

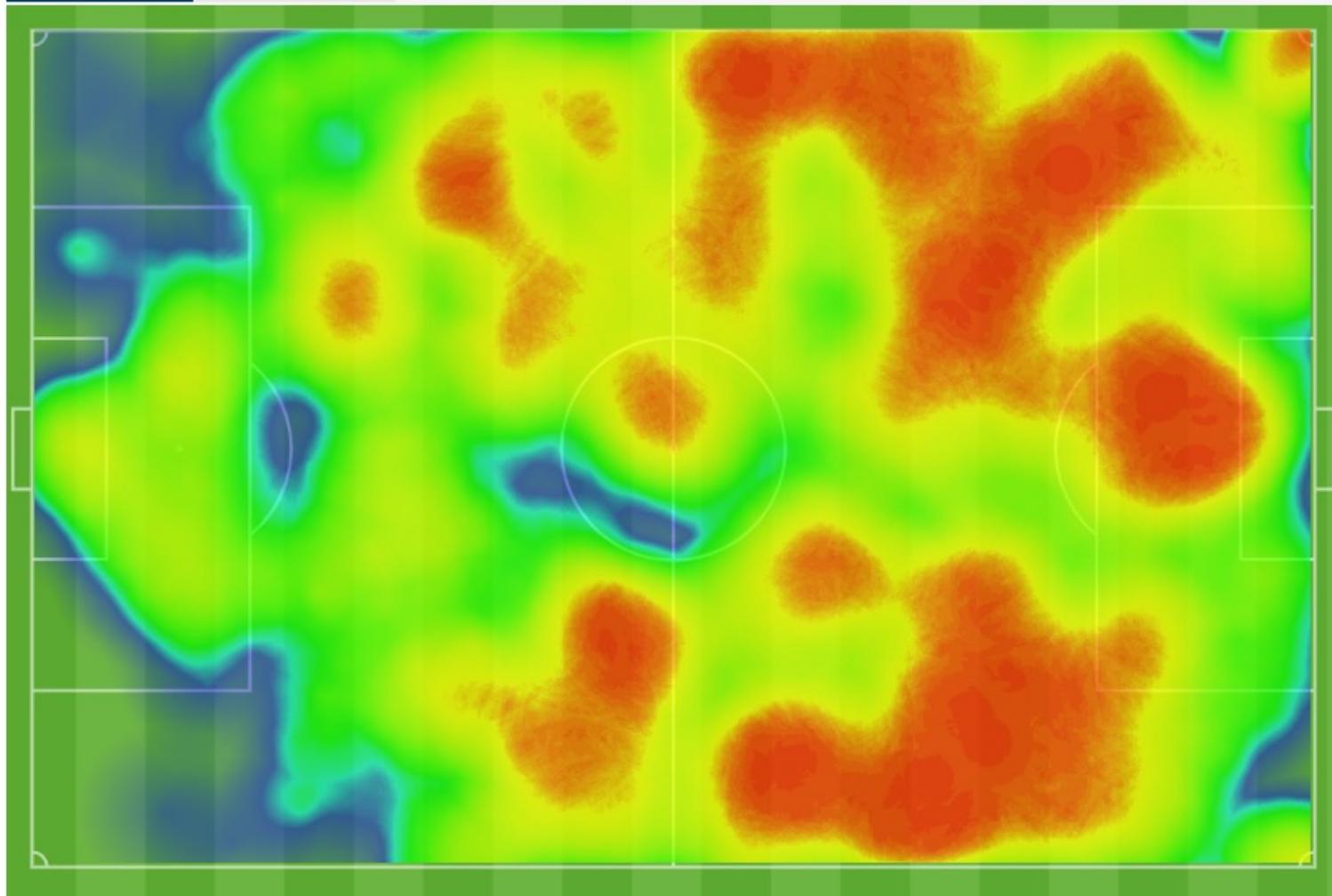
# Test Intelligence

Explore Your Own Data From Software Tests to Find More Errors in Less Time

## FC Bayern München

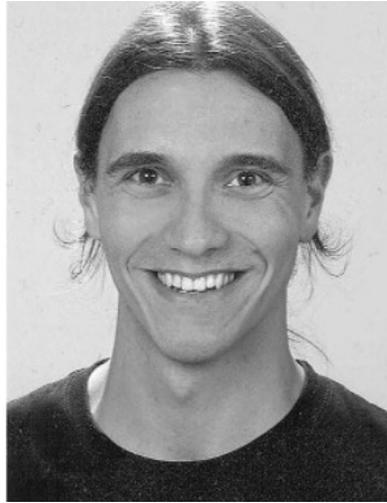
- FC Bayern München
- TW 1 Manuel Neuer
- AW 21 Lucas Hernández
- AW 5 Benjamin Pavard
- AW 4 Niklas Süle
- AW 27 David Alaba
- MF 29 Kingsley Coman
- MF 10 Leroy Sané
- MF 25 Thomas Müller
- MF 6 Joshua Kimmich
- MF 18 Leon Goretzka
- ST 13 Eric Maxim Choupo-Moting
- Einwechselfspieler
- 17 Jérôme Boateng
- 19 Alphonso Davies

## Heatmap Touchmap



## Paris Saint-Germain

- Paris Saint-Germain
- TW 1 Keylor Navas
- AW 5 Marquinhos
- AW 31 Colin Dagba
- AW 22 Abdou Diallo
- AW 3 Presnel Kimpembe
- MF 23 Julian Draxler
- MF 27 Idrissa Gueye
- MF 10 Neymar
- MF 15 Danilo Pereira
- MF 11 Ángel Di María
- ST 7 Kylian Mbappé
- Einwechselfspieler
- 25 Mitchel Bakker
- 18 Moise Kean
- 21 Ander Herrera
- 12 Rafinha

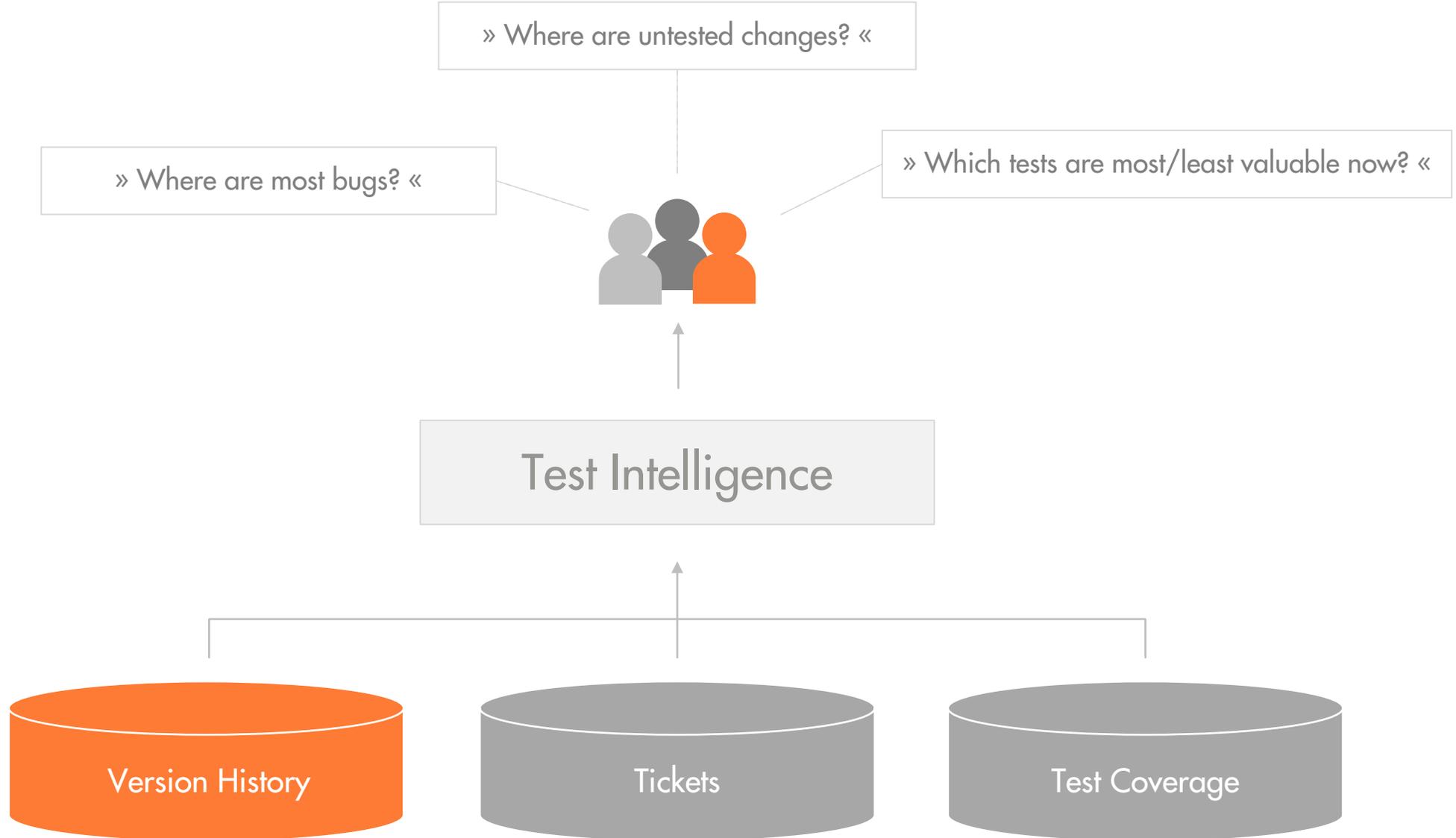


**TUM**



**CQSE**





```

23
24
25
26 /* package */class NamespaceRenames {
27
28     /** Maps from old name fragment to new name fragment */
29     public Set<ImmutablePair<String, String>> namespaceRenames = new HashSet<
30
31     /**
32     * Computes a rename rule from an old and a new namespace name based on a
33     * type name correspondence. <code>
34     * For name1 = a.oldnamespace.b.c.D and name2 = a.newnamespace.b.c.D, res
35     * </code>
36     * */
37     public static ImmutablePair<String, String> computeRenameRule(
38         String fqTypeName1, String fqTypeName2, String separator) {
39
40         if (fqTypeName1.equals(fqTypeName2)) {
41             return null;
42         }
43
44         String commonSuffix = StringUtils.longestCommonSuffix(fqTypeName1,
45             fqTypeName2);
46         if (StringUtils.isEmpty(commonSuffix)) {
47             return null;
48         }
49
50         int separatorPosition = commonSuffix.indexOf(separator);
51         if (separatorPosition != -1) {
52             commonSuffix = commonSuffix.substring(separatorPosition);
53         }
54
55         String from = StringUtils.stripSuffix(commonSuffix, fqTypeName1);
56         String to = StringUtils.stripSuffix(commonSuffix, fqTypeName2);
57
58         return new ImmutablePair<String, String>(from, to);
59     }
60
61
62
63
64

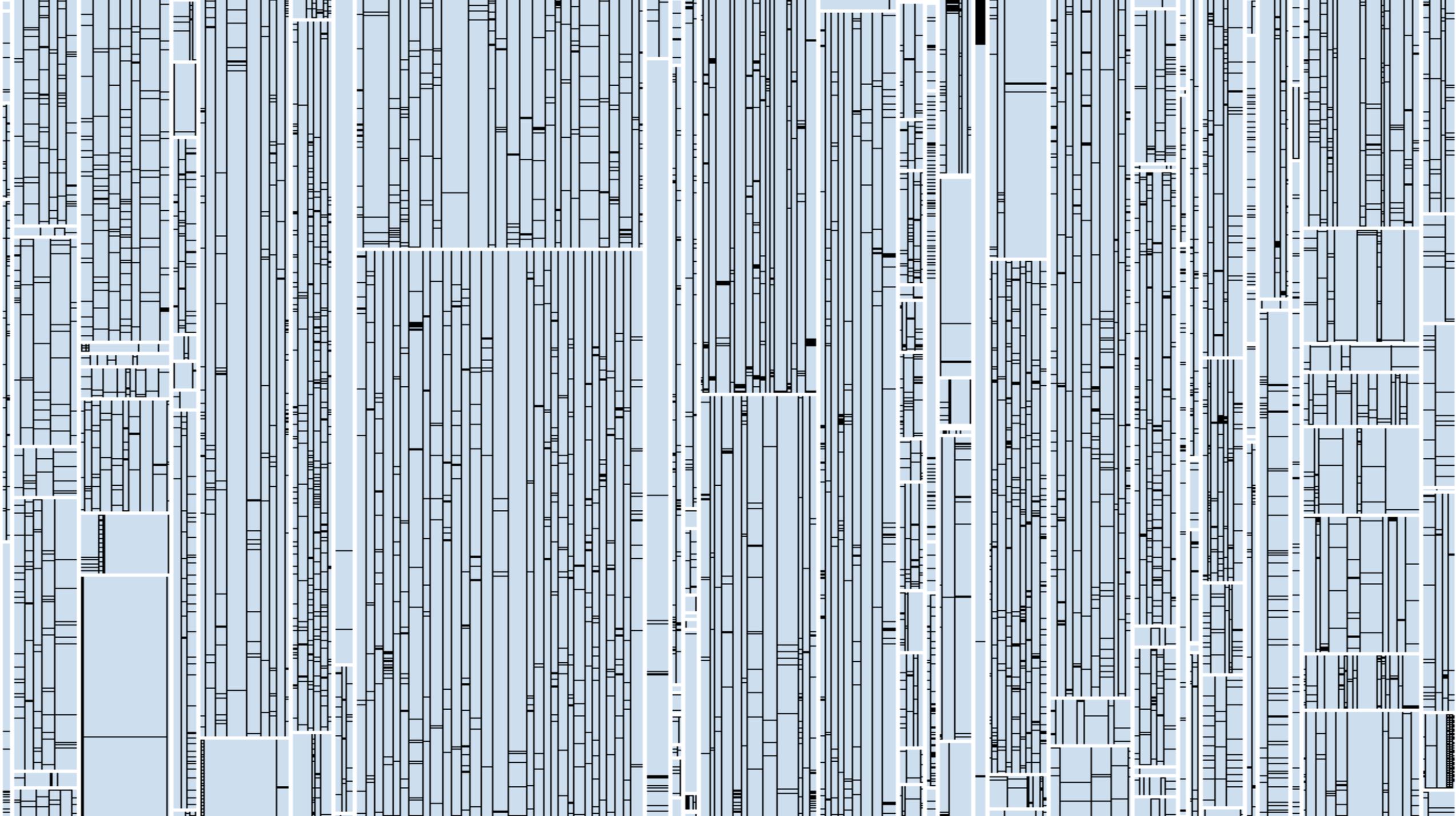
```

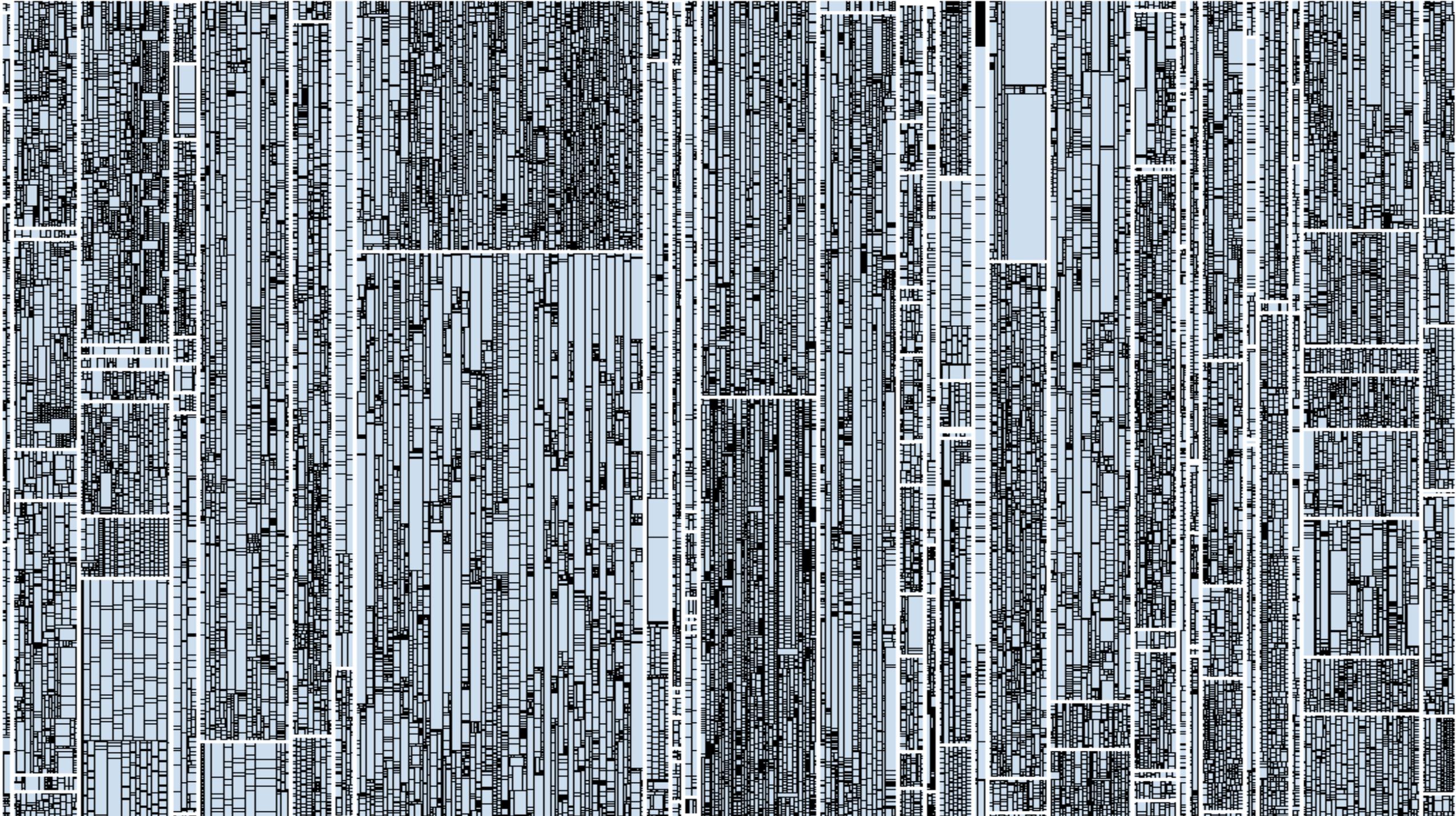
```

24
25
26 /* package */class NamespaceRenames {
27
28     /** Maps from old name fragment to new name fragment */
29     public Set<ImmutablePair<String, String>> namespaceRenames = new Has
30
31     // TODO (LH) Doc vs. method name : 'Compute' vs. 'find'
32     /**
33     * Computes a rename rule from an old and a new namespace name based
34     * type name correspondence. <code>
35     * For name1 = a.oldnamespace.b.c.D and name2 = a.newnamespace.b.c.D
36     * </code>
37     * */
38     // TODO (LH) Please reflect in identifier names that they refer to
39     // names
40     public static ImmutablePair<String, String> findRenameRule(String na
41         String name2, String separator) {
42
43         if (name1.equals(name2)) {
44             return null;
45         }
46
47         // TODO (LH) Looks like StringUtils is missing a 'longestCommon
48         String commonSuffix = reverse(StringUtils.longestCommonPrefix(
49             reverse(name1), reverse(name2)));
50         if (StringUtils.isEmpty(commonSuffix)) {
51             return null;
52         }
53
54         int separatorPosition = commonSuffix.indexOf(separator);
55         if (separatorPosition != -1) {
56             commonSuffix = commonSuffix.substring(separatorPosition);
57         }
58
59         // TODO (LH) Please reflect in identifier names that these are
60         // namespaces
61         String from = StringUtils.stripSuffix(commonSuffix, name1);
62         String to = StringUtils.stripSuffix(commonSuffix, name2);
63
64         return new ImmutablePair<String, String>(from, to);
65

```

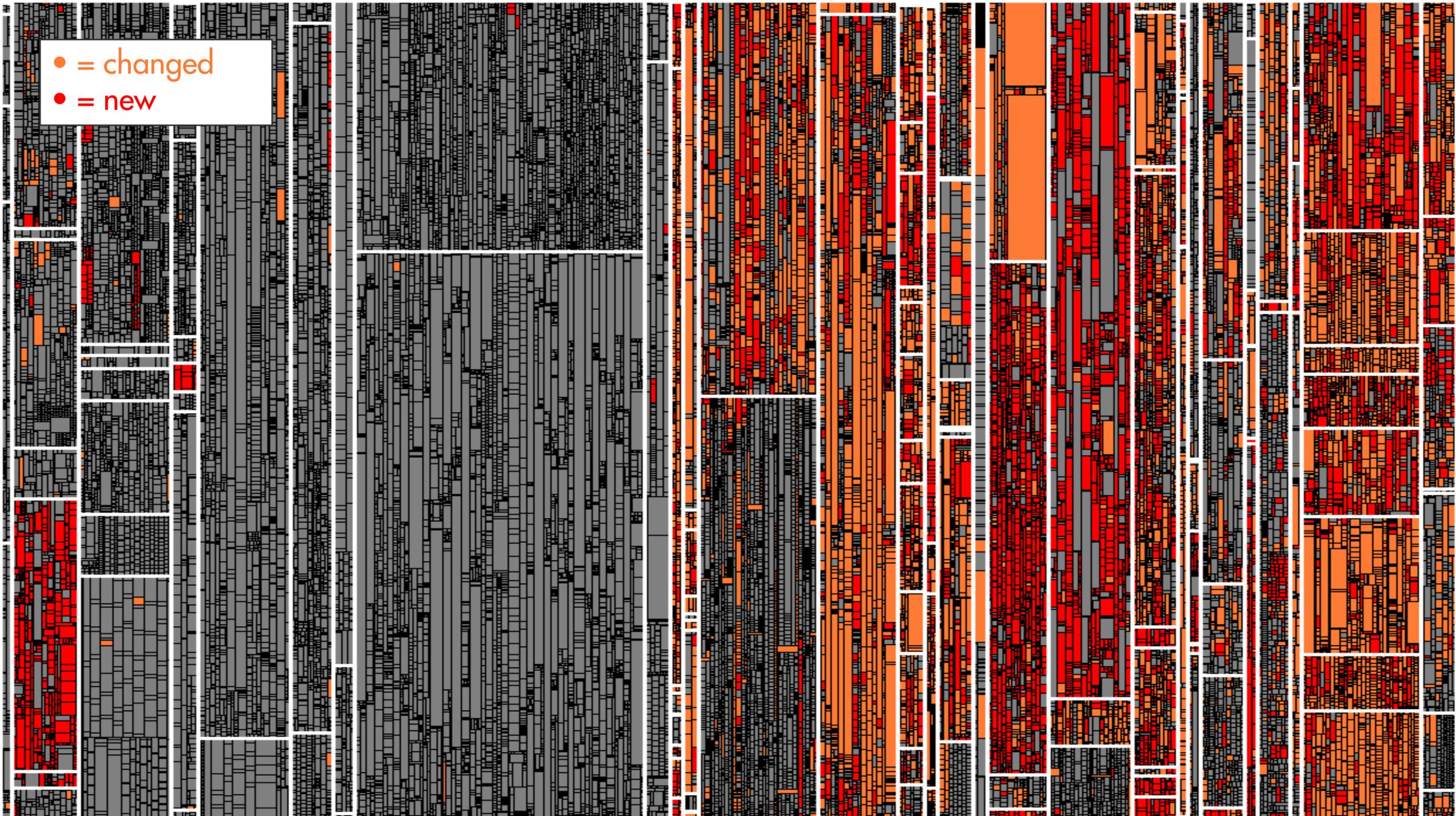


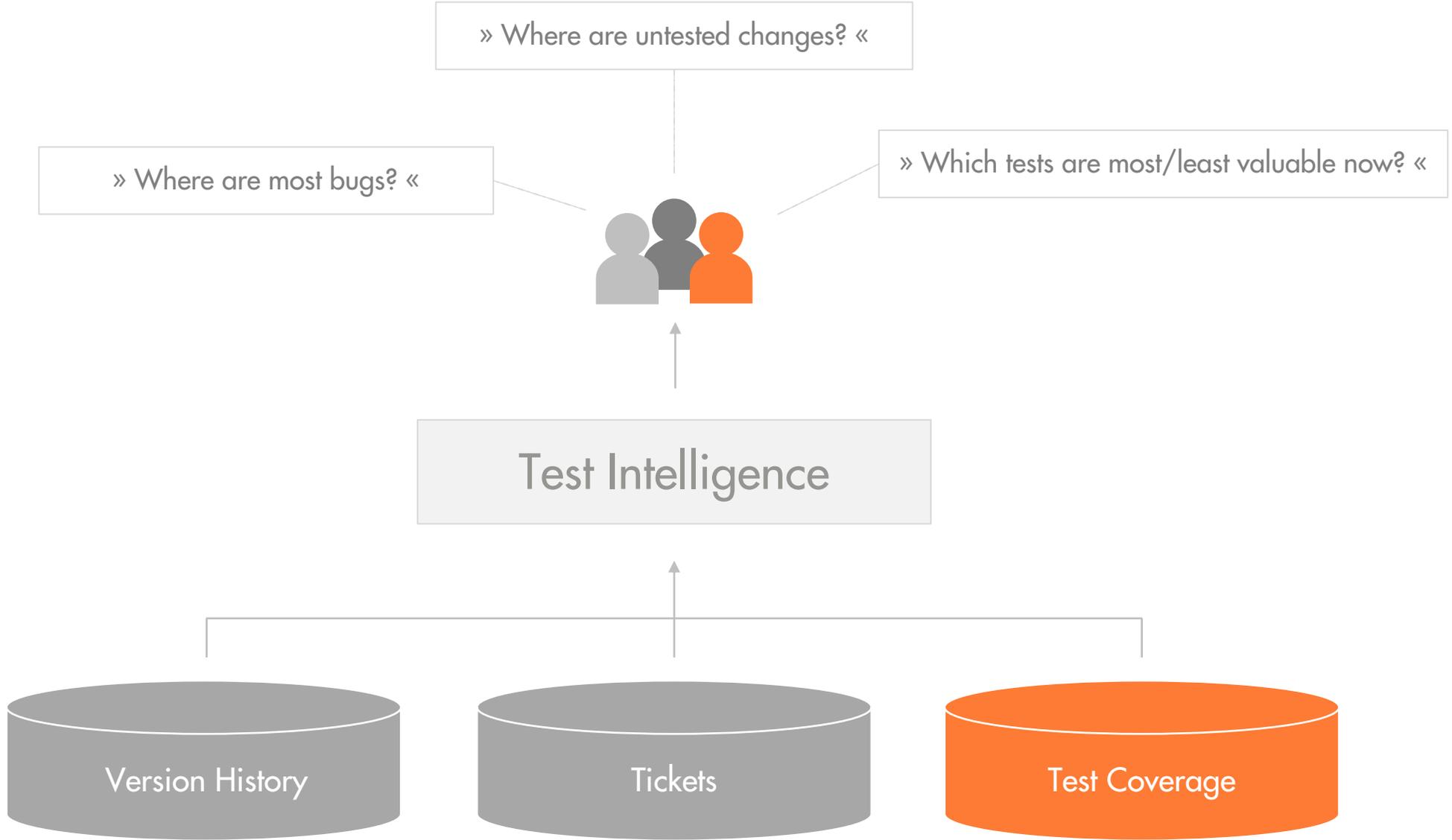




● = changed

● = new



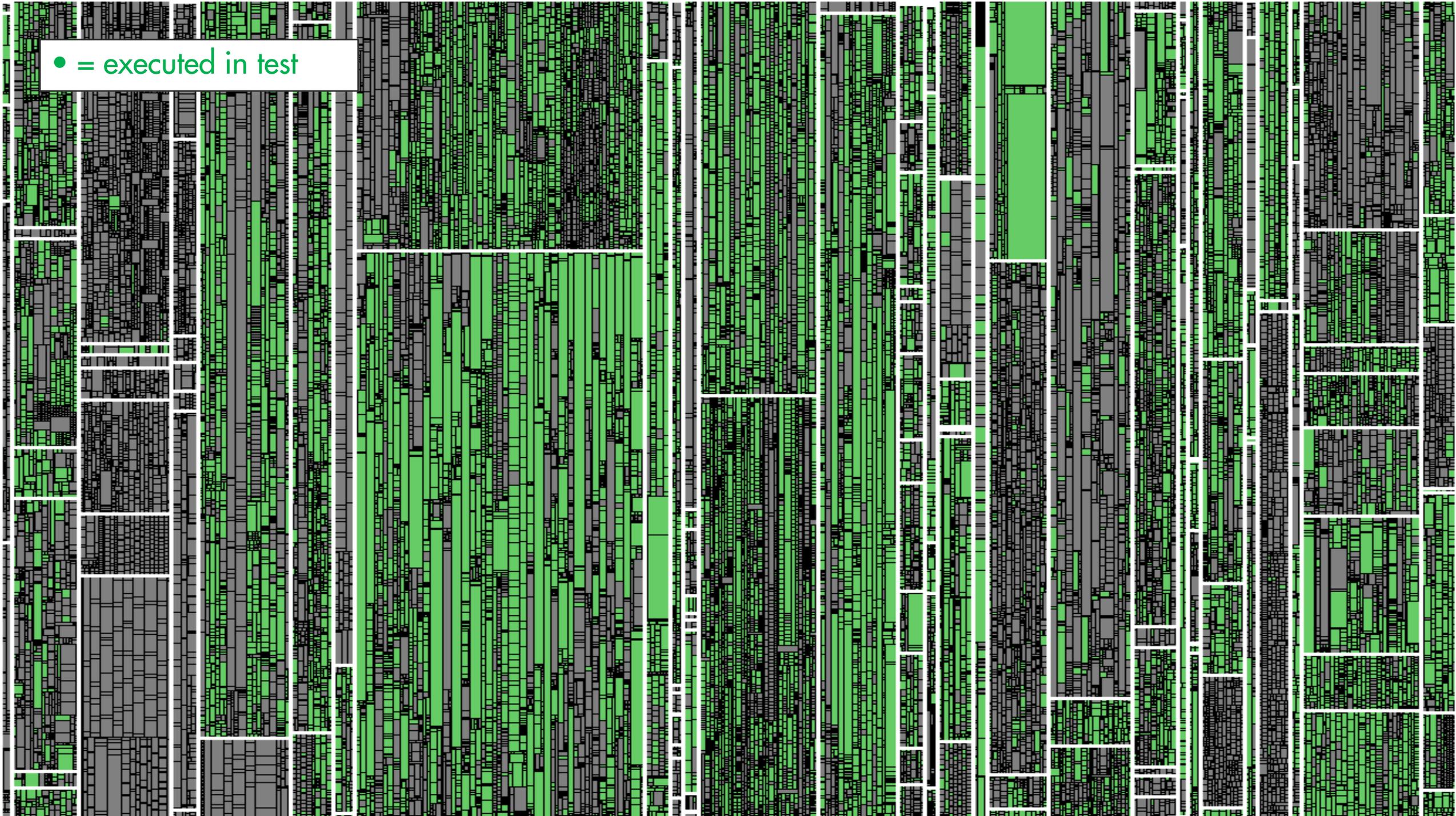


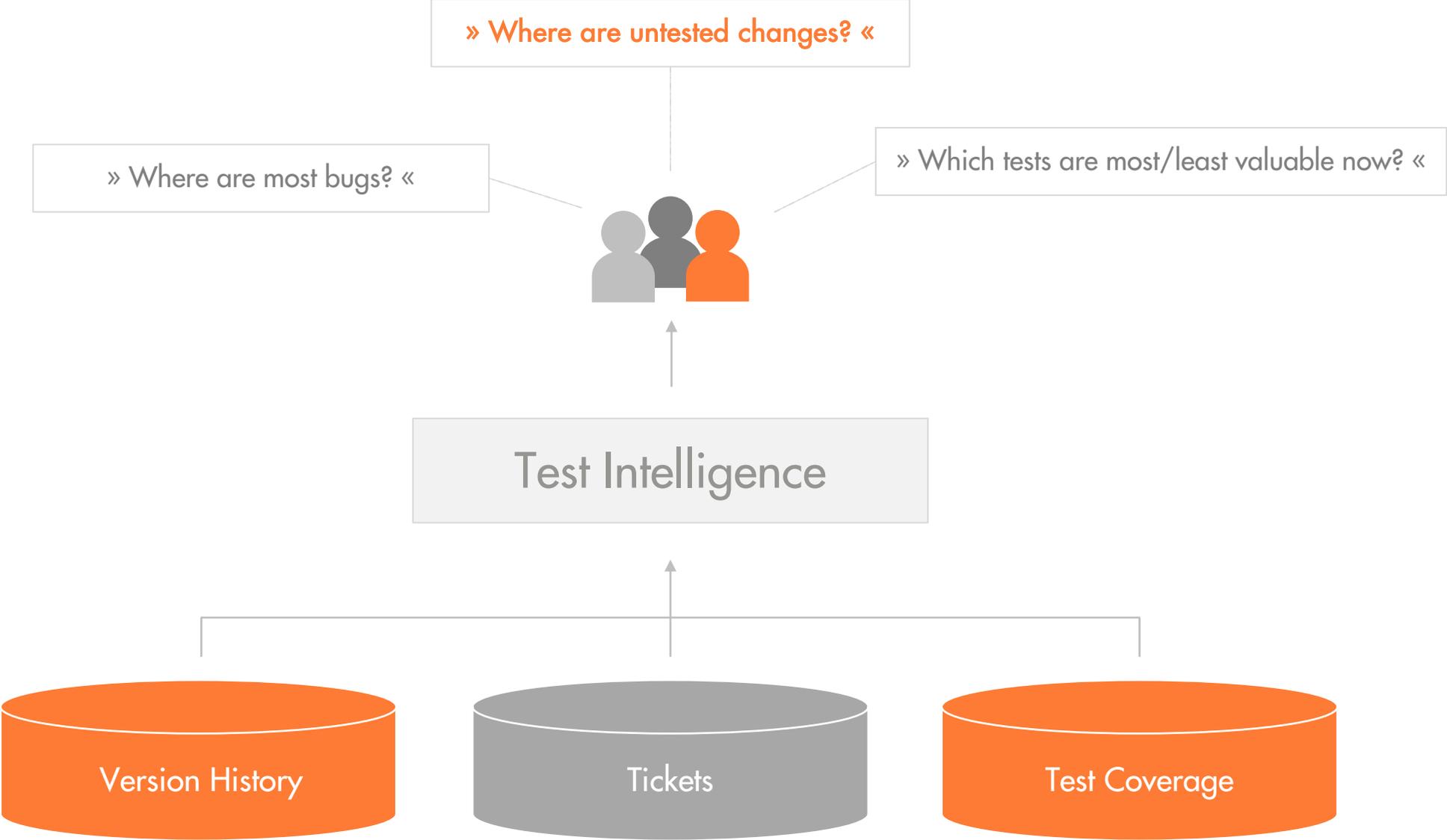
```

1  protected void calculateIndirectAmbiguities() {
2      Map<NucleotideCompound, List<NucleotideCompound>> equivalentMap = new HashMap<>>();
3
4      List<NucleotideCompound> ambiguousCompounds = new ArrayList<NucleotideCompound>();
5      for (NucleotideCompound compound : getAllCompounds()) {
6          if (!compound.isAmbiguous()) {
7              continue;
8          }
9          ambiguousCompounds.add(compound);
10     }
11
12     for (NucleotideCompound sourceCompound : ambiguousCompounds) {
13         Set<NucleotideCompound> sourceConstituents = sourceCompound.getConstituents();
14         for (NucleotideCompound targetCompound : ambiguousCompounds) {
15             Set<NucleotideCompound> targetConstituents = targetCompound.getConstituents();
16             if (targetConstituents.containsAll(sourceConstituents)) {
17                 NucleotideCompound lcSourceCompound = toLowerCase(sourceCompound);
18                 NucleotideCompound lcTargetCompound = toLowerCase(targetCompound);
19                 checkAdd(equivalentMap, sourceCompound, targetCompound);
20                 checkAdd(equivalentMap, sourceCompound, lcTargetCompound);
21                 checkAdd(equivalentMap, targetCompound, sourceCompound);
22                 checkAdd(equivalentMap, lcTargetCompound, sourceCompound);
23                 checkAdd(equivalentMap, lcSourceCompound, targetCompound);
24                 checkAdd(equivalentMap, lcSourceCompound, lcTargetCompound);
25             }
26         }
27     }
28
29     for (NucleotideCompound key : equivalentMap.keySet()) {
30         List<NucleotideCompound> vals = equivalentMap.get(key);
31         for (NucleotideCompound value : vals) {
32             addEquivalent((C) key, (C) value);
33             addEquivalent((C) value, (C) key);
34         }
35     }
36 }

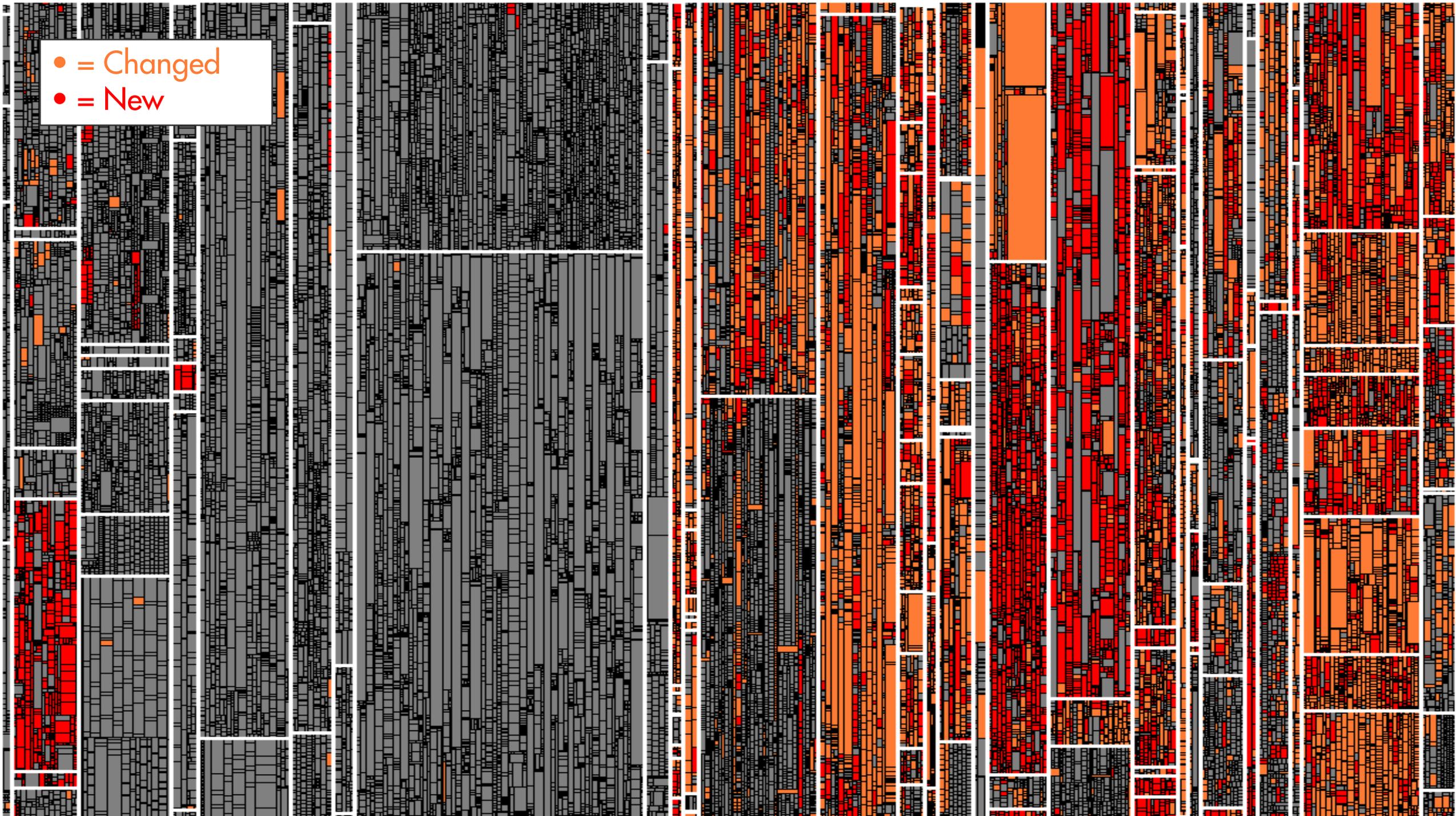
```

● = executed in test



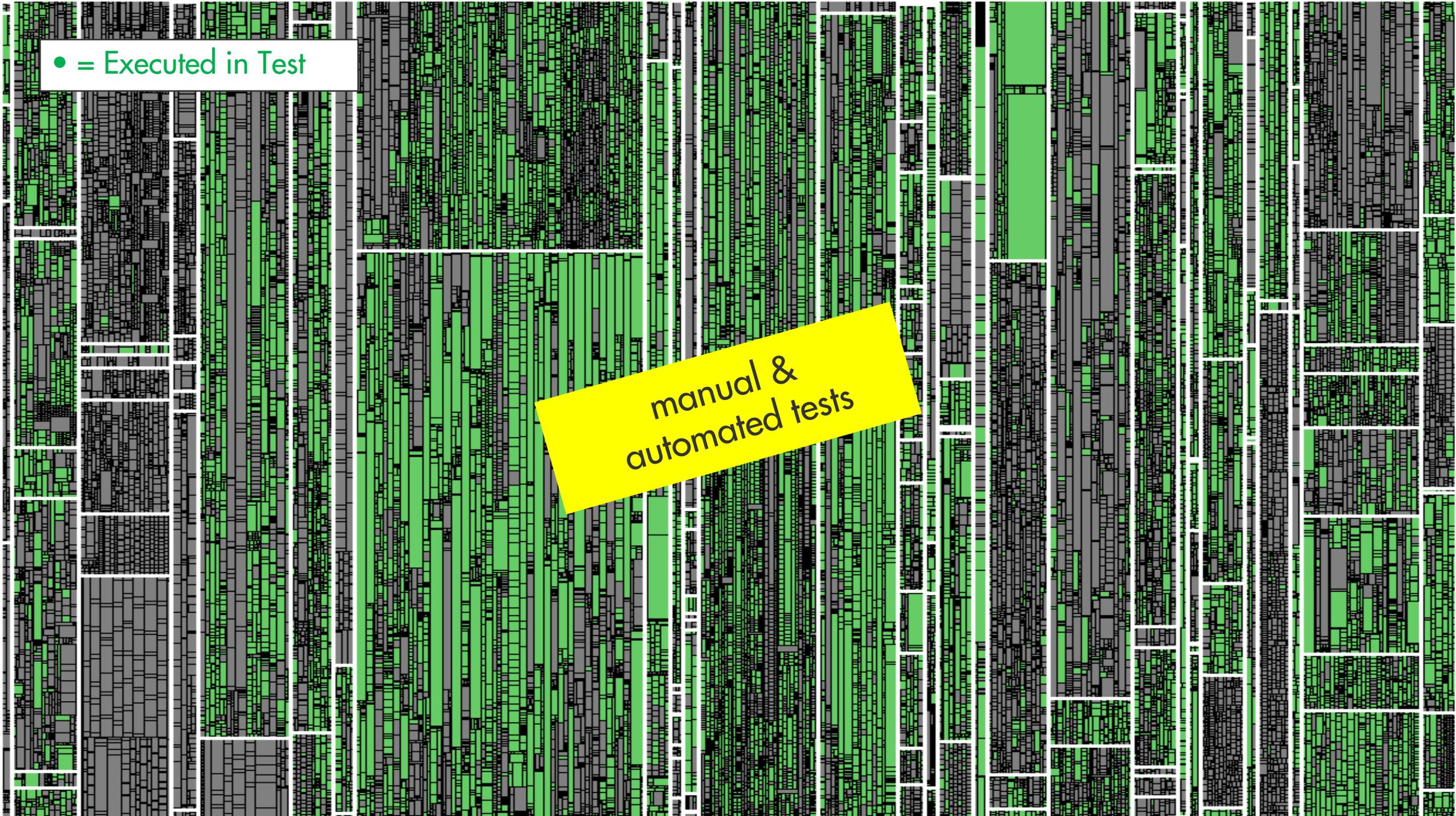


- = Changed
- = New

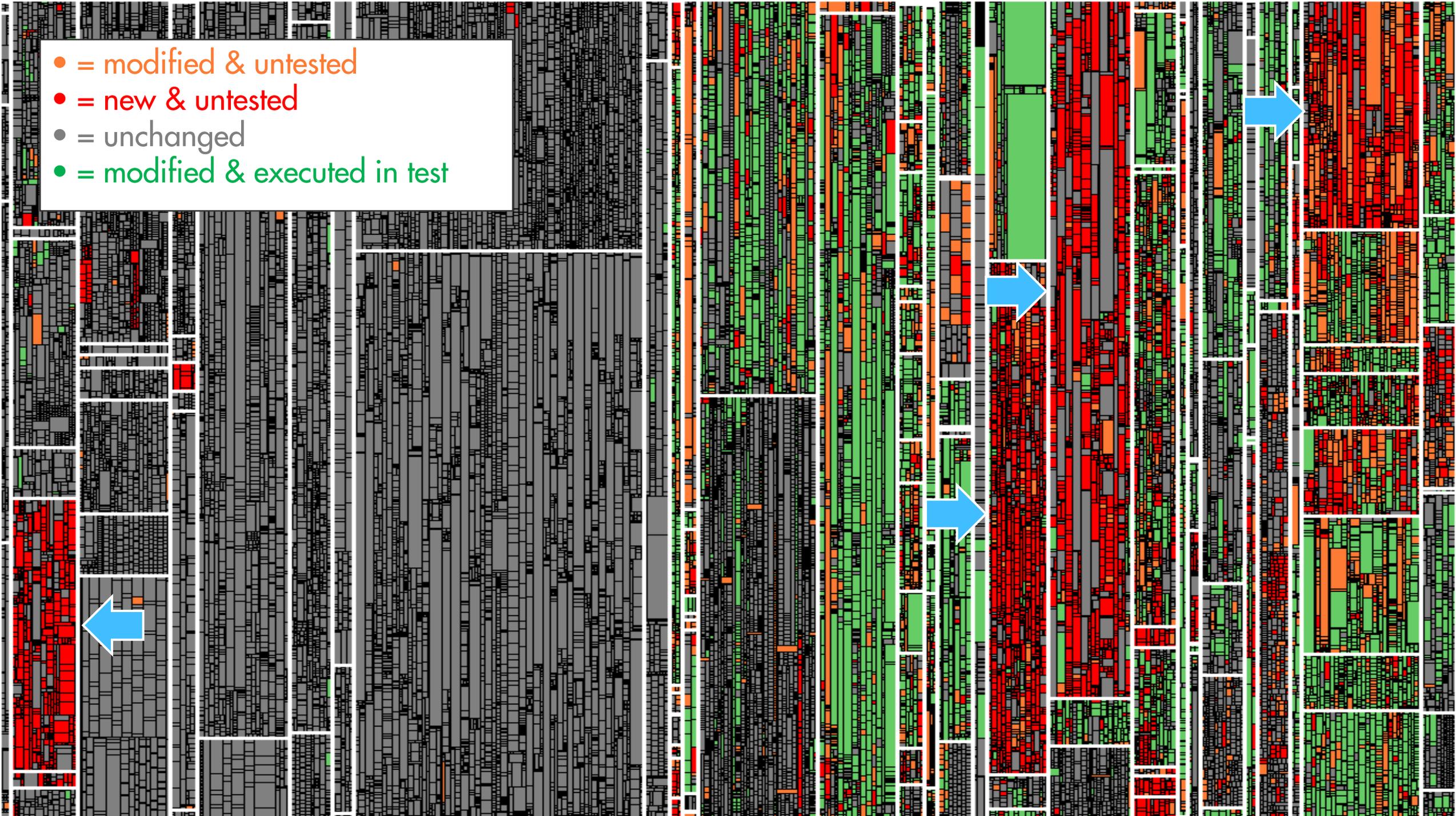


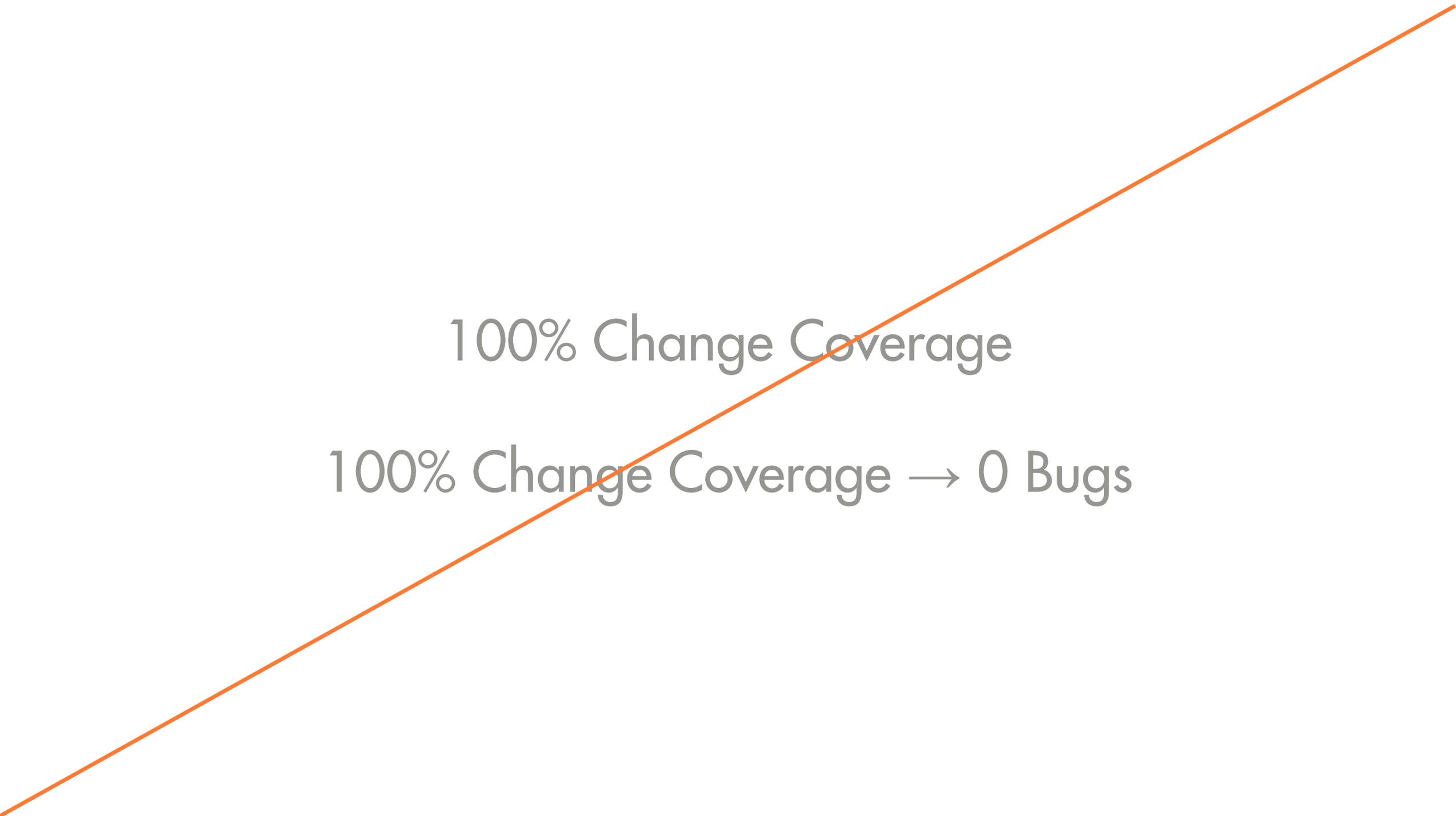
● = Executed in Test

manual &  
automated tests



- = modified & untested
- = new & untested
- = unchanged
- = modified & executed in test

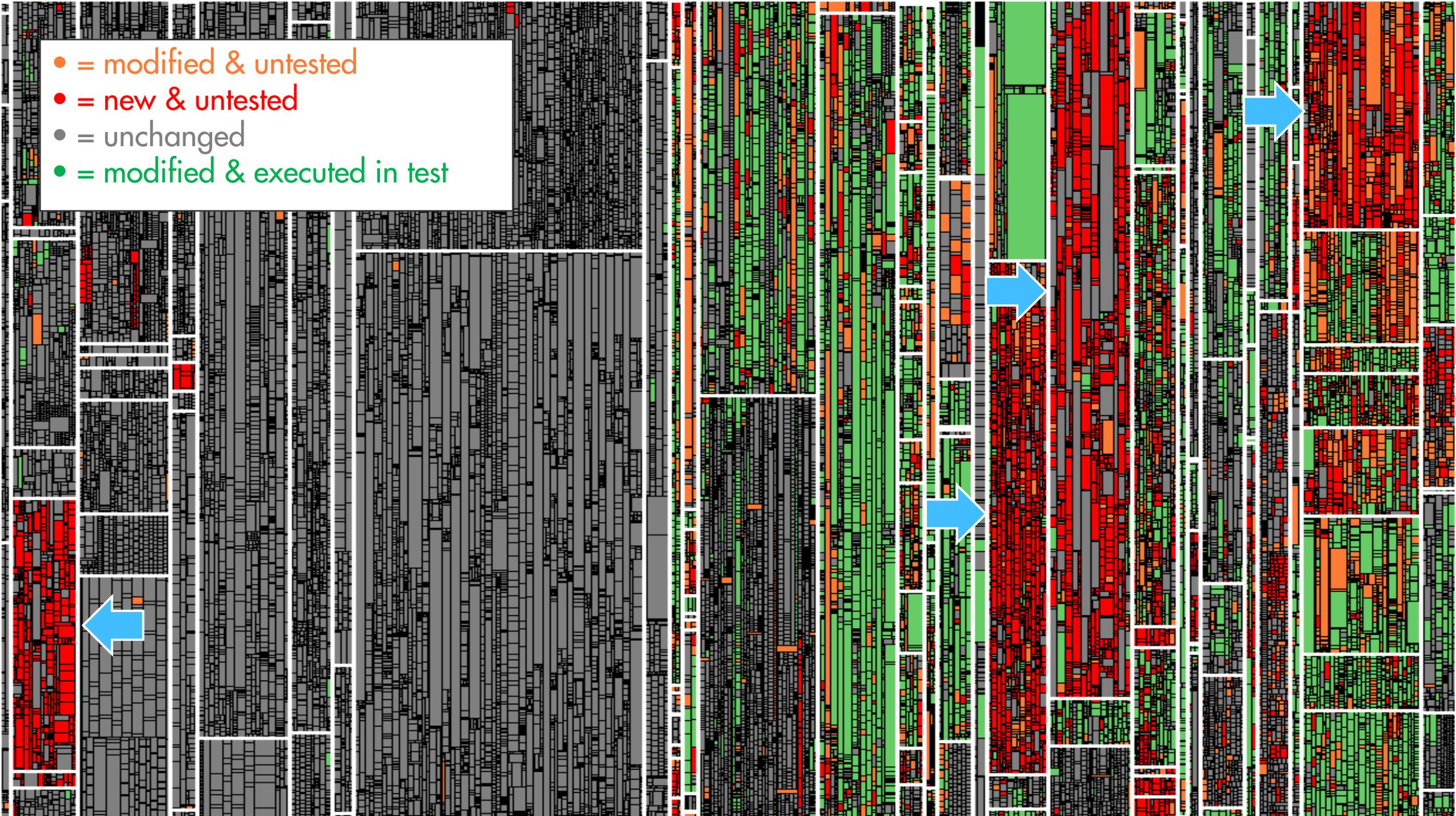




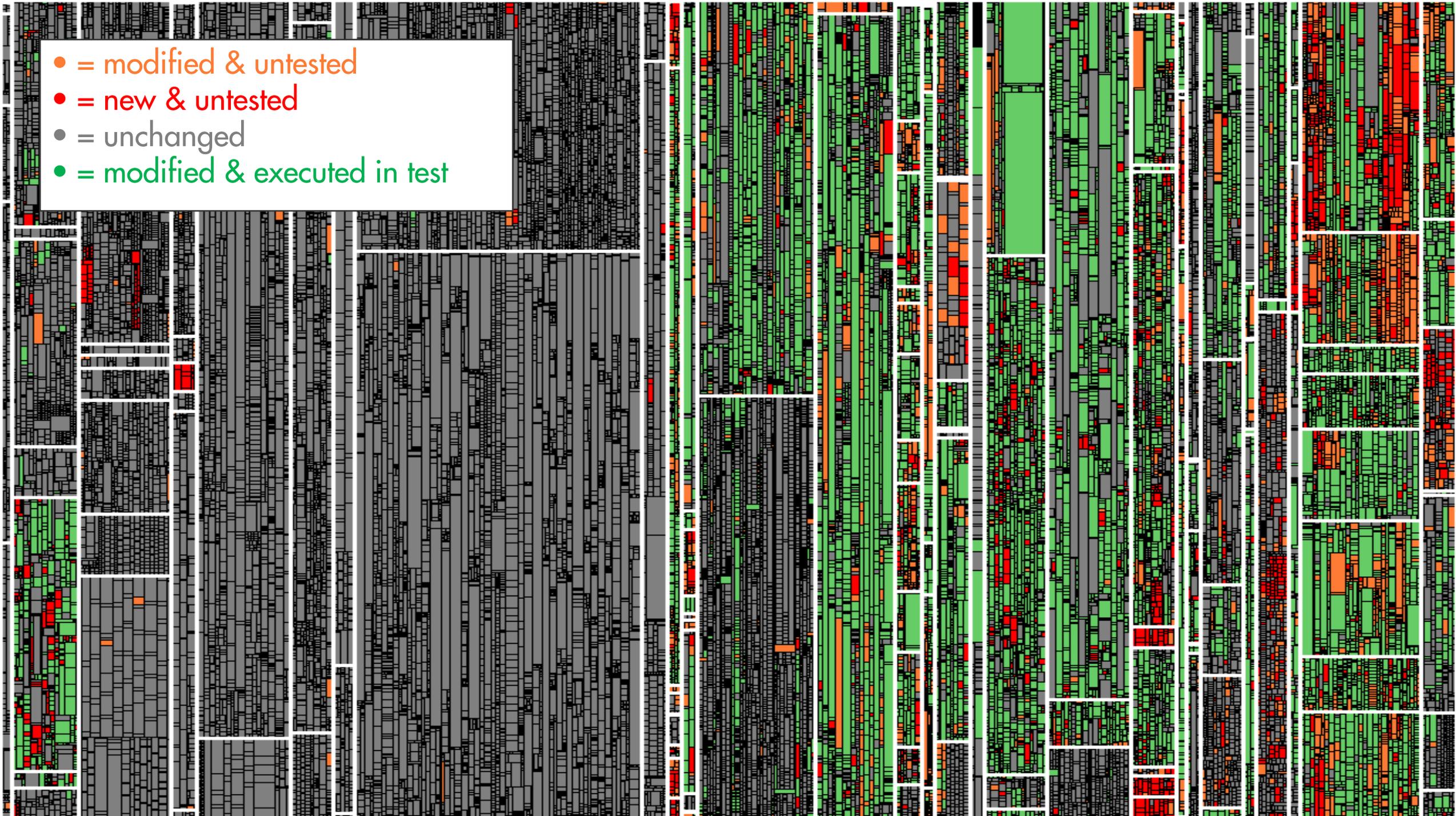
100% Change Coverage

100% Change Coverage → 0 Bugs

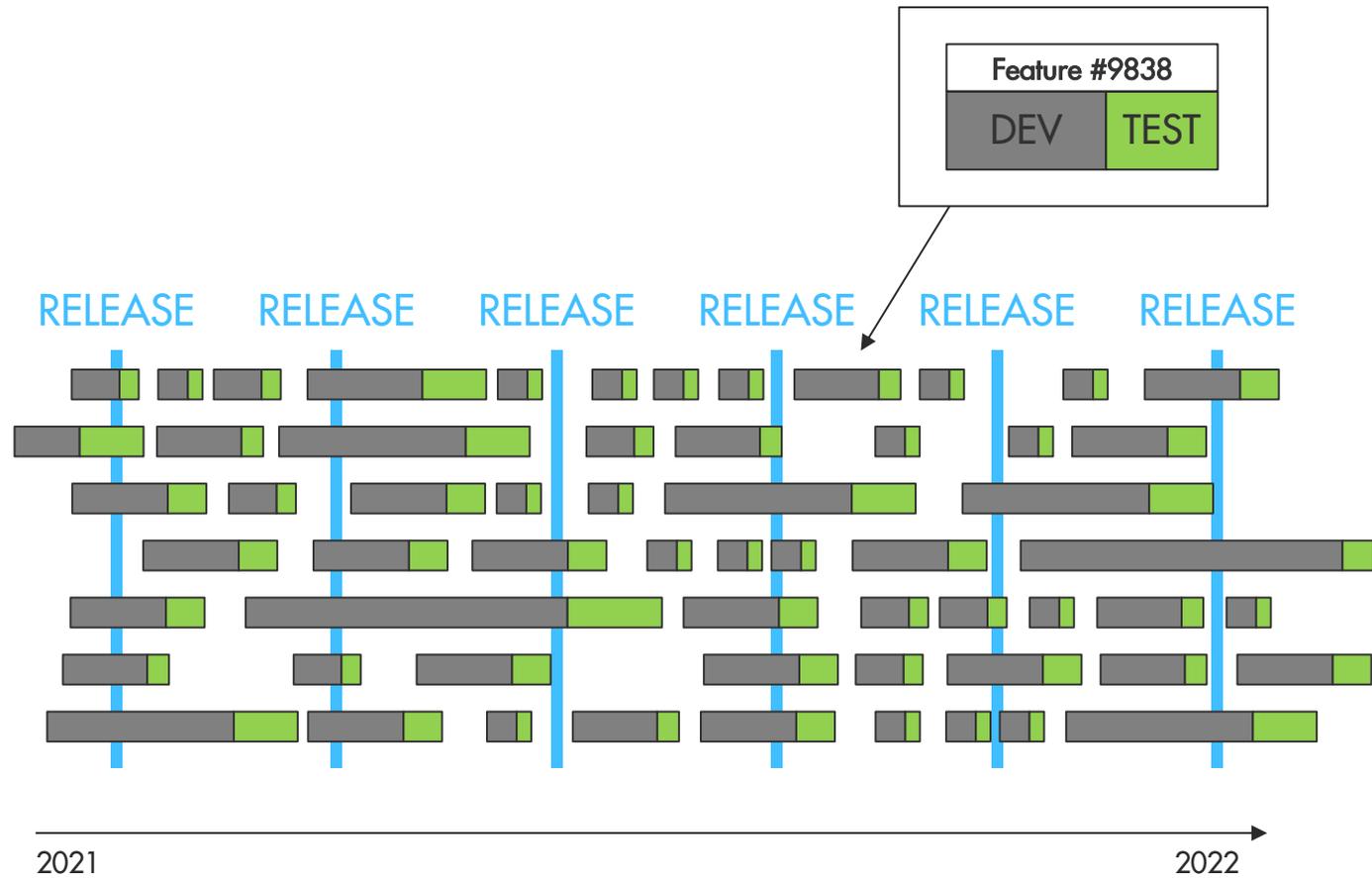
- = modified & untested
- = new & untested
- = unchanged
- = modified & executed in test



- = modified & untested
- = new & untested
- = unchanged
- = modified & executed in test



# Continuous Testing



Issue # <span>▼</span>	Subject	Done		Test Gap
<a href="#">TS-10549</a>	Undo/Redo for web-based architecture editor	Done		0% 
<a href="#">TS-10784</a>	Fix long method finding in TaintAnalysisRunner	Done		0% 
<a href="#">TS-10923</a>	Implement metric 'Nesting Depth' for Simulink	Done		29% 
<a href="#">TS-11364</a>	External findings are not registered during first upload	Done		14% 
<a href="#">TS-11942</a>	Manual test coverage upload during development	Done		43% 
<a href="#">TS-12050</a>	Tool for transferring findings blacklists and tasks	Done		50% 
<a href="#">TS-12262</a>	Cannot set or alter alias without reanalysis	Done		0% 
<a href="#">TS-13151</a>	Fetch parent relationship of TFS work items	Done		0% 

Issue # ▾	Subject		Test Gap
<a href="#">TS-14421</a>	Get rid of TestGapSynchronizer block	Done 	0% 
<a href="#">TS-14733</a>	Remove Dataflow blocks	Done 	22% 

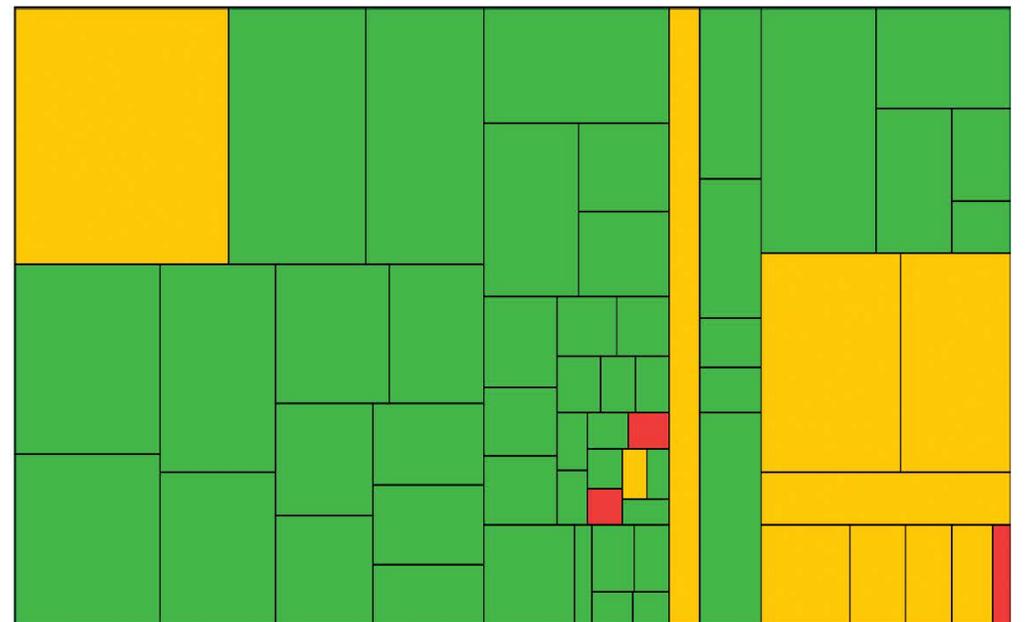
**Done Issue TS-14733 - Remove Dataflow blocks**

Creator:  (on Apr 06 2018 19:44) Last update: Aug 24 2018 09:32

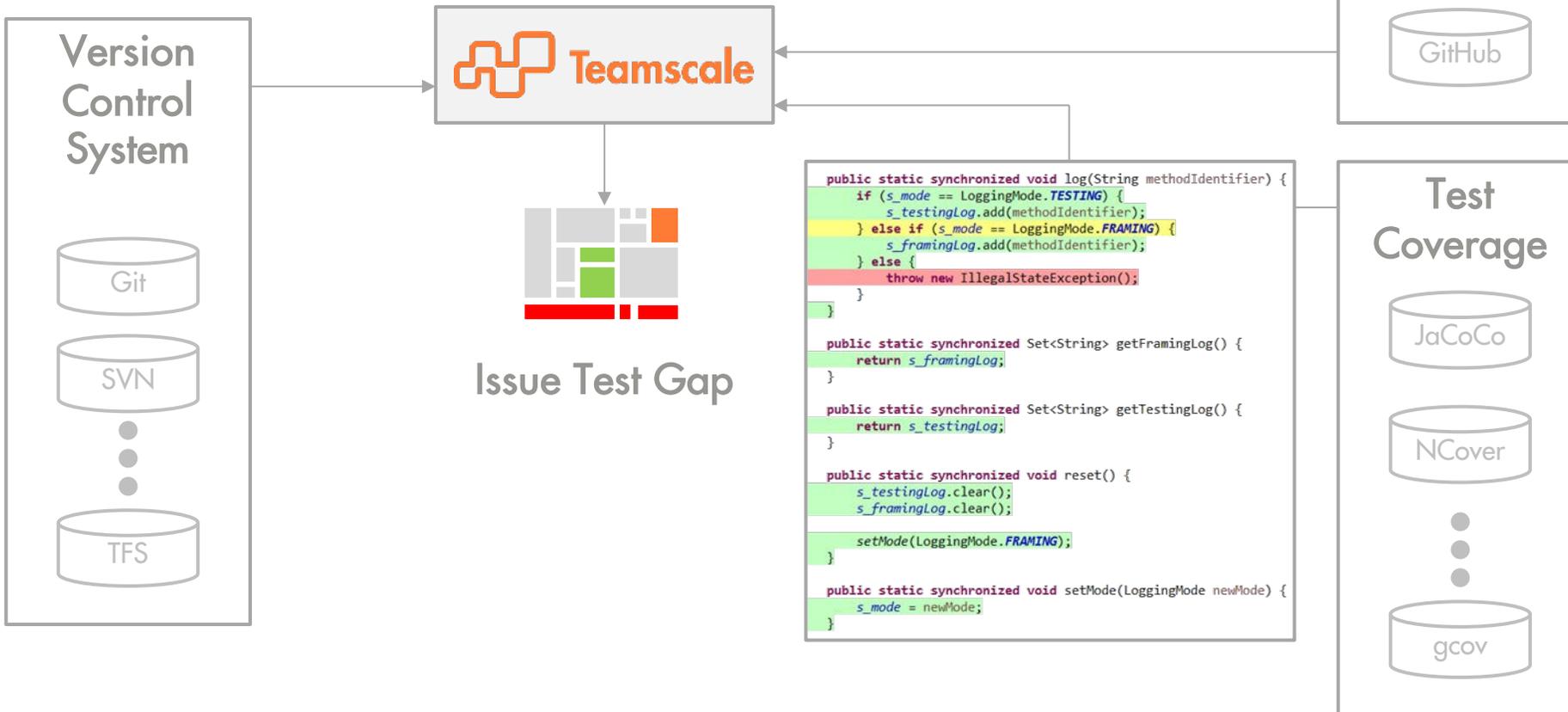
Assignee: 

Project	Type	Priority	Resolution	Fix Version
TS	Maintenance	Normal	Green	Teamscale 4.5
Component	Labels	Affected Version	Customer	Customer Issue
Backend	Performance			
Epic Name	Freshdesk URL	Merge Request		
		<a href="https://git.cqse.eu/cqse/teamscale/3621">https://git.cqse.eu/cqse/teamscale/3621</a>		

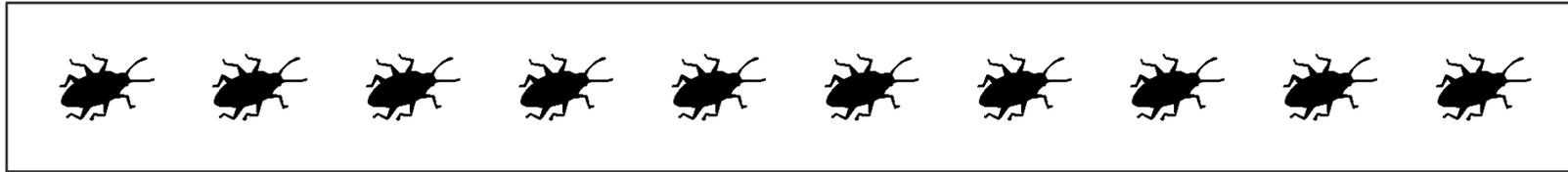
Aug 15 2018 12:37–Now | Test Gap: 22%



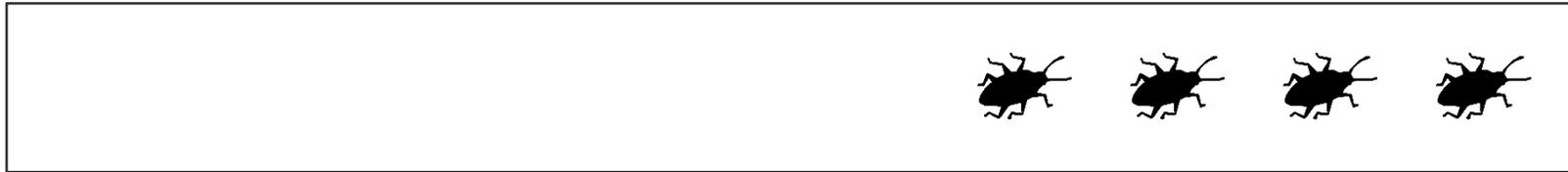
CR#9838: Added TODO	26.07.16 16:38
CR#9838: Adjust naming	26.07.16 15:33
CR#9533: RED	26.07.16 15:13
CR#9533: GREEN	26.07.16 15:12
CR#10181: Added new finding for deprecated classes, methods and fields	26.07.16 14:43
CR#10037: Moved ReviewMetricsSynchronizer to Crucible package and made some improvements to its internal structure	26.07.16 14:31
CR#10037: Updated aggregation strategy of open reviews so each review is only counted once, even over multiple files	26.07.16 13:04
CR#10203: Fixed "field could be made final" for Java interfaces	26.07.16 12:16
CR#10200: Rename pathRestriction -> subPath (1)	26.07.16 11:35
CR#10172: Removed unwanted colons from headers in the commit view of the activity perspective	26.07.16 11:20
CR#9838: Fix: only one color of a threshold is specified in a corridor	26.07.16 11:14
CR#0: Fix findings	26.07.16 11:01
CR#9838: minor improvement	26.07.16 10:56
CR#10199: Mail notifications do now support starTLS	26.07.16 10:52
CR#9533: working on developer feedback	26.07.16 09:50
CR#9838: Amend last commit	26.07.16 09:38
CR#9838: minor refactoring	26.07.16 09:05
CR#9838: Fix NPE	26.07.16 09:01



# Benefit Analysis of TGA

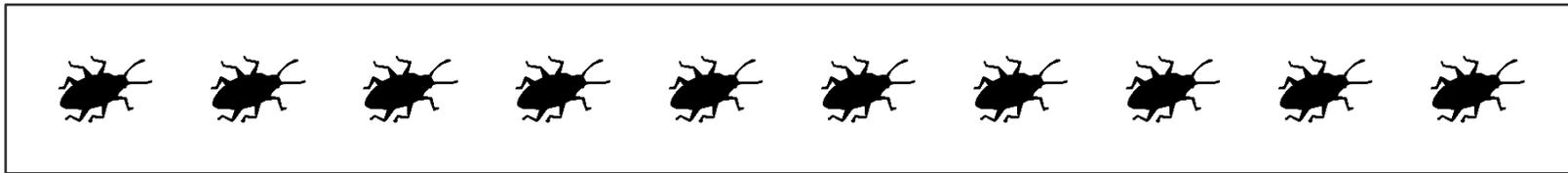


Test

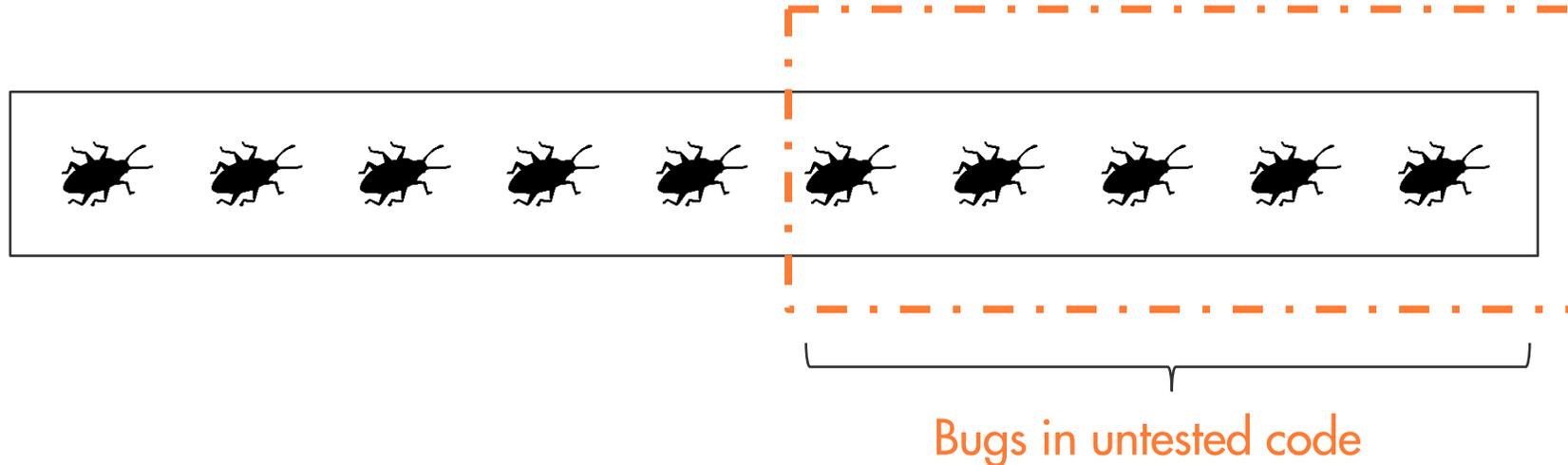


%RemainingBugs

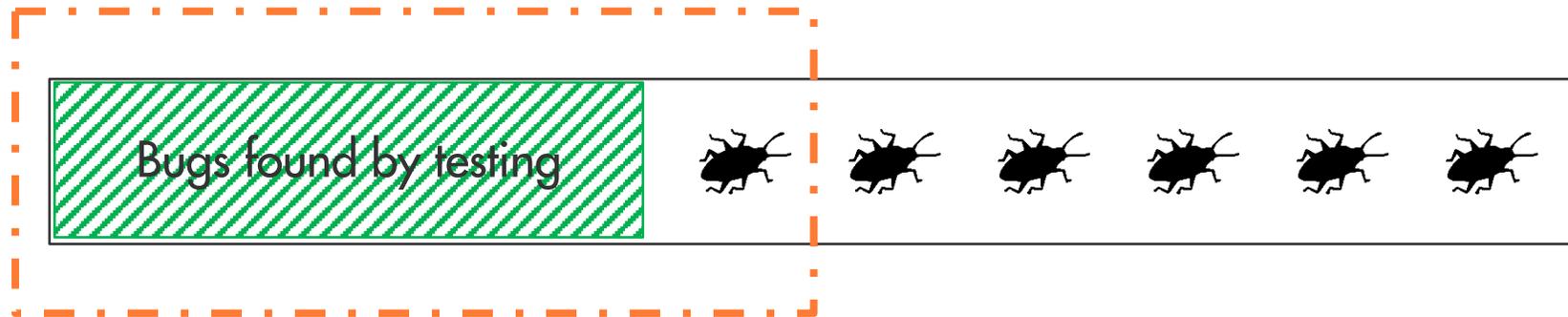
$$\%RemainingBugs = \%Tested * TestIneffectiveness + \%Testgap$$



$$\%RemainingBugs = \%Tested * TestIneffectiveness + \%Testgap$$



$$\%RemainingBugs = \%Tested * TestIneffectiveness + \%Testgap$$



Bugs that testing missed,  
despite running through this code

# Did We Test Our Changes? Assessing Alignment between Tests and Development in Practice

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**Abstract**—Testing and development are increasingly performed by different organizations, often in different countries and time zones. Since their distance complicates communication, close alignment between development and testing becomes increasingly challenging. Unfortunately, poor alignment between the two threatens to decrease test effectiveness or increase costs. In this paper, we propose a conceptually simple approach to assess test alignment by uncovering methods that were changed but never executed during testing. The paper's contribution is a large industrial case study that analyzes development changes, test service activity and field faults of an industrial business information system over 14 months. It demonstrates that the approach is suitable to produce meaningful data and supports test alignment in practice.

**Index Terms**—Software testing, software maintenance, dynamic analysis, untested code

I. INTRODUCTION  
A substantial part of the total life cycle costs of long-lived software systems is spent on testing. In the domain of business-information systems, it is not uncommon that successful software systems are maintained for two or even three decades. For such systems, a substantial part of their total lifecycle costs is spent on testing to make sure that new functionality works as specified, and—equally important—that existing functionality has not been impaired.

During maintenance of these systems, test case selection is crucial. Ideally, each test cycle should validate all implemented functionality. In practice, however, available resources limit each test cycle to a subset of all available test cases. Since selection of test cases for a test cycle determines which bugs are found, this selection process is central for test effectiveness. A common strategy is to select test cases based on the changes that were made since the last test cycle. The underlying assumption is that functionality that was added or changed recently is more likely to contain bugs than functionality that has passed several test cycles unchanged. Empirical studies support this assumption [1], [2], [3], [4].

If development and testing efforts are not aligned well, testing might focus on code areas that did not change,

or—more critically—substantial code changes might remain untested. Test alignment depends on communication between testing and development. However, they are often performed by different teams, often located in different countries and time-zones. This distance complicates communication and thus challenges test alignment. But how can we assess test alignment and expose areas where it needs to be improved?

**Problem:** We lack approaches to determine alignment between development and testing in practice.  
**Proposed Solution:** In this paper, we propose to assess test alignment by measuring the amount of code that was changed but not tested. We propose to use *method-level change coverage* information to support testers in assessing test alignment and improving test case selection.

Our intuition is that changed, but untested methods are more likely to contain bugs than either unchanged methods or tested ones. However, our intuition might be dead wrong: method-level churn could be a bad indicator for bugs, since changes can contain bugs although they have not changed in ages.

**Contribution:** This paper presents an industrial case study that explores the meaningfulness and helpfulness of method-level change coverage information. The case study was performed on a business information system owned by Munich Re. System development and testing were performed by different organizations in Germany and India. The case study analyzed all development changes, testing activity, and all field bugs, for a period of 14 months. It demonstrates that field bugs are substantially more likely to occur in methods that were changed but not tested.

II. RELATED WORK  
The proposed approach is related to the fields of defect prediction, selective regression testing, test case prioritization, and test coverage metrics. The most important difference to the named topics is the simplicity of the proposed approach and the fact that change coverage assesses the executed subsets of test suites, but does not give hints to improve them.

**Defect prediction** is related to our approach, because we identify code regions that were changed, but remained untested, with the expectation that there are more field bugs.

therefore useful for maintainers and testers to identify relevant gaps in their test coverage.

## B. Study Object

We perform the study on a business information system at Munich Re. The analyzed system was written in C# and its size are 340 KLOC. In total, we analyzed the system for 14 months. The system has been successfully in use for nine years and is still actively used and maintained. Therefore, there is a well implemented bug tracking and testing strategy. This allows us to gain precise data about which parts of the system were changed and why they were changed.

We analyzed two consecutive releases of the system. Release 1 was developed in five iterations in two months, and release 2 was developed in ten iterations in four months. Both releases were deployed to the productive environment but to hot fixes five times and were in productive use for six months. Note that one deployment may concern several bugs and changes in the system. The system contained 22123 (release 1) respectively 22712 (release 2) methods.

For both releases, test suites containing 65 system test cases covering the main functionality were executed three times.

C. Study Design and Execution  
For all research questions, we classify methods according to the categories shown in Figure 2. Tested or untested, changed or unchanged, and whether methods contained field bugs.

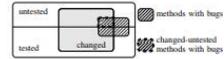


Fig. 2. Method categories used to evaluate change coverage

**Study Design:** First, we collect coverage and program data, then we answer RQ 1 and RQ 2 based on the collected data.

For answering RQ 1, we build method genealogies and identify changes during the development phase and relate usage data to these genealogies. With this information, we identify method genealogies that are changed-untested.

For answering RQ 2, we calculate the probability of field defects for every category of methods by detecting changes in the productive phase of the system in retrospective. This is valid for the analyzed system, since only severe bugs are fixed directly in the productive environment, which is defined by the company's processes.

We gain our results by identifying methods that are changed in the productive phase, which means they were related to a bug. We then categorize methods by change and coverage during the development phase. Based on this, we calculate the bug probability in the different groups of methods.

**Study Execution:** We used tool support, which consists of three parts: An ephemeral [18] profiler that records which methods were called within a certain time interval, a database that stores information about the system under consideration,

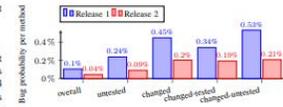


Fig. 3. Probability of fixes in both releases

and a query interface that allows retrieving coverage, change, and change coverage information. The same tool support was used in earlier studies [17], [19].

**Validity Procedures:** We focus on validity procedures and not on metrics to validity due to space limitations. We conducted manual inspections to ensure that every bug that is identified by our tool support is indeed a bug.

To confirm the correctness of method genealogies we build based on locality and signatures, we conducted manual inspections of randomly chosen method genealogies. We found no false genealogies and have therefore a high confidence in the correctness of our technique. We also used the algorithm in our former work [17], which provided suitable results as well.

D. Results  
RQ 1: Untested methods account for 34% in both releases we analyzed. 15% of all methods were changed during the development phase of the system, also in both releases. The equality of the numbers for both releases is a coincidence. 8% respectively 9% of all methods were changed-untested. Considering only changed methods, only 44% were tested in release 1 and 45% of these methods were tested in release 2. These numbers constitute that there are gaps in the test coverage of changed code in the analyzed system.

RQ 2: We found 23 fixes in release 1 and 10 fixes in release 2. The distribution of the bugs over the different change and coverage categories of methods is shown in Table I. The biggest part of bugs occurred in methods categorized as changed-untested with 43% of all bugs in release 1 and 40% of all bugs in release 2. In both releases, there are considerably less bugs in unchanged regions than in changed regions.

The probabilities of bugs are shown in Figure 3. With 0.53% in release 1 and 0.21% in release 2, the probability of bugs is higher in the group of methods that were changed-untested. This confirms that tested code or code that was not changed in the development phase is less likely to contain field defects.

E. Discussion  
RQ 1: With 15% of all methods being changed and 34% of all methods being not tested, untested code and changed code plays a considerable role in the analyzed system. The high amount of changed methods results from newly developed features, which means that many methods were added during the development phase of both releases.

There are several models for defect prediction [5]. In contrast to these models, we measure only changes in the system and the coverage by tests and do not predict bugs, but assess test suites and use the probability of bugs in changed, but untested code as validation of the approach.

The proposed approach is related to [6], which uses series of changes “change bursts” to predict bugs. The goal results that were achieved by using change data for defect prediction encourage us to combine similar data with testing efforts.

**Selective regression testing** techniques target the selection of test cases from changes in source code and coverage information [7], [8], [9].

In contrast to these approaches, the paper at hand focuses on the assessment of already executed test suites, because often experts decide which tests to execute to cover most of the changes made to a software system [10]. However, their estimations contain uncertainties and therefore possibly miss some changes. Our approach aims at identifying the resulting uncovered code regions. Therefore, our approach can only be used if testing activities were already performed.

Compared to [11], we are validating our approach by measuring field defects, and do not take defects into account that were found during development.

**Test coverage metrics** give an overview of what is covered by tests. Much research has been performed in these topics [12] and there is a plethora of tools [13] and a number of metrics available, such as statement, branch, or path coverage [14]. In contrast to these metrics, we focus on the more coarse grained metric coverage. Furthermore, we do not only consider static properties of the system under test, but changes.

**Empirical studies on related topics** focus to the best of our knowledge mainly on the effectiveness of test case selection and prioritization techniques [9], [15]. In our study, we assess test suites by their ability to cover changes of a software system, but do not consider sub sets of test suites.

## III. CONTEXT AND TERMS

In this work, we focus on *system testing* according to the definition of IEEE Std 610.12-1990 [16] to denote “testing conducted on a complete, integrated system to evaluate the system's compliance with its specified requirements”. System tests are often used to detect bugs in existing functionality after the system has been changed. In our context, many tests are executed manually and denoted in natural language.

Our study uses *methods* as they are known from programming languages such as Java or C#. Methods form the entities of our study and can be regarded as units of functionality of a software system. They are defined by a signature and a body. To compare different releases of a software system over time, we create *method genealogies* which represent the evolution of a single method over time. A genealogy connects all releases of a method in chronological order [17].

In the context of our work, the life cycle of a software system consists of two alternating phases (see Figure 1). In the *development phase*, existing functionality is maintained

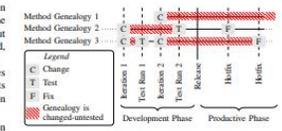


Fig. 1. Development life-cycle

or new features are developed. Development usually occurs in *iterations* which are followed by *test runs* which are the execution of a selection of tests aiming to test regressions as well as the changed or added code. A development phase is completed by a *release* which transfers the system into the *productive phase*. In the productive phase, functionality is usually neither added nor changed. If critical malfunctions are detected, *hot fixes* are deployed in the productive phase.

We consider a method as *tested* if it has been executed during a test run. If a method has been changed or added and been tested afterwards before the system is released we consider it as *changed-untested*. If a method change or addition has not been tested before the system is transferred in the productive phase, we consider the method as *changed-untested* (see genealogy 1 and 3 in Figure 1).

## IV. CHANGE COVERAGE

To quantify the amount of changes covered by tests, we introduce the metric *change coverage (CC)*. It is computed by the following formula and ranges between [0,1].

$$\text{change coverage} = \frac{\text{\#methods changed-tested}}{\text{\#methods changed}}$$

A change coverage of 1 ( $CC = 1$ ) means that all methods which have been changed since the last test run have been tested after their last change. On the contrary, a coverage of 0 ( $CC = 0$ ) indicates that none of the changed methods have been covered by a test.

## V. CASE STUDY

### A. Goal and Research Questions

The goal of the study is to show whether change coverage is a useful metric for assessing the alignment between tests and development. We formulate the following research questions.

**RQ 1: How much code is changed, but untested?** The goal of this research question is to investigate the existence of changed, but untested code, to justify the problem statement of this work. Therefore, we quantify changed and untested code.

**RQ 2: Are changed-untested methods more likely to contain field bugs than unchanged or tested methods?** The goal of this research question is to decide whether change coverage can be used as a predictor for bugs in large code regions and is

TABLE I  
DISTRIBUTION OF FIXES OVER THE DIFFERENT CATEGORIES

Category	Release 1		Release 2	
	Absolute	Relative	Absolute	Relative
changed-untested	5	22%	3	30%
changed-untested	10	43%	4	40%
unchanged-untested	0	0%	0	0%
unchanged-untested	8	35%	3	30%

43% respectively 40% of the changed methods were not tested in the analyzed system. These high numbers also result from features that are newly developed during the development phase. For these new features, there was only a very limited number of test cases.

**RQ 2:** With a probability of bugs in untested-changed methods of 0.53% respectively 0.21%, this group of methods contains most of the bugs. This means that the system itself contains few bugs at the current stage of development and bugs are brought into the system by changes.

Furthermore, the probability of bugs in untested code is, in both releases, less than half of the probability in changed-untested code. Hence, we conclude that only considering test coverage is not as efficient as considering change coverage.

The probability of bugs in changed code regions is also considerably higher than in untested regions. But the combination of both metrics, test coverage and changed methods points to code regions that are more likely to contain bugs than others. **Is Change Coverage Helpful in Practice?** We employed the proposed approach also in the context of Munich Re in currently running development phases. We showed the results to developers and testers by presenting code units, like types or assemblies ordered by change coverage. During the discussion of the results, we conducted open interviews with developers to gain knowledge about how helpful information about change coverage is during maintenance and testing.

Developers identified meaningful methods in changed but untested regions by using the static call graph to find methods they know. With these methods, the developers were able to identify features that remained untested. For example the processing of excel sheets in a particular calculation was changed, but remained untested afterwards. In this case, among other, the (re-)execution of particular test cases and the creation of new test cases were issued. This increased the change coverage considerably for the code regions where the features are located. This shows that change coverage is helpful for practitioners.

## VI. CONCLUSION AND FUTURE WORK

We presented an automated approach to assess the alignment of test suites and changes in a simple and understandable way. Instead of using rather complex mechanisms to derive code units that may be subject to changes, we are focusing on changed but untested methods and calculate an expressive metric from these methods. The results show that the use of

change coverage is suitable for the assessment of the alignment of testing and development activities.

We also showed that change coverage is suitable for guiding testers during the testing process. With information about change coverage, testing efforts can be assessed and redirected if necessary, because the probability of bugs is increased in changed-untested methods. Furthermore, we presented our tool support that allows us to utilize our technique in practice.

However, the number of bugs we found is too small to derive generalizable results. Therefore, we plan to extend our studies to other systems to increase external validity. But the first results that we presented in this work point out that the consideration of code regions that are modified, but not very well tested is important. This motivates future work on the topic and the inference of improvement goals.

One challenge is the identification of suitable test cases from code regions to give hints to testers and developers which test case to execute to cover more changed, but untested methods. Therefore, we plan to evaluate techniques related to trace link recovery to bridge the gap to test cases.

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# How Many Changes Remain Untested?

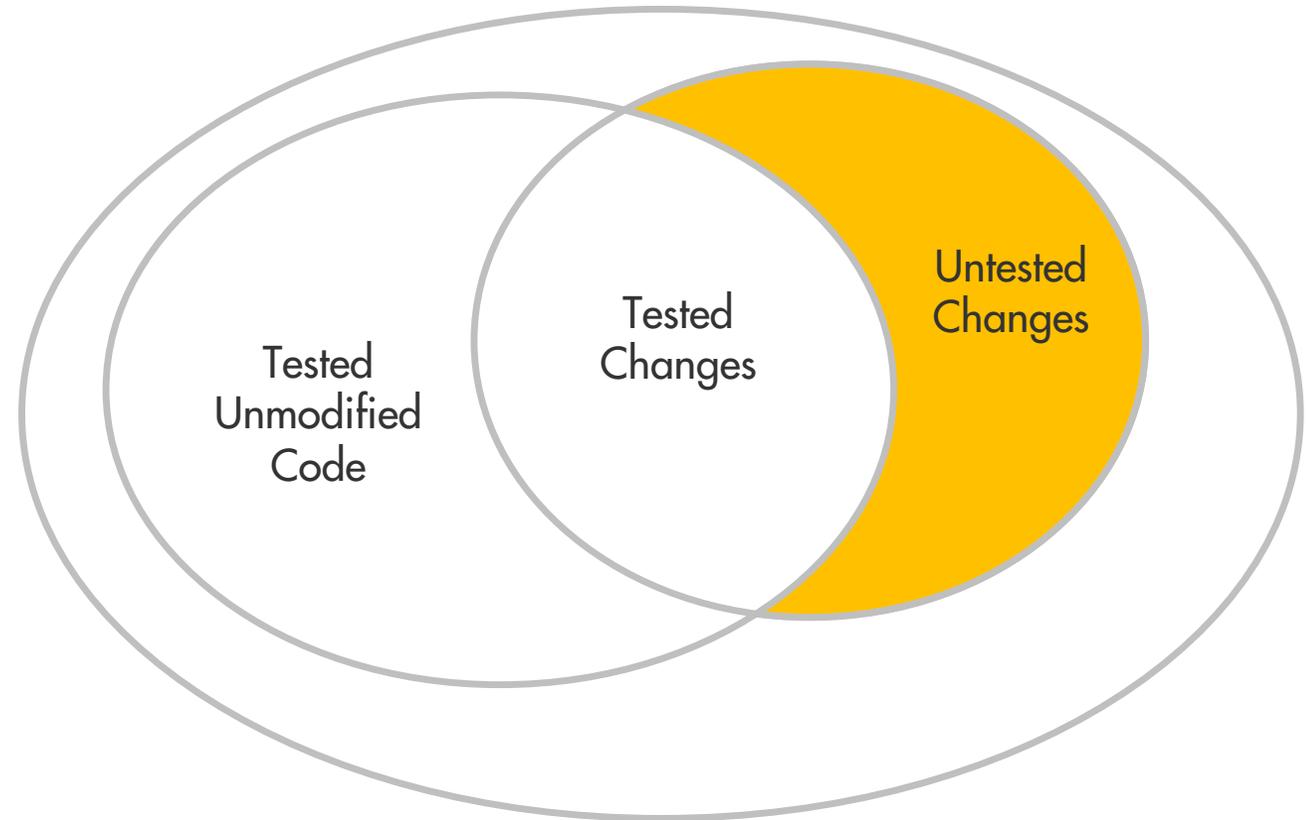
Study: C# System @ Munich Re

**Release A:**

15% Code new/modified,  
**>50% untested**

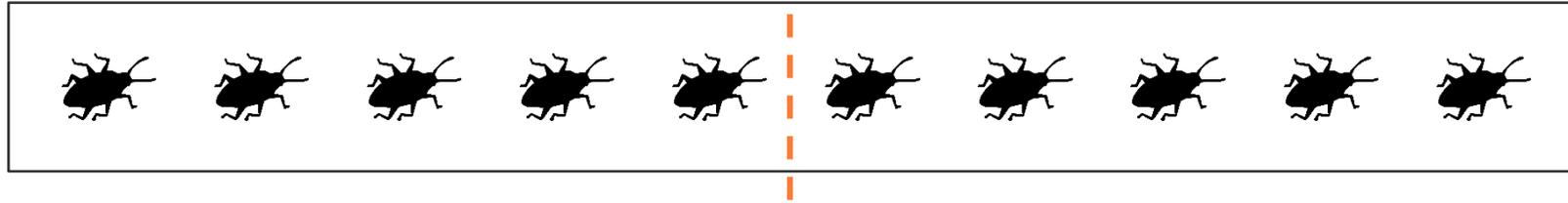
**Release B:**

15% Code new/modified,  
**>60% untested**

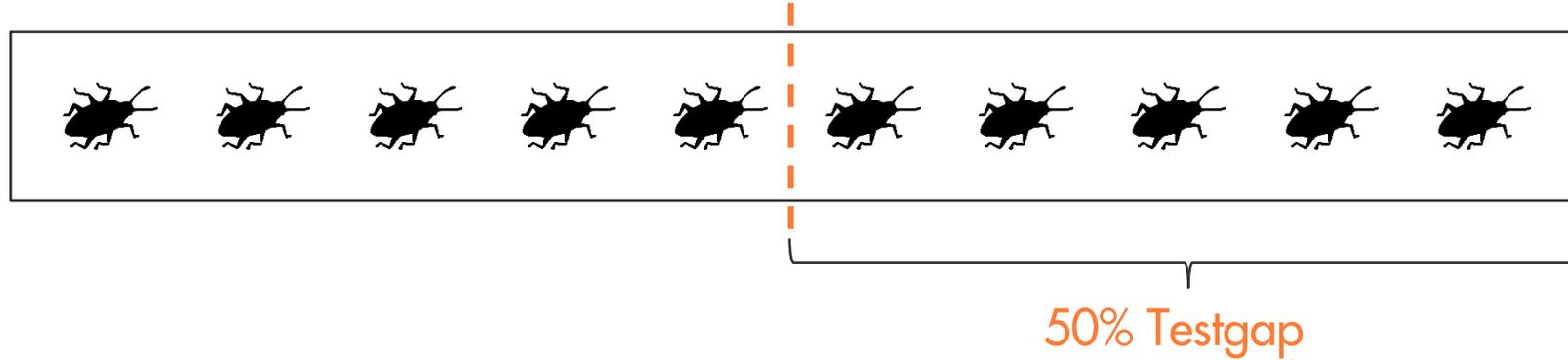


**Probability of remaining field bugs is 5x higher in untested changes!**

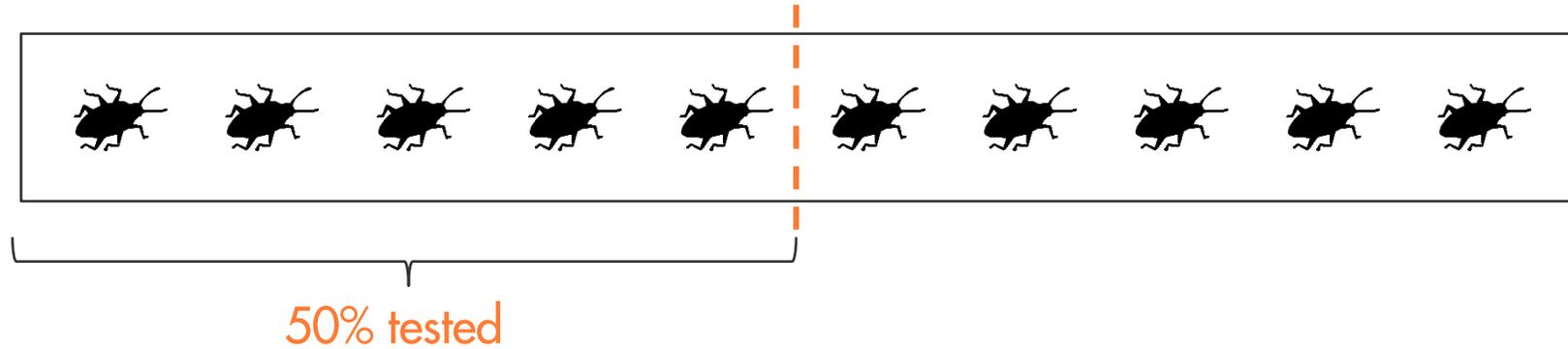
$$\%RemainingBugs = \%Tested * TestIneffectiveness + \%Testgap$$



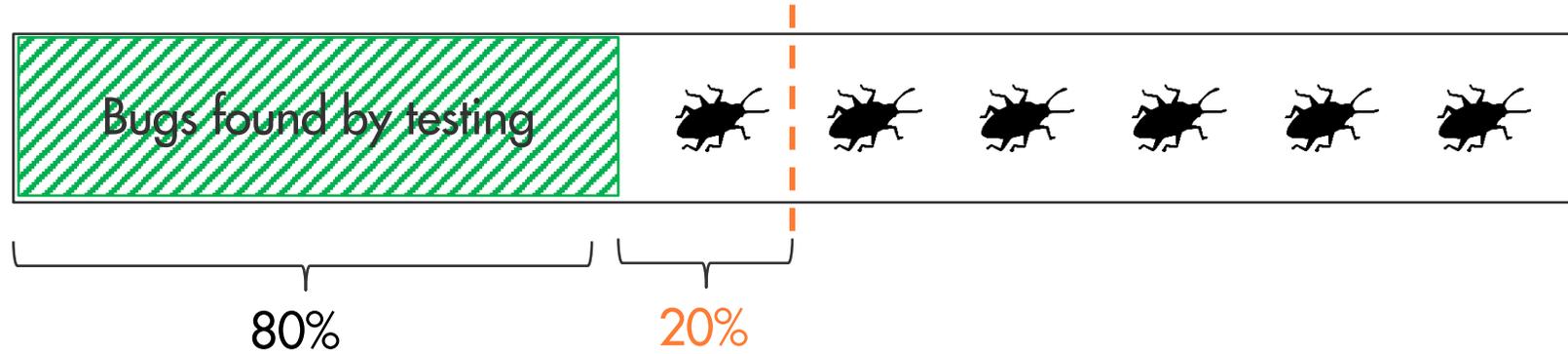
$$\%RemainingBugs = \%Tested * TestIneffectiveness + \%Testgap$$



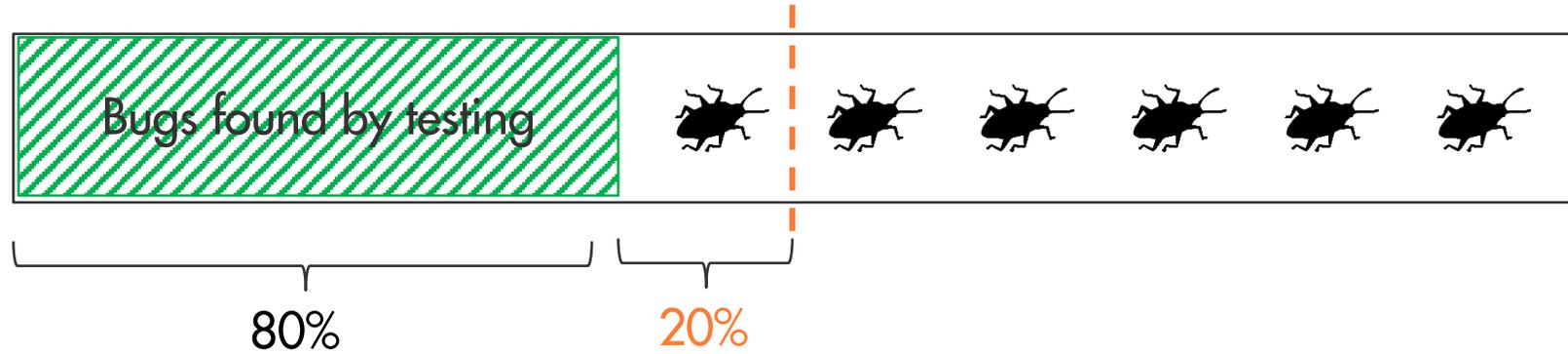
$$\%RemainingBugs = 50\% * TestIneffectiveness + \%Testgap$$



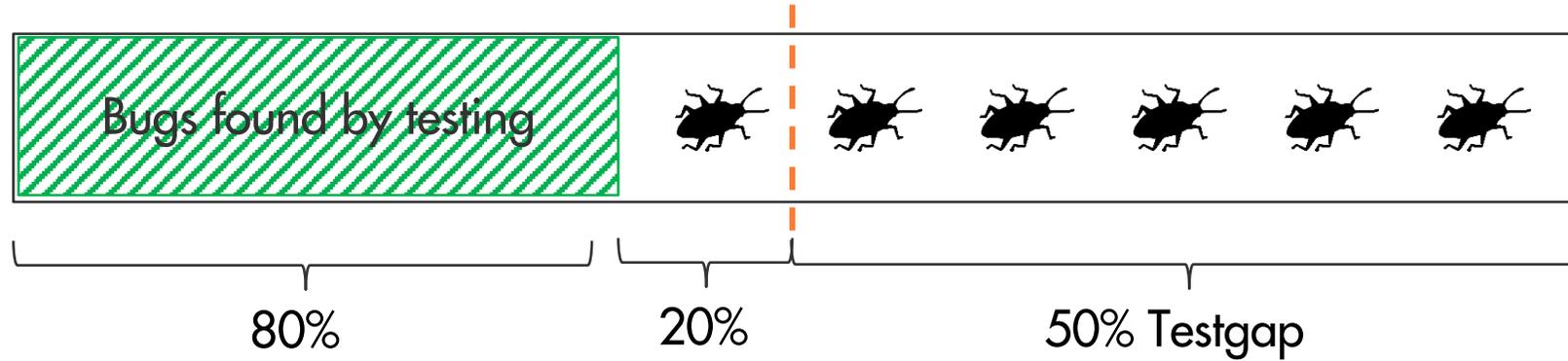
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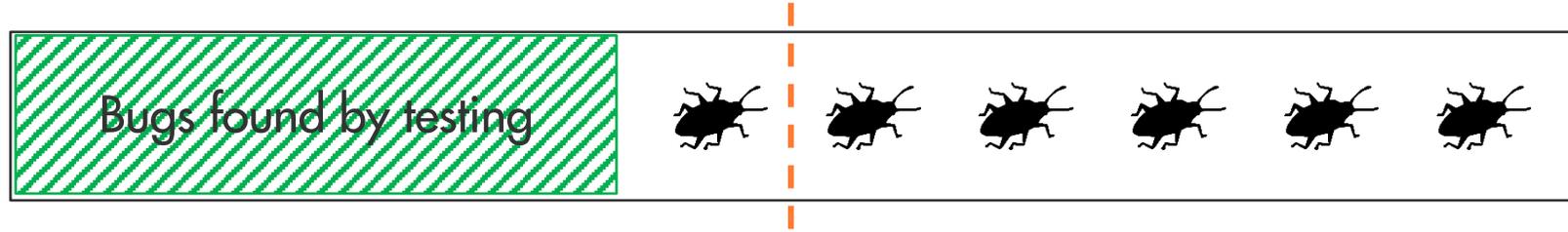
$$\%RemainingBugs = 50\% * 20\% + 50\%$$



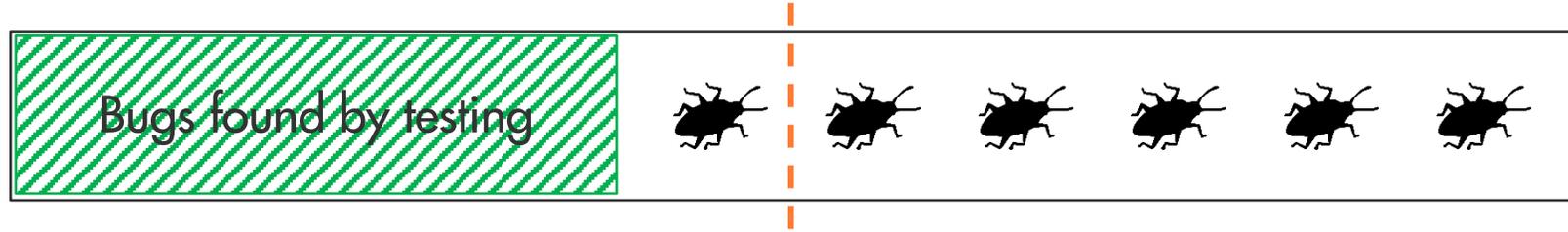
$$\% \text{Remaining Bugs} = 10\% + 50\%$$



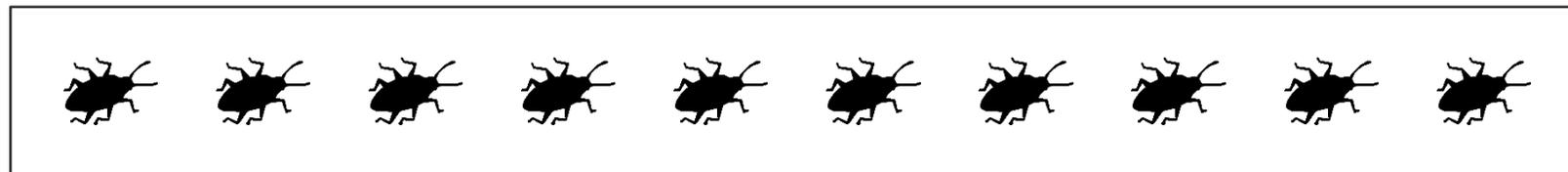
$\% \text{Remaining Bugs} = 60\%$



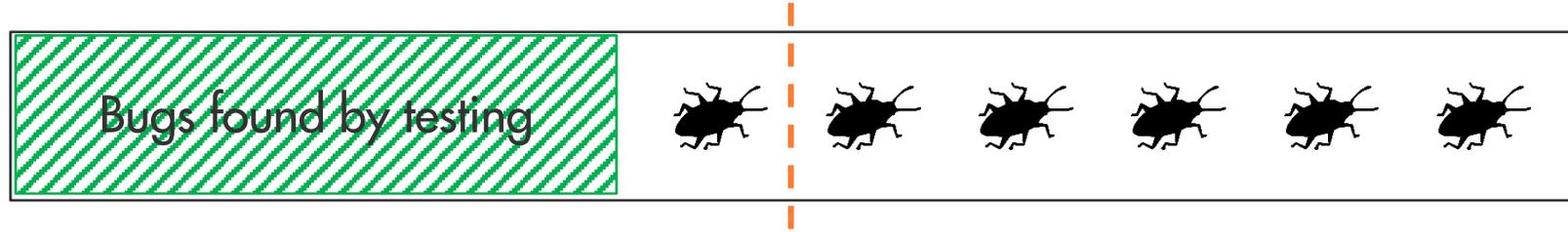
$$\%RemainingBugs = 60\%$$



$$\%RemainingBugs = \%Tested * TestIneffectiveness + \%Testgap$$



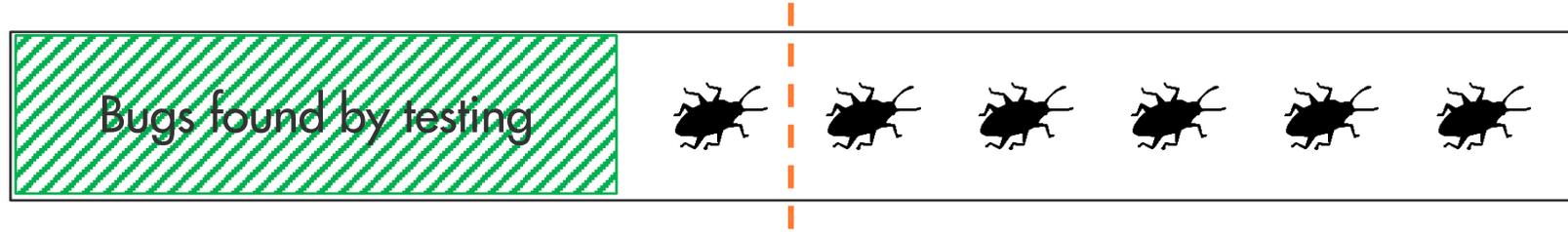
$$\%RemainingBugs = 60\%$$



$$\%RemainingBugs = 90\% * 20\% + 10\%$$



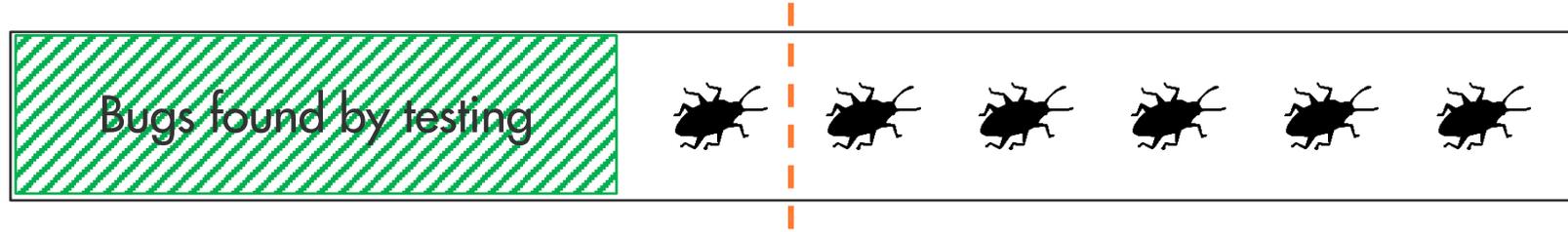
$$\%RemainingBugs = 60\%$$



$$\%RemainingBugs = 18\% + 10\%$$



$\%RemainingBugs = 60\%$

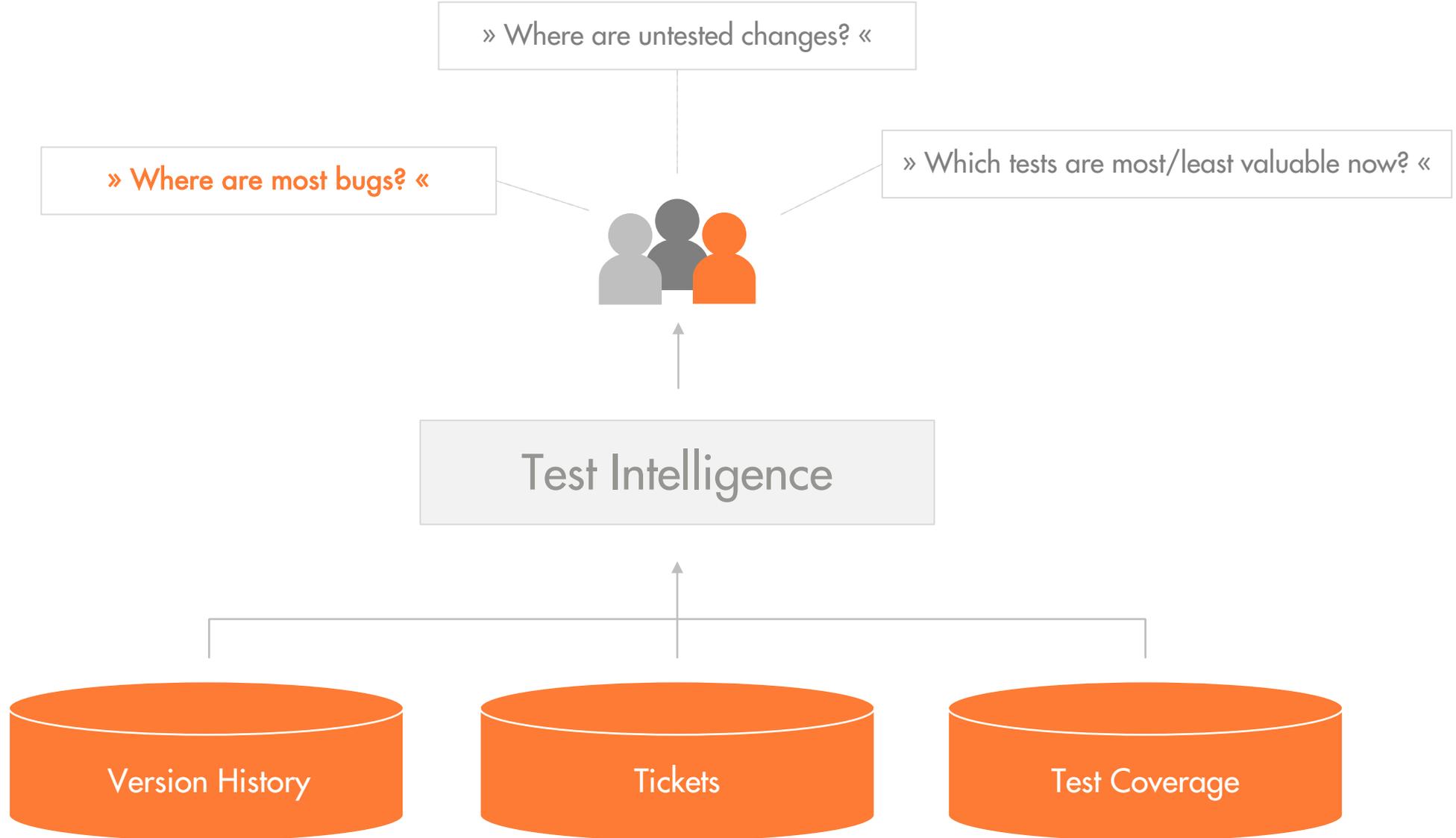


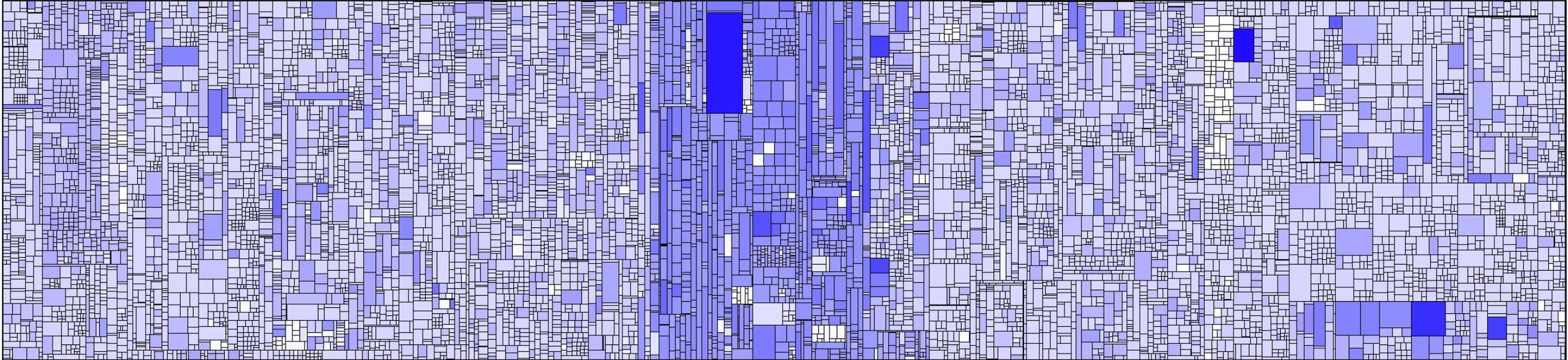
$\%RemainingBugs = 28\%$

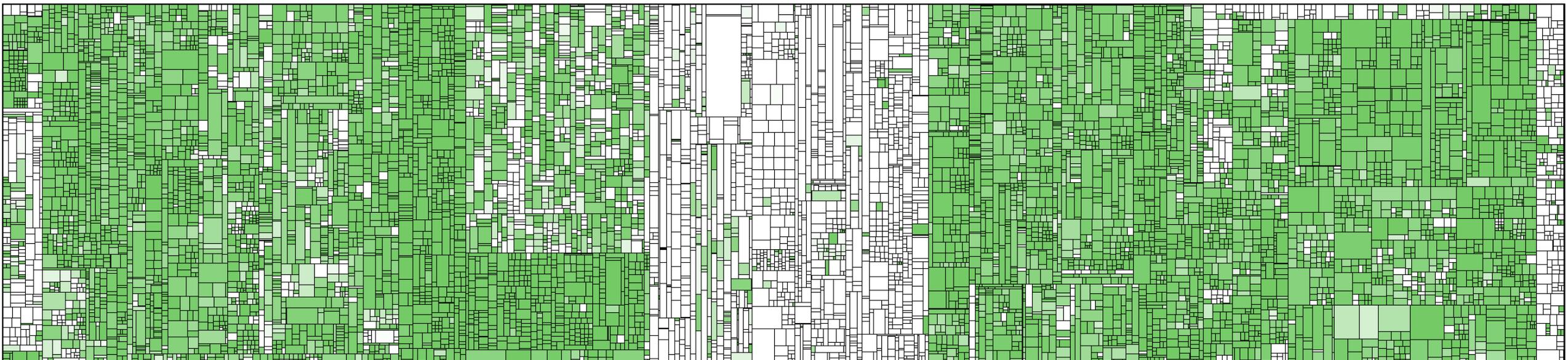


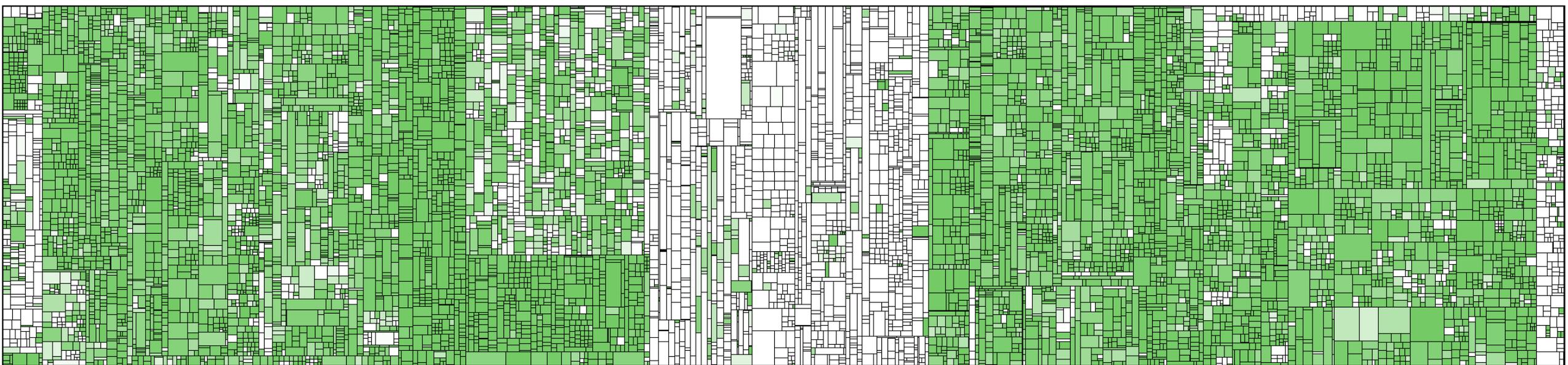
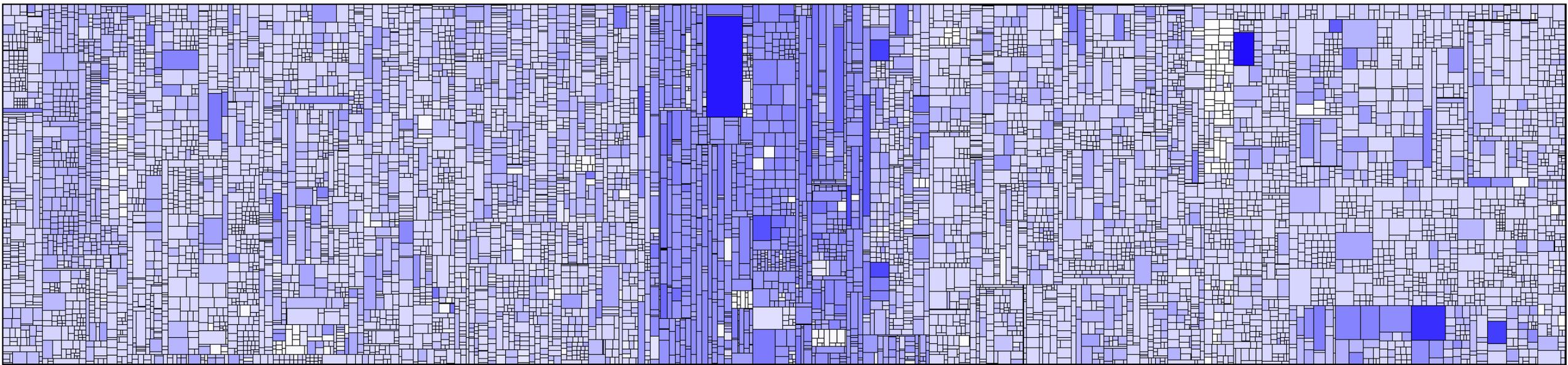
Remaining Field Bugs = **50%**

Test Gap Analysis reduced field bugs in applications of Munich Re by ½

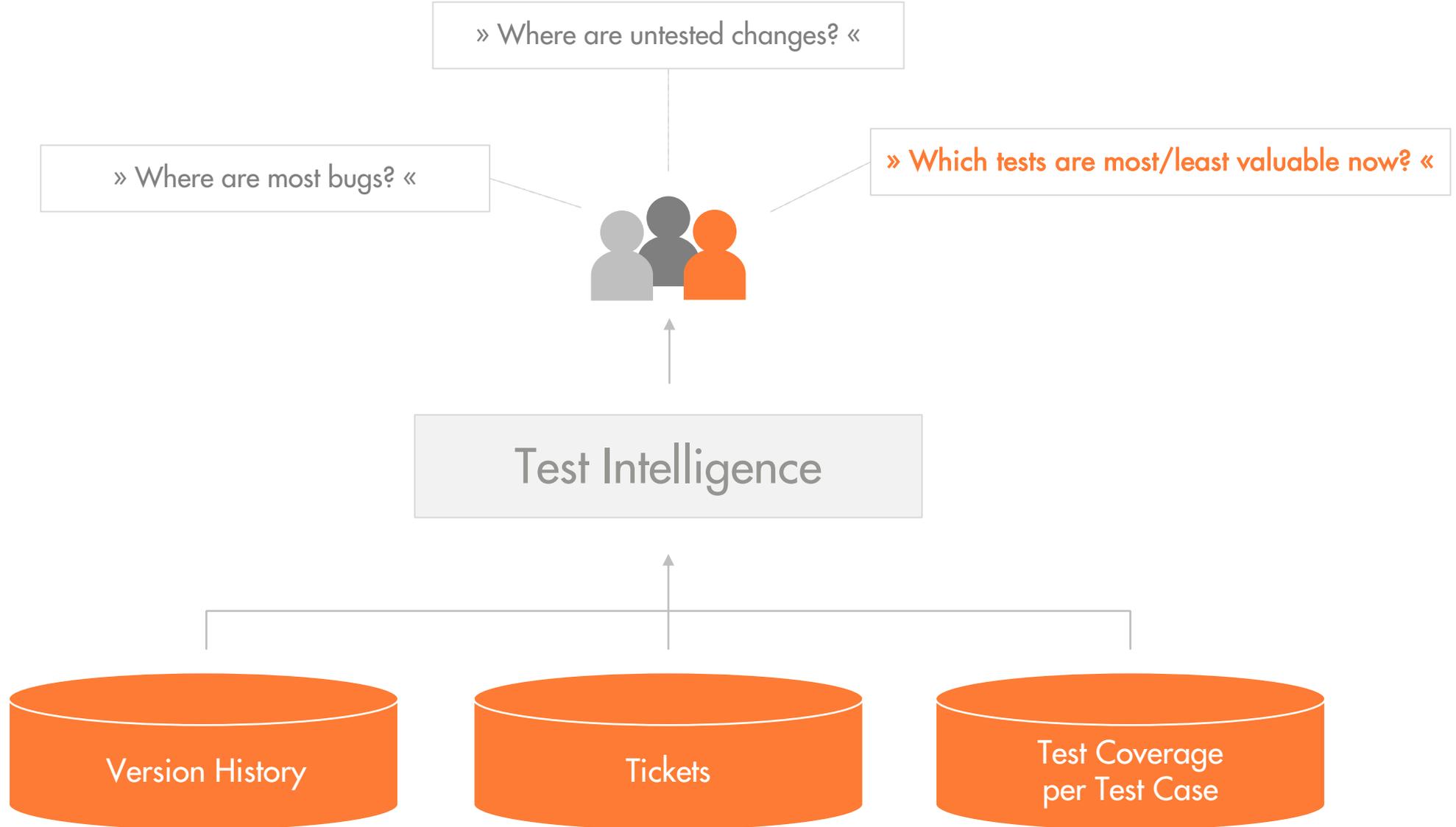


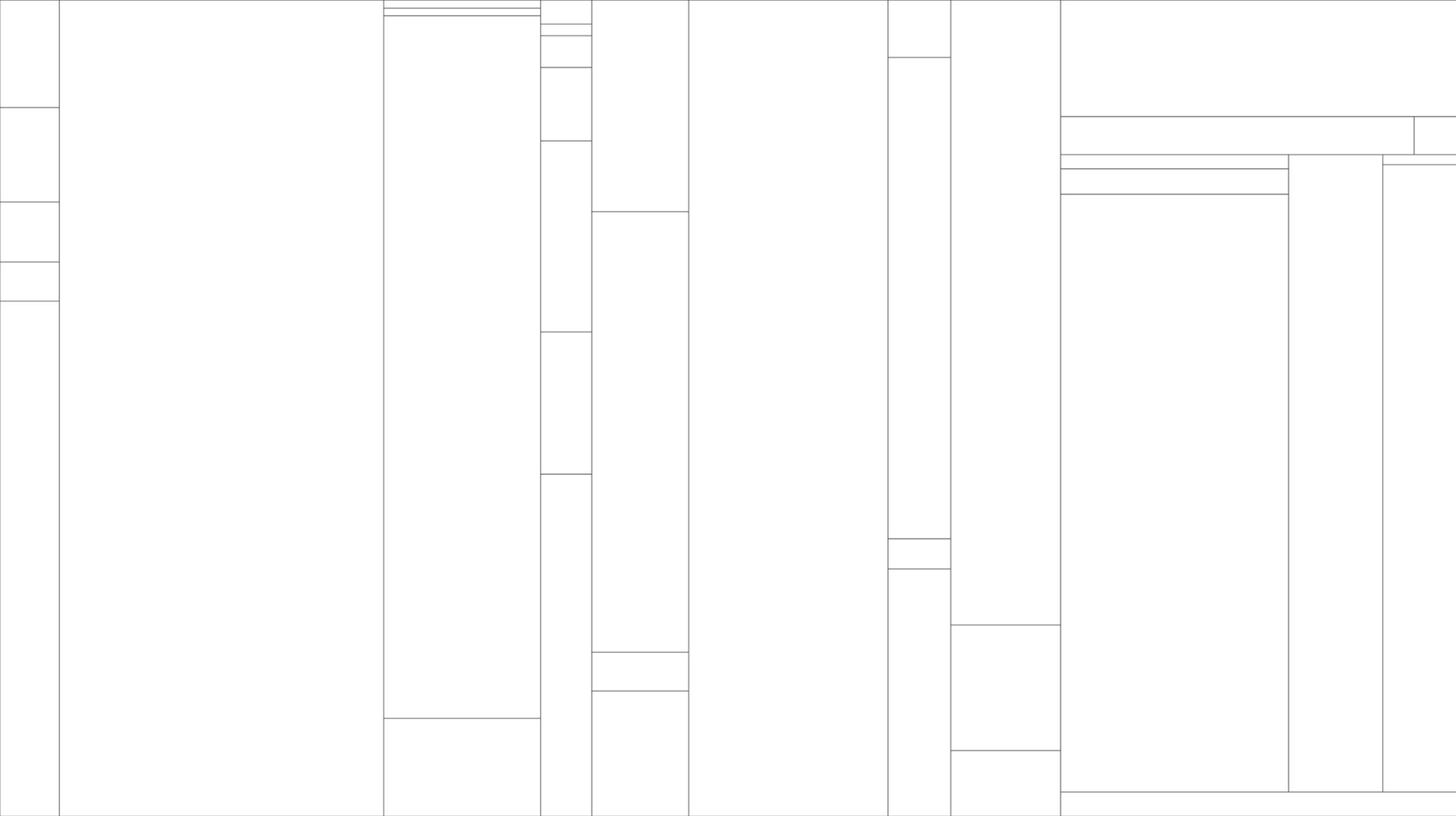


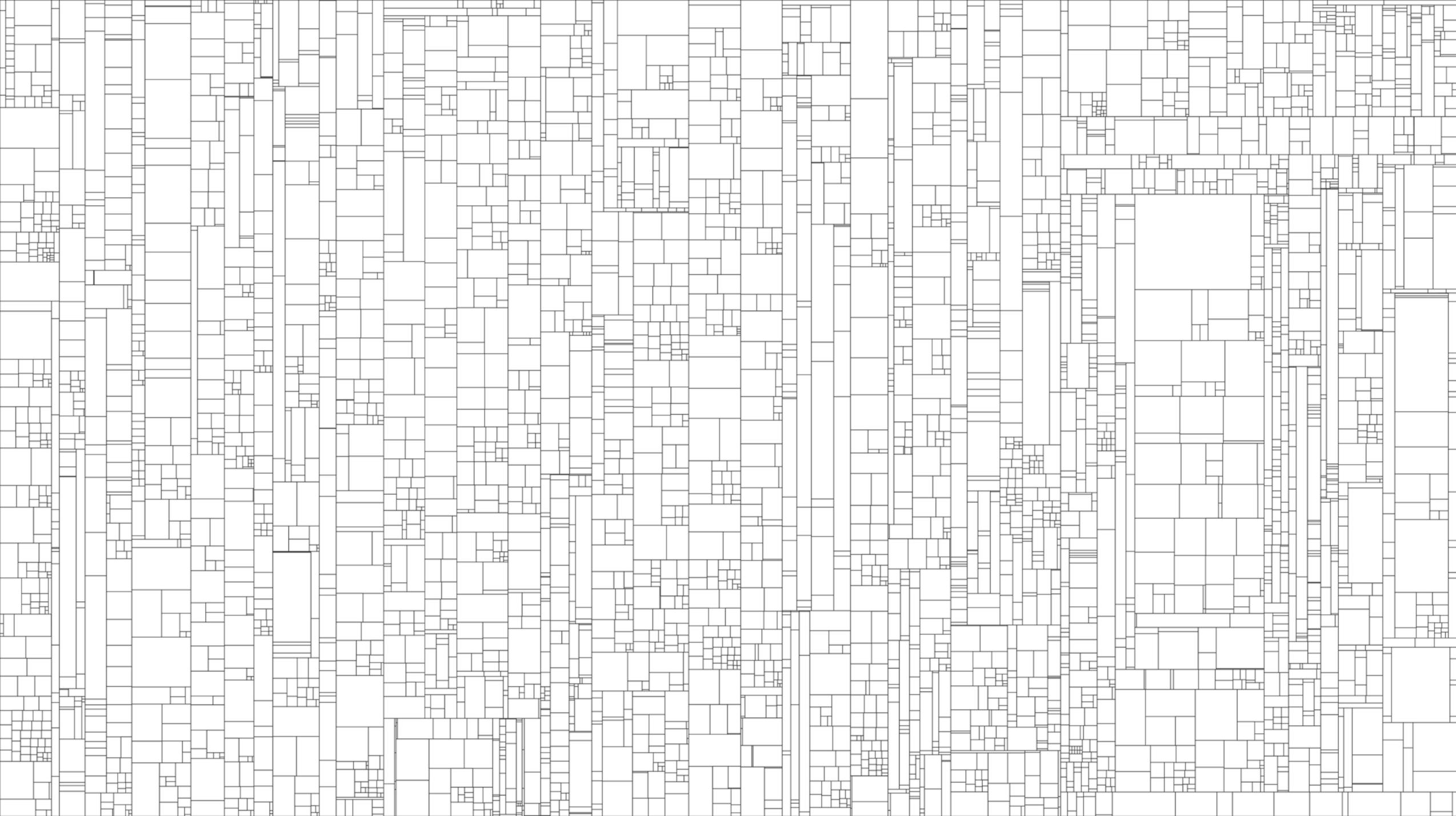


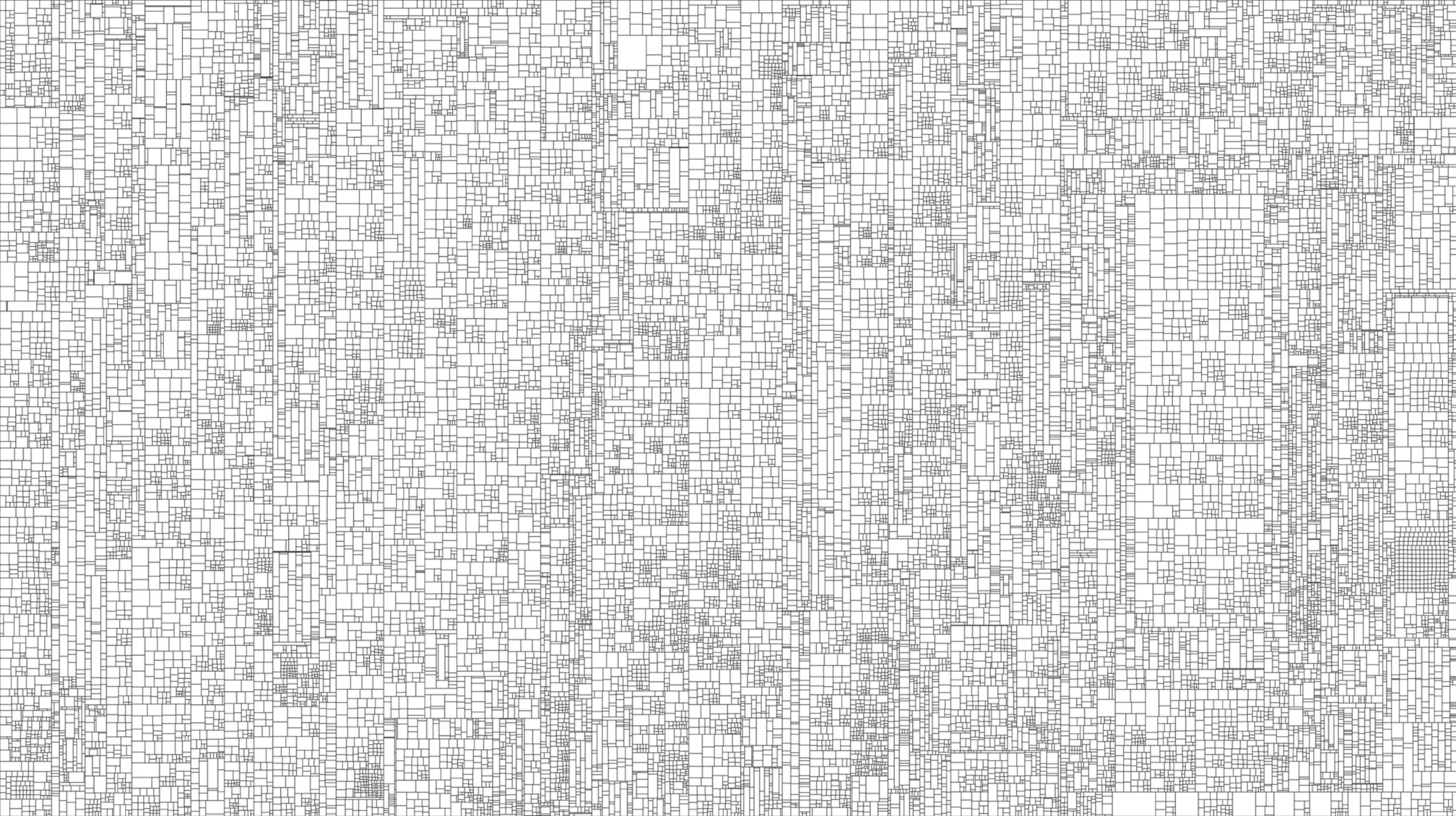














# Data Flow Analysis can not handle java lambdas (logs many errors currently)

- Edit
- Comment
- Assign
- More ▾
- Back to New

- Export

## Details

Type:	<span style="color: red;">❌</span> Bug	Status:	<span style="background-color: green; color: white; padding: 2px;">DONE</span> (View Workflow)
Priority:	<span style="color: orange;">↑</span> High	Resolution:	Green
Component/s:	Backend	Fix Version/s:	Teamscale 4.3
Labels:	<span style="border: 1px solid #ccc; padding: 2px;">dataflow</span> <span style="border: 1px solid #ccc; padding: 2px;">java</span>		
Affected Version:	master		
Merge Request:	<a href="https://git.cqse.eu/cqse/teamscale/merge_requests/2734">https://git.cqse.eu/cqse/teamscale/merge_requests/2734</a>		
PDash Task:	#4886		

## People

Assignee:	Andreas Sewe <a href="#">Assign to me</a>
Reporter:	Rainer Niedermayr
QA-Contact:	Alexander von Rhein
Votes:	<span style="border: 1px solid #ccc; border-radius: 50%; padding: 2px;">2</span> Vote for this issue
Watchers:	<span style="border: 1px solid #ccc; border-radius: 50%; padding: 2px;">3</span> Start watching this issue

## Description

Analysis profile: Java  
 Repository: JabRef, start revision 9efd23b71871747fe5e18e915e637891d7e55b6d

```

ERROR : An error occurred while trying to construct a CFG for function 'null' in element src/main/java/net/sf/jabref/exporter/layout/format/DOI
[STATEMENT: lambda expression: null (lines 33-33)
]
Tokens: doi . getURL ( )
Occurred in src/main/java/net/sf/jabref/exporter/layout/format/DOICheck.java:32-32 (com.teamscale.index.dataflow.DataFlowFindingsSynchronizer.c
org.conqat.engine.core.core.ConQATException: Could not find any rule that applies to the following entity list:
[STATEMENT: lambda expression: null (lines 33-33)
]
Tokens: doi . getURL ( )
Occurred in src/main/java/net/sf/jabref/exporter/layout/format/DOICheck.java:32-32
    at org.conqat.engine.sourcecode.dataflow.heuristics.ControlFlowCreator.findApplicableRule(ControlFlowCreator.java:164)
    at org.conqat.engine.sourcecode.dataflow.heuristics.ControlFlowCreator.transformOneStep(ControlFlowCreator.java:139)
    at org.conqat.engine.sourcecode.dataflow.heuristics.ControlFlowCreator.transform(ControlFlowCreator.java:92)

[...]

ERROR : An error occurred while trying to construct a CFG for function 'null' in element src/main/java/net/sf/jabref/exporter/layout/format/DOI
[STATEMENT: lambda expression: null (lines 31-31)
]
Tokens: doi . getDOI ( )
Occurred in src/main/java/net/sf/jabref/exporter/layout/format/DOIStrip.java:30-30 (com.teamscale.index.dataflow.DataFlowFindingsSynchronizer.c
org.conqat.engine.core.core.ConQATException: Could not find any rule that applies to the following entity list:
  
```

## Dates

Created:	24/Nov/16 8:35 AM
Updated:	4 days ago
Resolved:	08/May/18 12:42 PM

## Time Tracking

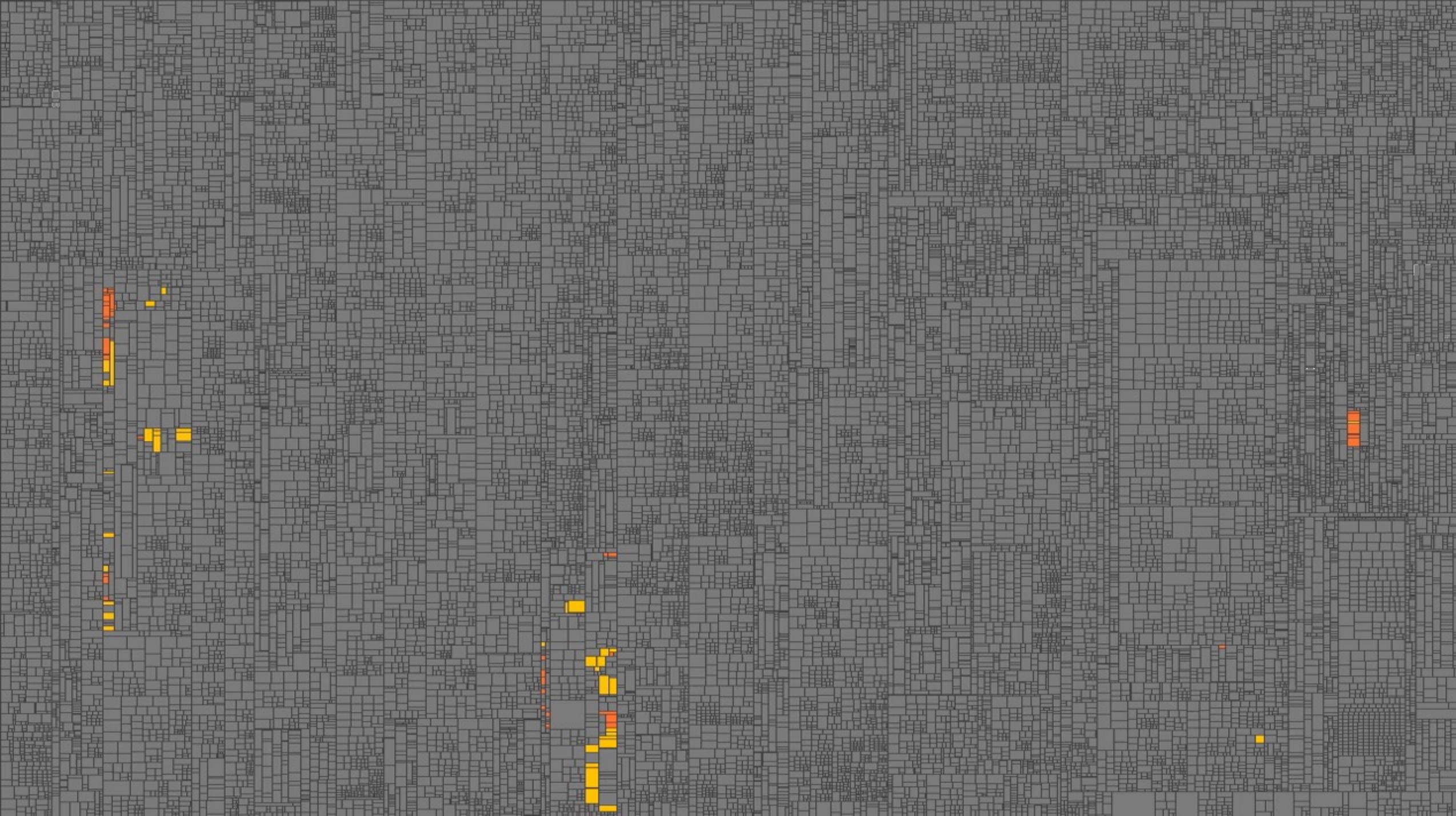
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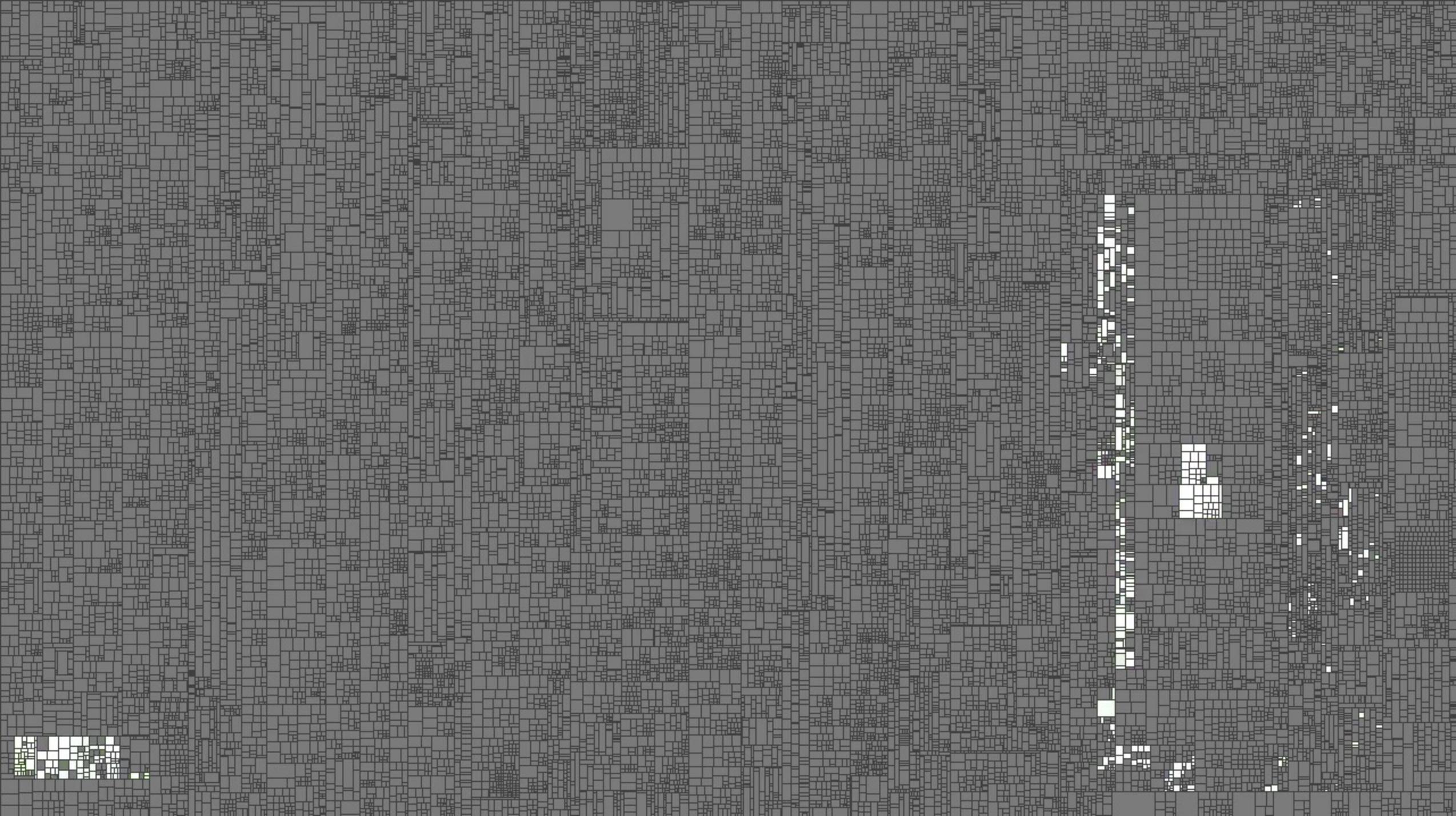
## Agile

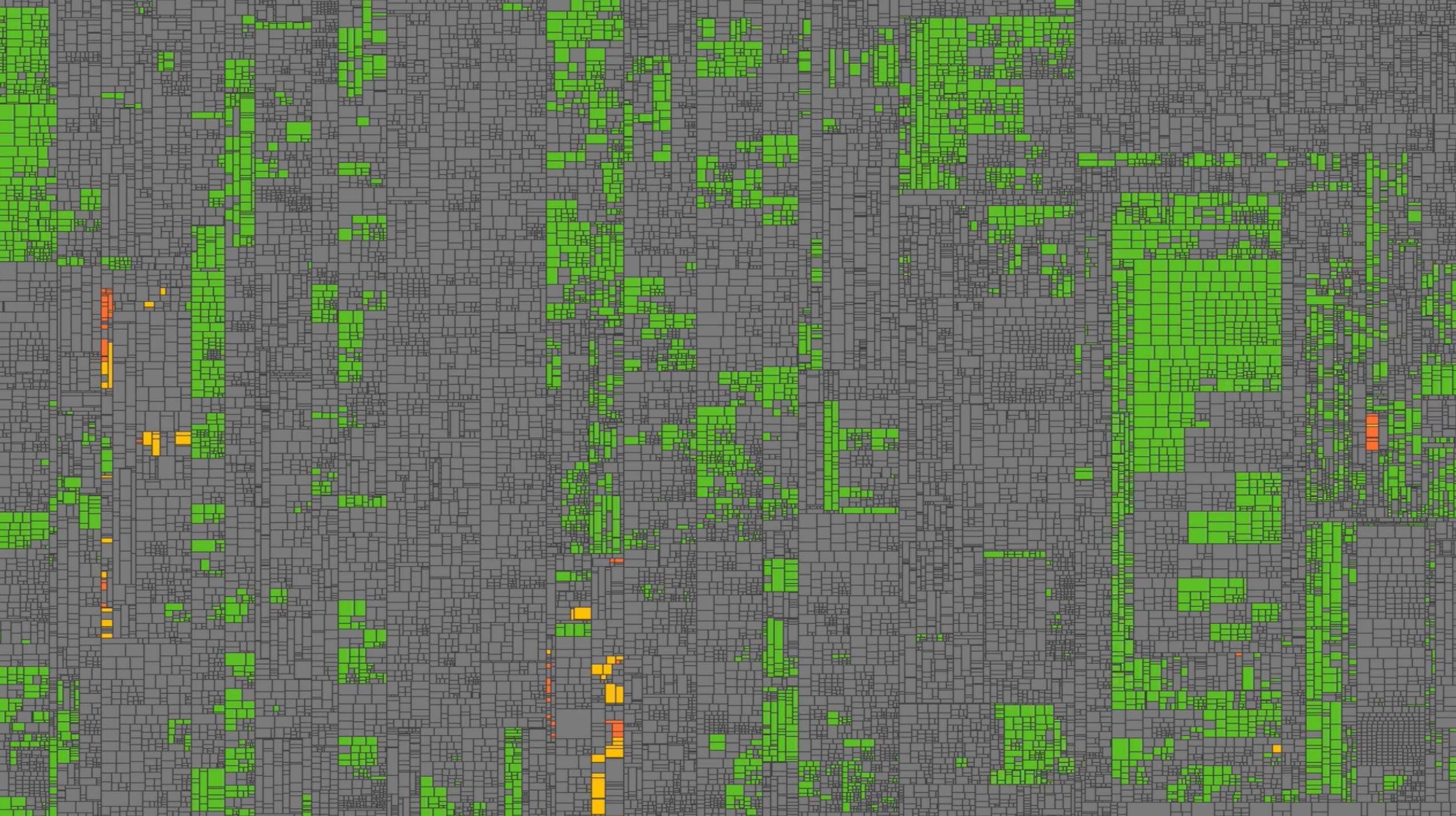
[View on Board](#)

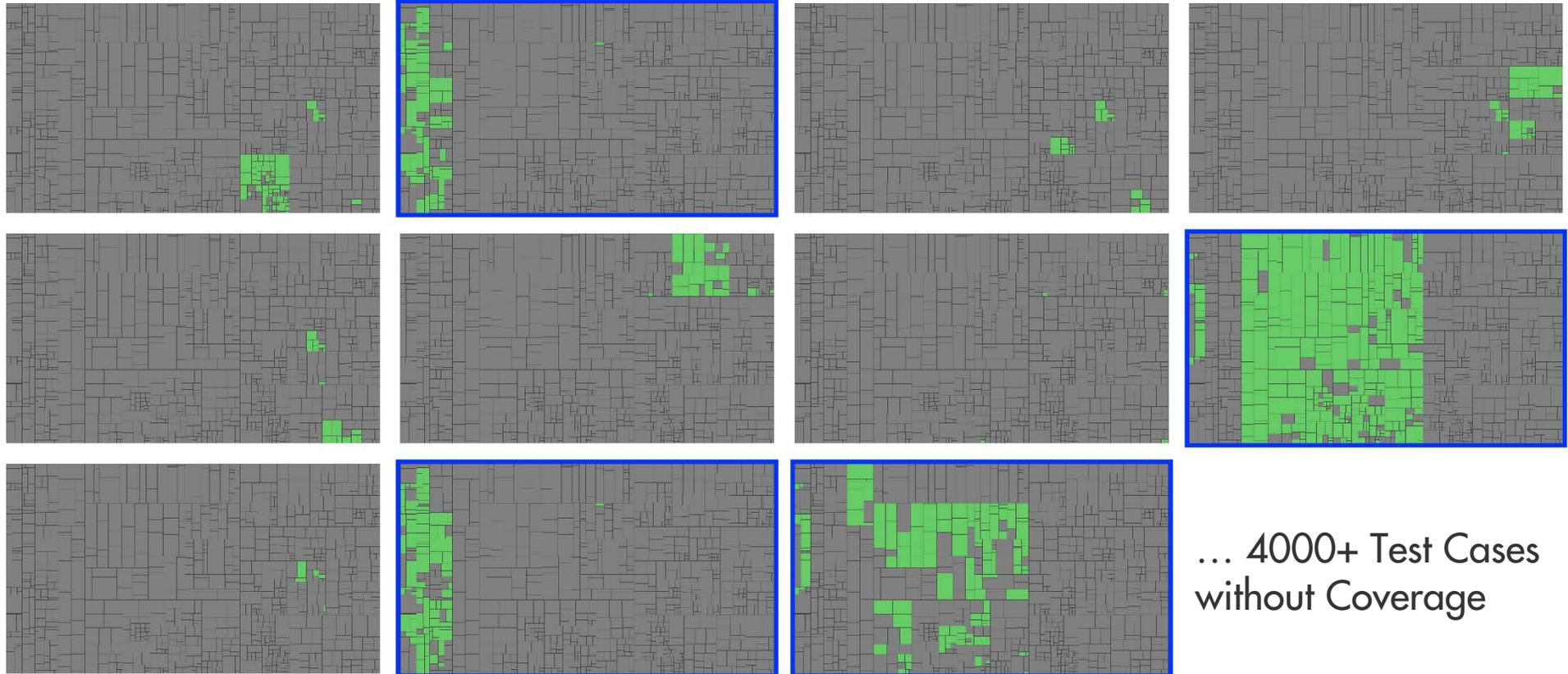
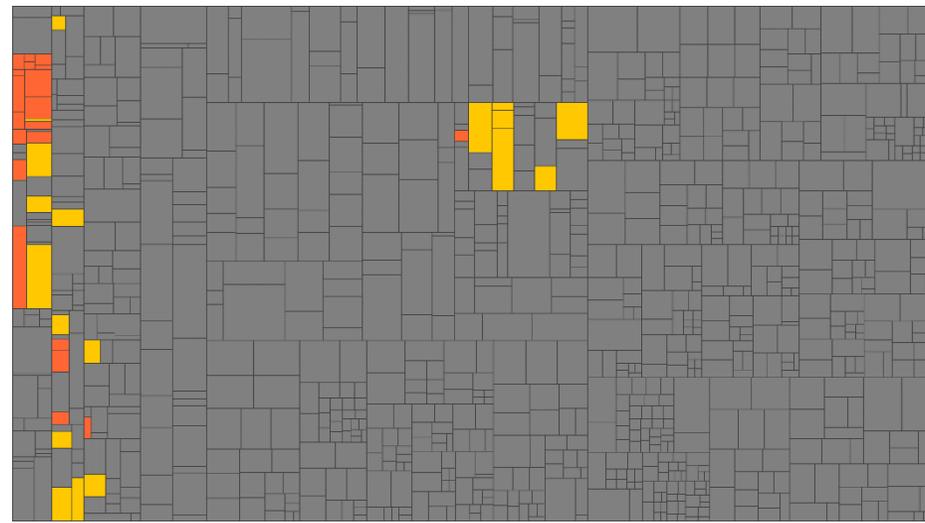
## Gitlab CI

Projects ▾
More ▾
⋮

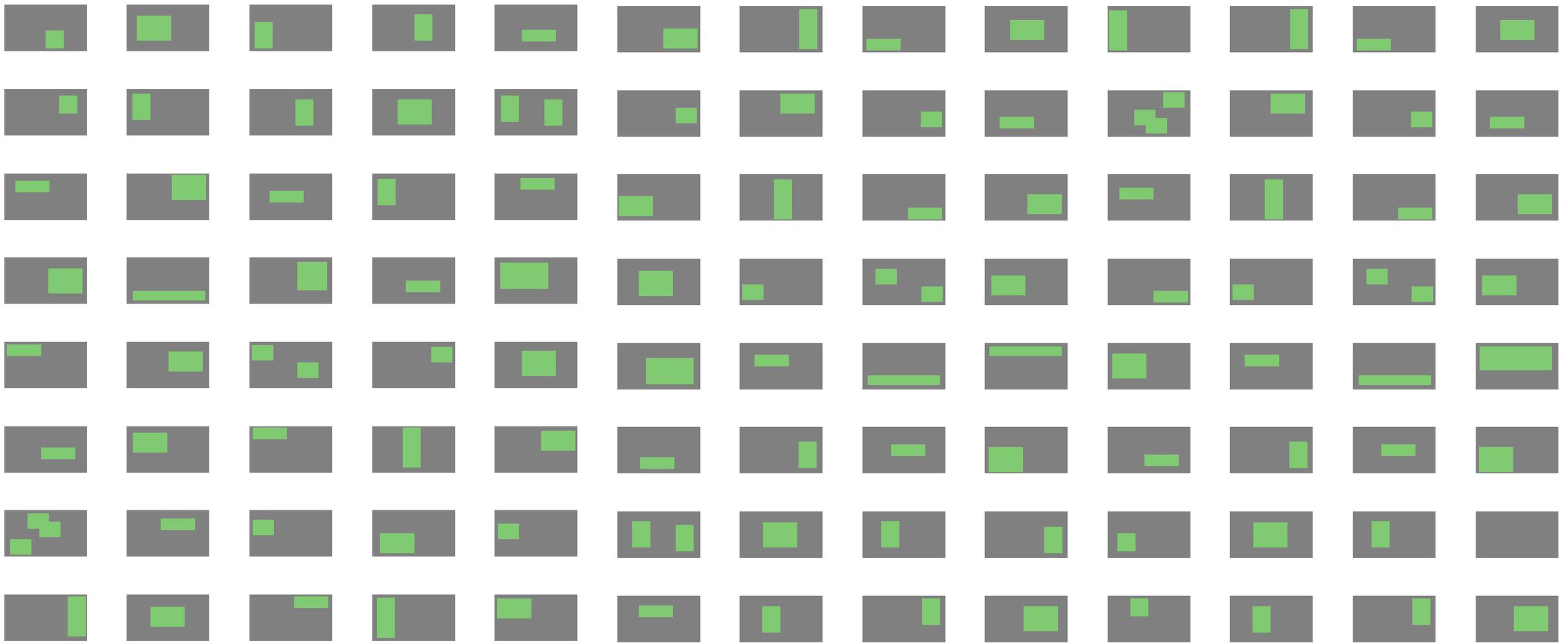








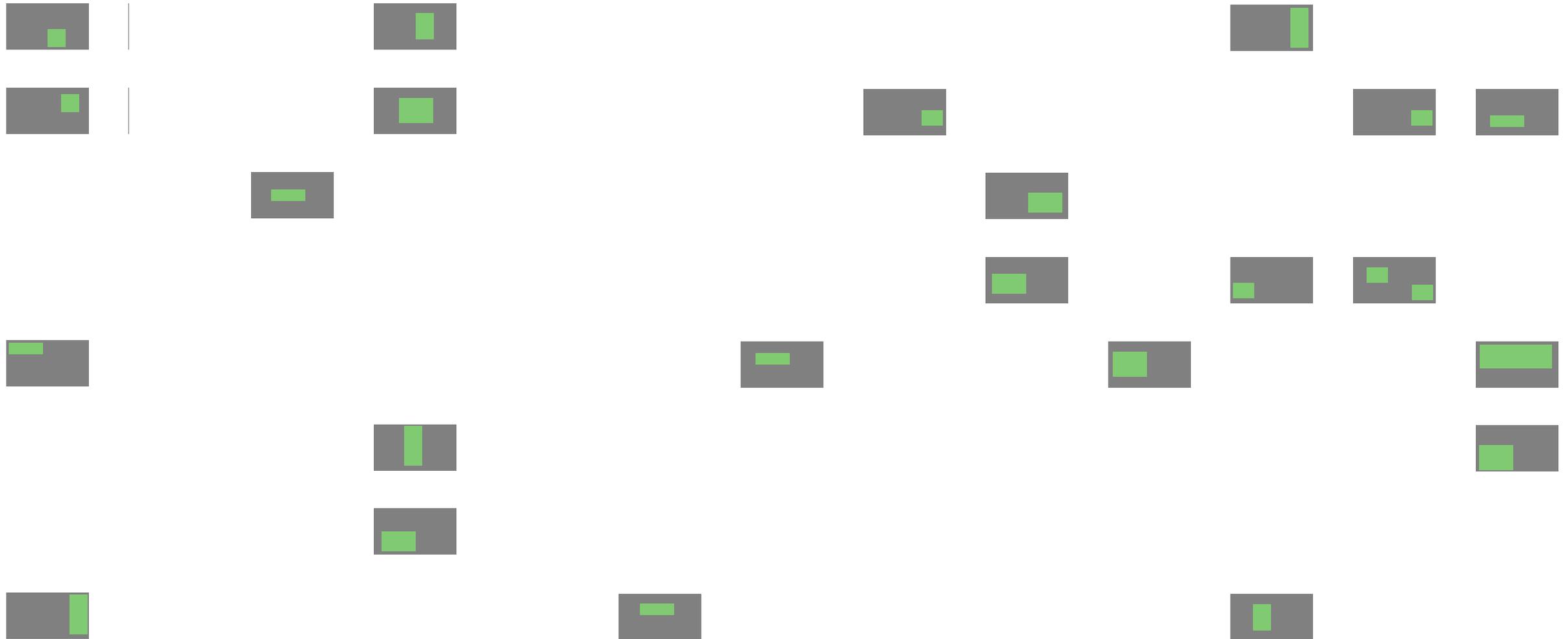
... 4000+ Test Cases  
without Coverage



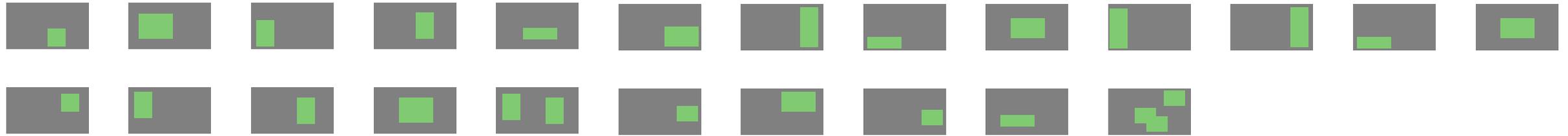
# Step 1: Selection of Impacted Tests



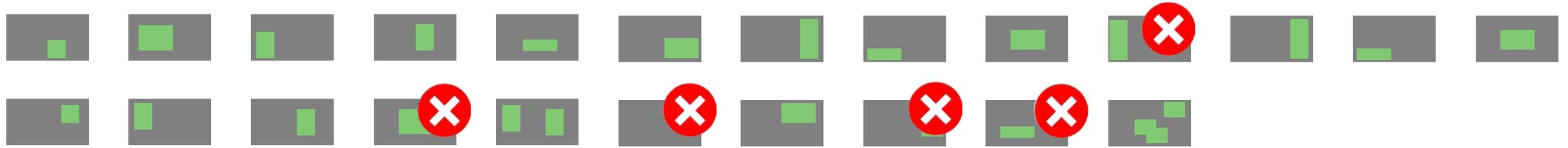
# Step 1: Selection of Impacted Tests



# Step 1: Selection of Impacted Tests



## Step 2: Prioritization of Impacted Tests





## Step 2: Prioritization of Impacted Tests

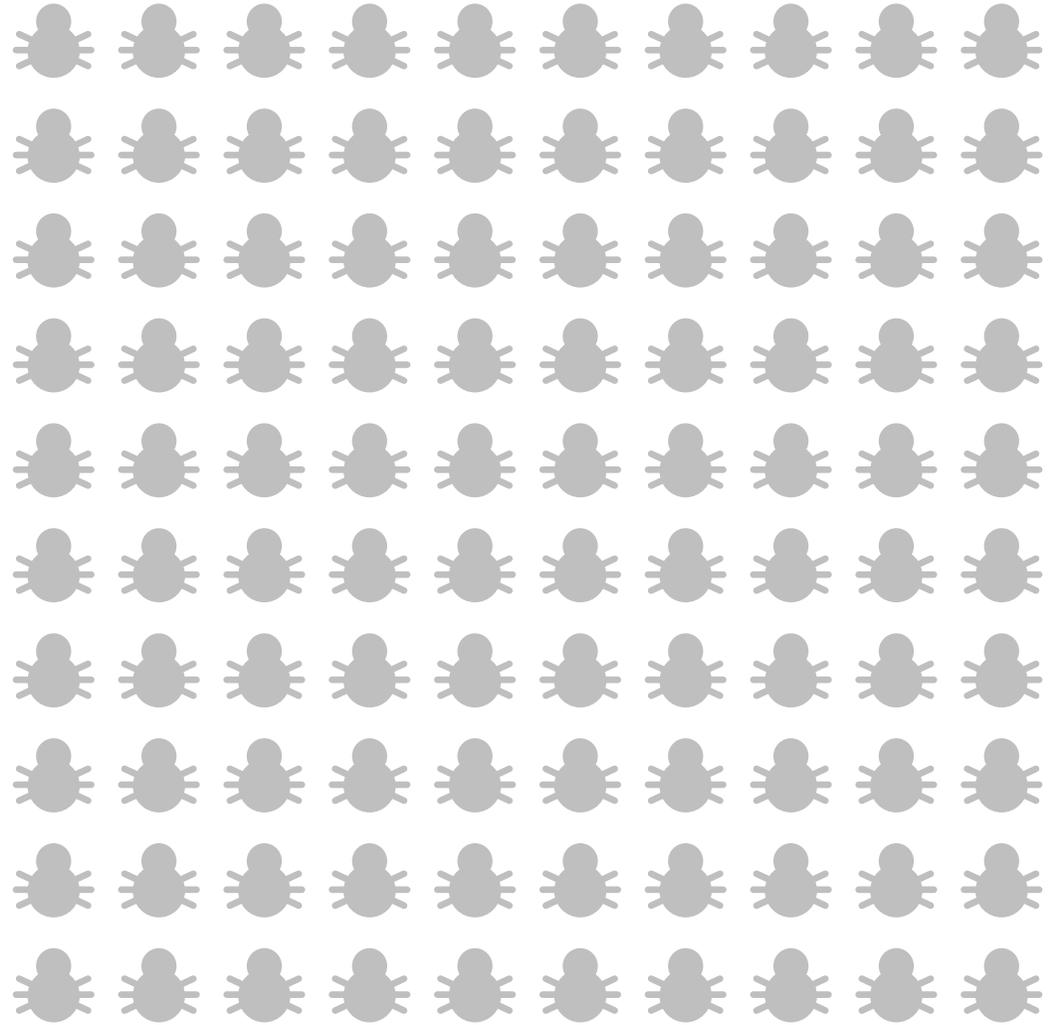
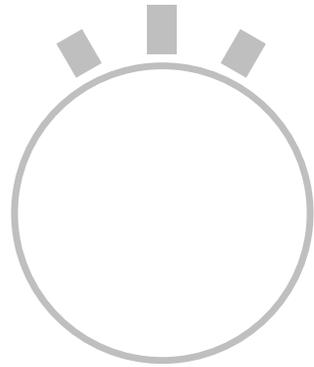


Change coverage

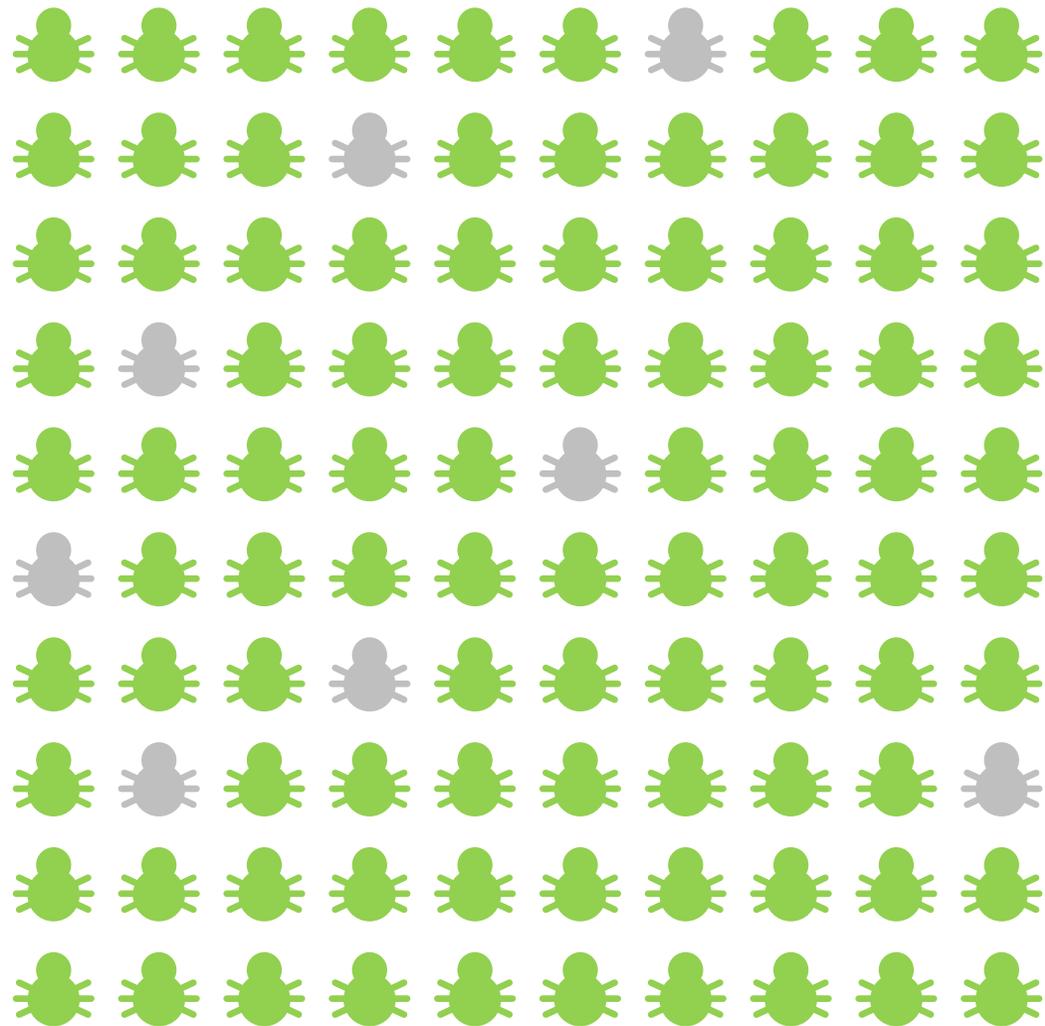
Execution time

## Step 2: Prioritization of Impacted Tests

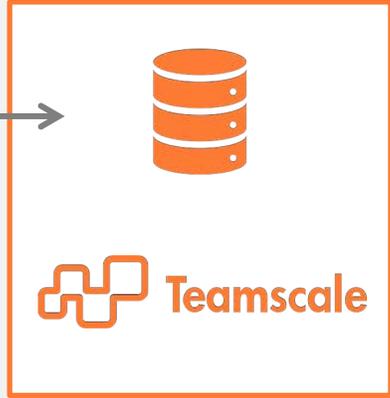
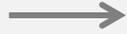






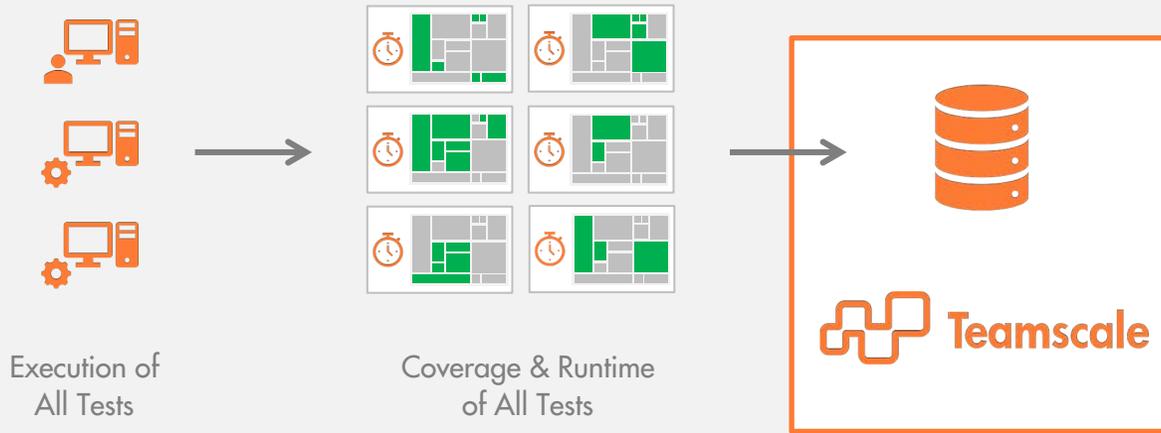


Initial Recording of all Tests



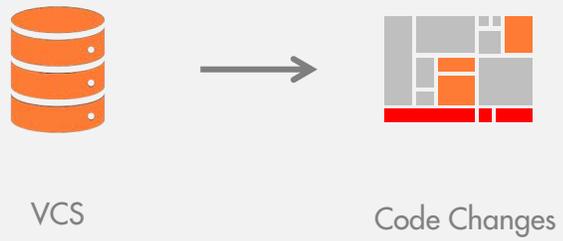
## Test-Impact Analysis

Initial Recording of all Tests

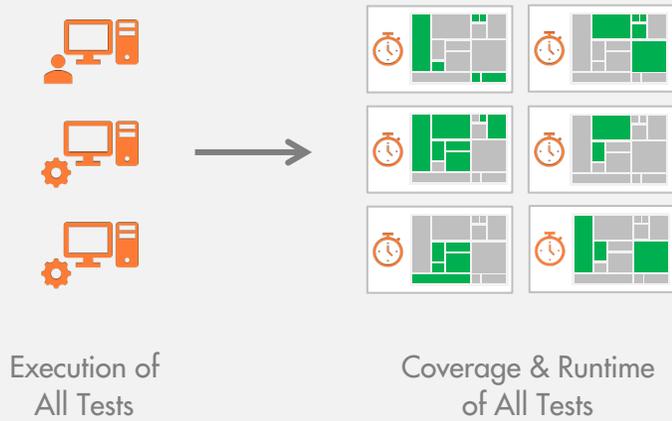


## Test-Impact Analysis

Test Execution after Changes

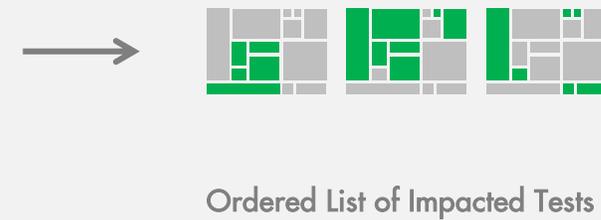
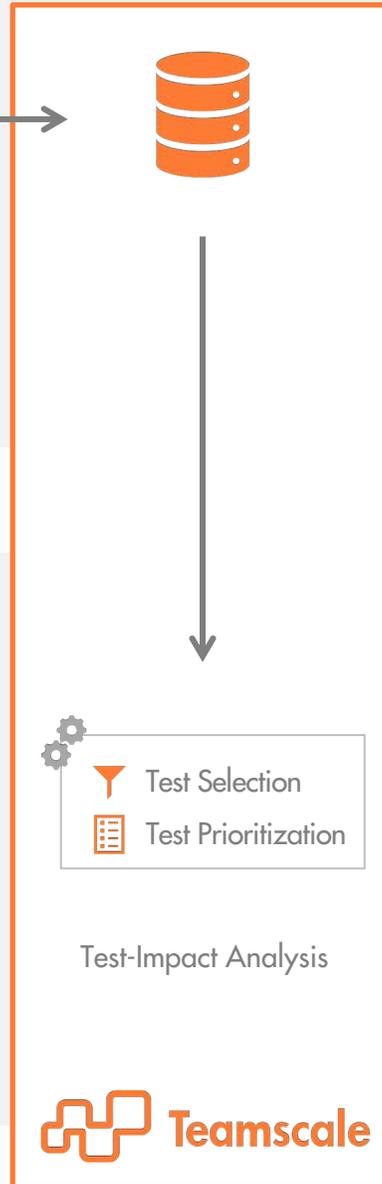
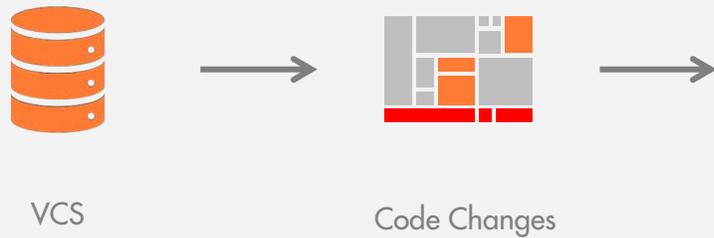


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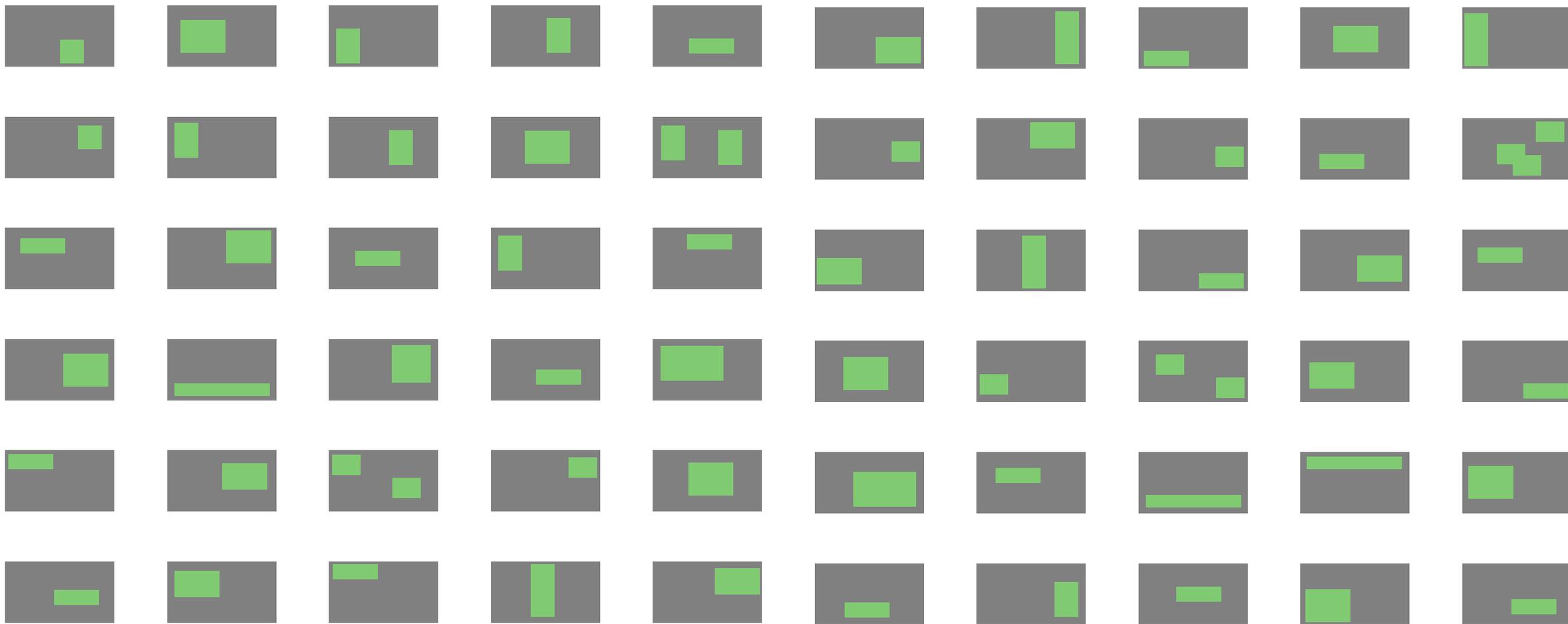


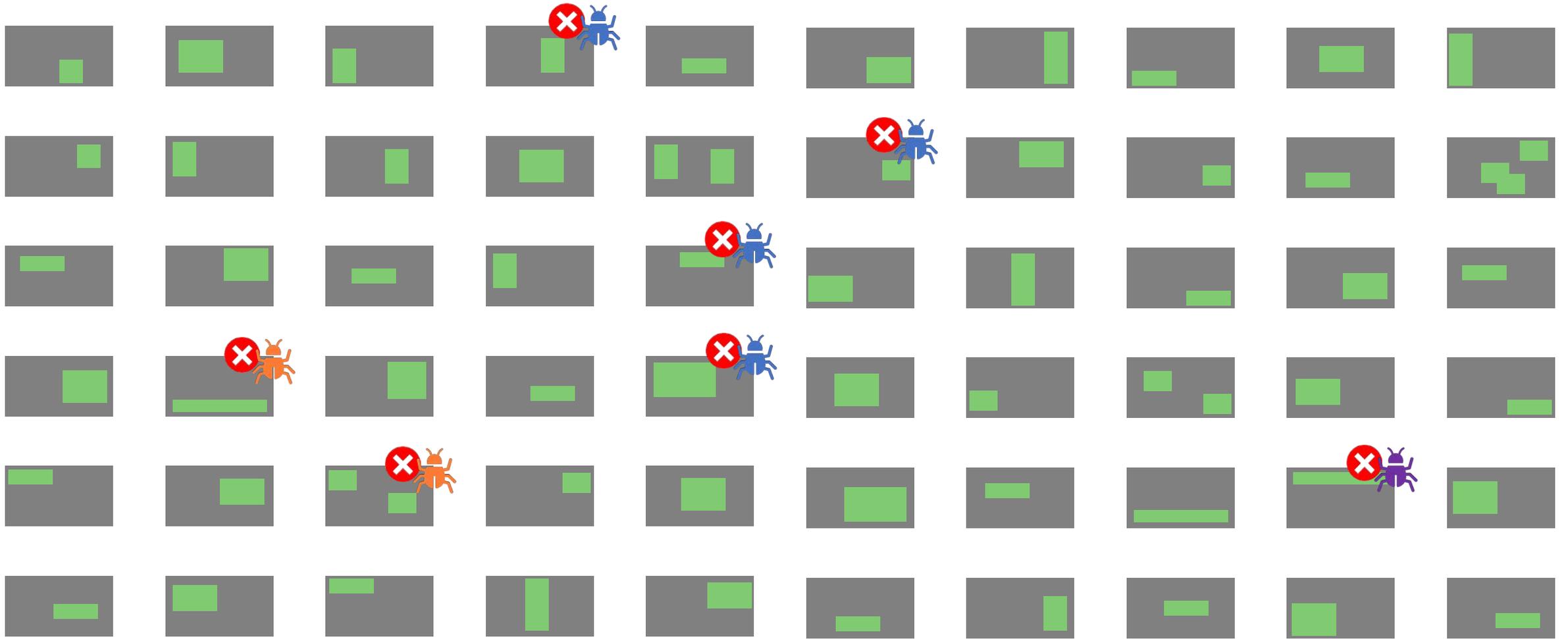
## Test-Impact Analysis

Test Execution after Changes

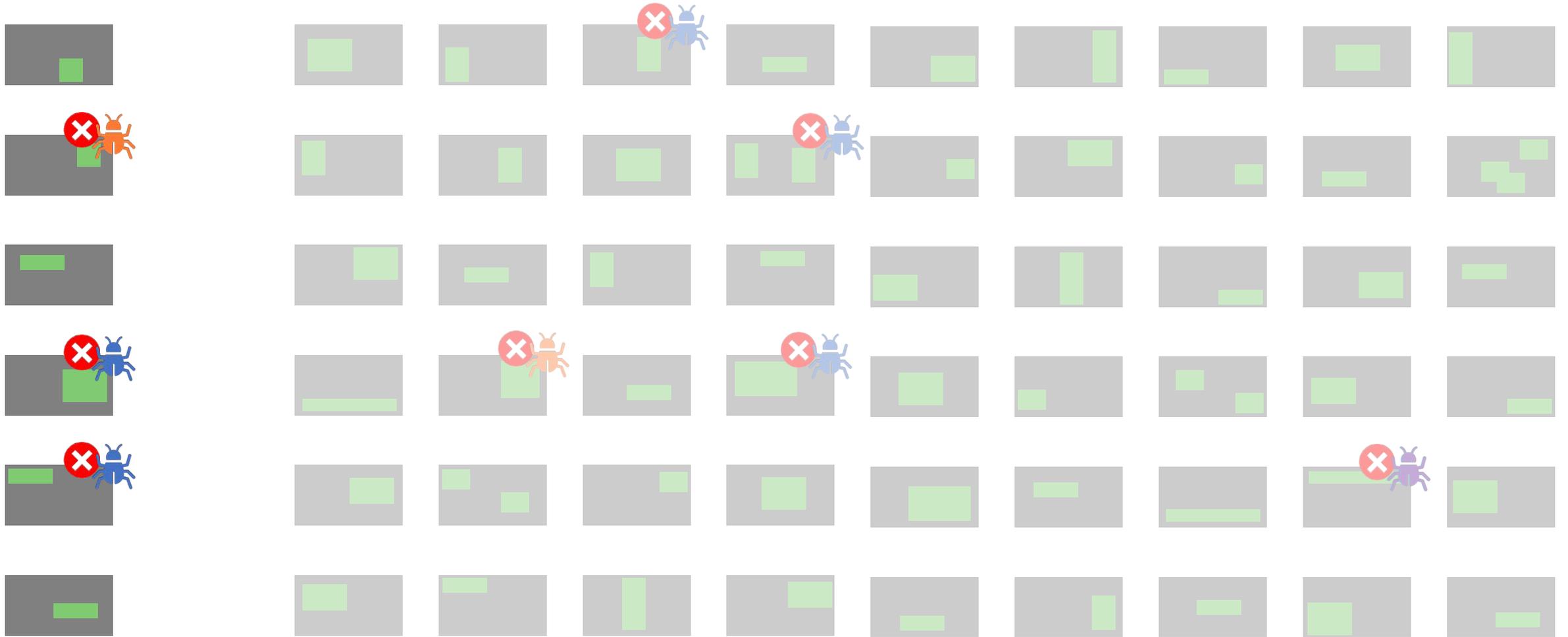


**Isn't there a simpler option?**





# Pareto Testing: 80/20 Optimization



Why is there potential for optimization?

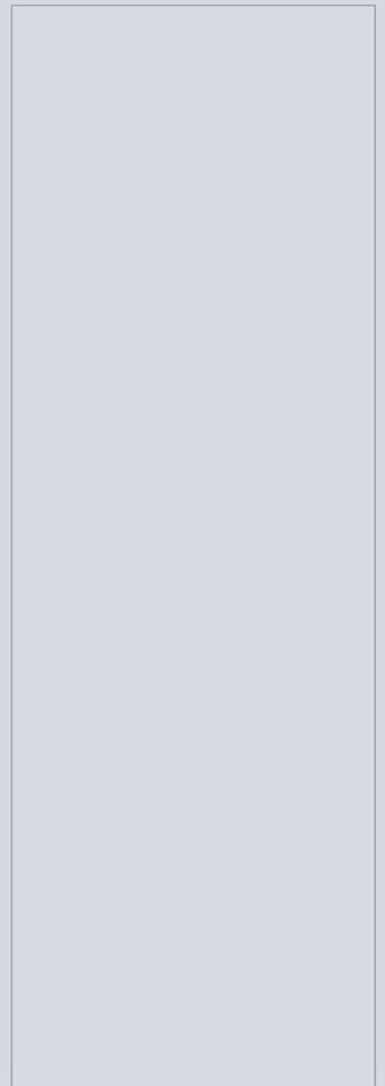
Sample Only the Active Layer/Mask

Untitled1 x Picture1.png x



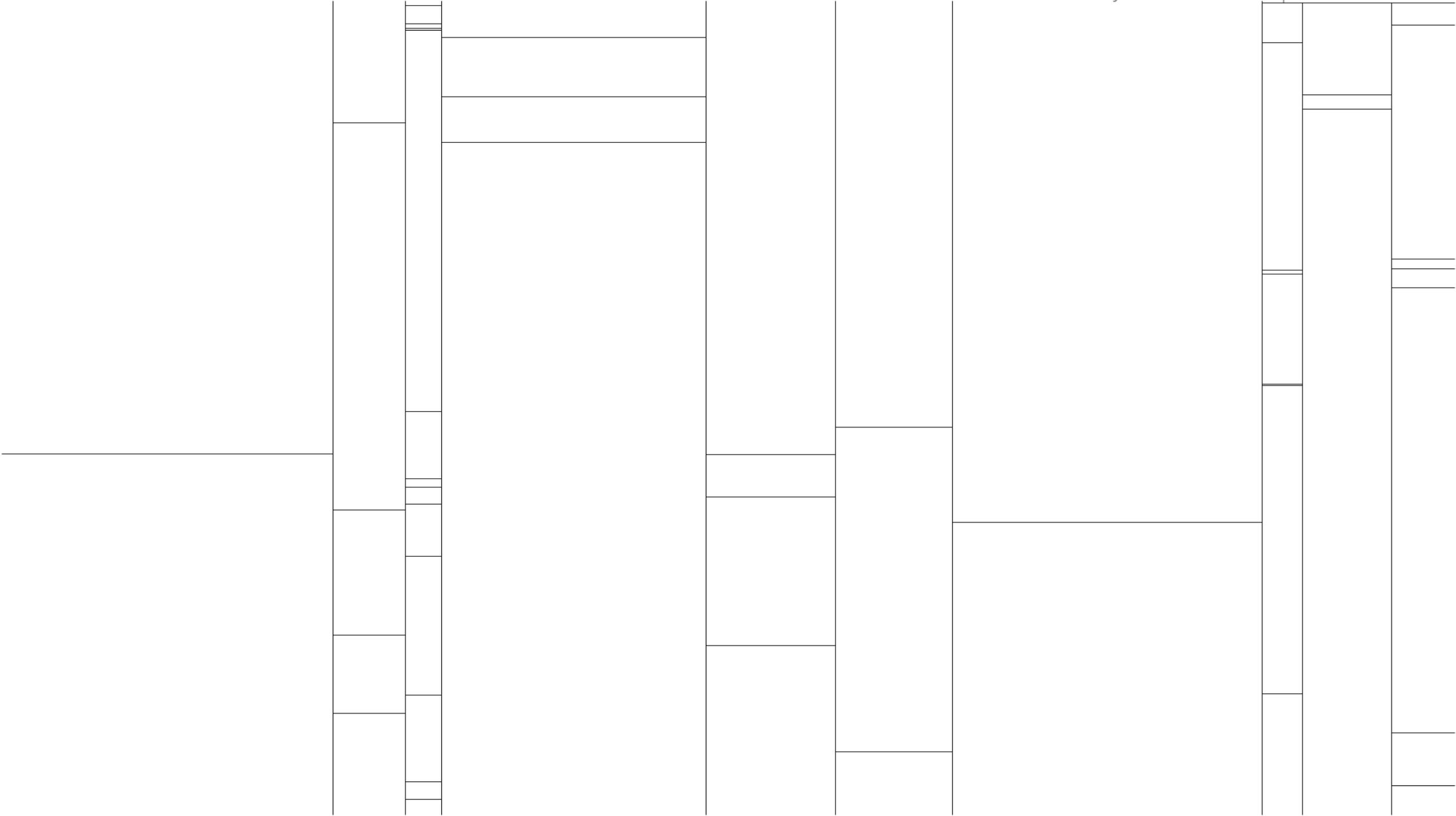
Layers

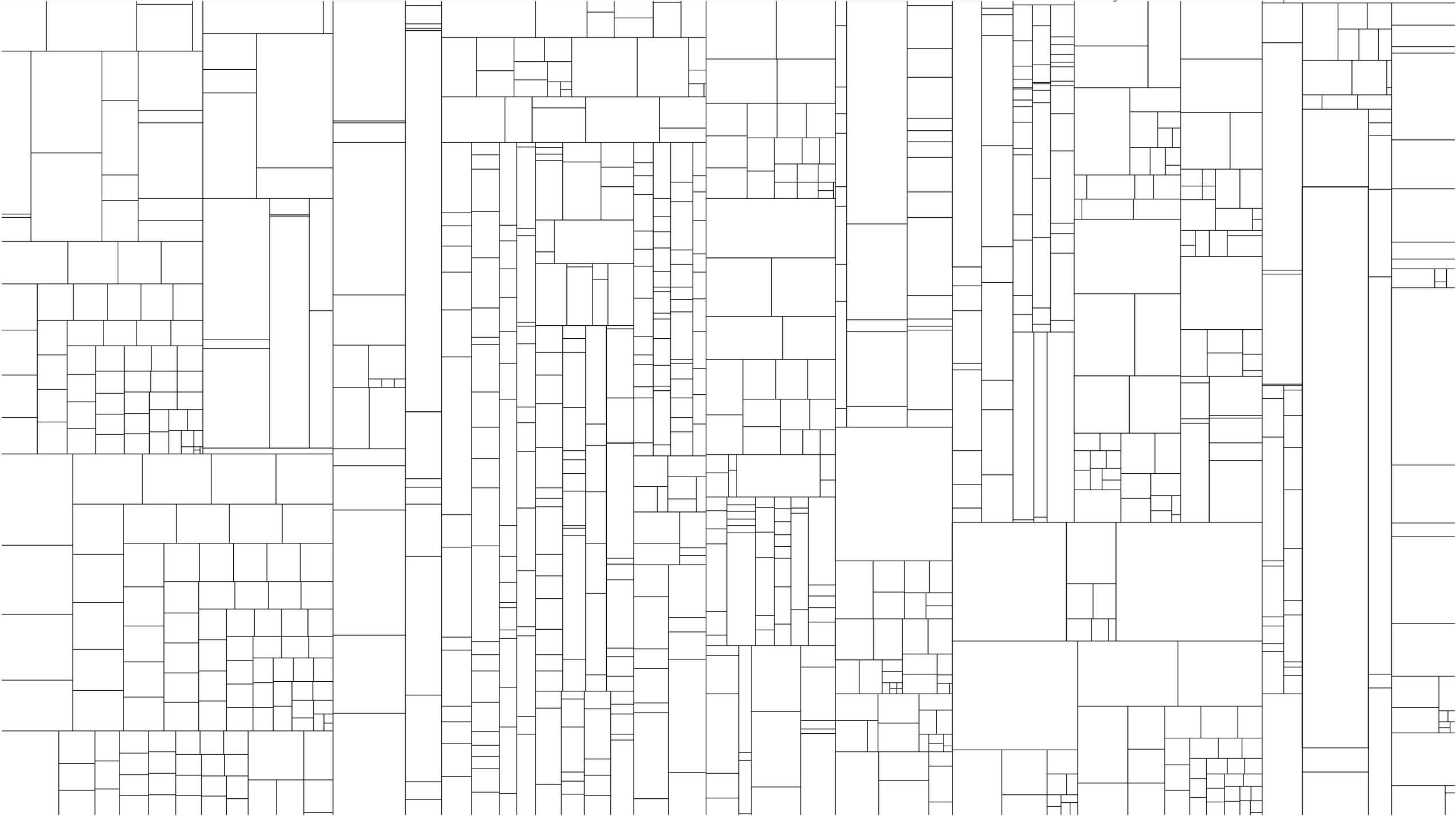
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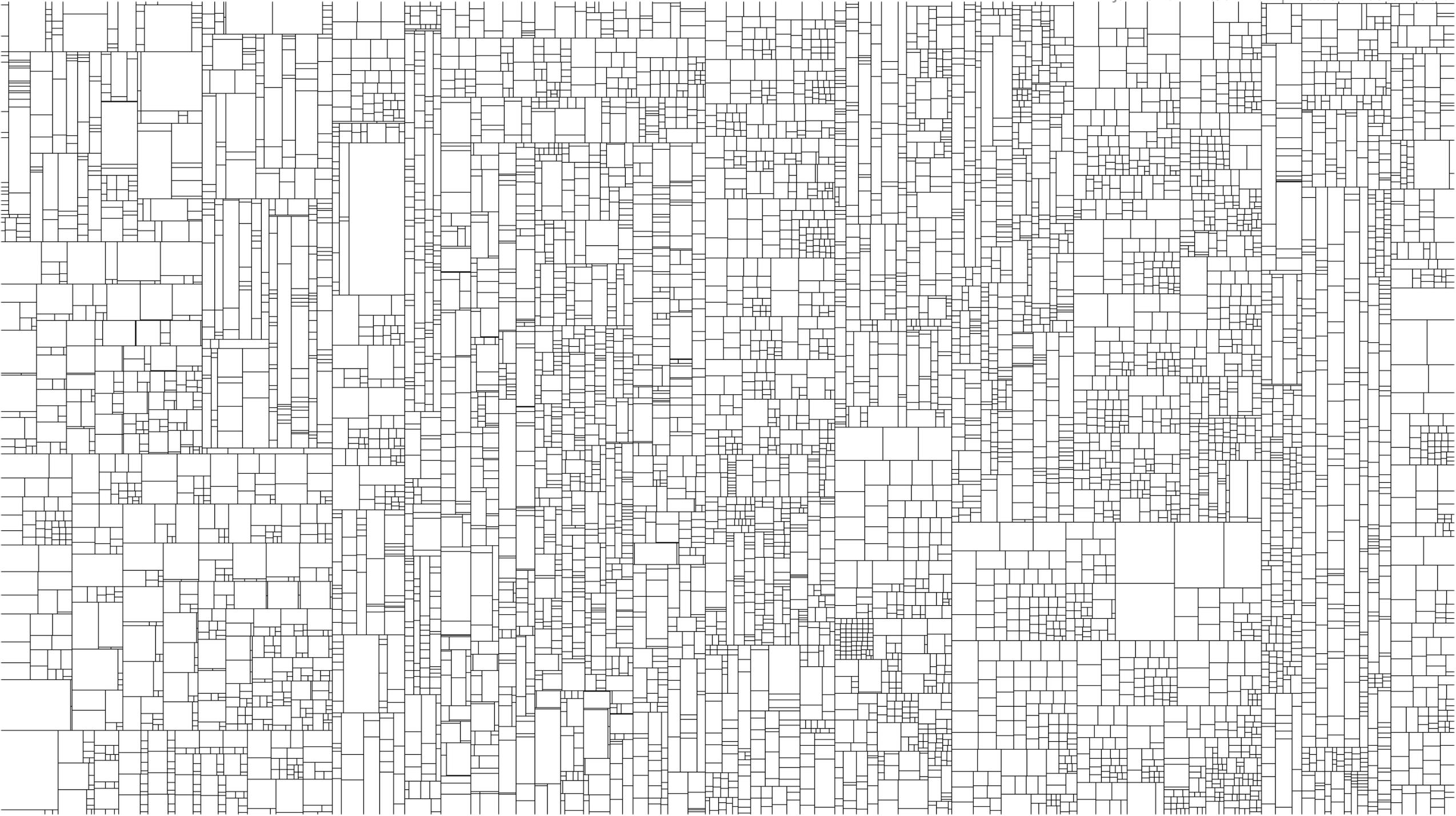


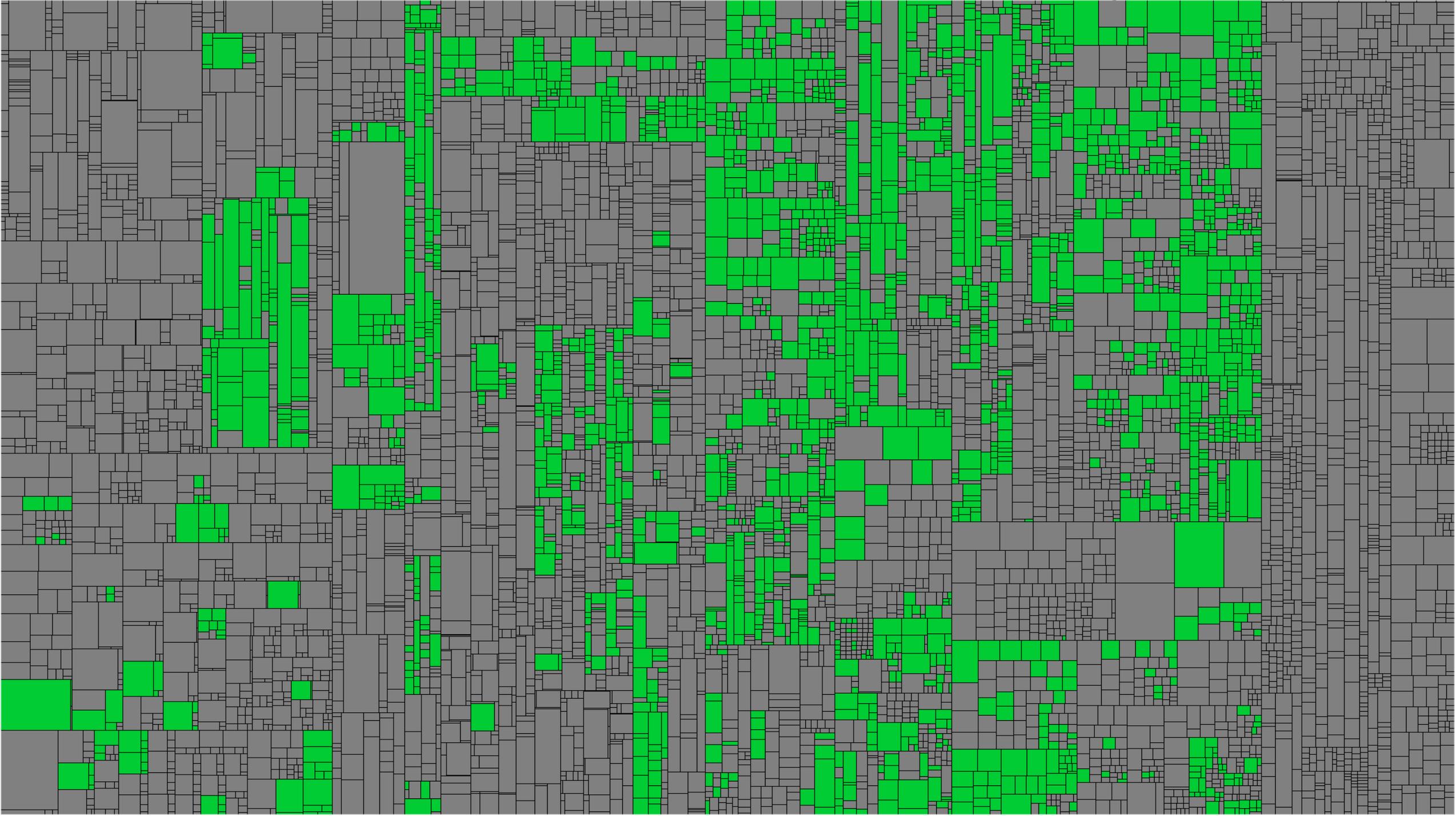
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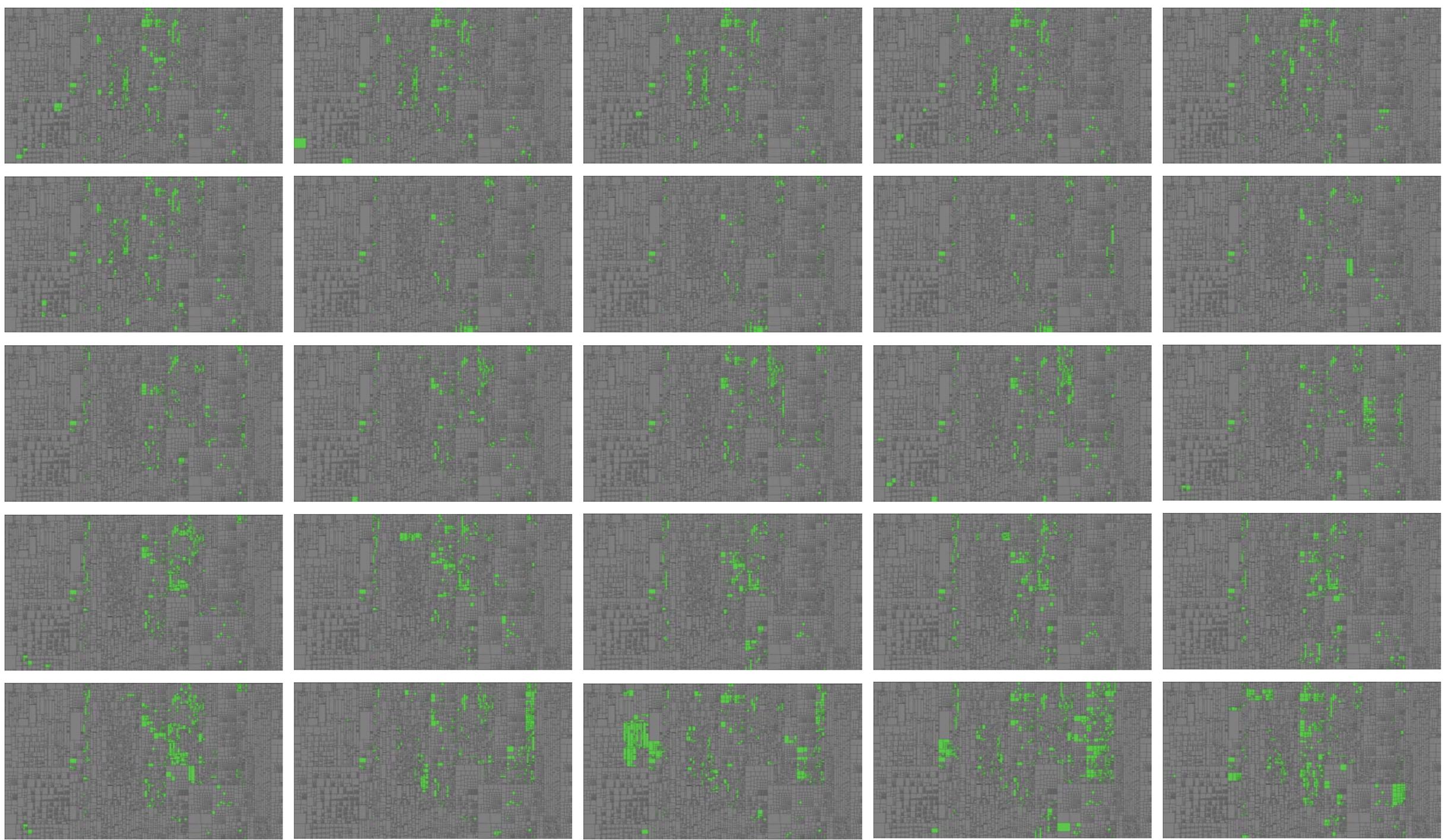


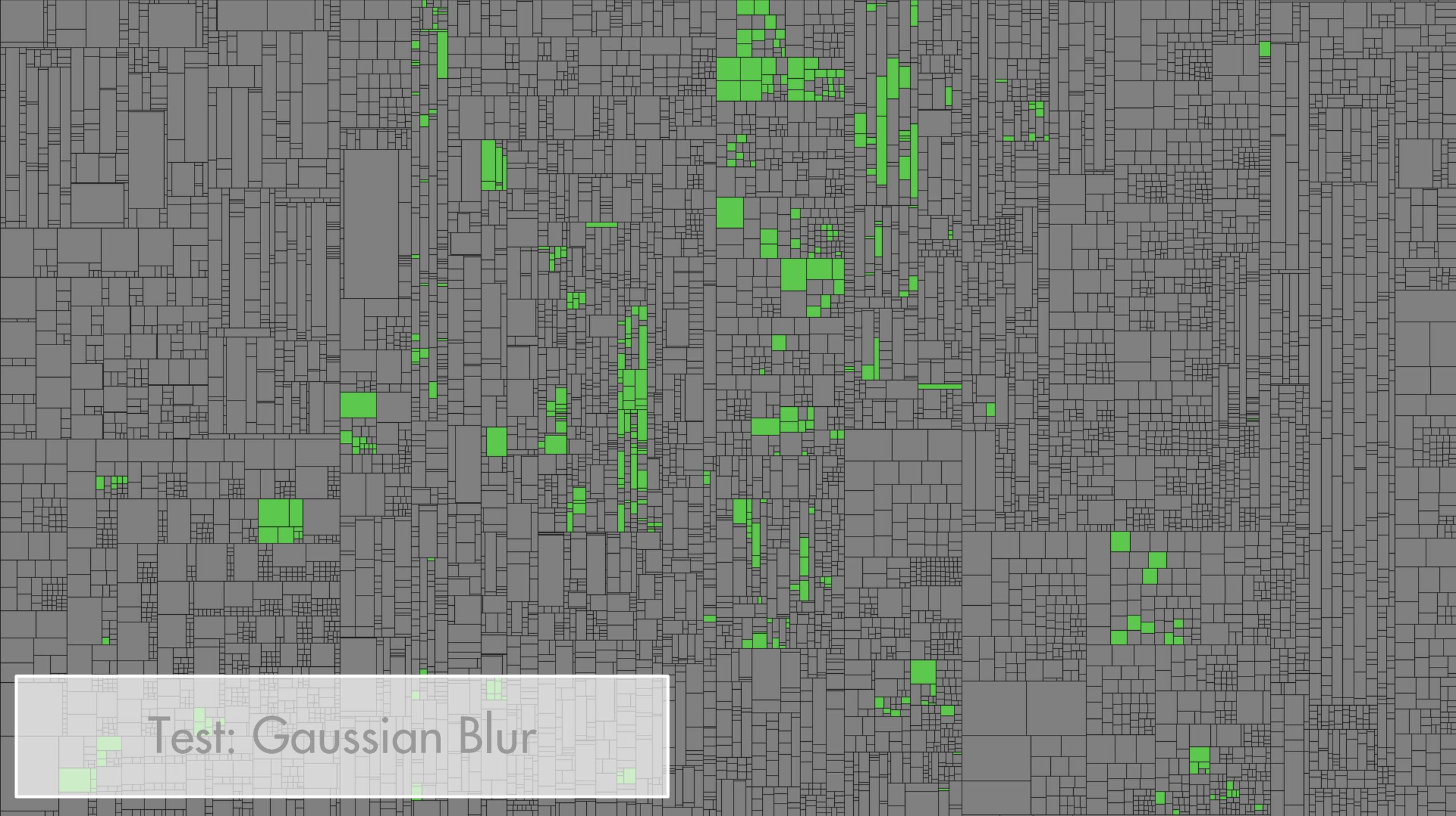




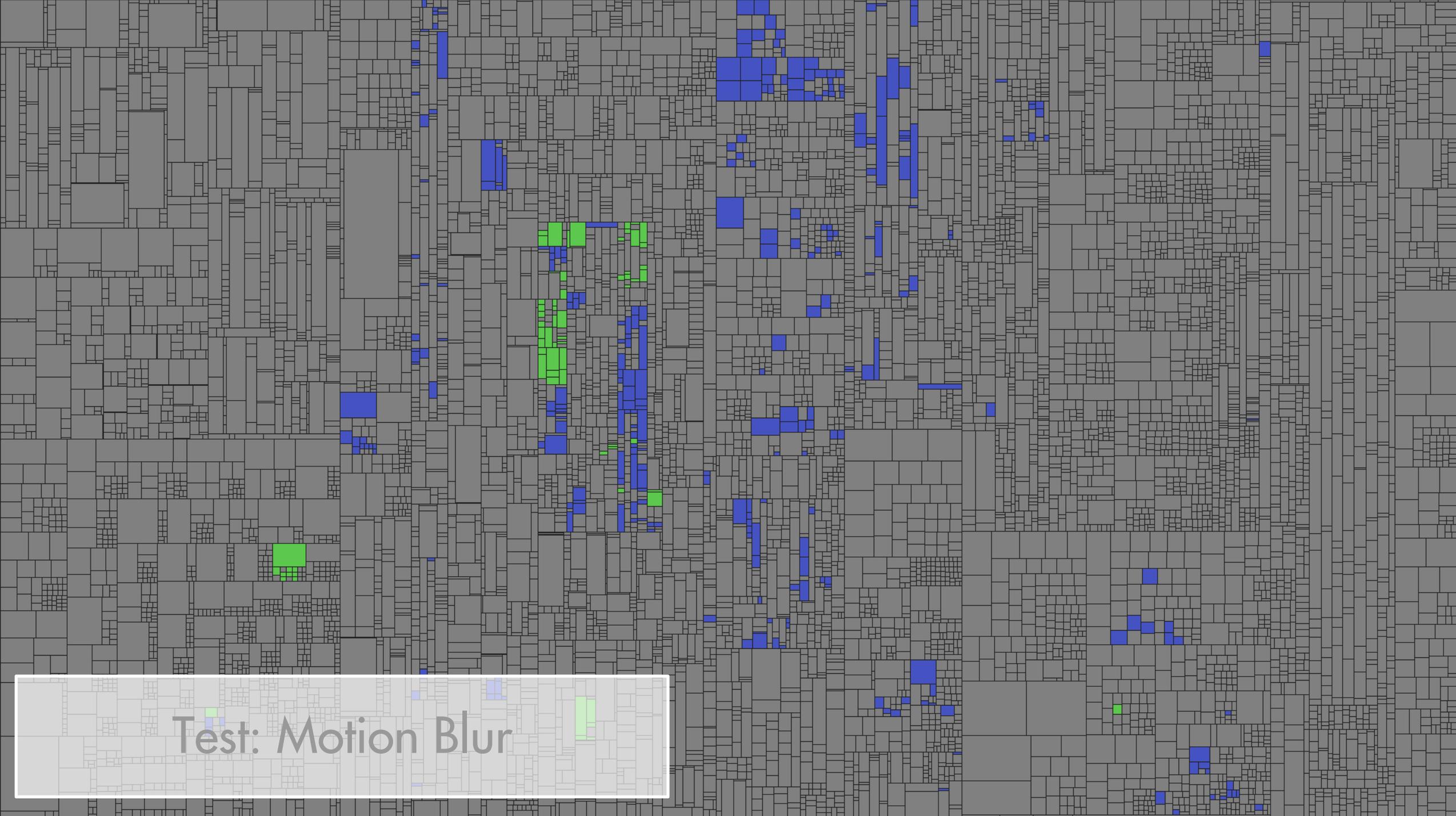




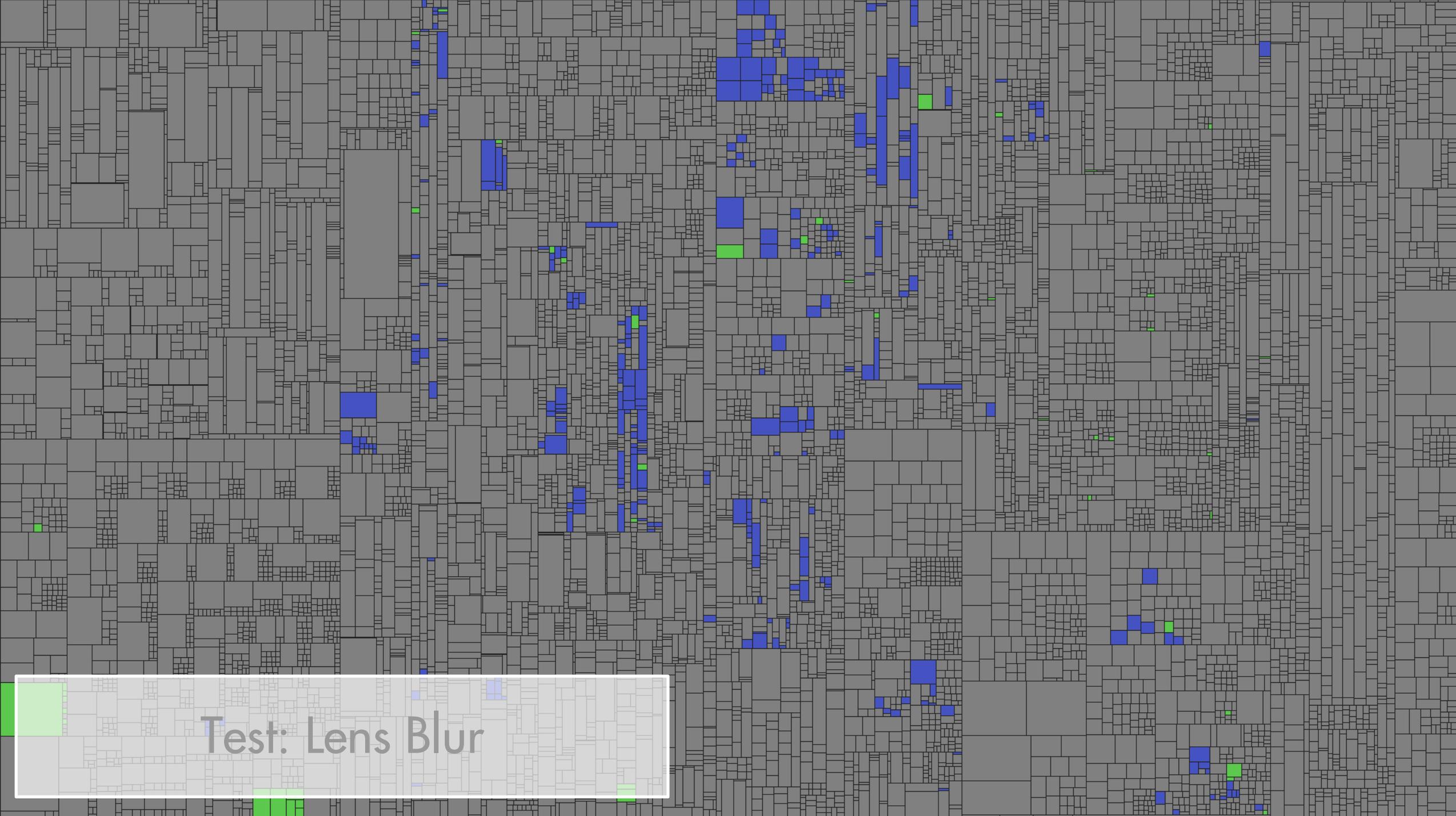




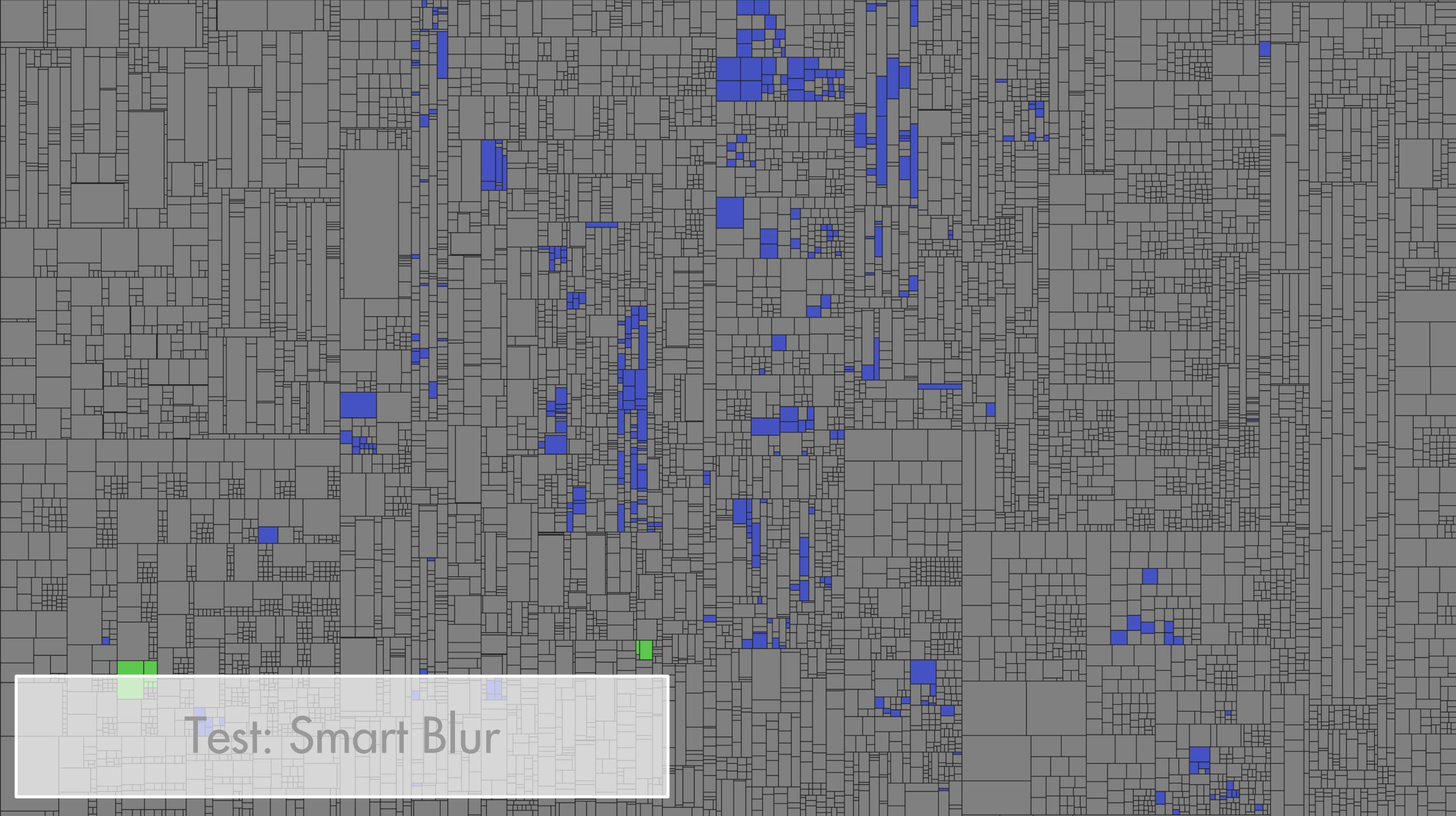
Test: Gaussian Blur



Test: Motion Blur

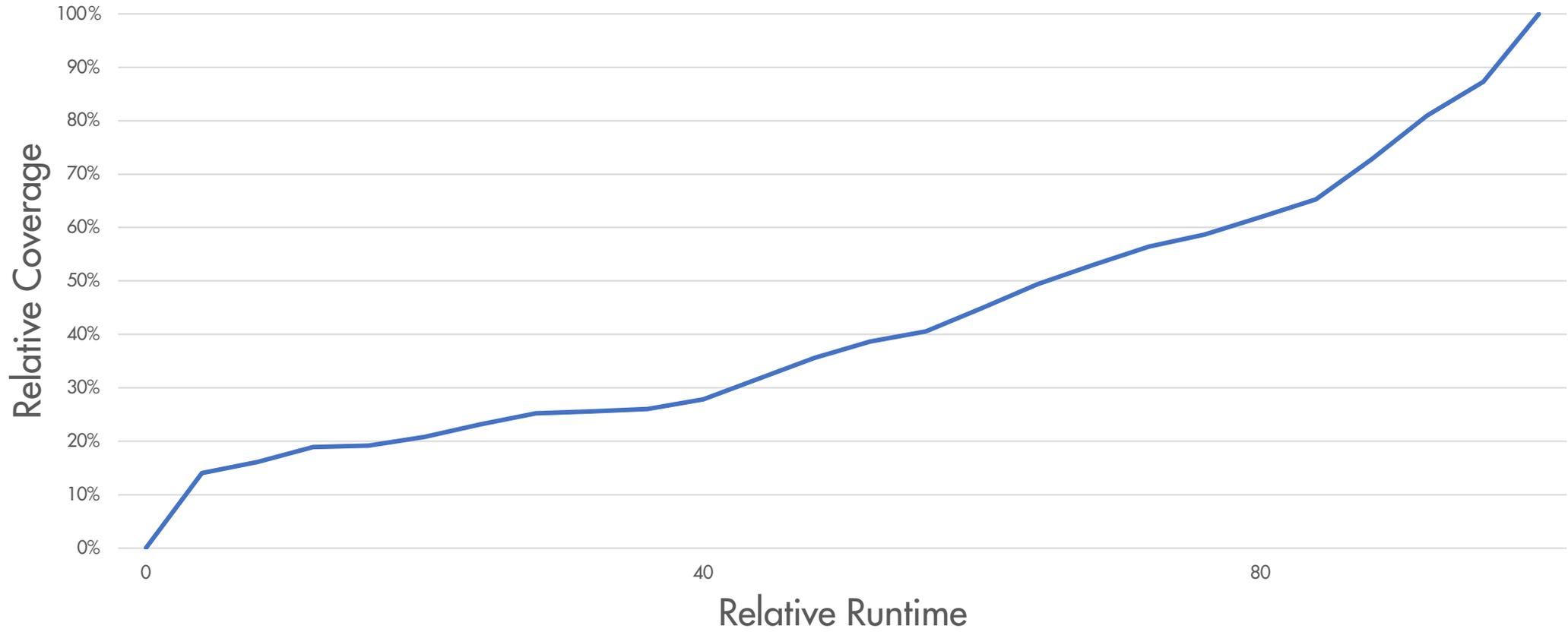
The image consists of a dense, overlapping grid of gray rectangles of various sizes and orientations. Scattered throughout this grid are several smaller rectangles in blue and green. The blue rectangles are more numerous and appear in various sizes and orientations, often forming small clusters or vertical lines. The green rectangles are fewer in number and are also scattered, often appearing as small squares or thin horizontal lines. The overall effect is a complex, textured pattern of overlapping shapes.

Test: Lens Blur



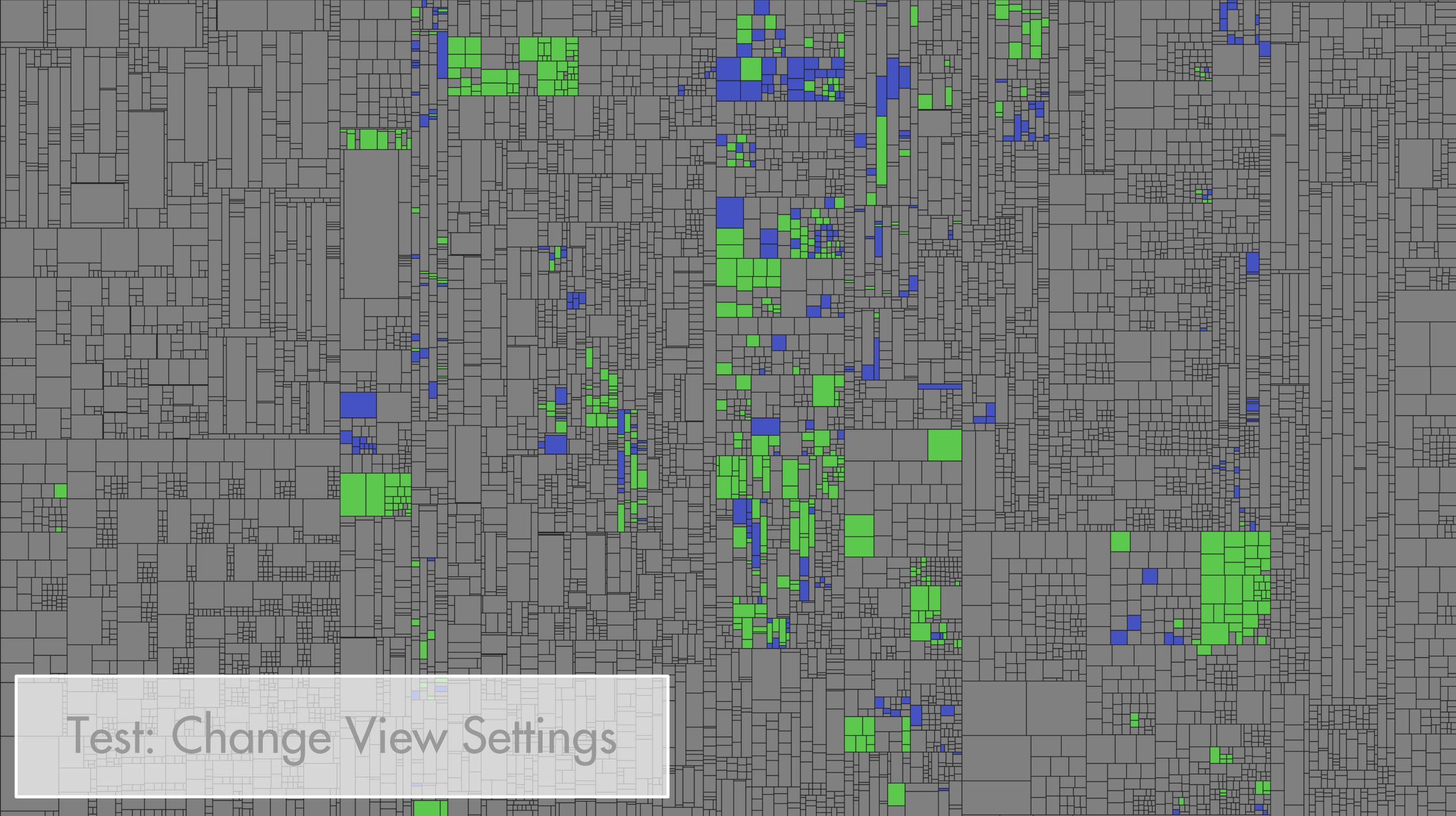
Test: Smart Blur

# Time vs Code Coverage

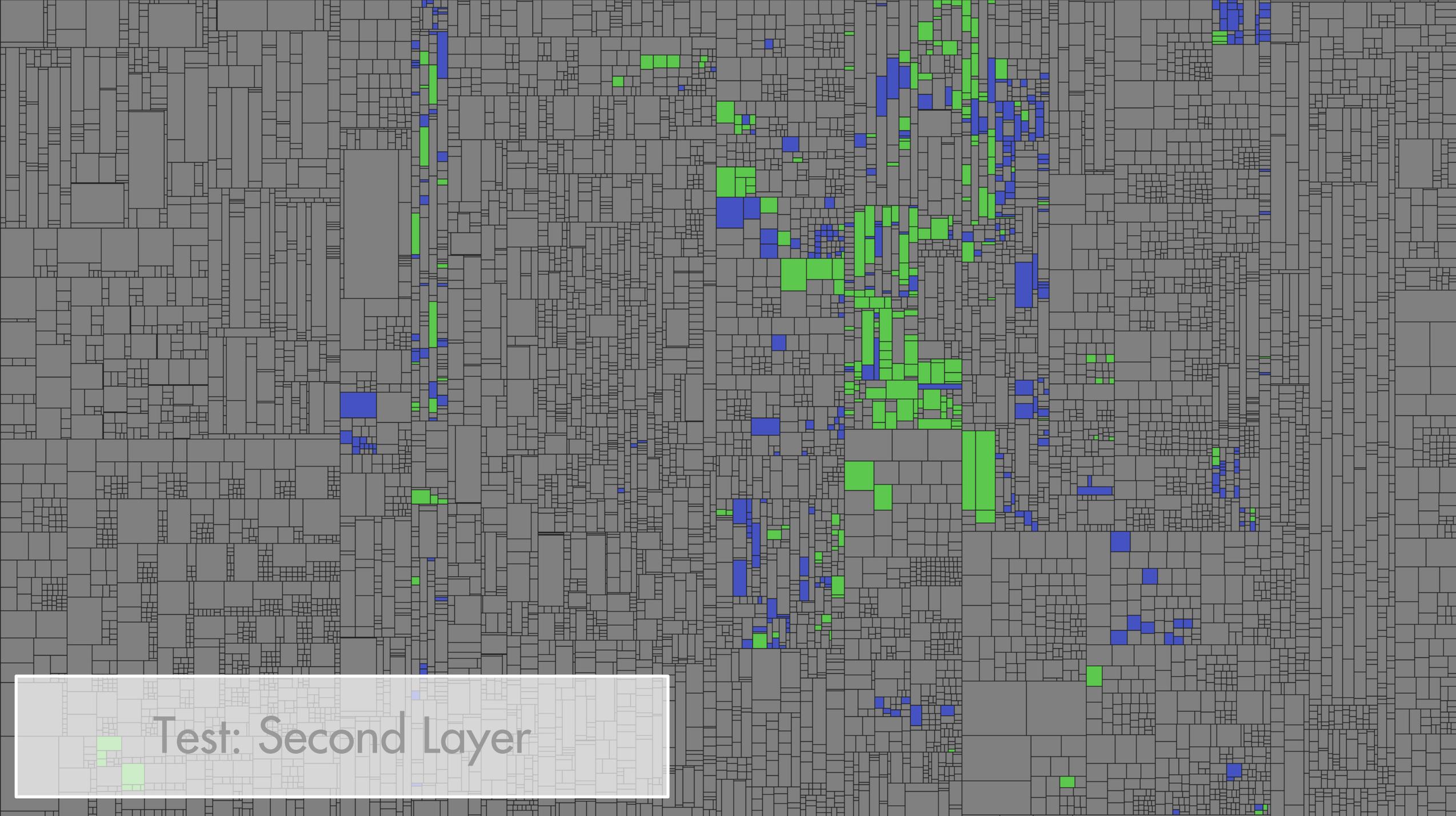




Test: Create and Modify  
Selection

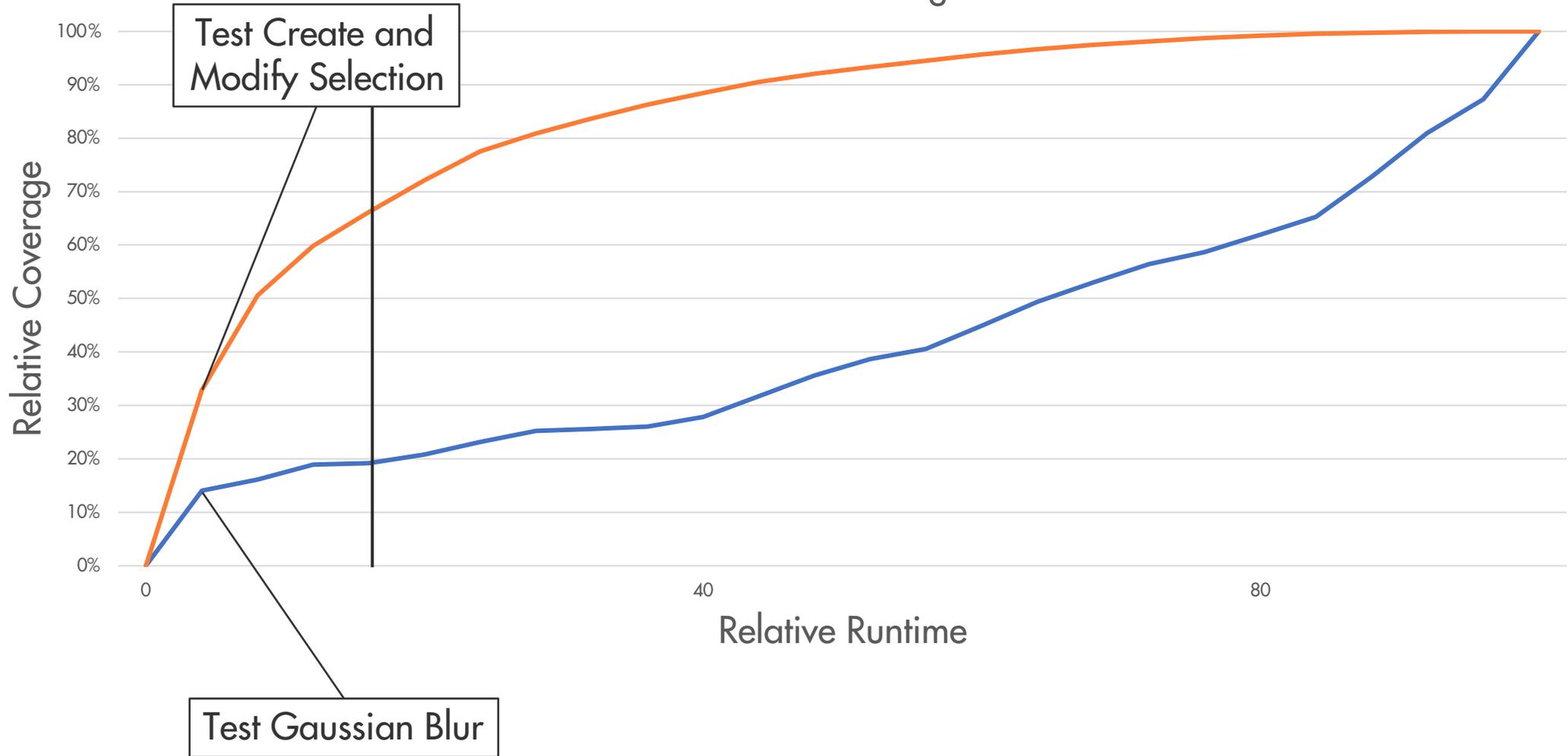


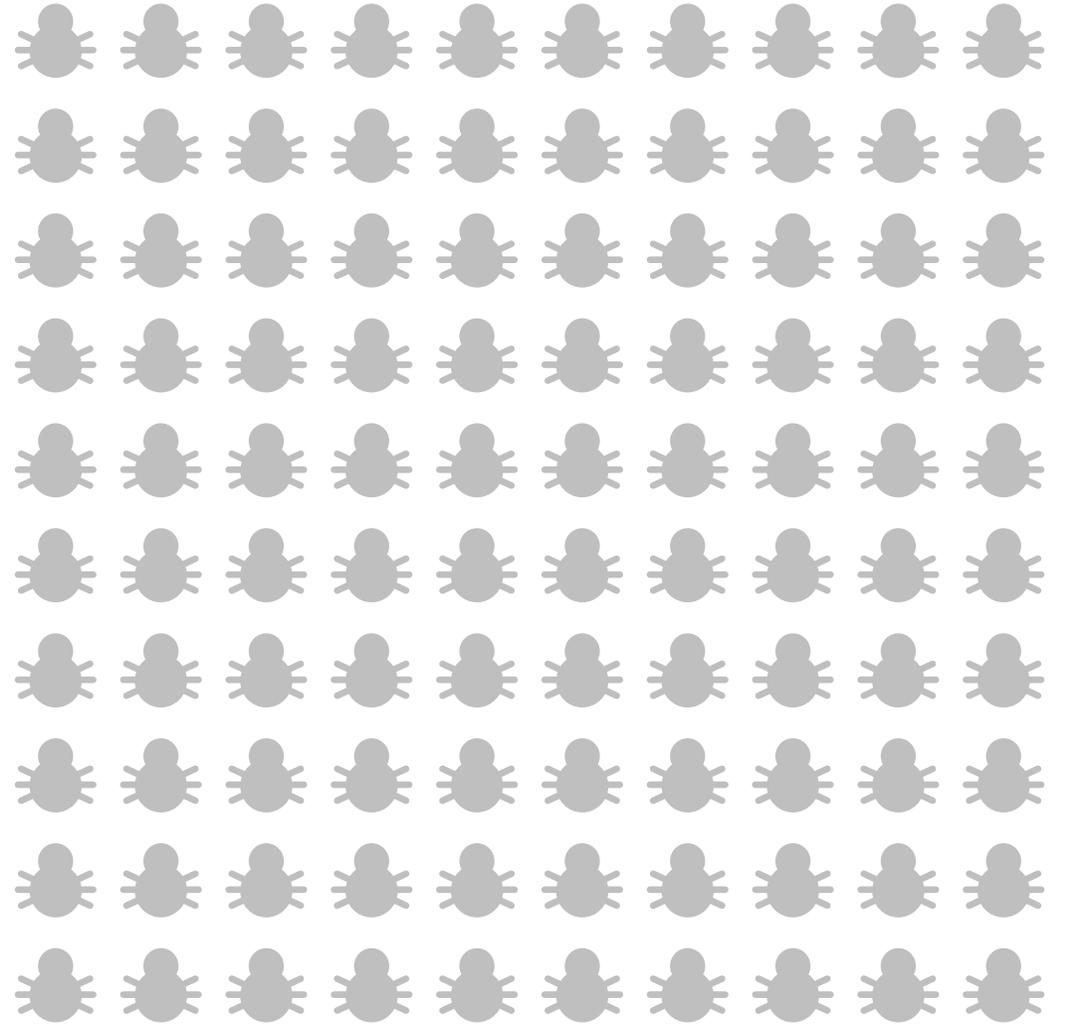
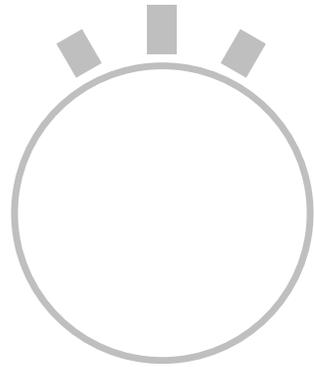
Test: Change View Settings

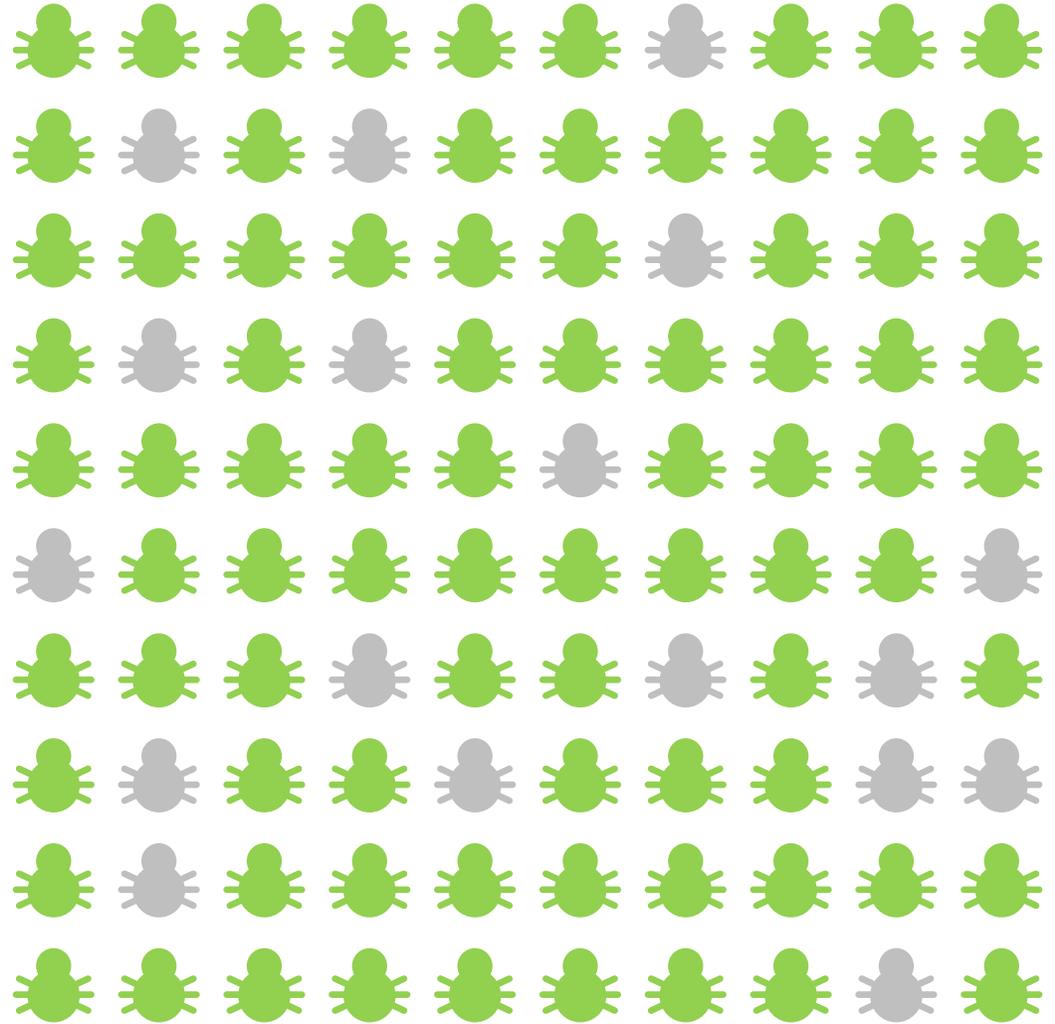


Test: Second Layer

Time vs Code Coverage





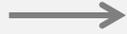




## Continuous Recording of all Tests



Execution of  
All Tests



Coverage & Runtime  
of All Tests

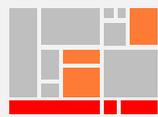


## Test-Impact Analysis

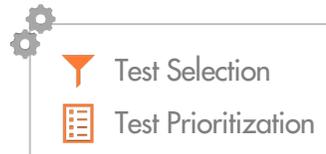
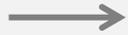
## CI Pipeline



VCS



Code Changes



Test-Impact Analysis



Ordered List of Impacted Tests



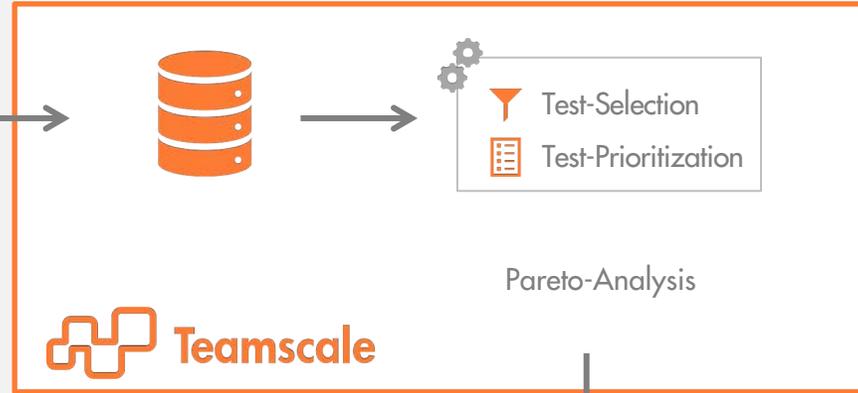
## Single Recording of all Tests



Execution of  
All Tests



Coverage & Runtime  
of All Tests



## Pareto-Optimization



## CI Pipeline



Ordered Subset  
of Tests

# Test-Impact-Analysis

Test selection **w.r.t. code changes**

90% of bugs found in 2% time

Requires continuous recording of coverage and tight integration with test automation framework.

**Higher speedup & higher effort**

# Pareto-Optimization

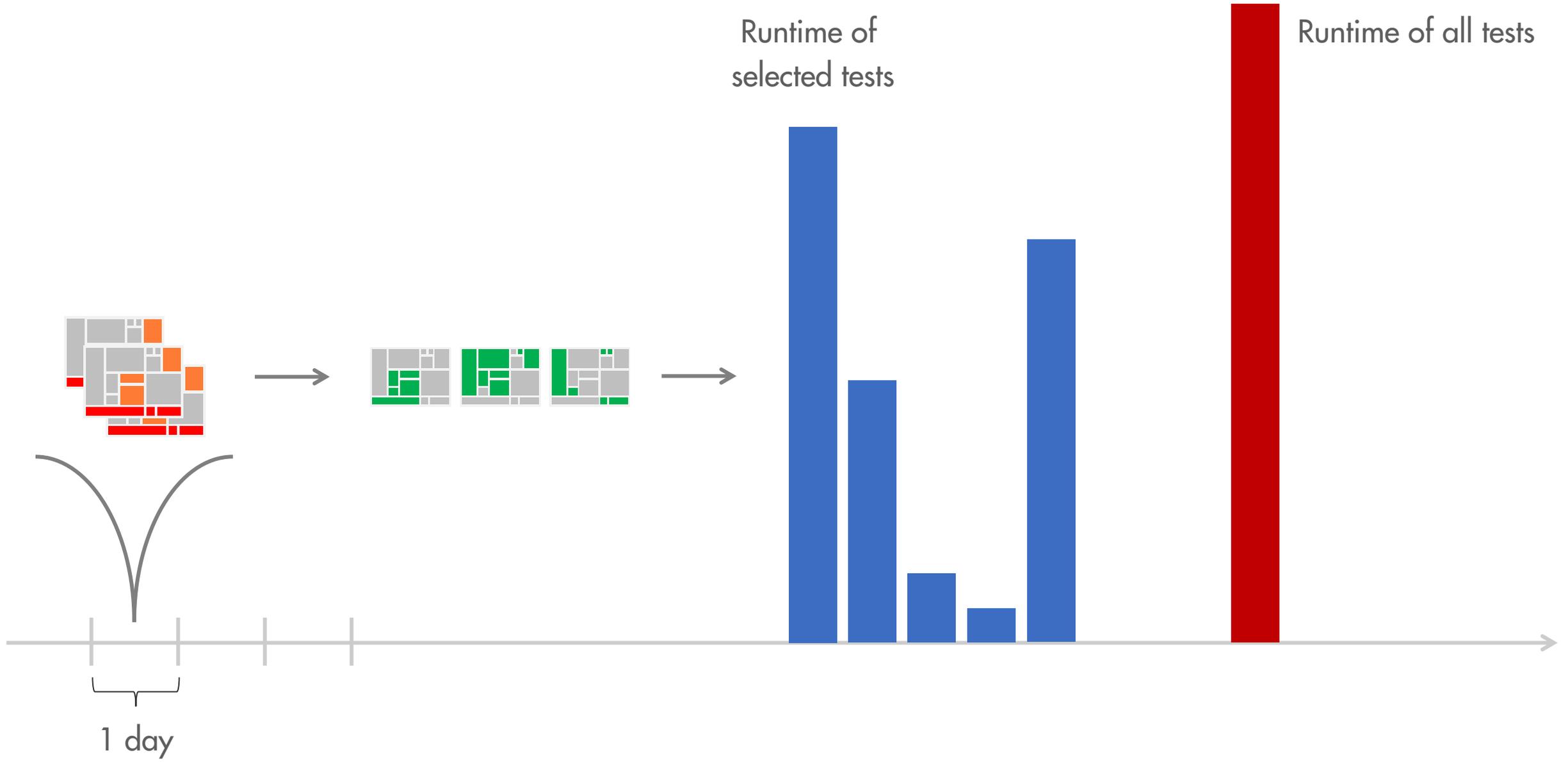
Tests selection **independent of** code changes

90% of bugs found in 11% time

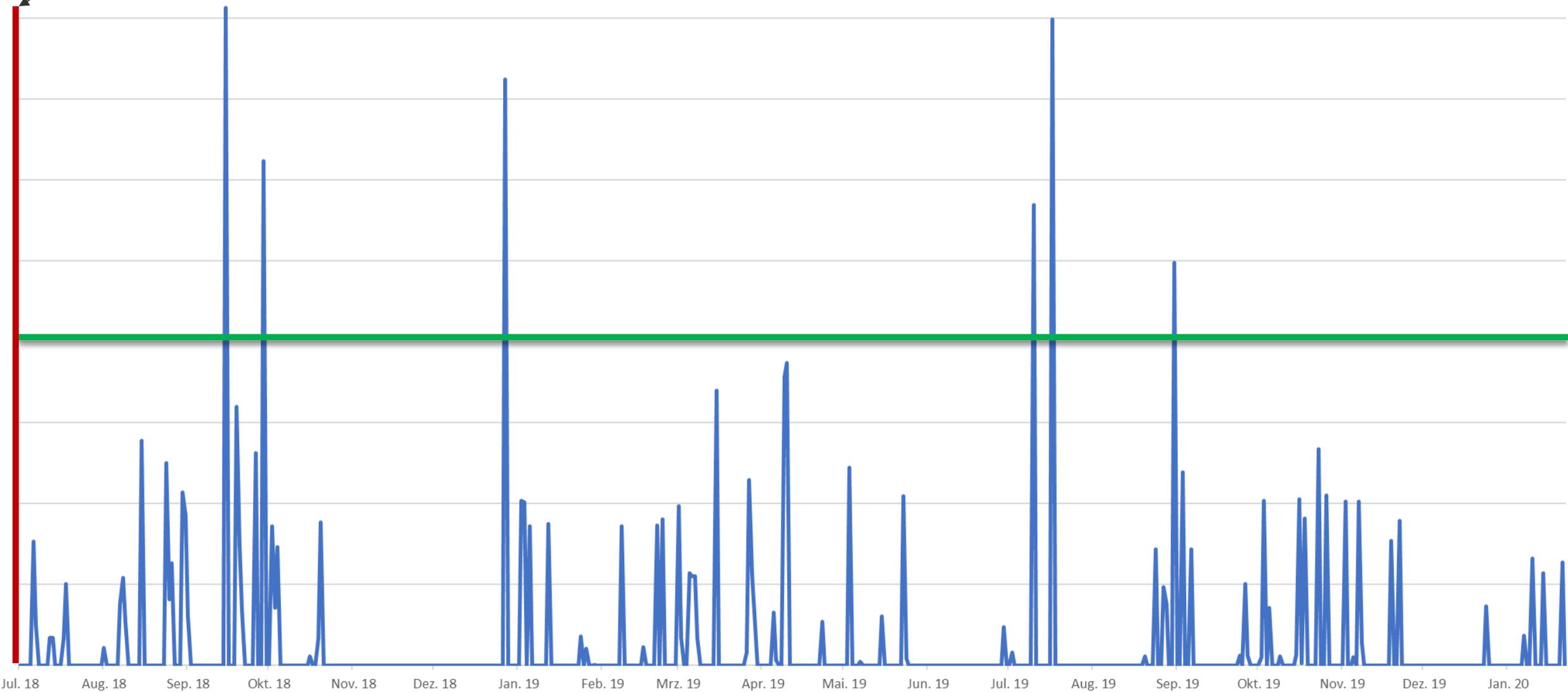
Record coverage once (per quarter)

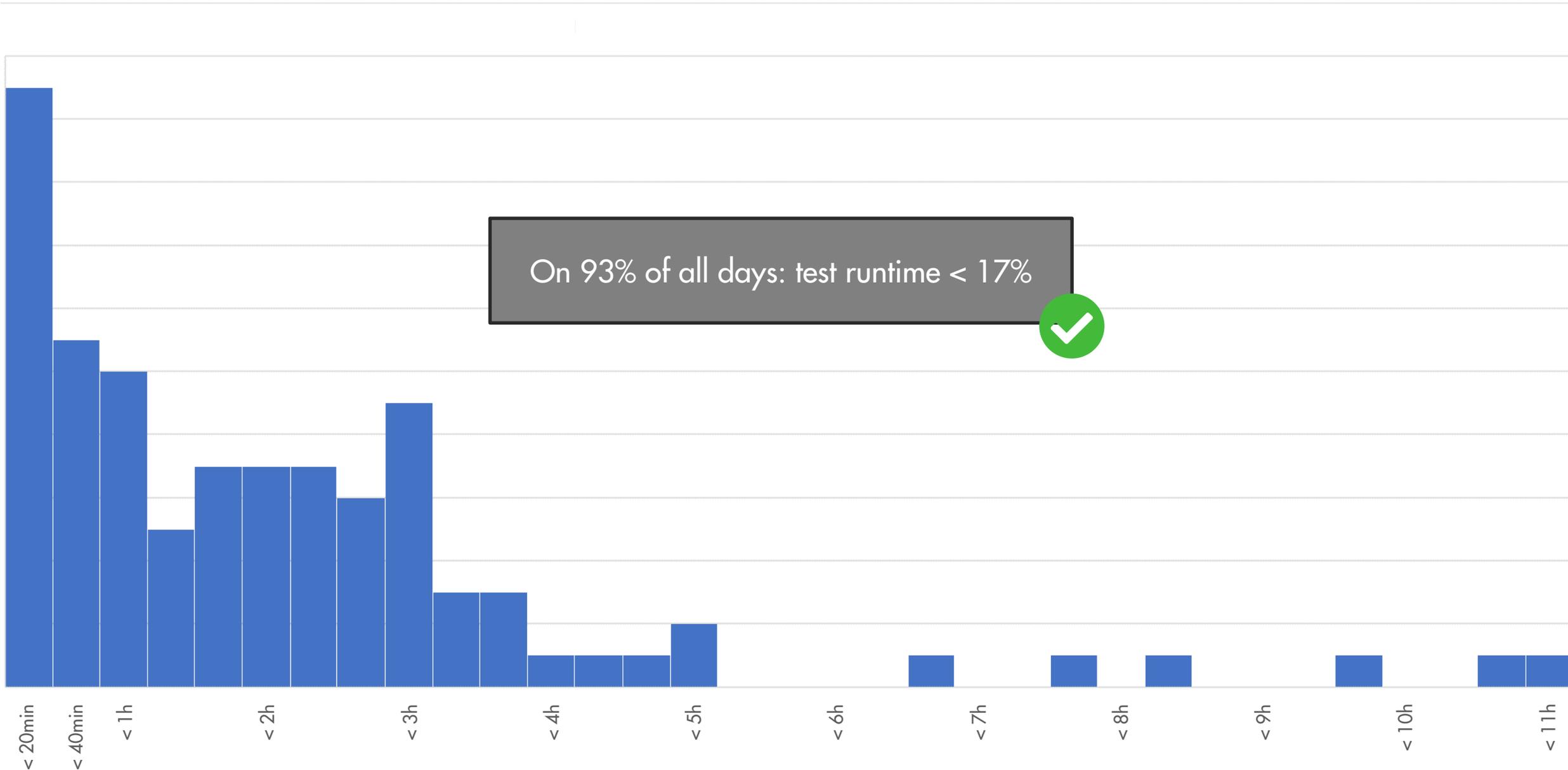
**Smaller effort & higher applicability**

**Evaluation: what's the benefit?**  
How much test time can we expect to save?



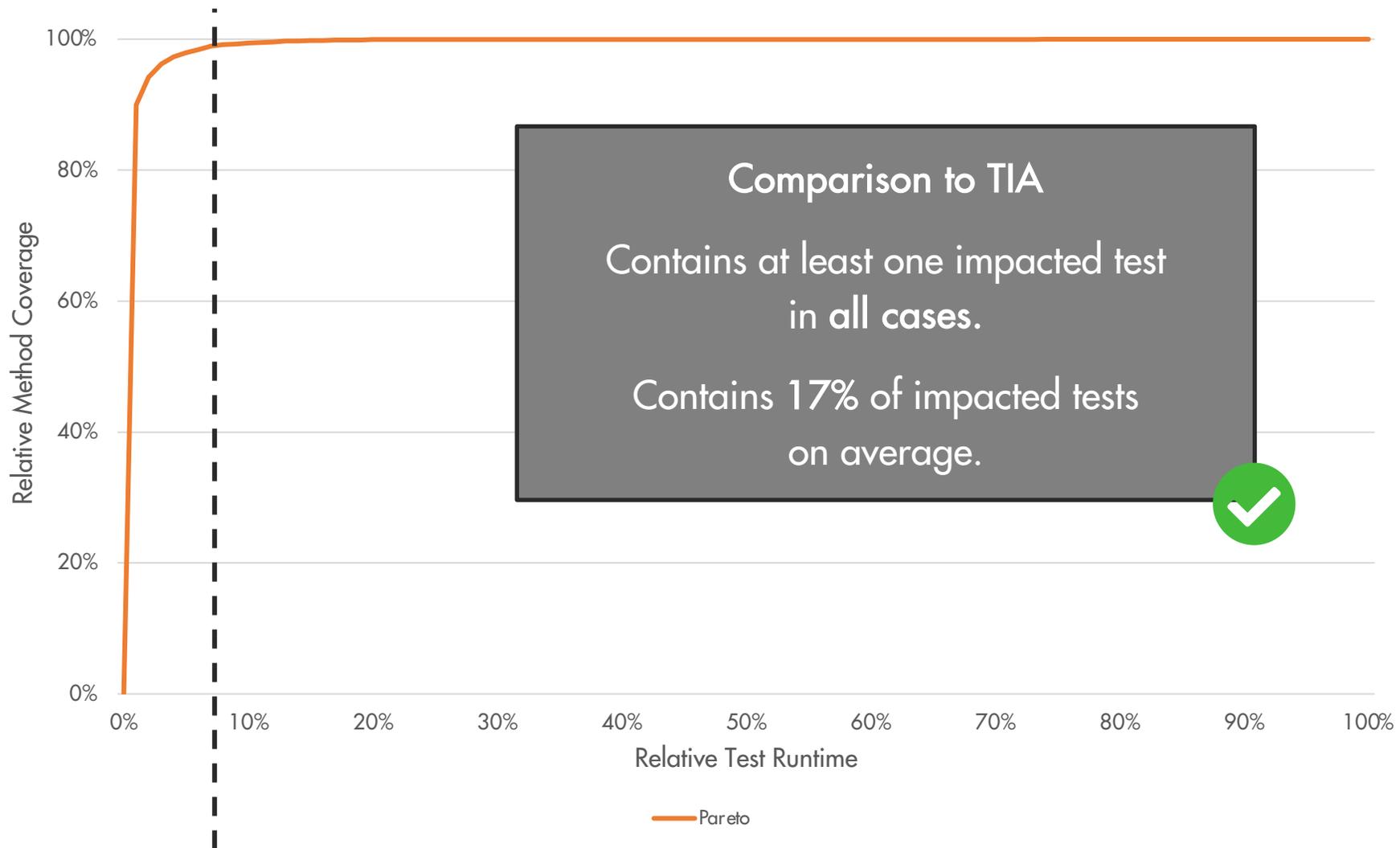
All Tests  
without TIA





On 93% of all days: test runtime < 17%





We achieve 99,2% relative method coverage with just 1h of test runtime.

# Using TIA

Before the Pilot: nightly „Re-run all“

Feedback only on the next day



Build

Test

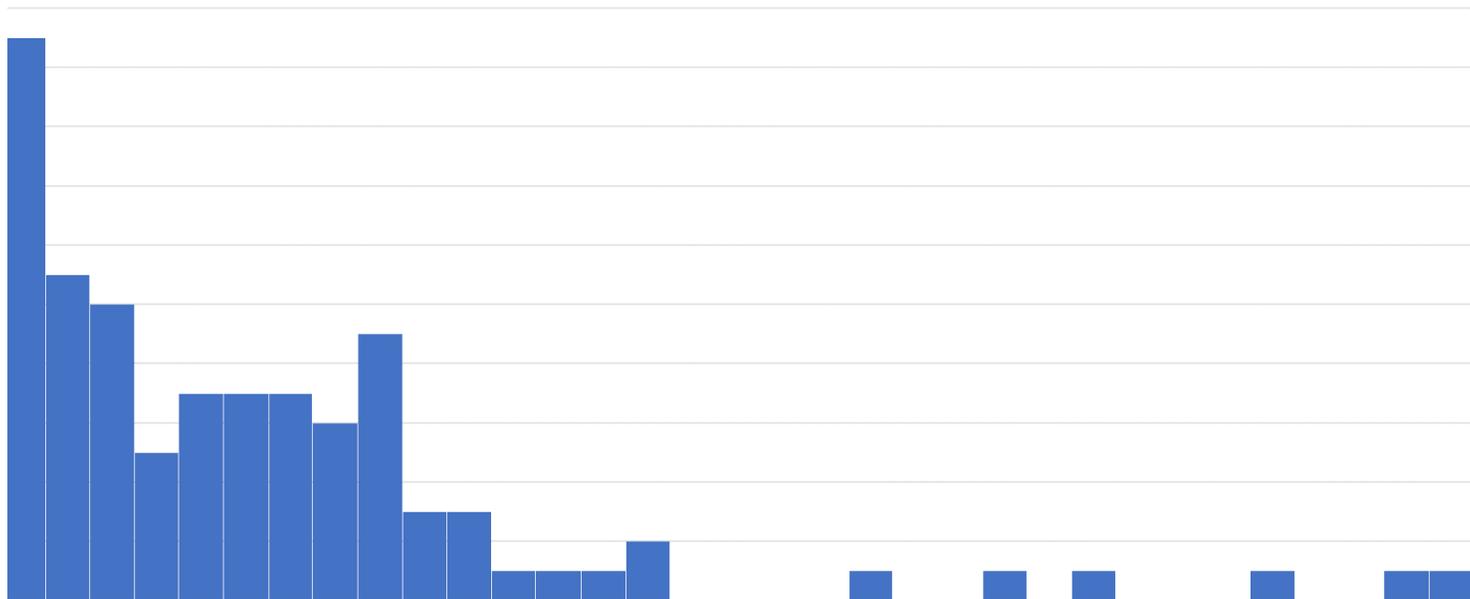
# Using TIA

Fast feedback during the day: TIA Timeboxing

First feedback on checked in changes within 2h.



Build Test max. 1h



# Using TIA

Fast feedback during the day: TIA Timeboxing

First feedback on checked in changes within 2h.



Build Test max. 1h

Still: nightly „Re-run all“, to update TIA data in Teamscale



# Using Pareto Testing

Fast feedback during the day: Pareto Timeboxing

First incomplete feedback on checked in changes within 2h.

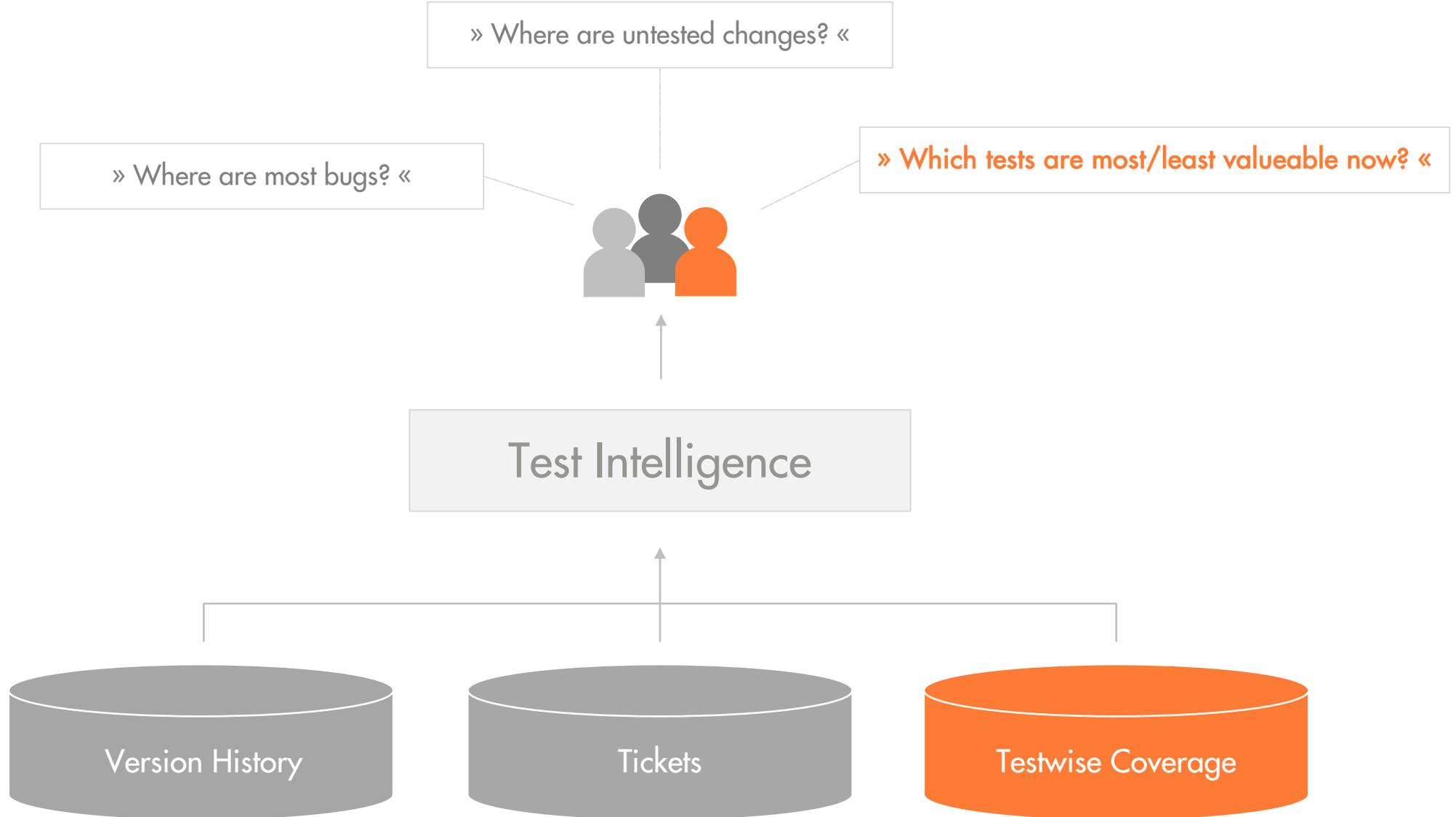


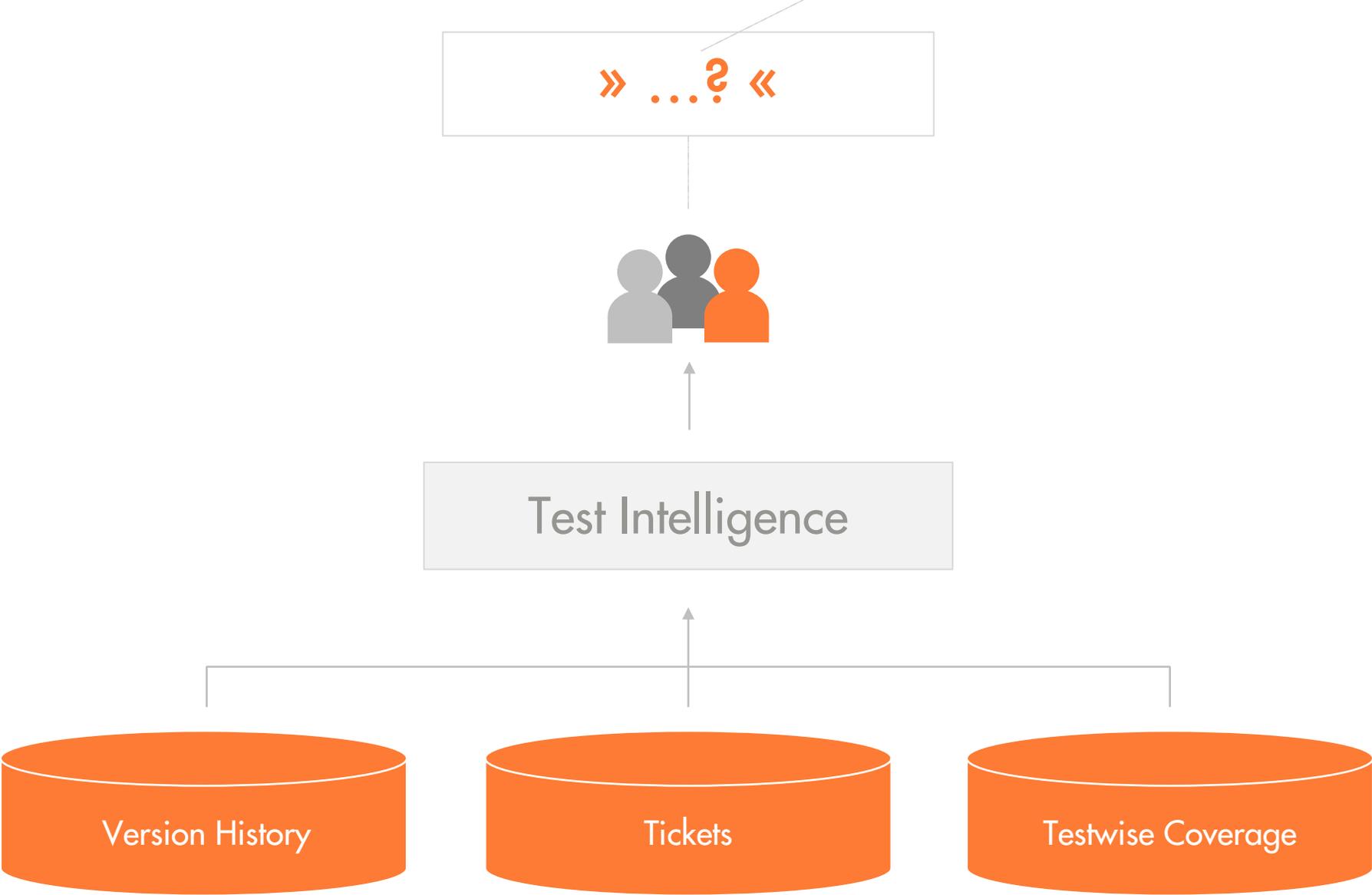
Build Test 1h

Still: nightly „Re-run all“



Per quarter year: update Pareto test list





Test Executions

Test Source Code

[org](#) / [conqat](#) / [lib](#) / [commons](#) / [string](#) / [StringUtilsTest](#) / [testGetKeyValuePairs\(\)](#)

› Test Execution History

1

SUCCESSFUL

0

SKIPPED

0

INCONCLUSIVE

1

FAILED

0

ERROR

FAILURE

Branch: feature/23972\_related\_changes\_in\_test\_view @ Feb 11 2022, 13:14

8.004s

PASSED

Branch: master @ Feb 10 2022, 13:28

4.002s

› Methods Run by the Test That Were Changed Since the Last Successful Test Pass

[diff/DiffDescription.java](#)

**Method** addLineRegion

**State** Changed after the last successful test run

[diff/DiffDescription.java](#)

**Method** calculateDistance

**State** Added after the last successful test run

Show test results from: **All**

Tests \ Specification Items		REQ DP-539	REQ DP-540	TST DP-547	TST DP-548
	$\Sigma$	1	0	1	1
tests/stack_tests.c/StackTests/Push	1				1
tests/stack_tests.c/StackTests/Pop	1			1	
tests/stack_tests.c/StackTests/Peek	1	1			

Linux SKIPPED  
Windows FAILURE

## Learn How to Improve Quality In Your Software Long-lastingly!

All events online & for free

**CQSE**  
Continuous Quality in Software Engineering

**RSE**  
re Engineering

### Software Intelligence Talk

Fast CI Despite Growing Test Suite at Dolby

Lars Kempe (Dolby Germany GmbH) and Sven Amann (CQSE) use Test Impact Analysis, to get fast feedback from an overall large number of tests by frequently running a subset of them. Crucial for the success of this approach is the selection of these tests. Learn more about the idea behind Test Impact Analysis and the experiences made at Dolby!



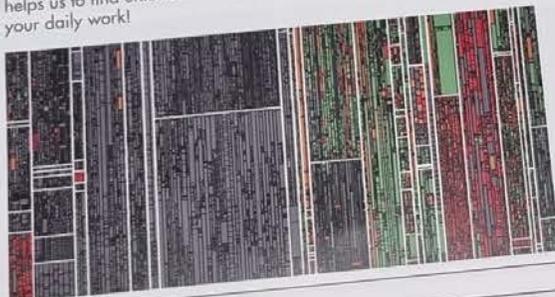
Sept. 28, 22  
10:30-12:00 CEST  
cqse.eu/sit-22-09-uc



### Workshop - Test Gap Analysis

Reveal Untested Changes in Source Code

Most errors in long-lived software occur in code areas that change a lot. To do things right, you have to ensure no important changes go live untested. Test Gap Analysis helps us to find untested changes. Learn how it works and what advantages it brings to your daily work!



Test coverage in the entire system, color scheme showing (un)tested but changed code



Oct. 19, 22  
10:30-12:00 CEST  
cqse.eu/tga-22-10-uc

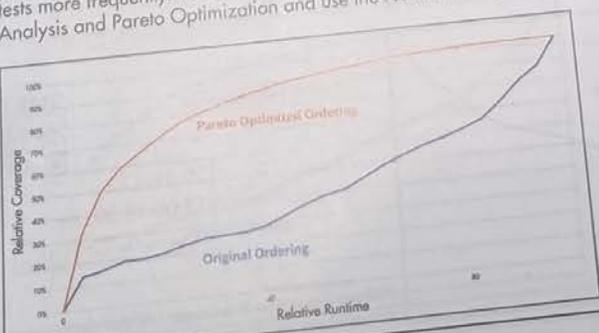


Nov. 16, 22  
17:00-18:30 CET  
cqse.eu/tga-22-11-uc

### Workshop - Fast Feedback from Long-Running Tests

Test Selection for Ever-Growing Test-Suites

As software systems grow, so does the number of their tests. The runtime takes time. To get fast feedback about new bugs despite slow test suites, we can run a subset of all tests more frequently. Learn how to choose the subset effectively with Test Impact Analysis and Pareto Optimization and use the results in daily work!



Higher coverage in shortened runtime, using Pareto Optimization



Oct. 26, 22  
10:30-12:00 CEST  
cqse.eu/ts-22-10-uc



Nov. 30, 22  
17:00-18:30 CET  
cqse.eu/ts-22-11-uc

**CQSE**  
Workshop

## Test Gap Analysis

Reveal Untested Changes in Source Code



October 19  
10:30-12:00 CEST  
cqse.eu/tga-22-10-ut



November 16  
17:00-18:30 CET  
cqse.eu/tga-22-11-ut

**CQSE**  
Workshop

## Fast Feedback from Long-Running Tests

Test Selection for Ever-Growing Test Suites



October 26  
10:30-12:00 CEST  
cqse.eu/ts-22-10-ut



November 30  
17:00-18:30 CET  
cqse.eu/ts-22-11-ut

Happy to meet you  
during the breaks!

*slides: [cqse.eu/2022/ucaat](https://cqse.eu/2022/ucaat)*



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