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Challenges and Strategies for Testing Automation Practices at Sandia National Laboratories

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Introduction: Automation for Software Development

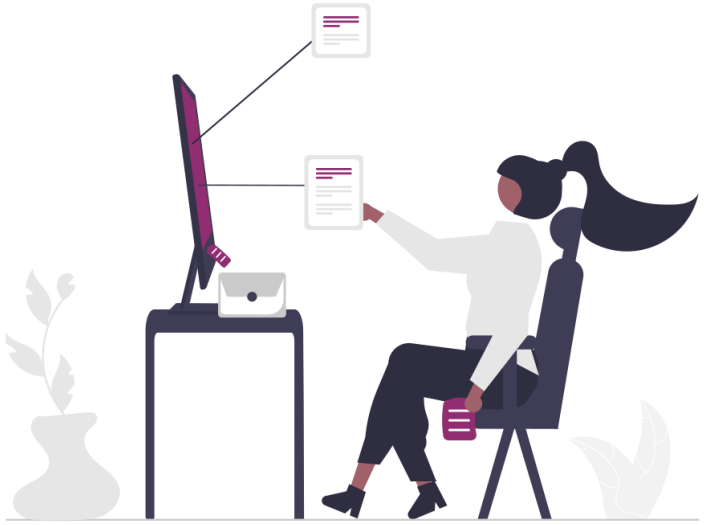
- Automation has been a topic of conversation in software development for decades
  - Automate **repetitive**, **labor-intensive tasks** in order to improve overall **developer and project productivity**
  - It enables **reproducibility** through automated workflows, **verification** through testing, and **better interdisciplinary teaming**

The Challenges in Computational Science and Engineering

- Scientific software **benefits from a range of testing practices** – but have **limited effectiveness**
- Only **half** of CSE teams have software engineering training
- Many institutions have **heterogeneous software environments**

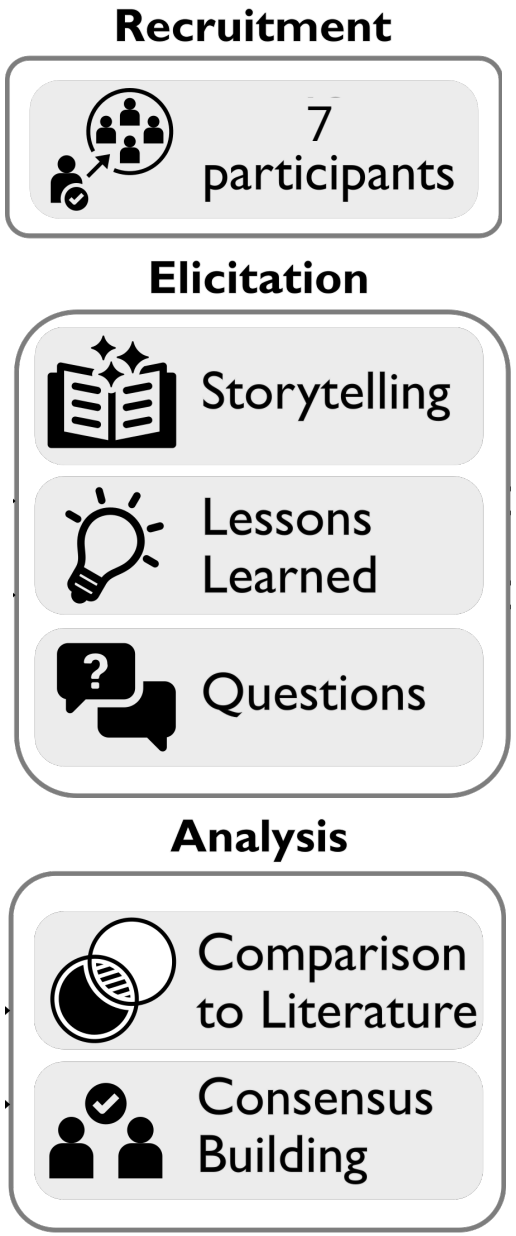
Our Research Questions

- **RQ1**: What are the **challenges** experienced by Research Software Engineers (RSEs) in testing automation at a large US national laboratory?
- **RQ2**: What **strategies** have been employed by Research Software Engineers (RSEs) to address these challenges?



Our Approach

- Conducted a **participatory action research study** to collect and analyze the experiences of RSEs at Sandia National Laboratories.
- Recruited RSEs to **share experience stories**: detailed narratives of challenges faced and accomplishments made in automation work at the laboratories.
- Analyzed their challenges and lessons learned through the lens of the **scholarly literature on automation** in industry contexts, and iterated on results with participants to **build consensus**



Results

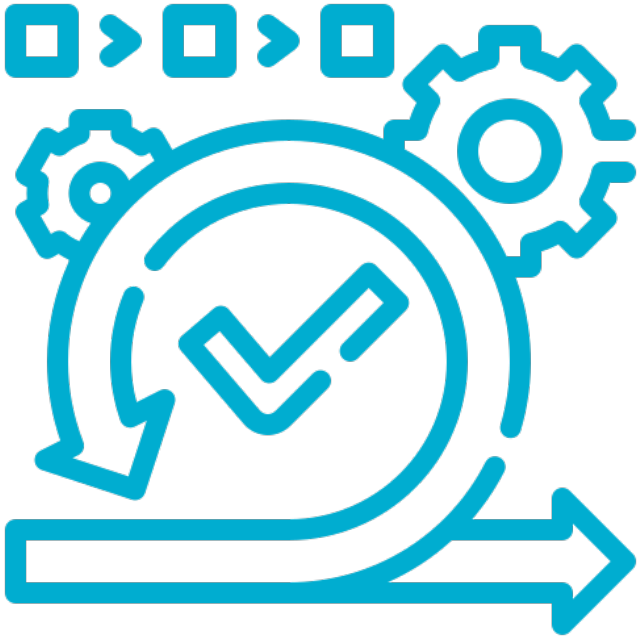
Summary of Experience Stories
(S1) Using pytest, nbmake, and GitLab pipelines to handle a specific dataset and environment
(S2) Using Rust to provide a computational back-end while providing an interface for Python and Julia
(S3) Creating a pipeline layer and a machine orchestration layer to manage a separation between the two
(S4) Creating randomized tests that check an invariant property
(S5) Distributing software components across two hosting services
(S6) Writing a simplified test with no compute for speed
(S7) Testing machine learning code by using small unit tests and checking expected invariants; running the program to see if it will crash as a basic test
(S8) Creating an automated pipeline to get performance benchmarks

- Collected and analyzed 8 experience stories
- Compared results to industry automation studies

Themes

Continuous Integration

The development of exascale codes on bleeding-edge hardware requires testing across a **variety of heterogeneous machines**. For each machine, there may be **multiple supported programming environments**, and for each environment, there may be **multiple ways to configure the code**. Ensuring the code clones, configures, builds, tests, installs, and runs successfully for the plethora of desired permutations is a daunting task. When considering the testing of multiple long-lived branches, and the desire to have both development and production versions of the CI infrastructure, you're looking at maintaining **hundreds of jobs**.

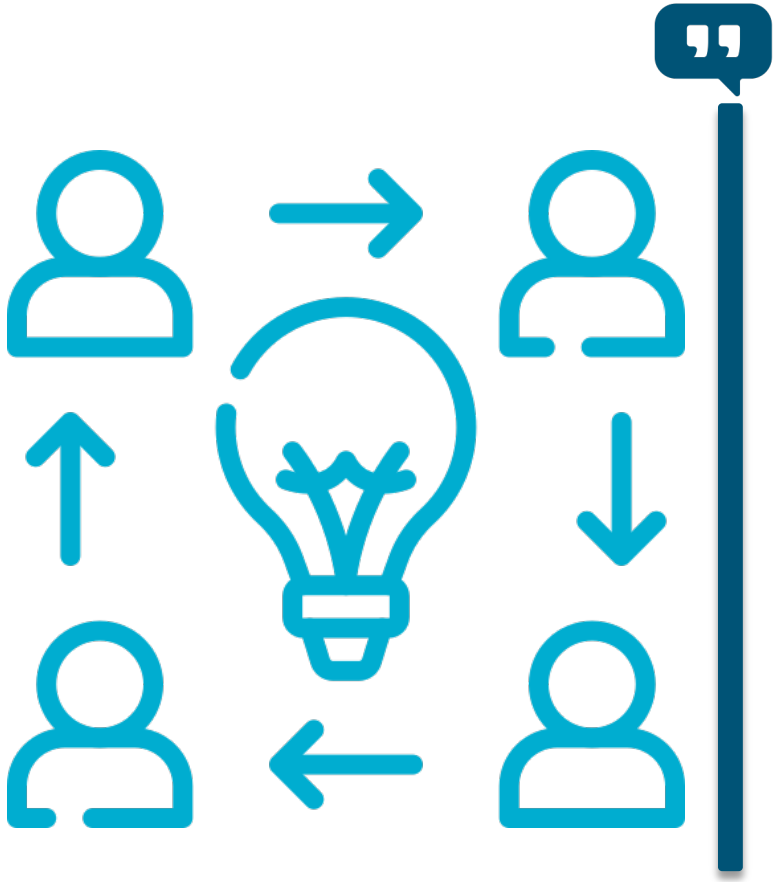


Heterogeneous Computing Environment

We developed one set of testing routines for Stitch-IO in Python that focused on ensuring that things functioned (not quite unit testing, but slightly more complex). We also had a test written in C that was supposed to represent how the application works in practice, but without the physics so it would be fast.

In spite of both the Python and C tests **all working correctly**, the application was having **data corruption issues**. The tests should have revealed the source of the errors, but they did not. After some analysis, we determined that the C application representation was not moving through the computational space exactly as it would for a production run. **The simplification should not have mattered, but it turns out that it did**.

Interdisciplinary Collaboration Requirements



Creating a “one build script to rule them all” in Python **removes cognitive load** from scientific subject-matter expert developers. **Making it easy for them to do the right thing helps everyone**. Also, providing a means for the team to contribute back to the “one script” allows **flexibility** to explore outside the box while still **controlling things as much as possible**.

Lack of Professionalization

Randomized property-based testing, despite all of its successes, is still not widely known in the software engineering world. I think that is mainly due to **lack of education**, and our schools need to do a better job of including it in their curricula. It is still viewed as an “Advanced Topic” despite being very **accessible**. I think that part of this view is that successfully employing this testing requires the developers to formulate invariants, etc., and this is another skill that is **not taught very well in schools**.

Addressing the Research Questions

RQ1: Challenges in Test Automation

Challenge Category[1]	Challenges[1]	Stories
Behavioural	• Process adherence • Organizational change • Too high expectations • Process deviations	• S3, S5 • (N/A) • S1, S3, S4, S6, S8 • S3, S5
Business and Planning	• Cost of ownership and operation • Automation too expensive for small projects • Lack of time, people, and funding	• S1, S3, S4, S5, S8 • S1 • S1
Skills	• Diversity • Steep learning curve	• S1, S2, S3, S5, S8 • S1, S2, S3, S4, S5, S6, S7, S8
Test System	• Inadequate development practices • Testware architecture • Untested test environment • Limitations in externally sourced tools • Environment configuration	• S1, S3, S4, S5, S7 • S1, S3, S4, S5, S8 • S1, S3, S6 • S1, S2, S3, S4, S5, S6, S7, S8 • S3, S5
System Under Test (SUT)	• SUT speed • SUT testability • Platform limitations	• S3, S4, S6 • S1, S2, S3, S4, S6, S7 • S1, S2, S3, S5, S6, S8

[1] K. Wiklund, S. Eldh, D. Sundmark, and K. Lundqvist, "Impediments for software test automation: A systematic literature review," Software Testing, Verification and Reliability, vol. 27, no. 8, p. e1639, 2017.

RQ2: Recommendations for Improvement

Challenges[1]	Recommendations[2]
• (Behavioural) Too high expectations	✓ Involve key stakeholders in strategy development ✓ Keep test professionals motivated about automation ✓ Define an effective test automation strategy ✓ Adjust the test automation strategy to the changes
• (Business and Planning) Cost of ownership and operation	✓ Provide enough resources
• (Skills) Diversity • (Skills) Steep learning curve • (Test System) Inadequate development practices	✓ Share available test automation knowledge ✓ Allow time for training and the learning curve ✓ Have competent test professionals ✓ Promote collaboration
• (Test System) Testware architecture • (Test System) Limitations in externally sourced tools	✓ Select the right test tools ✓ Arrange testware in good architecture
• (SUT) SUT testability	✓ Design the SUT for automated testability
• (SUT) Platform limitations	✓ Define test automation requirements ✓ Have control over changes of test automation requirements ✓ Arrange testware in good architecture

[1] K. Wiklund, S. Eldh, D. Sundmark, and K. Lundqvist, "Impediments for software test automation: A systematic literature review," Software Testing, Verification and Reliability, vol. 27, no. 8, p. e1639, 2017.
[2] Y. Wang, M. V. Mäntylä, Z. Liu, J. Markkula, and P. Raulamo-jurvanen, "Improving test automation maturity: A multivocal literature review," Software Testing, Verification and Reliability, vol. 32, no. 3, p. e1804, 2022.

Conclusion

- As software becomes more integral to the advancement of science, so do the processes and procedures used to create scientific software.
- In our study, we collected experiences from RSEs at a US national laboratory. We analyzed the commonalities and differences between industry and scientific software testing automation practices.