THE UNIVERSITY of ADELAIDE

Markus Wagner

# Maximising Axiomatization Coverage and Minimizing Regression Testing Time

# Who guards the guardians?

How to improve trust in **formal verification systems**?

$$a = b \vdash 2 = 1$$

Modern verification systems are large and complex systems

- Soundness bugs are not rare
- Such bugs are often hard to detect in a real proof

# "Auto-active" Verification Systems


Validating verification systems by

- Formal methods
- Code inspection
- Testing
- ...

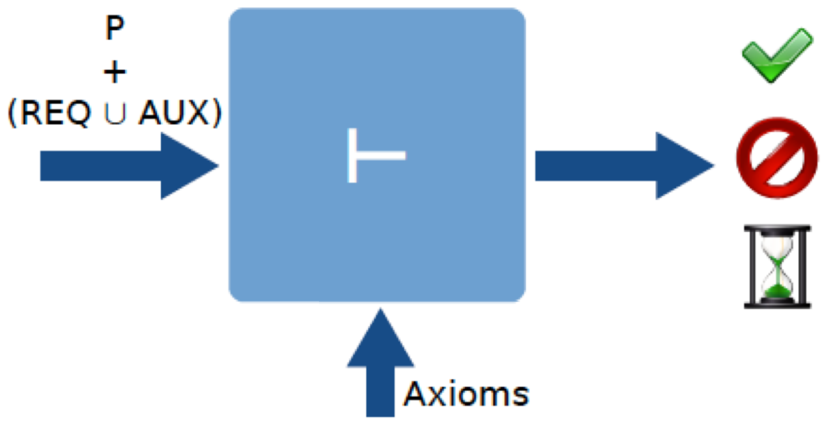
# Program Language Semantics


Static checkers Verifying compilers Logic frameworks

We have to test both!

But how to determine the quality of the test cases?

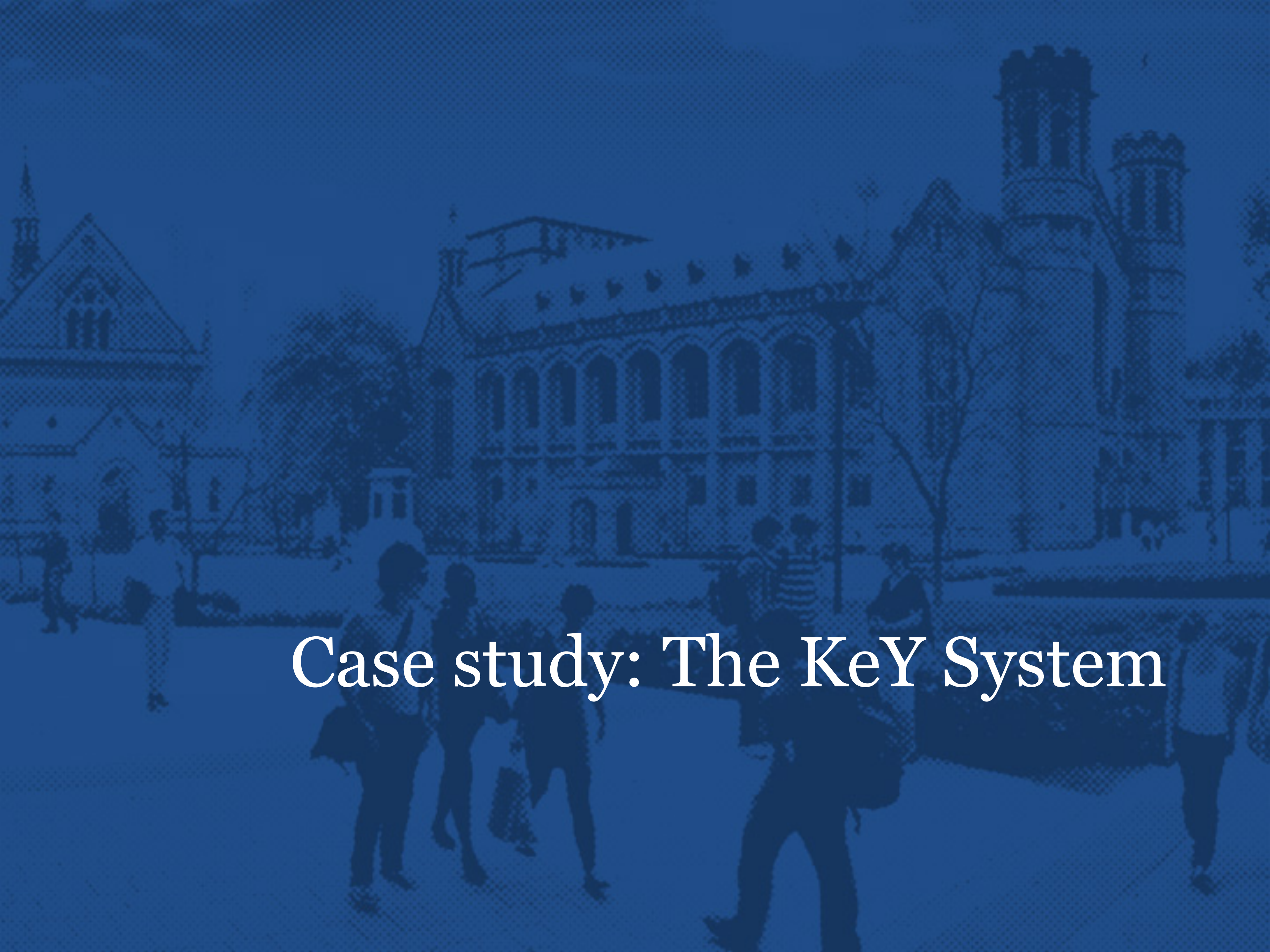
# Test Cases




A test case is a program *P*, together with requirement and auxiliary specifications.

Manually creating test cases is extremely time-consuming.

Computing coverage for the test cases takes from a few minutes to several hours.



# Case study: The KeY System

# The KeY System

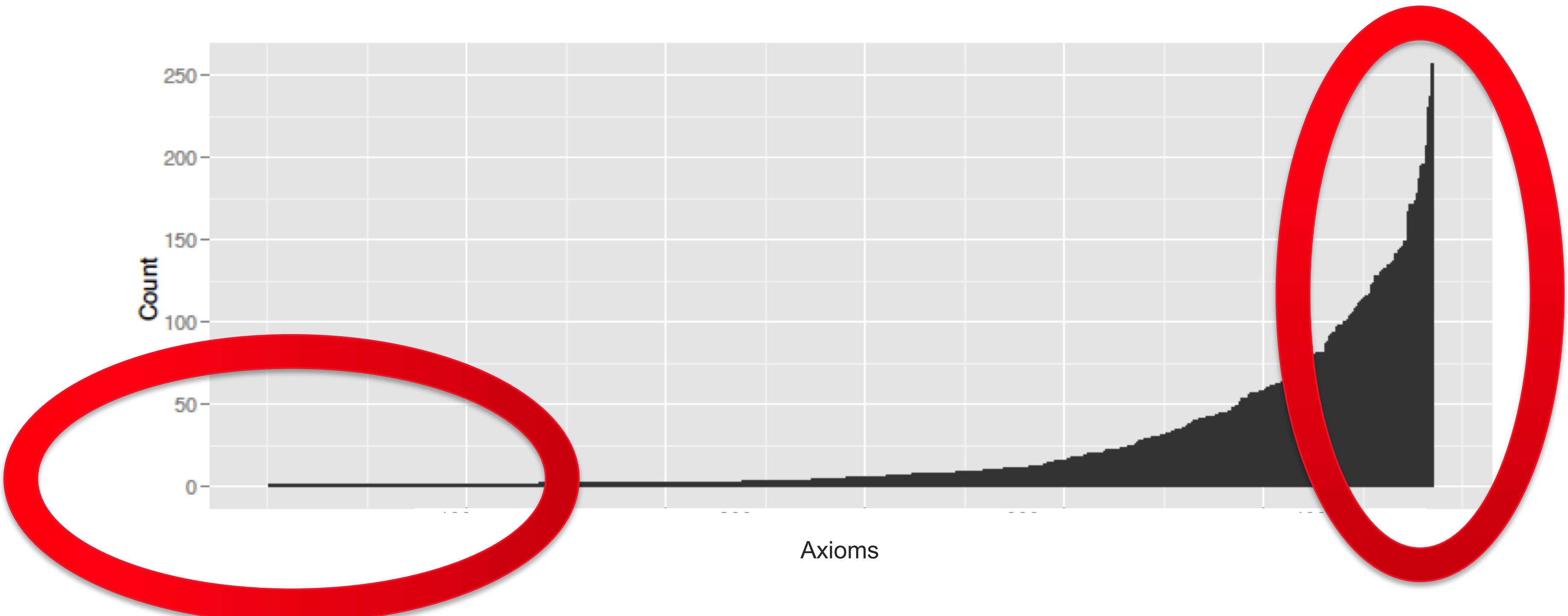
- Deductive verification system for JavaCard
- Sequent calculus for Java Dynamic Logic, uses symbolic execution for Java programs
- Interactive verification with automatic proof mode

Important

- The semantics of JavaCard is encoded in 1520 axioms ("small, well-understood set of sentences")

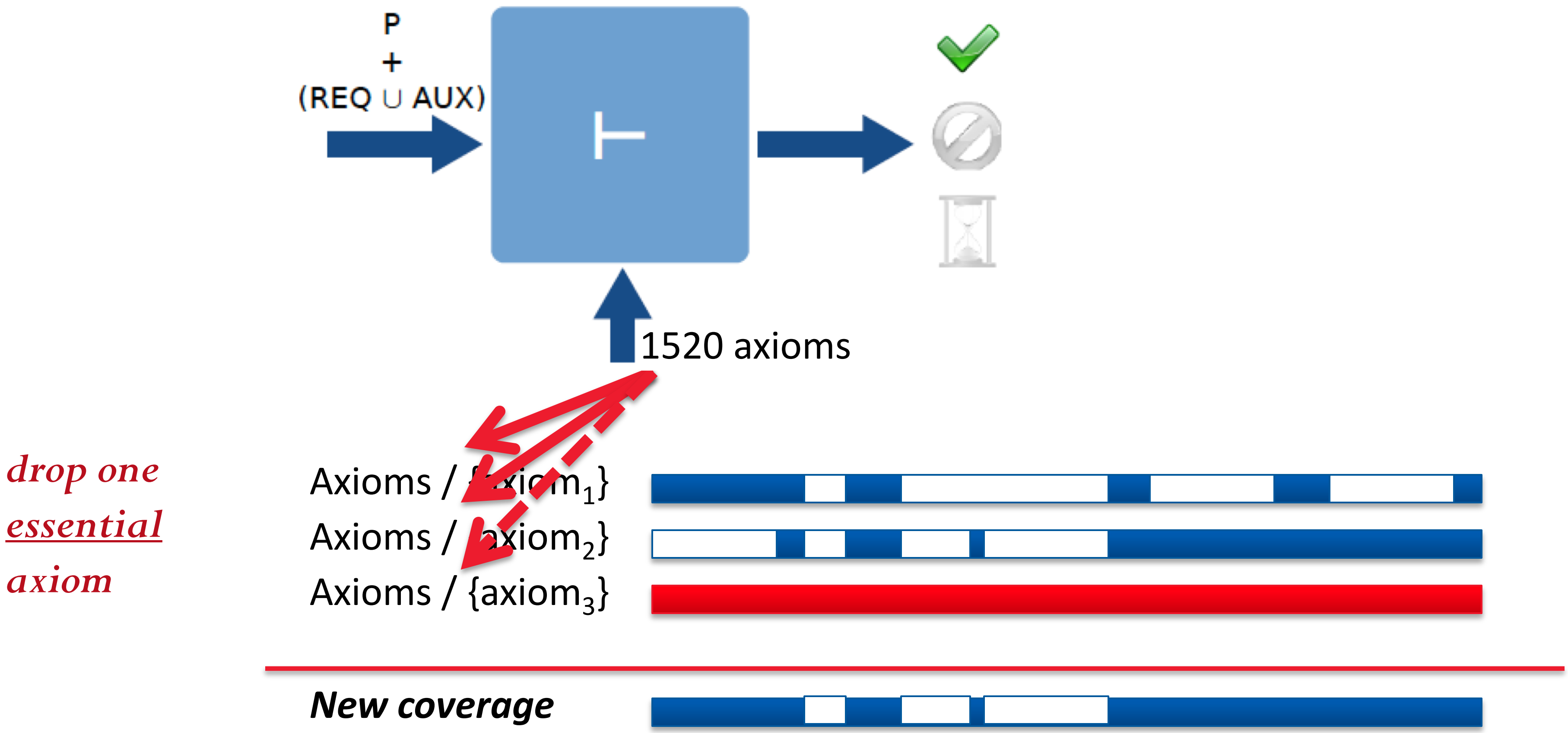
# Coverage Results (naïve, TAP 2013)

The 319 completeness tests of KeY covered 40% of all axioms (611 out of 1520).



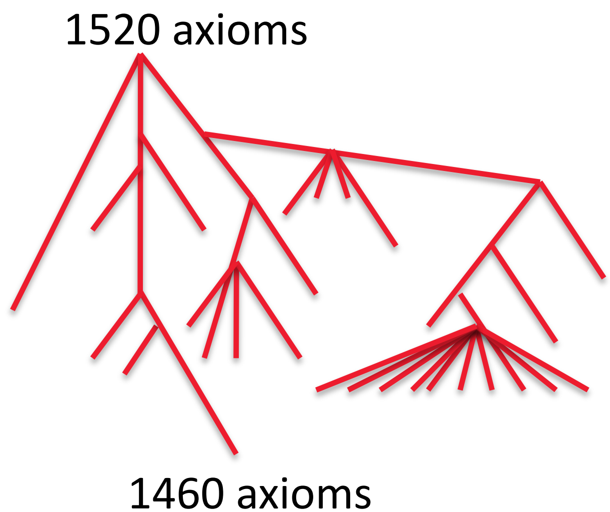
# Heuristic Approaches

# Reusing Test Cases




Idea: given a test case $T$, run the tool with just a subset of the 1520 axioms.

# Reusing Test Cases



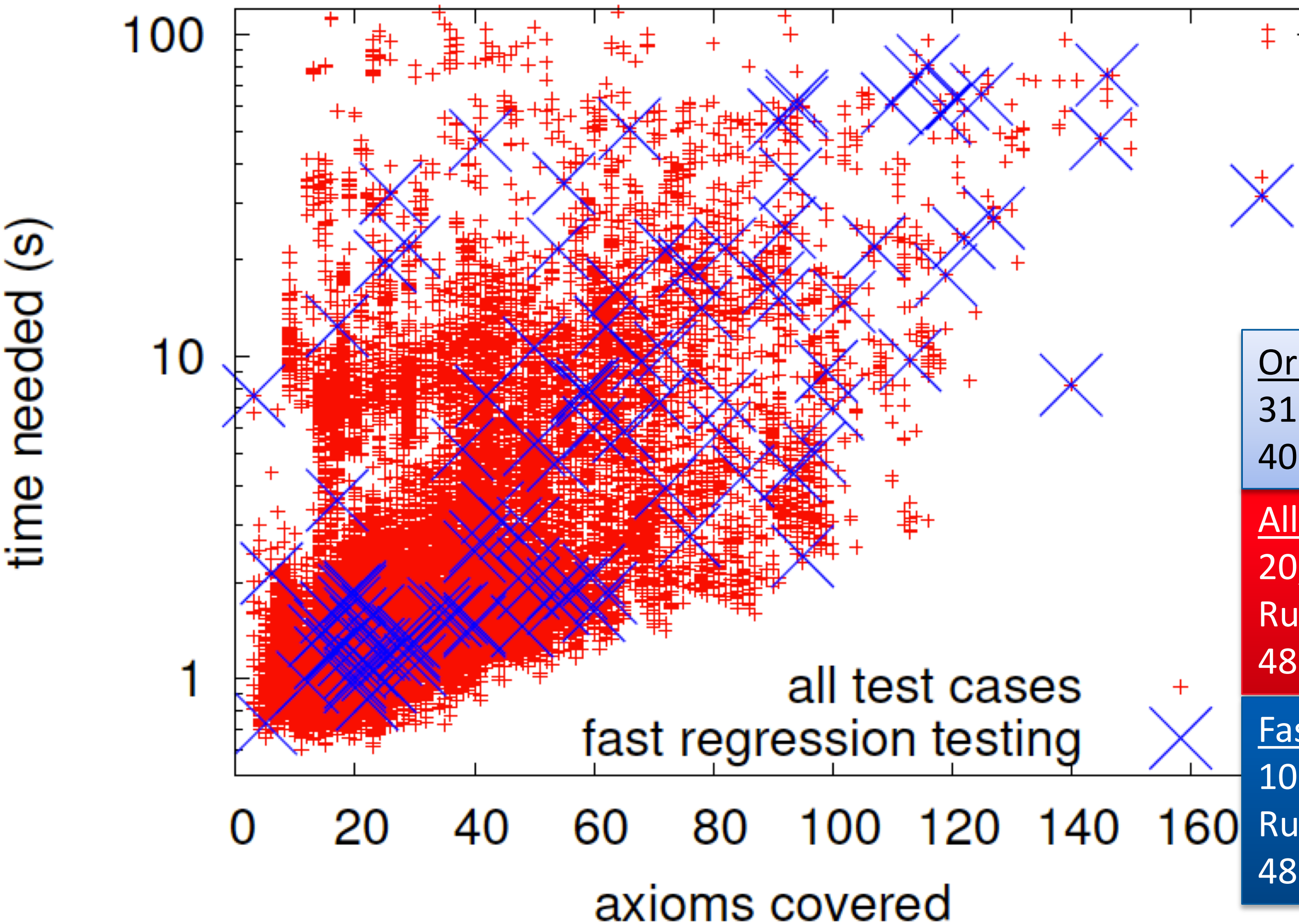

***Note:***
***- 24h per heuristic per test case***
***- Extremely fragile***

Three simple heuristics to pick the "next axiom to drop":

[0. Base case] 611 (40%)
1. Depth-first
2. Depth-first, ra
3. Greedy (try to
4. Breadth-first
5. Breadth-first, random selection

→ Complimentary by design, verified by experiments.

# Maximising Coverage & Minimising Time

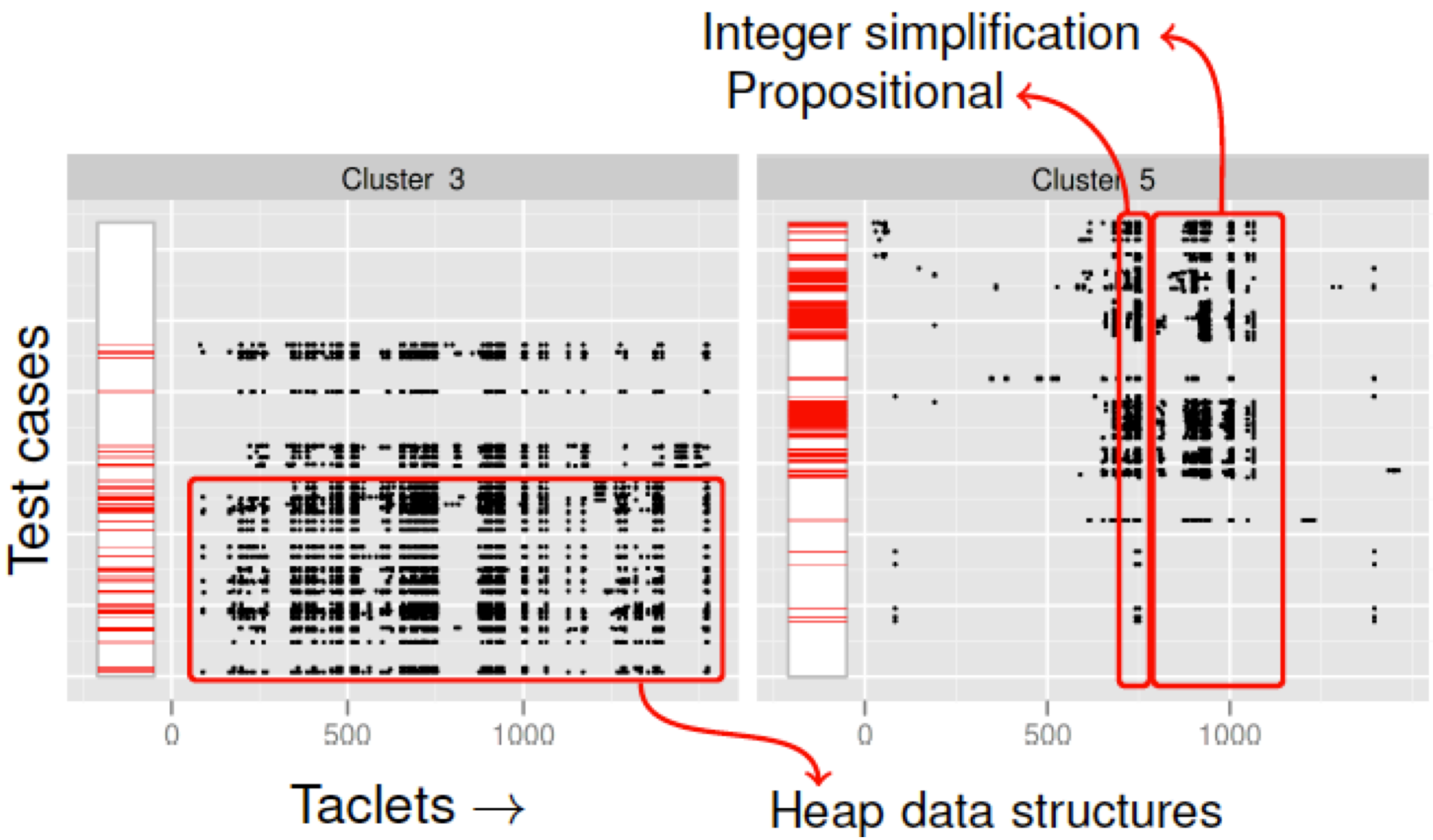



Originally
319 test cases
40% coverage

All test cases
20,000 test cases
Runtime: days
48% coverage

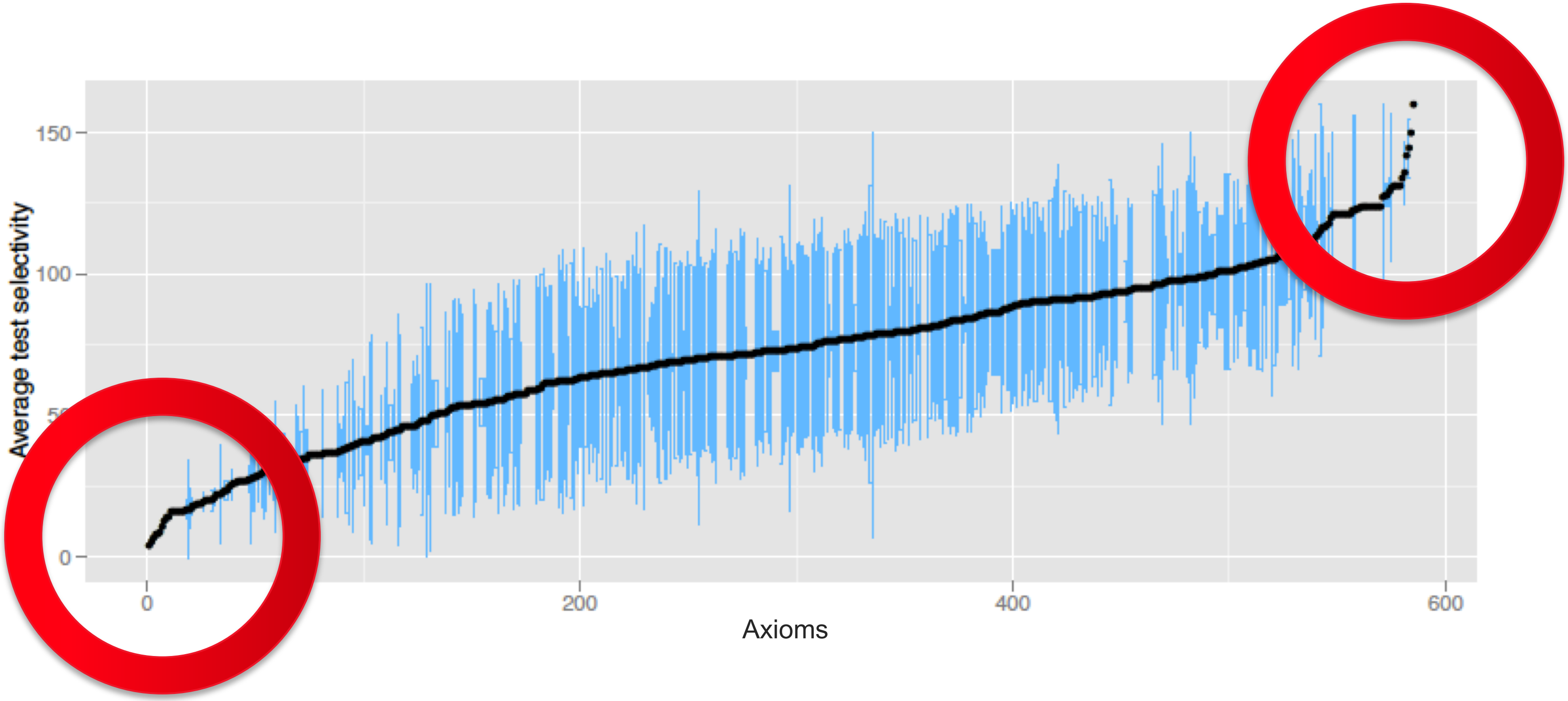
Fast Regr. Testing
100 test cases
Runtime: 1 h
48% coverage

# Clustering Results



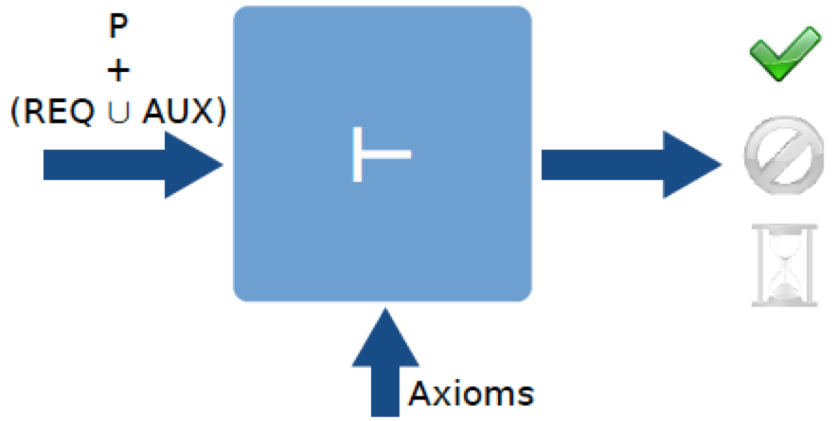

→ Problem understanding!

# Test Case Selectivity




Only specific test cases, or test cases with broad coverage for an axiom may not be sufficient.

# Completeness Coverage




Definition (Completeness Coverage, TAP 2013)

A test case $P + (REQ \cup AUX)$ covers the set of *Axioms* if

- $Axioms \vdash P + (REQ \cup AUX)$
- and this does not hold for $Axioms' \subsetneq Axioms$

Note: covered set *Axioms* is not uniquely defined by the test case

# Computing Completeness Coverage

Given: set of axioms *Ax* and completeness test case *T*

Result: completeness coverage by *T*

1. Run tool on *T*, record resource consumptions (to get upper limit for the subsequent runs).
2. If available, analyse proof artifacts to restrict the next step to a subset of *Ax*.
3. Remove stepwise from *Ax* and check if proof is still valid.

[repeat until a fix-point is reached]

Computing coverage for most test cases takes from a few minutes to several hours.