



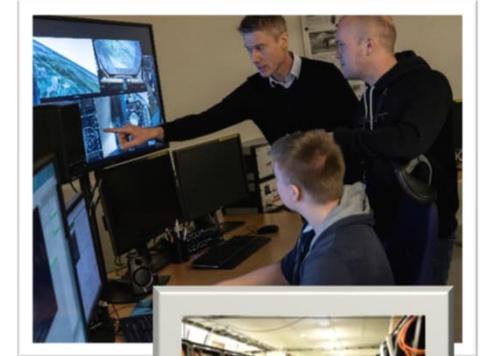
Testing and Test Environments for Large-Scale Cyber-Physical Systems: State of the Art and Emerging Challenges

Torvald Mårtensson, MODPROD 2026

Who am I?



- **Torvald Mårtensson PhD MSc**
- **Technical Fellow** within System Integration Testing at Saab Aeronautics
- **Associate Professor** (Senior Lecturer) at Linköping University
- Senior Associate Editor of **The Journal of Systems and Software**
- Member of **The Royal Aeronautical Society (MRAeS)**



Takeaways from this talk



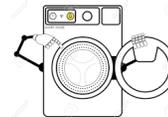
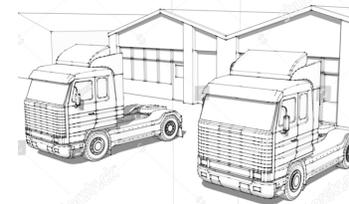
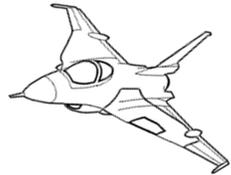
- Scale and coupling with hardware introduce additional challenges



- Future challenges



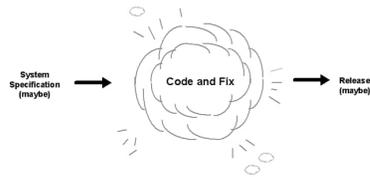
Large-scale cyber-physical systems



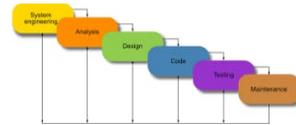
Developing large-scale systems



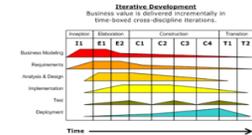
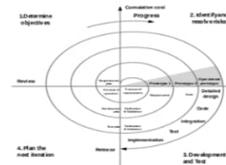
- Code and fix (1950s, 1960s)



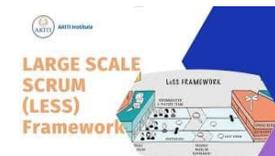
- Stage-gated waterfall model (1970s)



- Incremental development models (1980s, 1990s)



- Adaptive development frameworks (1990s -)



Continuous integration impediments



- **Activity planning and execution**

- Work breakdown
- Teams and responsibilities
- Activity sequencing



- **System thinking**

- Modular and loosely coupled architecture
- Developers must think about the complete system



- **Speed**

- Tools and processes that are fast and simple
- Availability of test environments
- Test selection
- Fast feedback from the integration pipeline



- **Confidence through test activities**

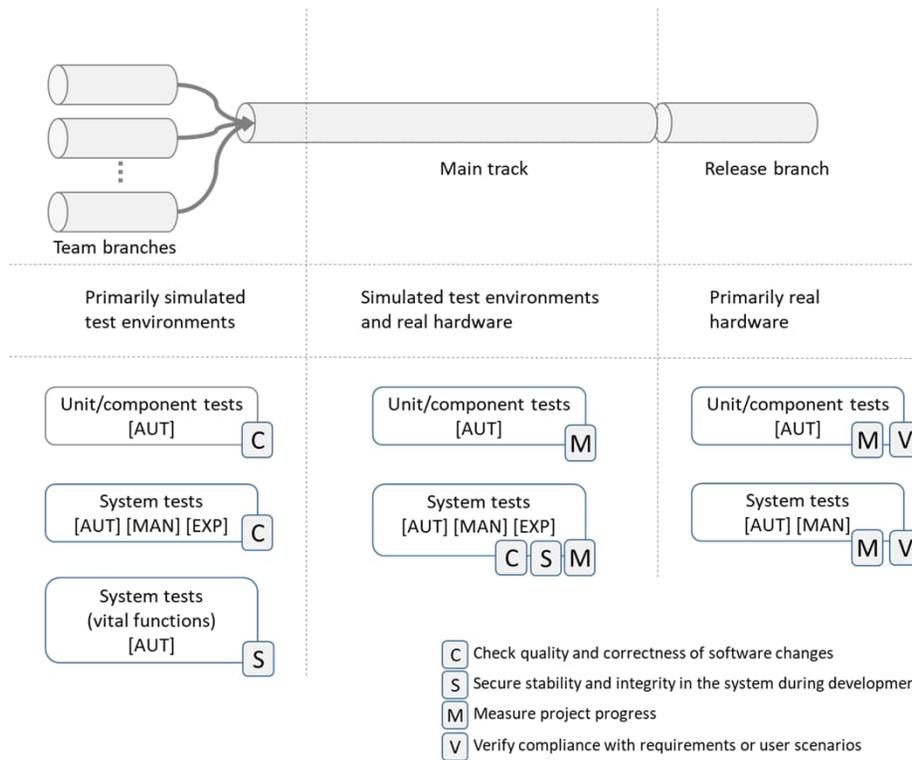
- Test before commit
- Regression tests on the mainline
- Reliability of test environments



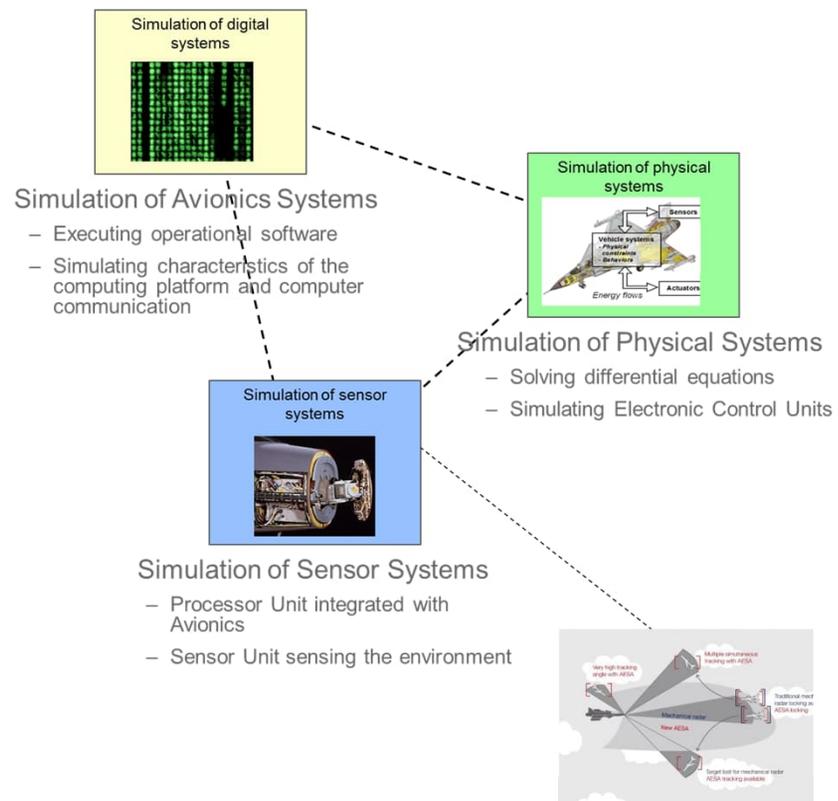
The continuous integration and delivery pipeline



Simulation or real hardware?



Testing in different types of test environments



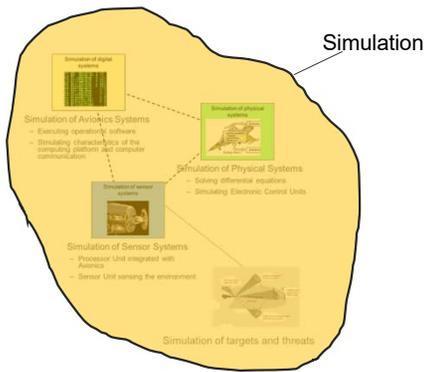
Simulation or real hardware?



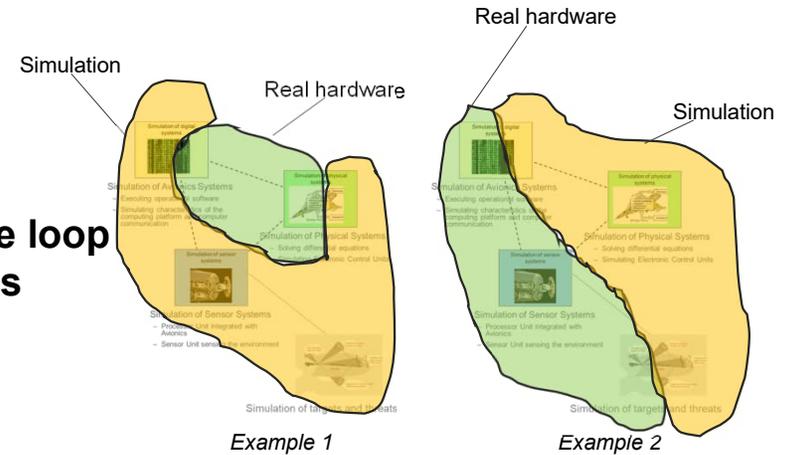
Testing in different types of test environments



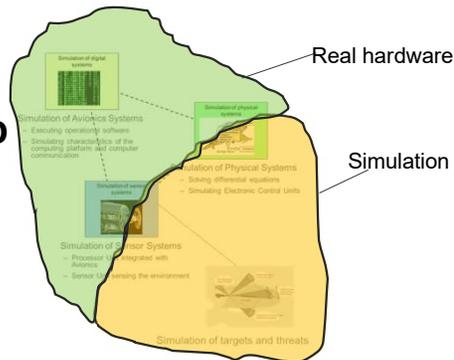
Software in the loop simulators



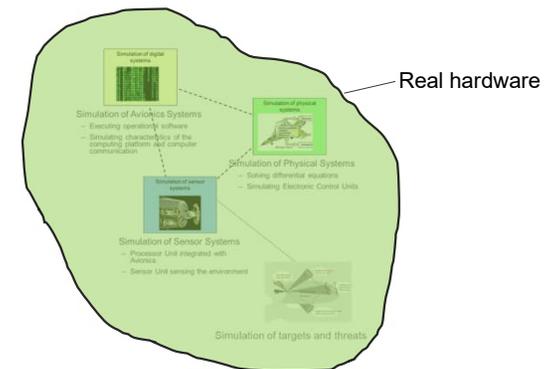
Hardware in the loop sub-system rigs



Hardware in the loop system rigs



Test aircraft



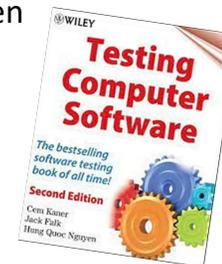
The ideal tester?



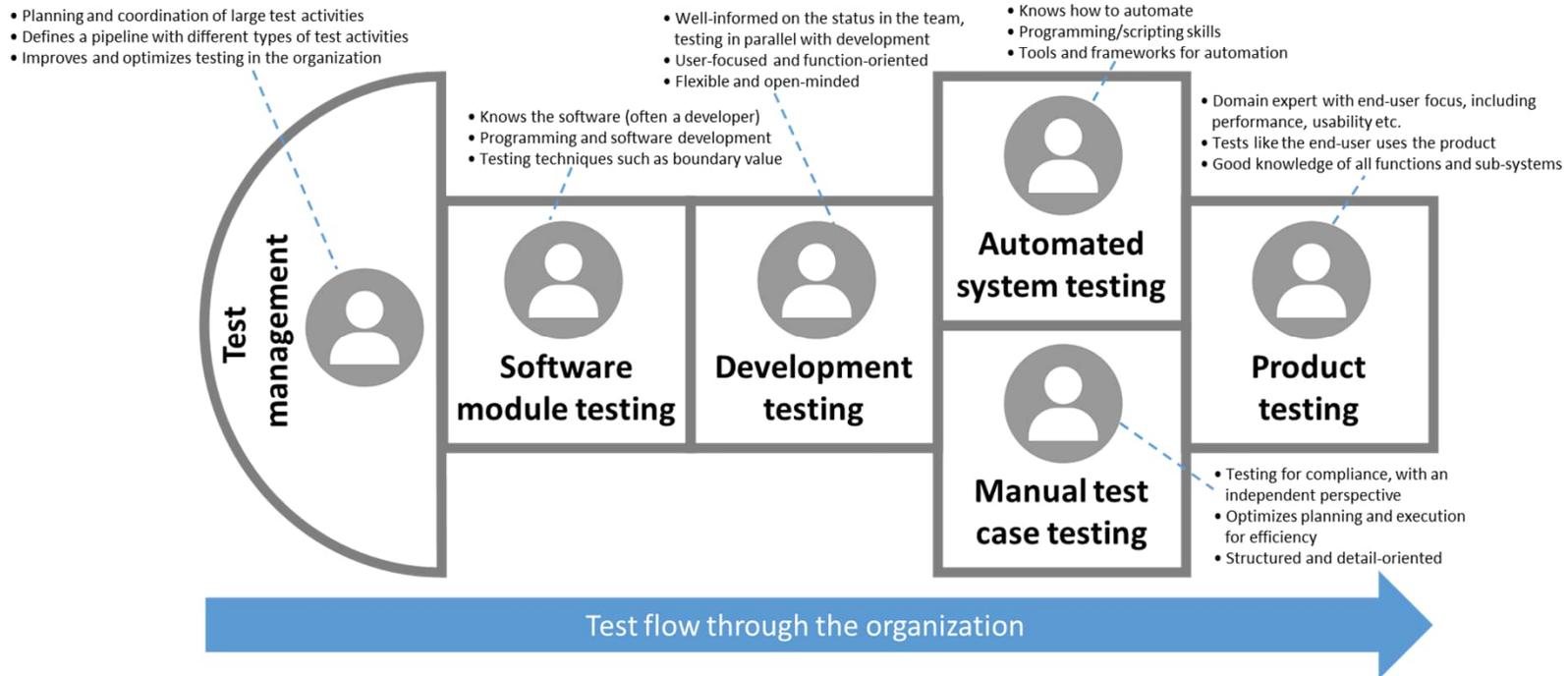
- In a large-scale and complex software system, testing spans from automated tests for a software unit to exploratory testing with an end-user perspective
- Even so, books and other publications often present lists of requested skills for “testers” as a single role, difficult or even impossible to combine in one person.

“In sum, the ideal tester is bright, articulate, attentive to detail but able to appreciate a larger picture, assertive without being obnoxious, creative, and possessed of a blend of management and technical skills.”

Cem Kaner, Jack Falk and Hung Quoc Nguyen
Testing Computer Software, 2nd ed



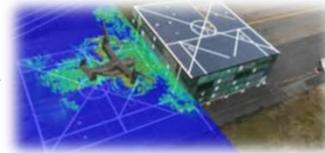
Stop looking for the perfect all-round tester



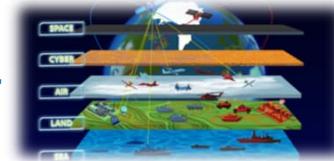
Future challenges



- Simulation for training and testing of AI and autonomy



- Test environments for system-of-system and cloud



- Onboard simulation for AI based decisions



Summary and takeaways



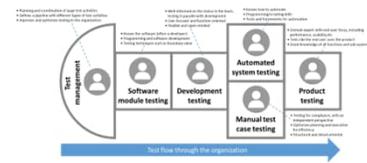
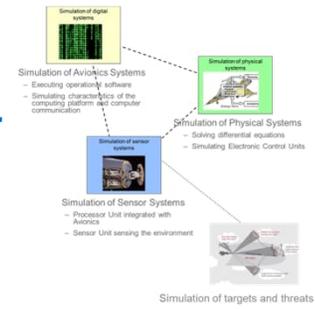
- Scale and coupling with hardware introduce additional challenges

- Continuous integration impediments

- Constructing CI/CD pipelines

- Finding solutions for different types of testers/engineers

- Future challenges





Keeping people and society **safe**