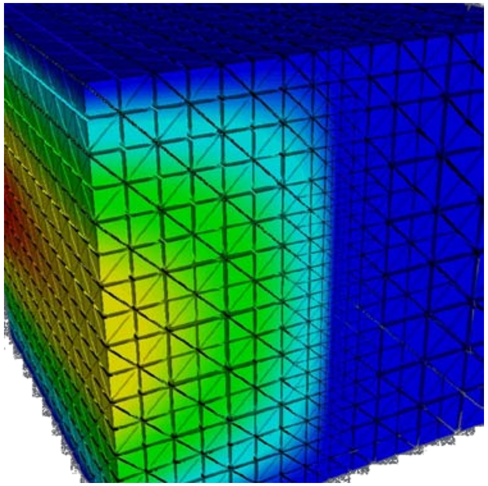
Design and Rationale of a Quality Assurance Process for a Scientific Framework

Hanna Remmel
Institute of Computer Science
Im Neuenheimer Feld 326
69120 Heidelberg, Germany
http://se.ifi.uni-heidelberg.de
remmel@informatik.uni-heidelberg.de

RUPRECHT KARL UNIVERSITY OF HEIDELBERG

Motivation and DUNE - Distributed and Unified Numerics Environment

- Focus in our research: quality assurance of scientific frameworks
- DUNE: solving partial differential equations
  - Grid-based methods
  - Supports parallelism
- Applying Software Product Line Engineering (SPLE)



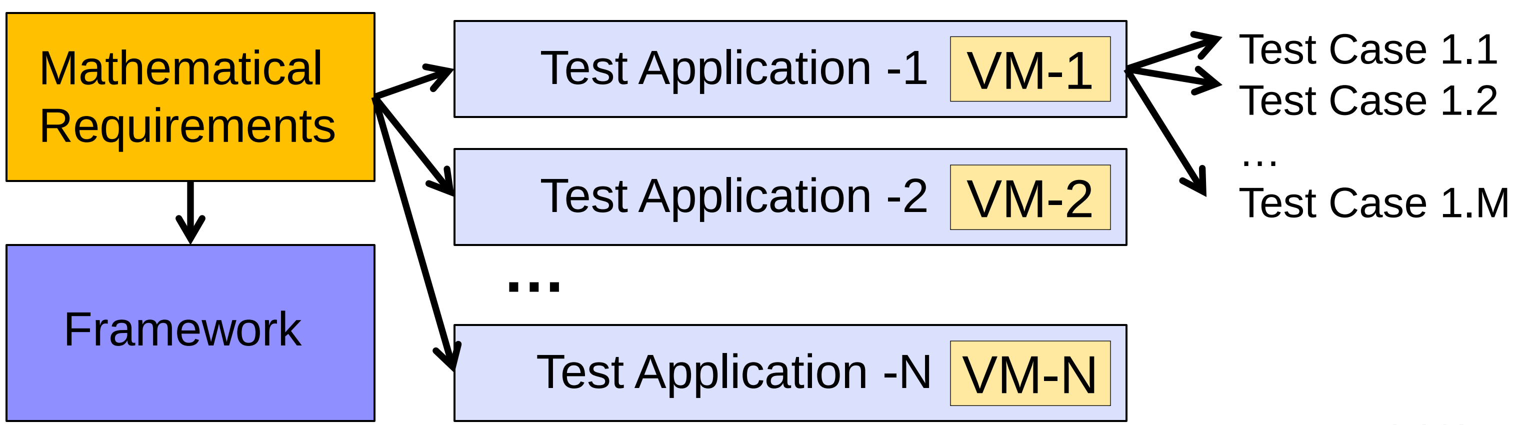
- DUNE applications include
  - Fluid mechanics
  - heat transport
  - flow and transport processes in porous media
  - …and many more
- More information: www.dune-project.org

Content

- Software Product Line (SPL) Test Strategy
- Characteristics of Scientific Software as Rationale for a
- Quality Assurance (QA) Process
- Contribution and Future Work

Variable Test Application Strategy for Frameworks (VAF)

- Criteria (CR) for a SPL test strategy for a framework:
  - CR1: Both commonality and the variability are tested in domain testing
  - CR2: Application testing is supported with reusable test artifacts
  - CR3: Product line applications still need to be tested in application testing
- VAF: reusable system test applications



VM = Variability Model

Characteristics of Scientific Software Development Relevant for the Design of a QA Process

- Manual literature review with over 200 papers

C1	Different possible sources for a software problem. Need for Code Verification, Algorithm Verification and Scientific Validation.
C2	Lack of test oracles.
C3	Most software requirements, except for high-level ones, are not known at the beginning of a software project. RQs stem from science.
C4	The cognitive complexity, the difficulty in understanding a concept, thought, or system, is high.

Characteristics of Scientific Software Development Relevant for the Design of a QA Process

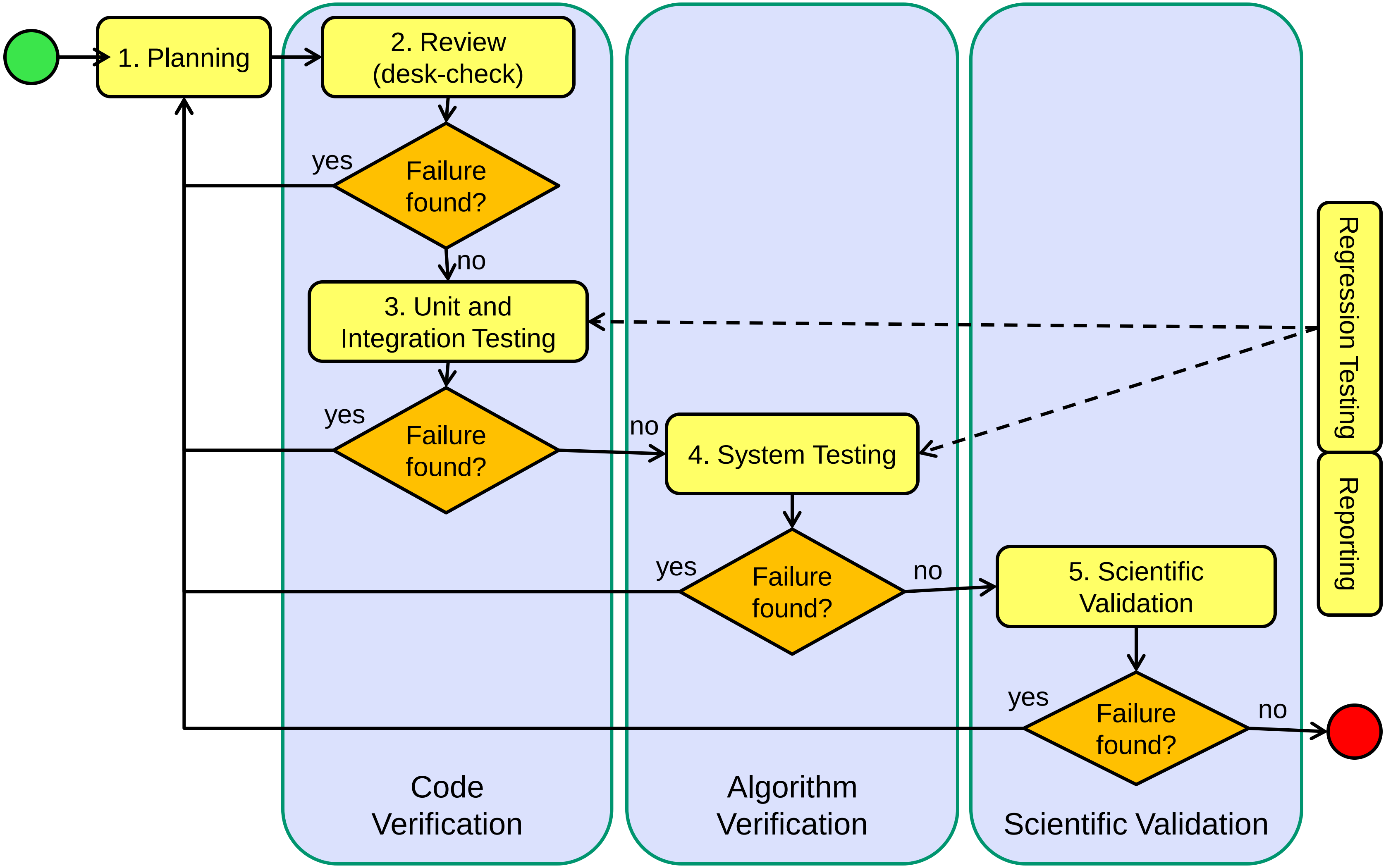
C5	Need for shared, centralized computing resources; high performance computing, parallelism.
C6	Calculations include rounding errors and machine accuracy.
C7	Most developers are domain scientists or engineers, not software engineers.
C8	There is a high turnover in the development team.

Characteristics of Scientific Software Development Relevant for the Design of a QA Process

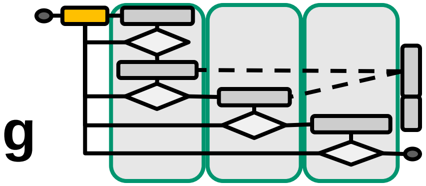
- Carver et al.: the most highly ranked project goals

C9	The most highly ranked project goals: 1. Correctness
C10	The most highly ranked project goals: 2. Performance
C11	The most highly ranked project goals: 3. Portability
C12	The most highly ranked project goals: 4. Maintainability

Design of a QA Process for a Scientific Framework



QA Process Step 1: Planning

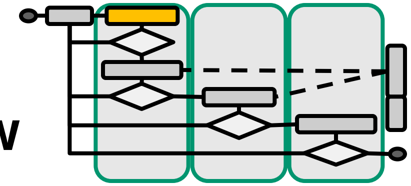


- Each developer is responsible for preparing tests for own source code
  - Add/adjust/remove unit test cases
  - Developers personal responsibility: thoroughly understands the source code (C4), might leave the team soon (C8)
  - Advisable: Test Driven Development, since specifications mostly do not exist in advance (C3)
- If mathematical requirements change
  - Add/adjust/remove variability models and system test applications

Rationale:

C4	The cognitive complexity, the difficulty in understanding a concept, thought, or system, is high.
C8	There is a high turnover in the development team.
C3	Most software requirements, except for high-level ones, are not known at the beginning of a software project. RQs stem from science.

QA Process Step 2: Review

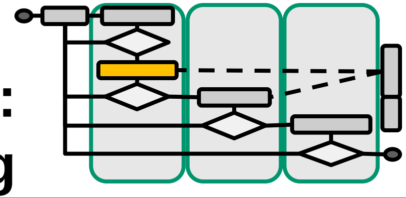


- Earliest possible point to find failures
- Review all created artifacts, e.g. code, unit tests
- Review code structure and readability
  - Understandability for complex code (C4)
  - Benefit for new colleagues (C8)
  - Improves maintainability (C12)
- No structured inspection or review to keep it simple (C7)

Rationale:

C4	The cognitive complexity, the difficulty in understanding a concept, thought, or system, is high.
C8	There is a high turnover in the development team.
C12	The most highly ranked project goals: 4. Maintainability
C7	Most developers are domain scientists or engineers, not software engineers.

QA Process Step 3: Unit and Integration Testing

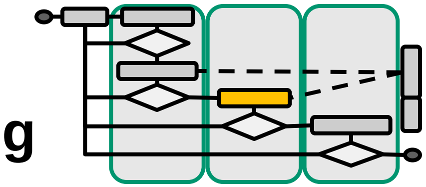


- Together with review build the code verification part in V&V (C1)
- Importance of unit tests is high
  - In contexts, where system tests only run on HPC (C5)
  - Alleviate the problem with missing test oracle (C2)

Rationale:

C1	Different possible sources for a software problem. Need for Code Verification, Algorithm Verification and Scientific Validation.
C5	Need for shared, centralized computing resources; high performance computing, parallelism.
C2	Lack of test oracles.

QA Process Step 4: System Testing

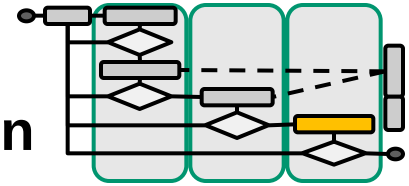


- Output for Algorithm verification (C1)
  - Expected output is determined analytically, if possible, and includes a tolerance range for rounding errors (C6)
  - Together with testing on different platforms significant for correctness (C9) and portability (C11)
- Suitable step for performance testing (C10)
- Together with unit and integration testing implement our SPL test strategy VAF

Rationale:

C1	Different possible sources for a software problem. Need for Code Verification, Algorithm Verification and Scientific Validation.
C6	Calculations include rounding errors and machine accuracy.
C9	The most highly ranked project goals: 1. Correctness
C11	The most highly ranked project goals: 3. Portability
C10	The most highly ranked project goals: 2. Performance

QA Process Step 5: Scientific Validation



- Third step in V&V for scientific software (C1)
- How accurate is the simulation (C9)
- Mostly no analytical solution available (C2)
  - Developers decide based on domain knowledge (C4), whether the simulation result is as expected
- System test environment compares graphical simulation output files
  - Consider rounding errors and machine accuracy (C6)

Rationale:

C1	Different possible sources for a software problem. Need for Code Verification, Algorithm Verification and Scientific Validation.
C9	The most highly ranked project goals: 1. Correctness
C2	Lack of test oracles.
C4	The cognitive complexity, the difficulty in understanding a concept, thought, or system, is high.
C6	Calculations include rounding errors and machine accuracy.

Contribution and Future Work

- Contribution
  - VAF – a SPL test strategy for frameworks
  - Special characteristics of scientific software as rationale for the
  - Design of a QA Process for a scientific Framework

- Future Work
  - Fully implement QA Process
  - Make reusable test applications available for DUNE users
  - Evaluate the feasibility and acceptance of the QA process with a Case Study

Hanna Remmel
Institute of Computer Science
Chair of Software Engineering
Im Neuenheimer Feld 326
69120 Heidelberg, Germany
http://se.ifi.uni-heidelberg.de
remmel@informatik.uni-heidelberg.de