CHALLENGES IN IOT TESTING

Ina Schieferdecker

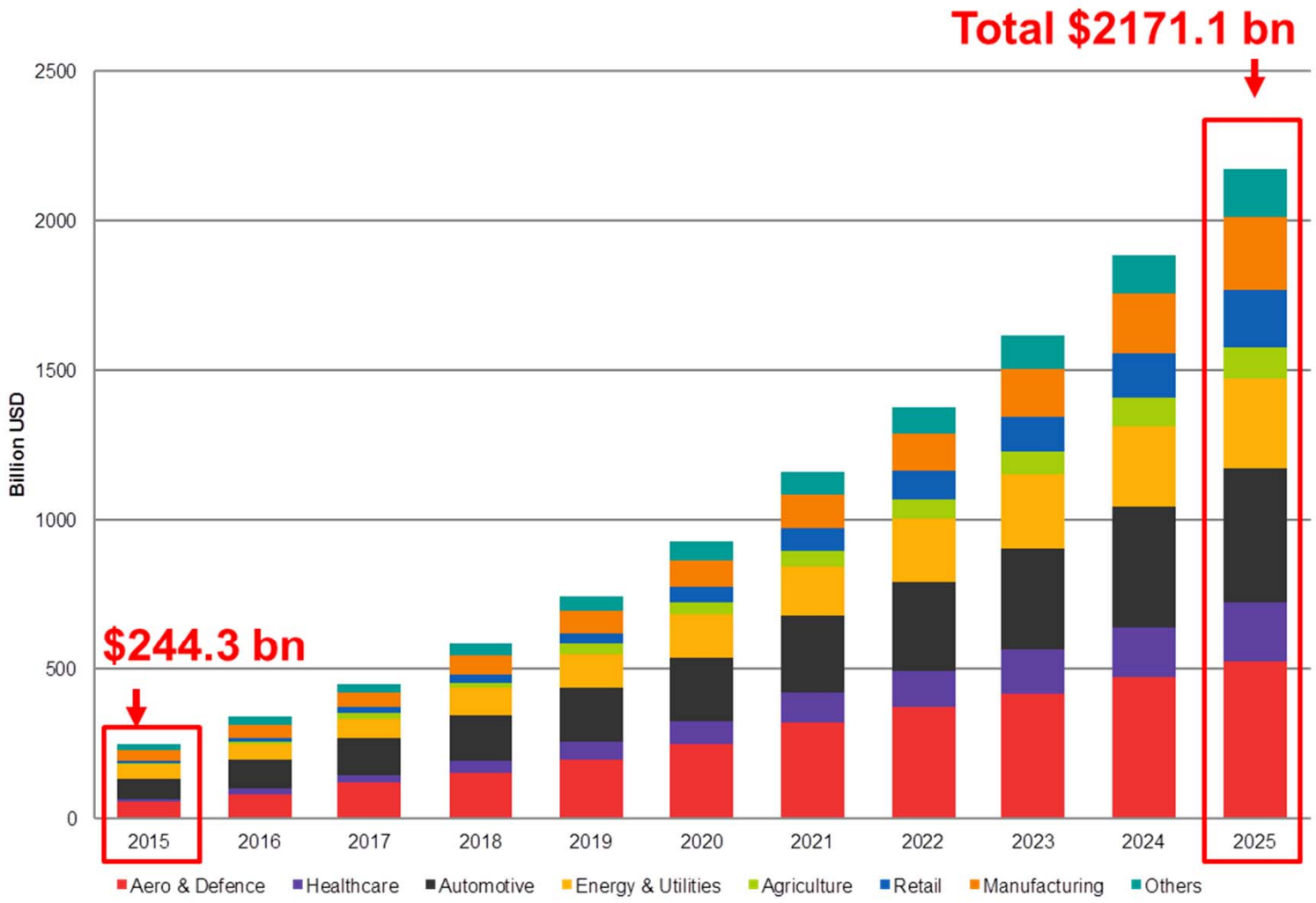
TestNet, May 11, 2016

Fraunhofer FOKUS

TALKING PLANTS, ANIMALS AND MORE

http://www.iot-a.eu/public

IOT MARKET FORECAST



Source: IoT Market Forecast, Visiongain

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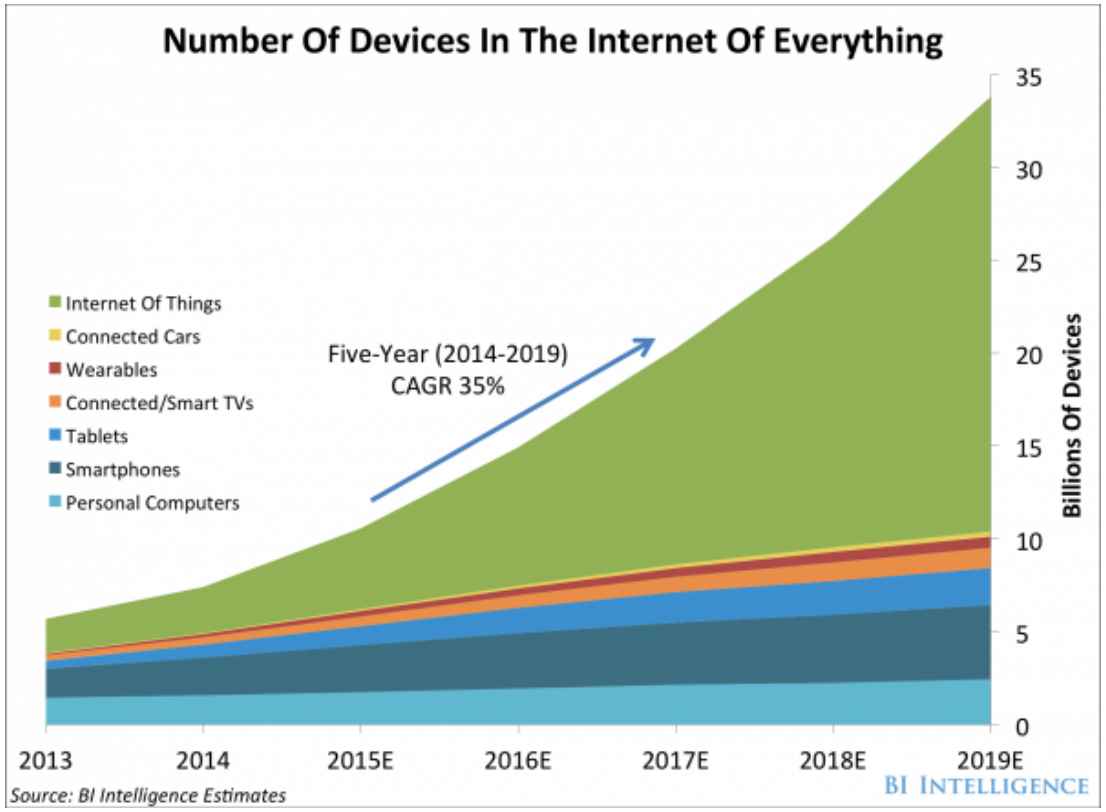
FURTHER FORECASTS



Connected Mobiles worldwide

Source: *Cisco Global Mobile Traffic Forecast Update, Gartner*

Global data streams in the Internet per Second in Terabyte

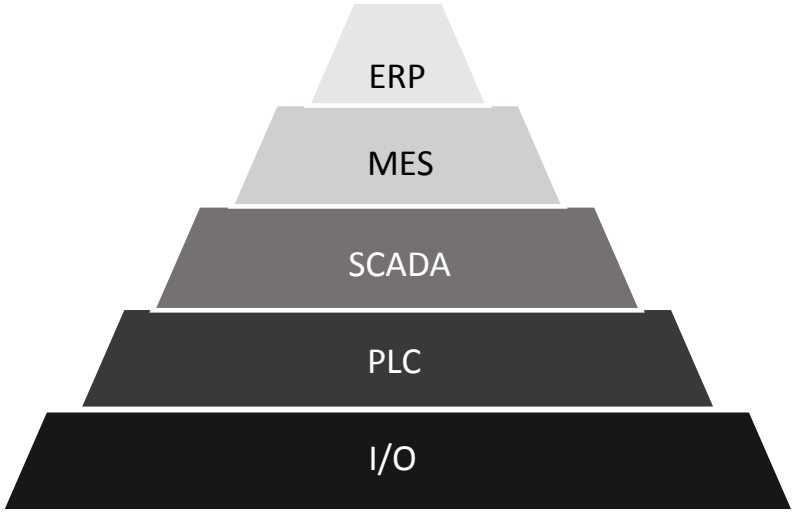
Source: *ITU ICT Facts and Figures 2015-2020*

IOT REFERENCE MODEL (ONE OF MANY)

NEW ARCHITECTURAL PARADIGM

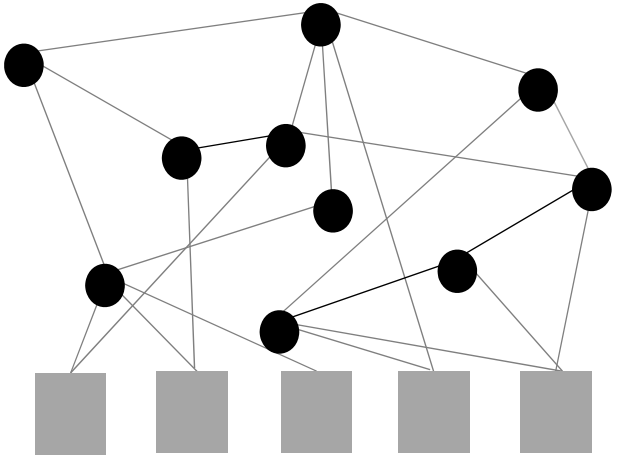
Today

Hierarchical



Upcoming

Orchestrated

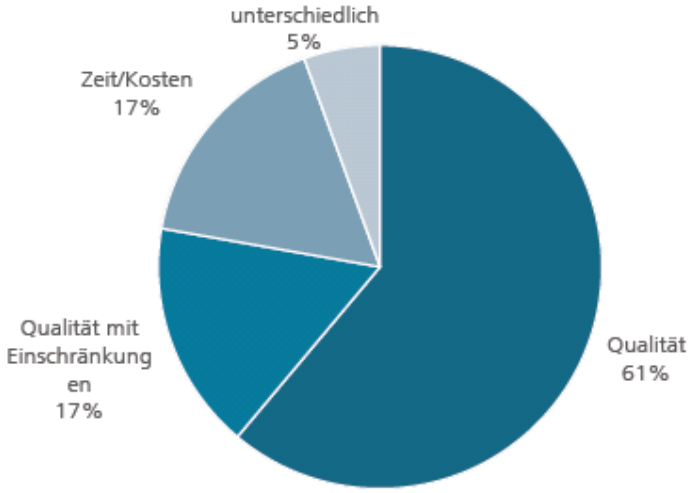


Openess, Dynamicity, Scalability

CRITICALITY IMPLY HIGH QUALITY REQUIREMENTS

»Implementation of real-time enabled CPS solutions will place **high demands on the availability of services and network infrastructure** in terms of space, technical quality and reliability.«

In: Securing the future of German manufacturing industry. Recommendations for implementing the strategic initiative INDUSTRIE 4.0, Forschungsunion, acatech, Apr. 2013.



Priorities of Quality, Time and Costs

In: Stand und Trends der Qualitätssicherung von vernetzten eingebetteten Systemen, Fraunhofer FOKUS Studie, Aug. 2014

ANYTHING NEW IN IOT TESTING ?!

Similar

- Protocol stacks
  - IETF-based: CoAP, MQTT, etc.
  - IEC-based: OPC-UA
  - ITU-based: M2M
- Application frameworks
  - Eclipse: Kura, Scada, etc.
  - Many others

Different

- Security
  - ISO: common criteria
  - Mitre: CWE list
  - Others
- Data
  - Semantic real-time data
- Protocol testing
  - Conformance
  - Interoperability
  - Performance
- Software testing
  - Component testing
  - Integration testing
  - System testing
- Security testing
  - Risk-oriented testing
  - Fuzz testing
  - Online testing
- Data quality

FURTHER ASPECTS

IoT solutions often are …

1. in harsh, unreliable environments

2. in highly dynamic configurations with large number of – typically diverse – sensors and actuators with open interfaces and

3. In resource-constrained environments

IoT test solutions need to …

– Integrate simulators for environmental conditions

– Systematically determine reference configurations

– Adjust and scale test configurations dynamically

– Be a real-time system by itself

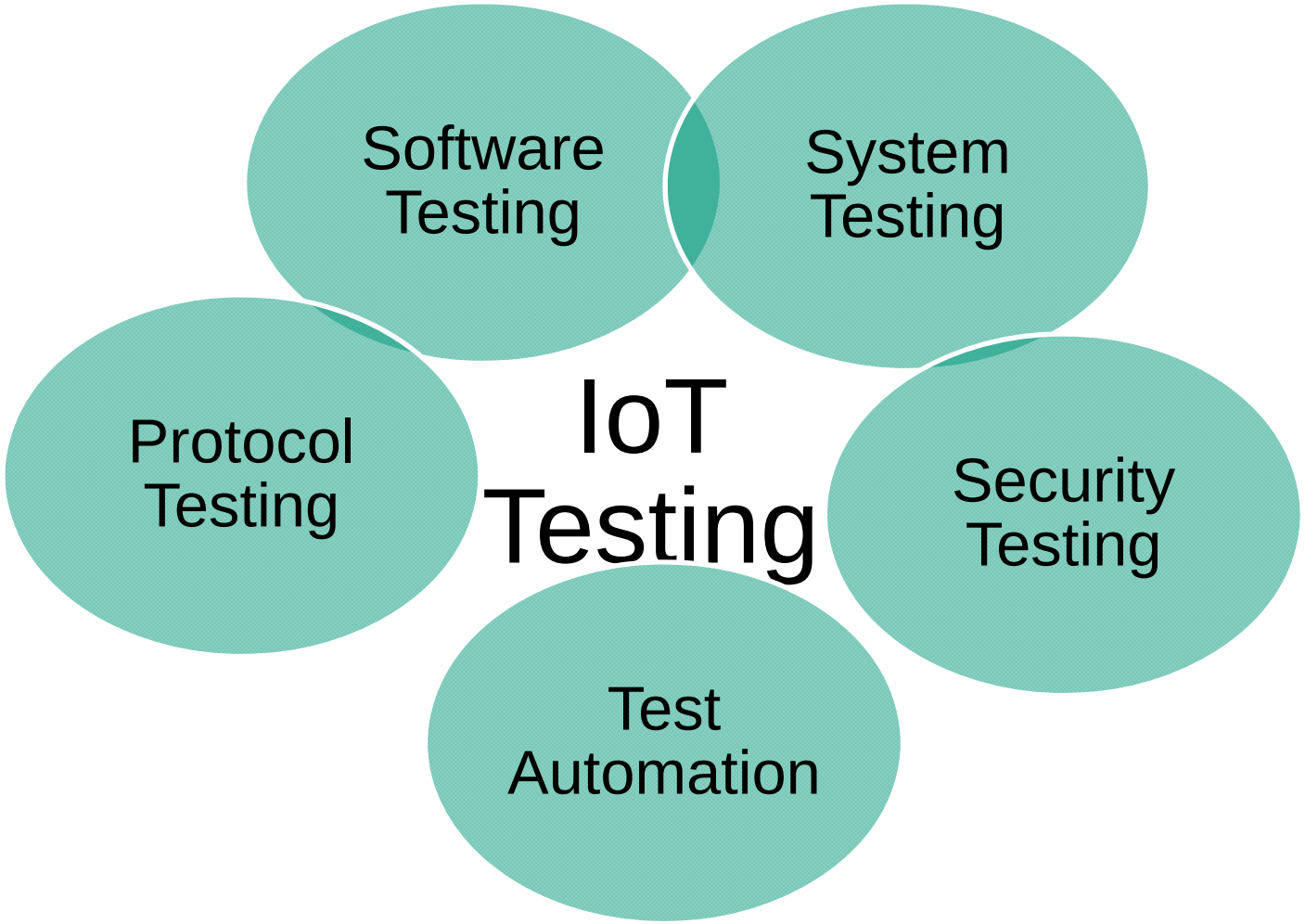
– Support test scenarios for hybrid systems (both events and streams)

→ ***Test platform for the Internet of Things***

embedded

virtualized

INTEGRATION OF SEVERAL TESTING APPROACHES



CHALLENGE TEST AUTOMATION

- TTCN-3 is the Testing and Test Control Notation
- Internationally standardized testing language for formally defining test scenarios. Designed purely for testing

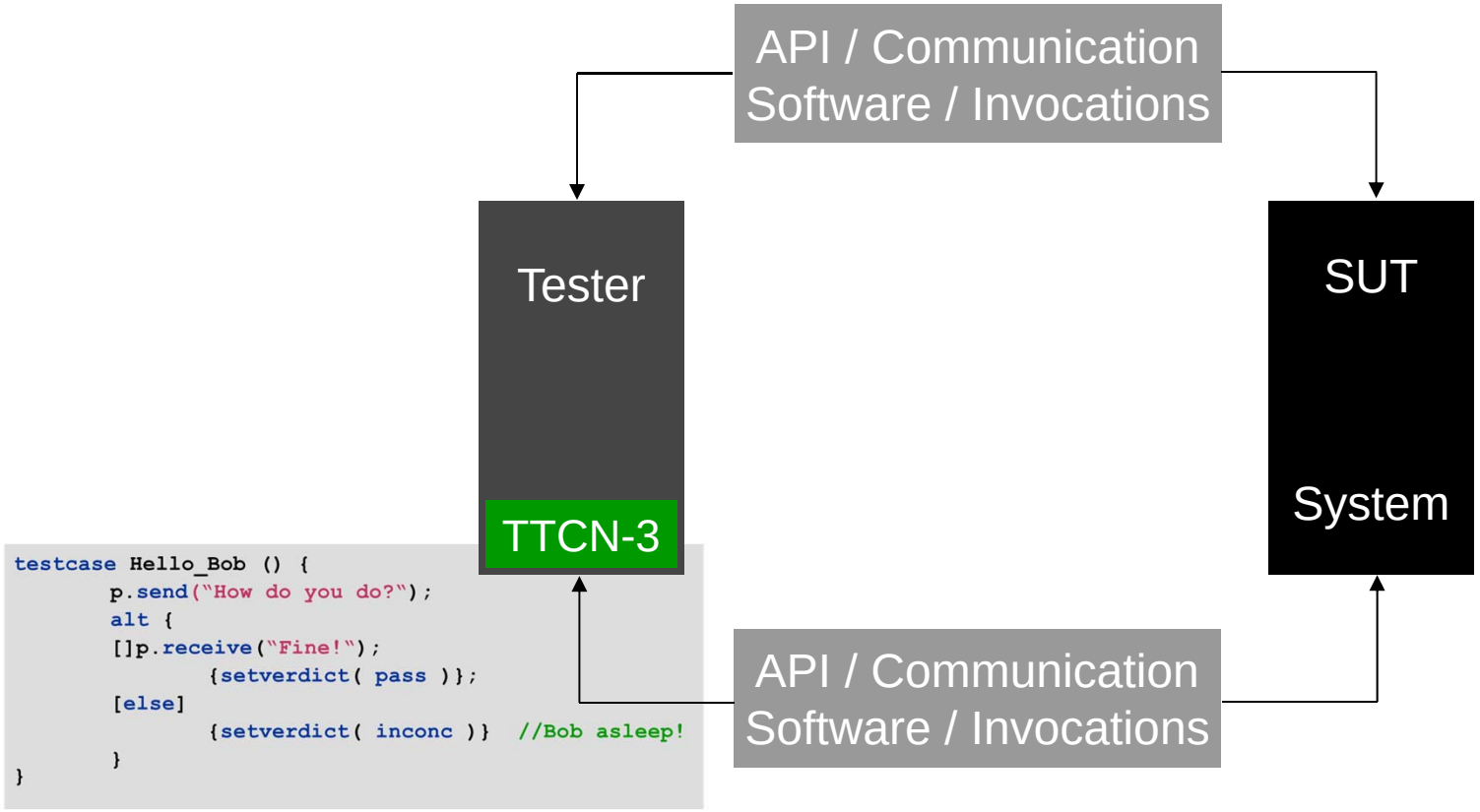
```
testcase Hello_Bob () {
        p.send("How do you do?");
        alt {
        []p.receive("Fine!");
                {setverdict( pass )};
        [else]
                {setverdict( inconc )}  //Bob asleep!
        }
}
```

DESIGN PRINCIPLES OF TTCN-3

- One test technology for different tests
  - Distributed, platform-independent testing
  - Integrated graphical test development, documentation and analysis
  - Adaptable, open test environment

- Areas of Testing
  - Regression testing
  - Conformance and functional testing
  - Interoperability and integration testing
  - Real-time, performance, load and stress testing
  - Security testing

TTCN-3 EXECUTION

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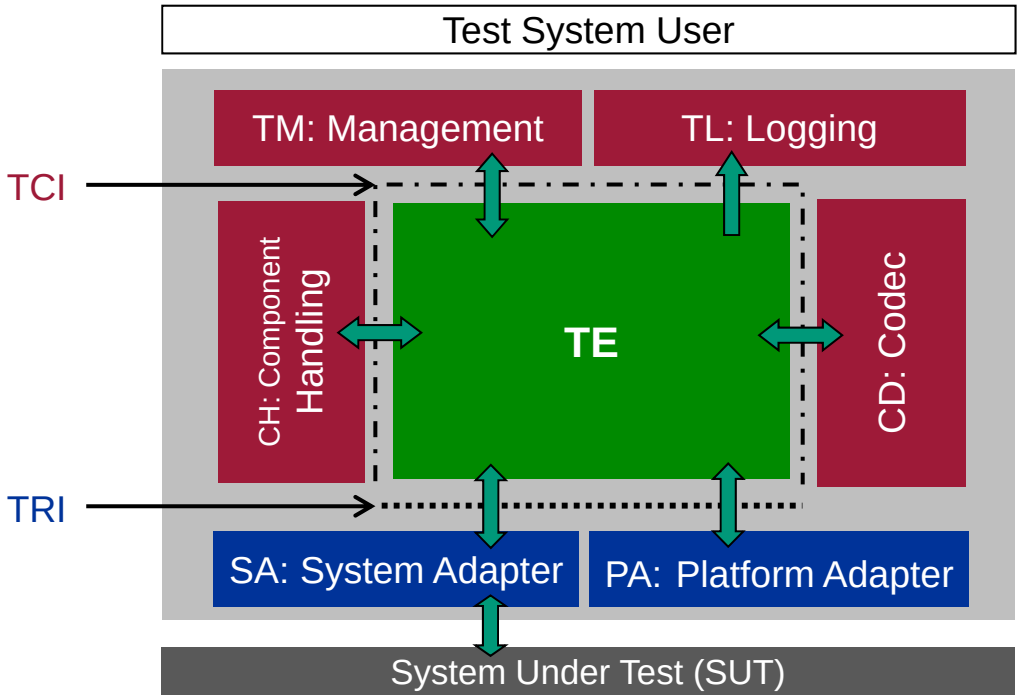
}
```

A TTCN-3 TEST SYSTEM

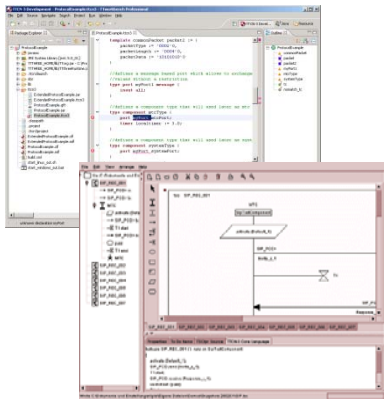


TE – TTCN-3 Executable
TM – Test Management
TL – Test Logging
CD – Codec
CH – Component Handling
SA – System Adapter
PA – Platform Adapter
SUT – System Under Test

ETSI ES 201 873-1 TTCN-3 Core Language (CL)
ETSI ES 201 873-5 TTCN-3 Runtime Interface (TRI)
ETSI ES 201 873-6 TTCN-3 Control Interfaces (TCI)

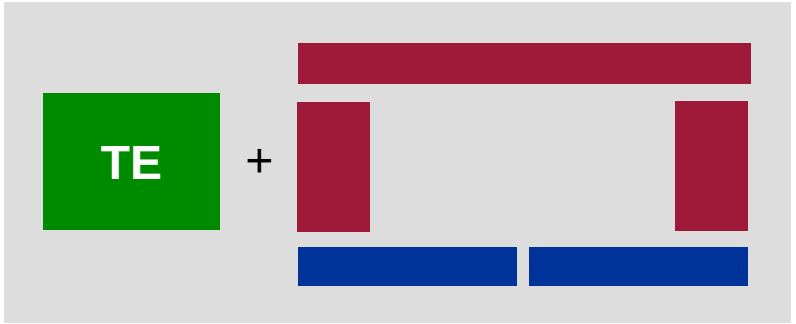
IMPLEMENTATION

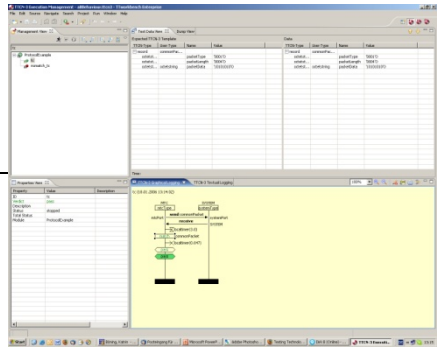
ATS



TTCN-3

Test System





SUT

Communication / Invocation

TTCN-3 DOMAINS: TELECOM

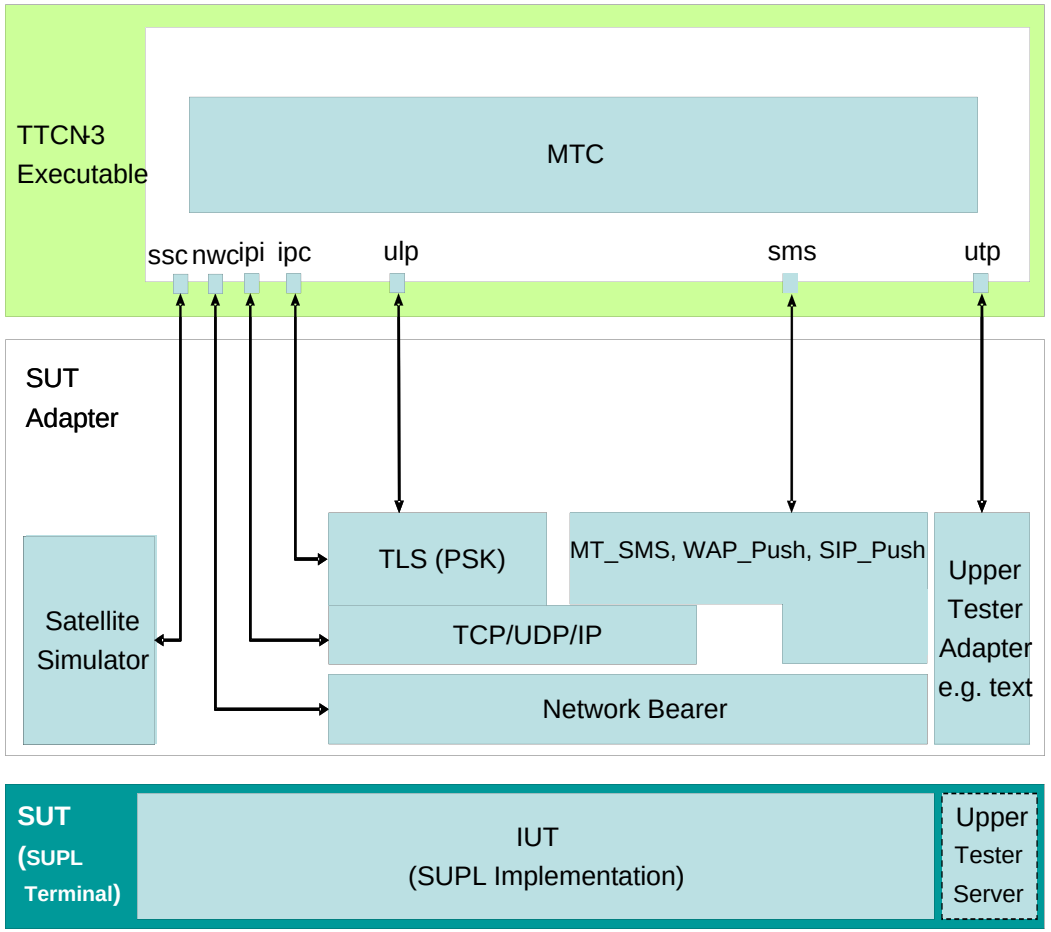
- Industrial use
  - Big companies with hundreds of TTCN-3 engineers: Ericsson, Nokia, Siemens, Motorola
  - large distribution among SMEs
- Standardization bodies
  - Standardized test suites:
    ETSI / 3GPP (LTE)/ OMA / TETRA and its members
  - IMS performance benchmarking:
    Intel, HP, BT and others
- Test tool manufacturer:
  - Commercial Tektronix, Catapult, Nexus, R&S, Spirent, …
  - Free tools by Eclipse and academics
- Certification program based on TTCN-3: e.g. WiMax forum

TEST SYSTEM EXAMPLE: OMA SUPL

Secure User Plane Location Protocol

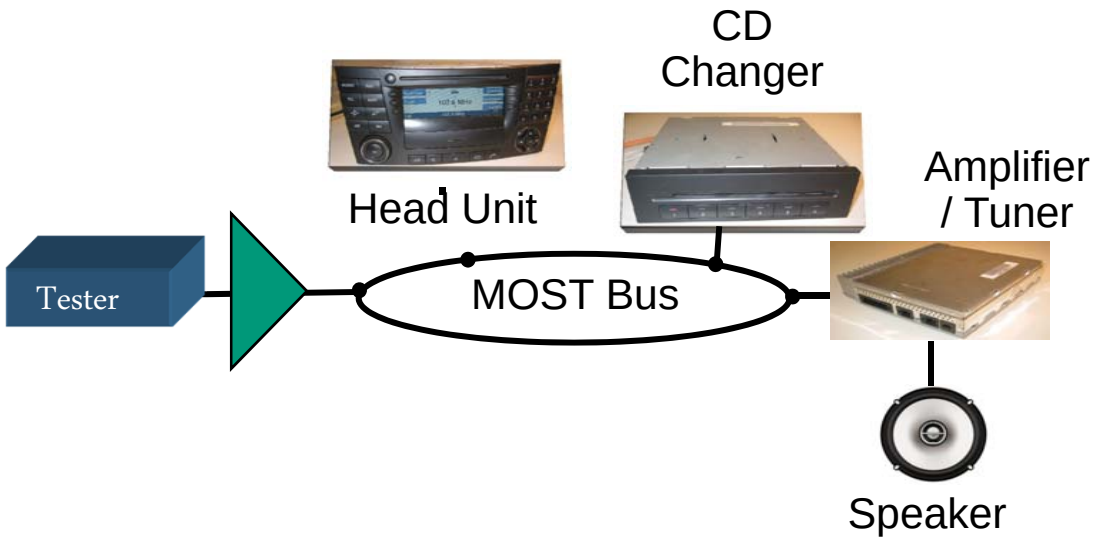
Single MTC controls e.g.:

- UlpPort (Lup interface)
- IpcPort (IP configuration)
- smsPort used for SMS
- UtpPort for upper tester commands
- IpiPort (IP information, e.g. release)
- NwcPort: network bearer control, e.g. handover trigger
- SscPort: satellite simulation control, e.g. scenario trigger



TTCN-3 DOMAINS: AUTOMOTIVE

- Cockpit systems
  - Edutainment
  - Head units
- Car-to-X communication
  - Car-to-car, car-to-roadside, car-to-backbone
  - Autonomic driving

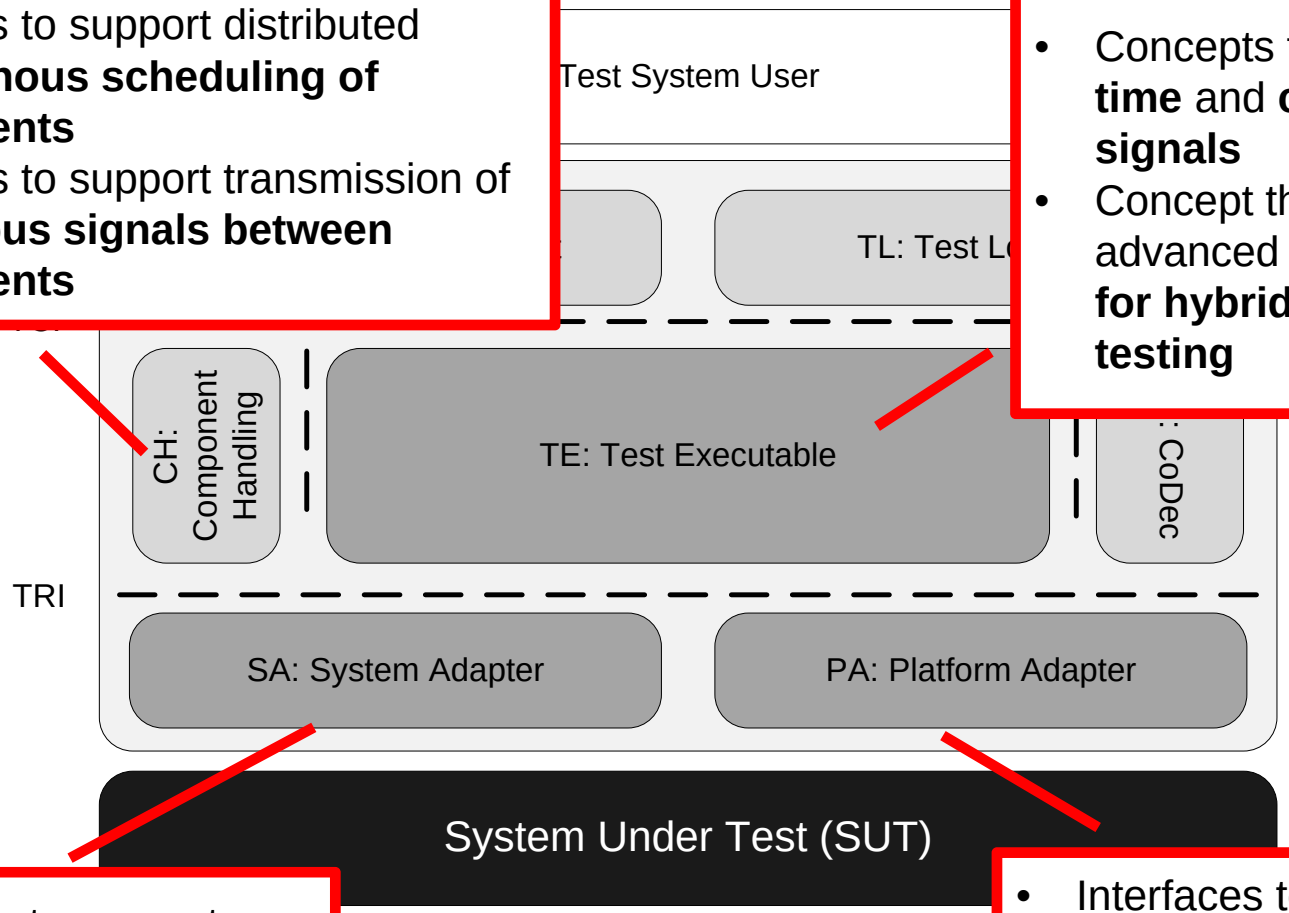


Telematics Applications in the Cockpit

- Audio (CD / Radio), Video
- Telephone, SMS
- Navigation
- Speech recognition
- User interface for body electronic

CHALLENGE EMBEDDED SYSTEMS

- Interfaces to support distributed **synchronous scheduling of components**
- Interfaces to support transmission of **continuous signals between components**

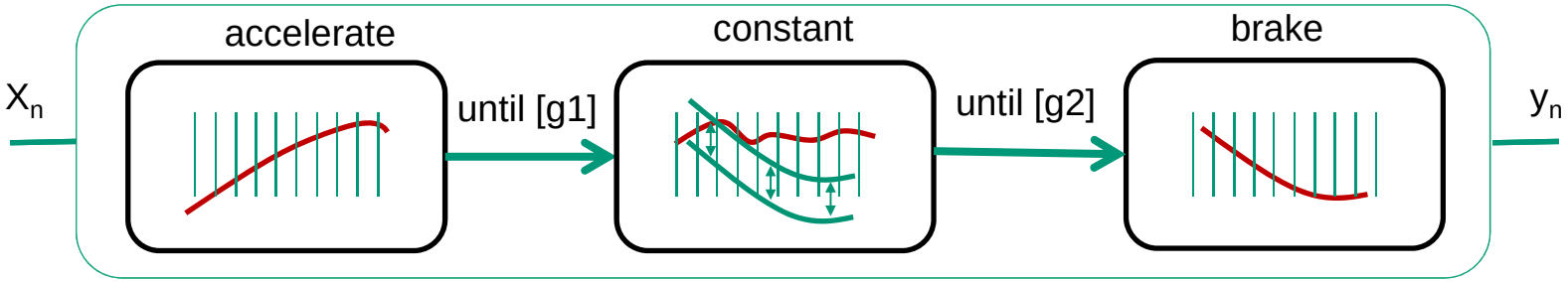


- Concepts to deal with **time** and **continuous signals**
- Concept that allow advanced **control flow for hybrid system testing**

- Interfaces to support **stimulation** with and **evaluation** of **continuous signals**

- Interfaces to support **access to time** and **sampling**

TTCN-3 EMBEDDED MODES



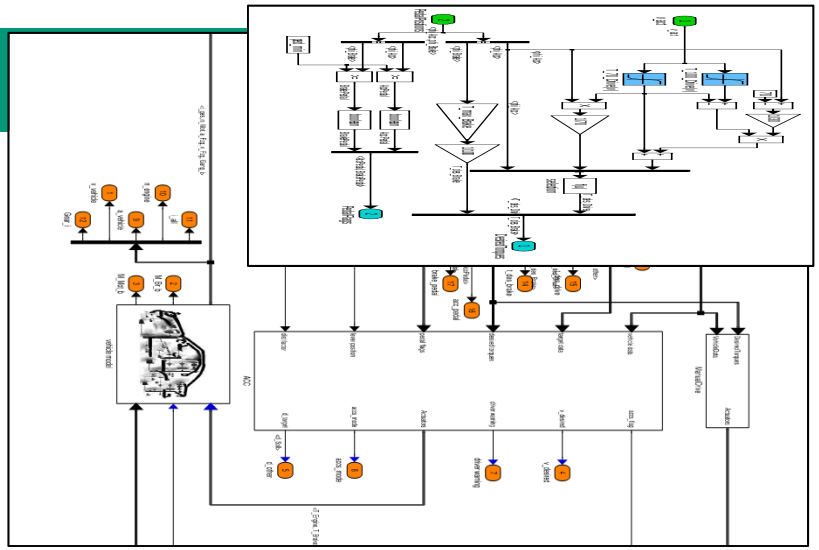
SIGNAL GENERATION BUILDING BLOCKS

```
testcase signal_generation() runs on mtcType{
 seq{
  apply_noise(Throttle, 5.0, 5.0);
  apply_noise(Throttle, 10.0, 5.0);
  apply_ramp(Throttle, 10.0, 10.0, 2.0, 3);
  …}
```

INTEGRATION IN ML/SL

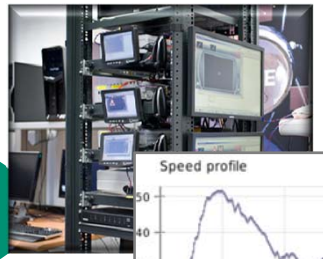
```
// accelerate vehicle until 35
//  ms and activate ACCS

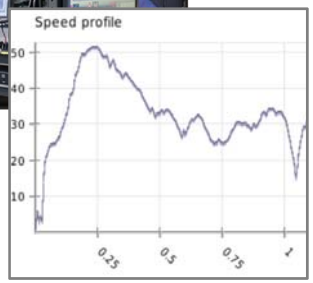
cont{
  onentry{v_other.value:= 25.0}
  phi_acc.value:=80.0;
}
until{
 [v_ego.value > 35.0] {
   phi_acc.value:=0.0;
   lever_pos.value:= MIDDLE;
 }
}
// wait for several seconds
wait(now+10.0);
// evaluate
cont{
  assert(v_ego.value <= 38.0); }
until{
 [d_other.value < sd] { ...
```



1. Introduce a vehicle ahead
2. Accelerate the ego vehicle until its velocity rises to more than 35 m/s.
3. Activate the cruise control.

AUTOMATED V2X TEST BED

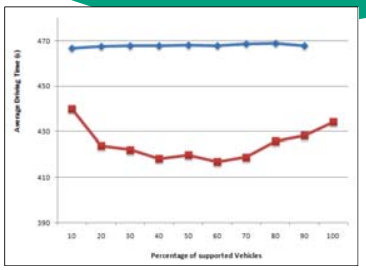


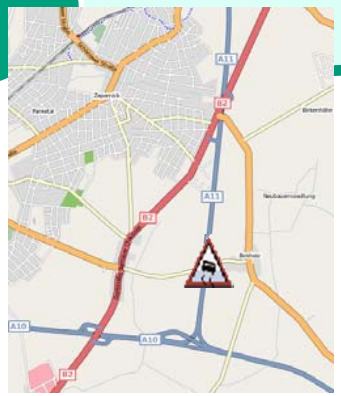


Test Execution

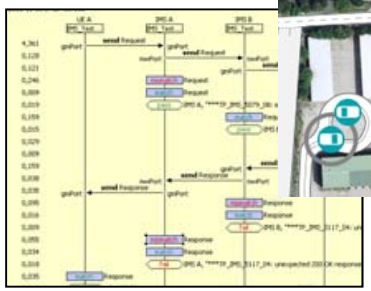
V2X Test Bed and Tool Suite

Test Data Generation (e.g. Traffic Simulation Data)





Log File Analysis and Visualization



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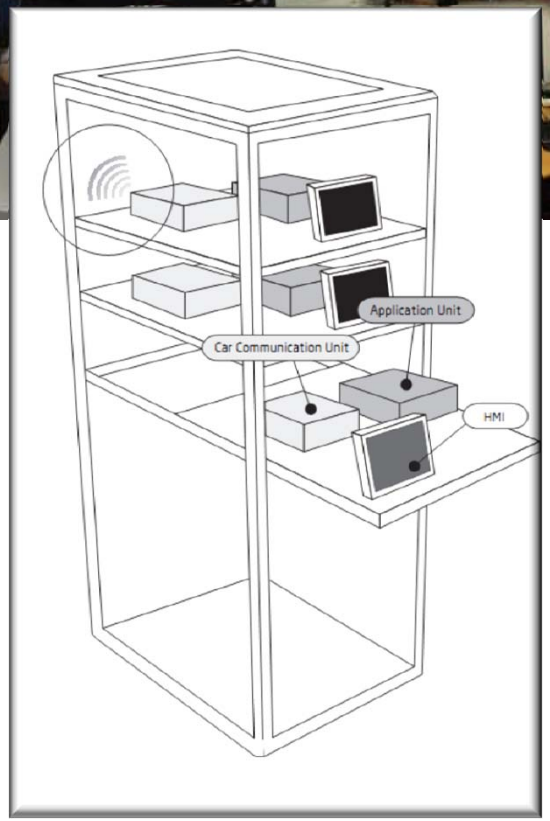
THE SIM^{TD} SET UP IN THE LAB

sim^{TD} Sichere Intelligente Mobilität Testfeld Deutschland



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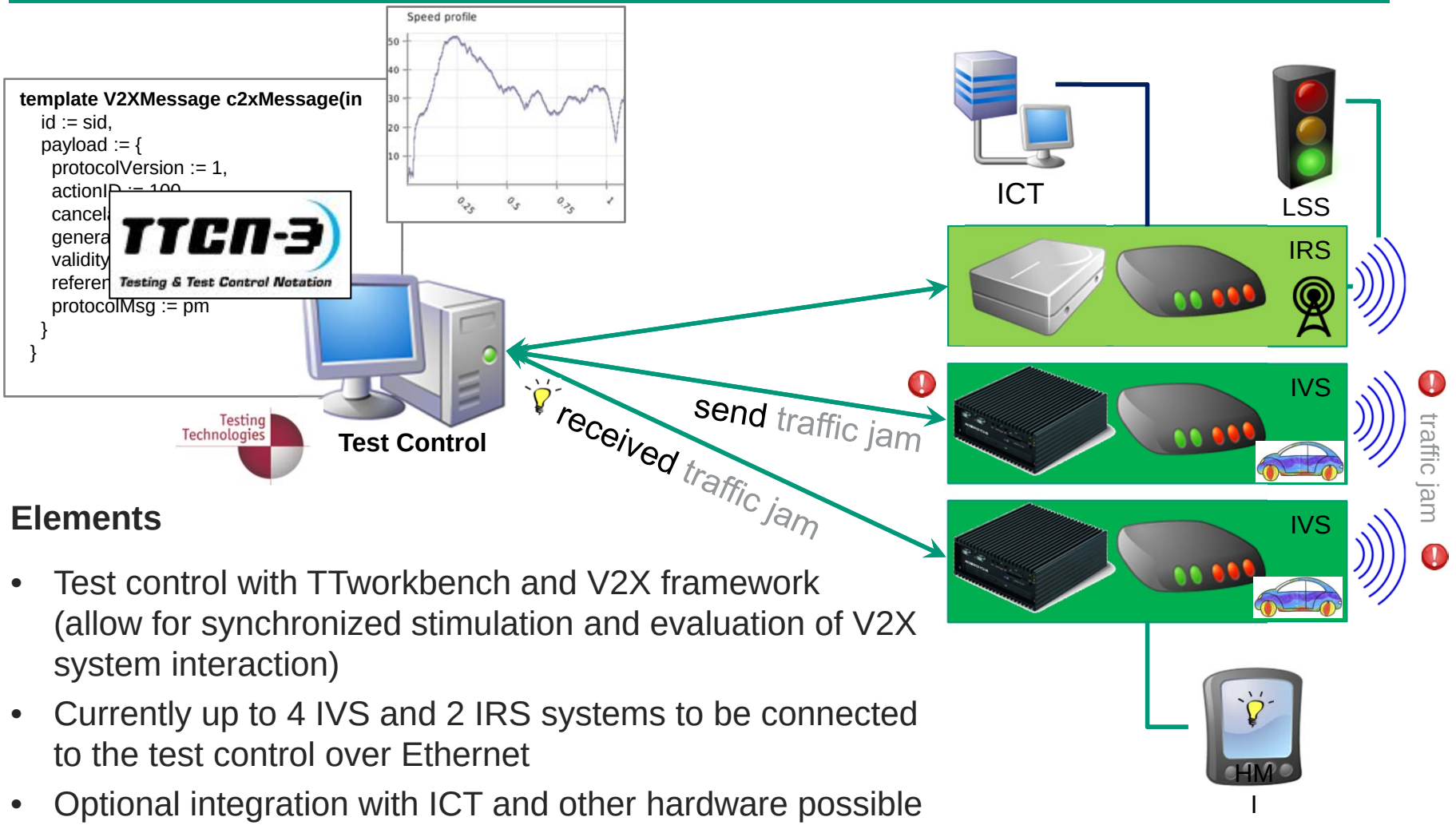
V2X TEST BED ARCHITECTURE



Elements

- Test control with TTworkbench and V2X framework (allow for synchronized stimulation and evaluation of V2X system interaction)
- Currently up to 4 IVS and 2 IRS systems to be connected to the test control over Ethernet
- Optional integration with ICT and other hardware possible

EXAMPLE: WEATHER WARNING

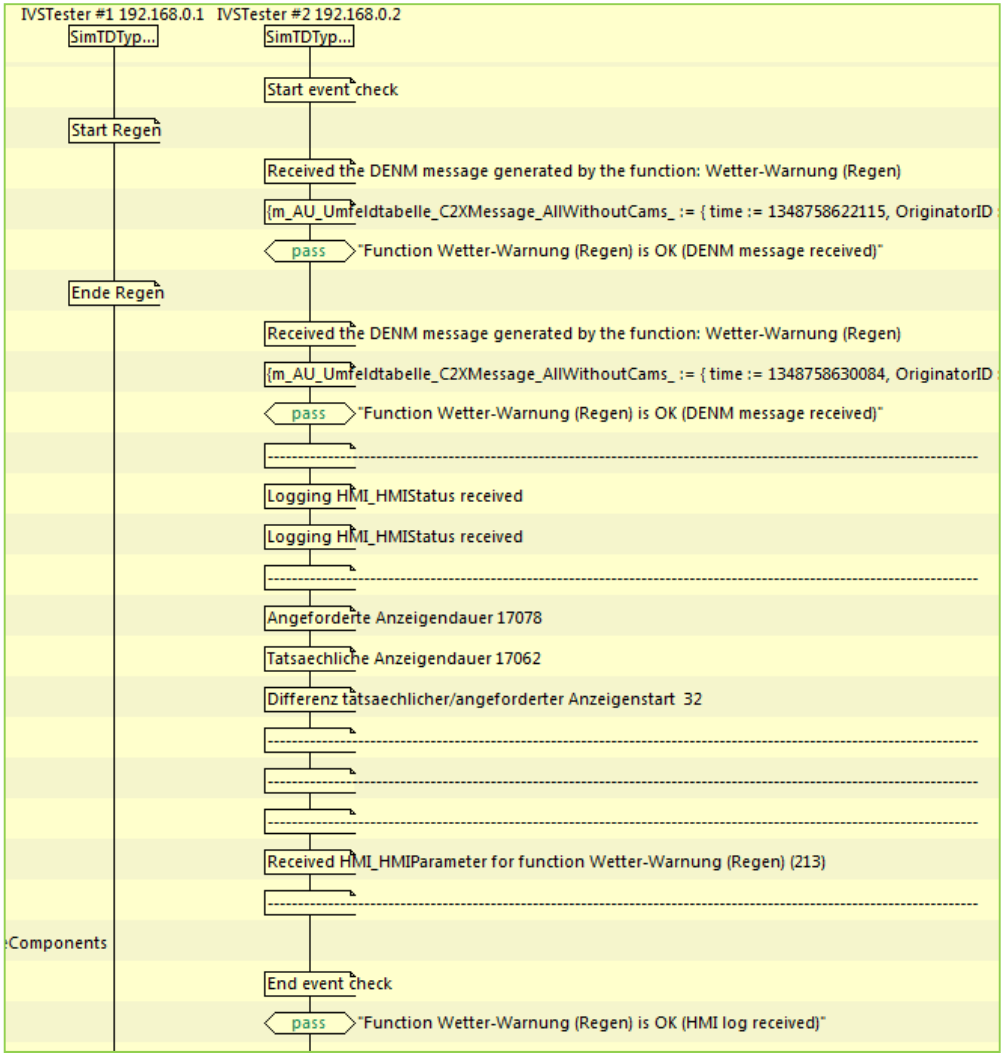
- IVS1: Generate situation

```
WiperSystem := {
    Front := "normal",
    Rear := "idle" }

WiperSystem := {
    Front := "fast",
    Rear := "idle" }
```

- IVS2: Check message reception
  - DENM message received ?

- IVS2: Check HMI interaction



DRIVE C2X REFERENCE TESTS

- Compatible with ETSI Standards
- Virtualized Test Environment

Tests available for:

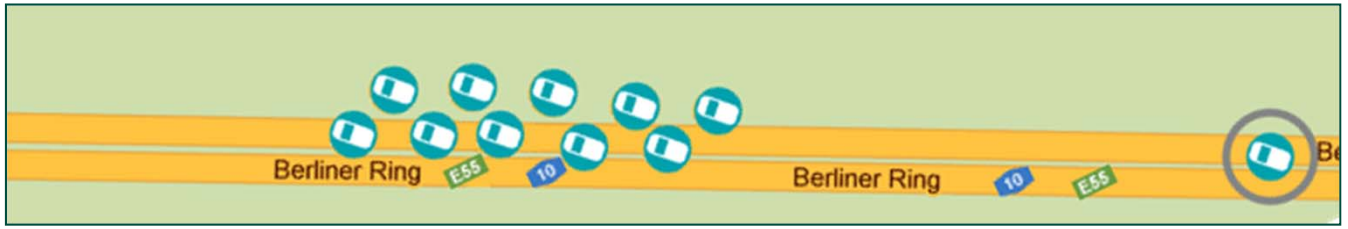
- Stationary vehicle warning
- Road works warning
- Slow vehicle warning
- Traffic jam ahead warning
- In vehicle signage
- Emergency vehicle warning,
- Emergency electronic brake lights

Example Traffic Jam Ahead Warning (TJAW):

Tests TJAW with different jam configurations by varying:

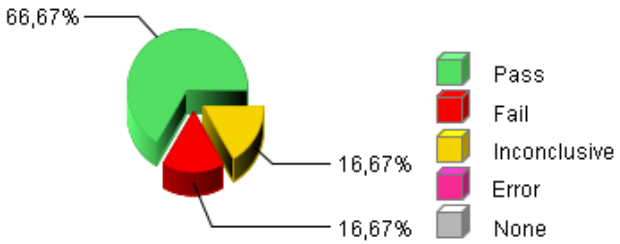
- number of vehicles in jam
- velocity of vehicles
- distance to EGO
- velocity of EGO

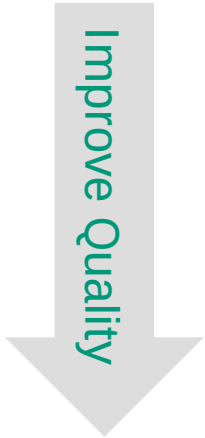
JAM is simulated by injecting CAM messages for the individual vehicles

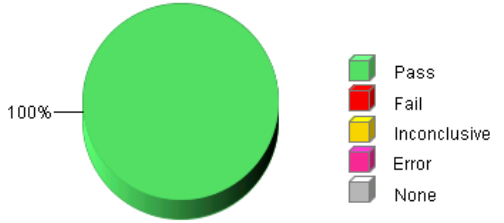


SIM^{TD} REFERENCE TESTS

- **40 Communication tests and test variants**
  - CAM variants
  - CAM frequencies, message life time handling etc.
  - DENM variants
- **20 Application tests**
  - testing event detection, propagation, handling and user notification for several V2X applications
- **Reference circuit**
  - event handling and user notification for several V2X applications
- **Reference circuit with load**
  - event handling and user notification for several V2X applications by applying networked and CPU load
- **Goals: <u>Integration</u>, <u>regression</u> and acceptance testing**





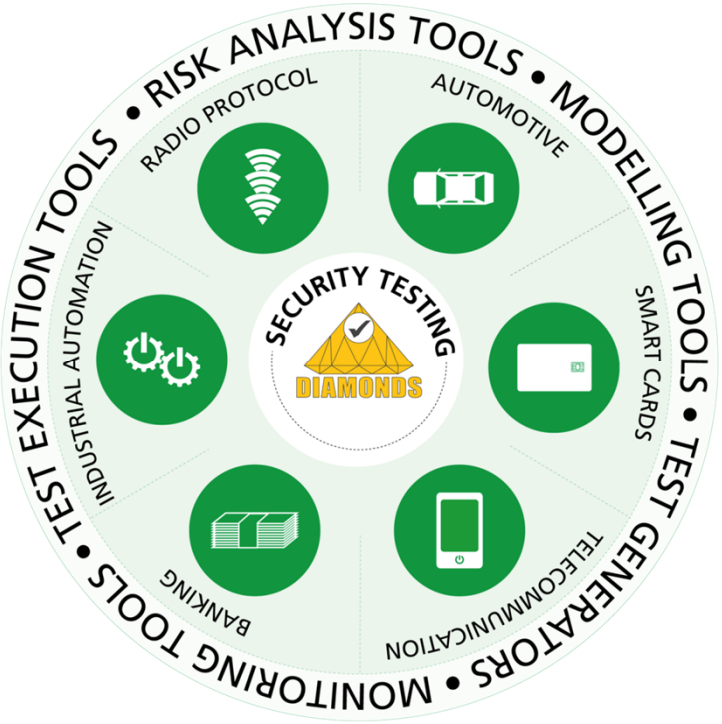


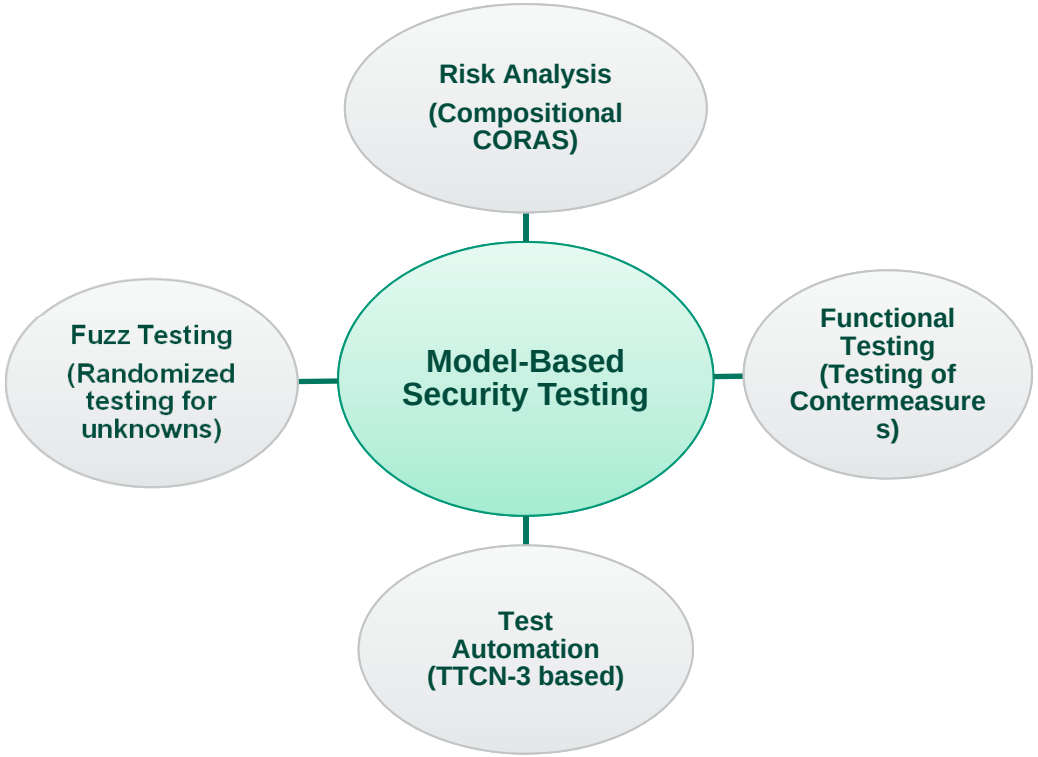
Project with Audi, Bosch, BMW, Continental, Daimler, Opel, Telekom, VW

CHALLENGE SECURITY TESTING

Security testing solutions for six industrial domains

http://www.itea2-diamonds.org/





Ina Schieferdecker, Model Based Security Testing: Selected Considerations (Keynote) Sectest 2011, Workshop on the 4th IEEE International Conference on Software Testing, Verification and Validation Berlin, Germany

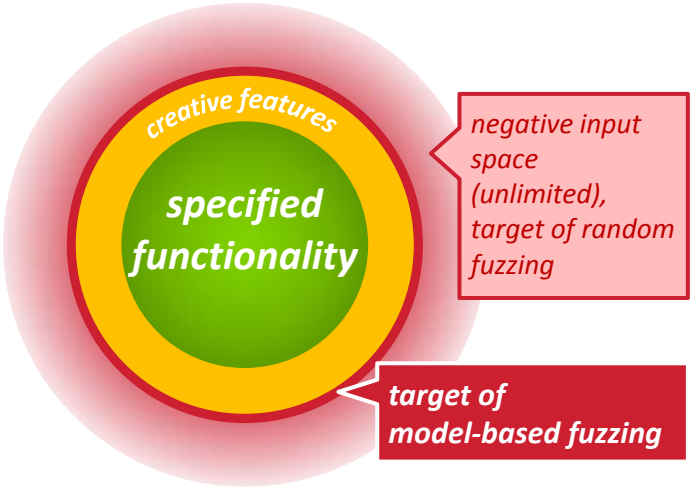
FUZZ TESTING

1. Fuzzing originally describes the random generation of test vectors (Miller et. al. in the early 1990s).

2. Fuzzing is about injecting invalid or random inputs in order
   - to reveal unexpected behaviour
   - to identify errors and expose potential vulnerabilities.

3. Ideally, fuzzers generate semi-valid input data, i.e. input data that is invalid only in small portions.

4. Depending on fuzzer's knowledge about the protocol, fuzzers can generate totally invalid to semi-valid input data

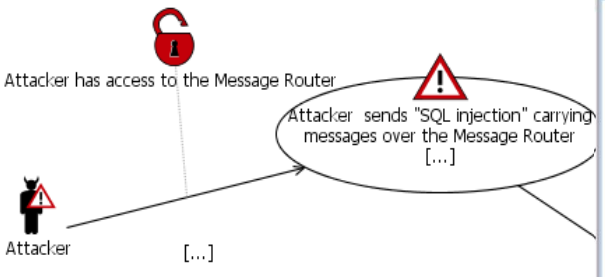


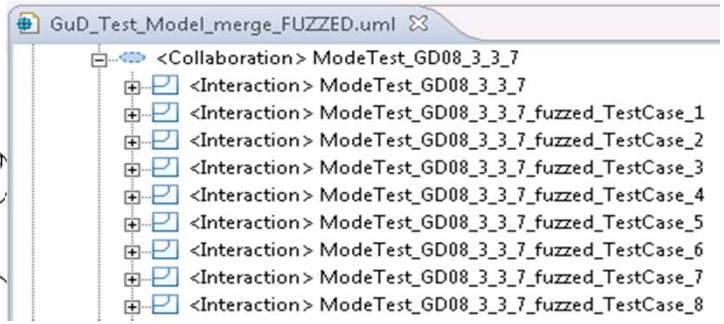
→ Developed in DIAMONDS new behavior-fuzzing approaches

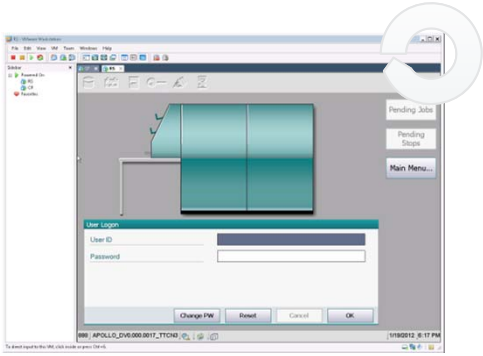
see also: Takanen, DeMott, Miller: Fuzzing for Software Security and Quality Assurance. Artech House, 2008.

G&D Case Study
Banknote Processing Machines

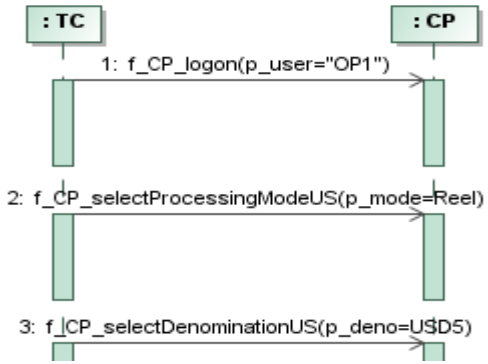
G&D Case Study
Methodology







Risk analysis → Modeling → Test generation → Test code generation → Test execution




```
testcase ModeTest_GD08_3_3_7_fuzzed_TestCase_219 ()
runs on Comp_CP_RS
system System_CP_RS
{
    var integer i, v_total, v_rjc;

    f_mtcSetup_CP_RS(CPRSStartingMode:All);

            f_CP_logon("OP1");
            f_CP_selectProcessingModeUS(ProcessingModeUS:Reel);
```

TTCN-3

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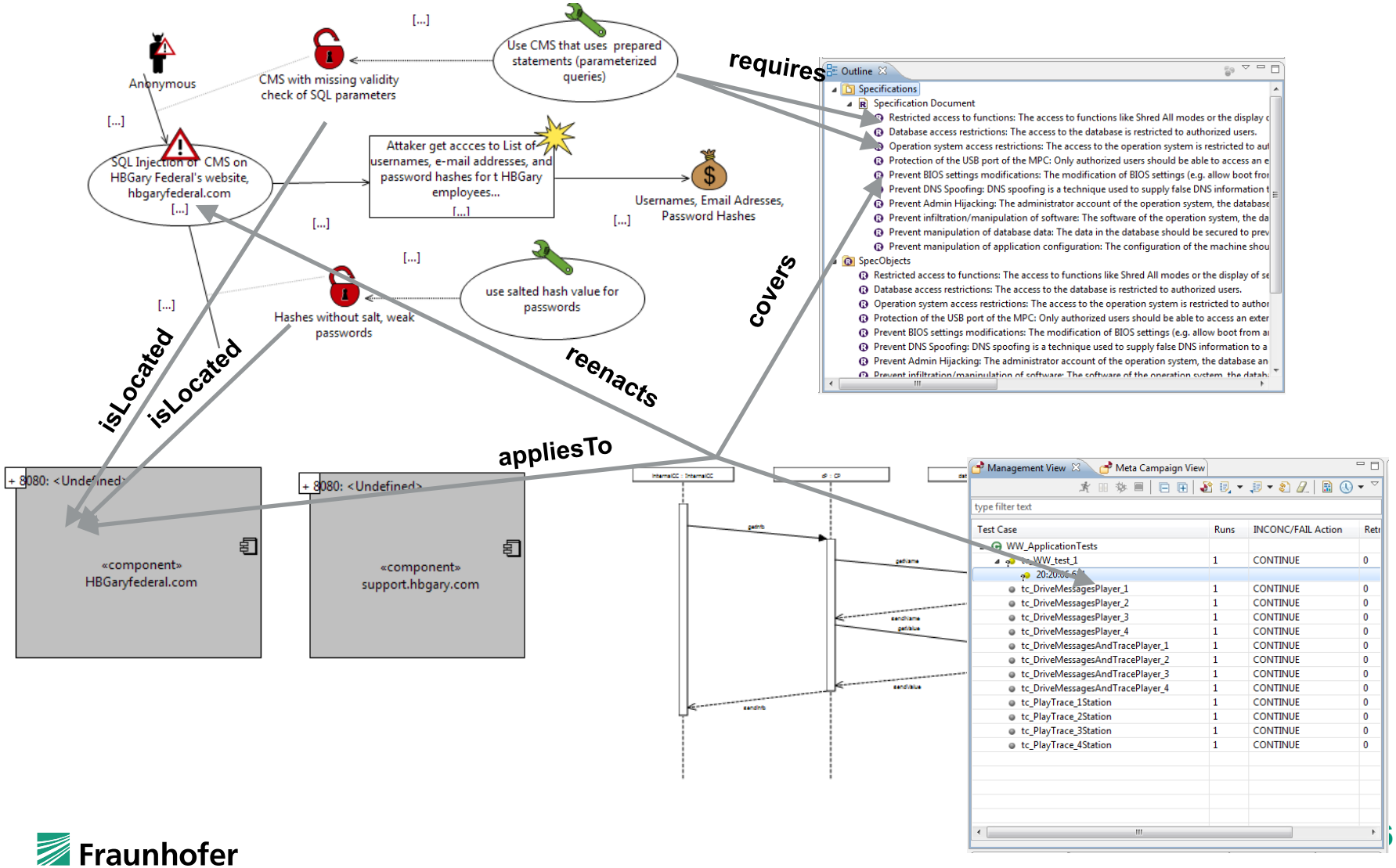
TRACING
with CORAS, Papyrus, ProR and TTworkbench



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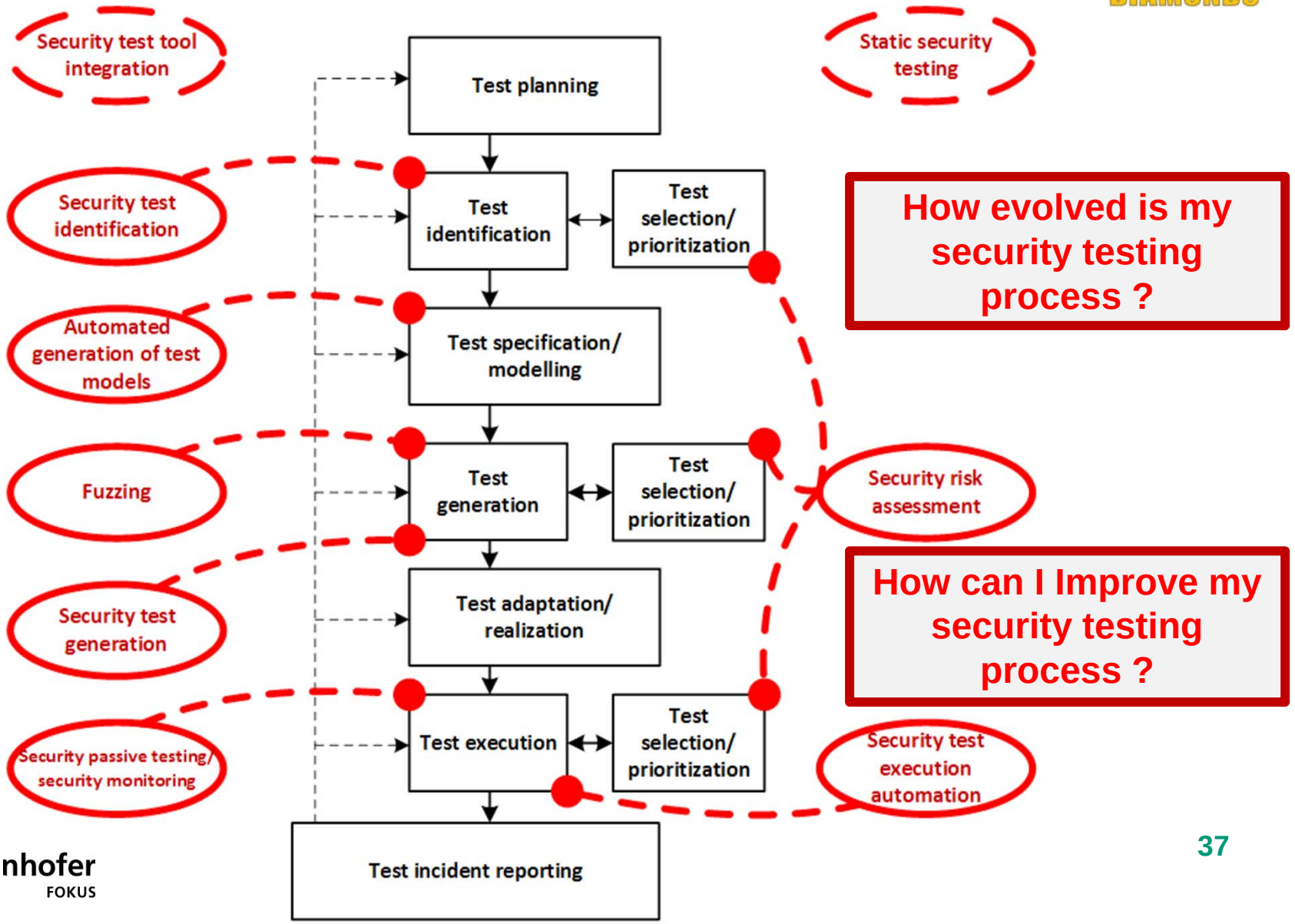
EVALUATION AND OPTIMIZATION



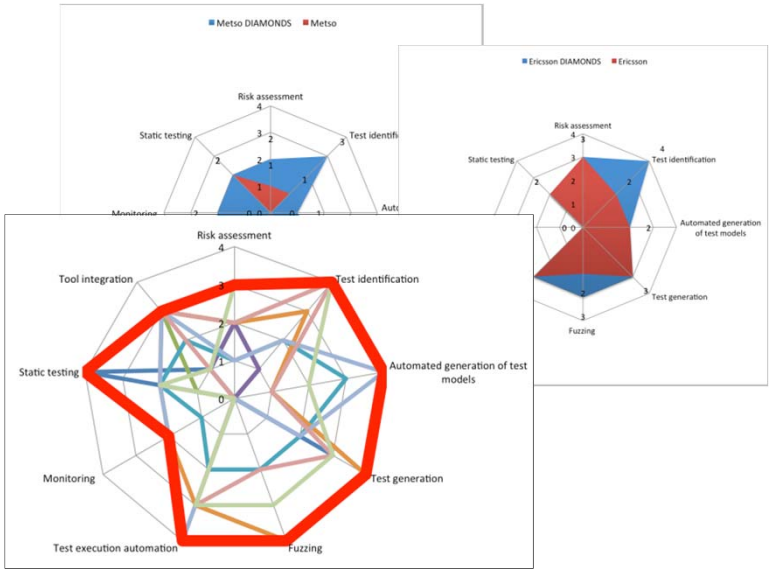
CASE STUDY RESULTS

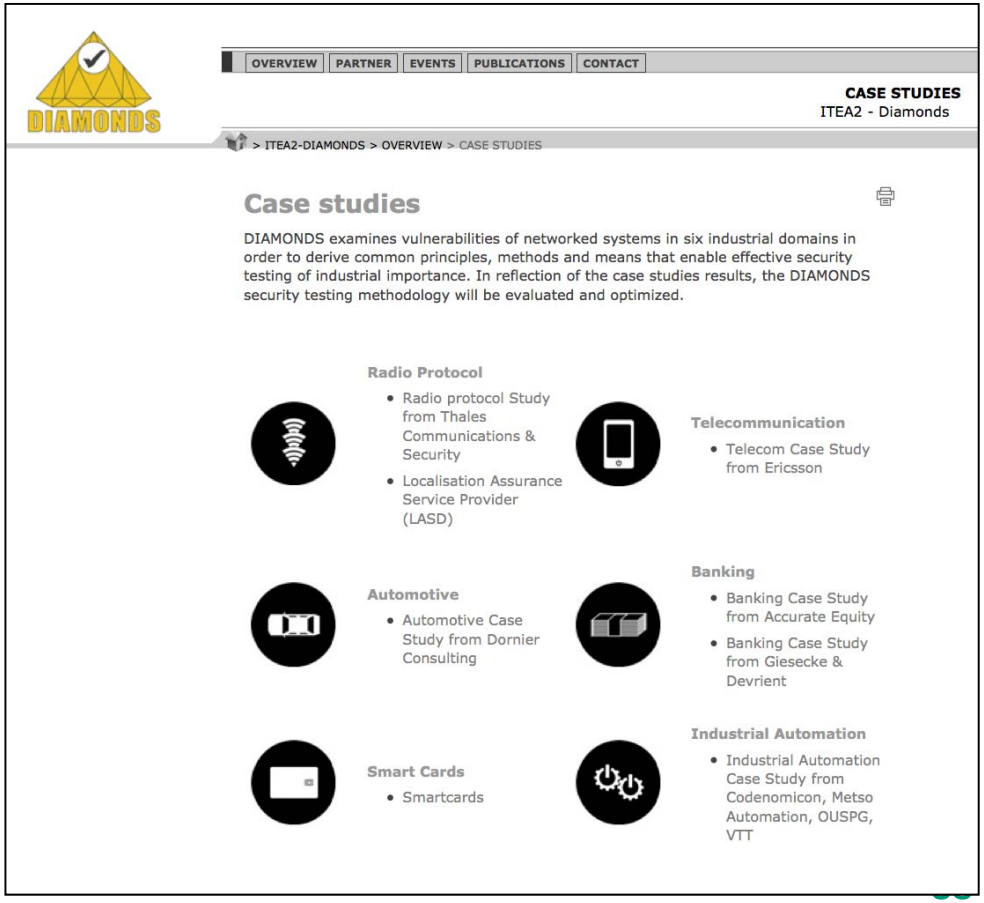
1. Collection of the experiences and results for all case studies

- Case study experience sheets (DIAMONDS web site)
- Case study experience report (ETSI document)

2. STIP Evaluation

- Shows progress in all case studies





The RACOMAT Tool

RASEN

Combines component based, low level risk assessment with security testing

- Risk analysis for component-based testing
- Reusable risk assessment artifacts
- Automated analysis of system components
- Integrates with external data bases like MITRE CAPEC and MITRE CWE

- Risk-Based Security Testing, Test-Based Risk Assessment and automation with the help of **Security Test Patterns** and **Security Testing Metrics**
- Semi-automated derivation of tests
- Automated execution of tests

RACOMAT
Risk Assessment COMbined with Automated Testing

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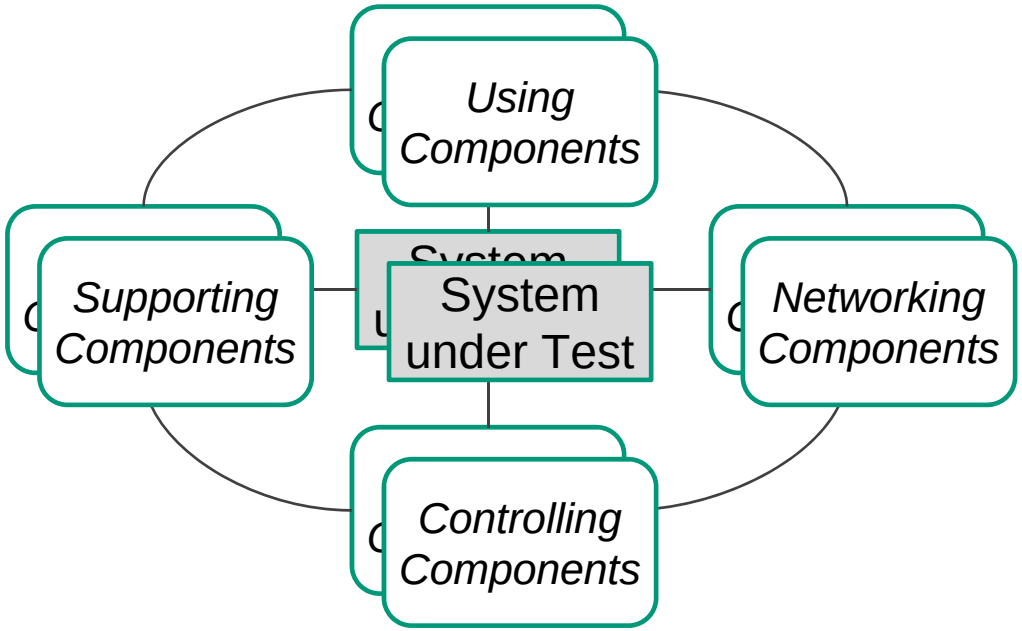
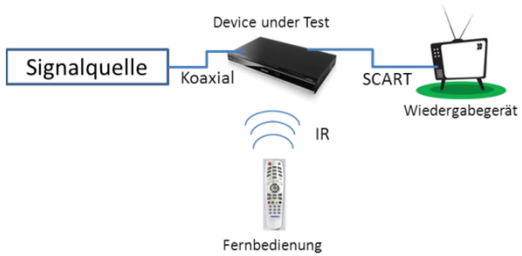
CHALLENGE SYSTEM OF SYSTEMS

– Test environments as part of test setups





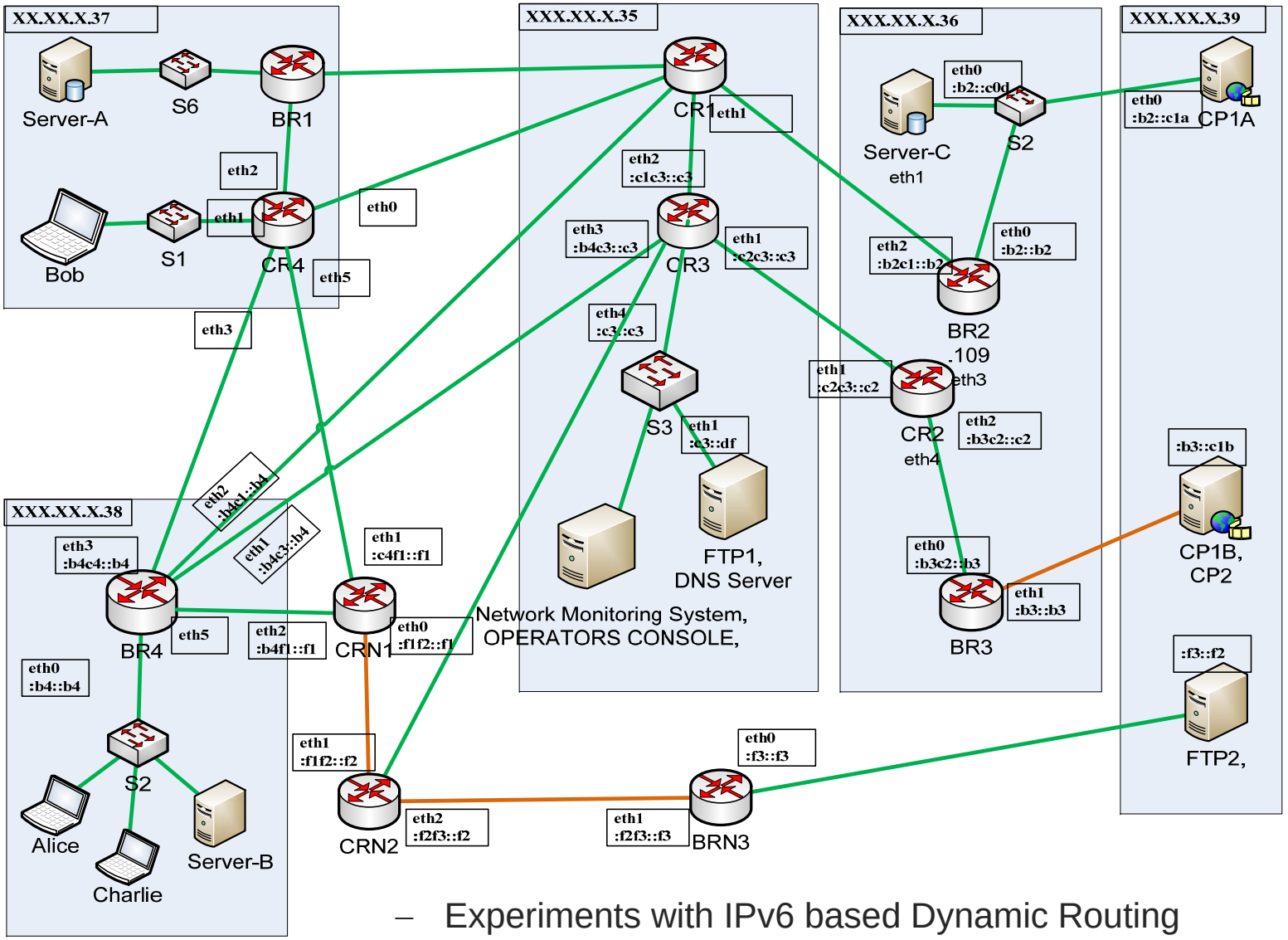
In: Testumgebungen für eingebettete Systeme im Griff. Carsten Weise, SIGS Datacom Online Testing Issue, 2012

– Combinations of real, virtualized and simulated components
– Integration of monitors and impairment components
– Management of test environments (configurations, versions, connections)

IPV6 TESTBED INFRASTRUCTURE

- **Hybrid infrastructure** running **virtualized images and real physical devices**
  - IPv6 Linux/FreeBSD/NetBSD/OpenBSD soft routers – XORP, Quagga, Zebra
  - Physical vendors‘ hardware (e.g. Cisco Routers)
  - Virtualization and Virtualization Management - VMware ESXi, Virtual Box, Xen and OpenStack/CloudStack (in the pipeline)
  - Test automatization and reporting based on scripting and various tools (tcpdump, wireshark, pcap, Perl, Python, bash)

IPV6 TESTBED INFRASTRUCTURE



– Experiments with IPv6 based Dynamic Routing (e.g. OSPFv3, BGP), QoS, and OpenFlow/SDN

FURTHER EXAMPLES

- HL7/IHE testing in eHealth
- TCMS testing in transport
- Performance testing in mobile communication
- Data platform testing in open data
- etc.

CERTIFIED TESTER FOR IOT ?!

	Main modules	Supplementary modules
CTEL	EL-ITP EL-TM	
CTAL	AL-TM AL-TA AL-TTA	Security Test Autom **Industrial IoT ?!** **Consumer IoT ?!**
CTFL	Software Foundation **Embedded Systems Foundation ?!**	Agile Auto motive MBT Usability Mobile **IoT ?!**

ASQF
Arbeitskreis Software-Qualität und -Fortbildung e.V.

is the network of excellence for the software development industry in German-speaking European countries.

1.400 globally active companies, specialists, institutions of higher education and research institutes are members of ASQF and share the commitment to guarantee quality standards in ICT.

iSQI

is a leading provider of certification examinations all over the world, headquartered in Germany with subsidiaries in London, Boston and Amsterdam.

Focusing on IT professions, iSQI plays a large role in certifying the know-how of professionals in over 90 countries on 6 continents in 10 languages. In 2015, iSQI examines more than 22.000 individuals.

Working group on IoT Quality Engineering

- Challenges and risks
- Concepts, methods and approaches
- Syllabus, exams, training material

- Mainly members from industry (e.g. Festo, Siemens, SAP)

- If you are interested in status/results, please drop me an email: ina.schieferdecker@asqf.de

CHALLENGES IN IOT TESTING

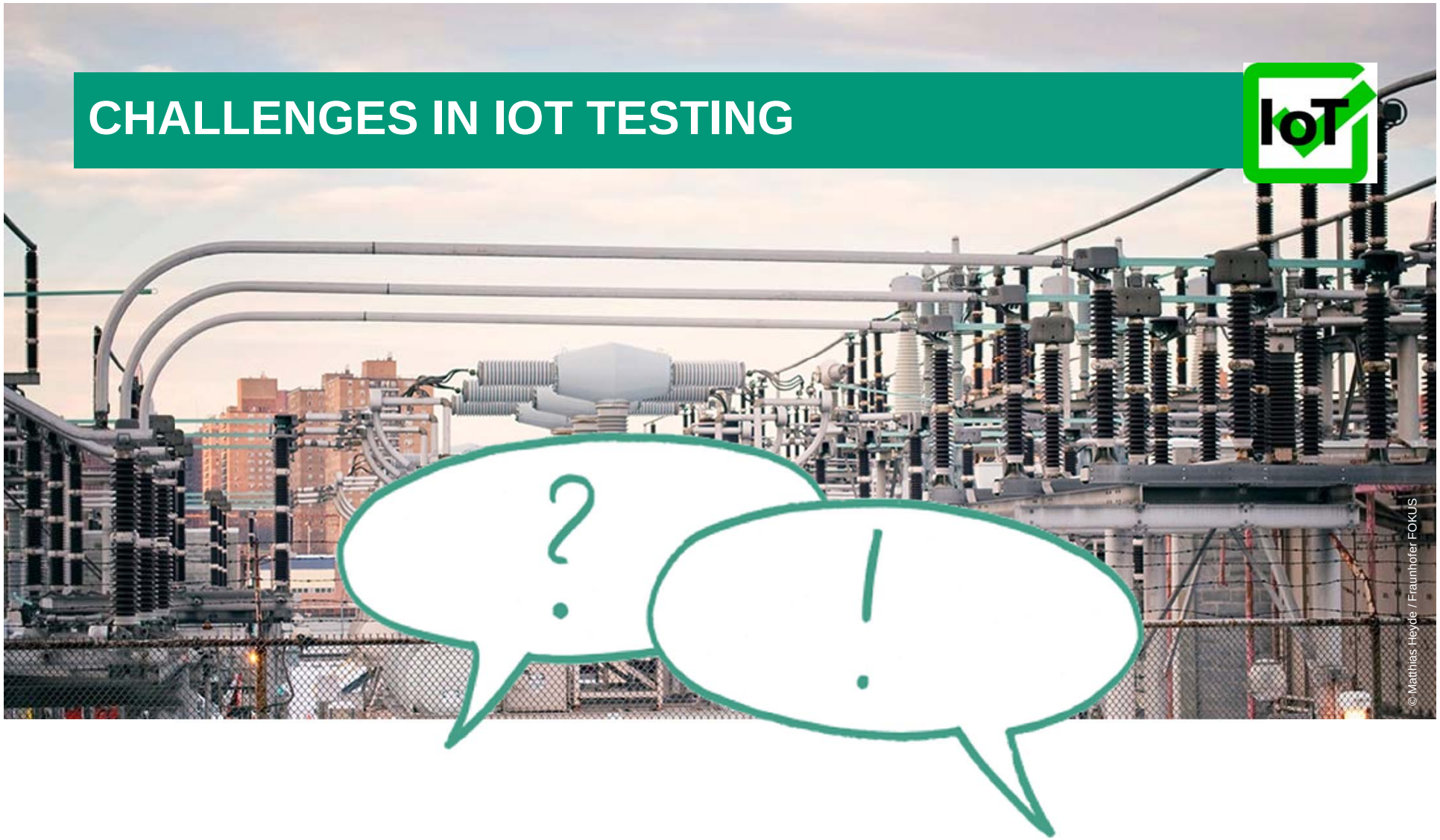
1. Combination of software, system, protocol and security testing

2. Need for high-degree of test automation

3. Managemet of distributed, flexible and/or virtualized test environments including test, simulation, SUT components and devices

4. Development of expertise and experiences in IoT Testing

CHALLENGES IN IOT TESTING



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iSQI