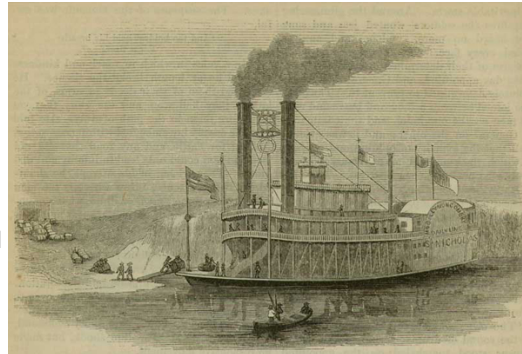**Motivation**

Introduction

☐ Steam engine and software
☐ Ariane 5
☐ Safety verification and reliability analyses
☐ Testing and verification

Introduction

... When George Ealer saw the chimneys plunging aloft in front of him, he knew what the matter was; so he muffled his face in the lapels of his coat, and pressed both hands there tightly to keep this protection in its place so that no steam could get to his nose or mouth.

He had ample time to attend to these details while he was going up and returning. He presently landed on top of the unexploded boilers, forty feet below the former pilot-house, accompanied by his wheel and a rain of other stuff, and enveloped in a cloud of scalding steam. All of the many who breathed that steam, died; none escaped. ...

Mark Twain: Life on the Mississippi

Introduction of the Steam Engine in the Industrial Revolution

☐ Well-known personalities (J. Watt among others) are warning of the dangers of high pressure machines.

☐ Use of the more efficient high pressure machines is prefered to the safer low pressure steam engine.

☐ From 1816 to 1848 in the United States 233 explosions of steamboats were recorded with 2562 people killed, 2097 people injured and a property damage of more than 3 million US$.

☐ Causes:

▪ Use of the new technology accelerates more than the required skills can be developed.

▪ The theoretic principles are not completely known.

▪ Construction standards and safety standards do not exist.

▪ Hardly any standard components do exist.

▪ Designers do not need a special training.

▪ No control authority controlling the safety of the system and no control regulation do exist.

Solution of the Problems

☐ Establishment of the engineering science engine construction with areas such as physics, material science etc.

☐ Construction of machines by special trained, skilled persons (engineers)

☐ Creation of construction and safety standards, together with the creation of standard components

☐ Establishing of test standards in the form of laws; (in Germany: "Reichs-Kesselgesetz" from 9. 1. 1910) and the formation of a testing/control organisation (steam engine inspection authority)

copmare: Joly: Technisches Auskunftsbuch für das Jahr 1919, 25. Auflage

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Solution of the Problems

Seite 3

Solution of Problems

Steam Engine and Software?

- ☐ Computer and software are – as once the steam engine in the industrial revolution – the new technologies on the threshold of the information society.

- ☐ Use of software accelerates more than the knowledge of their safe construction grows.

- ☐ Today in some areas the survival of people depends on the correct function of software.

- ☐ In the area of construction methods for software – the area of software engineering respectively software technology – methods and technologies are known, but only insufficiently established in practice (contructive and analytic QA-methods).

- ☐ Research deals with the realisation of standard components and the reusability of components (reuse, class libraries).

Software Quality Assurance

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Steam Engine and Software?

☐ Standards for the construction and quality assurance of software partially exist already (e.g., ISO 9001).

☐ A new science – computer science – is already established.

☐ No regulation exists yet concerning the qualification of software developers.

Ariane 5

June 4., 1996, Kourou / Fr. Guyana:
Maiden flight of the Ariane 5

```
...
declare
 vertical_veloc_sensor: float;
 horizontal_veloc_sensor: float;
 vertical_veloc_bias: integer;
 horizontal_veloc_bias: integer;
 ...
begin
 declare
  pragma suppress(numeric_error, horizontal_veloc_bias);
 begin
  sensor_get(vertical_veloc_sensor);
  sensor_get(horizontal_veloc_sensor);
  vertical_veloc_bias := integer(vertical_veloc_sensor);
  horizontal_veloc_bias := integer(horizontal_veloc_sensor);
  ...
 exception
  when numeric_error => calculate_vertical_veloc();
  when others => use_irs1();
 end;
end irs2;
```

Seite 5

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Ariane 5

☐ Cause

- 37 sec. after engine start (30 sec. after liftoff) Ariane 5 had a horizontal velocity of 32768.0 (internal units). The integer conversion of the 64-bit floating point variable caused a data overflow. The second flight controller experienced the same problem 72 msec before and thus was not operational at that time. Diagnosis data were propagated to the main flight computer. These data were interpreted as valid flight data. Incorrect steering commands were sent. These caused a mechanical overload and finally Ariane 501 exploded.

☐ Effect

- Total financial loss of 850 Million Euro

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Information concerning the Situation in the Development of software intensive systems

There is an expanded and more lengthy process of product approval because FDA has significantly increased the scope and complexity of the review process. These actions have led to much more uncertainty surrounding the regulatory process and have significantly increased the financial investment and time required to develop and commercialize new medical products. The net result of these policies has been significant delays in the approval of new products. It now takes a company more than two years, on average, to obtain f.e. pre market approval. Often, the process takes much longer. Review times have also climbed steadily.

(from: A. H. Magazine, "The Impact of Regulation", in: Medical Device Technology, March 1997, pp. 38 ff, ISSN 10 48 - 66 90)

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Trends

- ☐ Globalisation: verifications have to be uncomplicatedly adapted to changing national standards.
- ☐ Safety critical funtions in software: verifications have to record hardware as well as software.
- ☐ Increasing system complexity: automation
- ☐ Systems with dependent optimisation goals: consideration of interactions, e.g. between availability and safety
- ☐ Increasingly object-oriented software development

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Safety Verifications and Reliability Analyses

- ☐ Safety verifications by legal regulations or admission offices demanded, e.g.:
  - Rail traffic: EBA (Germany)
  - Medical technolog: FDA (USA)
- ☐ Reliability goals are increasingly demanded by customers/clients (e.g. automobile industry)
- ☐ Availability requirements as integral part of the contract are provided with penalties (e.g. public switching technology, rail traffic systems
- ☐ Performance validation of architecture alternatives is a substantial construction criterion.

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Testing and Verification

☐ Safety- and reliability models:
- FME(C)A (Failure Modes Effects (and Criticality) Analysis) (IEC 812)
- Reliability block diagram
- Fault tree analysis (IEC 61025)
- Markov-Analysis

☐ Stochastic reliability analysis

☐ Inspection

☐ Testing, Verification

☐ Supporting methods: TQM, QFD

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