High Confidence Embedded Systems

ARO Workshop, May 1-2, 2003

Industry Session – Tim Johnson

GE Global Research

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Industrial Motivation for High Confidence Embedded Software

- Increasing use of software in all products
- Increasing complexity of programming languages and constructs
- Requirements and coding are manual processes – need executable specifications
- Composability, distributed systems
- Software is the final common path to end product performance.

Software Disasters (MIT Tech Review, July 2002)

- Ariane 5 Launch
- NASA Mars Polar Lander Mission
- Radiation Therapy Overdose
- London Ambulance System Shutdown
- Civil Aircraft mistaken for military target
- Basic coding error rate: 100-150 errors/KLOC (professional programmers)

Some GE Products with Embedded Software

- Aircraft Engines
- Appliances
- Power Systems
  - Turbines
  - Generators
  - Substation Automation
- Locomotives
  - RR Signaling
- Industrial Systems
  - Breakers
  - Distribution Equipment
  - Security
- Medical Equipment
  - MR, X-Ray, CT
  - Hospital Networks
- MSNBC Next?

Many Standards must be Satisfied!

CENELEC: European Committee for Electromechanical Standardization.

Development of products which conform to European Standards for Homologation requires strict adherence to the criteria for:

- Quality Management
- Safety Management
- Technical Safety Reports

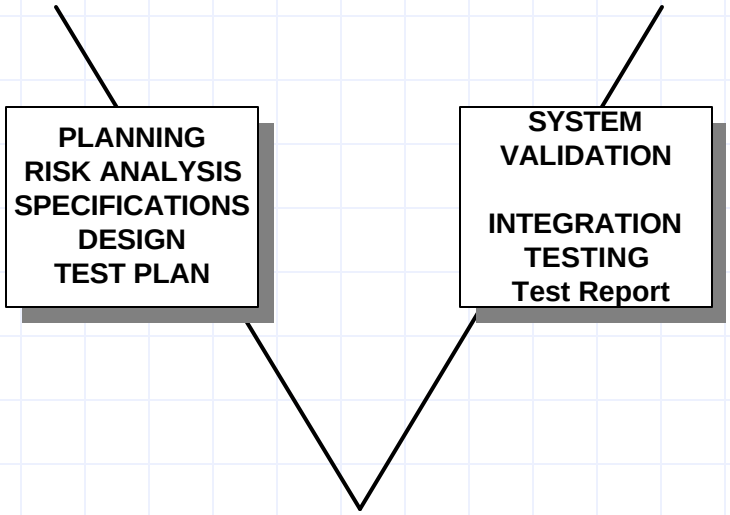
The norms are applied either "entirely" or "partially" depending on the required System Safety Integrity level [SIL] which is to be achieved

Verification is the activity which, through analysis and testing, checks that the result of every phase of the lifecycle is in accordance with CENELEC norms.

Validation is the activity that, through analysis and testing, checks that all the specified requirements are respected in accordance with CENELEC norms.

The process of **Verification** occurs at the end of each phase of the product development and it is therefore a "Top-Down" process.

By contrast, **Validation** is a "Bottom-Up" process starting from the lowest levels.



Traditional V&V Processes Are Manual – Cost/Reliability are Strong Automation Drivers

Safety Integrity Levels (SIL's)

SIL = 0 non-safety-related

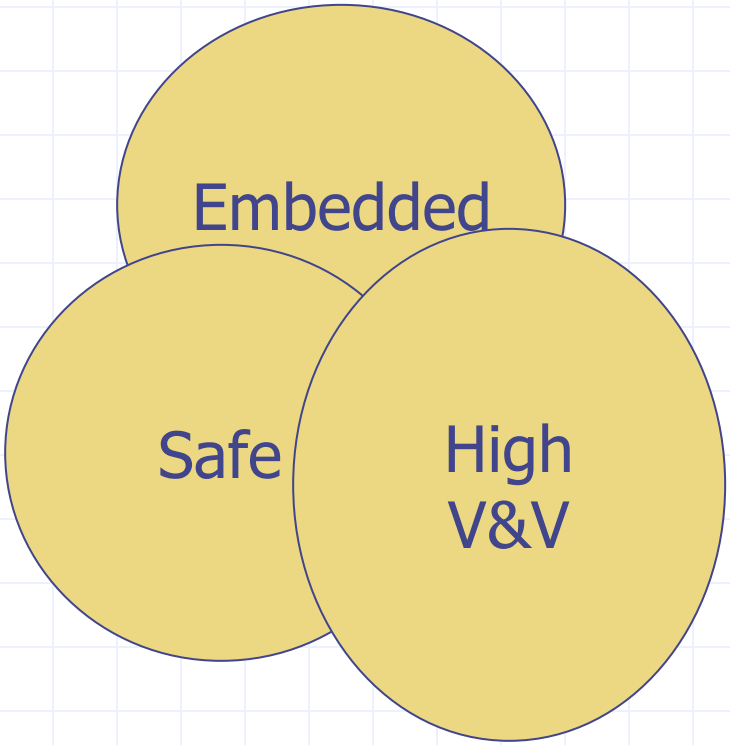
SIL = 2 only some specific functions are safety-related

SIL = 4 this is the maximum requirement level and is applied to all functions.

Many Control Systems are SIL = 4!

Embedded Systems, Safety, & V&V

- Partial overlap
- Embedded designs usually driven by performance requirements
- Safety may involve both embedded and non-embedded functions
- V&V needs usually high for both safety and embedded systems



Different Institutional Stakeholders Increase Complexity

Software Safety System Working Group
MIT, February 2003 – N. Leveson

Software System Safety Working Group 2003 Workshop - Microsoft Internet Explorer

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Address http://sunnyday.mit.edu/safety-club/workshop3/

3rd Meeting of the
U.S. Software System Safety Working Group
February 25th-27th 2003
@ MIT in Cambridge MA USA

The next neeting of the USSSWG will be February 25-27 at the MIT Stratton Center in Cambridge, Massachusetts. This year we will try something different---a real "working" workshop where the attendees can all interact and learn from each other instead of simply listening to a few people speak. The goal is to learn about, compare, and evaluate the different approaches used for dealing with safety in software-intensive systems.

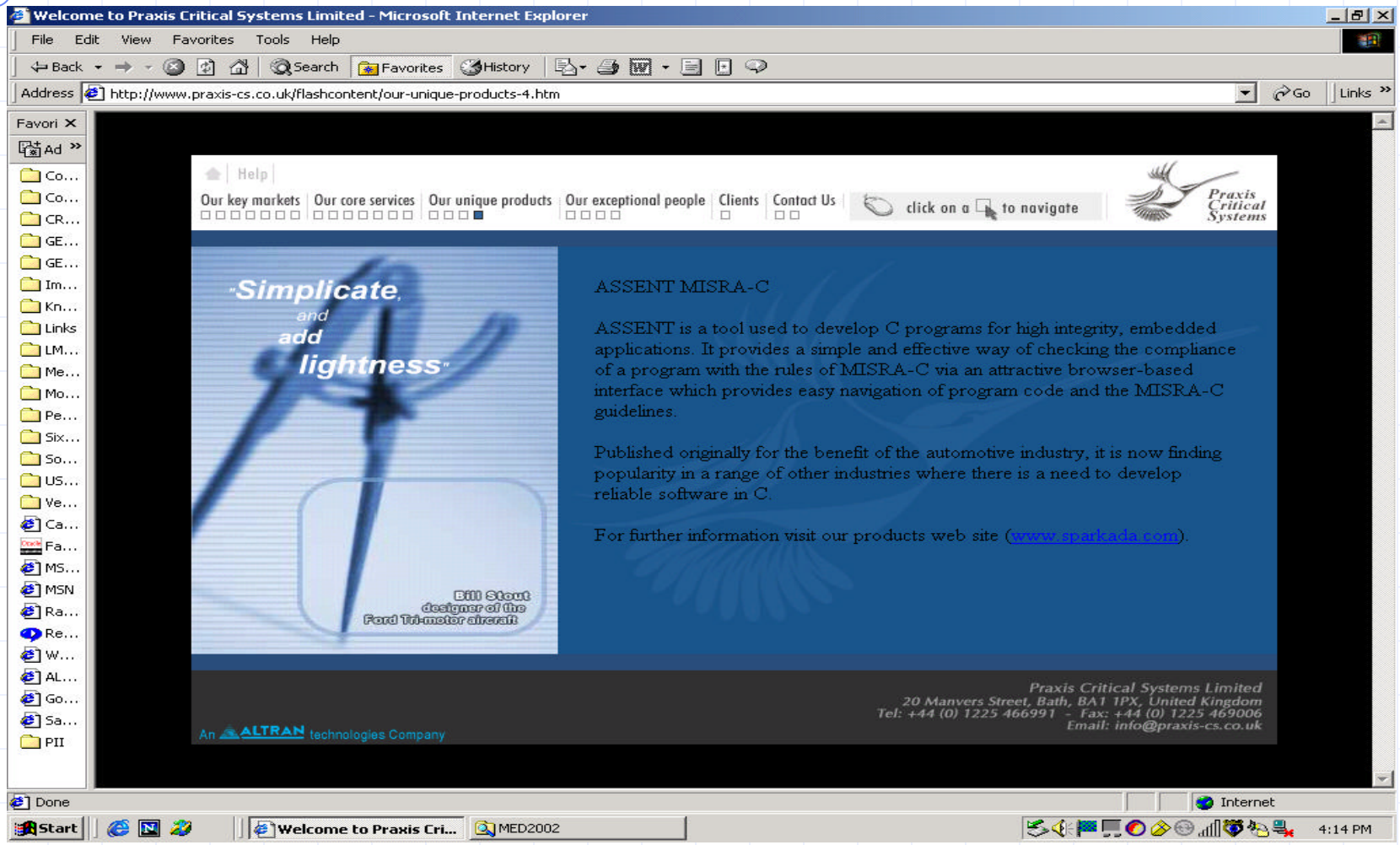
We will provide problems for small groups to work on together. The results of the small groups will be presented to the larger group for comparison and discussion. The example application and questions to be answered will be available before the workshop so attendees can think about them beforehand (although that is not necessary). The topics will include:

- hazard identification
- the safety engineering process
- hazard analysis
- requirements analysis
- COTS
- tool qualification
- hazard control (design for safety)

Good academic/industry/government mix

ADI's BEACON Successful in Aircraft Engines Use – Initiated at GE Research

Praxis Critical Systems – Commercial Tools



HyTech – Hybrid System Verification "Startup"

HyTech Home Page - Microsoft Internet Explorer

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Address http://www-cad.eecs.berkeley.edu/~tah/HyTech/ Go Links

HyTech: The HYbrid TECHnology Tool

HyTech is an automatic tool for the analysis of embedded systems. HyTech computes the condition under which a linear hybrid system satisfies a temporal requirement. Hybrid systems are specified as collections of automata with discrete and continuous components, and temporal requirements are verified by symbolic model checking. If the verification fails, then HyTech generates a diagnostic error trace. The standard reference to the HyTech algorithm is [1], and the standard reference to the HyTech tool, [2].

[1] R. Alur, T.A. Henzinger, and P.-H. Ho. *Automatic Symbolic Verification of Embedded Systems.* IEEE Transactions on Software Engineering 22:181-201, 1996.

[2] T.A. Henzinger, P.-H. Ho, and H. Wong-Toi. *HyTech: A Model Checker for Hybrid Systems.* Software Tools for Technology Transfer 1:110-122, 1997.

The HyTech Team

HyTech was developed by *Tom Henzinger*, *Pei-Hsin Ho*, and *Howard Wong-Toi*.

The HyTech Demo

The HyTech Papers

- Introduction, and guide to the literature
- The specification formalism of hybrid automata, and its theory
- The verification algorithm of polyhedral model checking, and some verification examples
- The original tool, and more verification examples

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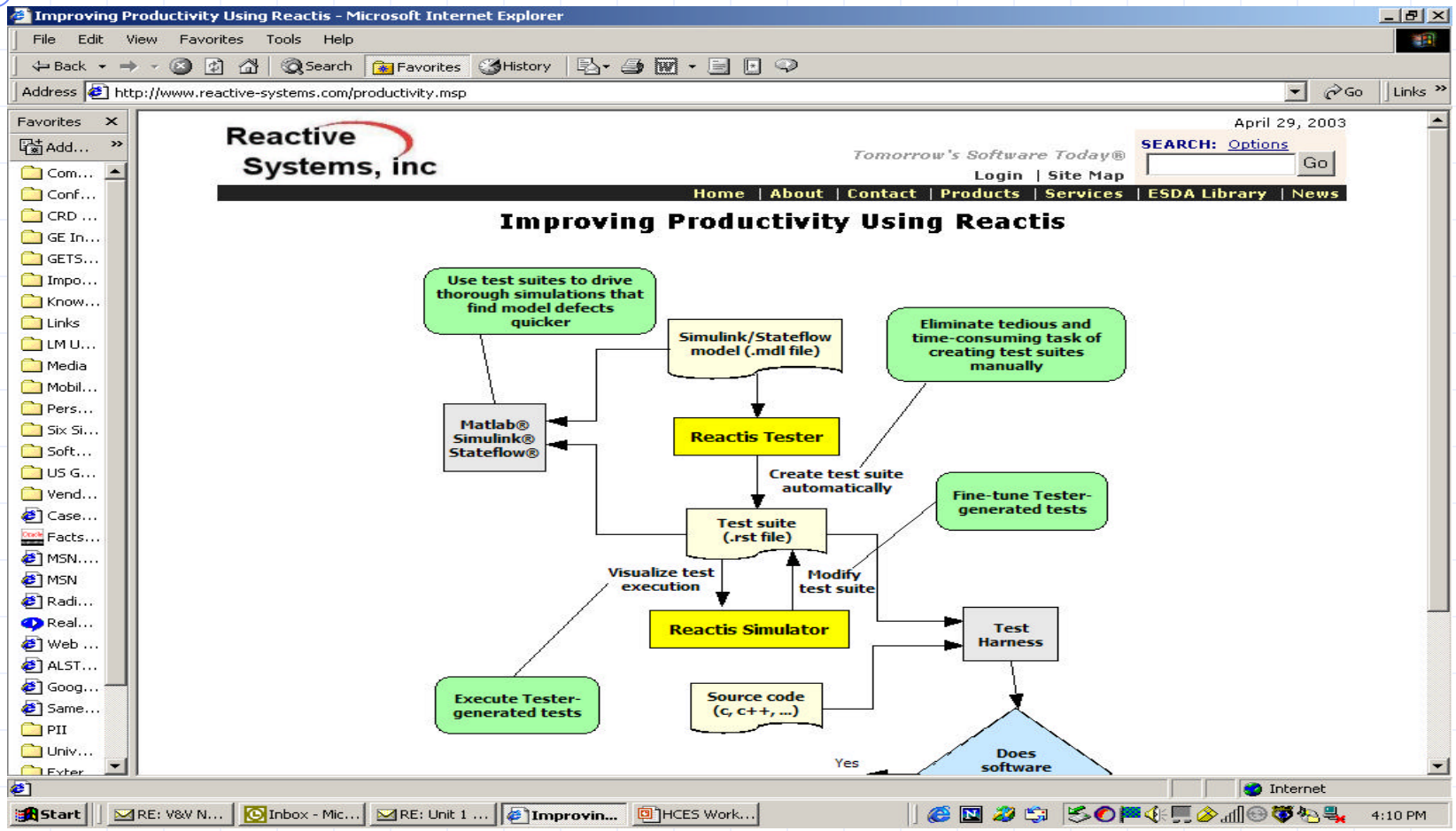
Reactive Systems "Tester" - Recent Commercial Entry



Example: 21st Century Electric Infrastructure Project

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Address http://www.e2i.org/ceids/technical/IECSA.html

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CEIDS

Consortium for Electric Infrastructure to Support a Digital Society

Electricity Innovation Institute

CEIDS Home > Technical Development > Current Projects > IECSA

Integrated Energy and Communications System Architecture

The project will develop an open, standards-based systems architecture for the data communications and distributed computing infrastructure that will enable the integration of a wide variety of intelligent electric power system components. This infrastructure will build upon prior industry infrastructure work, leverage the newest communications and distributed computing technologies available and will provide the interoperability/interworkability foundation for system development. This infrastructure will enable innovative services such as real-time pricing and energy management.

Project Goal

Develop an overall integrated energy and communications system architecture for the data communications networks and intelligent equipment necessary to support the self-healing grid and the integrated consumer communications interface.

Project Objectives

A. Develop a complete set of systems requirements and architecture documents to support industry-wide enterprise architecture for the self-healing grid and integrated consumer communications interface.
B. Contribute project results as appropriate to relevant Standards Development Organizations (SDO's) and industry consortia to effectively move the development of key open standards forward to develop a robust industry infrastructure.
C. Apply Systems Engineering to the development of the architecture including

Discussion Topics

- Are new Certification Standards Needed?
- Embedded Systems Requirements Capture – More rigorous approaches needed?
- Can Simulation of Operating Environment Help with Safety?
- Automatic Code Generation?
- Automatic Test Generation?
- Automatic Verification?
- Transition paths for University Research?