CSED601
Dependable Computing
Lecture 3

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POSTECH

References

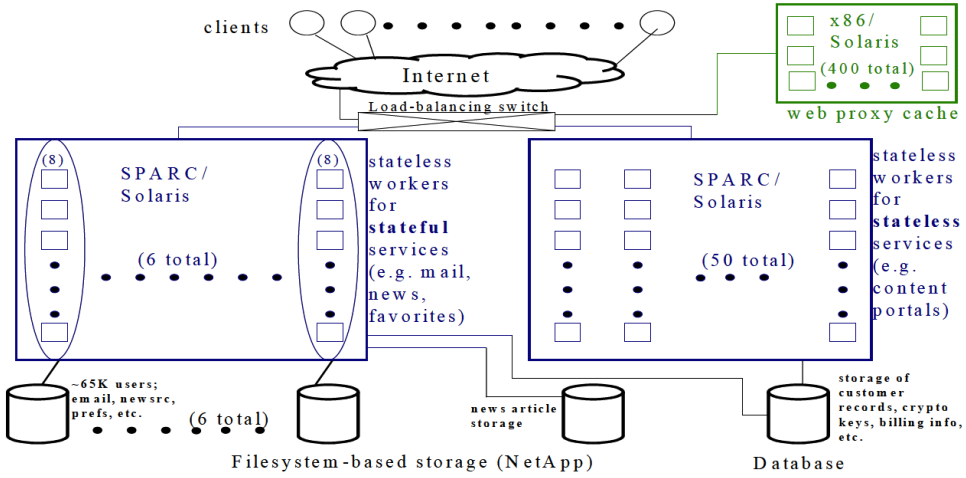
- George Candea, Stanford University http://www.stanford.edu/~candea/teaching/cs444a-fall-2003/slides/Humans.pdf

Study of Internet Failure

- Sequel Study
  - David Oppenheimer, Archana Ganapathi, and David A. Patterson, **"Why do Internet services fail, and what can be done about it?",** *4th Usenix Symposium on Internet Technologies and Systems (USITS '03)*, 2003.
- Original Study of 1986 Jim Gray Paper
  - J. Gray, "Why do computers stop and what can be done about it?", *Symposium on Reliability in Distributed Software and Database Systems (SRDS)*, 1986.
  - Study of classical computer systems and comparison with fault-tolerant computing systems.

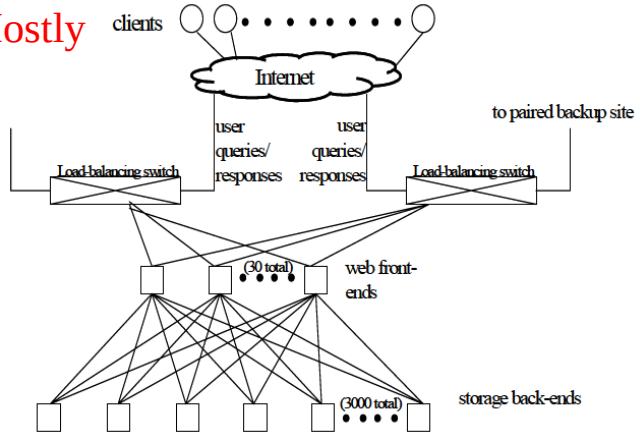
Three Types of Internet Service

- Classification based on Service characteristics
  - Online, ReadMostly, Content
- Service architecture
  - Front-end, Network, Backend

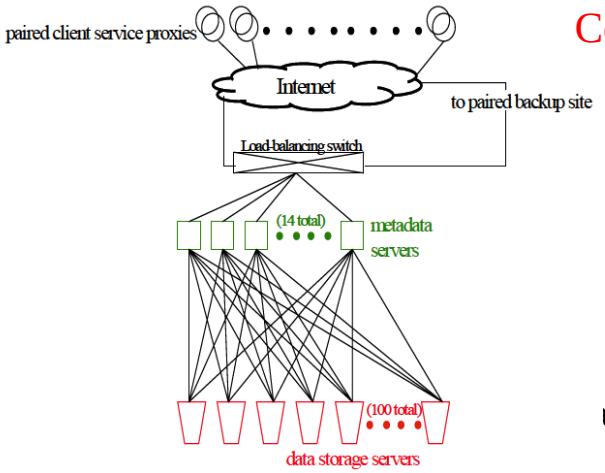


Online

ReadMostly



Content

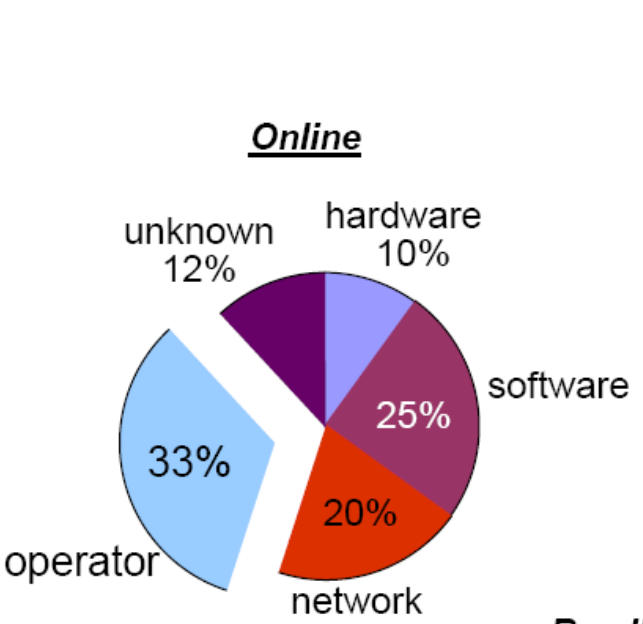


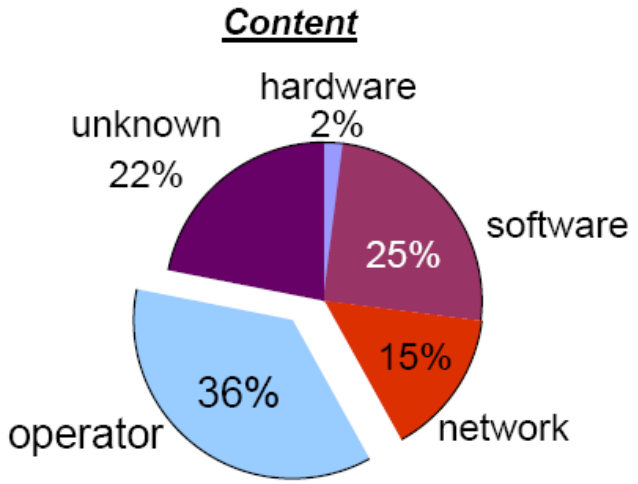
Internet Systems Survey

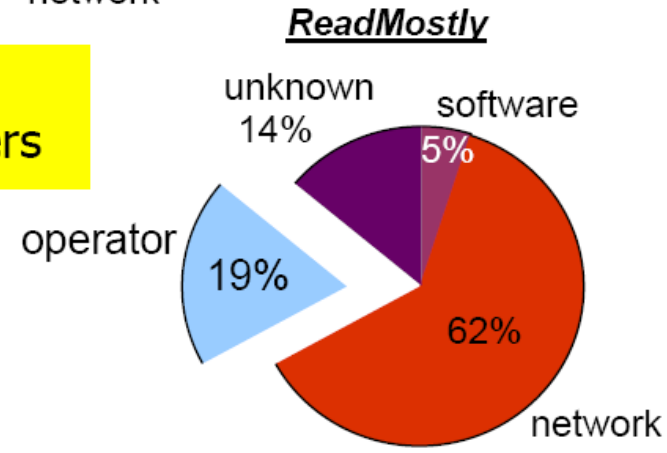
[Oppenheimer et al., 2003]

Attribute	***Online***	***ReadMostly***	***Content***
hits per day	~100 million	~100 million	~7 million
# of nodes	~500 / 2 sites	>2000 / 4 sites	~500 / ~15 sites
front end + middle tier	custom software Solaris SPARC & x86	custom software open-source OS x86	custom software open-source OS x86
back end	NetApp filers	– // –	– // –
period studied	7 months	6 months	3 months
# svc failures	40	21	56

Failure Occurrences



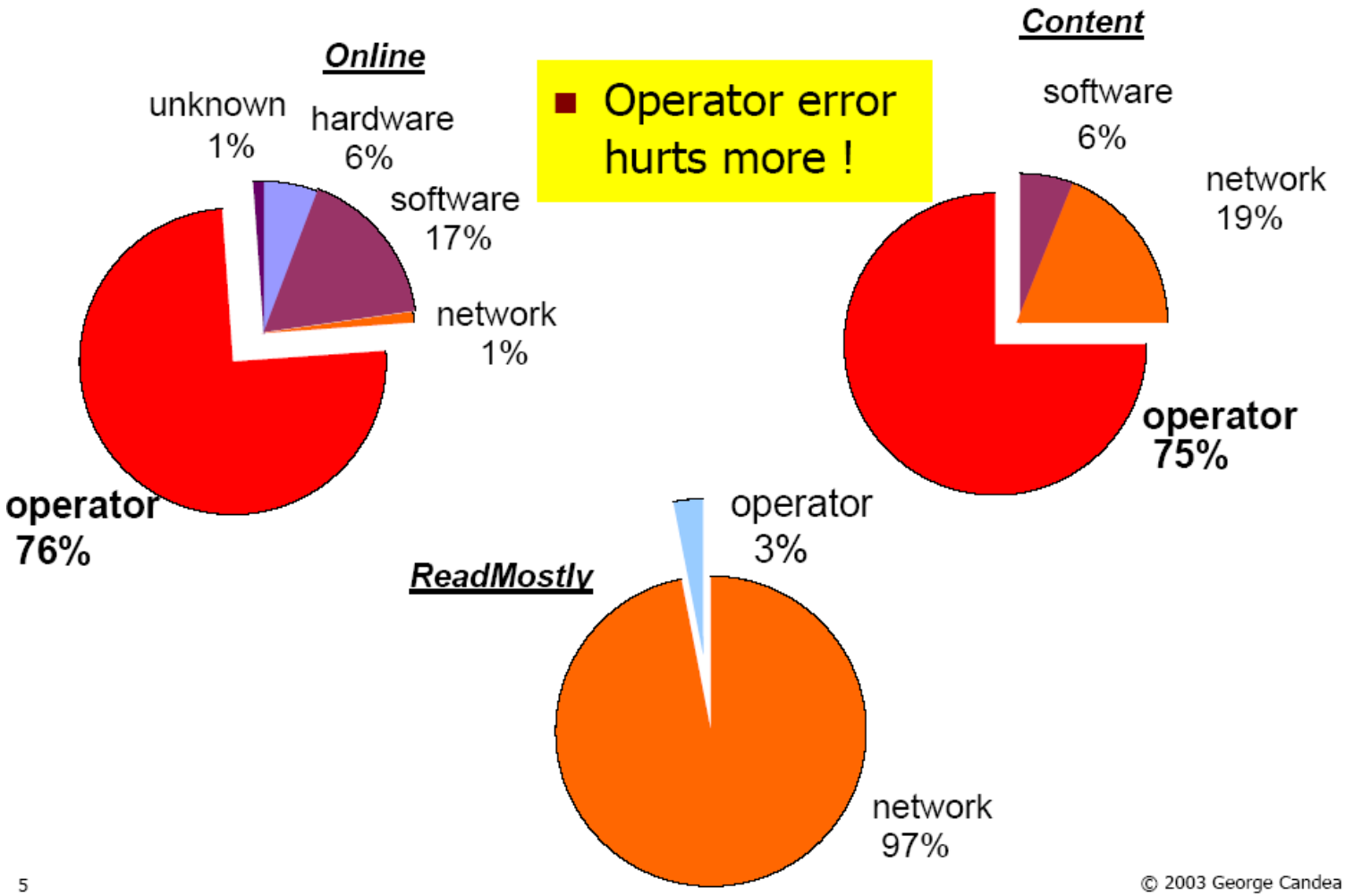




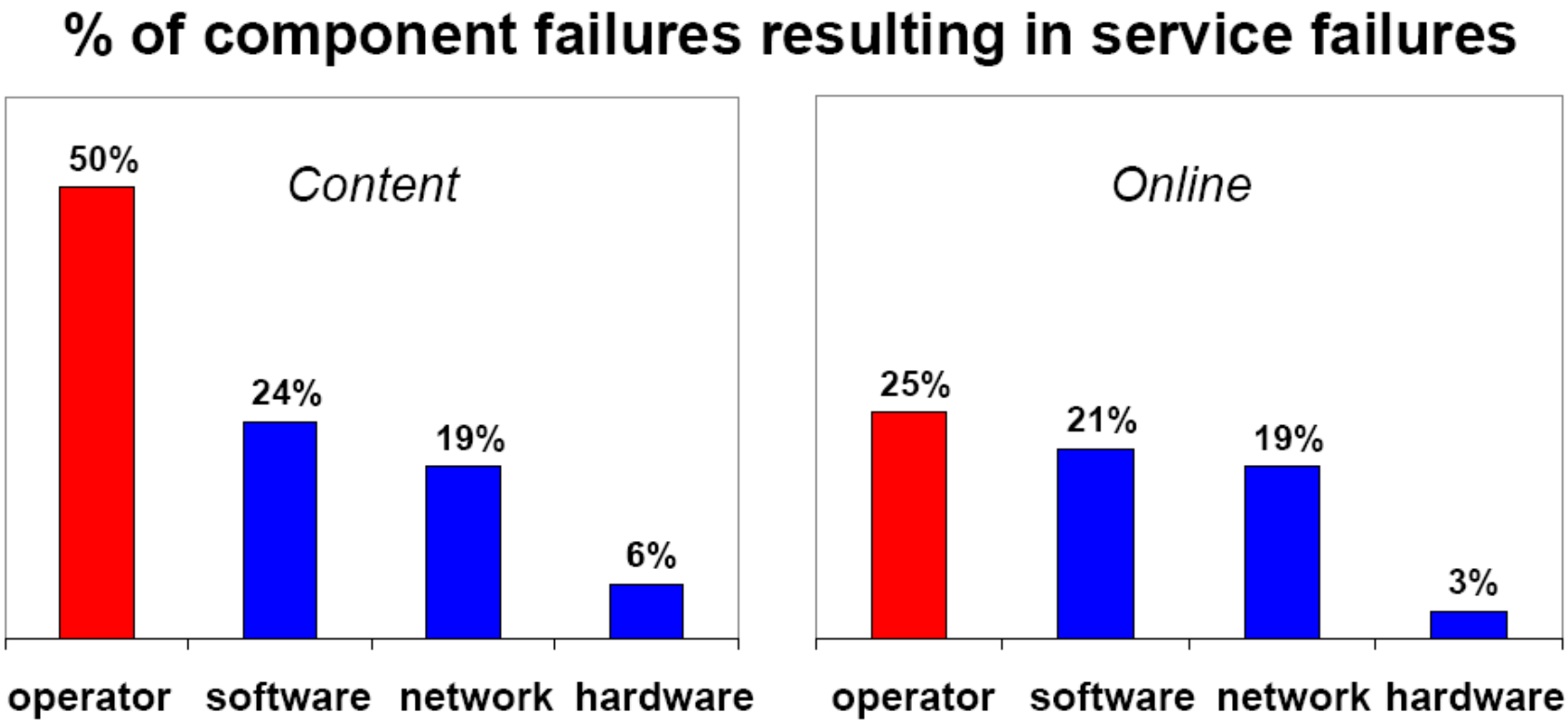
- similar numbers

- NKOB: network
  - hardware
  - software
  - operators

Occurrence X Duration



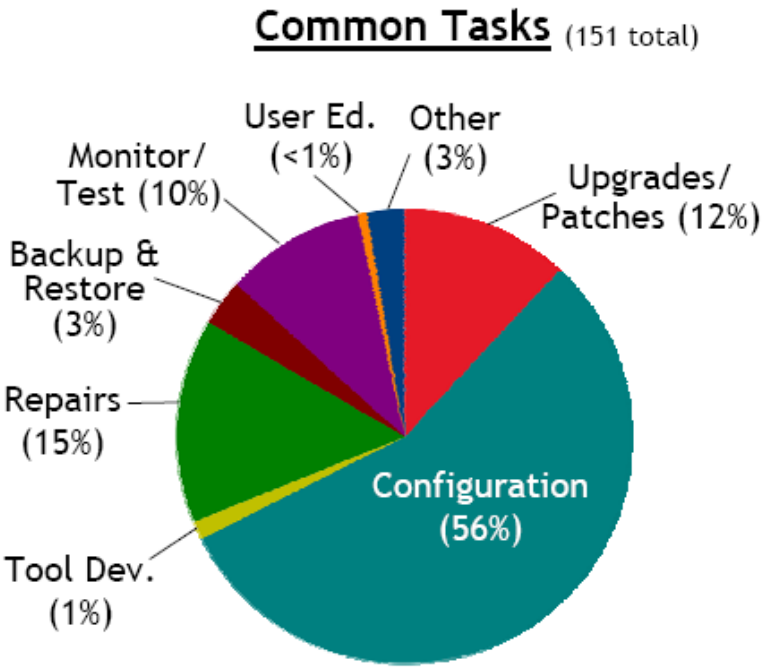
Why So Painful?

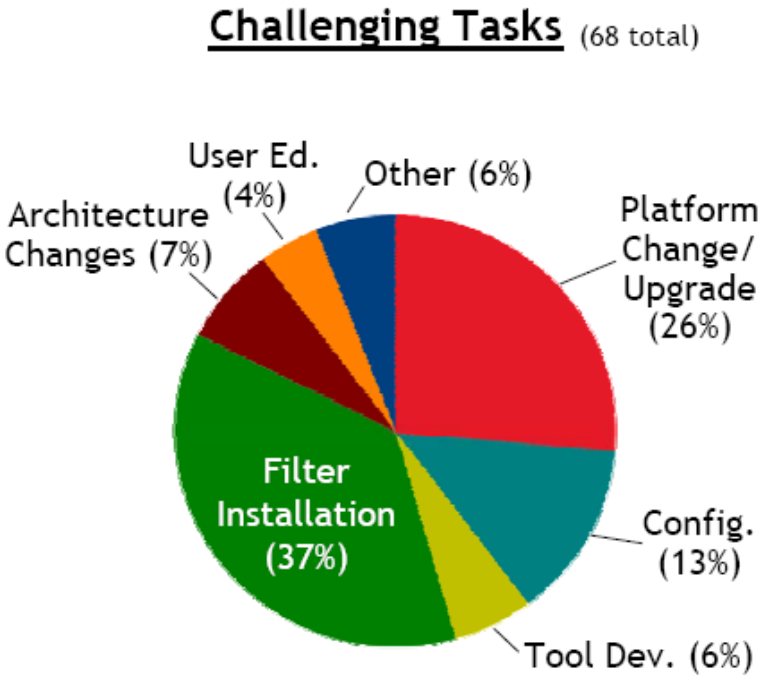


- Operator errors are the major reason of service failures.
- Not maskable?

Why Not Maskable?

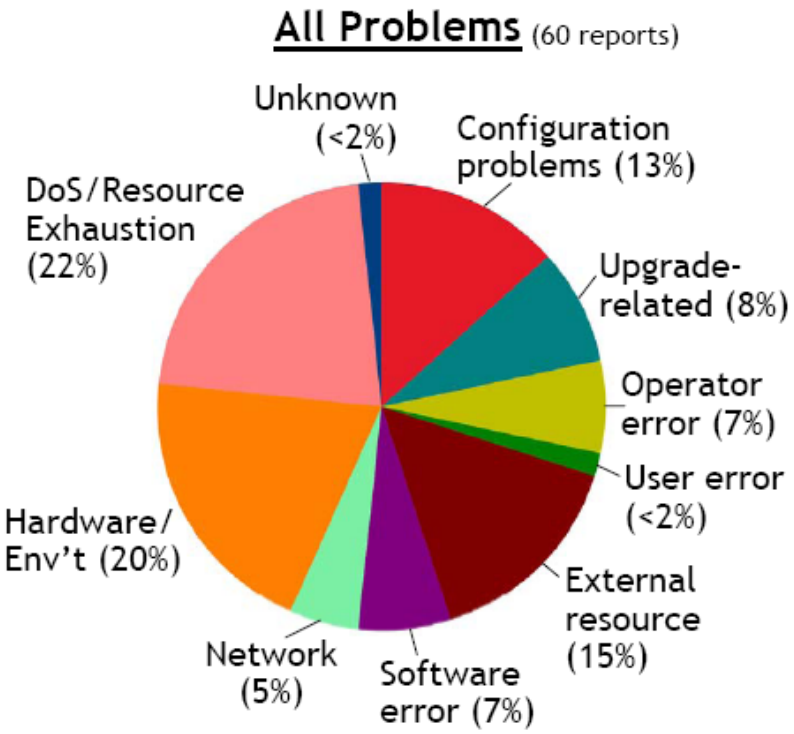
- Survey of e-mail admins [Kakes et al., 2002]
- Breakdown of common and challenging tasks

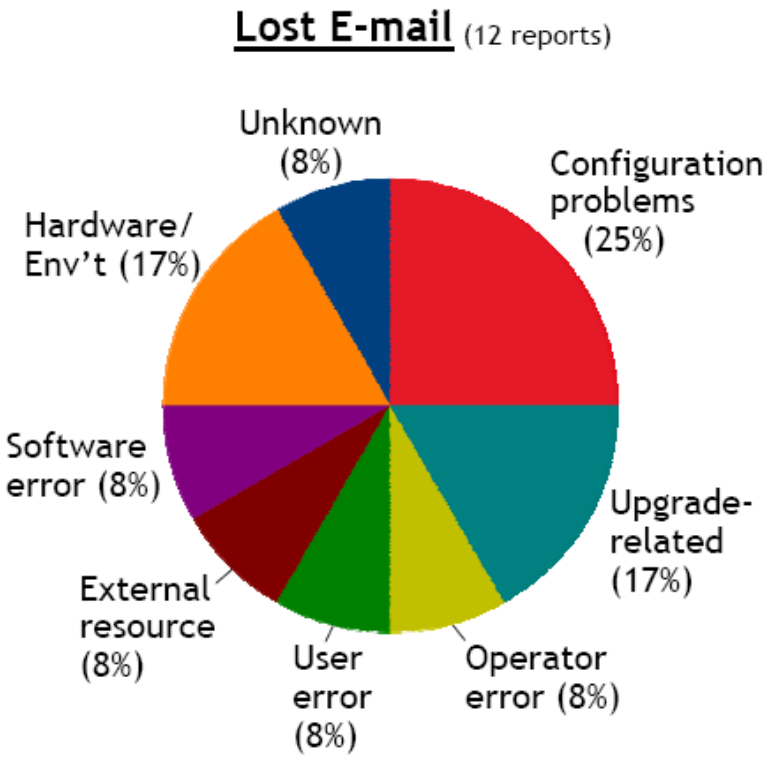




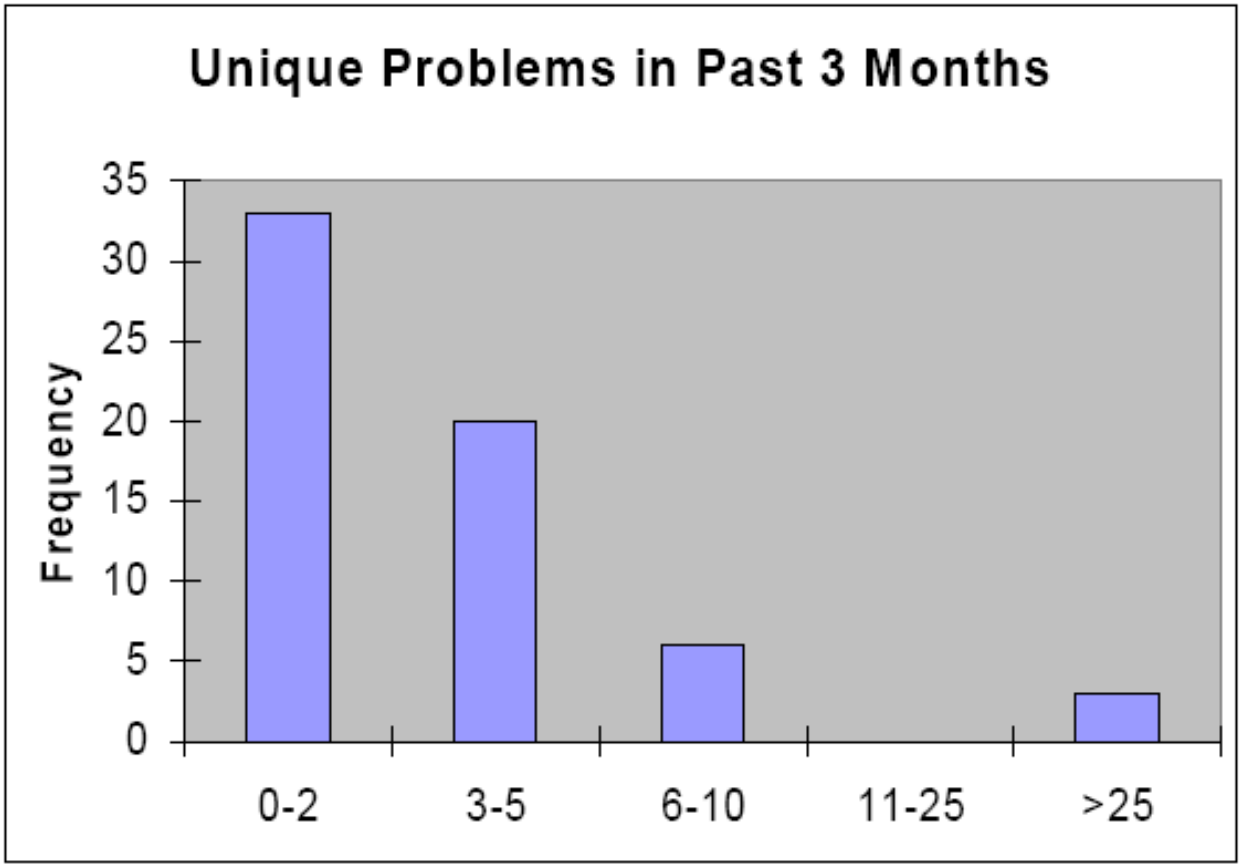
Consequences

- Causes of e-mail service outages





Few Unknown Problems



- Problem is not that hard.

Are Operators Incompetent?

- Combination of reasons
  - Poor training, less knowledge of the system
  - Poor tools (software)
  - Complex recovery procedures

Surprising Trends

Cause	Downtime/month (millions customer-minutes) **1992-1994**	Downtime/month (millions customer-minutes) **2000**	Trend
Software	15	155	**up 933%**
Human Error: internal	98	131	**up 34%**
Human Error: external	100	125	**up 25%**
Hardware	49	60	**up 22%**
Overload	314	2	**down 99%**
Vandalism	5	2	**down 60%**

- Need better software (self) recovery
- More human error-tolerant systems

Understanding Human Operators

- GEMS (Genetic Error-Modeling System)
  - An attempt to understand origins of human error
  - Distilled by Aaron Brown from 1990 paper
- 3 levels of cognitive task processing
  - Skill-based: familiar, automatic procedural tasks
    - Usually low-level, like knowing to type basic commands
  - Rule-based: tasks approached by pattern-matching from a set of internal problem-solving rules
    - "can ping web server, but no pages → http is hosed"
    - "http is hosed → should reboot the front end"
  - Knowledge-based: tasks approached by reasoning from first principles, when rules and experience don't apply (need to think)

GEMS and Human Errors

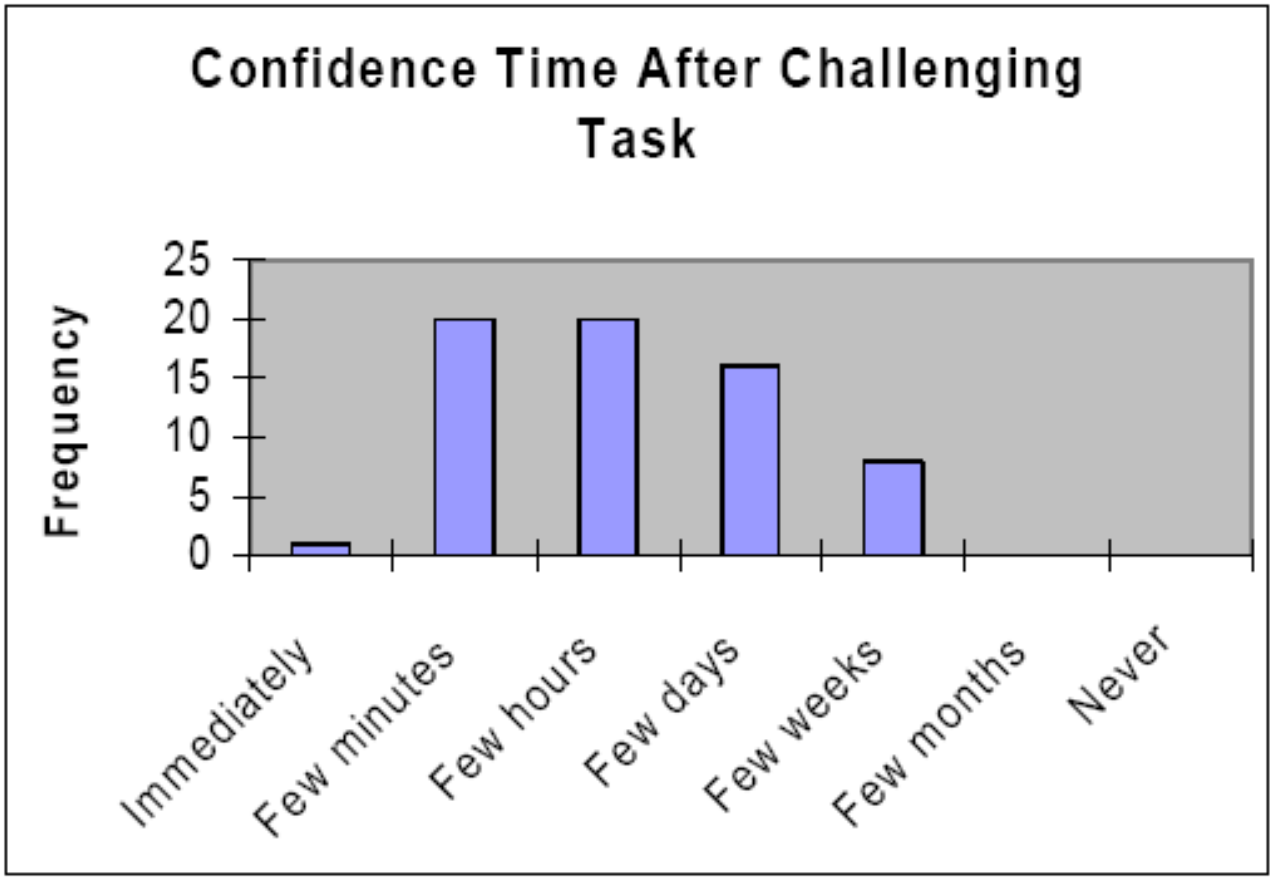
- Human error can occur at each level
  - Skill-based: usually errors of inattention or misplaced attention
  - Rule-based: picked inappropriate rule, misdiagnosed state of system, gambling, deficient rules
  - Knowledge-based: incomplete/inaccurate understanding of system, confirmation bias, overconfidence, cognitive strain, ….
- Human errors can result from operating at wrong level
  - Reluctant to move from rule-based to knowledge-based even if rules aren't working

Error Frequencies

- Raw frequencies in surveys
  - 61% of errors are at skill-based level
  - 27% of errors are at rule-based level
  - 11% of errors are at knowledge-based level
- If we include self-monitoring and self-correction
  - 70% of skill-based errors detected and corrected
  - 50% of rule-based errors detected and corrected
  - 25% of knowledge-based errors detected and corrected

Confidence Time

- E-mail admins survey [Kakes et al., 2002]



Automation Irony

- Automation often addresses skill-based + rule-based tasks → complex knowledge-based tasks left for human
  - Under stress (e.g., during service recovery), humans are ill-suited to knowledge-based tasks
- Automation hinders understanding and mental modeling
  - Decreases system visibility and increases complexity
  - Operators don't get hands-on control experience