Software Certification In practice

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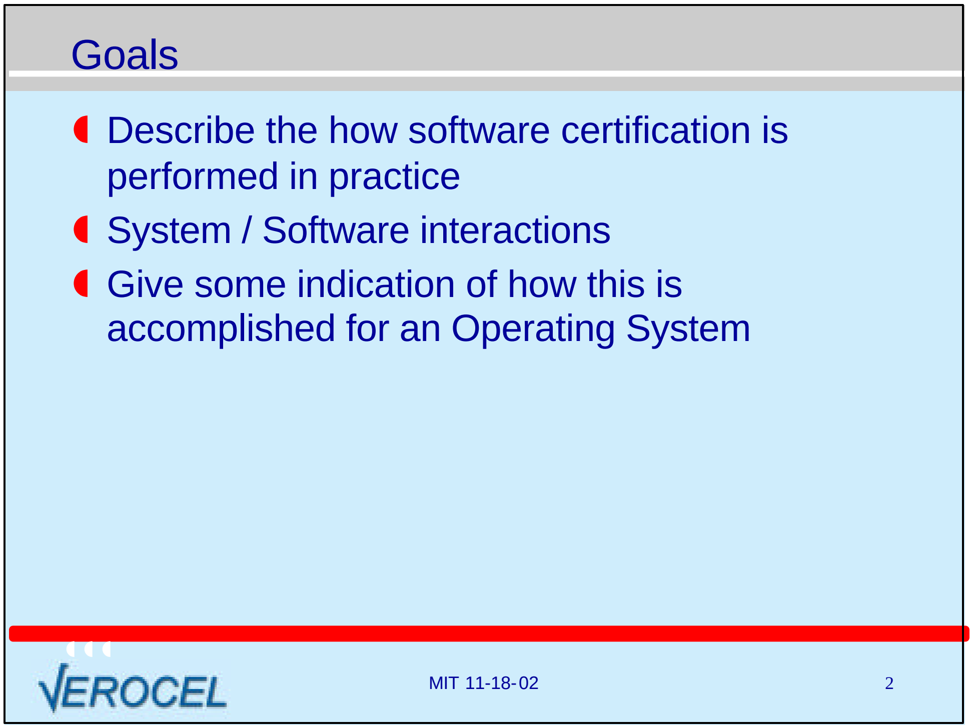
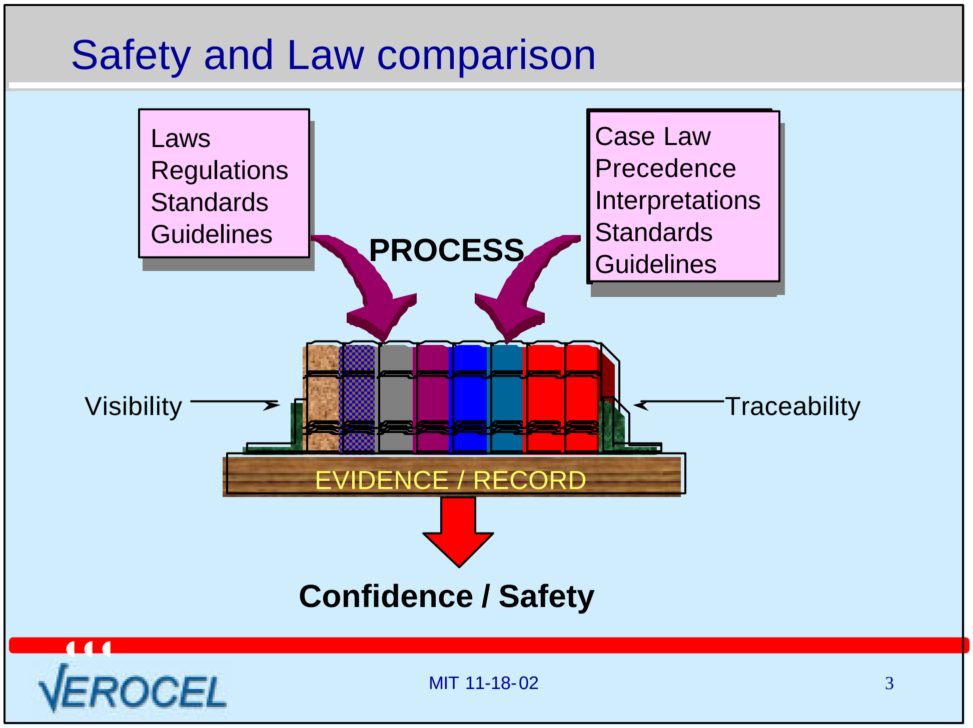


Goals

- Describe the how software certification is performed in practice
- System / Software interactions
- Give some indication of how this is accomplished for an Operating System



Safety and Law comparison

Laws
Regulations
Standards
Guidelines

Case Law
Precedence
Interpretations
Standards
Guidelines

PROCESS

Visibility

Traceability

EVIDENCE / RECORD

Confidence / Safety

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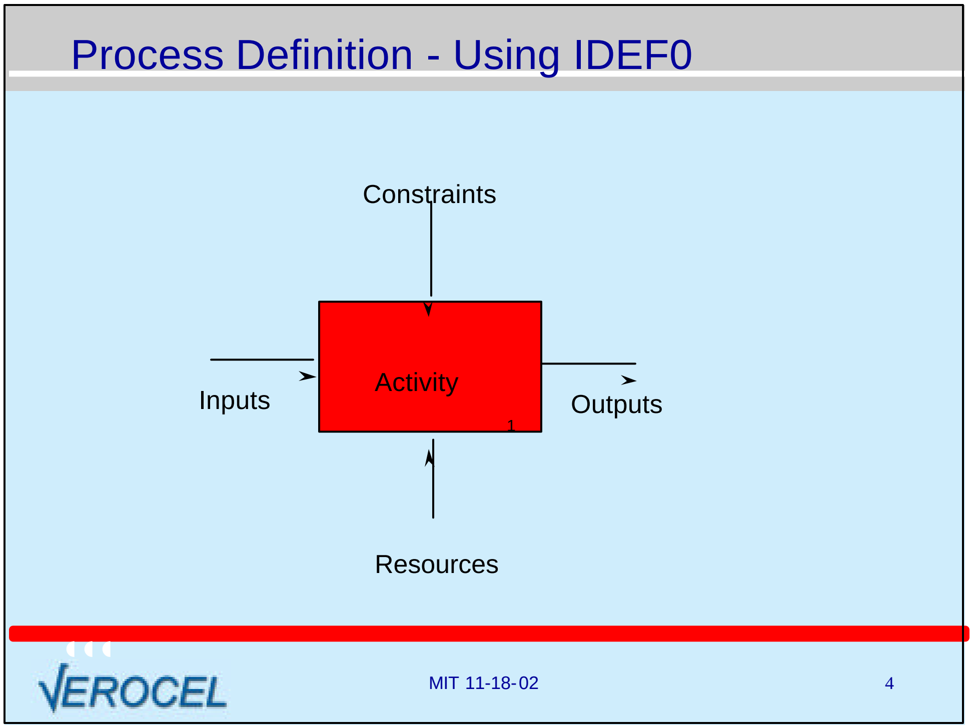

Process Definition - Using IDEF0

Constraints

Inputs

Activity

1

Outputs

Resources

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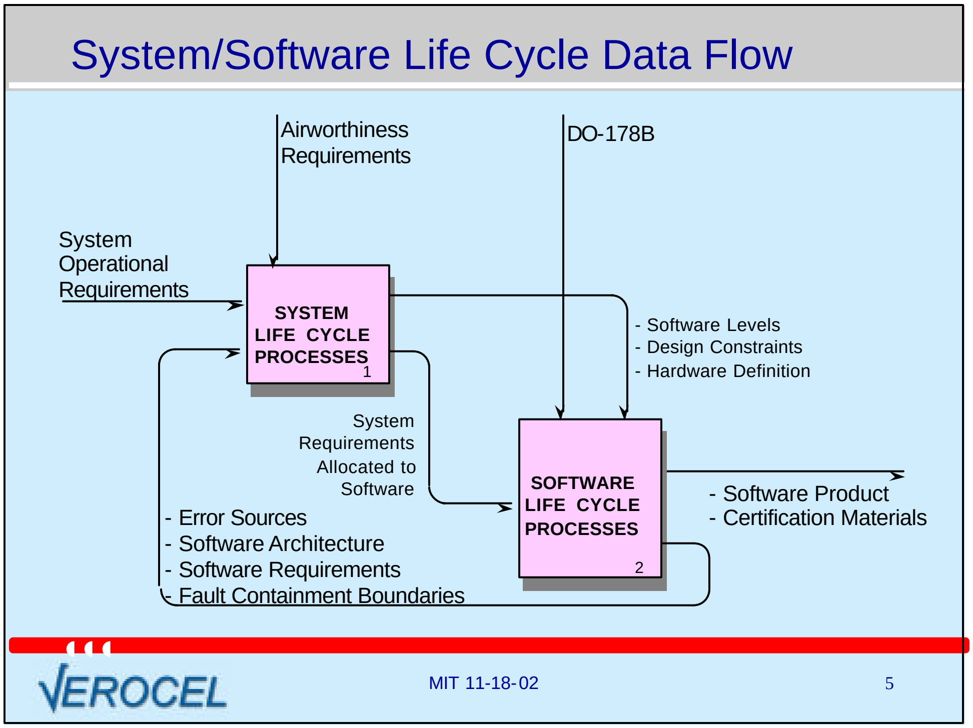

System/Software Life Cycle Data Flow

Airworthiness Requirements

DO-178B

System Operational Requirements

SYSTEM LIFE CYCLE PROCESSES 1

- Software Levels
- Design Constraints
- Hardware Definition

System Requirements Allocated to Software

SOFTWARE LIFE CYCLE PROCESSES 2

- Software Product
- Certification Materials

- Error Sources
- Software Architecture
- Software Requirements
- Fault Containment Boundaries

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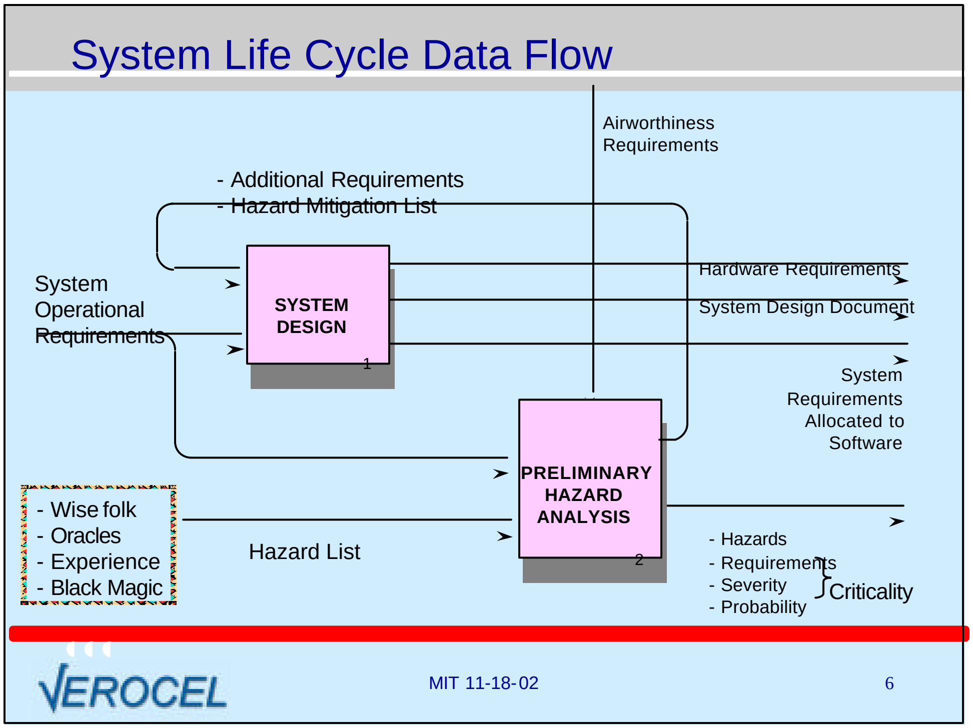

System Life Cycle Data Flow

Airworthiness Requirements

- Additional Requirements
- Hazard Mitigation List

System Operational Requirements

SYSTEM DESIGN 1

Hardware Requirements

System Design Document

System Requirements Allocated to Software

PRELIMINARY HAZARD ANALYSIS 2

- Wise folk
- Oracles
- Experience
- Black Magic

Hazard List

- Hazards
- Requirements
- Severity
- Probability

} Criticality

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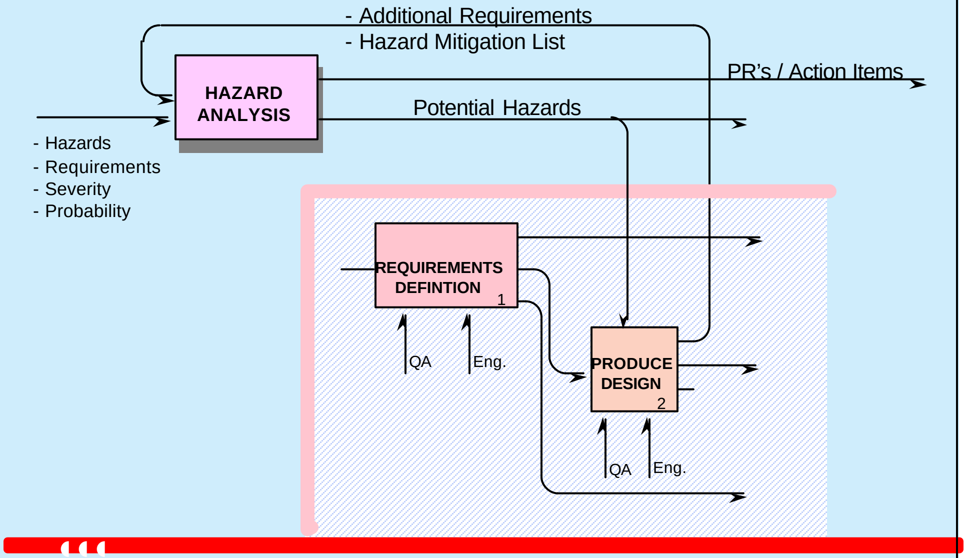
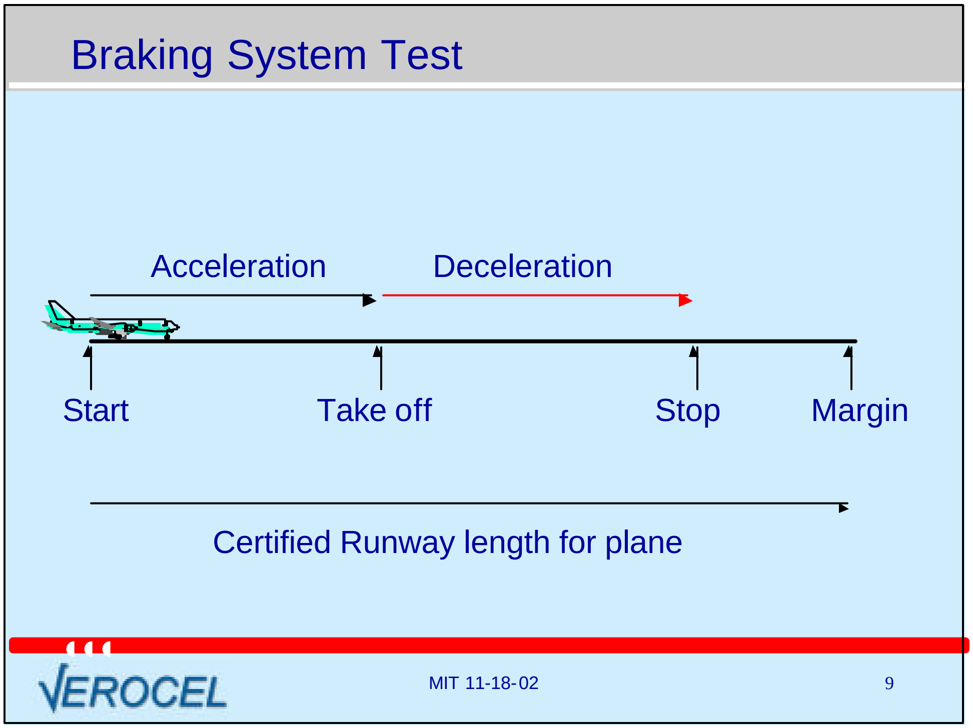
Subsystem Hazard Analysis



Braking System

- Boeing 777 – 14 wheels
- Each wheel has a braking system
- Each braking system has a computer (MC68332)
- Computer software verified independently
- System Test is required



Braking System Test

Acceleration

Deceleration

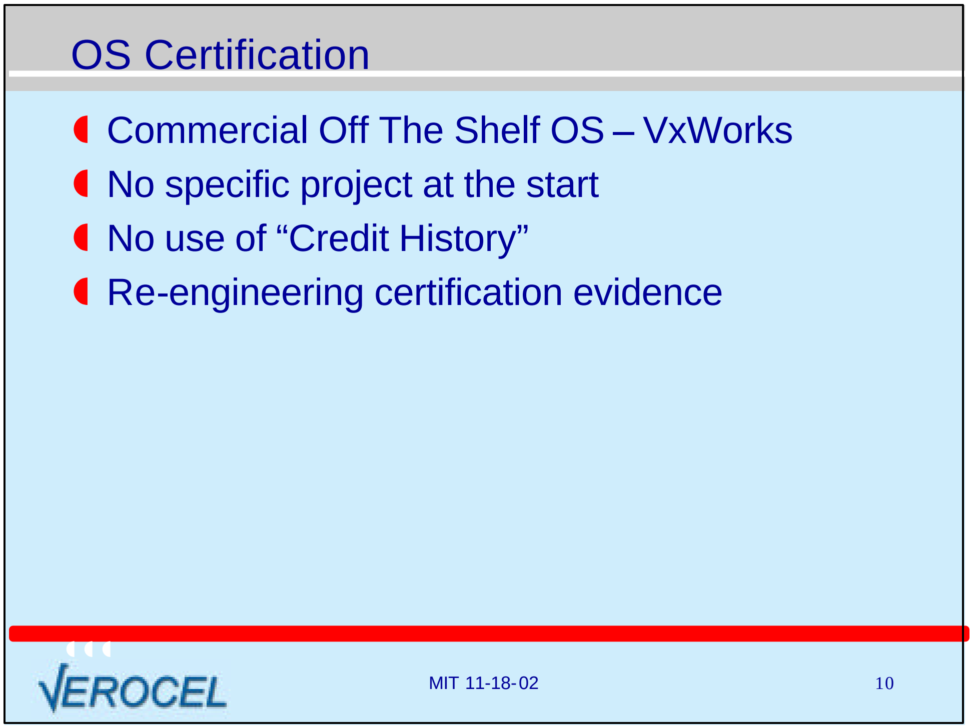
Start

Take off

Stop

Margin

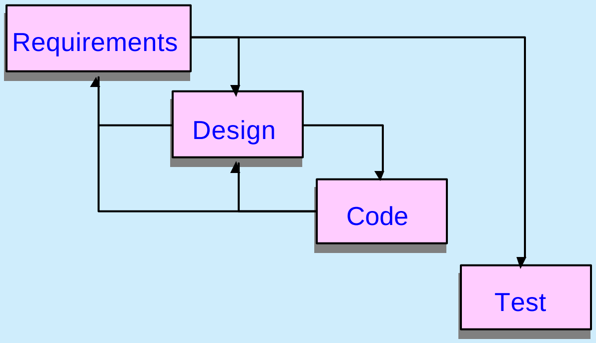
Certified Runway length for plane



OS Certification

- Commercial Off The Shelf OS – VxWorks
- No specific project at the start
- No use of “Credit History”
- Re-engineering certification evidence

Waterfall model



Requirements

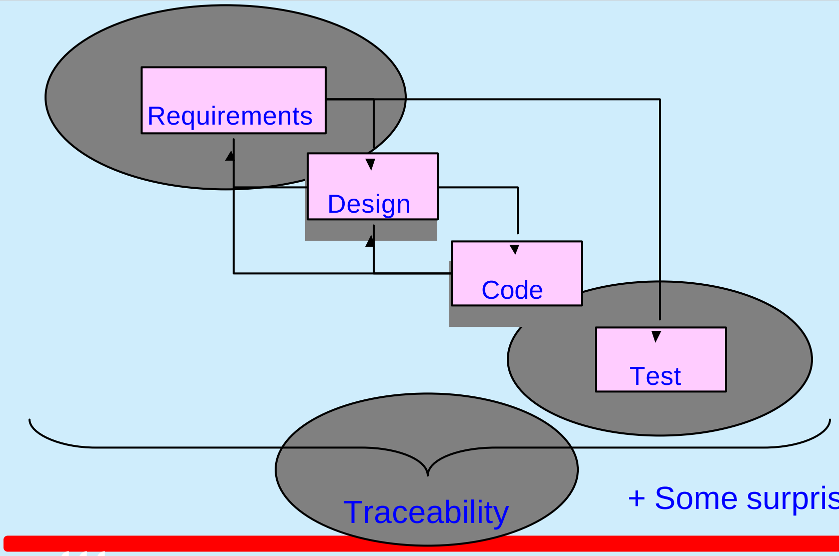
Design

Code

Test

Traceability

Focus on – Requirements, Test, Traceability



Requirements

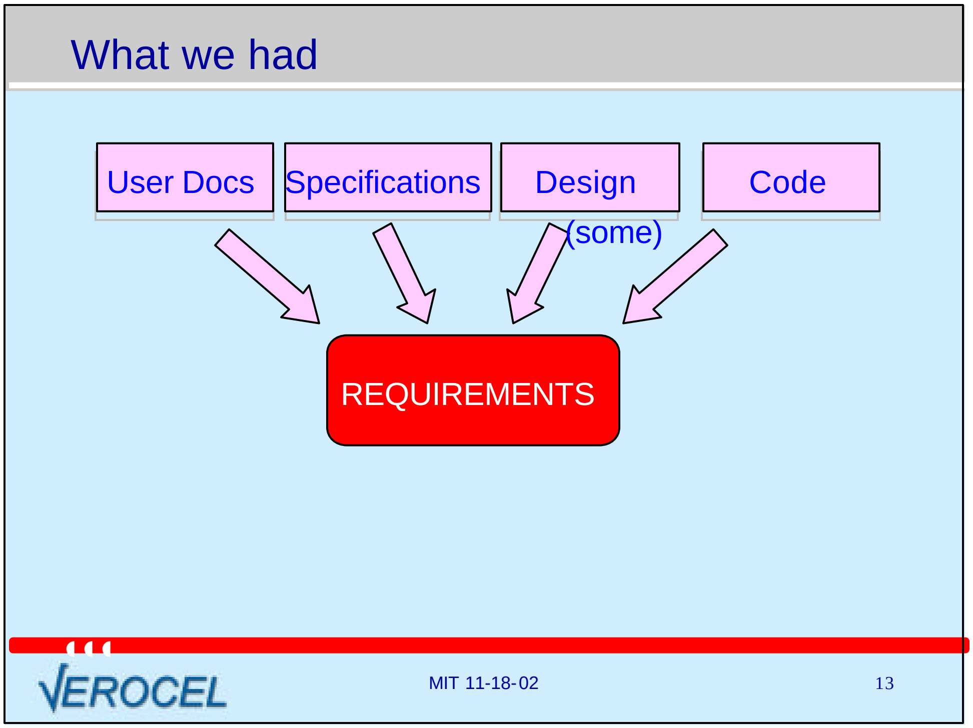
Design

Code

Test

Traceability

+ Some surprises



What we had

User Docs

Specifications

Design

Code

(some)

REQUIREMENTS

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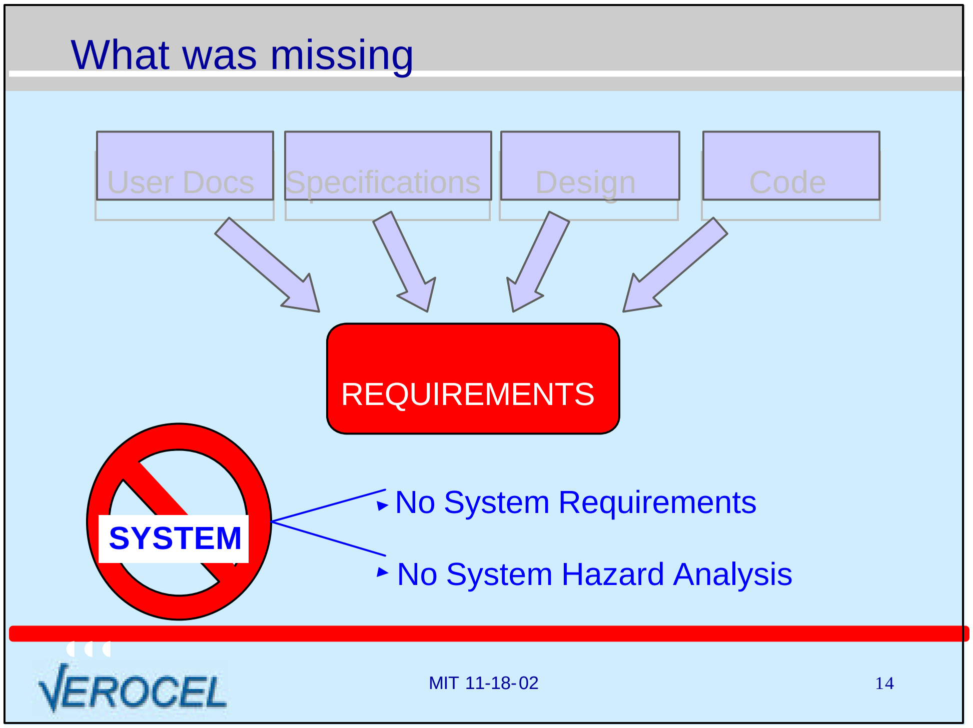

What was missing

User Docs

Specifications

Design

Code

REQUIREMENTS

SYSTEM

- No System Requirements
- No System Hazard Analysis

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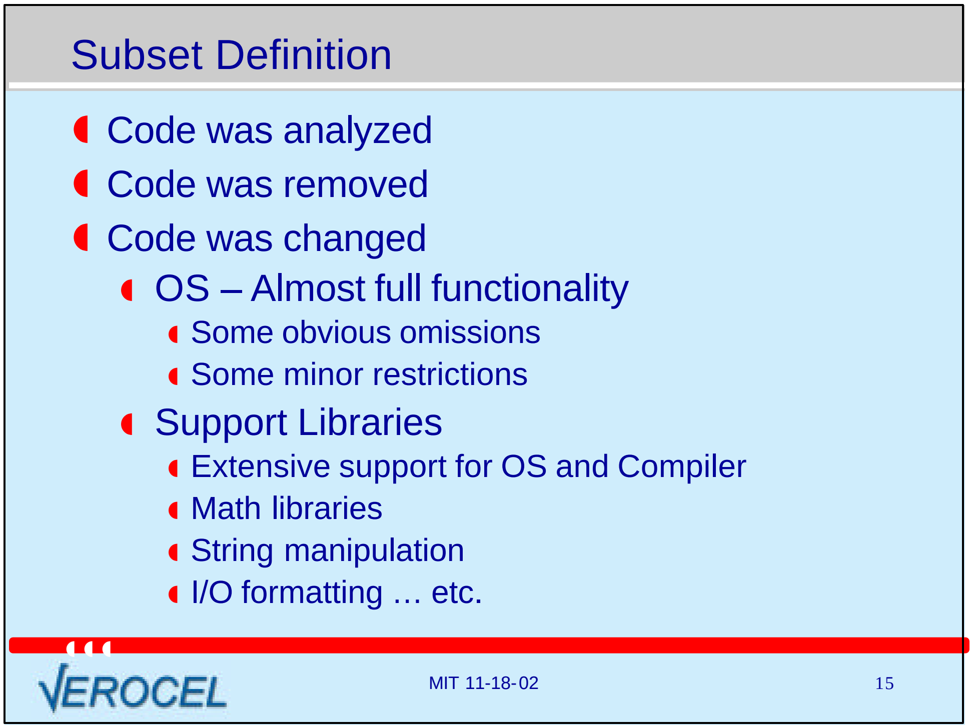
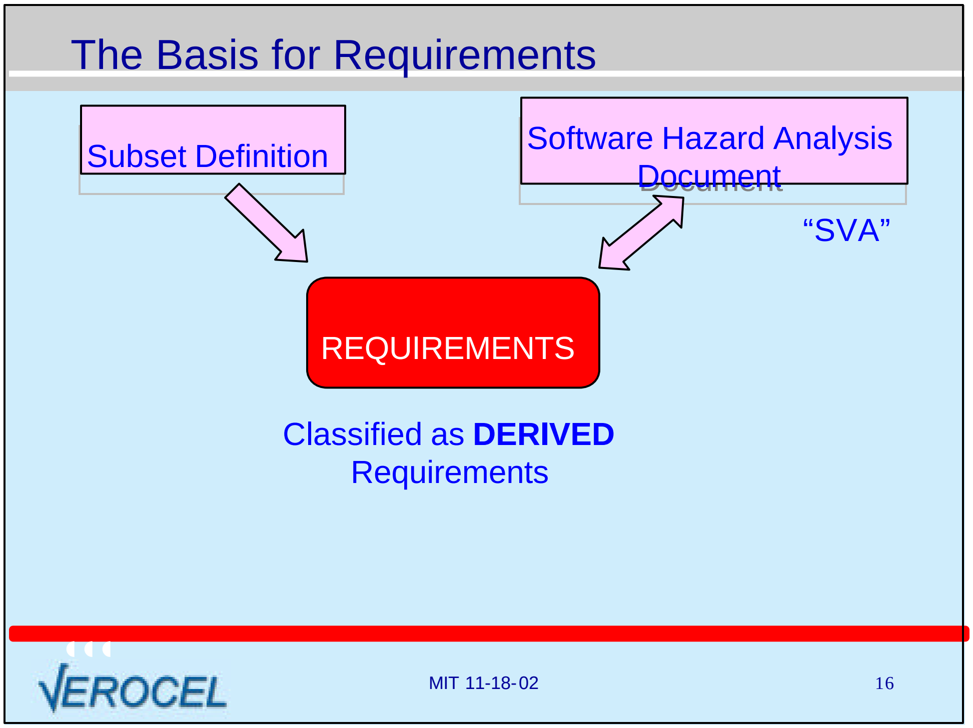


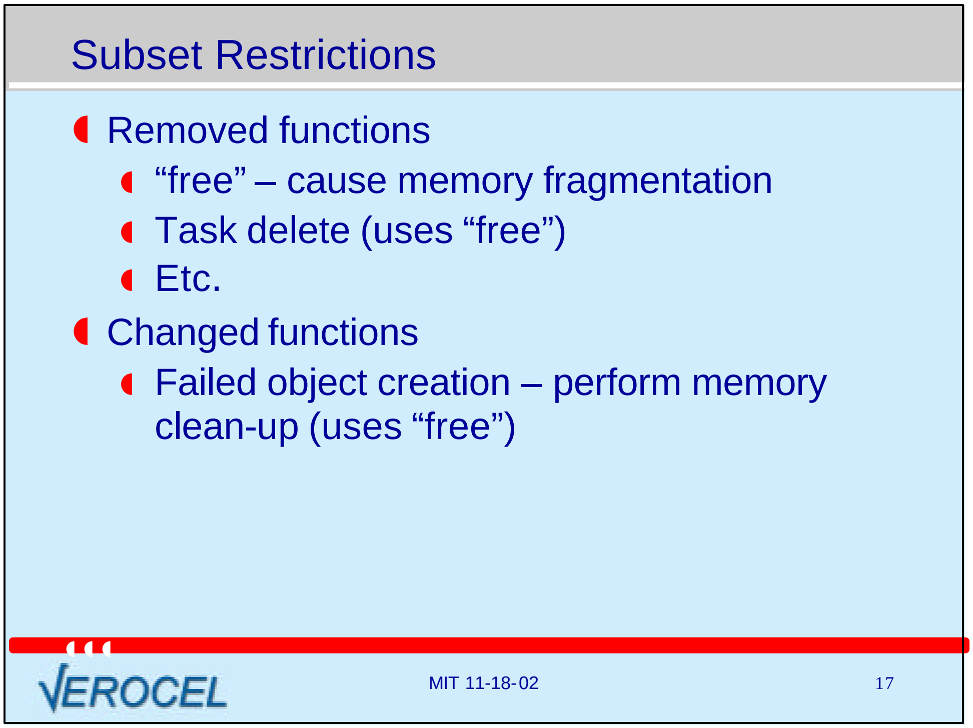
Subset Definition

- Code was analyzed
- Code was removed
- Code was changed
  - OS – Almost full functionality
    - Some obvious omissions
    - Some minor restrictions
  - Support Libraries
    - Extensive support for OS and Compiler
    - Math libraries
    - String manipulation
    - I/O formatting … etc.



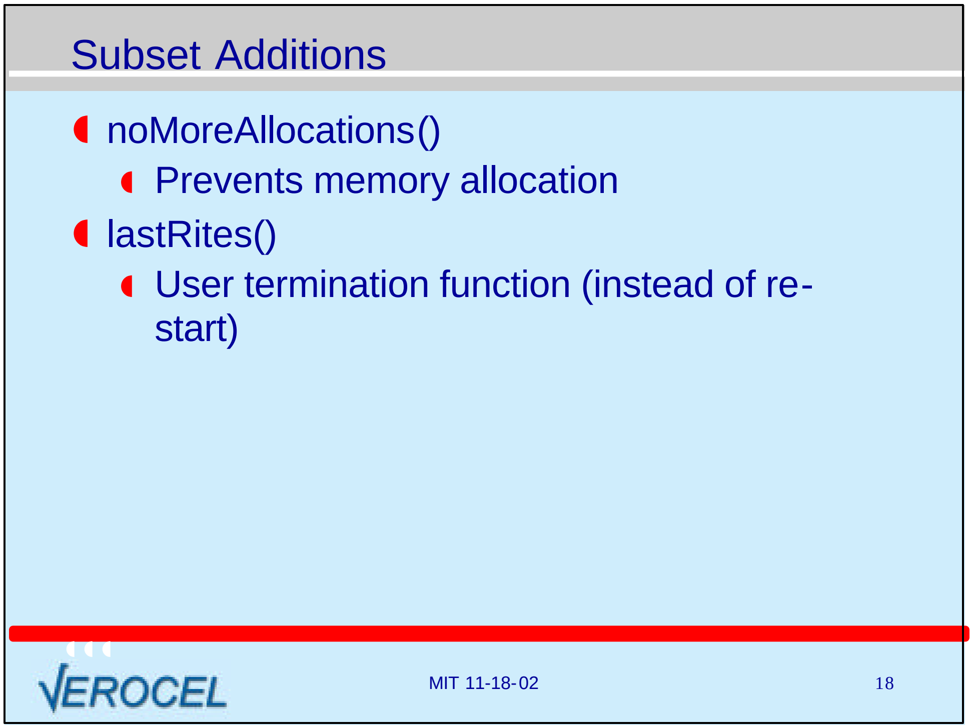
The Basis for Requirements

Classified as **DERIVED** Requirements



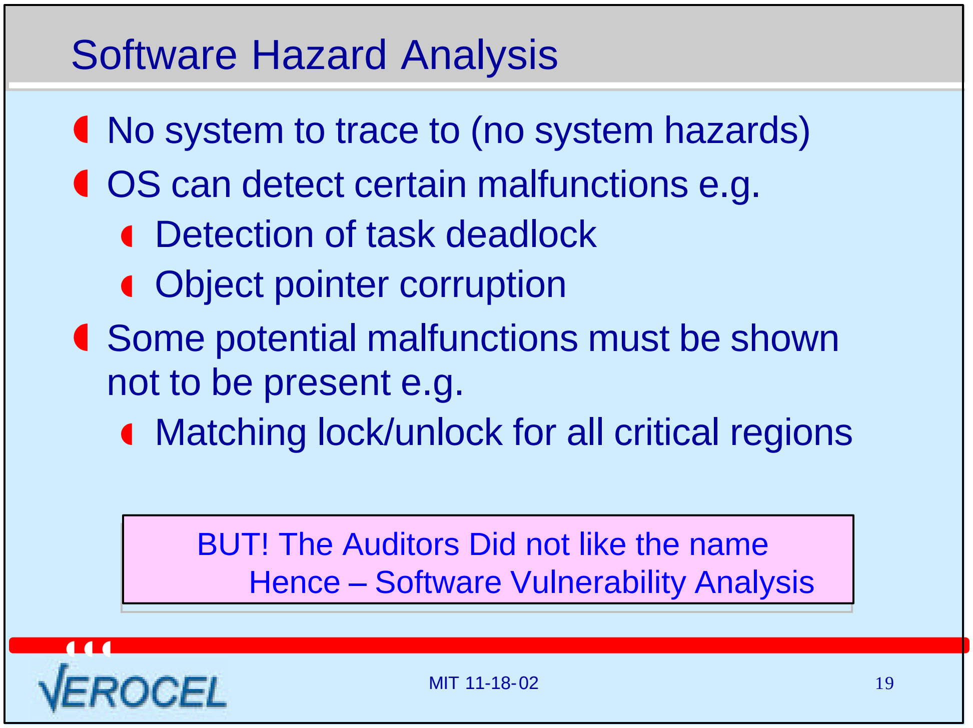
Subset Restrictions

- Removed functions
  - “free” – cause memory fragmentation
  - Task delete (uses “free”)
  - Etc.
- Changed functions
  - Failed object creation – perform memory clean-up (uses “free”)



Subset Additions

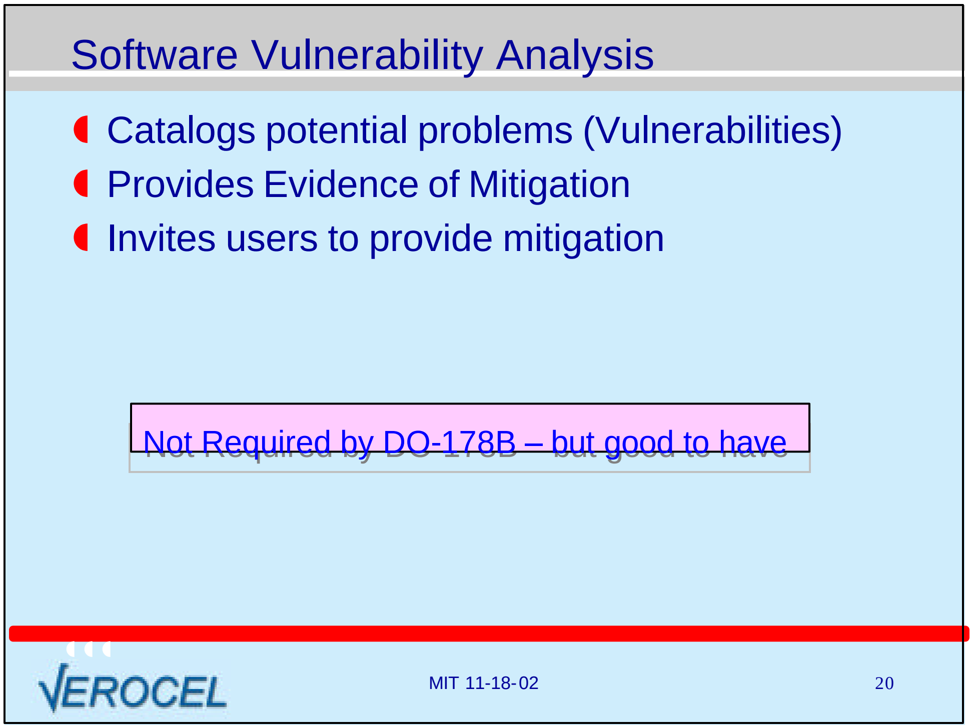
- noMoreAllocations()
  - Prevents memory allocation
- lastRites()
  - User termination function (instead of re-start)



Software Hazard Analysis

- No system to trace to (no system hazards)
- OS can detect certain malfunctions e.g.
  - Detection of task deadlock
  - Object pointer corruption
- Some potential malfunctions must be shown not to be present e.g.
  - Matching lock/unlock for all critical regions

BUT! The Auditors Did not like the name
Hence – Software Vulnerability Analysis

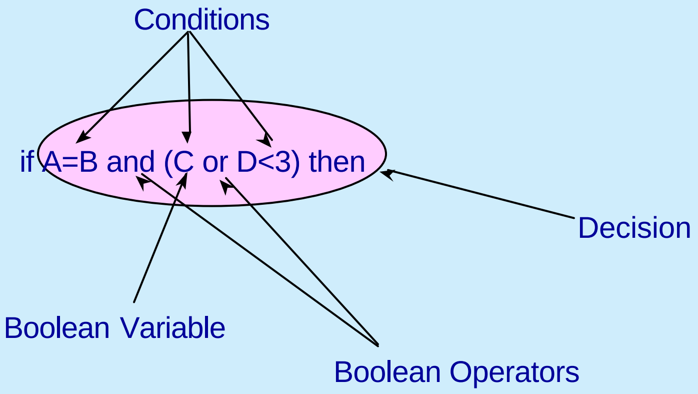


Software Vulnerability Analysis

- Catalogs potential problems (Vulnerabilities)
- Provides Evidence of Mitigation
- Invites users to provide mitigation

Not Required by DO-178B – but good to have

Conditions/Decisions



Conditions

if A=B and (C or D<3) then

Decision

Boolean Variable

Boolean Operators

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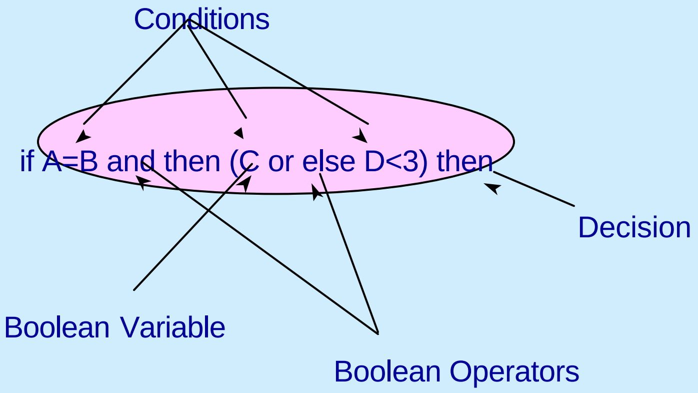
Short –Circuit Forms



Conditions

if A=B and then (C or else D<3) then

Decision

Boolean Variable

Boolean Operators

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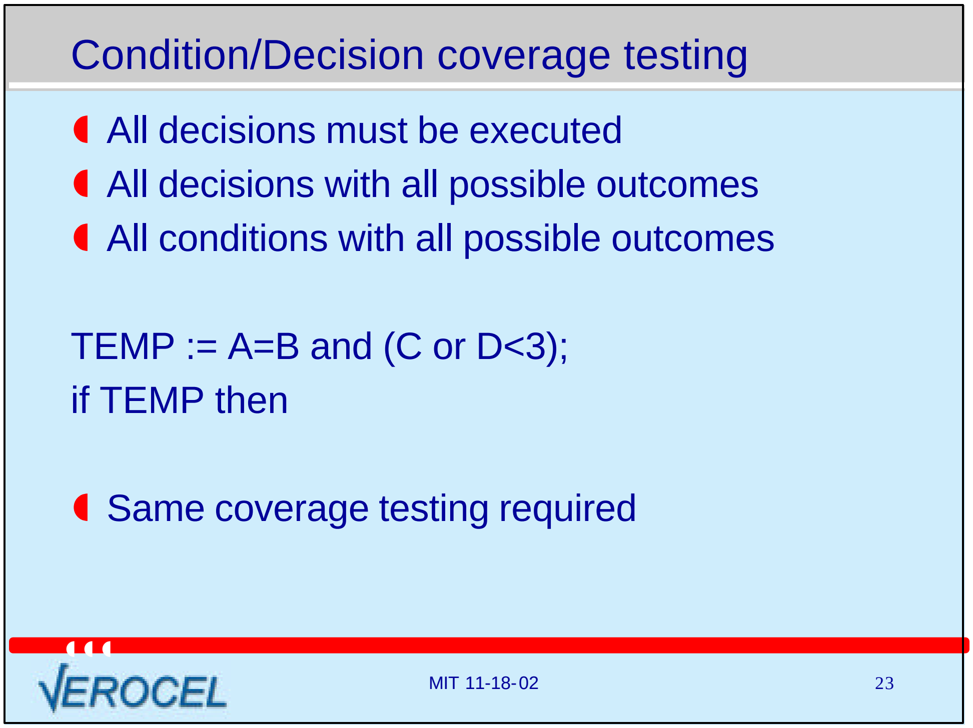
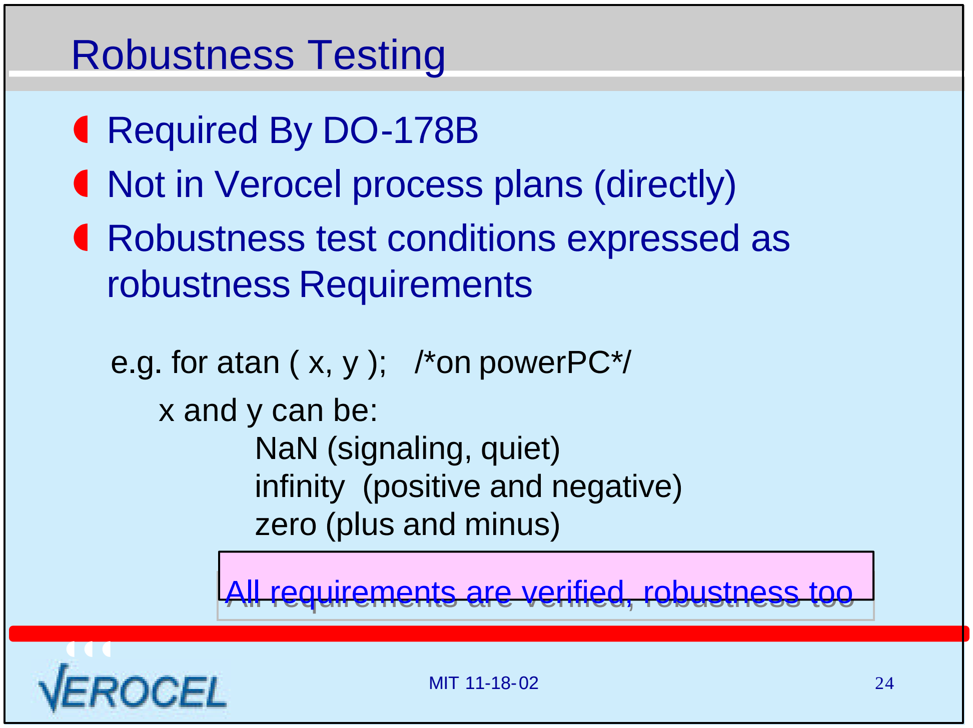


Condition/Decision coverage testing

- All decisions must be executed
- All decisions with all possible outcomes
- All conditions with all possible outcomes

TEMP := A=B and (C or D<3);
if TEMP then

- Same coverage testing required



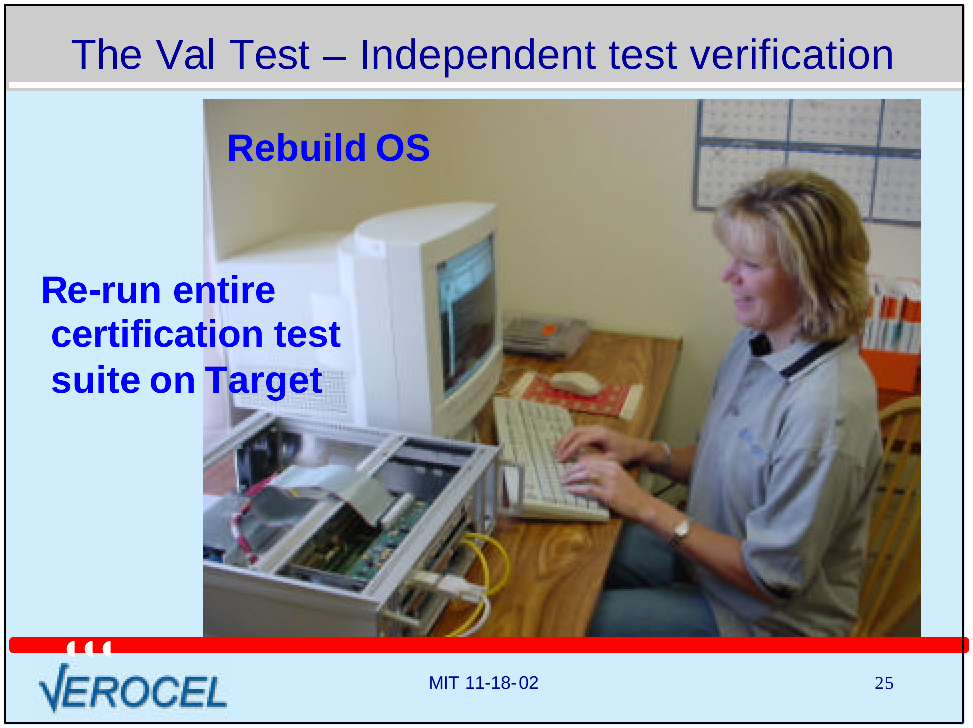
Robustness Testing

- Required By DO-178B
- Not in Verocel process plans (directly)
- Robustness test conditions expressed as robustness Requirements

e.g. for atan (x, y); /*on powerPC*/

x and y can be:
NaN (signaling, quiet)
infinity (positive and negative)
zero (plus and minus)

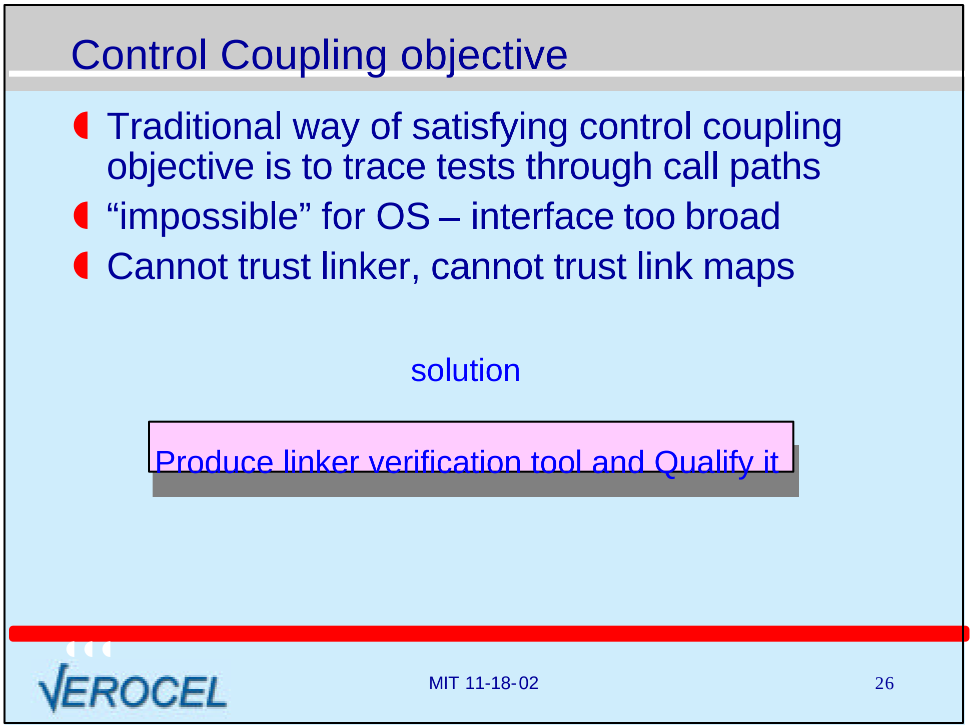
All requirements are verified, robustness too



The Val Test – Independent test verification

Rebuild OS

Re-run entire certification test suite on Target



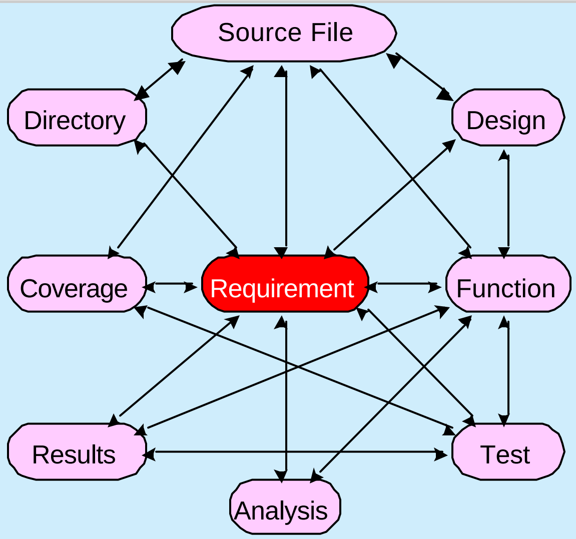
Control Coupling objective

- Traditional way of satisfying control coupling objective is to trace tests through call paths
- “impossible” for OS – interface too broad
- Cannot trust linker, cannot trust link maps

solution

Produce linker verification tool and Qualify it

Requirements are Central to Traceability



Source File
Directory
Design
Coverage
Requirement
Function
Results
Test
Analysis

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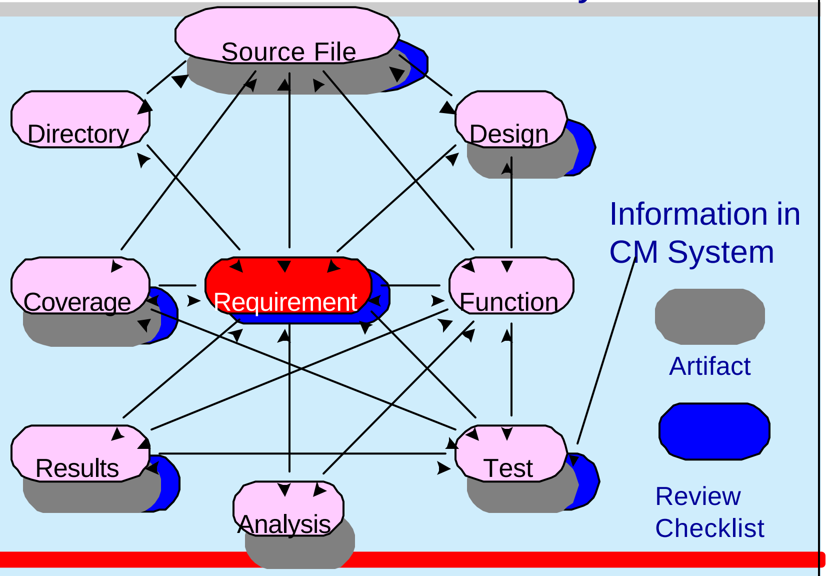
Artifacts/Reviews are held in CM system



Source File
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Information in CM System

Artifact

Review Checklist

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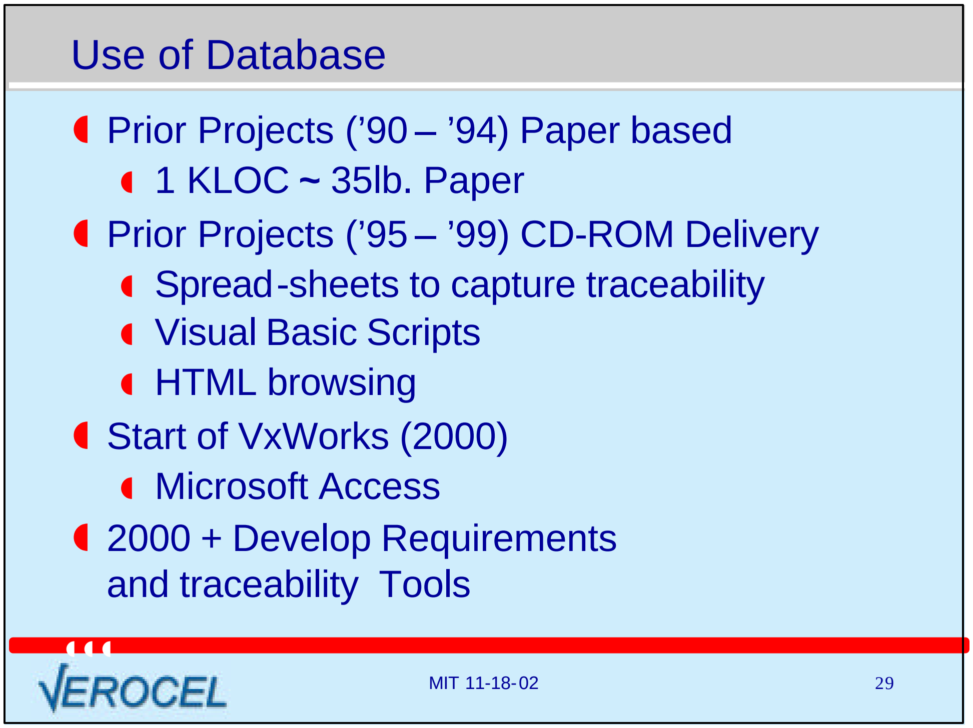
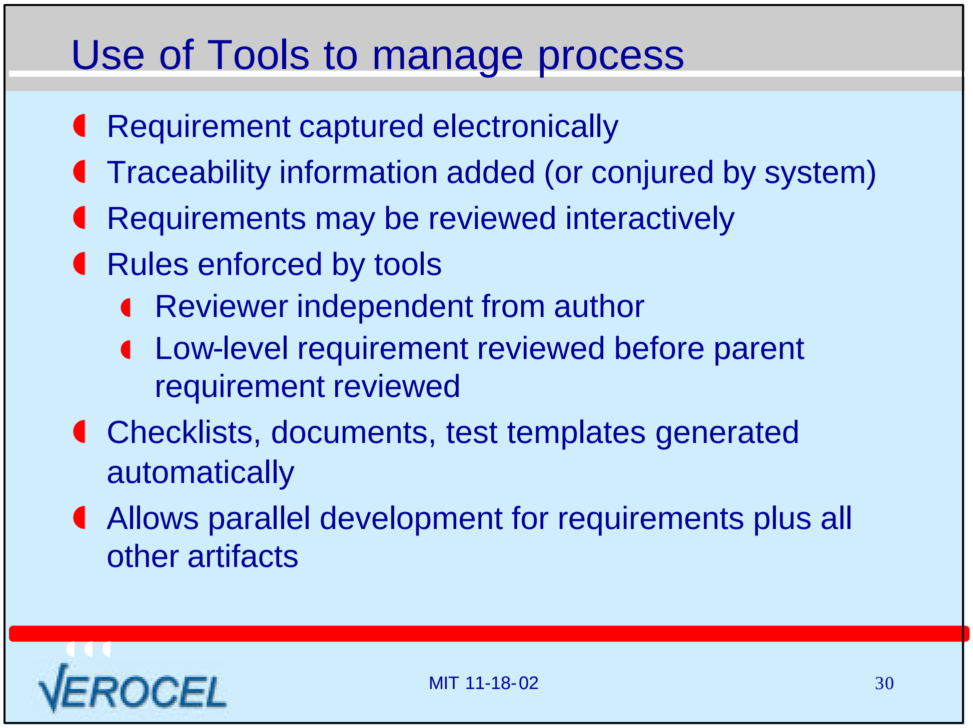


Use of Database

- Prior Projects ('90 – '94) Paper based
  - 1 KLOC ~ 35lb. Paper
- Prior Projects ('95 – '99) CD-ROM Delivery
  - Spread-sheets to capture traceability
  - Visual Basic Scripts
  - HTML browsing
- Start of VxWorks (2000)
  - Microsoft Access
- 2000 + Develop Requirements and traceability Tools



Use of Tools to manage process

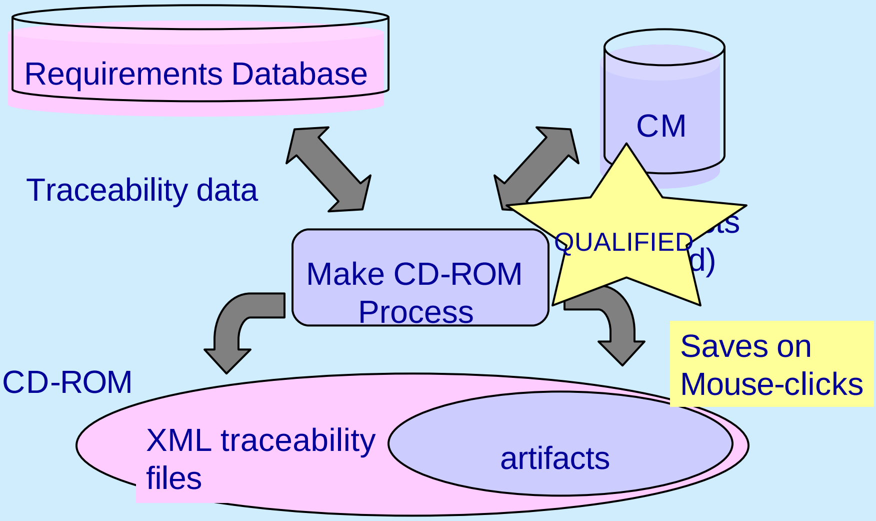
- Requirement captured electronically
- Traceability information added (or conjured by system)
- Requirements may be reviewed interactively
- Rules enforced by tools
  - Reviewer independent from author
  - Low-level requirement reviewed before parent requirement reviewed
- Checklists, documents, test templates generated automatically
- Allows parallel development for requirements plus all other artifacts

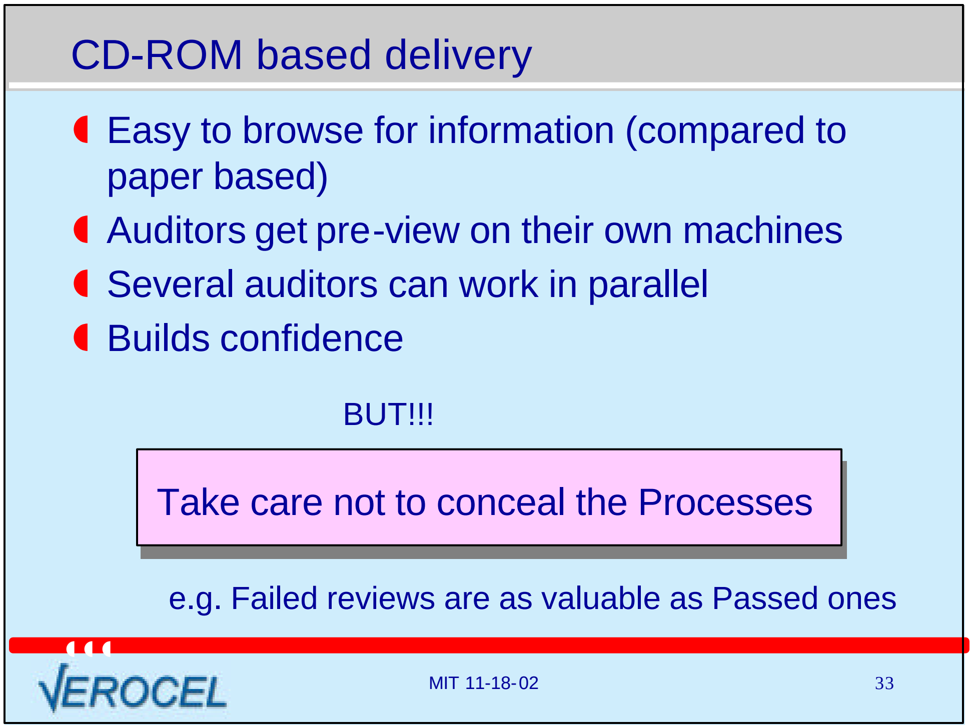
The Numbers – VxWorks/Cert – no BSP

Lines of Code	12,000 *
Requirements	1,300
Test Files	720
Lines of test	48,000
Review Files	2,900
XML Traceability Files	14,600

* Includes many support libraries

Delivery medium – CD-ROM





CD-ROM based delivery

- Easy to browse for information (compared to paper based)
- Auditors get pre-view on their own machines
- Several auditors can work in parallel
- Builds confidence

BUT!!!

Take care not to conceal the Processes

e.g. Failed reviews are as valuable as Passed ones

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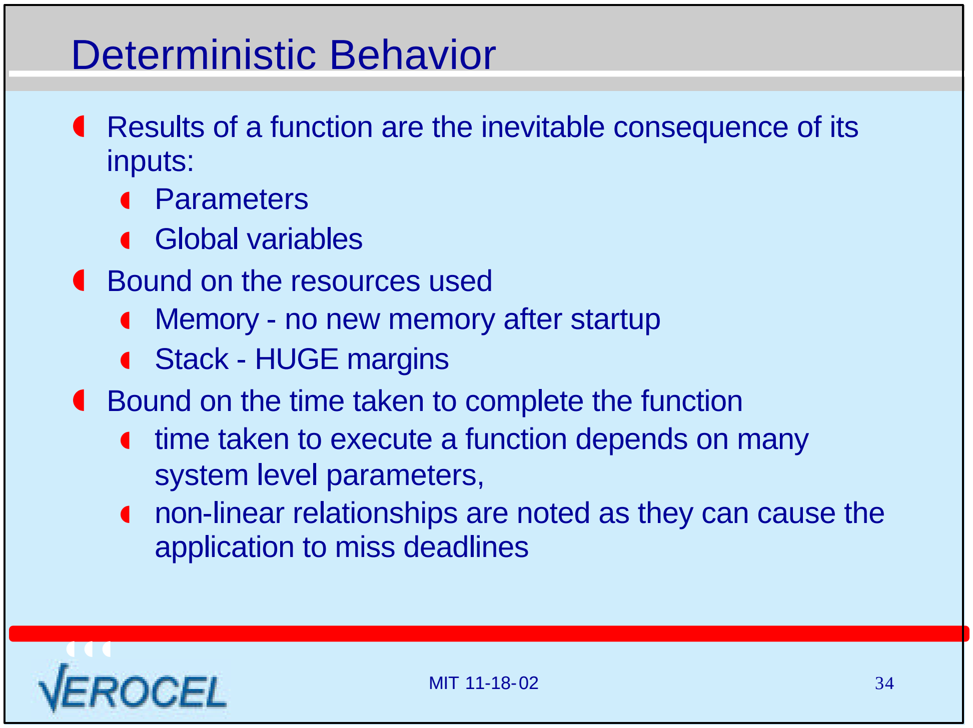

Deterministic Behavior

- Results of a function are the inevitable consequence of its inputs:
  - Parameters
  - Global variables
- Bound on the resources used
  - Memory - no new memory after startup
  - Stack - HUGE margins
- Bound on the time taken to complete the function
  - time taken to execute a function depends on many system level parameters,
  - non-linear relationships are noted as they can cause the application to miss deadlines

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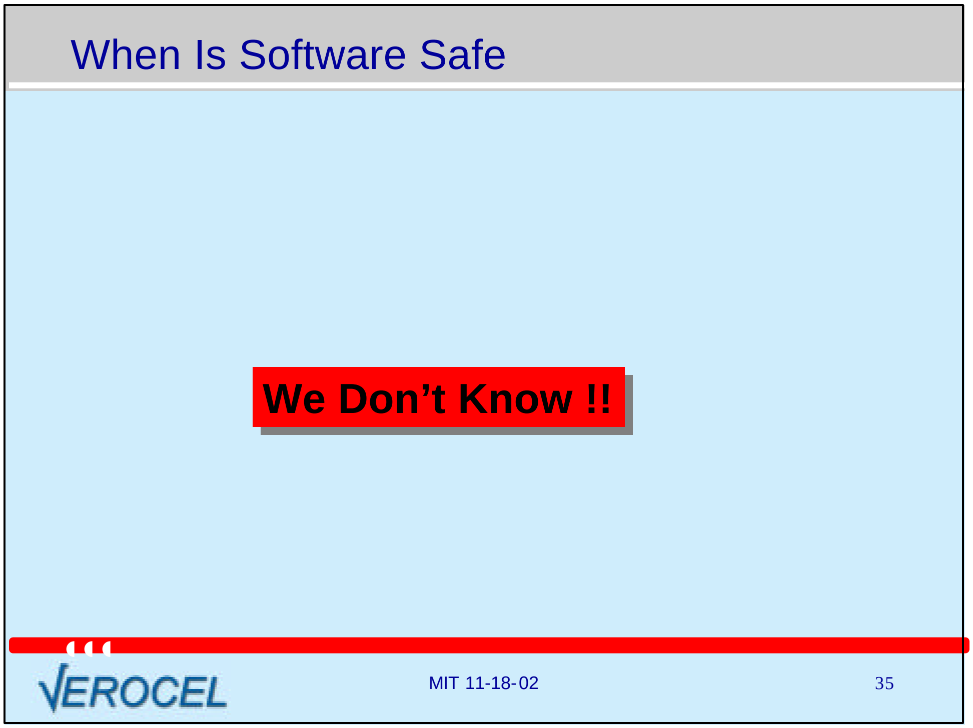

When Is Software Safe

We Don't Know !!

What is our best guess about the safety

- When applicable processes have been followed
- When we have verified the code "from within"
- When this has been checked
  - and checked
  - and checked
  - and checked
  - and checked
  - and checked
  - and checked