Software Verification

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Today

Aims of the course

Introduction to issues of software quality

Course organization

Lecturers: Bertrand Meyer, Carlo Furia, Sebastian Nanz

Assistant: Chris Poskitt

Webpage: http://se.inf.ethz.ch/courses/2015b_fall/sv/

Monday lectures

10-12, RZ F21 Classical lecture

Wednesday lecture (14-15, RZ F21):

Variable slot: seminar by guest, or extra lecture

Exercise session: Wednesday, 15-17, RZ F21

Purpose of this course

To present available techniques for ensuring better software quality

Topics (see Web page for details)

Axiomatic semantics Auto-active verification Separation logic Theory of Programs	Program proofs
Static analysis Abstract interpretation	Program analysis
Model checking Real-time systems	Model checking
Testing	Testing

Guest lecturers

Chris Poskitt (auto-active verification; separation logic)

Scott West, Google (topic TBA)

Alexey Kolesnichenko (AutoTest)

Max (Yu) Pei (AutoFix)

Grading

Project: 30%

Written exam (Monday 14th December): 70%

All material considered during regular lecture slots and exercise classes is examinable

Overview of software verification

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Your PC ran into a problem and needs to restart. We're just collecting some error info, and then we'll restart for you. (0% complete)

If you'd like to know more, you can search online later for this error: HAL_INITIALIZATION_FAILED

The more general notion: software quality assurance

A set of policies and activities to:

- Define quality objectives
- Help ensure that software products and processes meet these objectives
- Assess to what extent they do
- Improve them over time

Verification

The Quality Assurance activity devoted to enforcing quality, in particular:

- Detecting deviations from quality
- Correcting them

Common distinction ("V & V"):

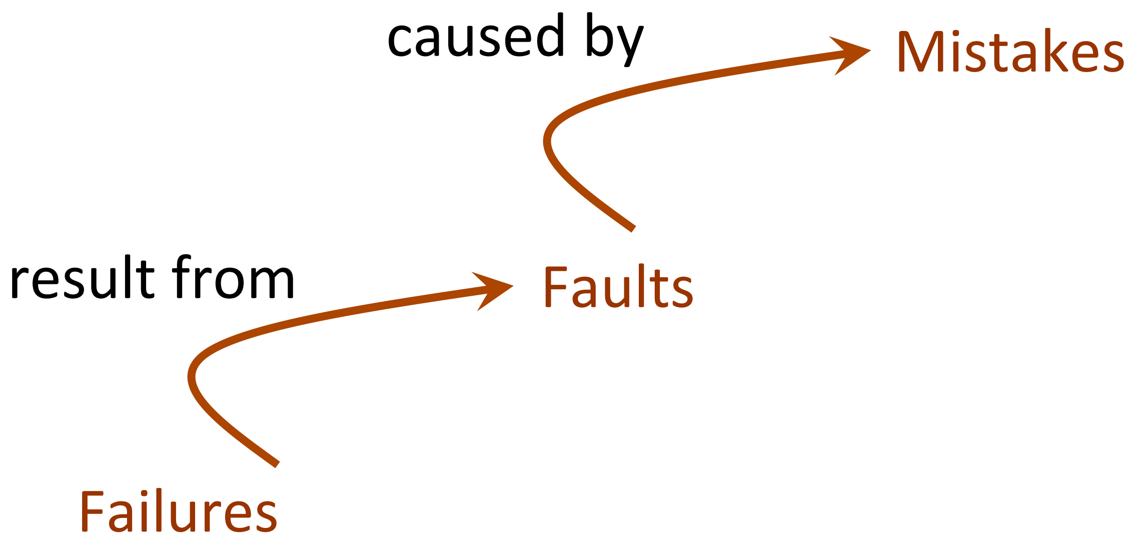
- Validation: assessment of any product relative to its specification ("checking that it is doing the right things")
- Verification: assessment of internal quality ("checking that it is doing things right")

In this course, "Verification" covers both

The product side

Quality is the absence of "deficiencies" (or "bugs").

More precise terminology (IEEE):



What is a failure?

For this discussion, a failure is any event of system execution that violates a stated quality objective

Verification techniques

A priori techniques

- Build system for quality; e.g.: process approaches, proof-guided construction, Design by Contract

A posteriori techniques

- Static: from software text only
  - Program proofs
  - Program analysis / abstract interpretation
  - Model checking
- Dynamic: execute software
  - Testing

Software quality: external vs internal

External factors: visible to customers

(not just end users but e.g. purchasers)

- *Examples* : ease of use, extendibility, timeliness

Internal factors: perceptible only to developers

- *Examples* : good programming style, information hiding, documentation

Only external factors count in the end, but the internal factors make it possible to obtain them.

Software quality: product vs process

Product: properties of the resulting software

For example: correctness, efficiency

Process: properties of the procedures used to produce and "maintain" the software

Some external factors

Product quality (immediate):

- Reliability
- Efficiency
- Ease of use
- Ease of learning

Process quality:

- Production speed (timeliness)
- Cost-effectiveness
- Predictability
- Reproducibility
- Self-improvement

Product quality (long term):

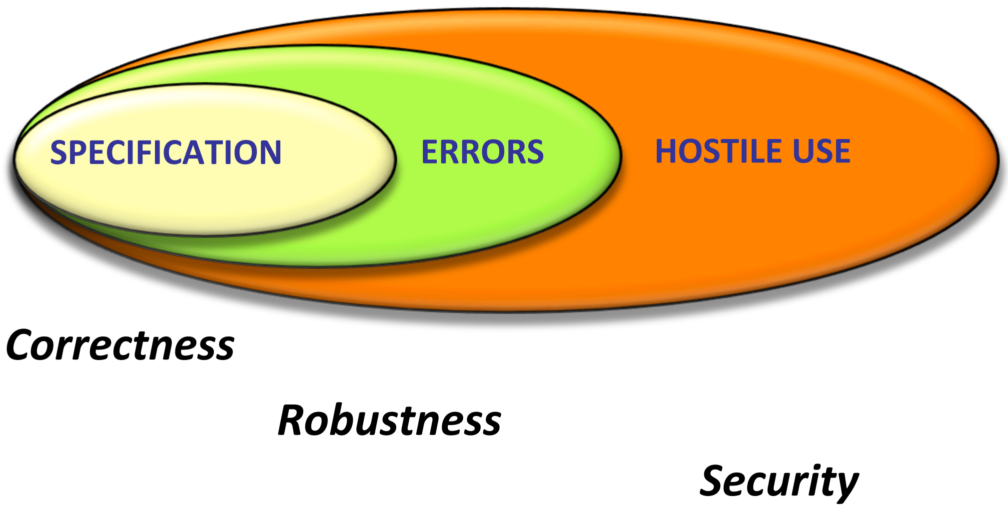
- Extendibility
- Reusability
- Portability

Reliability

Correctness:
The systems' ability to perform according to specification, in cases covered by the specification

Robustness:
The systems' ability to perform reasonably in cases not covered by the specification

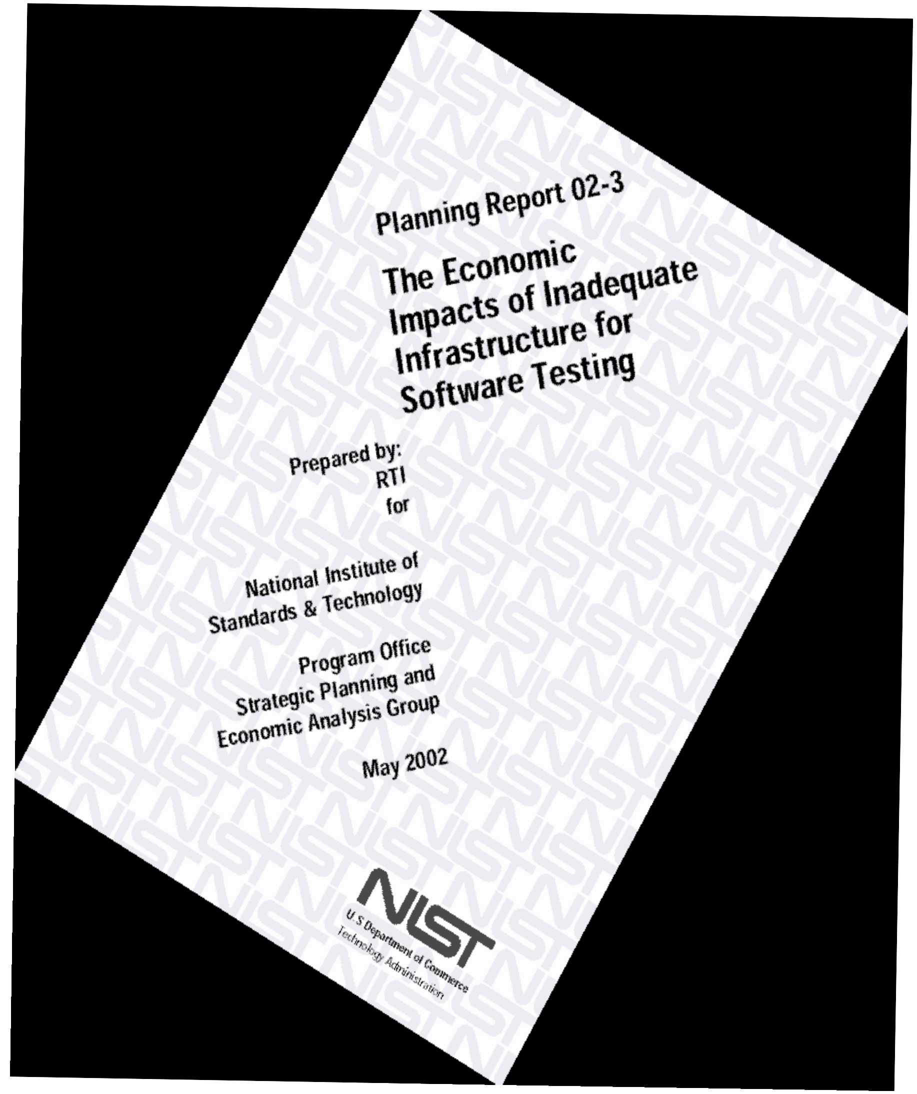
Security:
The systems' ability to protect itself against hostile use



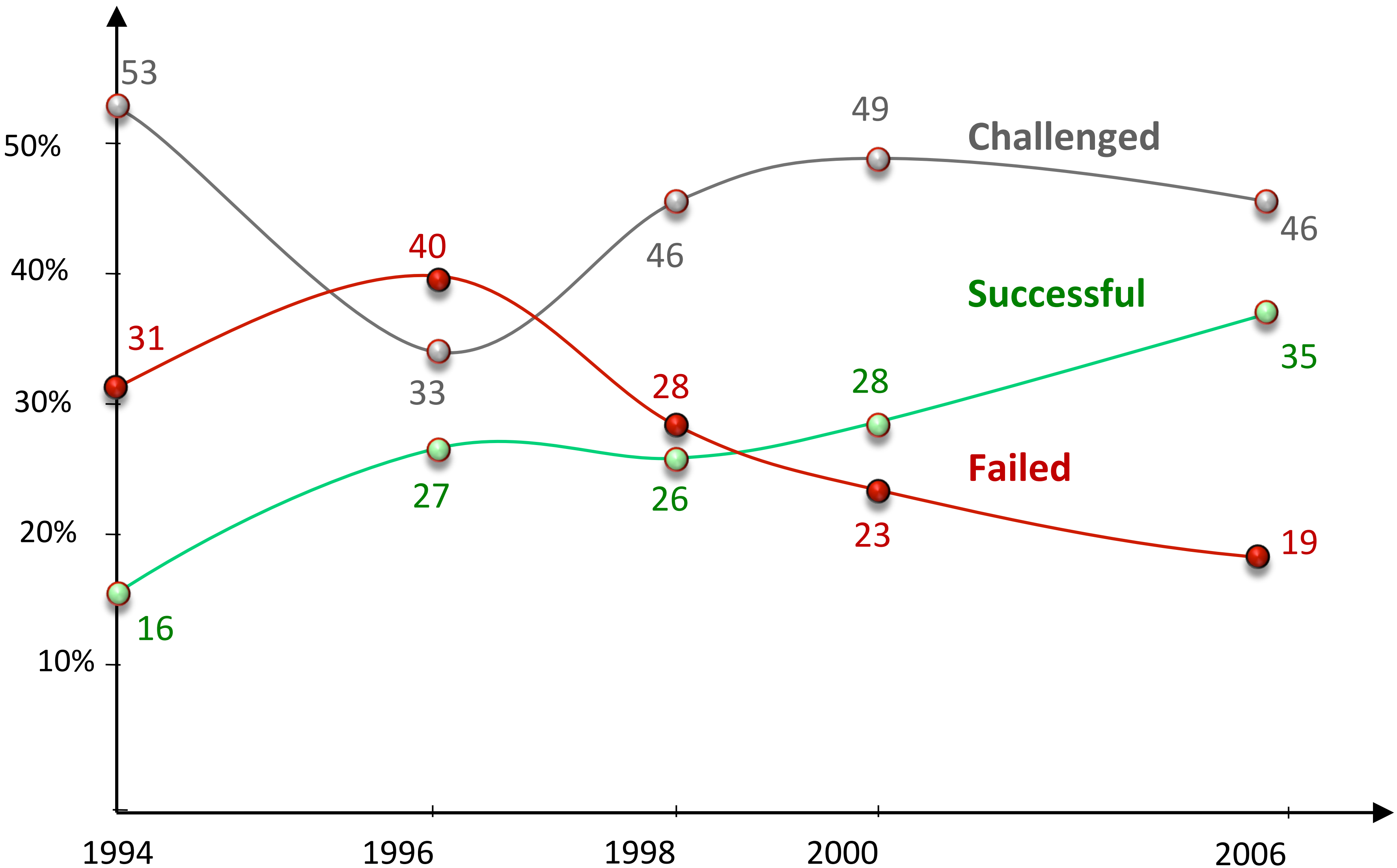
NIST report on testing (May 2002)

Financial consequences, on developers and users, of "insufficient testing infrastructure"

$ 59.5 B.



Software projects according to Standish



Some famous failures

Ariane 5

Therac

Patriot

London Ambulance System

Mars Orbiter Vehicle

Buffer overflows

…

Mars Climate Orbiter

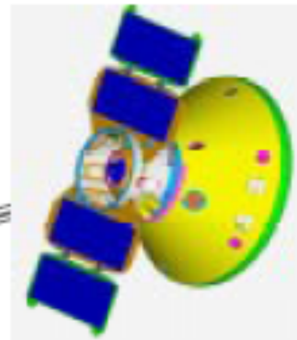
Mishap Investigation Board

Phase I Report

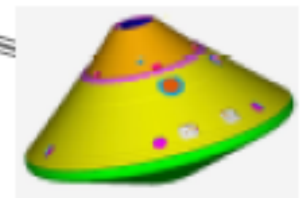
November 10, 1999

Mars Polar Lander

Cruise
- RCS attitude control
- Four trajectory correction maneuvers, Site Adjustment maneuver 9/1/99, Contingency maneuver up to Entry – 7 hr.
- 11 Month Cruise
- Near-simultaneous tracking w/ Mars Climate Orbiter or MGS during approach

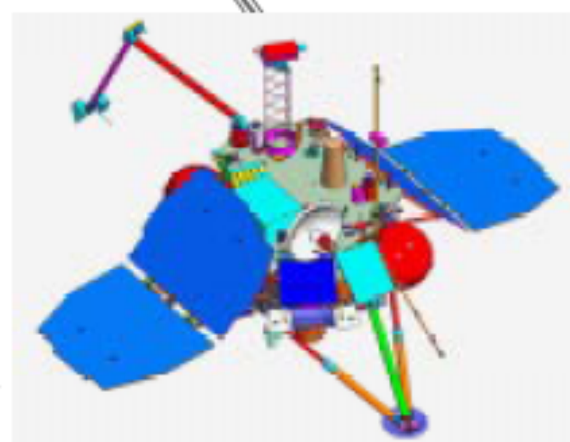


Entry, Descent, and Landing
- Arrival 12/3/99
- Jettison Cruise Stage
- Microprobes sep. from Cruise Stage
- Hypersonic Entry (6.9 km/s)
- Parachute Descent
- Propulsive Landing
- Descent Imaging [MARDI]



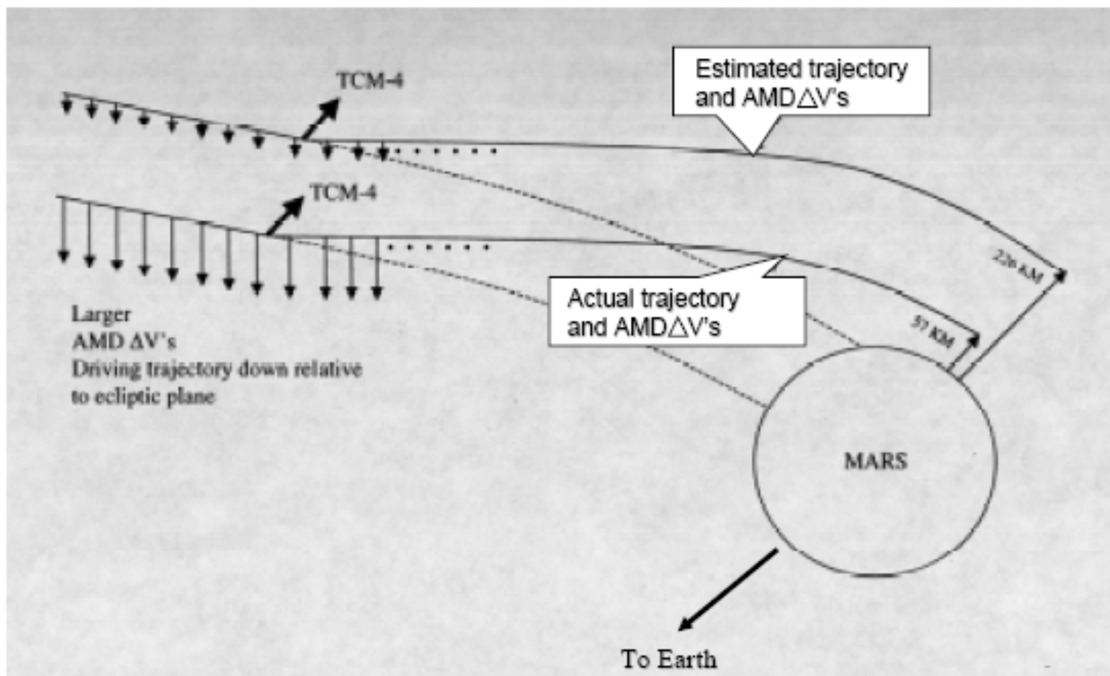
Launch
- Delta 7425
- Launch 1/3/99
- 576 kg Launch Mass

Landed Operations
- 76° S Latitude, 195° W Longitude
- Ls 256 (Southern Spring)
- 60–90 Day Landed Mission
- MVACS, LIDAR Science
- Data relay via Mars Climate Orbiter or MGS
- Commanding via Mars Climate Orbiter or direct-to-Earth high–gain antenna



The problem

On September 27, 1999, the operations navigation team consulted with the spacecraft engineers to discuss navigation discrepancies regarding velocity change (ΔV) modeling issues. On September 29, 1999, it was discovered that the small forces ΔV's reported by the spacecraft engineers for use in orbit determination solutions was low by a factor of 4.45 (1 pound force=4.45 Newtons) because the impulse bit data contained in the AMD file was delivered in lb-sec instead of the specified and expected units of Newton-sec.



Ariane-5 maiden launch, 1996

37 seconds into flight, exception in Ada program not processed; order given to abort mission. Loss estimated to $10 billion.

Exception was caused by an incorrect conversion: a 64-bit real value was incorrectly translated into a 16-bit integer.

Systematic analysis had "proved" that the exception could not occur – the 64-bit value ("horizontal bias" of the flight) was proved to be always representable as a 16-bit integer !

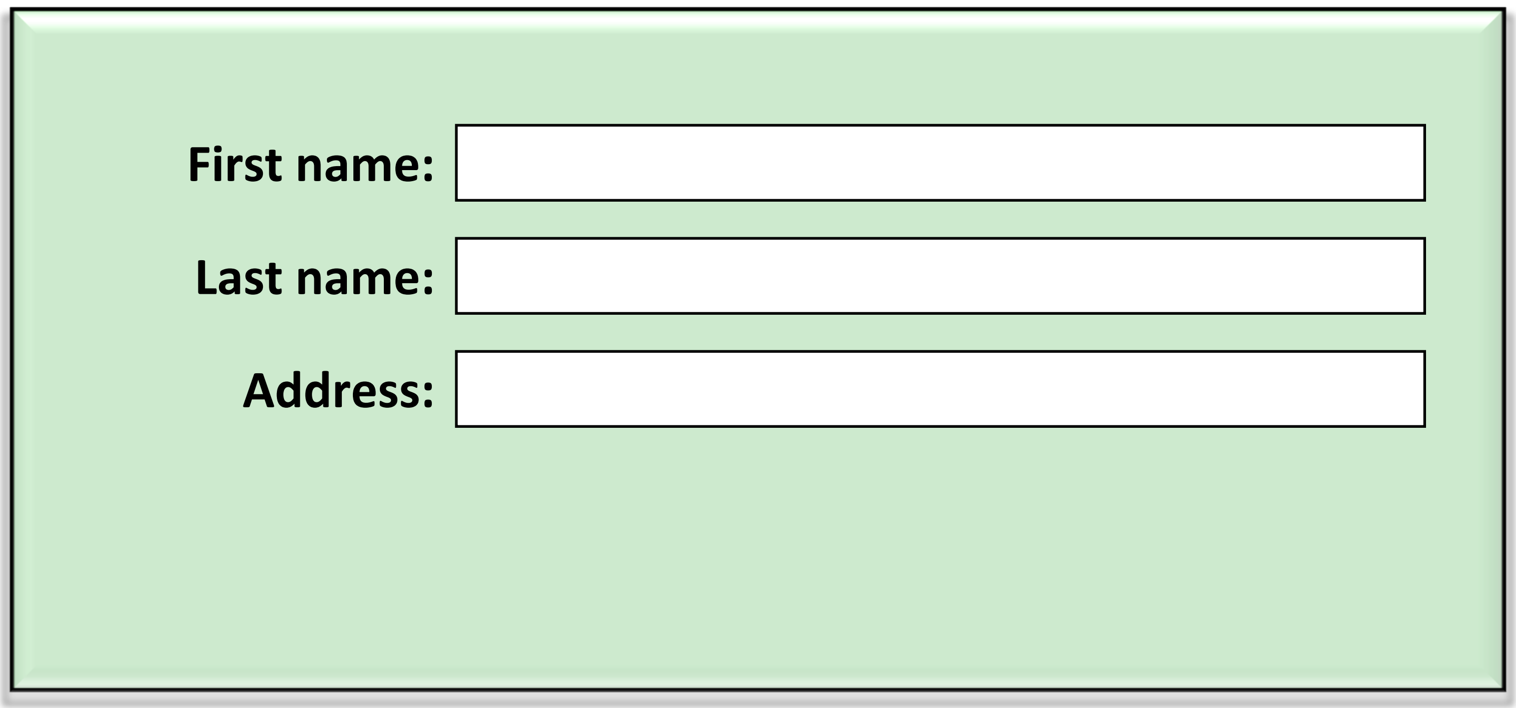
It was a REUSE error:

- The analysis was correct – for Ariane 4 !
- The assumption was documented – in a design document !

See Jean-Marc Jézéquel & Bertrand Meyer, "Design by Contract: The Lessons of Ariane, IEEE *Computer*, January 1997, available at se.ethz.ch/~meyer/publications/computer/ariane.pdf

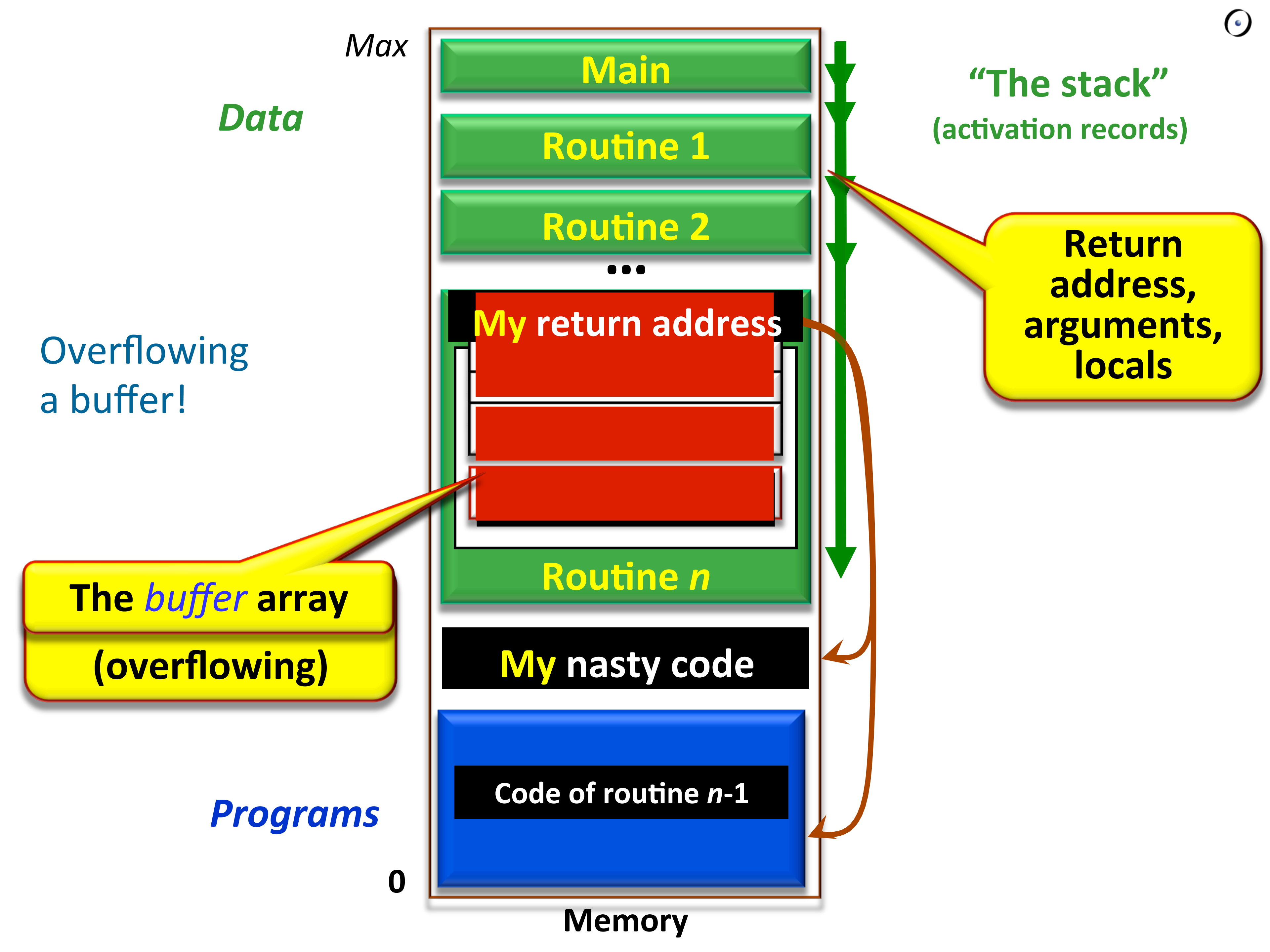
Security example: the buffer overflow

System expects some input from an external user:



Getting the input

```
from i := 1 until
        i > input_size
loop
        buffer [i ] := input [i ]
        i := i + 1
end
```



Max
Data
Main
Routine 1
Routine 2
…
My return address
Routine n
"The stack"
(activation records)
Return address, arguments, locals
Overflowing a buffer!
The buffer array
(overflowing)
My nasty code
Code of routine n-1
Programs
0
Memory

Getting the input

```
from i := 1 until
        i > input_size        or i > buffer_size
loop
        buffer [i ] := input [i ]
        i := i + 1
end
```

Verification in the software lifecycle

Quality assurance techniques

Process		*Product*
Manual		*Tool-supported*
Technology-generic		*Technology-specific*
Phase-generic		*Phase-specific* *(analysis, design, implementation…)*
Product-generic	vs	*Product-specific* *(code, documentation…)*
Build (a priori)		*Assess (a posteriori)*
Static		*Dynamic*
Informal		*Mathematical*
Complete		*Partial*

Quality assurance throughout the process

"Software" is not just code!

Quality affects code, documentation, design, analysis, management, the software process, and the software quality policy itself.

Most of the techniques presented will, however, be for code.

Process-based approaches to quality assurance

- Lifecycle models
- Process models: CMMI, ISO 9001:2000
- Inspections
- Open-source process
- eXtreme Programming (XP)

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