CodeScene

Code Red: The business impact of code quality

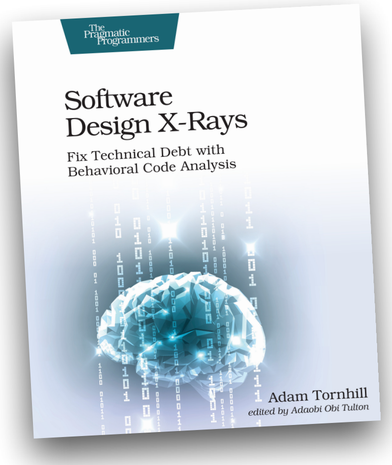
10 years of trauma & research in technical debt

June 2022

@AdamTornhill

codescene.com

What is Technical Debt?



“Technical debt is code that’s more expensive to maintain than it should be.”

Software Design X-Rays, 2018

What we actually know:

Research on Technical Debt

Waste

Software developers spend **23-42%** of their work week dealing with technical debt and bad code.[1, 2, 3]

Vulnerabilities

There is a statistically significant correlation between software vulnerabilities and code smells like Brain Classes, complex implementations, and large classes.[4]

[1] Besker, T., Martini, A., Bosch, J. (2019) “Software Developer Productivity Loss Due to Technical Debt”

[2] Stripe, (2018), “The Developer Coefficient: Software engineering efficiency and its $3 trillion impact on global GDP”

[3] https://codescene.com/technical-debt/whitepaper/calculate-business-costs-of-technical-debt.pdf

[4] Sultana, K. Z., Codabux, Z., & Williams, B. (2020, December). Examining the relationship of code and architectural smells with software vulnerabilities.

Technical Debt: where we are as an industry

Research finds that developers are **frequently forced to introduce new Technical Debt** as companies keep trading code quality for short-term gains like new features.[1]

[1] T Besker, A Martini, and J Bosch. 2019. “Software developer productivity loss due to technical debt—a replication and extension study examining 1207 developers’ development work”

Why short-term gains win over long-term maintainability:

Hyperbolic Discounting

> “There's never enough time to do something right, but there's always enough time to do it over.”*
>
> Melvin E. Conway (1968). “How Do Committees Invent?”

* Thanks, Kevlin Henney

Fighting hyperbolic discounting:

Visualise accidental code complexity

Code Health: beyond a single metric

Code health as a proxy for code quality:

1. Detect properties of the code that are known to correlate with increased maintenance costs and with higher risks of defects.
2. Aggregate the metrics, normalize, and visualize.

Examples on Code Health Issues

Module Level:

Low Cohesion, many responsibilities

Brain Class, low cohesion, large class, at least one Brain Method

Function Level:

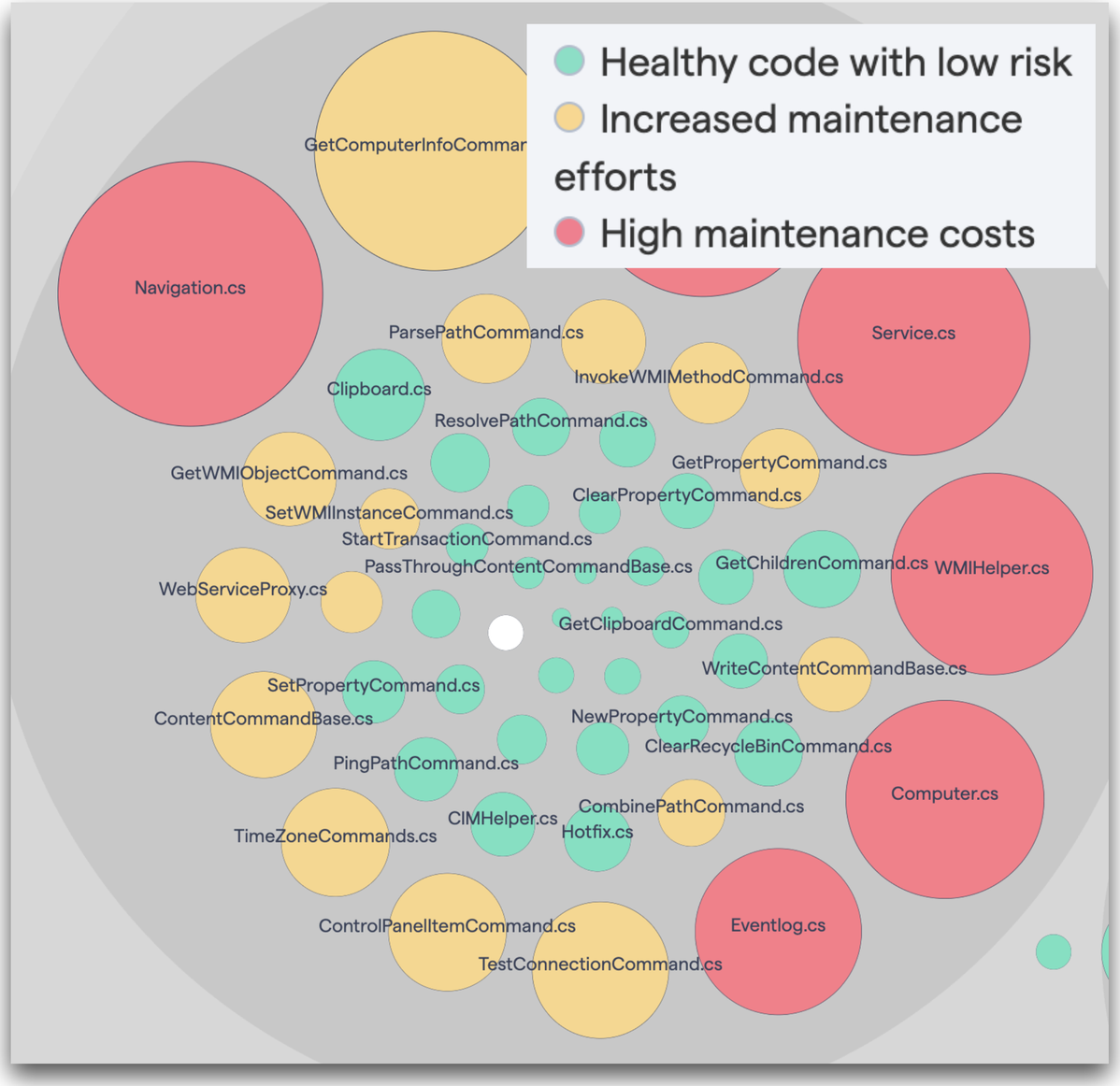
Brain Methods, complex functions that centralize the behavior of the module

Copy-pasted logic, missing abstractions, DRY violations

Implementation Level:

Deeply Nested Logic, if-statements inside if-statements

Primitive Obsession, missing a domain language



Learn More: https://codescene.com/blog/measure-code-health-of-your-codebase/

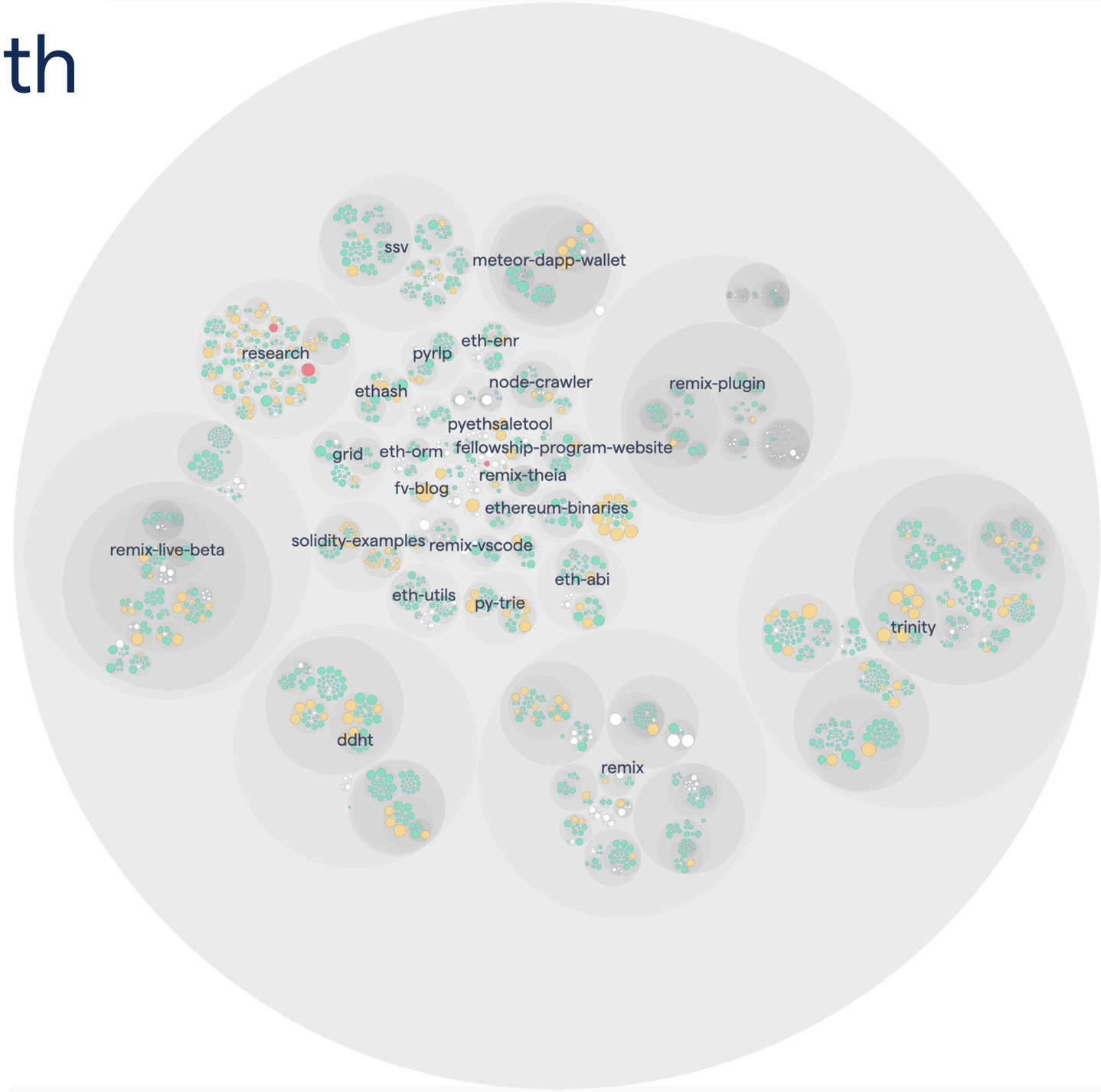
Visualizing code health

Ethereum: a decentralized, open-source blockchain with smart contract functionality

Example on 50 repositories

600k lines of code

https://github.com/ethereum



Visualizing code health

Ethereum: a decentralized, open-source blockchain with smart contract functionality

Example on 50 repositories

600k lines of code

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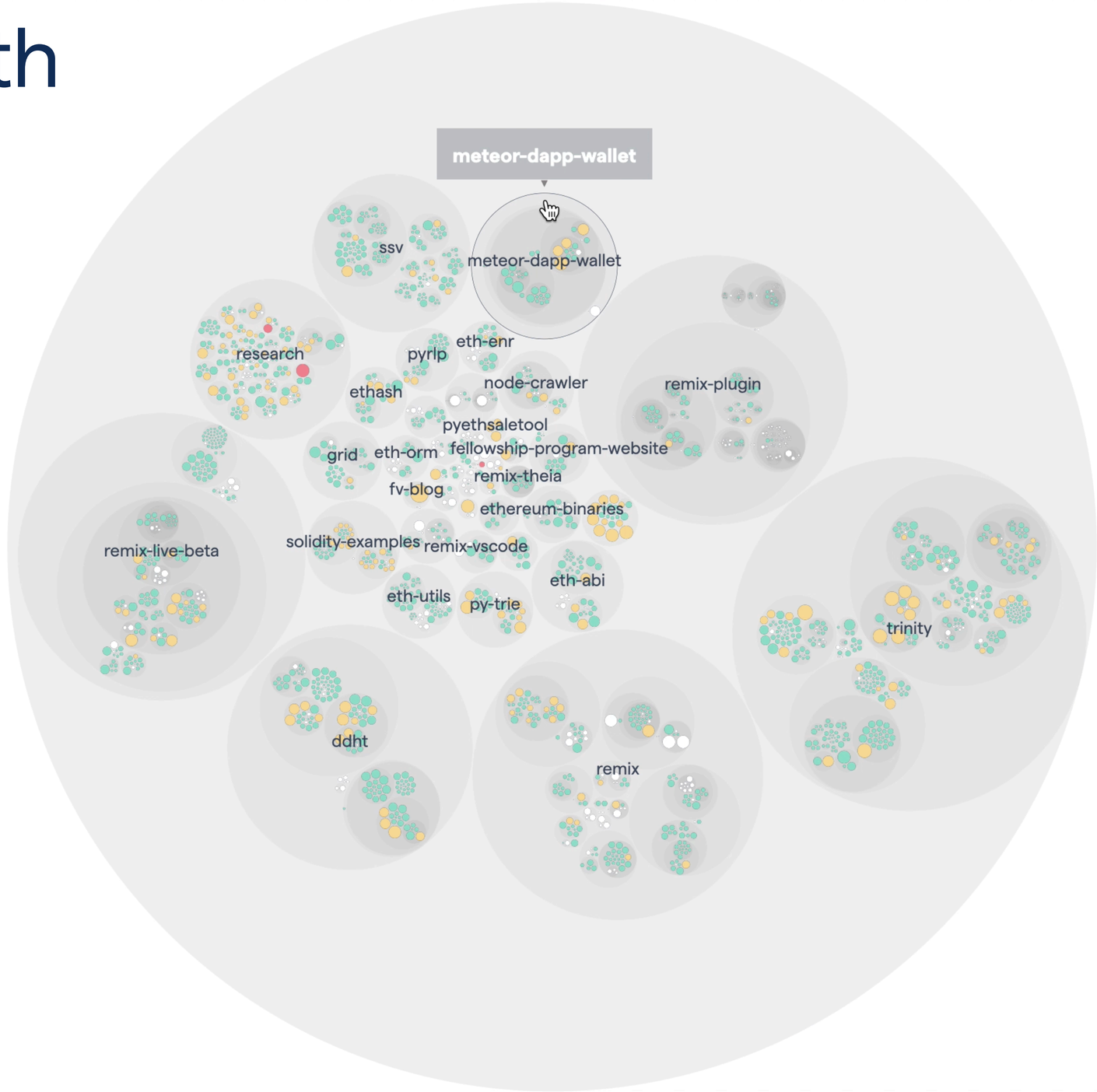

Visualizing code health

Ethereum: a decentralized, open-source blockchain with smart contract functionality

Example on 50 repositories

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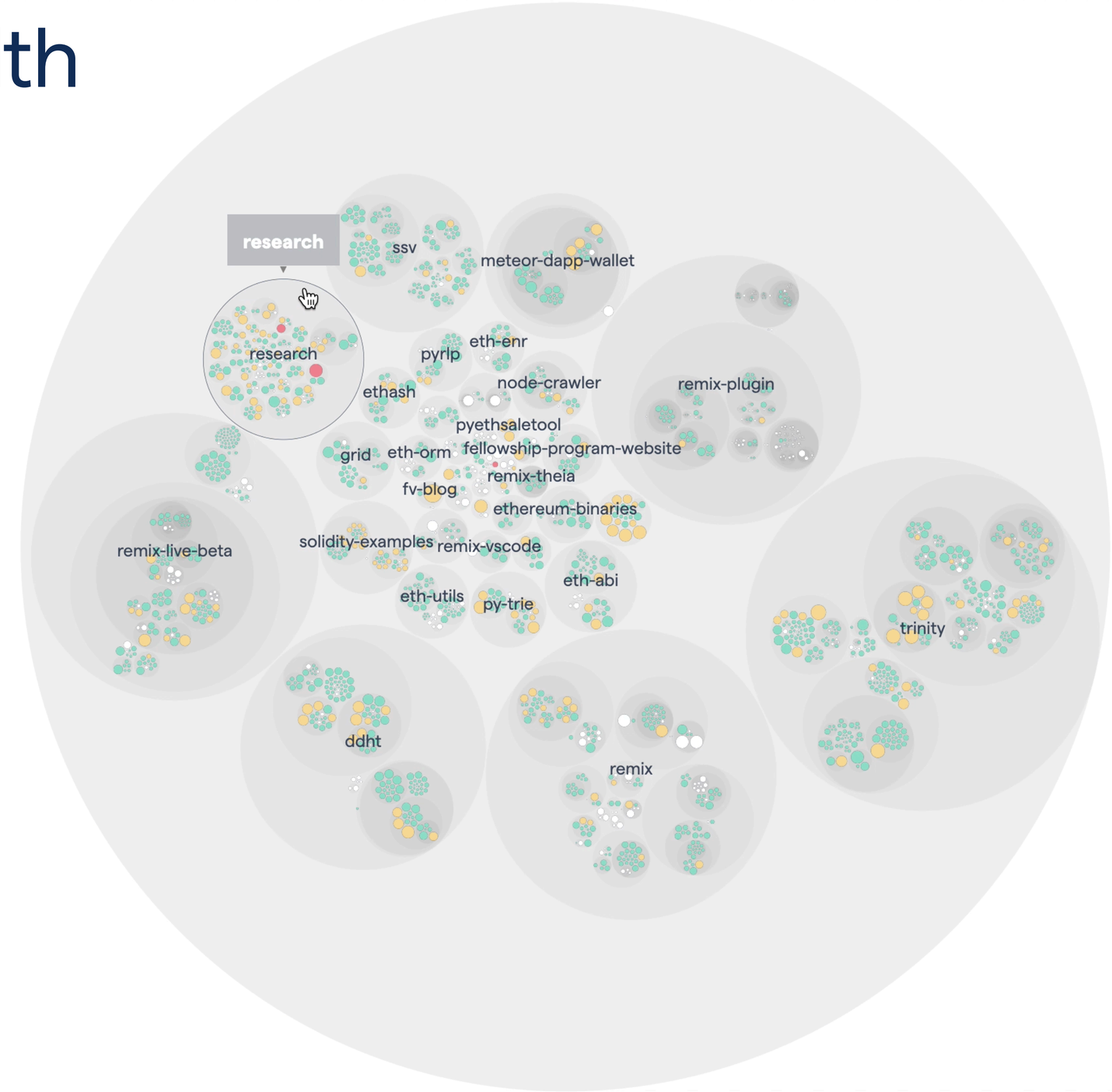
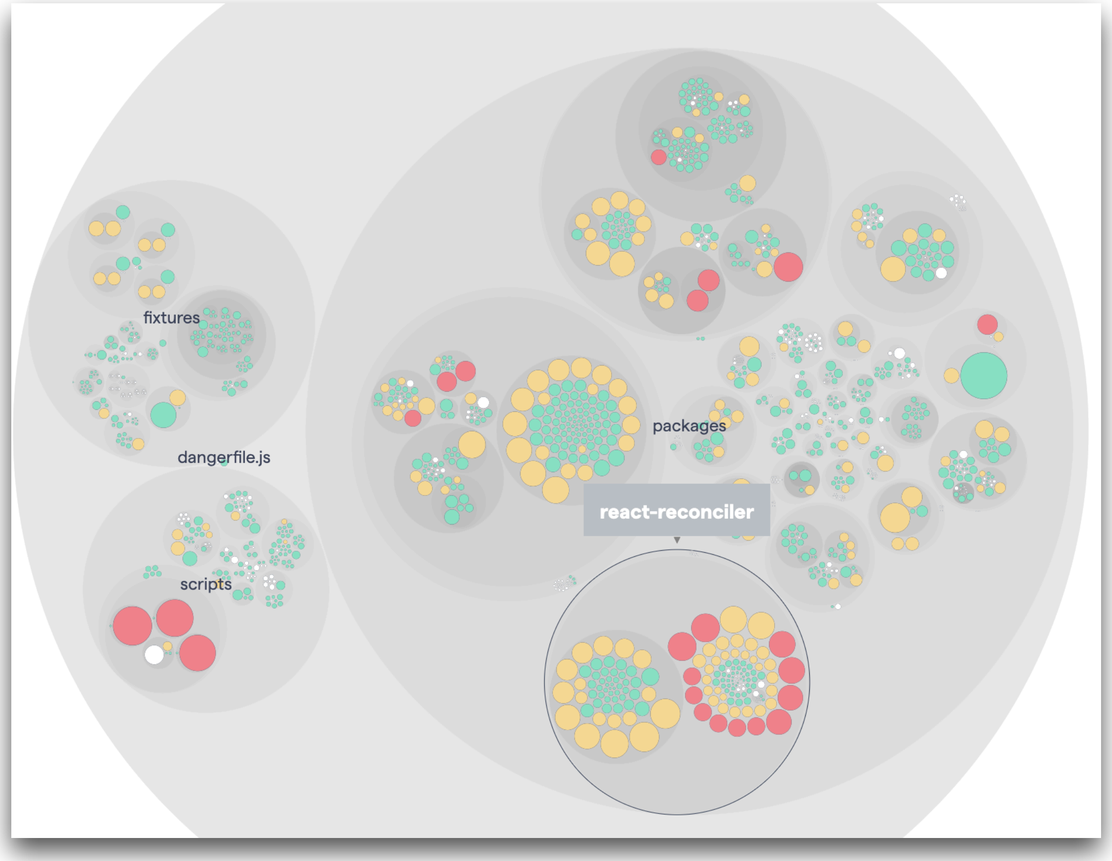


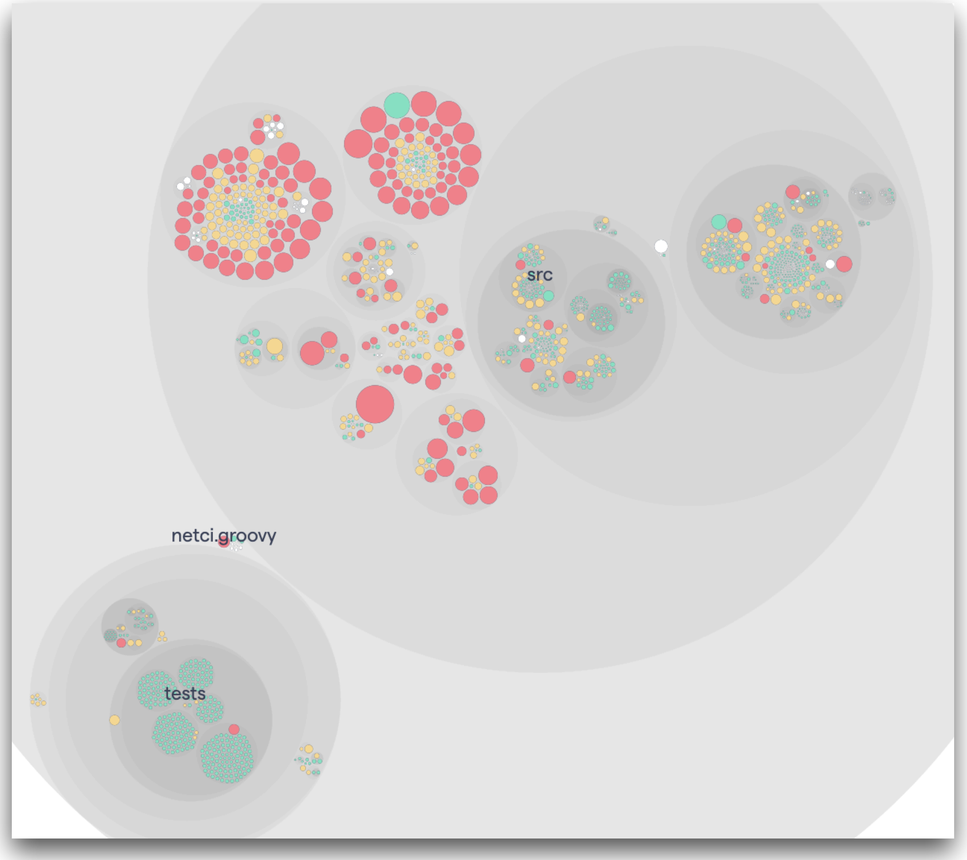
Examples: **a gallery of code**



React: a UI library

340k lines of code

https://github.com/facebook/react



CoreCLR: the runtime for .Net

8.5 million lines of code

https://github.com/dotnet/coreclr

From “knowing” to knowing:

Quantify the business impact of complex code

Research to quantify the impact of code quality: scope & data

- A quantitive large-scale study of code quality impact.
- Data from 39 commercial codebases.
- Analysed more than 40 000 software modules.
- Many different industry segments.
- Tested across 14 programming languages.
- Using the CodeScene tool to automated the analyses.
- Our research findings are statistical significant and peer reviewed for the International Conference on Technical Debt 2022[1]

Code Red: The Business Impact of Code Quality – A Quantitative Study of 39 Proprietary Production Codebases

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ABSTRACT

Code quality remains an abstract concept that fails to get traction at the business level. Consequently, software companies keep trading code quality for time-to-market and new features. The resulting technical debt is estimated to waste up to 42% of developers' time. At the same time, there is a global shortage of software developers, meaning that developer productivity is key to software businesses. Our overall mission is to make code quality a business concern, not just a technical aspect. Our first goal is to understand how code quality impacts 1) the number of reported defects, 2) the time to resolve issues, and 3) the predictability of resolving issues on time. We analyze 39 proprietary production codebases from a variety of domains using the CodeScene tool based on a combination of source code analysis, version-control mining, and issue information from Jira. By analyzing activity in 30,737 files, we find that low quality code contains 15 times more defects than high quality code. Furthermore, resolving issues in low quality code takes on average 124% more time in development. Finally, we report that issue resolutions in low quality code involve higher uncertainty manifested as 9 times longer maximum cycle times. This study provides evidence that code quality cannot be dismissed as a technical concern. With 15 times fewer defects, twice the development speed, and substantially more predictable issue resolution times, the business advantage of high quality code should be unmistakably clear.

KEYWORDS

code quality, mining software repositories, business impact, developer productivity, technical debt, software defects

ACM Reference Format:
Adam Tornhill and Markus Borg. 2022. Code Red: The Business Impact of Code Quality – A Quantitative Study of 39 Proprietary Production Codebases. In *Proceedings of ACM Conference (Conference'17).* ACM, New York, NY, USA, 10 pages. https://doi.org/10.1145/nnnnnnn.nnnnnnn

1 INTRODUCTION

Efficient software development is a competitive advantage that allows companies to maintain a short time-to-market [20]. To succeed, companies need to invest in their software to ensure efficient and fast marketplace results [37]. Adding to that challenge, software companies are also facing a challenge in that there is a global shortage of software developers [13]; demand substantially out-weights supply. Moreover, several analyses forecast that the shortage of software developers will only be exacerbated as the digitalization of society continues [11, 13, 29, 43, 48]. At the same time as the software industry is struggling with recruiting enough talent, research indicates that up to 42% of developers' time is wasted dealing with Technical Debt (TD) where the cost of subpar code alone comes to $85 billion annually [57]. This implies that there is an untapped potential in software projects if the code quality is improved and TD paid down.

Unfortunately, the software industry often moves in the opposite direction: research finds that developers are frequently forced to introduce new TD [10] as companies keep trading code quality for time to market and new features [24]. This is a decision-making bias known as *hyperbolic discounting*, i.e., humans make choices today that their future selves would prefer not to have made [35].

One reason for the hyperbolic discounting of code quality is that the business impact of code quality remains vague [32]. This was painfully visible in a study of 15 large software organizations where the benefits of paying down TD is not always clear to managers, and consequently some managers would not grant the necessary budget, nor priorities, for refactoring [38]. The lack of clear and quantifiable benefits makes it hard to build a business case for code quality and, hence, easy to trade short-term wins for long-term sustainability and software maintenance; there are no standard Key Performance Indicators (KPIs) for code quality that are relevant to companies in the way that financial KPIs are [5]. Consequently, in a study involving 1,831 participants, only 10% reported that their business manager was actively managing TD [21]. To make a change, we conclude that TD needs visibility throughout the whole organization, which includes business managers, not just developers and architects.

Second, software organizations lack a way of tracking the time wasted on TD with sufficient accuracy [26]. Further, enforcing such detailed time tracking could be perceived as exercising too much control over employees [51] as well as adding too much administrative burden [10]. In consequence, Besker *et al.* report from a study surveying 43 developers that "none of the interviewed companies had a clear strategy on how to track and address the wasted time" [10]. This means that while the overall development costs (e.g. staffing) are known, there is a need for better ways of mapping those overall costs to the additional time spent working on production code of various quality, i.e., the TD interest.

In this paper, we report how code quality impacts development time in 39 proprietary production codebases. We do that by considering CodeScene's Code Health metric[1] as a proxy for code quality. Moreover, we explore an algorithm to capture the development

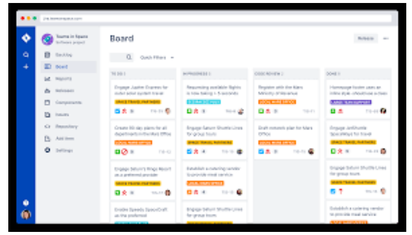
Conference'17, July 2017, Washington, DC, USA
2022. ACM ISBN 978-x-xxxx-xxxx-x/YY/MM…$15.00

[1] Research publication: https://arxiv.org/abs/2203.04374

The costs of low code quality: why is it so hard to measure?

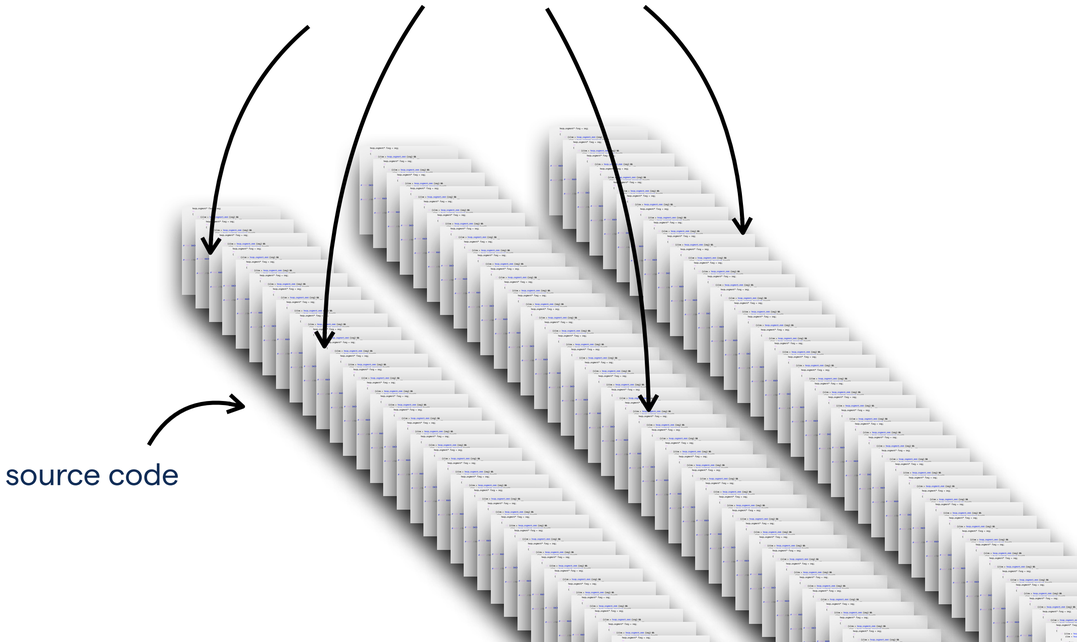
We know the staffing costs..

..and we could (in theory) get the costs per ticket...



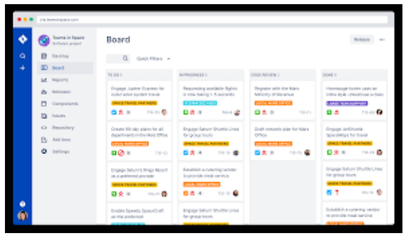
- Organizations don’t know the development costs of individual modules. [1]
- Hence, related numbers (i.e. on technical debt impact) come from surveys and self-reported estimates. [2]

..but we have no way of knowing how those costs are distributed across code of various quality!



1. Tracking detailed time in development would be a significant overhead. A few organisations enforce “Time Spent” to be reported in Jira, but that time is per task level, not per code module
2. Gartner (2021): , McKinsey (2020), Stripe (2018)

Time-In-Development: how do we measure it?

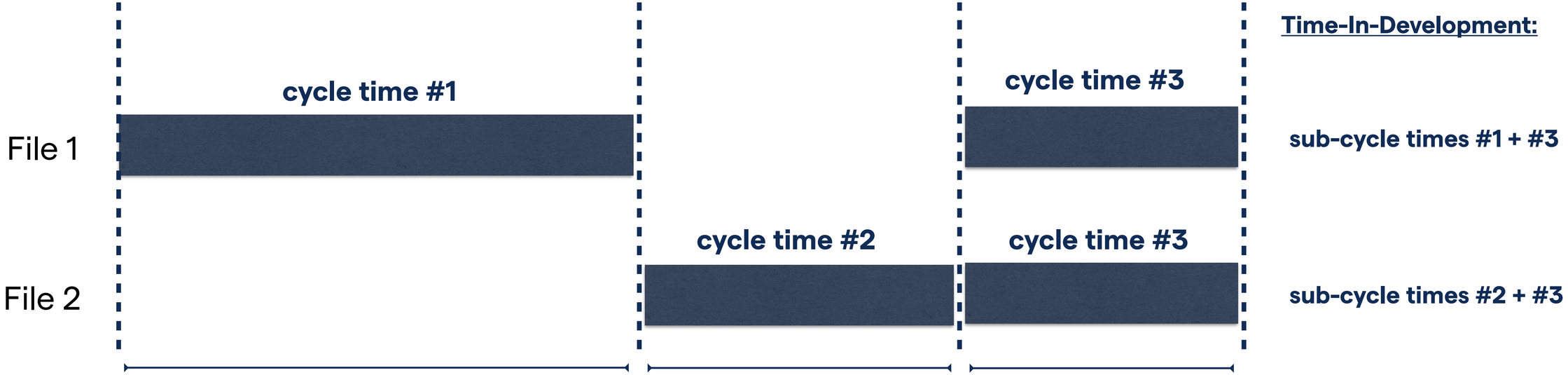


Data source: Jira

Data source: Jira + Git

Jira Issue X moved to “In Progress”:
starts the sub-cycle time #1

commit #1 commit #2 commit #N

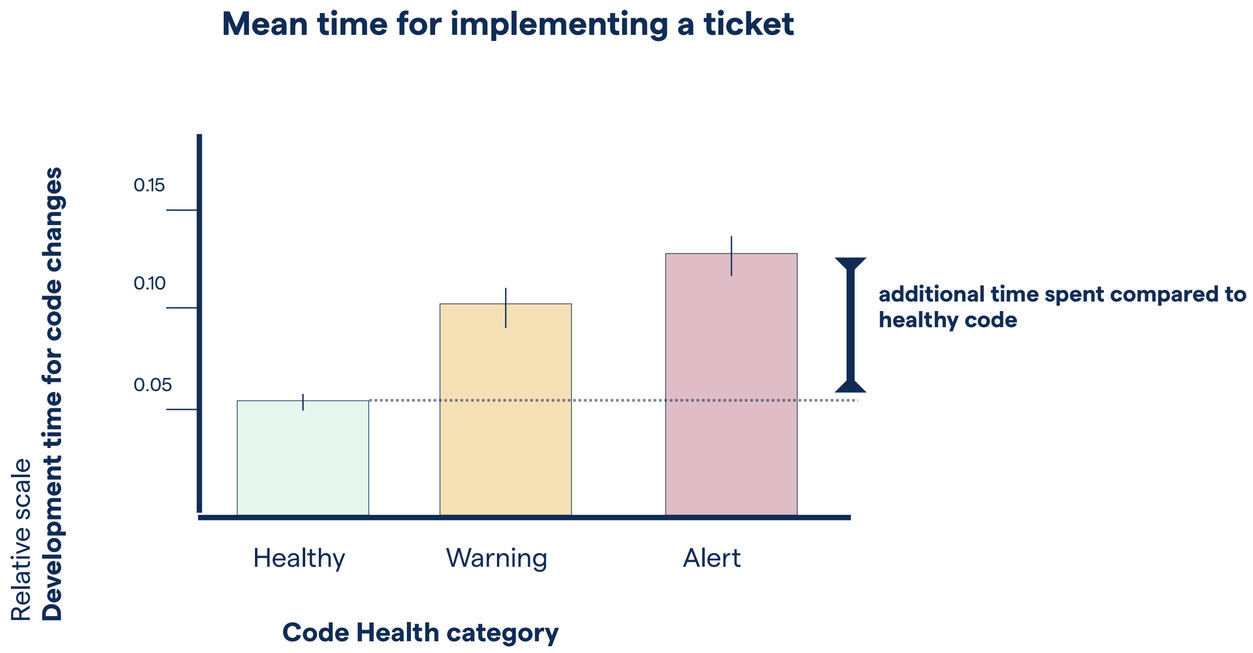


Time-In-Development:

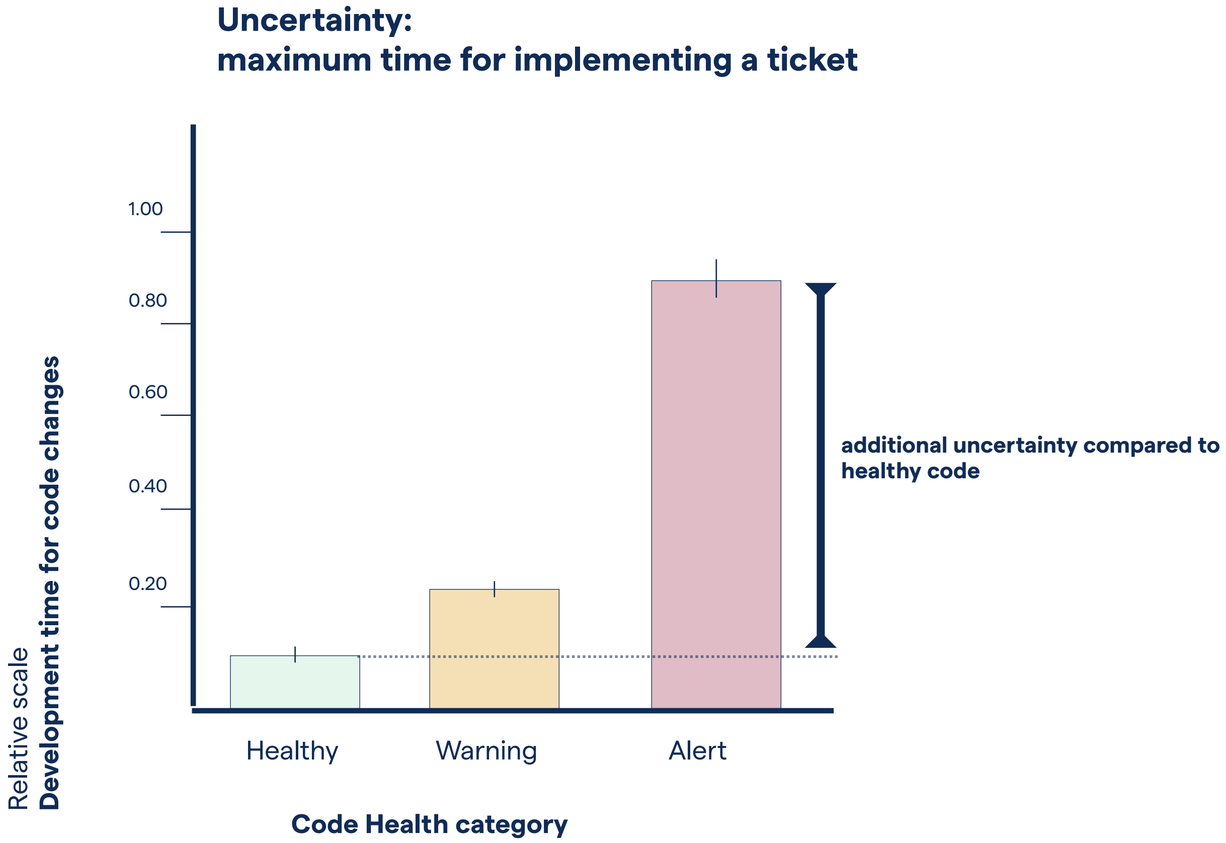
The results:

Does code quality matter?

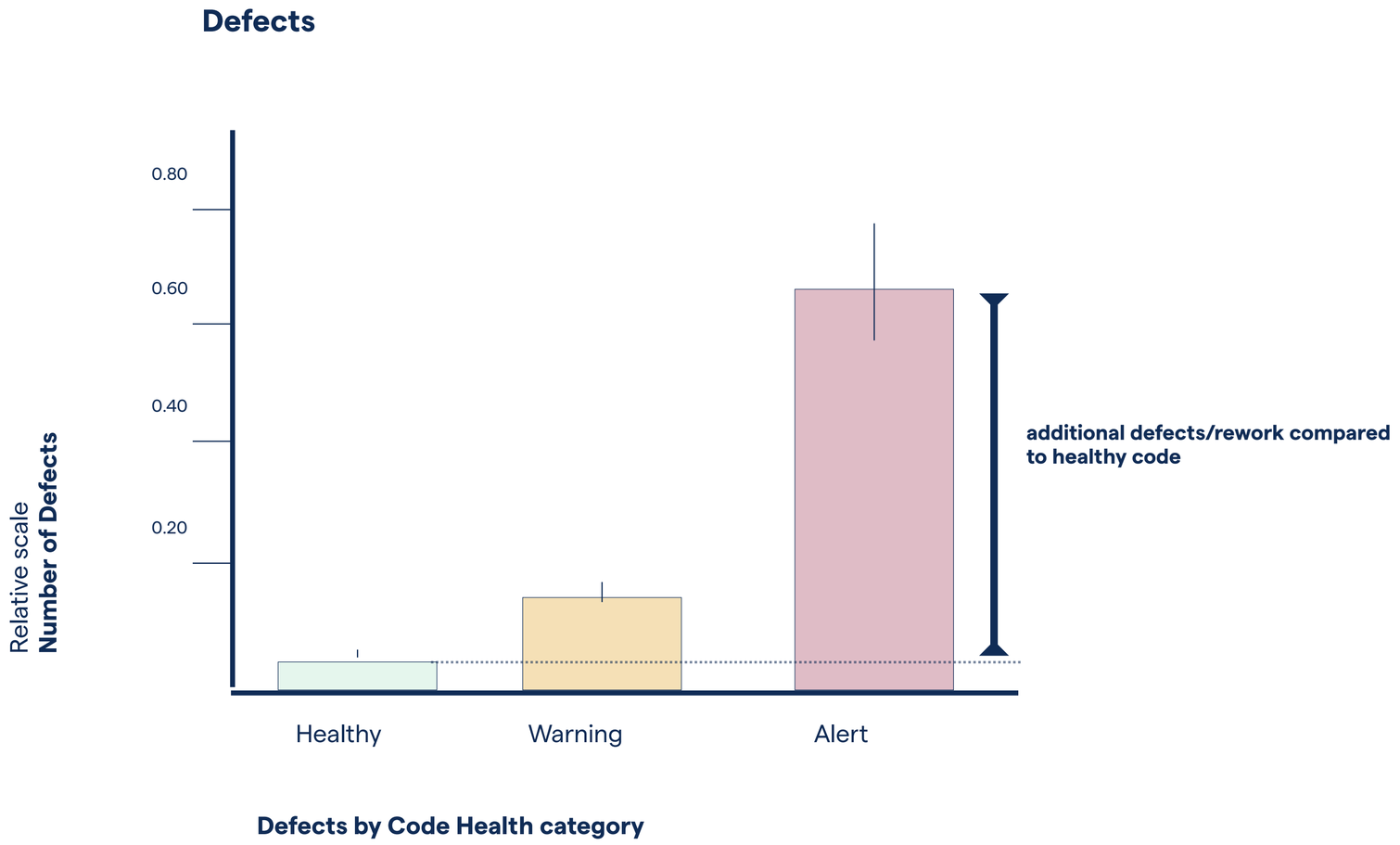
Green Code: Implementing a feature is twice as fast



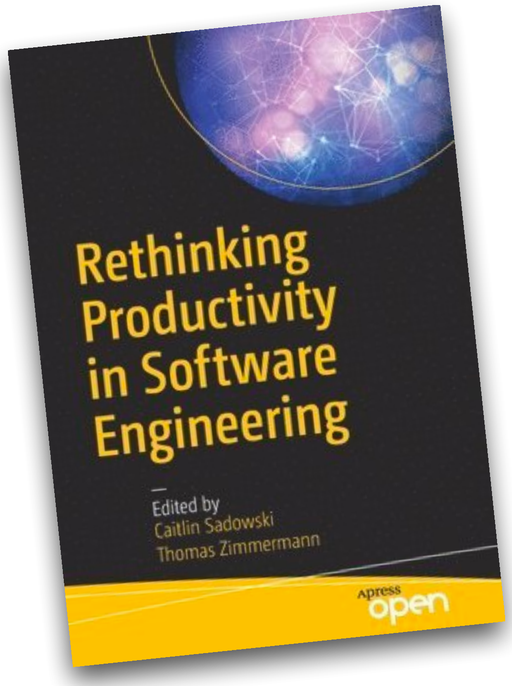
Red Code: A feature can take up to 9 times longer



Red Code: 15 times more defects



The programmer perspective: **how low quality code impacts development teams**



The most frequent causes of unhappiness:

1. Stuck in problem-solving
2. Time pressure
3. Work with bad code

“[Developers] suffer tremendously when they meet bad code that could have been avoided in the first place”

Grazitotin, D., & Fagerholm, F. (2019). “Happiness and the Productivity of Software Engineers"

Theory into practice: how would we use this data?

Code quality constraints a business

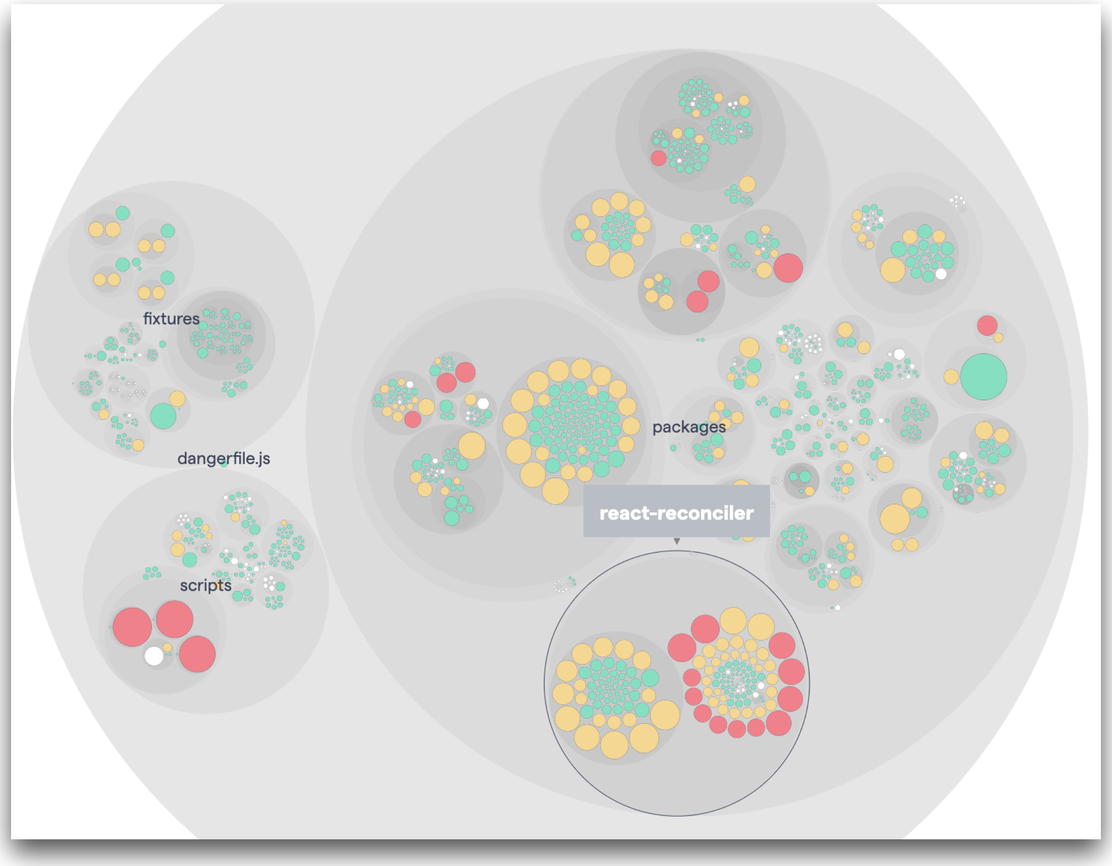
- Give all stakeholders — devs, product, management — the same situational awareness of where the strong and weak parts are.

Fight hyperbolic discounting:

- Discussing future risks primes you for starting to address them.

Build a business case for improvements:

- Refactoring and larger improvements can come with a business expectation.

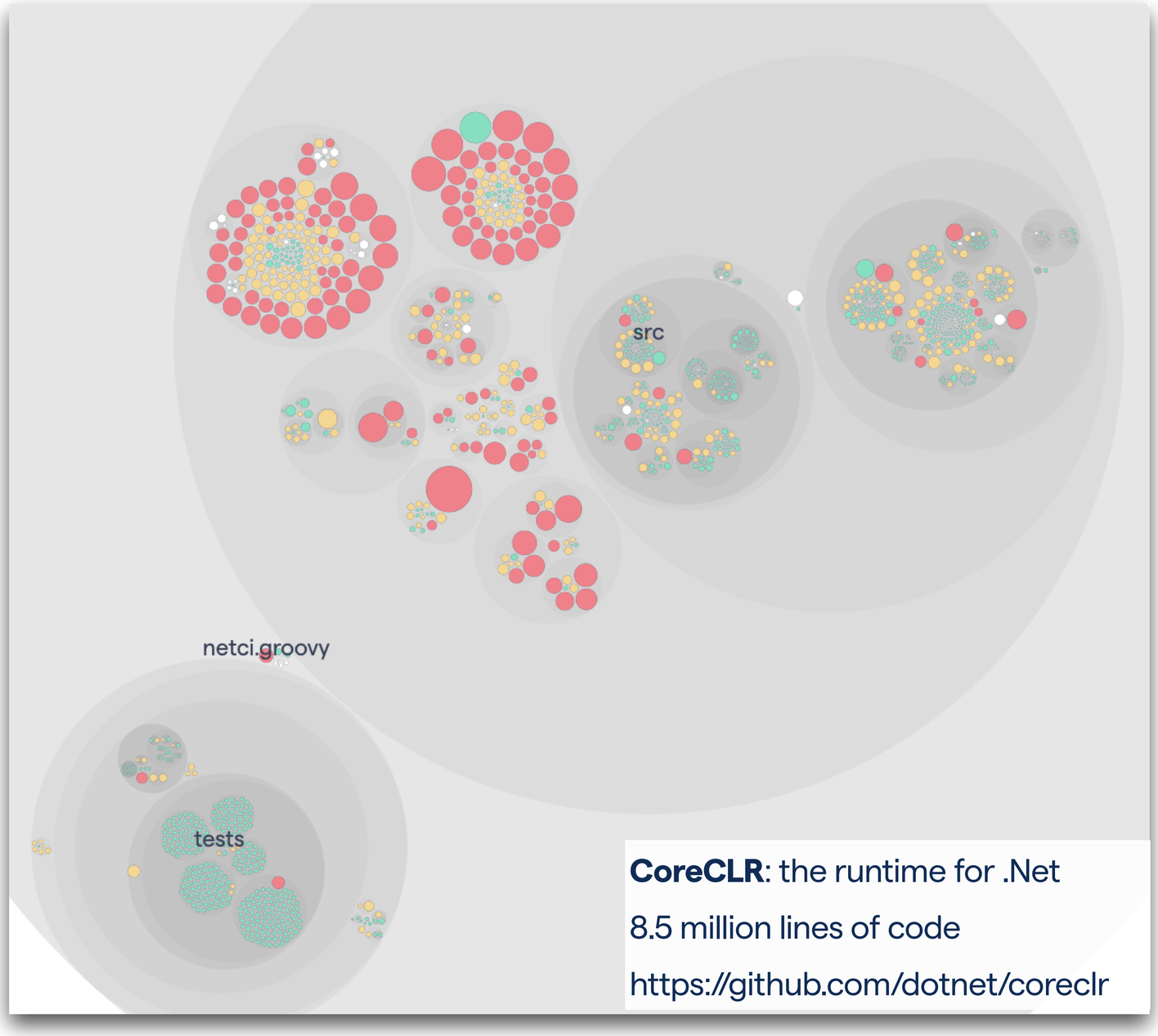


Making it actionable by combining People + Code:

Prioritize large amounts of technical debt

Red Code:

Where do we start?



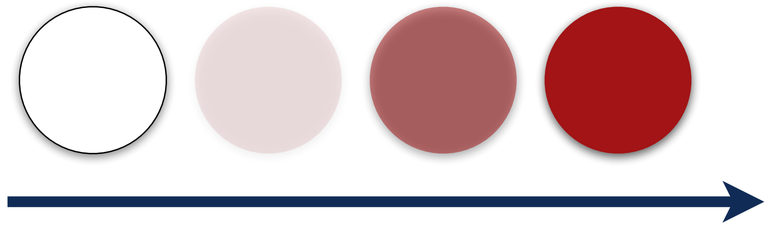
CoreCLR: the runtime for .Net

8.5 million lines of code

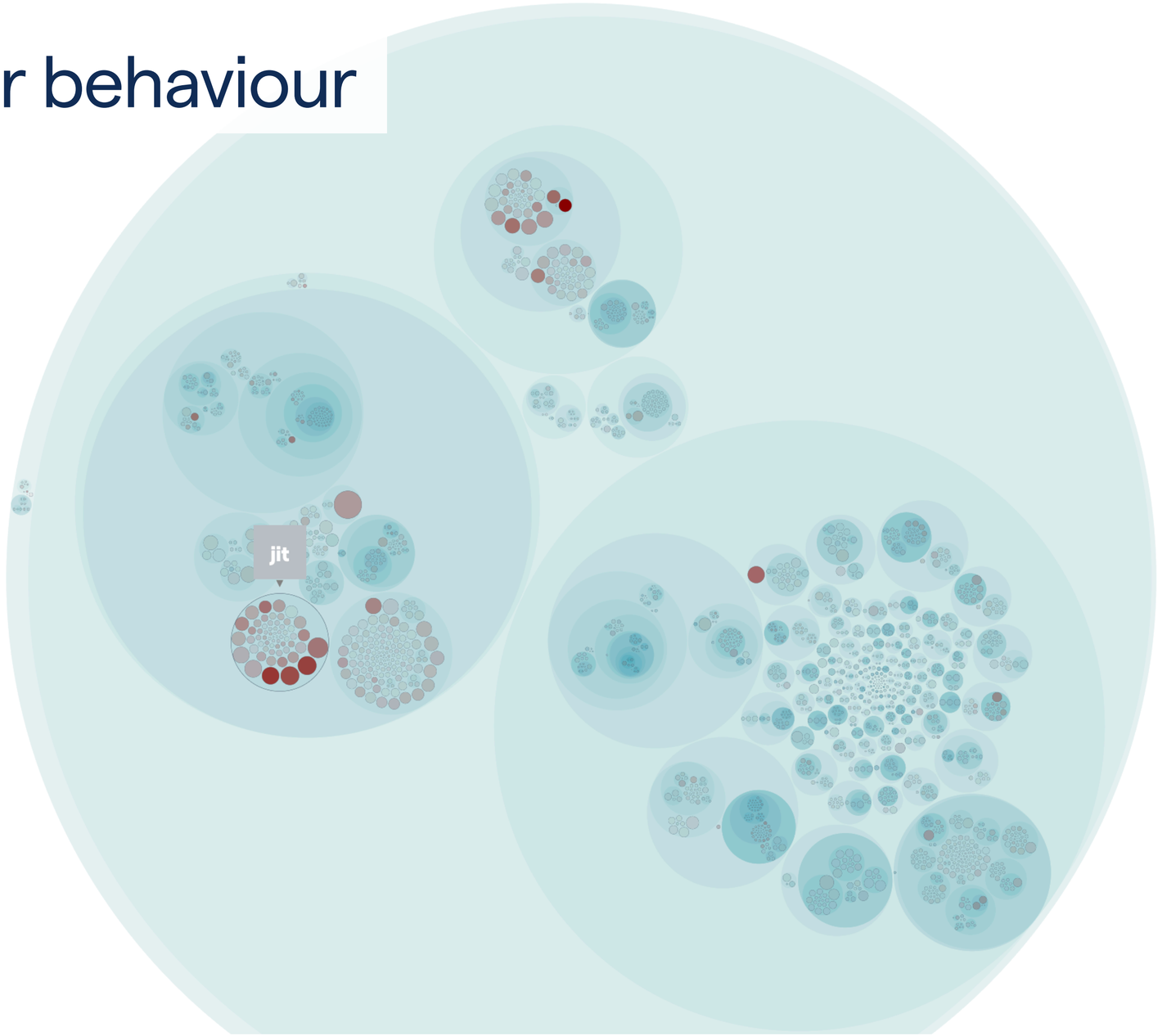
https://github.com/dotnet/coreclr

Hotspots:

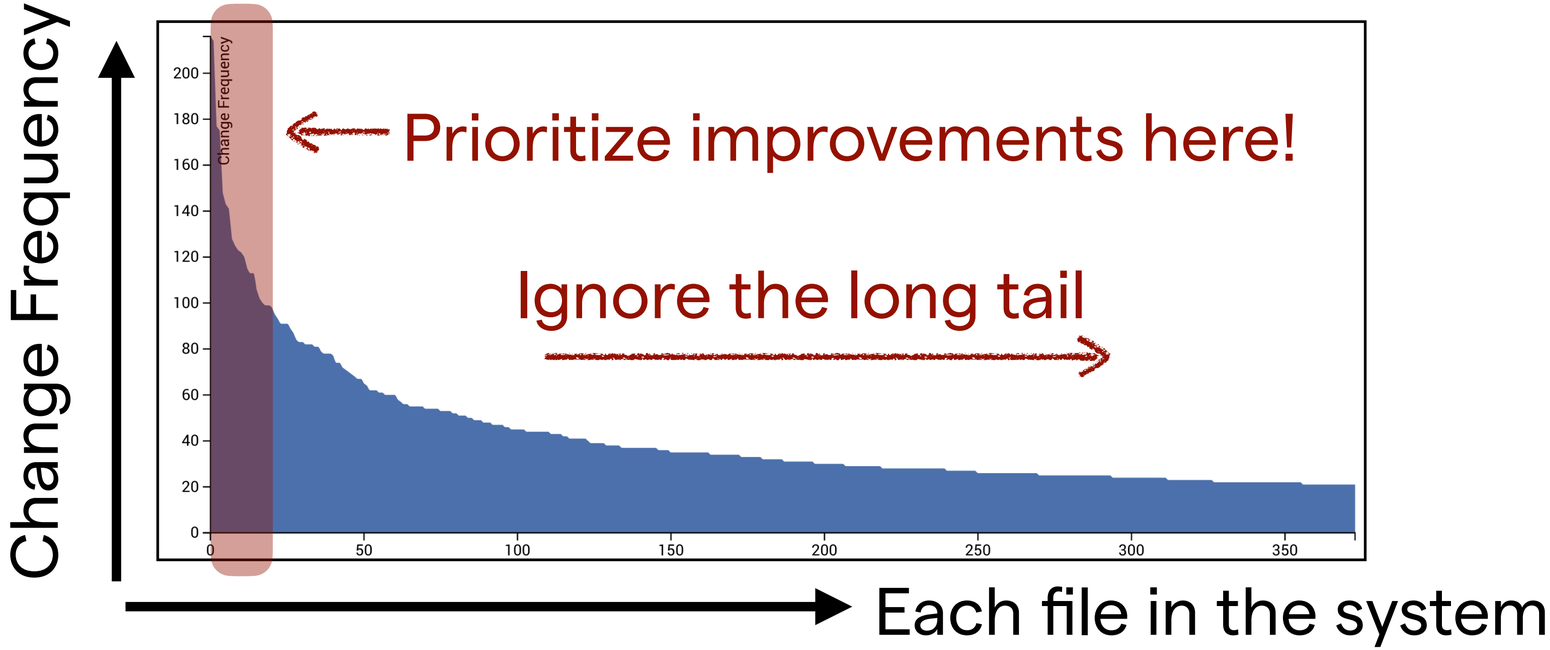
Prioritize based on developer behaviour



Interest rate: Code Change Frequency



Hotspots: why you don't have to fix all tech debt

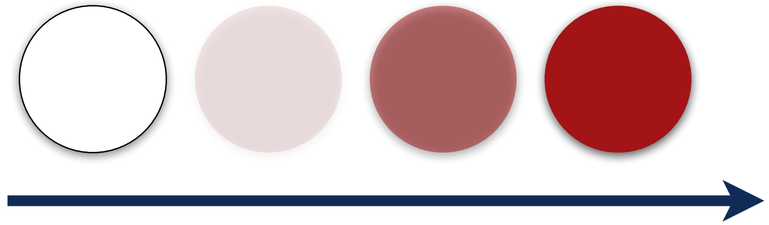


Key take-aways:

- Most code is in the long-tail. This is low-interest debt.
- Hotspots only make up 2-4% of the total codebase, but attract 20-70% of all development activity!
- Code health issues in a hotspot are expensive. This is high-interest debt.

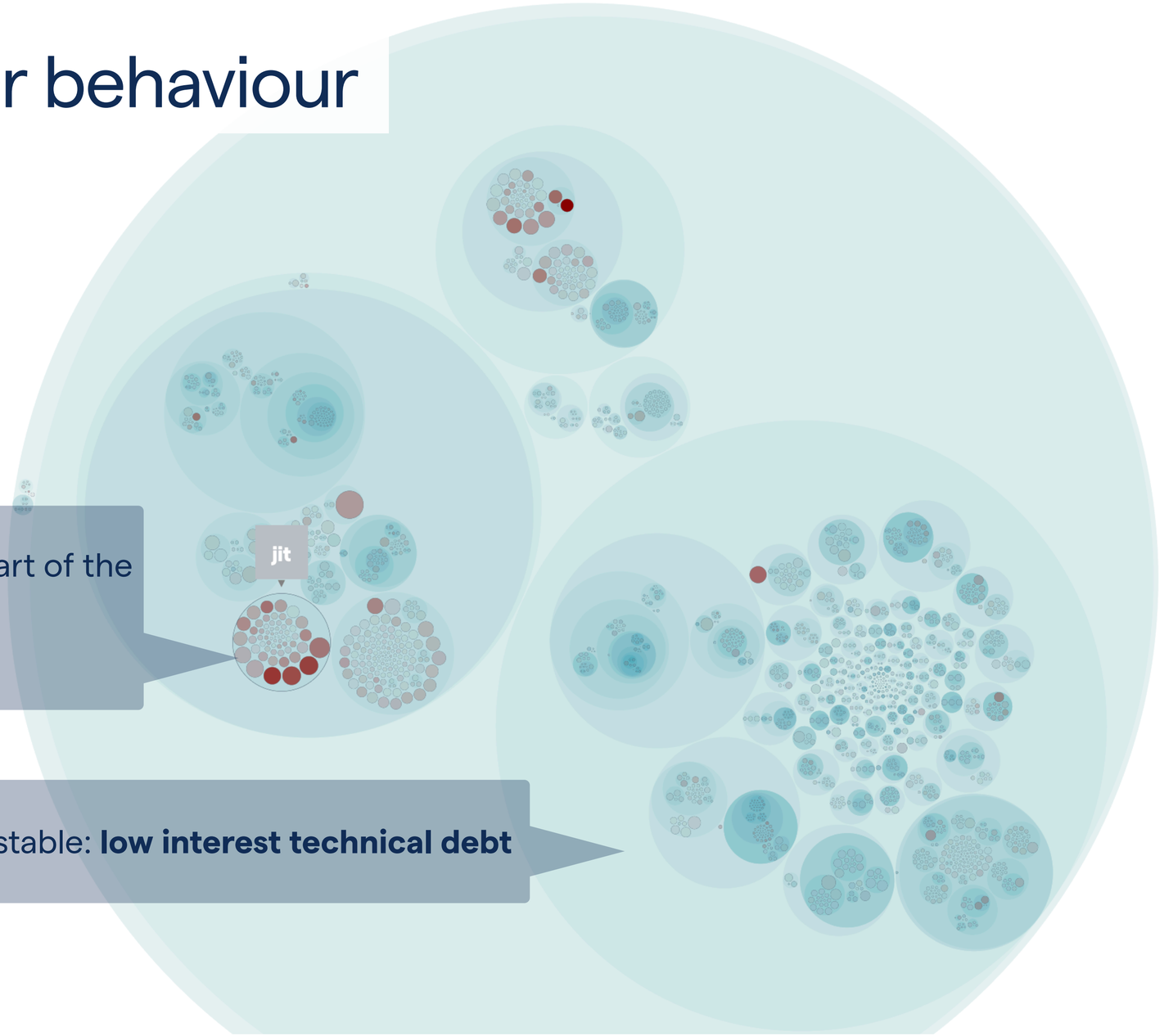
Hotspots:

Prioritize based on developer behaviour



Interest rate: Code Change Frequency

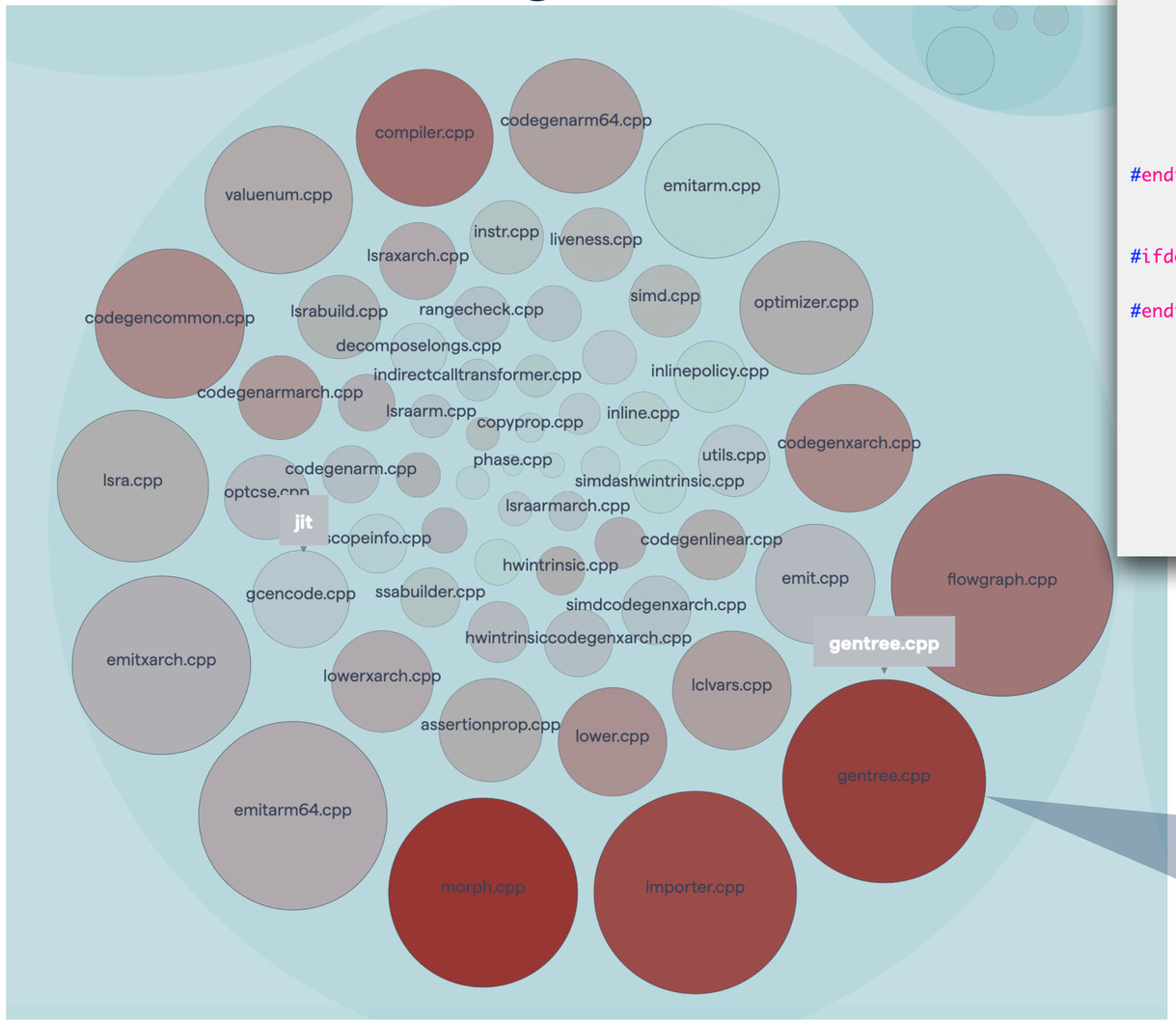
Most development activity is in a small part of the codebase: **high interest technical debt**



Most code is stable: **low interest technical debt**

CodeScene

A look into the *Jit* package:
Actionable Insights?

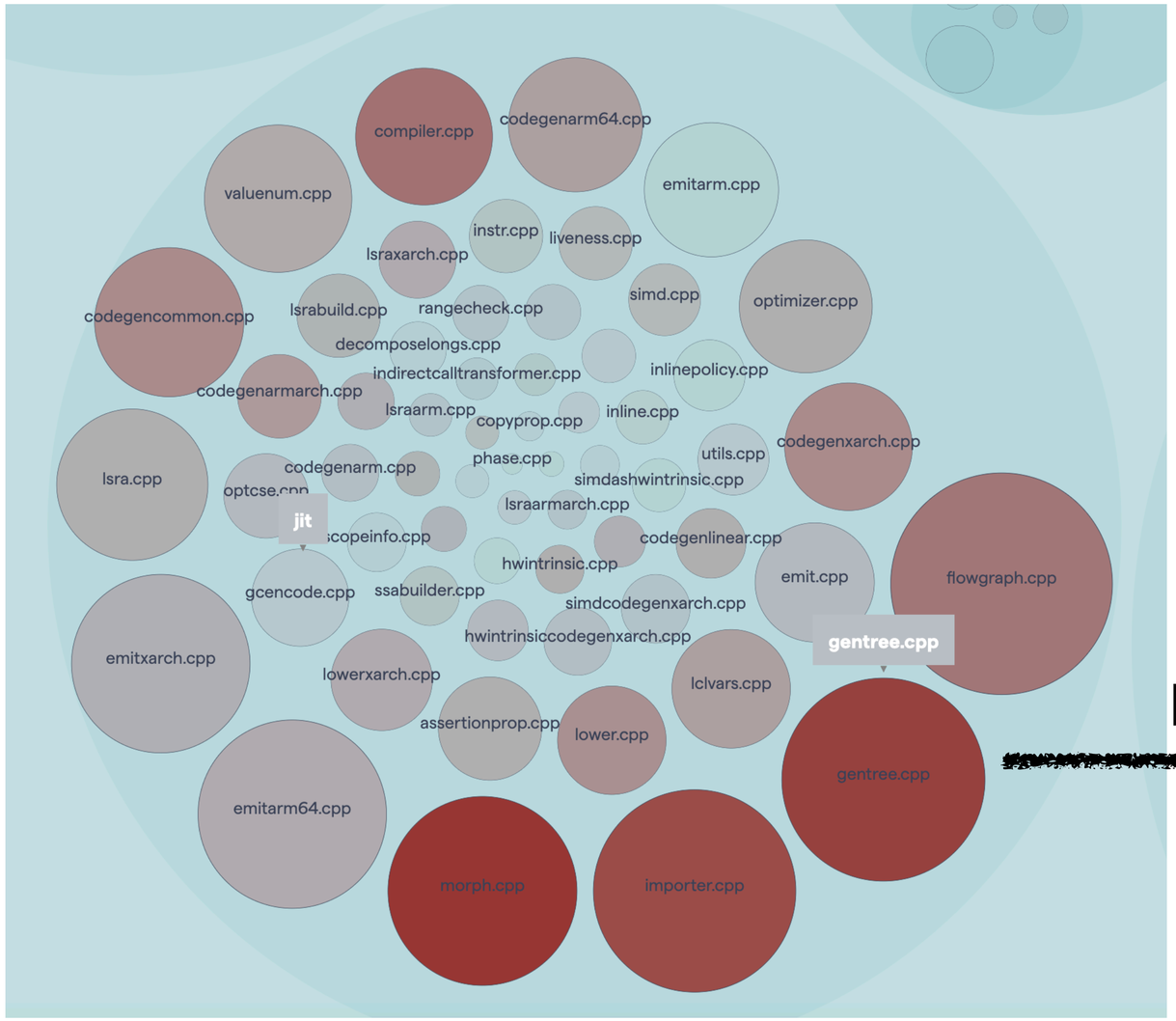



```
    if (kind & (GTK_CONST | GTK_LEAF))
    {
        switch (oper)
        {
            case GT_CNS_INT:

#if defined(LATE_DISASM)
                if (tree->IsIconHandle())
                {
                    copy =
                        gtNewIconHandleNode(tree->AsIntCon()->gtIconVal, tree->gtFlags, tree->AsIntCon(
                    copy->AsIntCon()->gtCompileTimeHandle = tree->AsIntCon()->gtCompileTimeHandle;
                    copy->gtType                          = tree->gtType;
                }
                else
#endif
                {
                    copy = gtNewIconNode(tree->AsIntCon()->gtIconVal, tree->gtType);
#ifdef DEBUG
                    copy->A
#endif
                    copy->A
                    copy->A
                }
                goto DONE;

            case GT_CNS_LNG
                copy = gtNe
                goto DONE;
```

```
case GT_LCL_VAR:

    if (tree->AsLclVarCommon()->GetLclNum() == varNum)
    {
        copy = gtNewIconNode(varVal, tree->gtType);
        if (tree->gtFlags & GTF_VAR_ARR_INDEX)
        {
            copy->LabelIndex(this);
        }
    }
    else
    {
        // Remember that the LclVar node has been cloned. The flag will
        // be set on 'copy' as well.
        tree->gtFlags |= GTF_VAR_CLONED;
        copy = gtNewLclvNode(tree->AsLclVar()->GetLclNum(),
                             tree->gtType DEBUGARG(tree->AsLclVar()->gtLclILoffs));
        copy->AsLclVarCommon()->SetSsaNum(tree->AsLclVarCommon()->GetSsaNum());
```

14,000 Lines of Code!

Hotspots: X-Ray: `gentree.cpp`



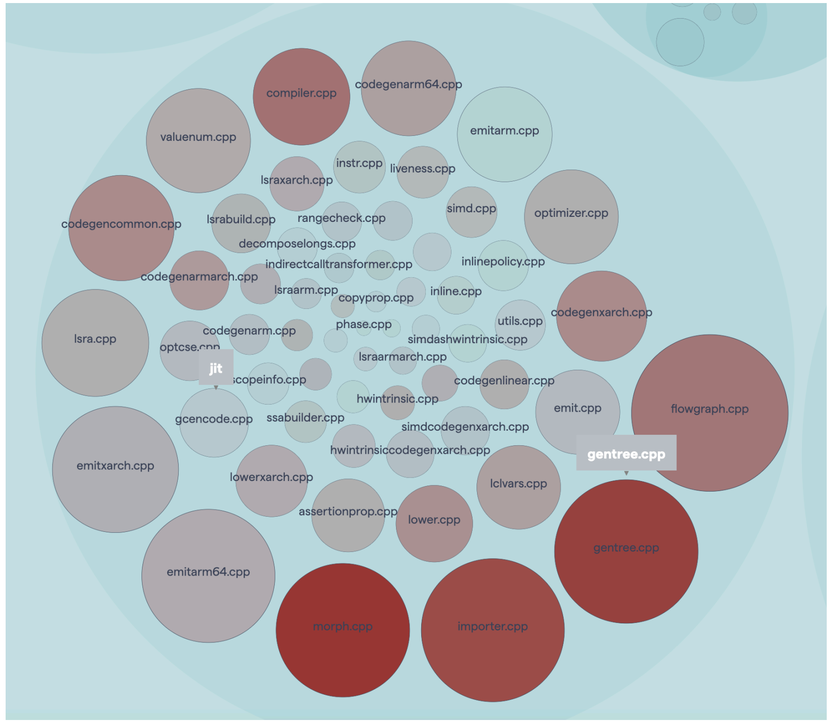
Parse

Function Level Hotspots

Recommended functions to improve.

From https://pragprog.com/book/atevol/software-design-x-rays

X-Ray of `gentree.cpp`

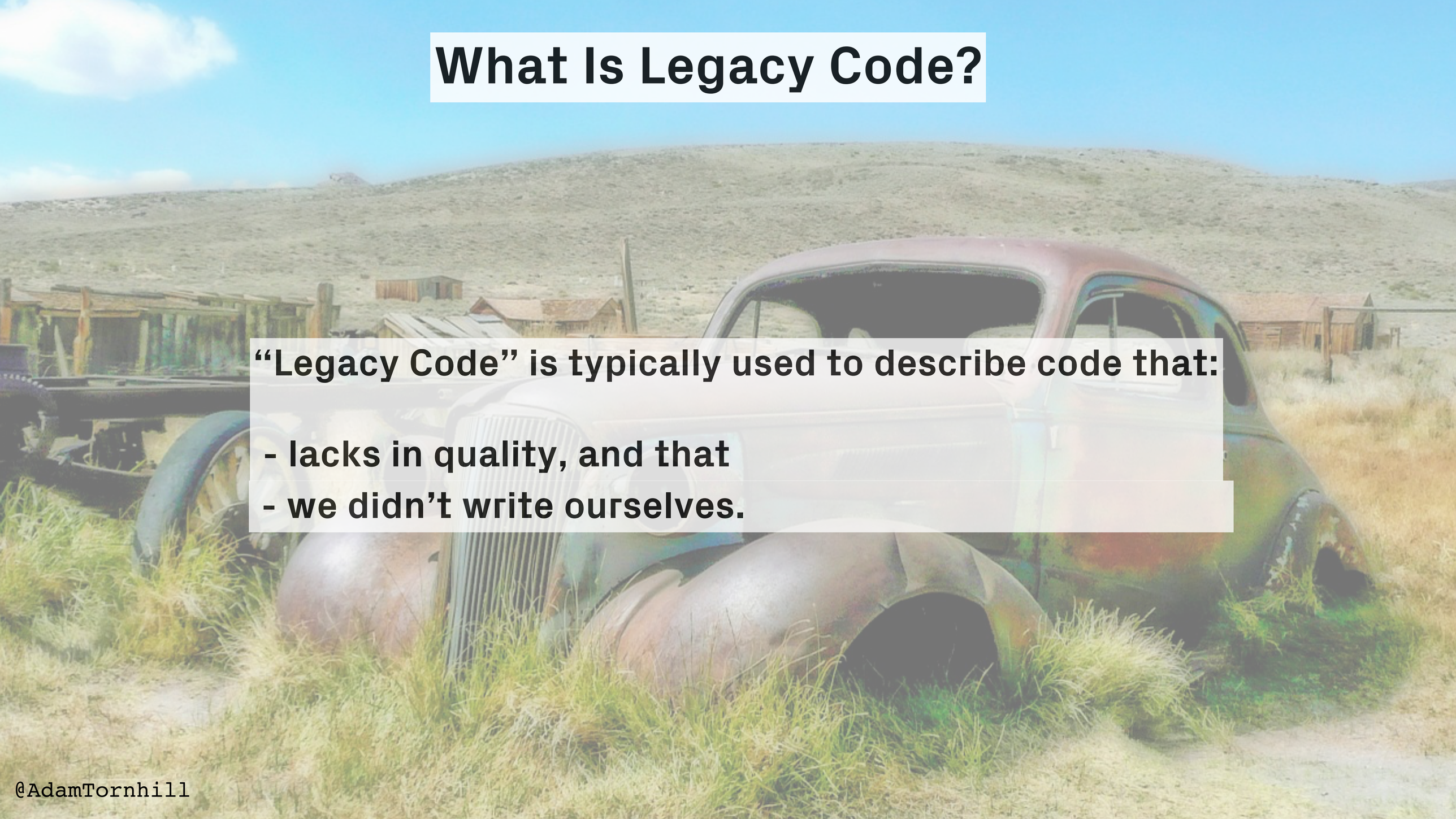


Function	Change Frequency	Lines of Code	Cyclomatic Complexity
`Compiler::gtCloneExpr` View Complexity Trend | View Function Code	42	586	112
`Compiler::gtHashValue` View Complexity Trend | View Function Code	40	335	66
`GenTree::Compare` View Complexity Trend | View Function Code	34	390	110
`Compiler::gtSetEvalOrder` View Complexity Trend | View Function Code	29	1,531	291
`Compiler::gtDispTree` View Complexity Trend | View Function Code	23	578	130
`Compiler::gtDispNode` View Complexity Trend | View Function Code	18	510	125

CodeScene

Green Code:
a guarantee for maintainable codebases?

What Is Legacy Code?



“Legacy Code” is typically used to describe code that:

- lacks in quality, and that
- we didn’t write ourselves.

The Technical Debt That Wasn't

Product #1	Product #2	Product #3
		?

Case Study:

How quick can you turn your current codebase into legacy code?

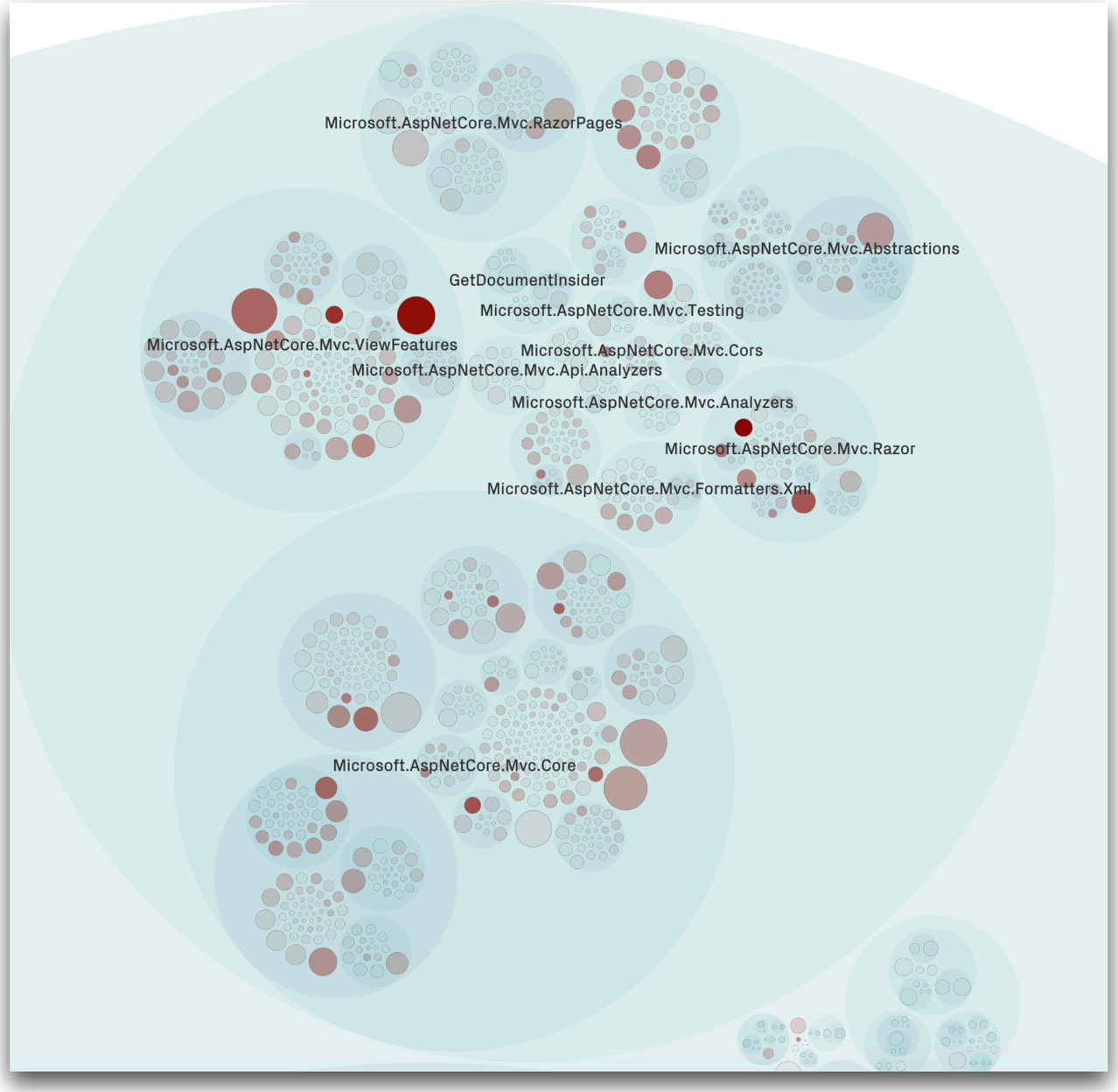
Case Study: ASP.NET MVC Core

ASP.NET MVC Core

~180 Contributors

350,000 Lines of Code

Main language: C#



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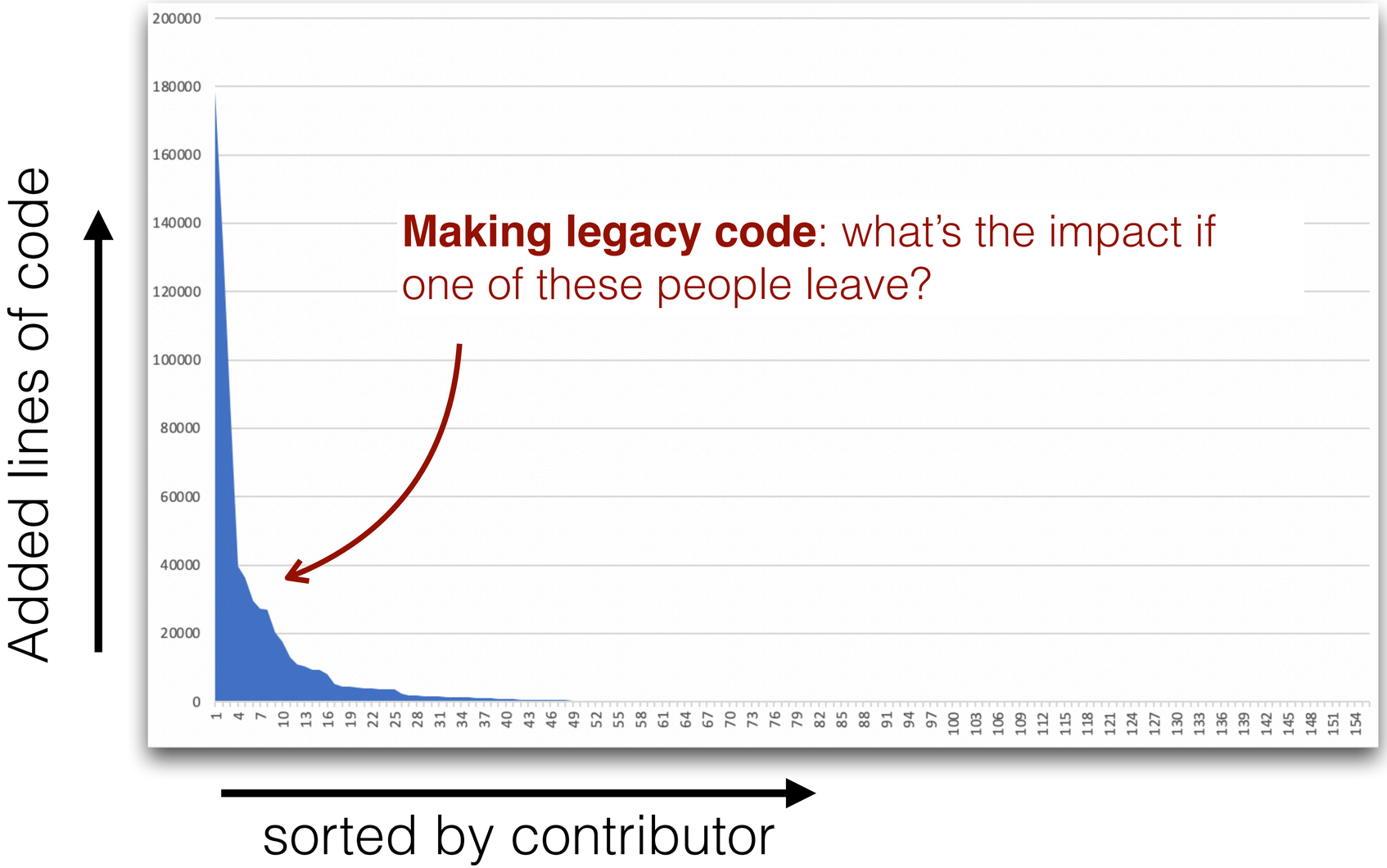
Software Evolution: power laws are everywhere



Case Study: Off-Boarding

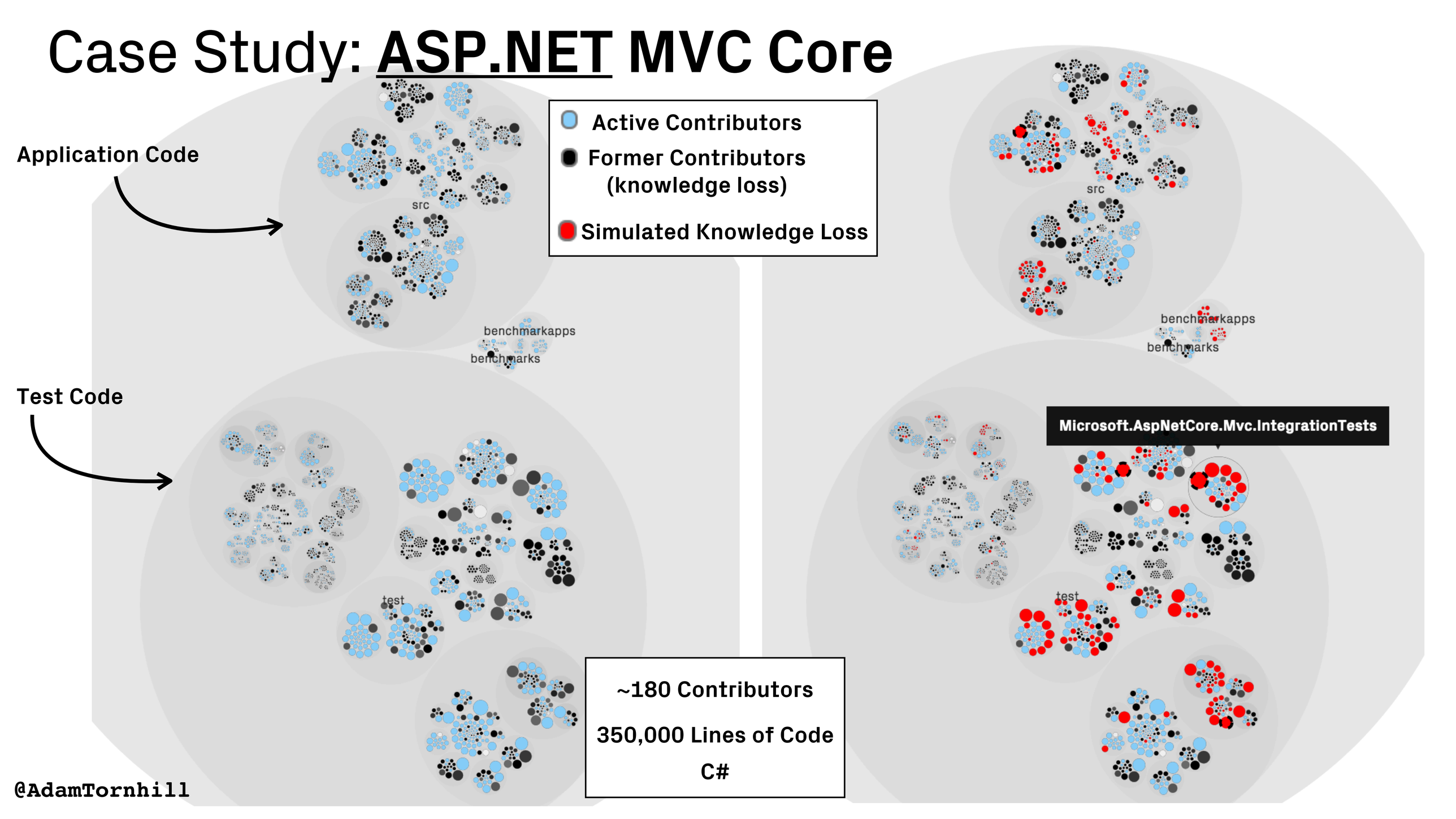
Identify the main developers behind each module

```
Commit: b557ca5
Date: 2016-02-12
Author: Kevin Flynn

    Fix behavior of StartsWithPrefix

     27   src/Mvc.Abstractions/ModelBinding/ModelStateDictionary.cs
     10   src/Mvc.Core/ControllerBase.cs
     1    src/Mvc.Core/Internal/ElementalValueProvider.cs
1    39   src/Mvc.Core/Internal/PrefixContainer.cs

Commit: fd6d28d
Date 2016-02-10
Author: Professor Falken

   Make AddController not overwrite existing IControllerTypeProvider

8    1    src/Core/Internal/ControllersAsServices.cs
48   0    test/Core.Test/Internal/ControllerAsServicesTest.cs
13   0    test/Mvc.FunctionalTests/ControllerFromServicesTests.cs

Commit: 910f013
Date :2016-02-05
Author Lisbeth Salander

   Fixes #4050: Throw an exception when media types are empty.

20   1    src/Mvc.Core/Formatters/InputFormatter.cs
```

Case Study: ASP.NET MVC Core

Application Code

Test Code



~180 Contributors

350,000 Lines of Code

C#

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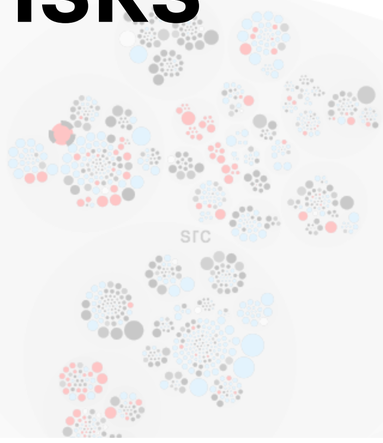
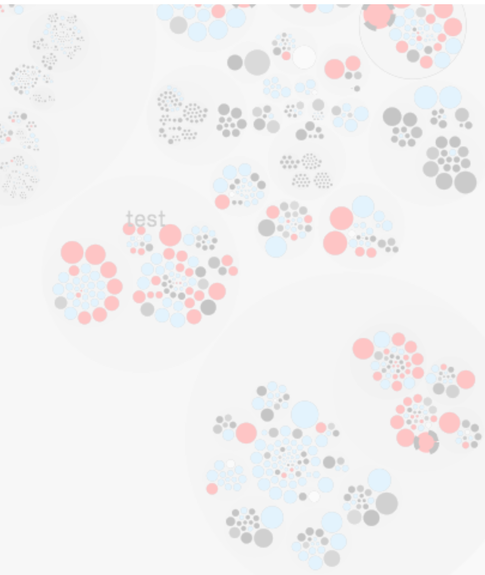
Mitigate off-boarding risks

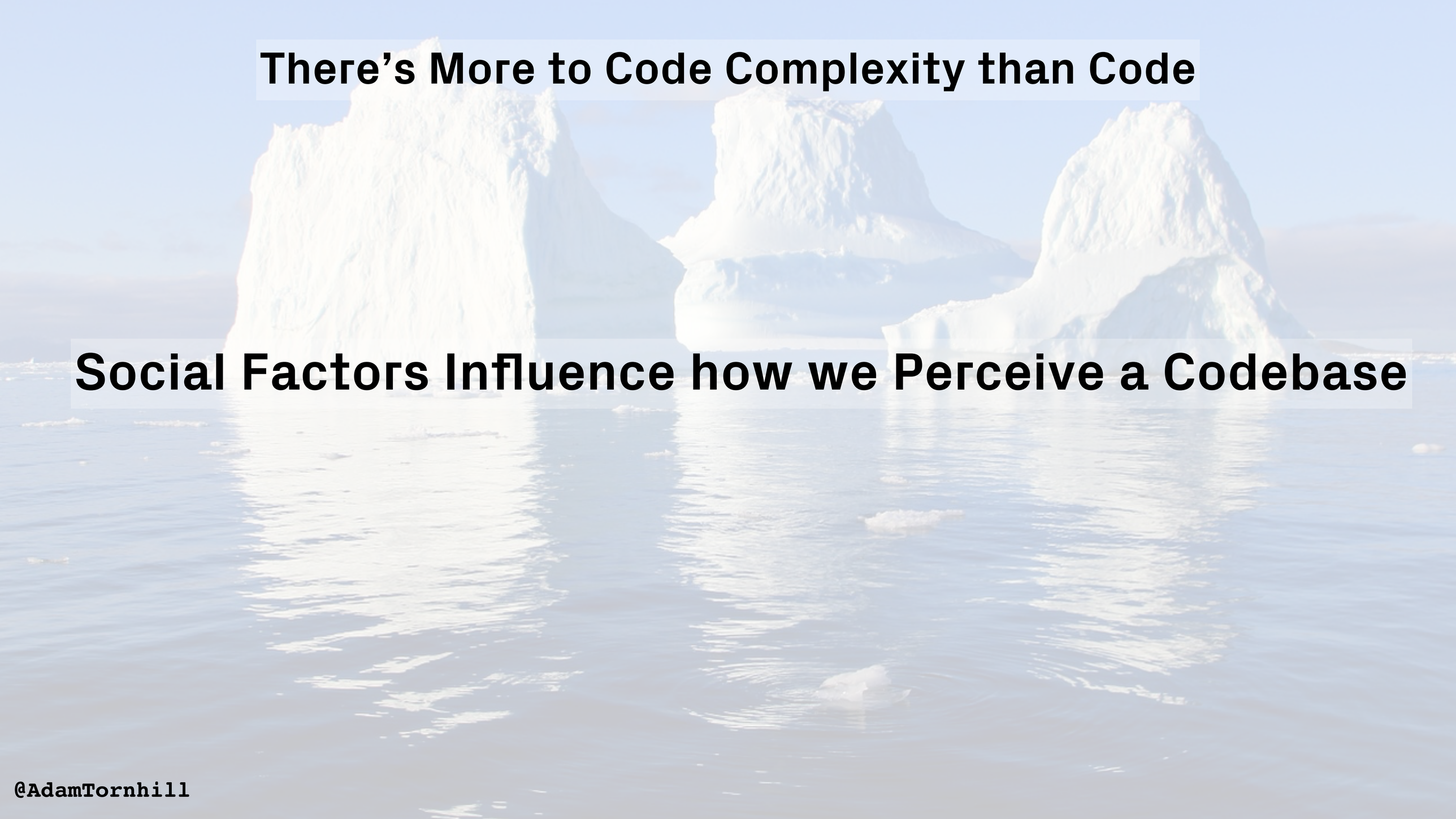


Identify risks by combining three properties:

```
knowledge loss + relevance (hotspot) + impact (complexity).
```

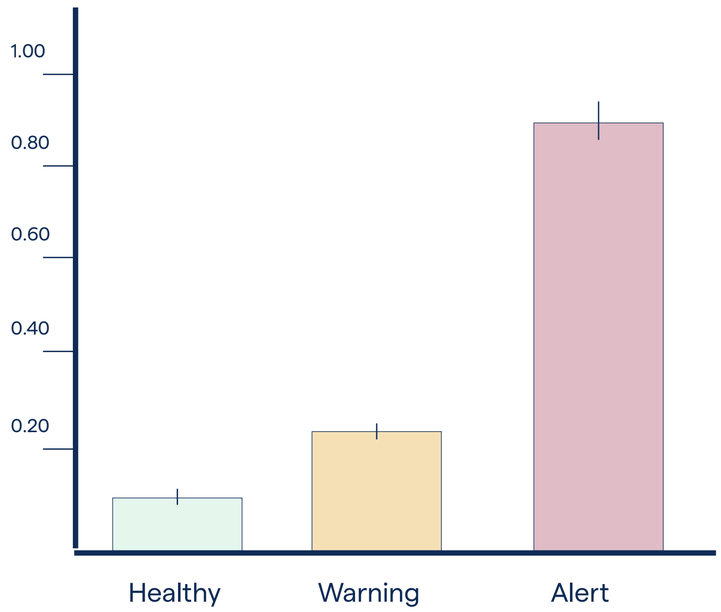
Limit the data to what's actionable.



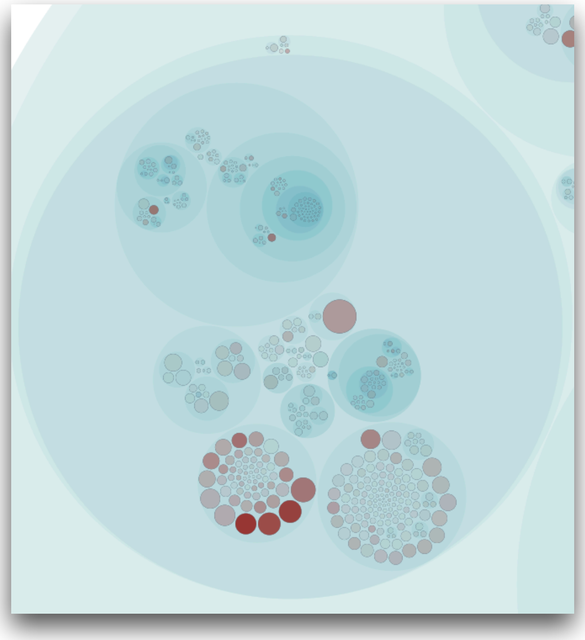

There’s More to Code Complexity than Code
Social Factors Influence how we Perceive a Codebase
@AdamTornhill

Speed + Quality: you can have it all

> “Our results indicate that improving code quality could free existing capacity; with 15 times fewer bugs, twice the development speed, and 9 times lower uncertainty in completion time, the business advantage of code quality should be unmistakably clear.”
>
> A. Tornhill & M. Borg (2022)

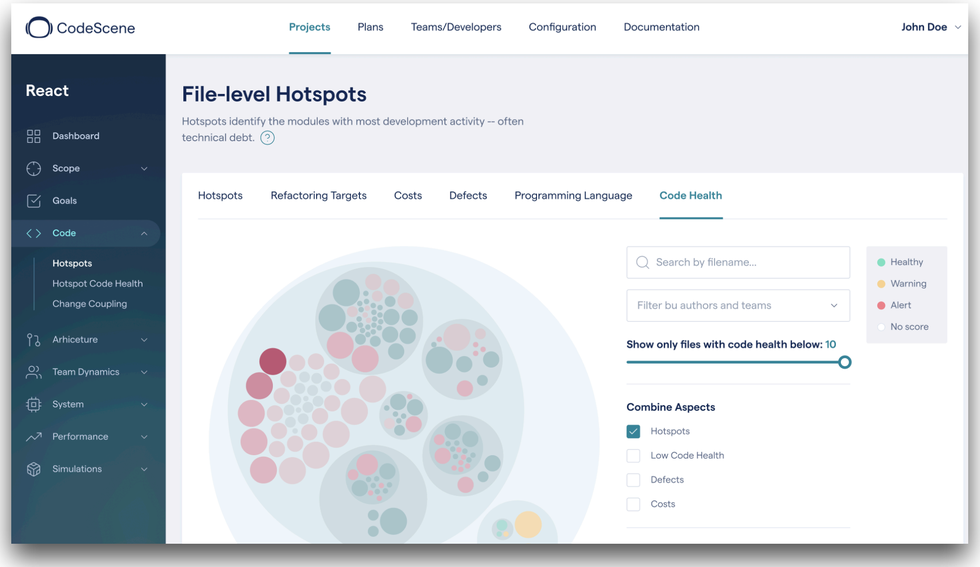


Quality dimension: where are the risks and opportunities?

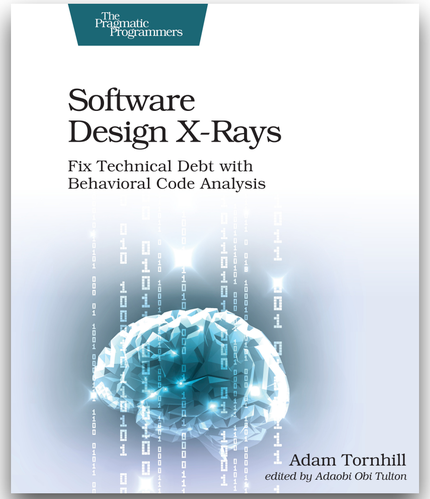


Hotspot dimension: what’s the impact and priorities?

Tools + examples: https://codescene.com/

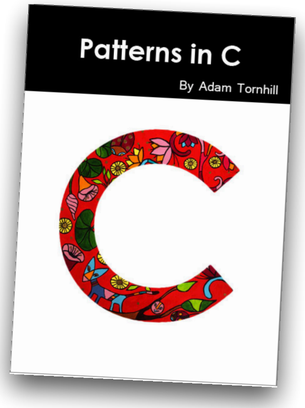


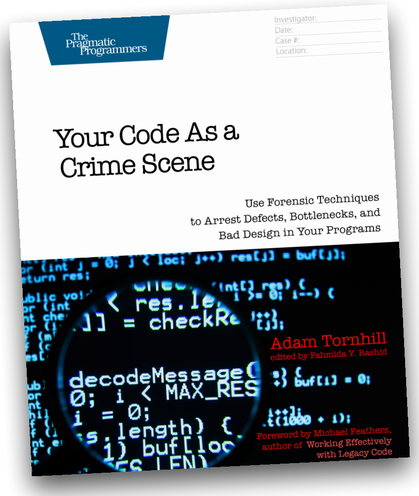
behavioral code analysis techniques, tech debt, teams, microservice analyses



Blogs on Software Evolution, Technical Debt, and Code

- https://www.codescene.com/blog/
- https://adamtornhill.com/





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