Faces of Software Quality

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Motivation

- A key software engineering objective is to improve quality via practices and tools supporting requirements, design, implementation, verification, and maintenance
- Needs of a user: reliability, maintainability, availability, backward compatibility, cost, and features
- Primary objectives
  - Can we measure quality *in vivo*?
  - Is the common wisdom about software quality correct?
- Secondary (background) objectives
  - Can we show if or where software engineering works?
  - Can information hidden in support systems provide additional insights?

Outline

- Quality for communications
- Ways to observe and estimate quality *in vivo*
- Questions
  - Can we compare quality among releases?
  - Does hardware or software have more impact on quality?
  - Which part of the life-cycle affects quality the most?
  - Can we approximate quality using easy-to-obtain measures?
- Answers
  - Yes, software, service, no
- Discussion

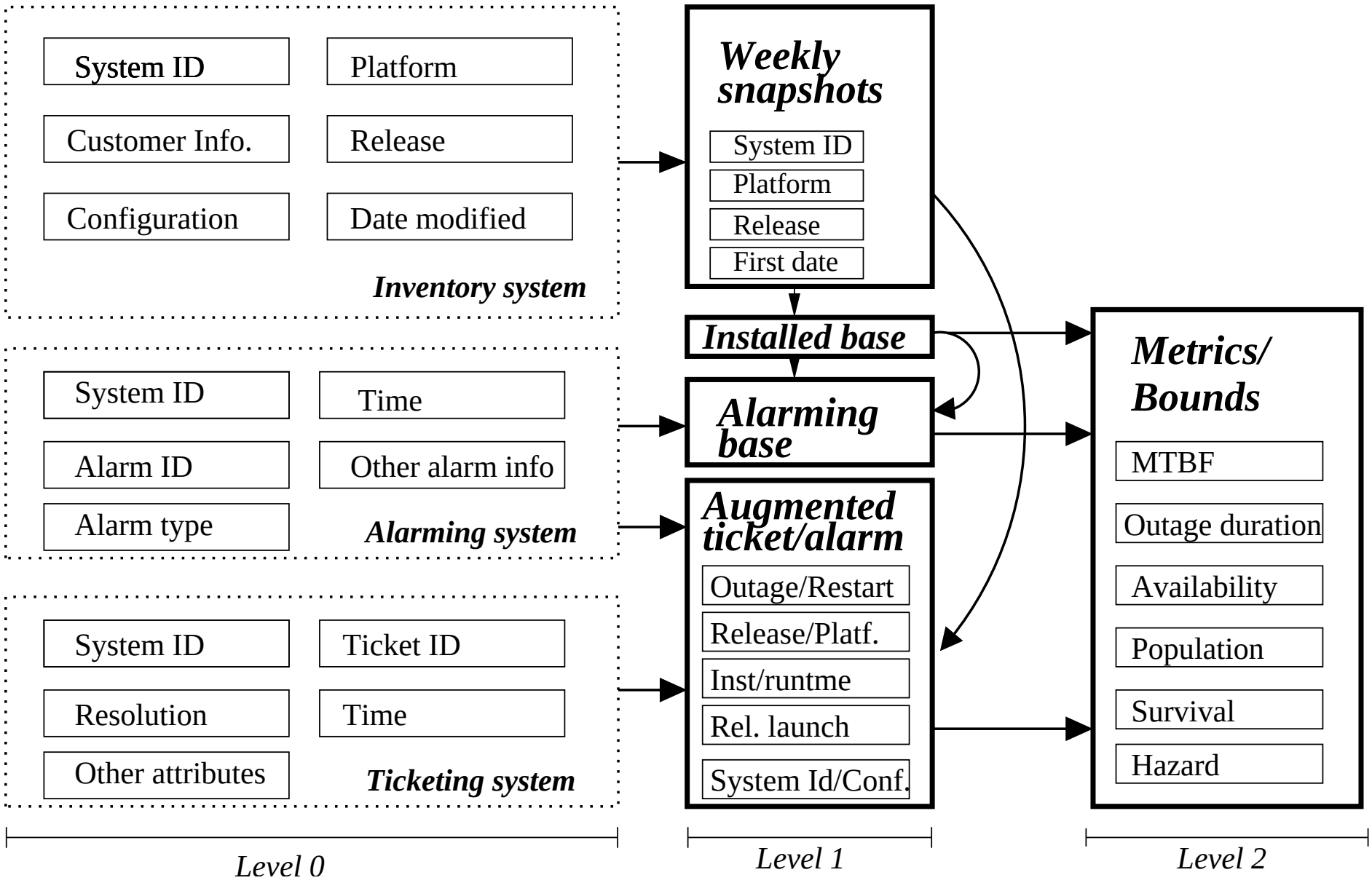
Common Approaches

- Measuring quality
  - Theoretical models [16]
  - Simulations (*in silico*)
  - Observing indirectly (test runs, SW defects)
  - **Observing directly** *in vivo* via recorded user/system actions (not opinion surveys)
    - More realistic
    - More accurate
    - Provides higher level of confidence
    - *In vivo* research is more suited to observe an overall effect than *in vitro* research
    - More relevant

Communications Quality [6]

- Context: military and commercial communication systems, 1960-present
- Goals: system outage, loss of service, degradation of service
  - Downtime of 2 hours over 40 yr, later "5 nines" (or 5 min per year)
  - Degradation of service, e.g., $< .01\%$ calls mishandled
  - Faults per line per time unit, e.g., errors per 100 subscribers per year
  - MTBF for service or equipment, e.g, exchange MTBF, $\%$ subscribers with $MTBF > X$
  - Duplication levels, e.g., standby HW for systems with > 64 subscribers

Observing *in vivo* — architecture



Observing *in vivo* — sources

- Service tickets
  - Represent requests for action to remedy adverse events: outages, software and hardware issues, and other requests
  - Manual input: not always accurate
  - Some issues may be unreported
- Software alarms
  - Complete and detailed list for the systems set to generate them
  - Irrelevant events are included, e.g, experimental, misconfigured systems that are not in production use at the time
- Inventory
  - Type, size, configuration, install date for each release
- **Link between deployment dates and tickets/alarms**

Issues with commonly available data and published analyses

- Present
  - Problem reports by month (hopefully grouped by release)
  - Sales by month (except for freely downloadable SW)
- Absent
  - No link between install time and problem report $\Longrightarrow$ no way to get accurate estimates of hazard trends
  - No complete list of software outages $\Longrightarrow$ no way to get rough estimates of the underlying rate

Data Remedies

- Only present state of inventory is kept $\Longrightarrow$ collect snapshots to reconstruct history
- The accounting aggregation (by solution) is different from service (by system) or production (by release/patch) aggregation $\Longrightarrow$ remap to the finest common aggregation
- Missing data
  - Systems observed for different periods $\Longrightarrow$ use survival curves
  - Reporting bias $\Longrightarrow$ divide into groups according to service levels and practices
- Quantity of interest not measured $\Longrightarrow$ design measures for upper and lower bounds

Practical questions

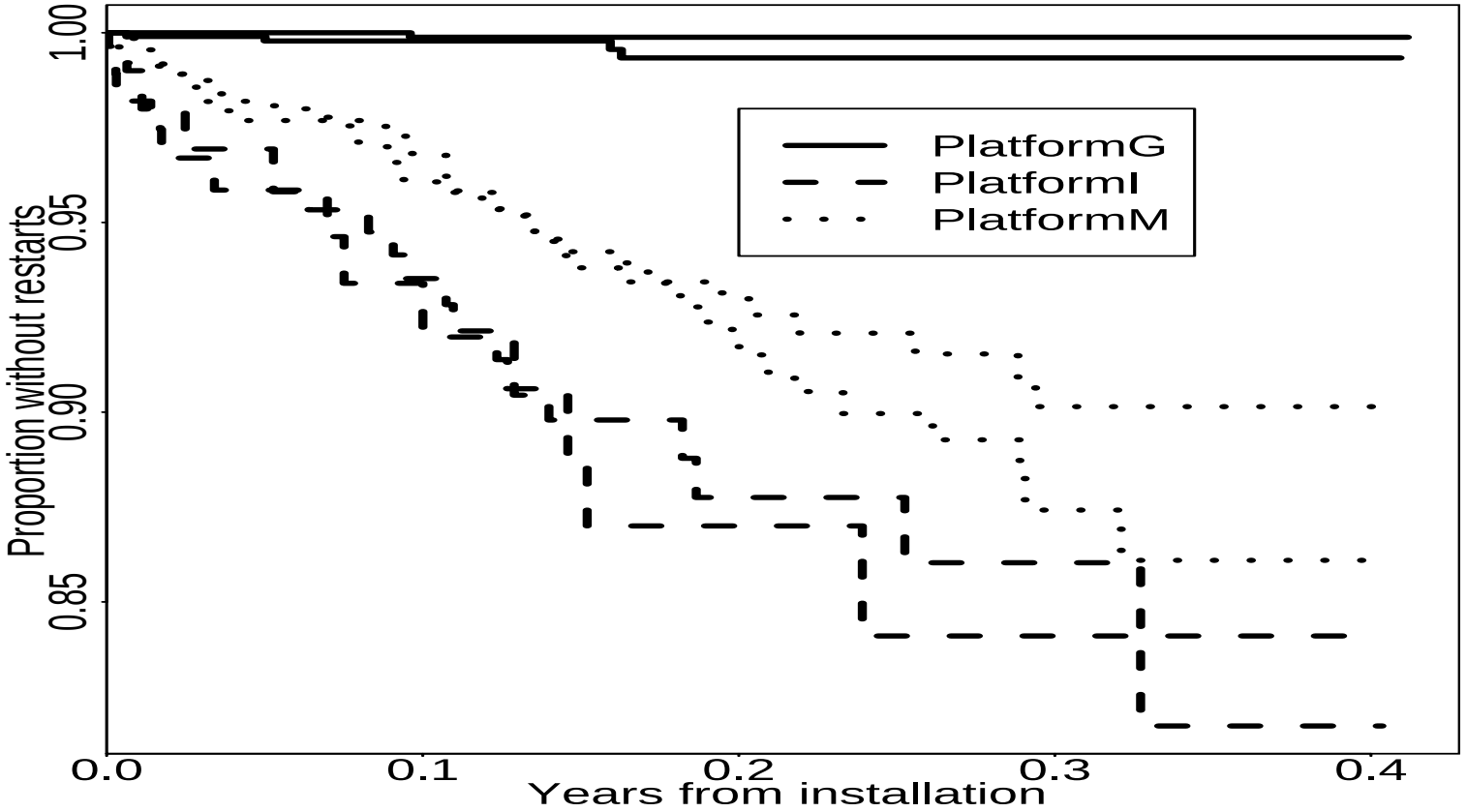
- Can we compare quality among releases to evaluate the effectiveness of QA practices?
- Does hardware or software have more impact on quality?
- Which part of the production/deployment/service life-cycle affects quality the most?
- Can quality be approximated with easy-to-obtain measures, e,g., defect density?

Naive reliability estimates

- Naive estimate: $\frac{\text{calendar time} \times \text{installed base}}{\text{\# software restarts}}$
- Naive+ estimate: $\frac{\text{runtime}|\text{simplex systems}}{\text{\# restarts}|\text{simplex}}$
- Alarming syst. estimate: $\frac{\text{runtime}|\text{simplex,generating alarms}}{\text{\# restarts}|\text{simplex}}$

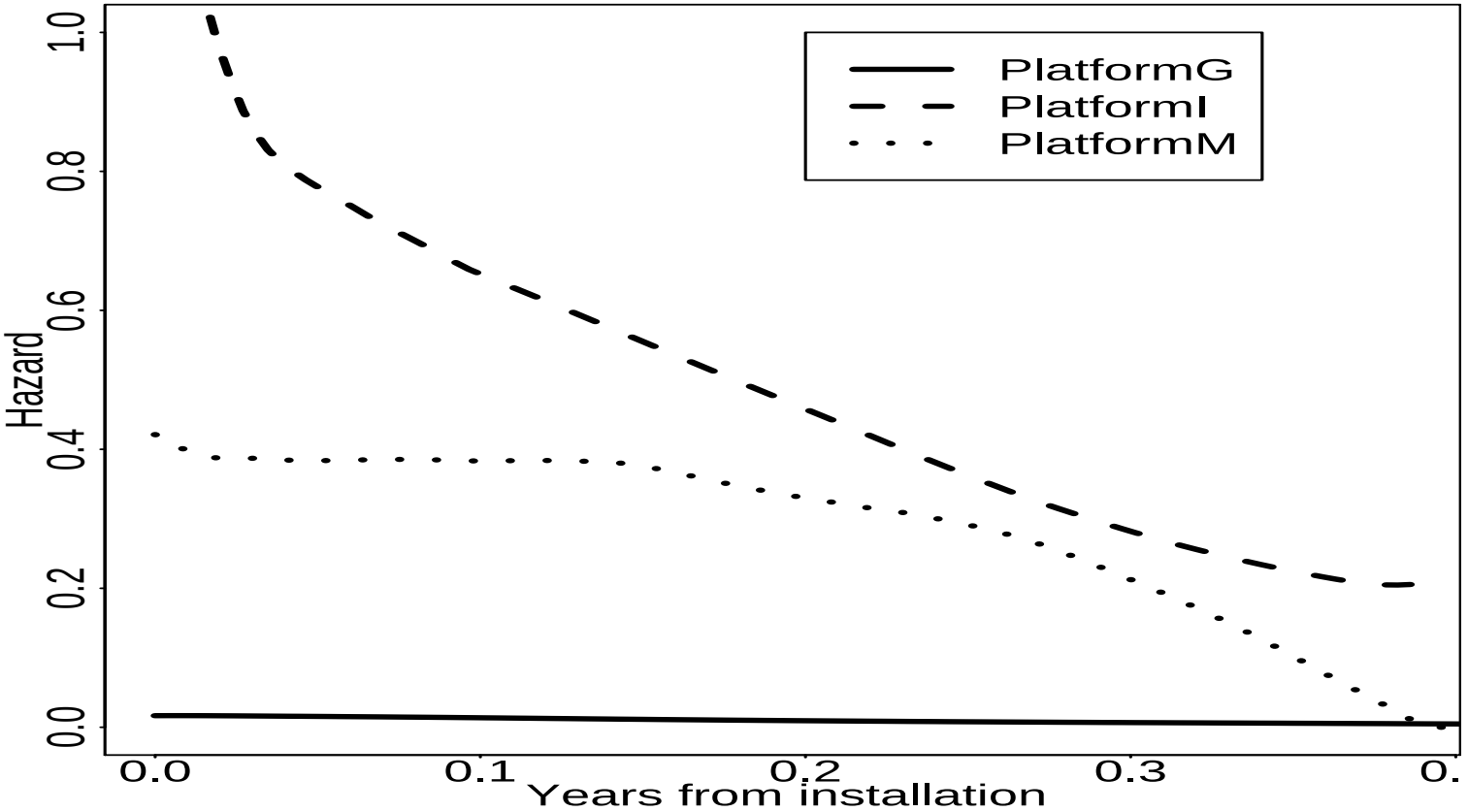
	Naive	Naive+	Alarming
Systems	80000	1011	761
Restarts	14000	32	32
Period	.5	.25	.25
MTBF (years)	3	7.9	5.9

What affects restart rates?



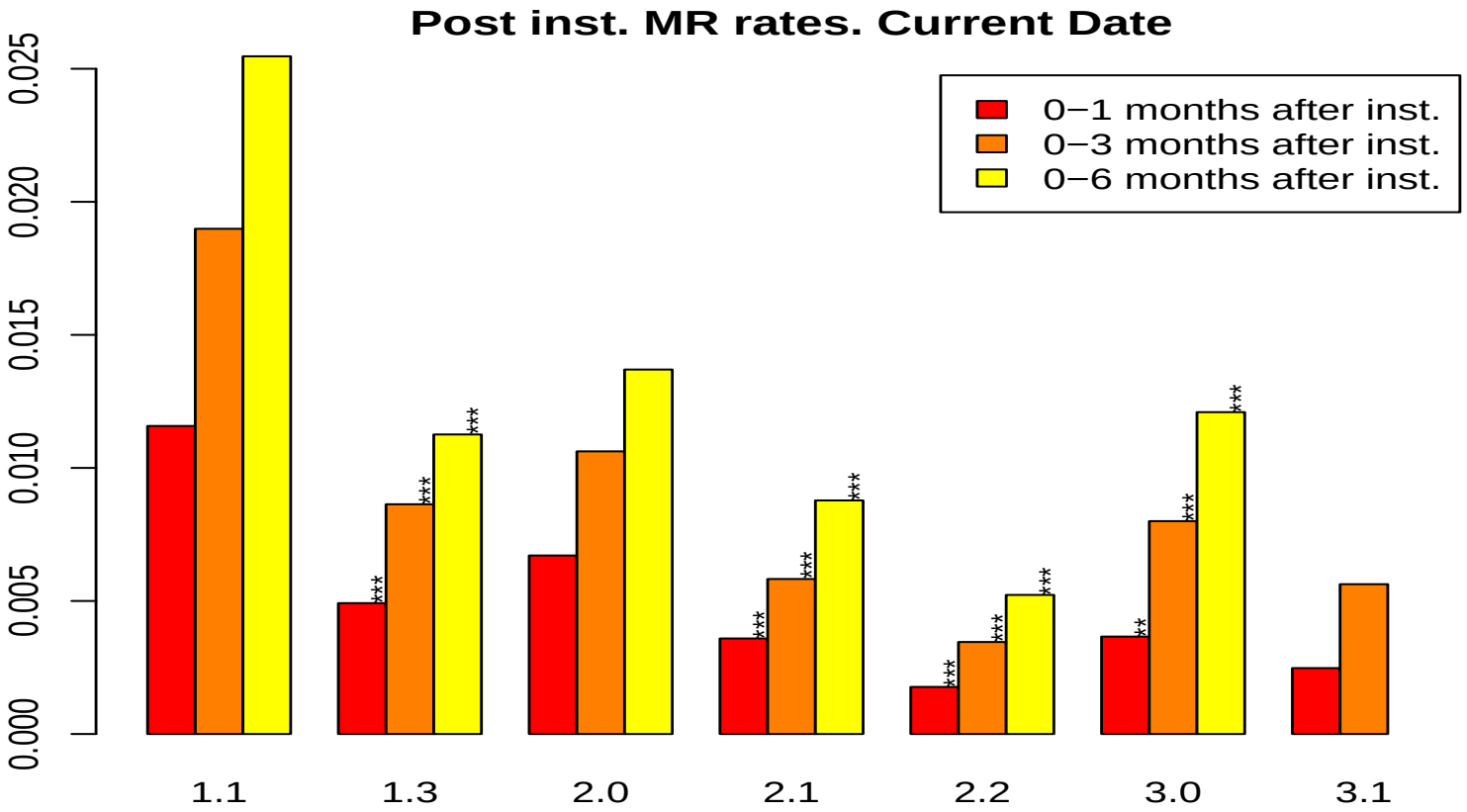
- Kaplan-Meier estimates of the survival curves for three platforms and two releases
- Differences between releases dwarfed by differences among platforms [8]

Hazard function



- Have to adjust for runtime and separate by platform or the MTBF will characterize the currently installed base, not release quality
- So how to compare release quality?

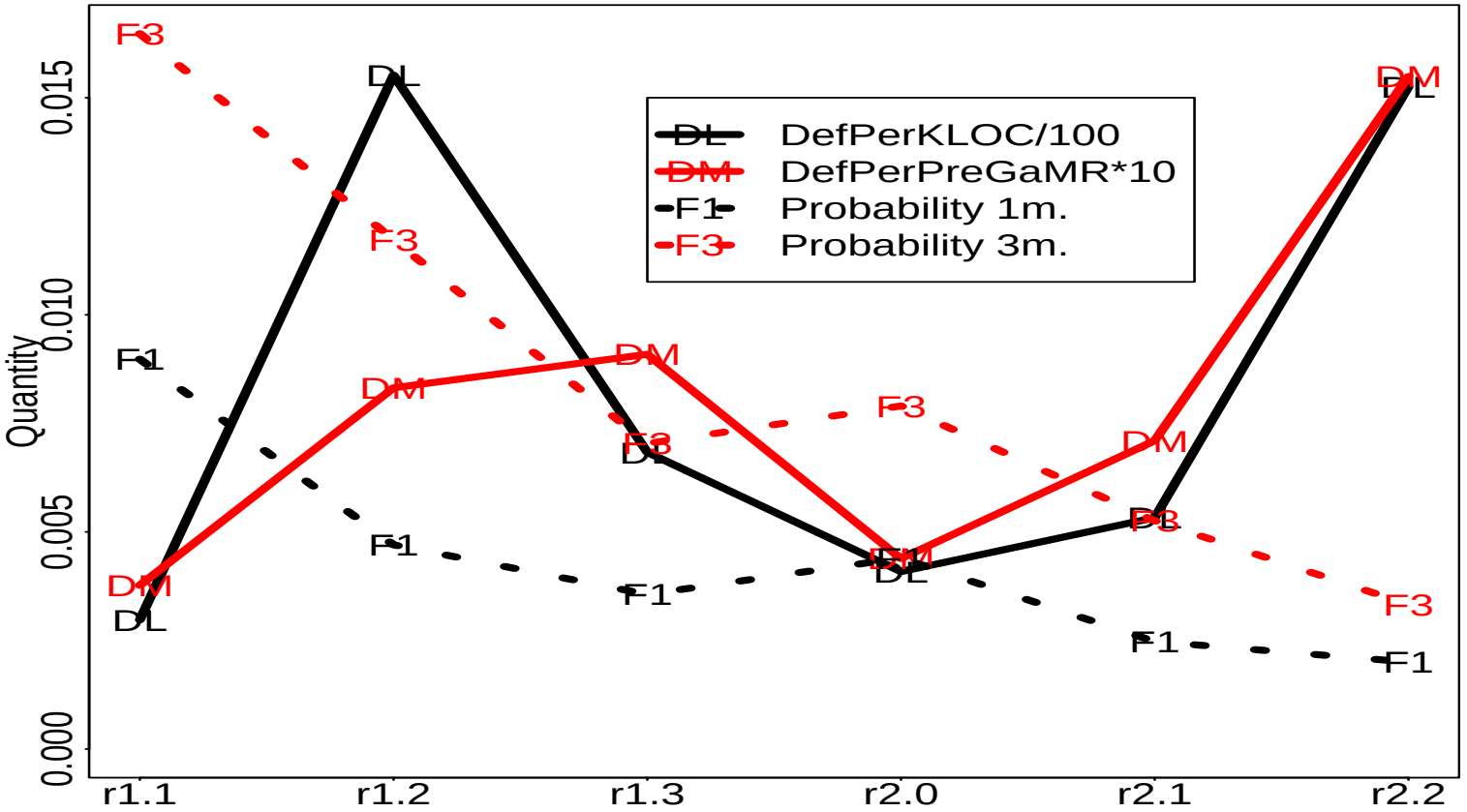
Interval Quality



- Fraction of customers that report software failures within the first few months of installation
- Does not account for proximity to launch, platform mix
- Significant differences marked with “*”

- “We live or die by this measure”

Can we use easy-to-obtain defect density?



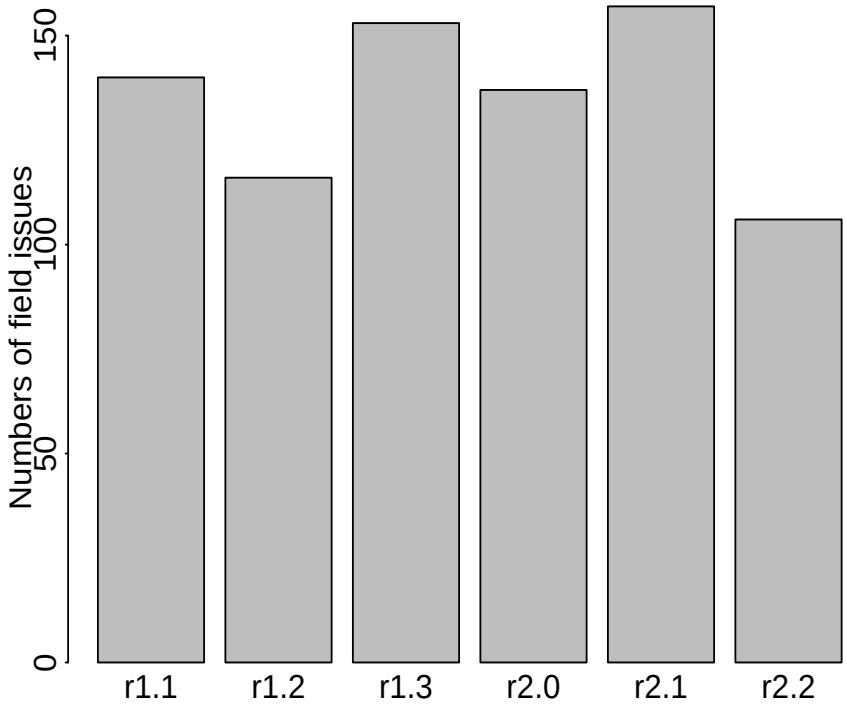
- anti-correlated

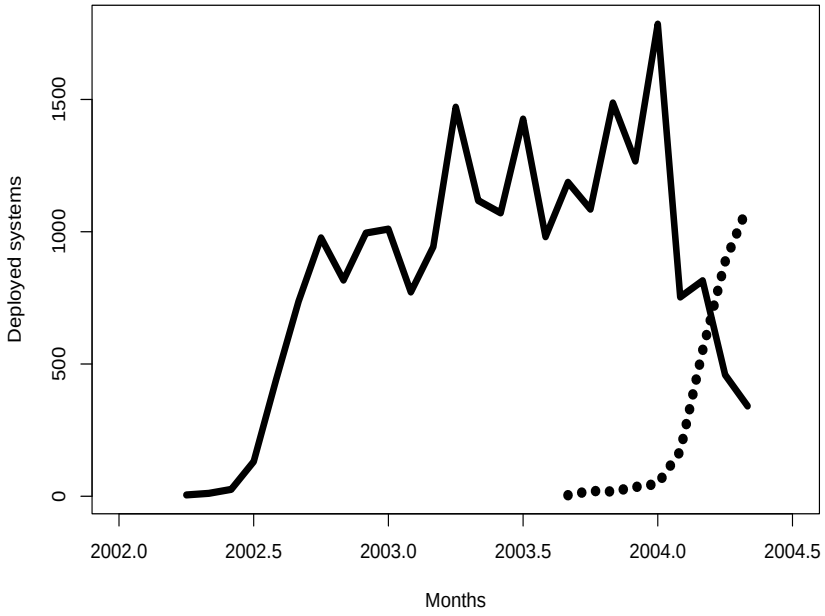
High defect density leads to satisfied customers???

- What does any human/organization strive for?

Stability

- The rate at which customer problems get to Tier IV is almost constant despite highly varying deployment and failure rates

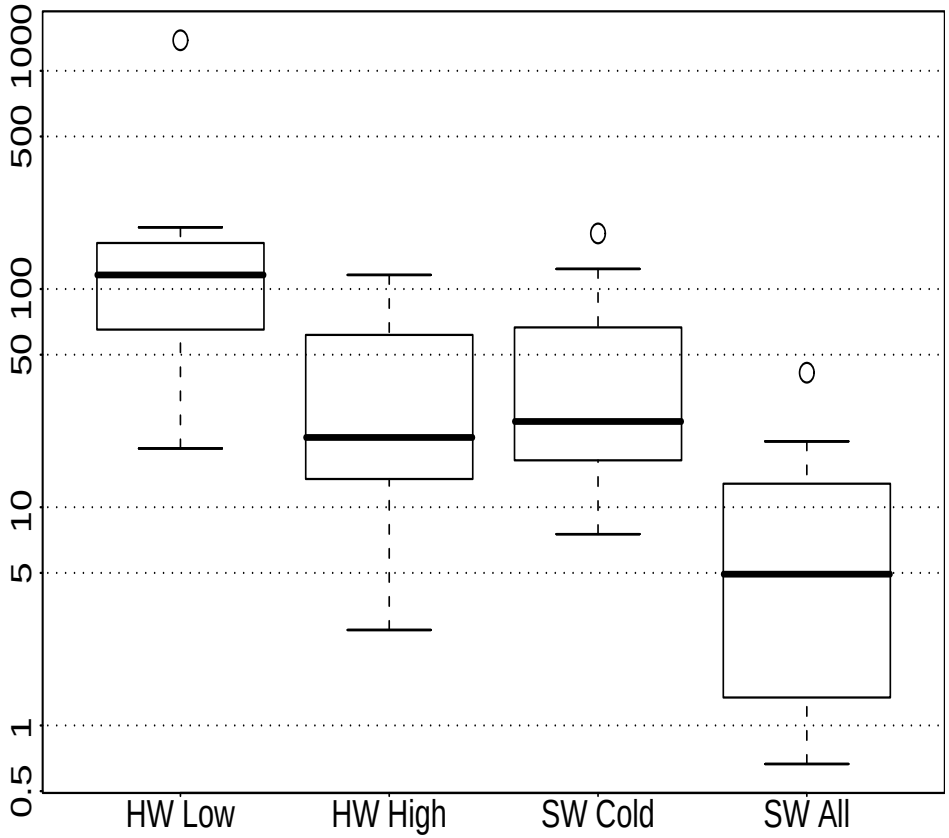




Major versus Minor releases

- Defect density numerator is about the same as for IQ because
  - Major releases are deployed more slowly to fewer customers
  - For minor releases a customer is less likely to experience a fault so they are deployed faster and to more customers
- The denominator diverges because
  - Major releases have more code changed and fewer customers
  - Minor releases have less code and more customers

Hardware vs Software

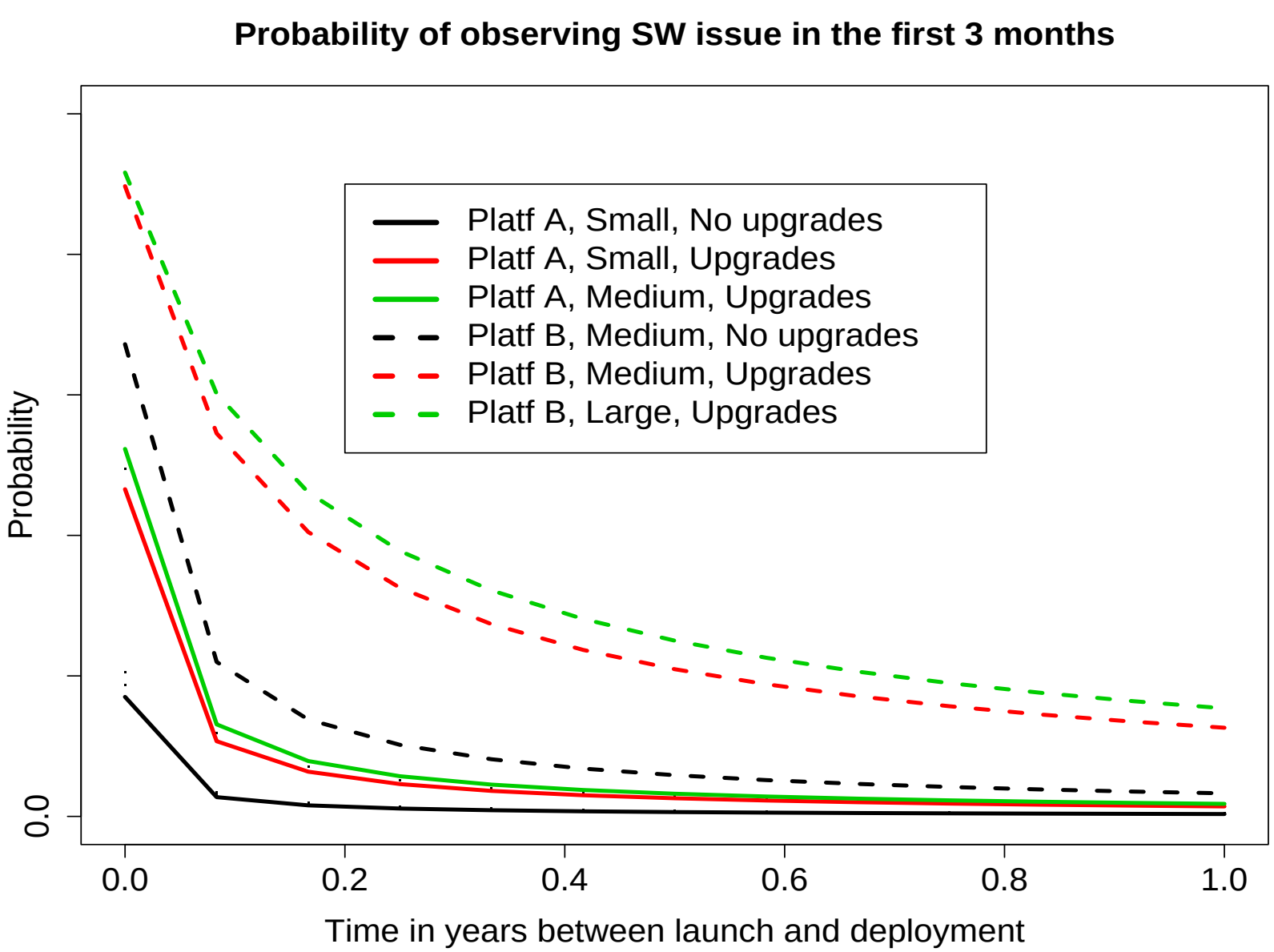


- Limitations
  - Durations of SW Warm, SW Cold, HW differ by orders of magnitude
  - Warm rst. don't drop calls
  - High/Critical cfg. may by unaffected
  - HW-High ultra conservative
  - Variability for each estimate may be high

- Distribution of MTBF for 15 platform/release combinations

Which part of the software production and delivery contributes most to quality?

- Development perspective - fraction of MRs removed per stage
  - Development $\rightarrow$ features, bugs introduced, and resolved
  - Verification $\rightarrow$ 40% of development stage MRs (post unit-test)
  - α/β trials $\rightarrow$ 7% of development stage MRs
  - Deployment $\rightarrow$ 5% in major and 18% in minor releases
- Customer perspective - probability of observing a failure
  - may drop up to 30 times in the first few months post-launch [15]


Probability of observing SW issue in the first 3 months
Platf A, Small, No upgrades
Platf A, Small, Upgrades
Platf A, Medium, Upgrades
Platf B, Medium, No upgrades
Platf B, Medium, Upgrades
Platf B, Large, Upgrades
Probability
0.0
0.0
0.2
0.4
0.6
0.8
1.0
Time in years between launch and deployment

More detailed information $\Longrightarrow$ new insights

- New insights gleaned via support systems
- Results become an integral part of development practices — continuous feedback on production changes/improvements
- Measurement hints
  - Pick the right measure for the objective — no single "quality" exists
  - Adjust for relevant factors to avoid measuring demographics
  - Navigate numerous pitfalls of missing, biased, irrelevant data, bound the quantity of interest
- Action hints
  - Maintenance — the most important quality improvement activity
  - Development process view does not represent customer views
  - Software tends to be a bigger reliability issue with a few exceptions

Thank You.

Limitations

- Different characteristics of the project including numbers of customers, application domain, software size, quality requirements are likely to affect most of the presented values
- Many projects may not have as detailed and homogeneous service repositories

Methodology: Validation

- Interview a sample of individuals operating and maintaining relevant systems
  - Go over recent cases the person was involved with
    - to illustrate the practices (what is the nature of the work item, why you got it, who reviewed it)
    - to understand/validate the meaning of attribute values: (when was the work done, for what purpose, by whom)
    - to gather additional data: effort spent, information exchange with other project participants
    - to add experimental/task specific questions
- Augment data via relevant models [8, 11, 1, 12]
- Validate and clean retrieved and modeled data
- Iterate

Methodology: Existing Models

- Predicting the quality of a patch [12]
- Work coordination:
  - What parts of the code can be independently maintained [13]
  - Who are the experts to contact about any section of the code [10]
  - How to measure organizational dependencies [4]
- Effort: estimate MR effort and benchmark practices
  - What makes some changes hard [5]
  - What practices and tools work [1, 2, 3]
  - How OSS and Commercial practices differ [9]
- Project models
  - Release schedule [14]
  - Release readiness criteria [7]
  - Consumer perceived quality [15, 8]

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Abstract

Improving software quality is a primary concern of software engineering. It is, therefore, of interest how various software engineering approaches impact software quality. The quality of software is commonly measured via defect density often assuming that it will relate to some of customer experiences with software. We set out to quantify customer experiences of a deployed software system to provide a basis for quality improvement actions. First, we process and model information gathered from a variety of service support systems to obtain estimates of software reliability and discover the hazard function to vary with time elapsed from installation. This suggests a quality measure based on the customers' probability of failure within the first few months of installation. Surprisingly, the customer perceived quality has negative correlation with defect density. The large magnitude of quality improvement after system verification stage suggests that the most efficient way to achieve the highest levels of quality is to manage the deployment practices by, for example, adjusting the deployment rate, by providing adequate resources to resolve post-launch problems, and by conducting extensive alpha and beta trials.

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Audris Mockus is interested in quantifying, modeling, and improving software development. He designs data mining methods to summarize and augment software change data, interactive visualization techniques to inspect, present, and control the development process, and statistical models and optimization techniques to understand the relationships among people, organizations, and characteristics of a software product. Audris Mockus received B.S. and M.S. in Applied Mathematics from Moscow Institute of Physics and Technology in 1988. In 1991 he received M.S. and in 1994 he received Ph.D. in Statistics from Carnegie Mellon University. He works in the Software Technology Research Department of Avaya Labs. Previously he worked in the Software Production Research Department of Bell Labs.