

Analysis of Pervasive Multiple-Component Defects in a Large Software System

Z. Li*, M. Gittens*[§], S. S. Murtaza*, N. H. Madhavji*

*University of Western Ontario, London, Canada

[§] University of the West Indies, Cave Hill, Barbados

A. V. Miranskyy⁺, D. Godwin⁺, E. Cialini⁺

⁺IBM Canada Ltd., Toronto, Canada

One-Minute Message

- A certain type of defects:
 - requires **more changes** to fix
 - relates to **sustained** defect-prone components
 - Across system phases and releases
- This talk focuses on a **case study** of a large-scale system where we **identified** and **characterised** this type of defects.

Preliminary Motivation

- From the people dealing with the subject system, **we learnt:**
 - Some defects span phases and releases
 - Some defects require relatively more fixes
 - Some components have sustained defects across phases and releases

Literature Background

- Software defects are not uniform, e.g.,
 - 20% of defects – 60-80% of correction efforts [Ebert et al., 2005]
- System components are not uniform, e.g.,
 - 20% of components – 80% of defects [Boehm and Basili, 2001]

Literature Background

- Software defects are not uniform, e.g.,
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- System components are not uniform, e.g.,
 - 20% of components – 80% of defects [Boehm and Basili, 2001]
- **Multiple-Component Defects (MCDs)**
 - % of defects that require fixes to **multiple** components:
 - 5% [Endres, 1975],
 - 11% [Basili and Perricone, 1984],
 - 6-15% [Basili and Shull, 2005],
 - 4-24% [Weiss, 1979]

Research Gap

- The **fix-effort** profile of **MCDs**
- The **relationship** between **MCDs** and defect-prone components

Benefit: This can help in improving maintenance processes.

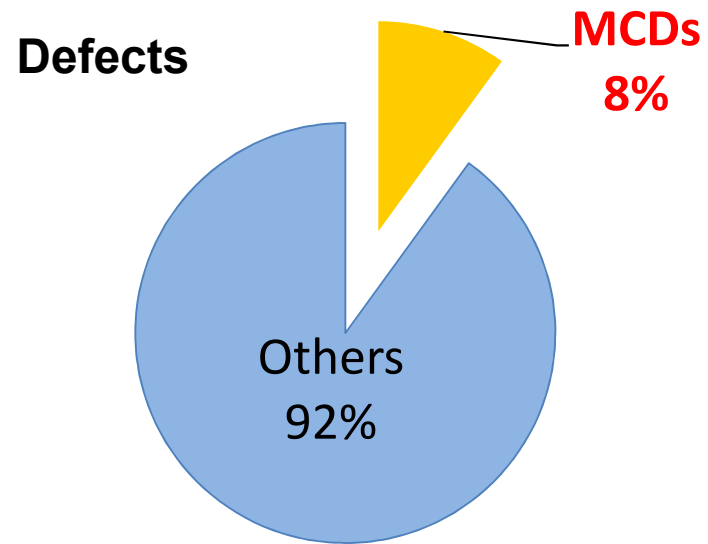
The Case Study

- The Subject System
- The Subject Data
- Research Questions
- Hypotheses
- Findings
- Summary of Findings
- Threats to Validity
- Implications for SW Maintenance

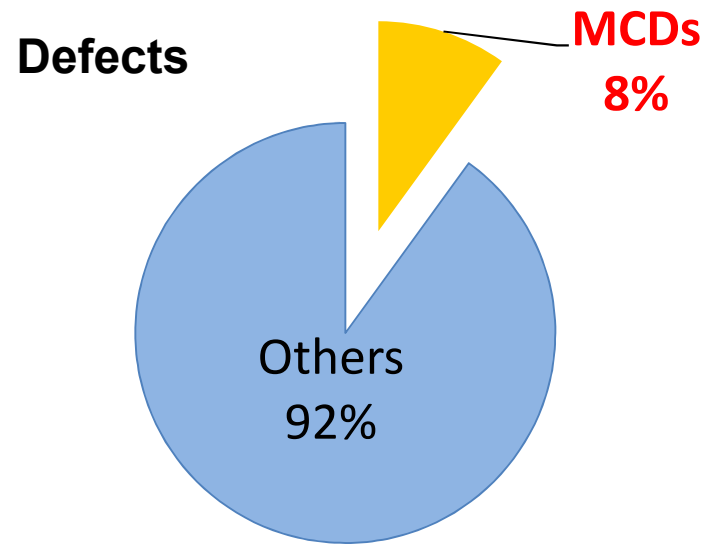
The Subject System

- A complex, large-scale, commercial system
 - >20 million physical lines of code
 - 6 of 9 major releases
 - >17 years
 - Approx. 275 components
- Focus of study: **In-process defects**

The Subject Data

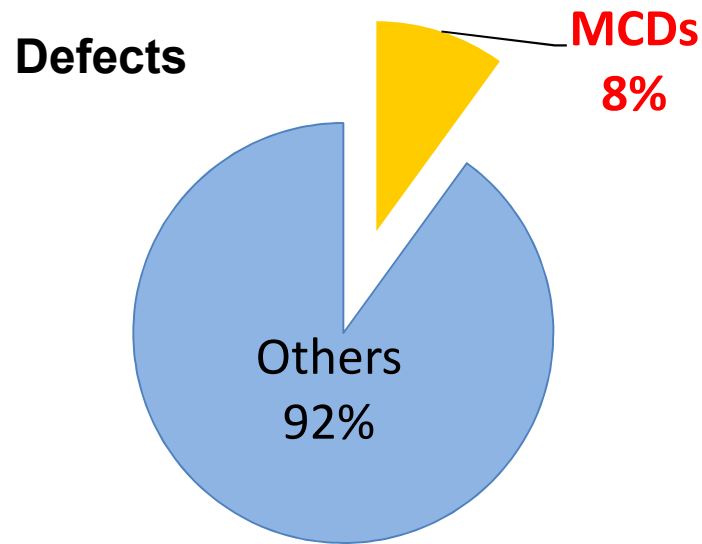


The Subject Data



- If fixing a MCD requires changes in components **A**, **B** and **C**, then these components have a **fix-relationship**.

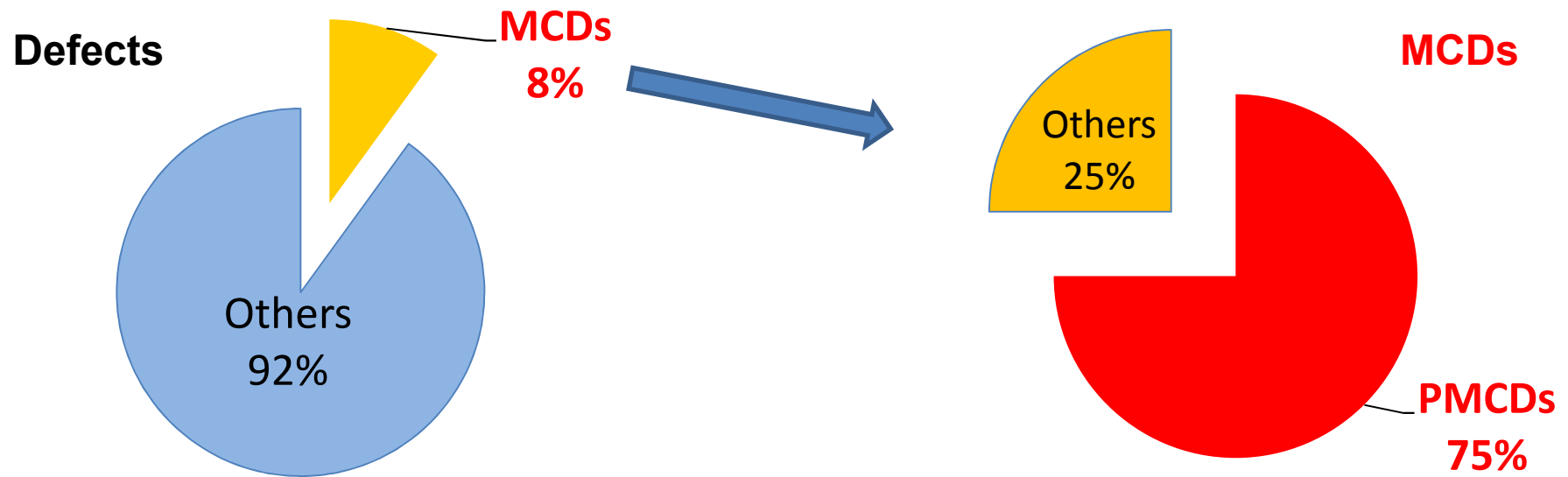
The Subject Data



- If fixing a MCD requires changes in components **A**, **B** and **C**, then these components have a **fix-relationship**.
- A MCD is **pervasive (PMCD)** if it is related to the top 10% of the most frequently occurring fix-relationships. (*insidious, invasive*)
 - 75% of MCDs involve 10% of fix-relationships

The Subject Data

- In the subject system:



- PMCDs are the **most problematic** defects.
- The case study focuses on PMCDs.

Research Questions

1. How do **PMCDs** differ from other defects?
 - W.r.t. the **quantity of fixes**
2. How do **PMCDs** relate to **sustained defect-prone** components?
 - Defect-prone components are top 20% of the most defective components.
 - “sustained” – across phases and releases.

Hypotheses

Hypothesis 1 (Defects): PMCDs, in comparison with other defects, consume more effort to fix.

Hypothesis 2 (Components): Defect-prone components containing PMCDs are relatively more likely to remain defect-prone across phases and releases.

Hypothesis 1

H1 (Defects): PMCDs, in comparison with other defects, consume more effort to fix.

Sub-hypotheses: H1a and H1b.

- H1a: The average **number of fixes** for PMCDs is greater than that for all defects.
- H1b: The average **% of PMCDs** crossing phases or releases is greater than that for all defects.

Findings -- Hypothesis 1a

H1a: The average **number of fixes** for PMCDs is greater than that for all defects.

- The average number of fixes for a PMCD is **20-30** times that for a general defect.
- Although PMCDs are **6%** of all defects (75% of MCDs), they require **35-50%** of all fixes.
 - **Insidious!**

Findings -- Hypothesis 1b

H1b: The average % of **PMCDs** crossing phases or releases is greater than that for all defects.

- The average % of PMCDs crossing phases or releases is **4-7** times that for all defects.

Findings -- Hypothesis 1b

H1b: The average % of **PMCDs** crossing phases or releases is greater than that for all defects.

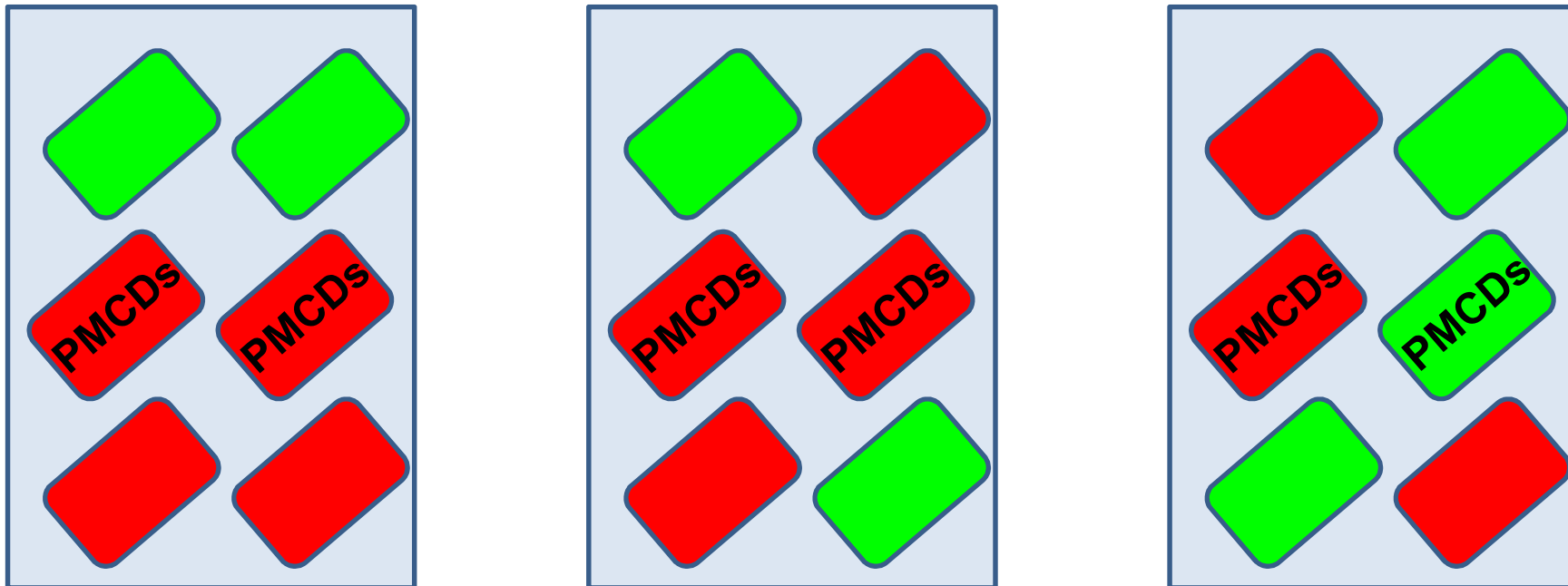
- The average % of PMCDs crossing phases or releases is **4-7** times that for all defects.

Thus, Hypothesis 1 is supported:

H1 (Defects): PMCDs, in comparison with other defects, consume more effort to fix.

Hypothesis 2

- **H2 (Components)**: Defect-prone components containing PMCDs are relatively more likely to remain defect-prone across phases and releases.



Version 1



Version 2

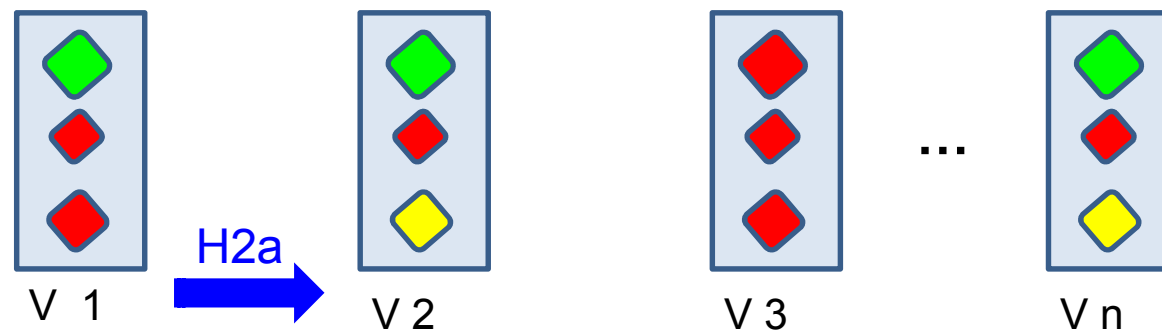


Version 3

Hypothesis 2

Sub-hypotheses: H2a and H2b.

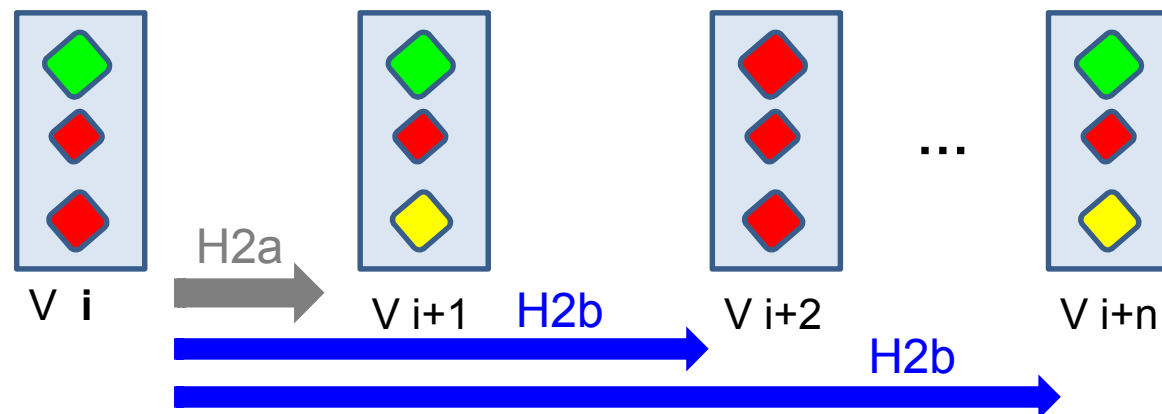
- H2a: Defect-prone components containing PMCDs are relatively more likely to remain defect-prone across **one** phase or release.



Hypothesis 2

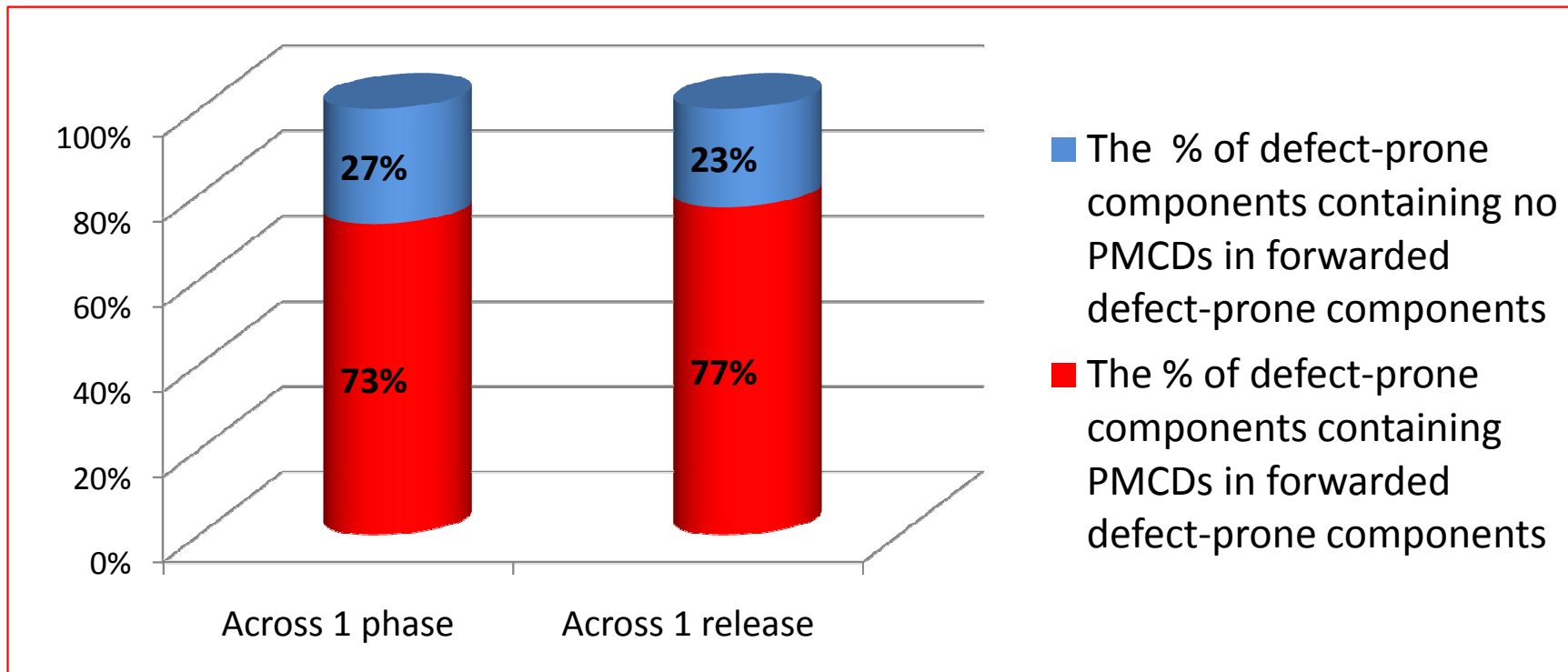
Sub-hypotheses: H2a and H2b.

- H2a: Defect-prone components containing PMCDs are relatively more likely to remain defect-prone across **one** phase or release.
- H2b: The **persistence** of defect-prone components containing PMCDs is relatively stronger across **multiple** releases.



Findings – Hypothesis 2a

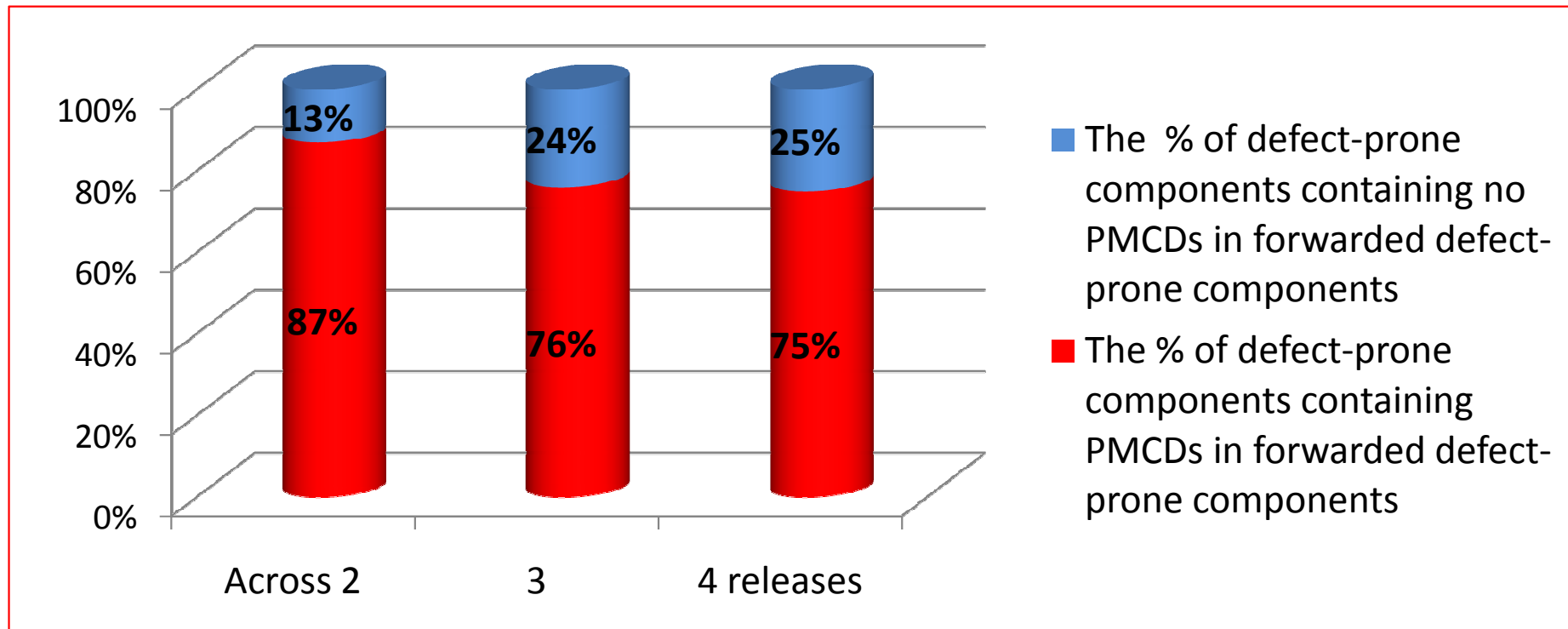
H2a: Defect-prone components containing PMCDs are relatively more likely to remain defect-prone across **one** phase or release.



$\frac{\% \text{Defect-prone components containing PMCDs}}{\% \text{Defect-prone components containing no PMCDs}}$: Approx. 3 times

Findings – Hypothesis 2b

H2b: The **persistence** of defect-prone components containing PMCDs is relatively stronger across **multiple** releases.



$$\frac{\% \text{Defect-prone components containing PMCDs}}{\% \text{Defect-prone components containing no PMCDs}} : \text{Approx. 3 times}$$

Findings – Hypothesis 2

$\frac{\% \text{Defect-prone components containing PMCDs}}{\% \text{Defect-prone components containing no PMCDs}}$: Approx. 3 times

Across:

1 phase or release

2, 3, or 4 releases

Thus, Hypothesis 2 is supported:

H2 (**Components**): Defect-prone components containing PMCDs are relatively more likely to remain defect-prone across phases and releases.

Summary of Findings

1. How do PMCDs differ from other defects?

- PMCDs consume more effort to fix, e.g.,
 - The average **number of fixes** for PMCDs is **20-30** times that for all defects.

Summary of Findings

1. How do PMCDs differ from other defects?

- PMCDs consume more effort to fix, e.g.,
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2. How do PMCDs relate to defect-prone components?

- PMCDs relate to sustained defect-prone components, e.g.,
 - Over **70%** of defect-prone components containing PMCDs remain defect-prone across phases and releases (2-4).

Threats to Validity

Data noise:

- Only **80%** of defect logs **explicitly** specify **fix-relationships**.
 - Legacy, large system data logs
- It was not possible to exclude the rest **20%** from the dataset.
 - Natural language data, etc.

Implications for SW Maintenance

- Separating **Pervasive MCDs** from **MCDs** can help focus special attention on these *hard-to-fix* defects.
- Identifying the **persistence** of defect-prone components may help in defect correction and prevention.
- The findings may also help in:
 - advancing the quality of software systems
 - reducing maintenance costs
 - improving customer or end-user satisfaction

Conclusion & Future Work

- We conducted a case study on a large system.

PMCDs are defects that:

Require **more fixes**

Relate to **sustained defect-prone** components

- Future work:
 - Comparing MCDs to PMCDs
 - Investigating techniques to reduce data noise
 - Study replication in other domains

Q & A