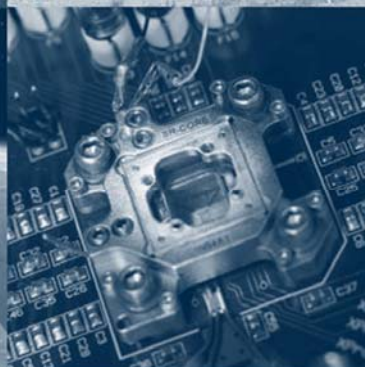
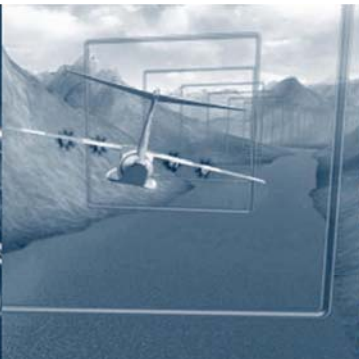


Improved Software Quality with Code Coverage Analysis

Ingo.Nickles@vectorcast.com

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 About Vector Software

Our Company

> Vector Software develops embedded software testing products

- > U.S. Based company founded in 1990 by embedded developers
 - > *First product (Ada) released in 1994 for Lockheed Martin's C-130J "Super" Hercules*
- > Corporate headquarters in Rhode Island
- > Sales and support office worldwide
 - > Providence
 - > Boston
 - > Jacksonville
 - > Denver
 - > Phoenix
 - > London
 - > Kempen (NRW)
 - > Shanghai



solid reference accounts in multiple industries

Aerospace



DO-178B | ED-12B

Automotive



ISO 26262

Medical



FDA | IEC 62304

Railway



CENELEC | EN 50128

Industrial



IEC 61508

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BAE Systems
Cessna Aircraft
EADS
Electric Boat
Goodrich Aerospace
General Dynamics
Hamilton Sundstrand
Honeywell
ITT Communications
India Space Research
Korean Aerospace
Lockheed Martin
L-3 Communications
Northrop Grumman
Pratt & Whitney
Raytheon
Rockwell Collins
Rolls Royce
Saab Group
Thales
Turkish Aerospace
U.S. Air Force
XMobots Robotic

Aerospace



DO-178B | ED-12B

Autoliv
Autoeversystems
AIV
Beko
Bosch
Chang'an Automotive
Delphi
Dongfeng Automotive
ENSO
Fujitsu
Hyundai
Magna Powertrain
Magneti Marelli
MOTONIC
Siemens
TRW
Valeo
Yura

Automotive



ISO 26262

Abbott Laboratories
Acist Medical
Baxter Healthcare
Beckman Coulter
Boston Scientific
Biosafe
Cardinal Health
Covidien
Enteromedics
GE Healthcare
Hoana Medical
Hospira Medical
Impact Instrumentation
Medtronic
Philips Medical
Sirona Dental
Smiths Medical
Terumo Heart
Varian

Medical



FDA | IEC 62304

ABB
Allied Telesis
Alcatel
Ansaldo Signal
Alstom
Brunel
Bombardier
CAP Gemini
Elin EBG
Electro-Motive Diesels
GE Transportation
Invensys Rail
ŠKODA ELECTRIC
Safetran Systems
Siemens
Triconex
Thales
Union Switch & Signal
Verocel

Railway



CENELEC | EN 50128

Amazone
Analog Devices
Arçelik
Bechtel Bettis
Berthold Technologies
British Energy
Brunel
Caterpillar
Changzhou Scale Ltd.
Claas
Endress+Hauser
Flextronics
Foster Miller
General Electric
HAWE Hydraulik
ICS Tripex
Invensys
Ingersoll Rand
Itron
Krauss-Maffei
Mettler Toledo AG
NetApp
Oak Systems
Sanmina
Sunways
ViaSat
Wilco
ZIEHL

Industrial



IEC 61508

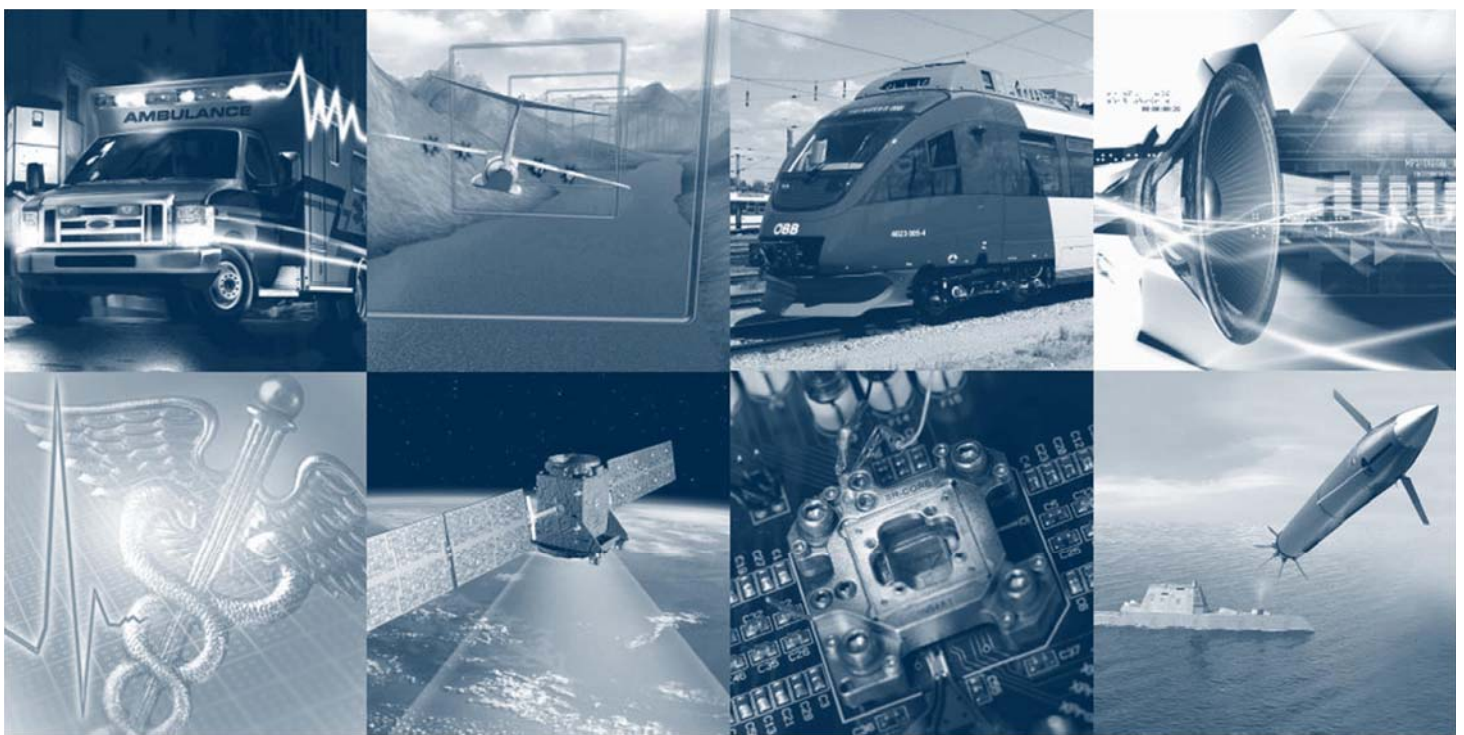
Companies who...

- have safety or business critical applications
- have processes which specify rigorous testing
- have unit and integration testing requirements
- need the ability to automate regression testing
- have requirements to prove code coverage
- realize that **NOT testing... is NOT an option**

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> Understanding Code Coverage Analysis



What is Code Coverage Analysis?

- > Data gathered during execution of an application or a unit test environment
- > Highlights what lines of code have been executed
- > More important is which lines were NOT executed
 - > Indicates poorly tested areas of the application
 - > The more unexecuted code, the more risk of bugs
- > Can be deployed during all phases of testing
 - > Unit testing
 - > Module integration testing
 - > Software integration testing
 - > Functional testing
 - > System testing
- > Can be deployed from different kinds of testing
 - > Requirements based testing
 - > Interface based testing
 - > Code based testing
 - > ...

Other Levels of Testing

> Static Analysis

- > Compliance with coding standards like MISRA
- > MISRA focuses on language restrictions to mitigate reliability faults
- > Finding errors in code statically, by analyzing use of memory for instance

> Dynamic Analysis

> Unit Testing

- > *Testing smallest piece of testable software*
- > *Unit is C/C++ source file or Ada package*
- > *Requires generation of test stubs and drivers*
- > *Driver simulates calling unit and stub(s) simulates called unit*
- > *Enables generation of tests to ensure complete code coverage*

> Integration Testing

- > *Logical extension of unit testing*
- > *Allows testing of all units that make up a functional process*
- > *Requires multiple units under test at the same time*
- > *Identifies problems when units are combined*

Code Coverage Requirements in Different Industries

Requirement	Statement	Branch	MC/DC
DO-178 B/C (Avionics)			
Level A	•	•	•
Level B	•	•	
Level C	•		
ISO-26262 (Automotive)			
ASIL D	•	•	•
ASIL B/C	•	•	
ASIL A	•		
IEC-61508 (Industrial)			
SIL 4	•	•	•
SIL 3	•	•	
SIL 1/2	•		
EN-50128 (Railway)			
SIL 4	•	•	•
SIL 3	•	•	
SIL 1/2	•		
IEC-62304 (Medical)			
Class C	•	•	•
Class B	•	•	
Class A	•		

Levels of Code Coverage

Statement

```
procedure ADD_INCLUDED_DESSERT ( ORDER : in out TYPES.ORDER_TYPE ) is
begin
1   *   if ORDER.ENTREE   = STEAK and
      ORDER.SALAD     = CAESAR and
      ORDER.BEVERAGE  = MIXED_DRINK
      then
2   *   ORDER.DESSERT := PIE;
      elsif ORDER.ENTREE = LOBSTER and
      ORDER.SALAD     = GREEN and
      ORDER.BEVERAGE  = WINE
      then
3   ORDER.DESSERT := CAKE;
      end if;
end ADD_INCLUDED_DESSERT;
```

Decision or Branch (If Statements, loops, case statements)

```
0   (T)   procedure ADD_INCLUDED_DESSERT ( ORDER : in out TYPES.ORDER_TYPE ) is
      begin
1   (T) ( )   if ORDER.ENTREE   = STEAK and
      ORDER.SALAD     = CAESAR and
      ORDER.BEVERAGE  = MIXED_DRINK
      then
      ORDER.DESSERT := PIE;
2   ( ) ( )   elsif ORDER.ENTREE = LOBSTER and
      ORDER.SALAD     = GREEN and
      ORDER.BEVERAGE  = WINE
      then
      ORDER.DESSERT := CAKE;
      end if;
end ADD_INCLUDED_DESSERT;
```

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Levels of Code Coverage (Cont.)

Modified Condition/Decision Coverage

```
0   (T)   procedure ADD_INCLUDED_DESSERT ( ORDER : in out TYPES.ORDER_TYPE ) is
      begin
1   (T) (F)   if
1.1 (T) ( )   ORDER.ENTREE = STEAK AND
1.2 (T) (F)   ORDER.SALAD = CAESAR AND
1.3 (T) ( )   ORDER.BEVERAGE = MIXED_DRINK
      then
      ORDER.DESSERT := PIE;
2   ( ) (F)   elsif
2.1 ( ) (F)   ORDER.ENTREE = LOBSTER AND
2.2 (T) ( )   ORDER.SALAD = GREEN AND
2.3 ( ) (F)   ORDER.BEVERAGE = WINE
      then
      ORDER.DESSERT := CAKE;
      end if;
end ADD_INCLUDED_DESSERT;
```

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Modified Condition/Decision Coverage (MC/DC)

Code example

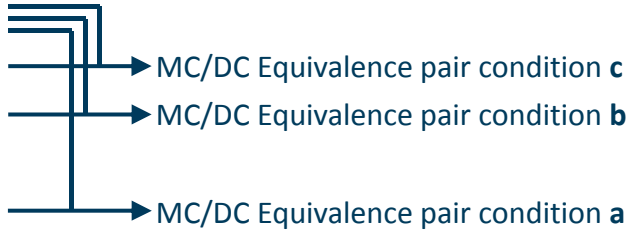
```
if ORDER.ENTREE = STEAK and  
ORDER.SALAD = CAESAR and  
ORDER.BEVERAGE = MIXED DRINK
```

Simplified expression:

```
if (a and b and c)
```

Truth table

	Cond. a	Cond. b	Cond. c	Decision Result
→	True	True	True	True
→	True	True	False	False
→	True	False	True	False
→	True	False	False	False
→	False	True	True	False
	False	True	False	False
	False	False	True	False
	False	False	False	False



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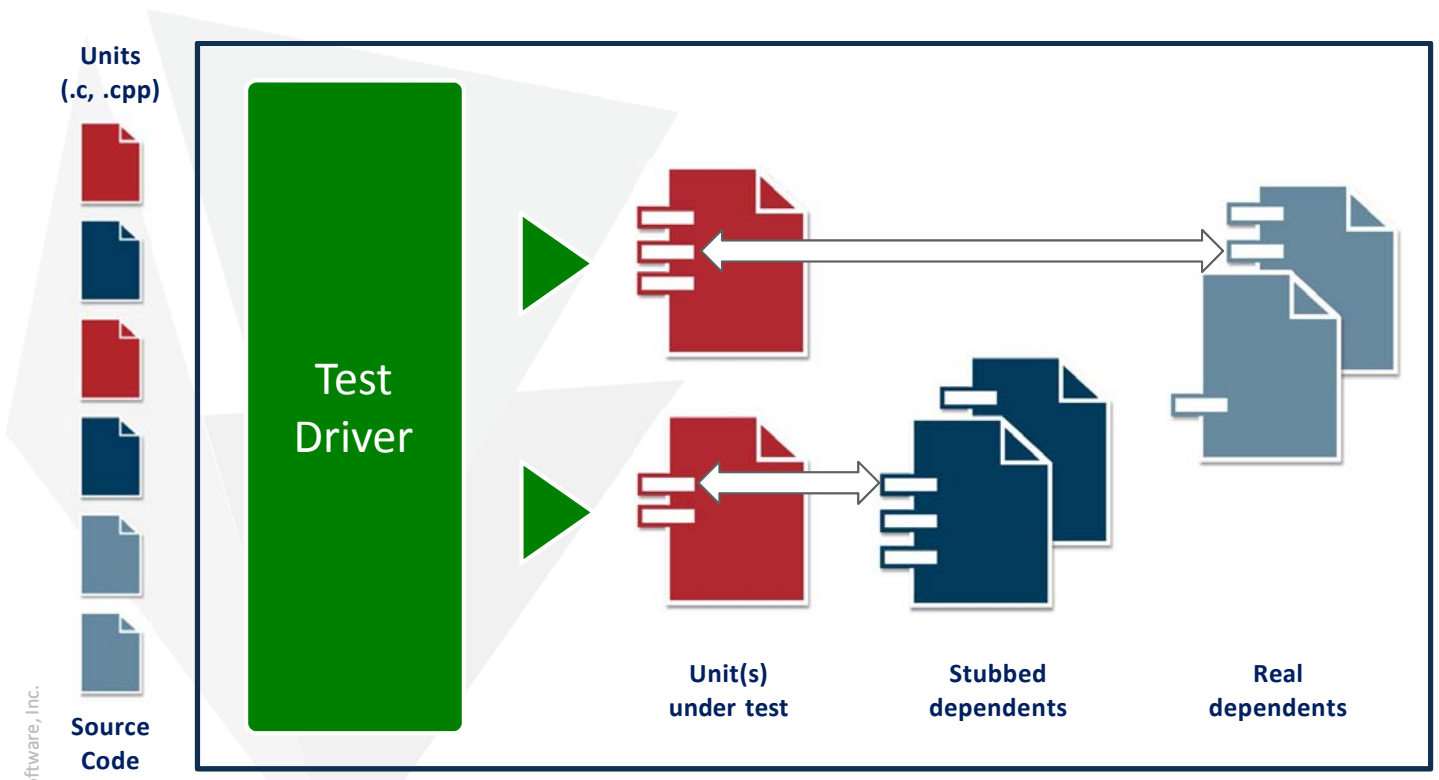
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➤ Testing Methodologies



Testing Methodologies: Unit and Integration Testing



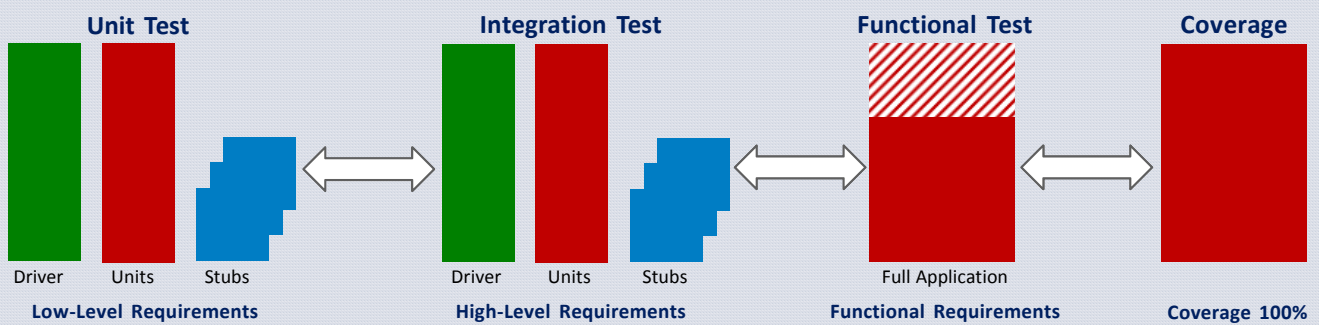
Unit Test Harness

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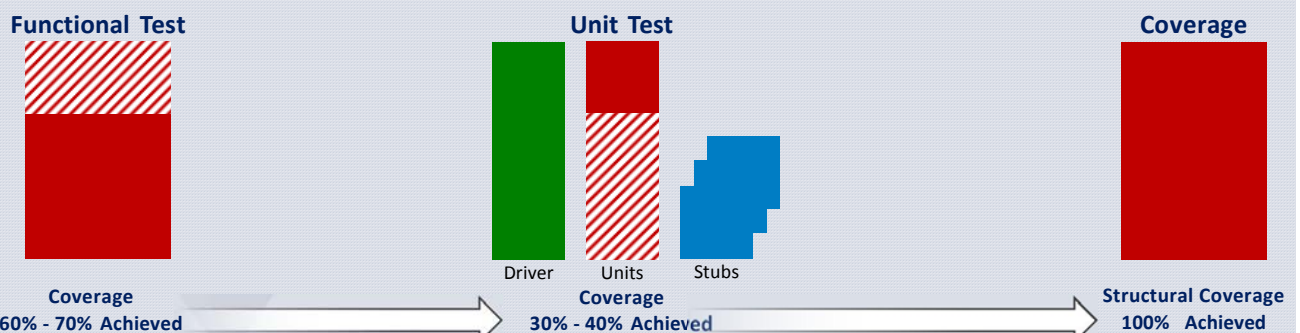


Testing Methodologies: Processes

Method 1: New Development



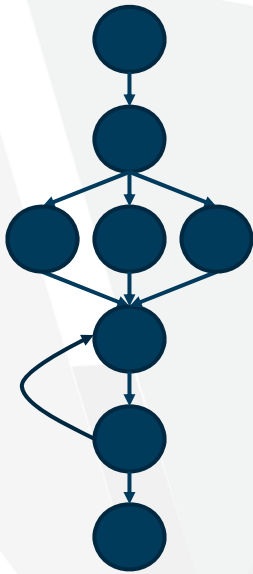
Method 2: Legacy Application



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Testing Methodologies: Basis Path



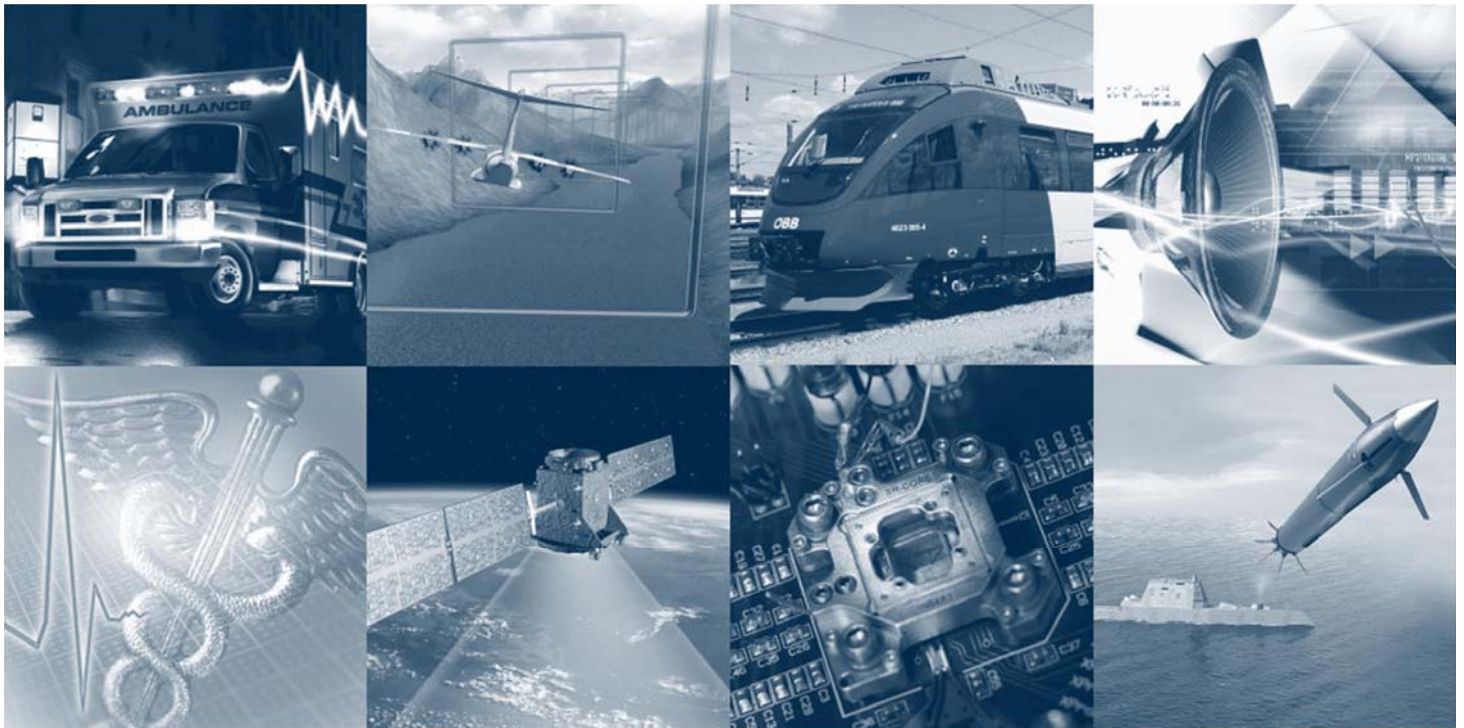
- > The challenge of testing:
A good starting set of test cases
 - > Eliminate redundant testing
 - > Provide adequate test coverage
 - > Allow more effective testing

- > Basis Path Testing
 - > Mixture of Path and Branch Testing
 - > Test all linearly independent paths, no iterations
 - > Minimum number of tests for complete statement/branch coverage

- > Build Instructions (Thomas J. McCabe)
 - > Draw a control flow graph
 - > Calculate Cyclomatic complexity
 - > Choose a “basis set” of paths

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> Demonstration



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