Mike Bartley, TVS

# Testing Complex Cyber Physical Systems with a Safety Framework

**Test and Verification Solutions**

***Helping companies develop products that are:***
***Reliable, Safe and Secure***

TVS
Test and Verification Solutions

# Agenda

- **About TVS**
- **What are cyber physical systems?**
- **What are the opportunities and challenges?**
- **Applying Hardware Verification Techniques in Software Testing?**
  - Constrained random techniques
  - Functional Coverage
  - Assertion-based checking
- **Compliance to Safety Standards**
  - Requirements-Driven Test and Verification

# About TVS

- **Focused on HW verif and SW test**
  - Services
  - Products
- **130 engineers world wide**
- **Trusted by wide range of clients and partners**
- **Delivering T&V Solutions since 2008**


***Helping companies develop products that are: Reliable, Safe and Secure***

# What are cyber physical systems?

- Cyber-Physical Systems (CPS) are integrations of computation, networking, and physical processes.
- Embedded computers and networks monitor and control the physical processes, with feedback loops where physical processes affect computations and vice versa.
- They may also have some self-learning aspects but this is not a necessity

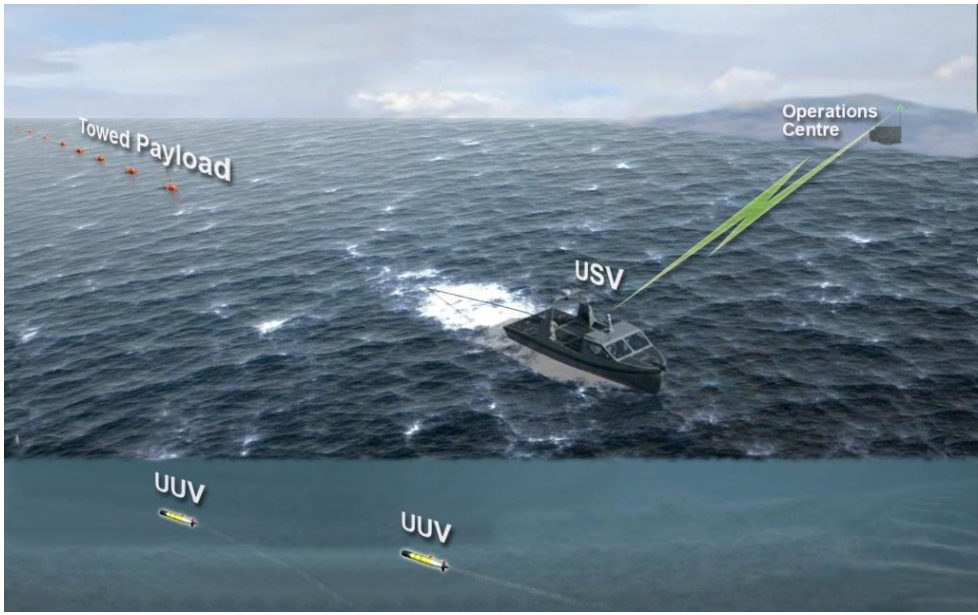
# Examples of Cyber Physical Systems

- **Dyson Autonomous Vacuum Cleaner**

- **Must**
  - Be good at cleaning the room
  - With minimal floor coverage
  - SAFELY!

# Examples of Cyber Physical Systems

- **Autonomy and Offboard Systems**
  - Unmanned Surface Vehicle steers its way from A to B
  - Potentially towing a payload
  - Steering clear of obstacles and collaborating with Unmanned Underwater Vehicles
  - Communicating via a central operations centre
  - Multiple goal driven behaviours




- **Must**
  - Get from A to B
  - With minimal time and fuel
  - SAFELY!

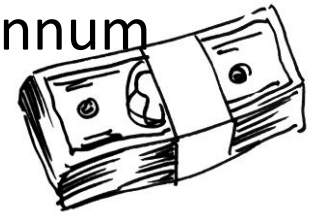
# Examples of Cyber Physical Systems

- **Autonomous Vehicles**

- **Must**
  - Get from A to B
  - With minimal time and fuel
  - SAFELY!

# Opportunities and Challenges

- **For example: Automotive**
  - ADAS and Driverless cars
  - Electronics in automotive is set to rise at 19% per annum for the next 5 years



- **Many other opportunities**
  - Drones, IoT, robotics, etc.
- **These new systems have many challenges**
  - Safety
    - Demonstrating compliance to standards (e.g. ISO26262, DO254/178C)
  - System Complexity impacting V&V

# The V&V Challenge

- **Cyber Physical Systems introduce a complex software testing challenge**
  - A large input space
  - Difficulty predicting expected response
- **Hardware faced a similar problem 20 years ago**
  - Over the past 20 years a number of “Advanced Hardware Verification Techniques” (AHVT) have been introduced
  - To automate test generation and response checking
- **Can this be done within a safety framework?**

# The Innovate UK Research Project

- **Investigate the feasibility of applying Advanced Hardware Verification Techniques to the testing of software for Cyber Physical Systems**
  - Technical feasibility
  - Market feasibility
- **TVS**
  - Producing tools for evaluation by end user partners

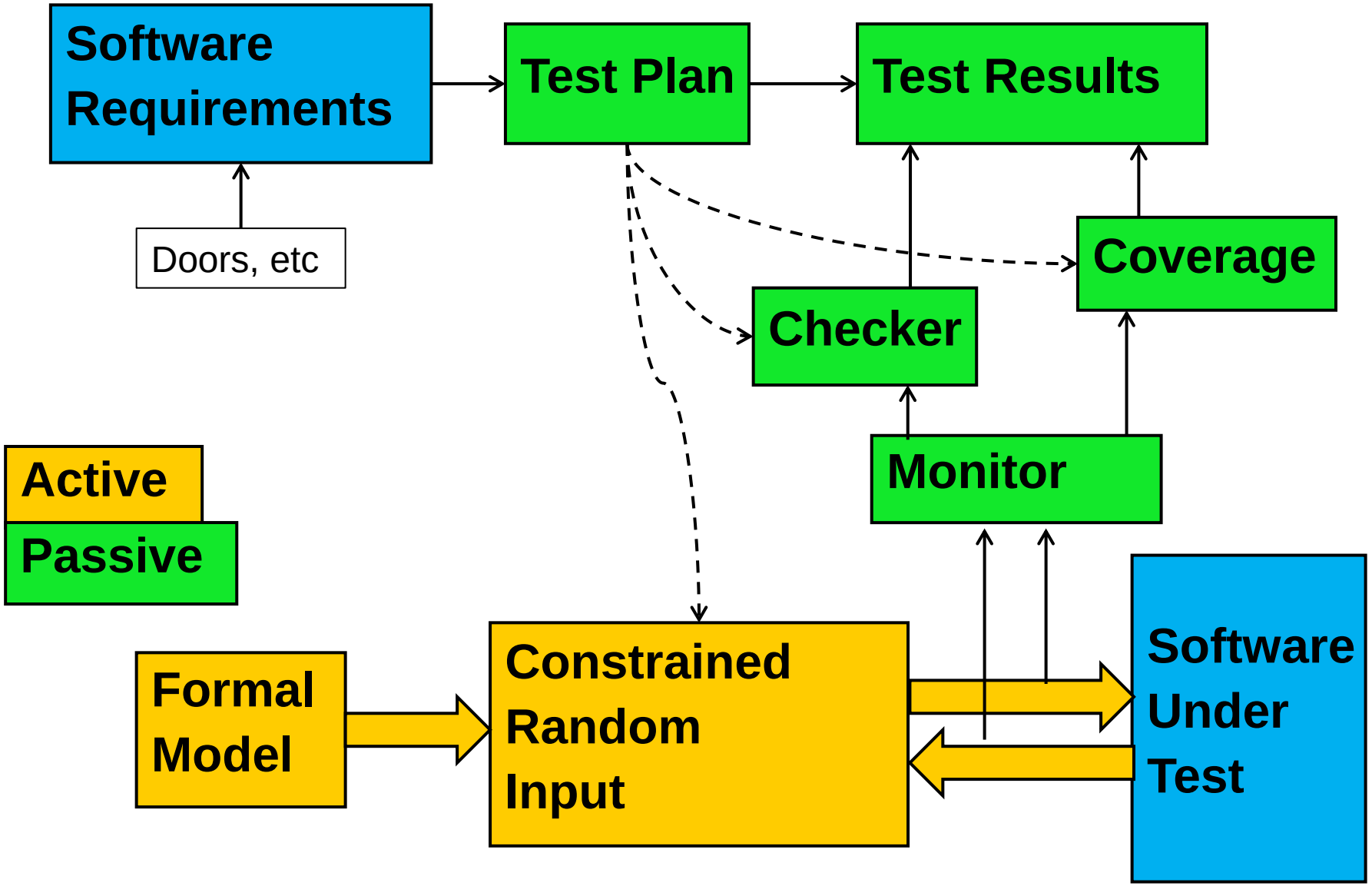

Test generation from formal models


Robotic Vacuum Cleaner


Software for Autonomous Vehicles


Autonomy and Offboard Systems

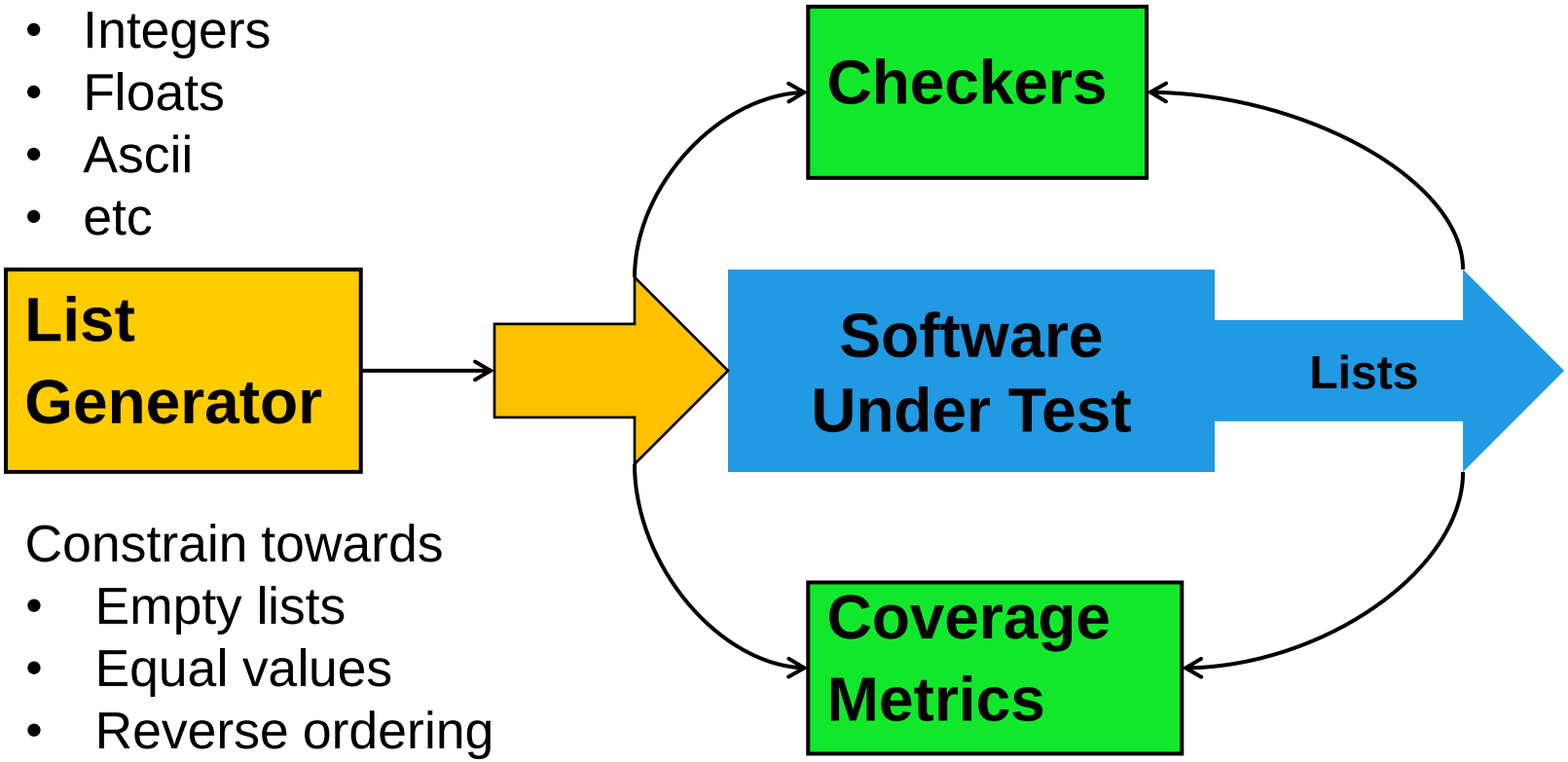
# Advanced Hardware Verification Techniques



# Results of Bubble Sort "Proof of Concept"

- Check output list is ordered
- Output list contents == input list contents

Lists of
- Integers
- Floats
- Ascii
- etc




Constrain towards
- Empty lists
- Equal values
- Reverse ordering

- Empty List
- Reverse ordered
- Error cases (mix integers, floats, ascii
- etc

# Example Constrained Random Inputs

- **Mimic sensor input data**
- **Need to constrain those inputs**
  - Only the legal space
  - Hit the corner cases
- **Example scenarios**
  - Valid ranges for data
  - Relationships between inputs
  - Next input within certain “distance” to prior input

# Functional Coverage

From Kerstin Eder of the University of Bristol

- **Requirements coverage**
- **"Cross-product" coverage**

*[O Lachish, E Marcus, S Ur and A Ziv. Hole Analysis for Functional Coverage Data. Design Automation Conference (DAC), June 10-14, 2002, New Orleans, Louisiana, USA.]*

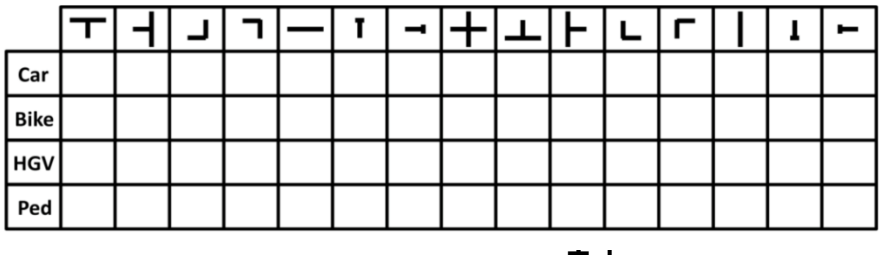
A cross-product coverage model is composed of the following parts:

1. A semantic **description** of the model (story)
2. A list of the **attributes** mentioned in the story
3. A set of all the **possible values** for each attribute (the attribute value **domains**)
4. A list of **restrictions** on the legal combinations in the cross-product of attribute values

A **functional coverage space** is defined as the Cartesian product over the attribute value domains.

- **Situation coverage**

*[R Alexander et al. Situation coverage – a coverage criterion for testing autonomous robots. University of York, 2015]*



# Example Checkers

- **Do not accelerate too fast**
  - Assert that output to motor is not too high
- **“always respond correctly”**
  - If A&B&C occur then check X happens
    - Assertion coverage “check A&B&C occurs” for free
- **Always safe**
  - Do not get too close to other objects
  - Requires some level of modelling
- **Minimise resources**

# Safety compliance (asureSIGN)

- **Managing Requirements**
  - Importing and editing requirements
- **Decomposing requirements to verification goals**
- **Tracking verification execution**
  - Automating import of verification results (VectorCAST)
  - Automate accumulation and aggregation of verification results
- **Impact analysis**
  - Managing changes in requirements and verification
- **Demonstrating safety compliance – for example**
  - DO254/178C, ISO26262, IEC 60601, IEC 61508, EN 50128, IEC 61513
- **Supply chain management**
  - Exporting requirements and test plans
  - Importing test results

# asureSIGN™ at the heart of HW/SW V&V

Requirements
- Excel
- Doors
- Jira
- Etc

Word via XML

SystemC Simulation

UCIS API

Hardware Simulation
- Coverage — Cadence
- Assertions — Mentor, Aldec
- Etc.

Formal Verification
- OneSpin

asureSIGN™

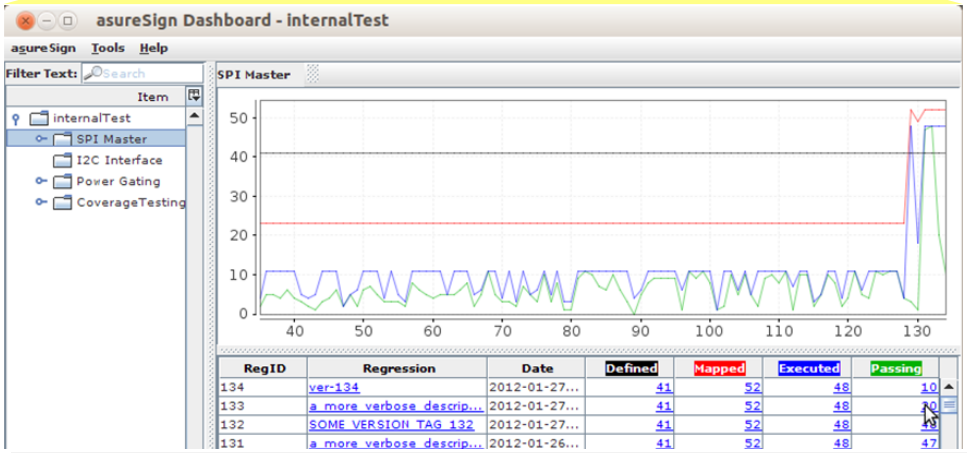
Run API

Manual API

Directed test results

Automated SW Test Tool
**VectorCAST**

Lab Results




Matlab

SW Test Tools

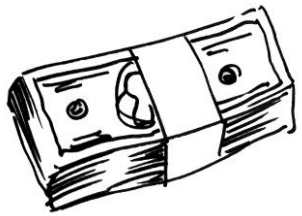
Requirements Engineering tools

# The Status and the Opportunity

http://www.testandverification.com/projects/

- **Requirements Driven Verification**
  - Tool released to partners
- **Partner V&V Requirements Analysis**
  - Understanding how to adapt AHVT to software
  - Tooling being adapted
    - Checkers
    - Coverage
    - Test Generation
- **The Opportunity**
  - Able to deliver the tooling to new partners
  - Contact Mike Bartley
    - mike@testandverification.com 07796 307958

# Conclusions



- **The market opportunity is there**
- **But there are barriers to entry!**
  - Demonstrating compliance to safety standards
  - System Complexity impacting Software V&V
- **TVS Solutions**
  - Requirements Driven Test and Verification – PROVEN
    - **Automated with VectorCAST**
  - asureSIGN – PROVEN
  - Constraint-driven testing with functional coverage & assertions
    - Hardware – PROVEN
    - Software – partially PROVEN, working with partners

**Get Involved**

# Contact details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