# Specification and Testing of Banknote Processing Systems with Coloured Petri Nets

Thomas Schnattinger, Andrej Pietschker

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30th TAV

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Creating Confidence.

## Agenda

- Automated testing in the software development process
- Motivation for system specifications with formal methods
- Excursion: Basics of Coloured Petri Nets (CPNs)
- A Coloured Petri Net model for BN processing and jam recovery
- A Coloured Petri Net model as System Under Test (SUT)
- Conclusions



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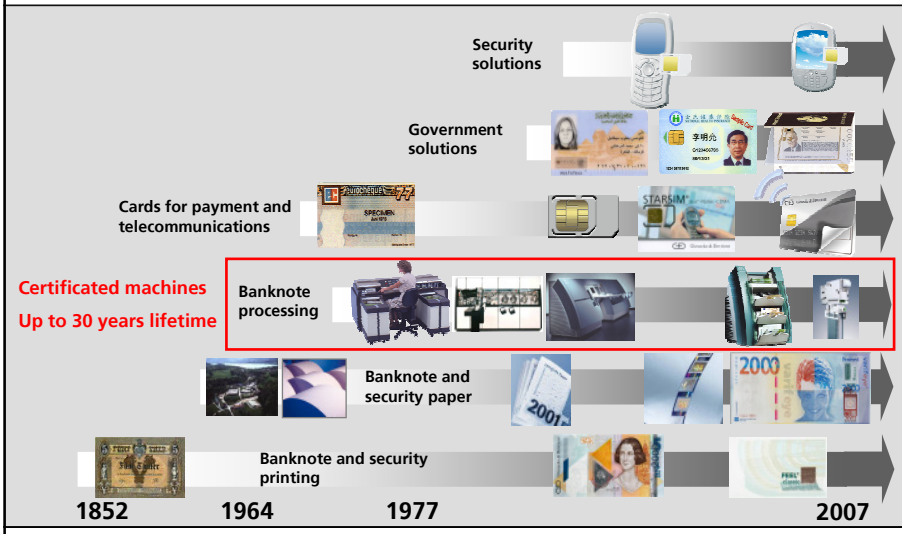
## Giesecke & Devrient — From Printing Paper Securities to Providing High-Tech Solutions



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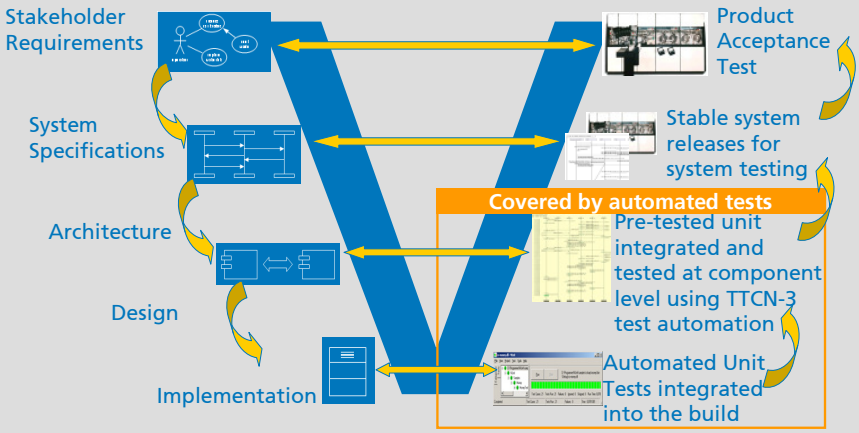
## Automated SW-Testing – Where do we Stand?



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## Automated SW-Testing – Potential Extensions

Test-cases should be applied as early as possible

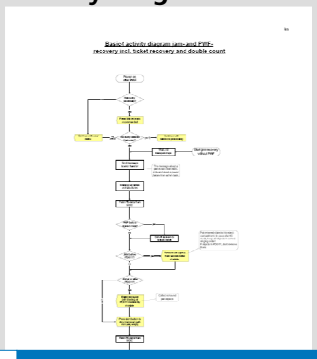
Test-cases should be available and verified as early as possible

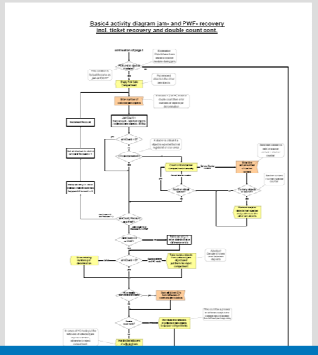
**We need an *executable model* as a System Under Test (SUT) to apply and verify the test cases *already in the first phases* of the development process**



## System Specifications – Our Current Approach

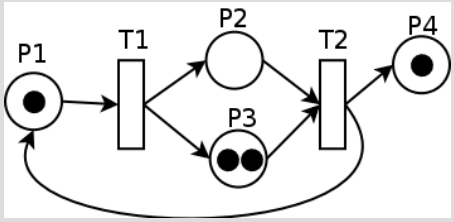
**How do we currently tackle these issues in the specifications?**
**"Activity diagrams":**





**We need formal, *executable* high-level descriptions for the specifications, e. g. Petri Nets**

## Excursion: Coloured Petri Nets (CPNs)



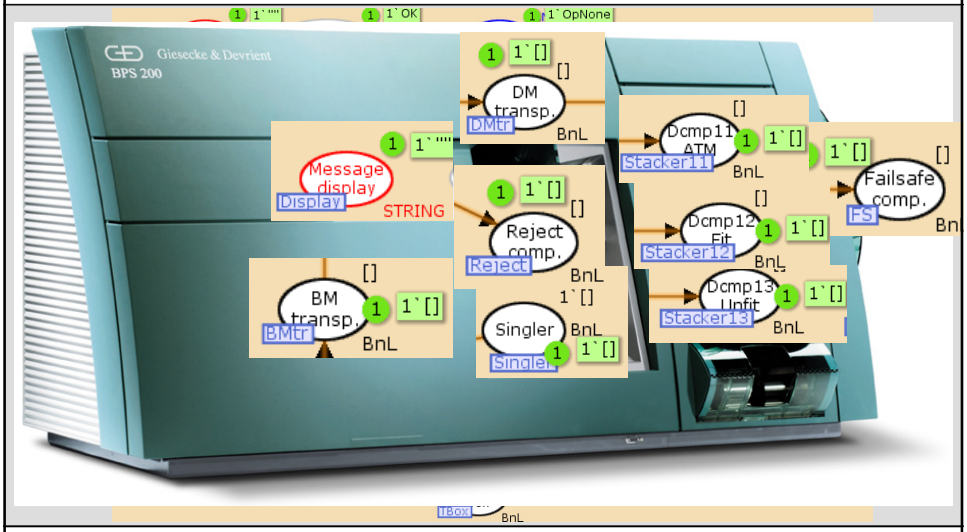

**Coloured Petri Net =**
**Petri Net +**
**elaborated type system +**
**arbitrary data manipulation**

### Some benefits of Coloured Petri Nets

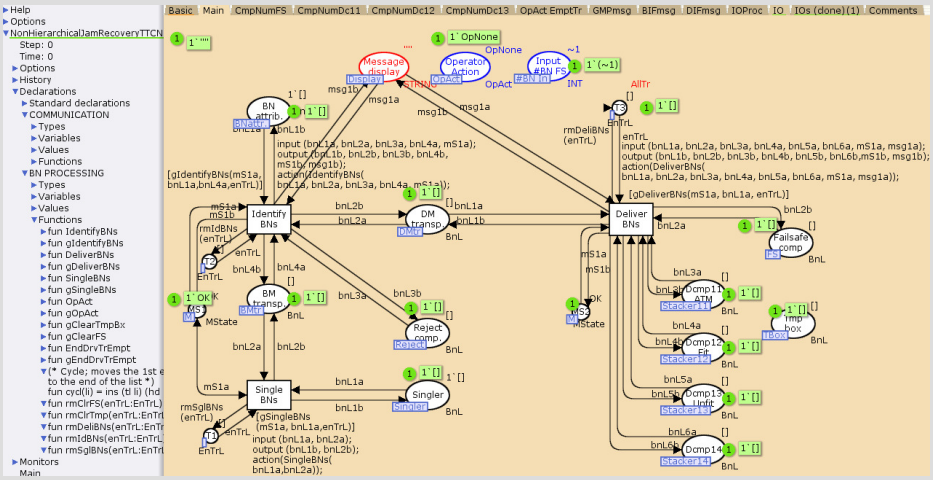
- graphical oriented language with a well-defined semantics for design, specification, simulation and verification of systems
- hierarchical descriptions (subnets)
- description of states and actions (data manipulation)
- formal analysis methods
- tool support → **CPN Tools**



## Banknote Processing with Coloured Petri Nets



## Banknote Processing with Coloured Petri Nets – Details



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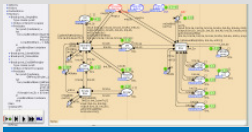
## Automated Model Testing – Coupling with TTCN-3



Comms/CPN

TTCN-3

TCP/IP Adapter

TCP/IP Connections



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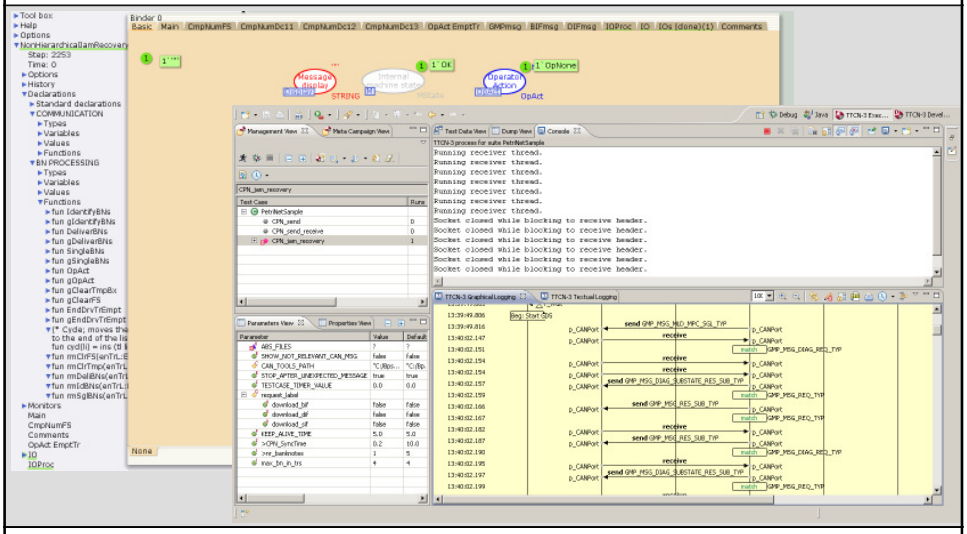
## Coupling of CPN with TTCN-3 – Demonstration





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## Automated System Release Testing – Coupling with TTCN-3


TTCN-3

CAN Adapter

CAN bus

**The new approach allows for testing specifications and system releases with the same test-cases**



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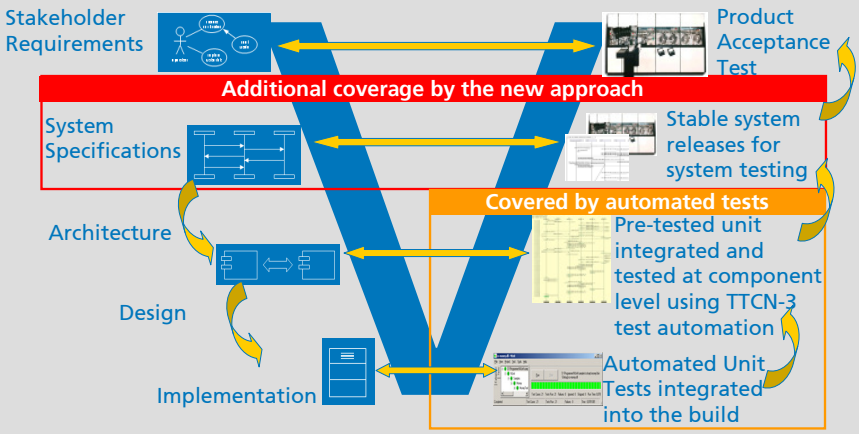
## Automated SW-Testing – The New Picture



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## Outlook

**Model extensions**

- Inclusion of timing/performance aspects in the CPN model
- Refinement to the level of single CAN messages

**Tool extensions**

- CPN model support for SW-architecture decisions
- Test case generation from the model
- Code generation from the CPN model



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## Conclusions

**CPN require more effort during specifications, but**

- CPN Tools facilitates *explicit*, *unambiguous* and *complete* descriptions and thus *better specifications*
- The v*isual representation* allows an abstract view, focused on the core elements
- The specifications can be used in automatic and interactive simulations
- Coupling with TTCN-3 allows to use the specifications as a *System Under Test* (SUT) in automated testing
- Test cases can be validated as soon as the specifications are available