- Use reverse engineering
- Automatic fault identification

The Problem of System Debugging

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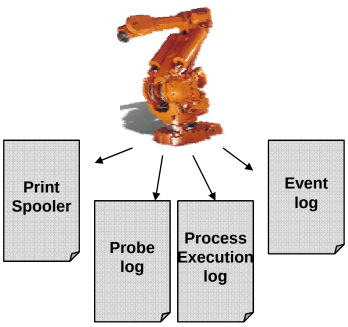
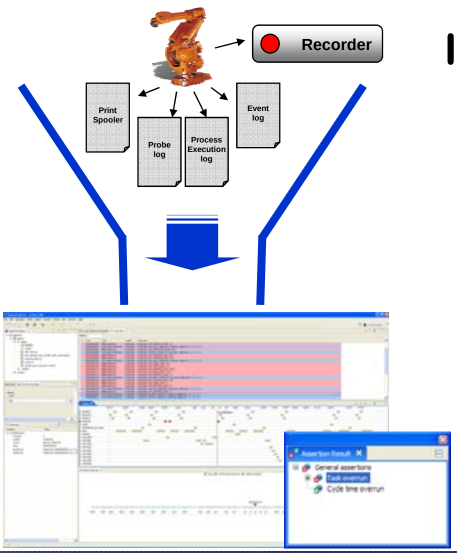
Current Industrial Situation

Poor Trouble Shooting



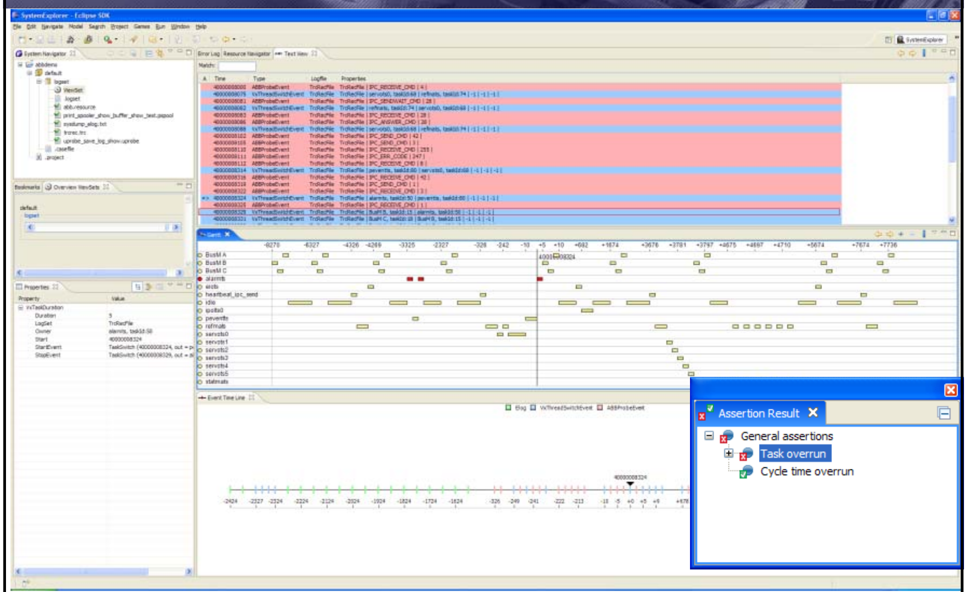
- General
  - Non Stop Behavior
  - Non Determinism
- Many logs/recordings
  - Different formats
  - Difficult to read and understand
  - No synchronization

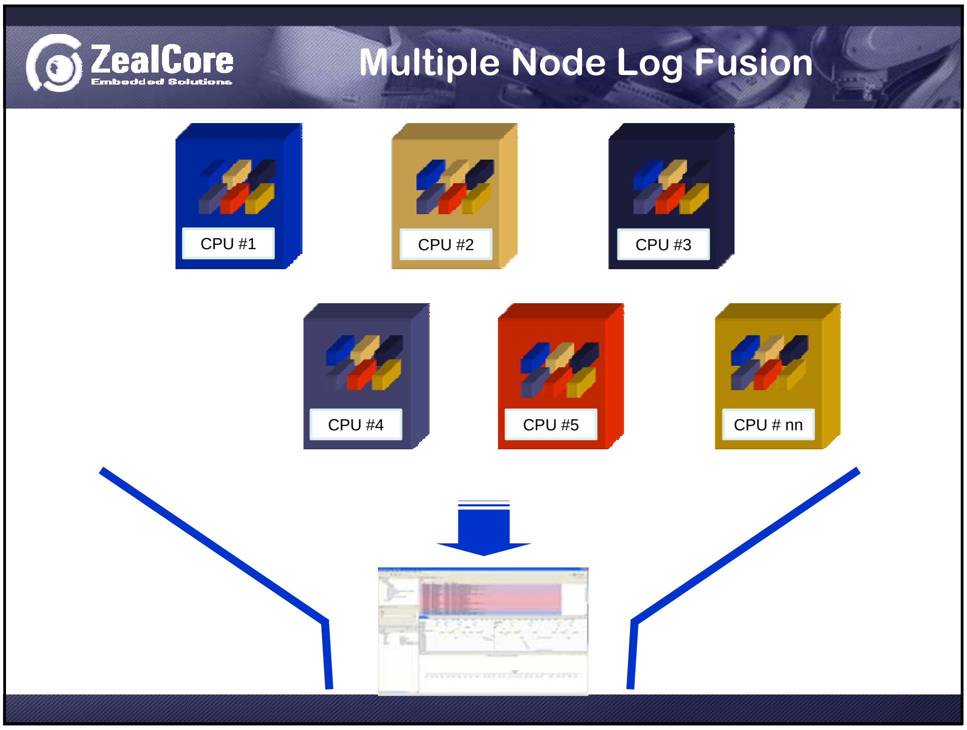
Our System Debugger Approach



Information Funnel

- System Level Debugger
  - Import and synchronization of Logs
  - Correlation of Data
- Automatic Fault Identification
- Automatic Trend Analysis
- Visualization & Reanimation
- Works on-top of existing tools
- Eclipse Based

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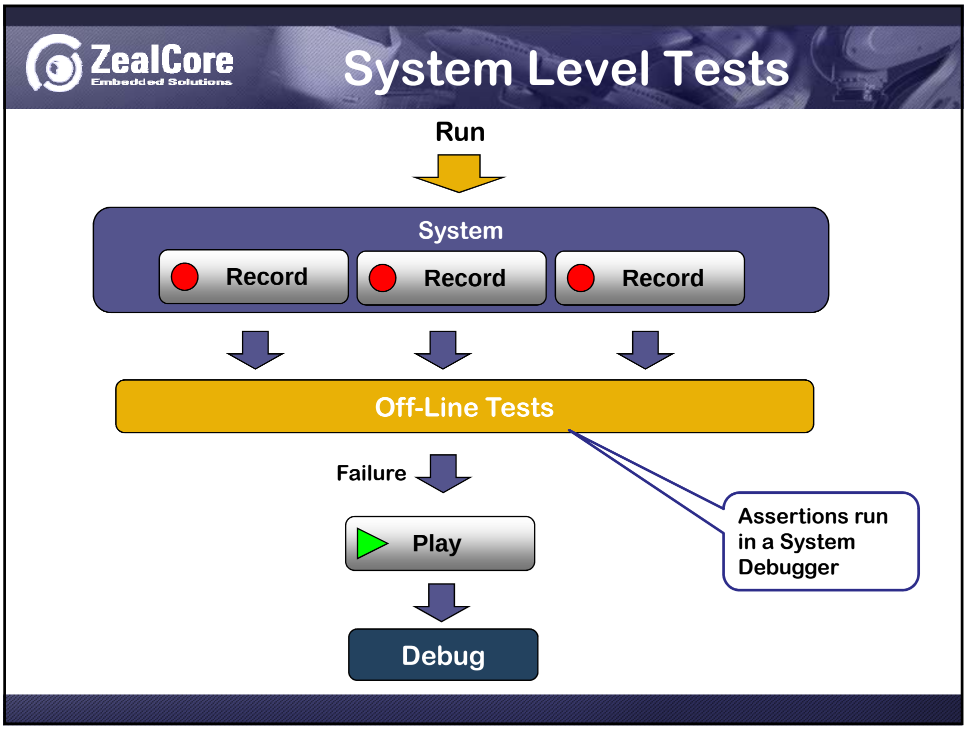
Multiple Node Log Fusion
CPU #1
CPU #2
CPU #3
CPU #4
CPU #5
CPU # nn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System Level Tests
Run
System
Record
Record
Record
Off-Line Tests
Failure
Play
Debug
Assertions run in a System Debugger

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Application Example

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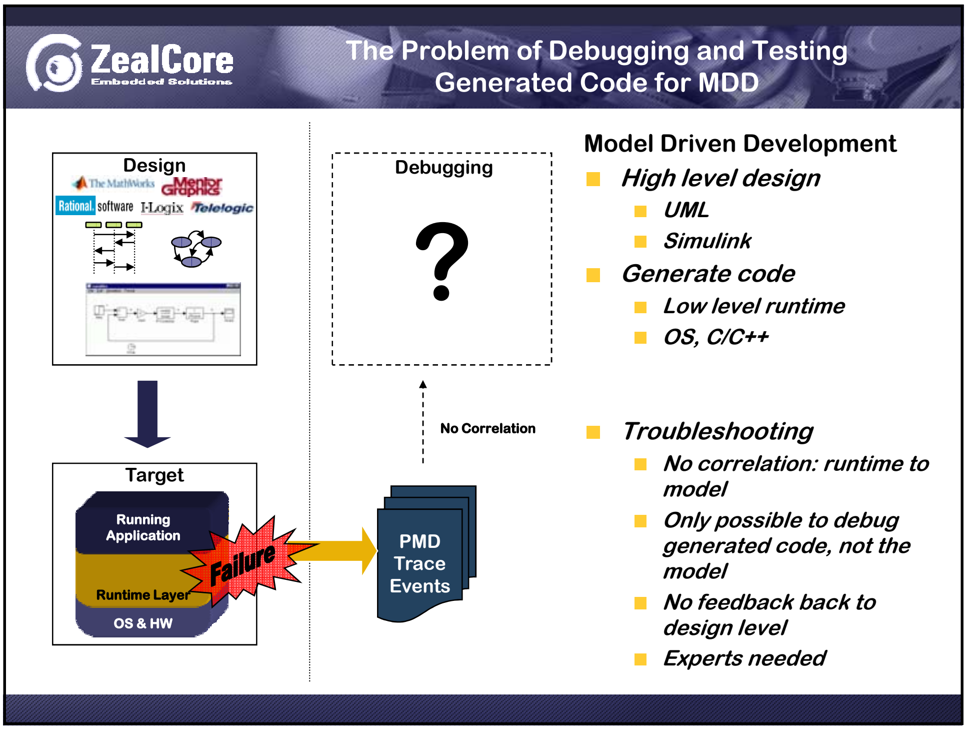
Approach # 1

Replay Debugging and Testing for Automatic Code Generation

Record

Play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The Problem of Debugging and Testing Generated Code for MDD
Design
Rational. software
I-Logix
Telelogic
Target
Running Application
Runtime Layer
OS & HW
Failure
Debugging
?
No Correlation
PMD Trace Events
Model Driven Development
High level design
UML
Simulink
Generate code
Low level runtime
OS, C/C++
Troubleshooting
No correlation: runtime to model
Only possible to debug generated code, not the model
No feedback back to design level
Experts needed


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The Solution
Record
Play

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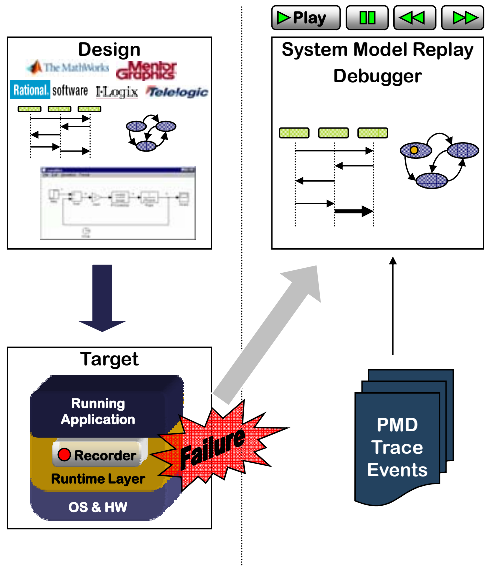
ZealCore's Replay Debugger



- ***Use software recorder***
- ***Fuse data***
- ***"Do reverse engineering"***
- ***Replay***
  - *State machines, signaling and states*
  - *Animate sequence- and state diagrams*
  - ***Exact representation of runtime behavior***
- ***Correlate***
  - *Model + OS-events*
  - *Program modules*
  - *Processors*
  - *Native logs*
- ***Automatic fault identification***

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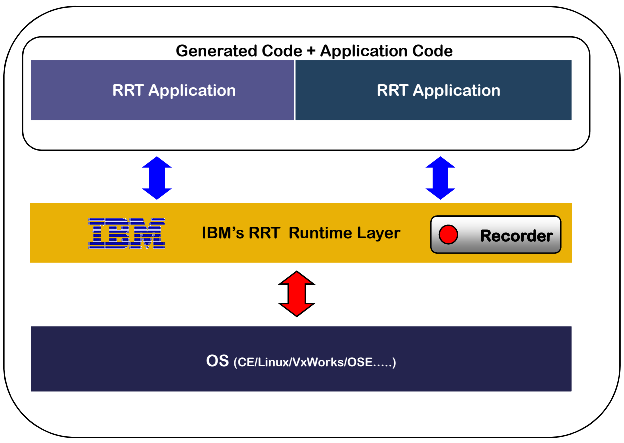
Rational Rose Real-Time (RRT) & ZealCore System Recorder Integration



Recorder

- **Only Added to the Rose Real-Time Runtime Library**
- **No Modification of the Application**
- **Footprint is so Small that recorder can be Enabled even in Deployed Systems**
  - PowerPC 705 (700MHz)
  - Heavy application 80-100% CPU Load
  - ~ 550 k Events/s (40Byte)
  - Recording cost: ~ +1 % CPU Load
  - Code footprint: ~ 2K lines C code

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Other Integrations

Mentor Graphics

I-Logix Telelogic

The MathWorks dSPACE

ENEA WIND RIVER

Ready for IBM. Rational. software

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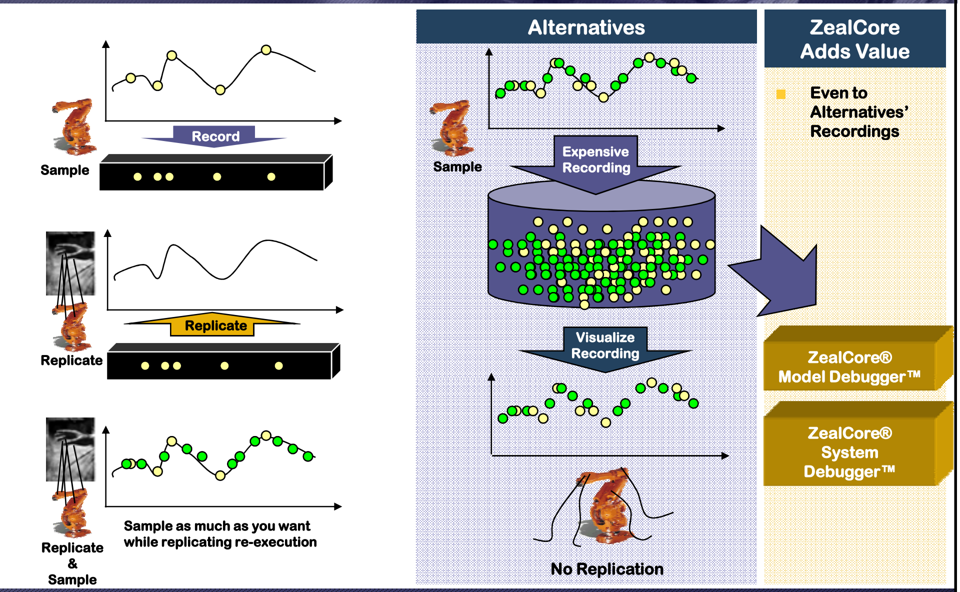
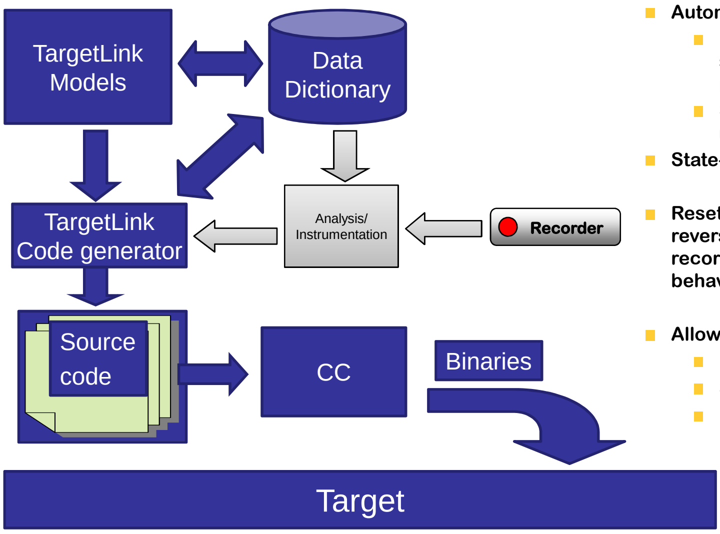
A Step Further: Replication



Simulink/TargetLink ZealCore System Recorder Integration



- Automatic minimal set
  - Identification of stimuli and persistent state
  - Source code modification
- State-of-the-art recorder
- Resetting state and reversing stimuli from recording replays system behavior
- Allows replay on
  - Binary level
  - Source code level
  - Model level

Summary

- There is an increasing need for debugging methods that can handle system level faults
  - The ever increasing complexity of software
    - Abstraction & computer aided analysis
  - Need to handle
    - Observability
    - Reproducibility
  - Equally important
    - Field debugging
    - Lab debugging

Challenges

The ever increasing complexity of software in terms of size but also concurrency and timeliness:

- How to achieve confirmation (regression) testing on the system level (i.e., taking concurrency and real-time aspects into account)
- How to monitor software using technologies that scale to deployed systems, i.e., large populations of systems with minimal and predictable probe-effects (new systems as well as legacy)
- How to increase the use of the collected/monitored information such that it can be understood by people or automatically analyzed by computers for debugging, or testing.
- How to manage the collected information over time
  - How to make trend or regression analysis based on historical data.
- How to achieve reproducible debugging environments (problem related to confirmation testing)

- Equally important
  - Field use
  - Lab use

THANK YOU!

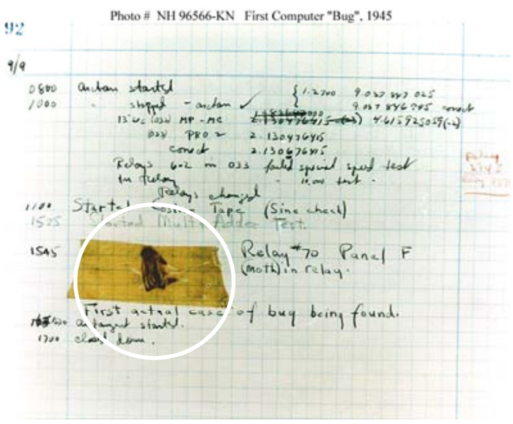


Figure 1. Allegedly the first computer bug - found by Grace Hopper's Team in 1945. Exhibited at the Museum History of American Technology/Smithsonian

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