

DevOps

Martin Kellogg

Reading quiz: DevOps

Q1: **TRUE** or **FALSE**: Google intentionally hires people for SRE teams who will quickly become bored by performing tasks by hand

Q2: As an example of automation gone awry, the “Emergency Response” article discussed:

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- C. a self-replicating AI system that took over a datacenter

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Announcements

- Reminder: preliminary demos this week. Double-check the time of your team's demo with me.
 - Sorry to those of you who I've had to reschedule
- Team survey #2 will open this afternoon. You should fill it out after you've finished both of your preliminary demos but before the Thanksgiving holiday
- No class on November 26 (one week from today)
 - It's a Friday schedule

DevOps

Today's agenda:

- **Operations, Toil, and the DevOps philosophy**
- **Achieving reliability**
 - the service reliability hierarchy + SLAs/targets
 - monitoring and reliability testing
 - incident/emergency response
 - preventing problems before they occur
 - post-mortems + learning from failure

Operations

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- deploying new versions of the software

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 - other advantages: easy to staff for, off-the-shelf tooling, etc.

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can work in either of these models!

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These problems **do not** mean that the traditional approach to operations is bad in all circumstances!

- But, they are serious concerns for modern systems with high release cadences, especially those that are:
 - microservices
 - delivered via the web
 - use “continuous delivery”

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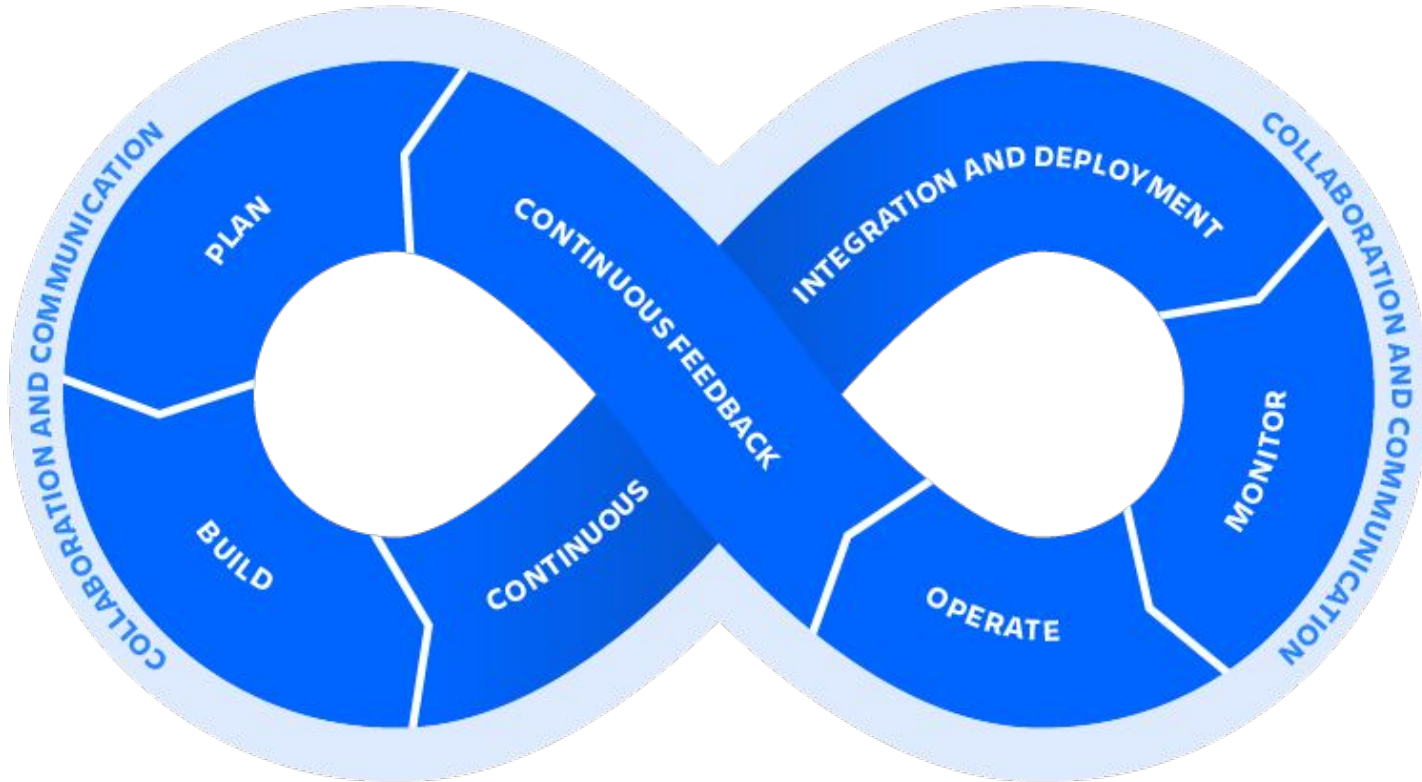
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- operational burden is **shared** by the developers who are building the system
 - better alignment of incentives between developers and operators, since same people perform both roles
- encourage operators to automate **toil**
- may still have some dedicated ops roles (e.g., SREs at Google)

Operations: the DevOps approach



Operations: toil

“ *If a human operator needs to touch your system during normal operations, you have a bug. The definition of normal changes as your systems grow.* ”

Carla Geisser, Google SRE

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A key advantage of DevOps is that it encourages **removing** toil

- if operators are separate from devs, devs have no incentive to avoid toil

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- **repetitive:** if you're performing a task for the first time ever, or even the second time, this work is not toil
- **automatable:** if human judgment is essential for the task, there's a good chance it's not toil

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- **no enduring value:** if your service remains in the same state after you have finished a task, the task was probably toil
- **$O(n)$ with service growth:** if the work involved in a task scales up linearly with *service size*, *traffic volume*, or *user count*, that task is probably toil

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- **tactical:** toil
 - **no enduring value:** A task doesn't need to have **all** of these attributes to be toil. But, the more closely you have fit, the more likely it is to be toil.
 - **$O(n)$ with scale:** work matches one or more of these descriptors, the **more likely** it is to be toil.
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 - e.g., cleaning up the entire alerting configuration for your service and removing clutter may not be fun, but it's not toil

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- **overhead** is also different than toil
 - tasks like team meetings, setting and grading goals, and HR paperwork (that are not tied to operations) are overhead

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What's **so bad** about toil?

- career stagnation (it doesn't get you promoted)
- lowers morale (it's boring)
- creates confusion (easy to forget to do a manual task!)
- slows progress (could be doing useful work instead)
- sets precedent (avoid letting toil become normal!)
- promotes attrition ("I want to work on something interesting!")

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- creates context switches
- slows progress
- sets precedence
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Despite all this, a **little bit** of toil is often okay. After all, engineers only have so many productive hours in every day, and sometimes a **mental break** is nice :)

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 - SRE team manages ops for all of these systems

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- SRE motto: “Hope is not a strategy”

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 - makes technical debt riskier to take on (why?)

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 - preventing problems before they occur
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 - so, availability is the first thing we need to worry about when trying to make a service reliable

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 - **durability** (how much of your data can you still retrieve after a fixed time has passed)

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Sometimes SLAs are written into contracts with your customers!

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E.g., consider two systems:

- system A serves 200 requests in every even-numbered second, and 0 requests in every odd-numbered second
- system B serves 100 requests every second

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 - this avoids hiding details like the example on the last slide

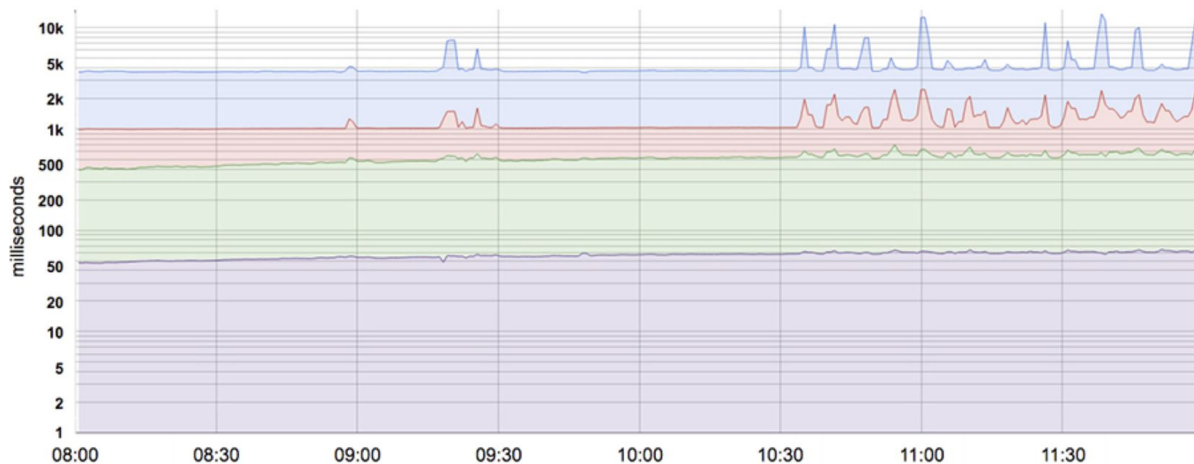
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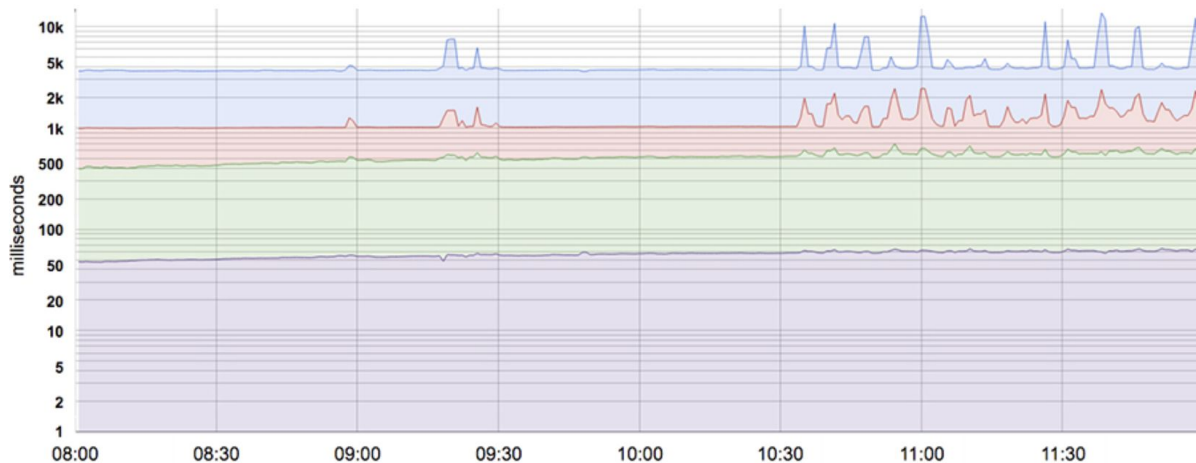
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 - this avoids hiding details like the example on the last slide



green is
85th %
latency

Aside: subtleties in metrics

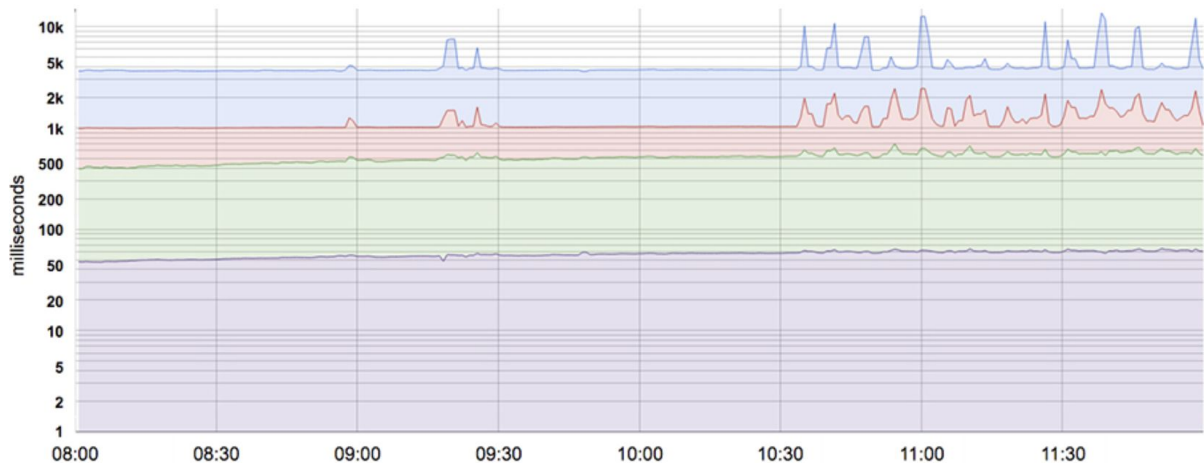
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Aside: subtleties in metrics

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Finally, watch out for **Goodhart's Law**:
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- regularly re-examine the set of metrics that you're using to make sure they actually correlate with qualitative “good” system health

Reliability: meeting expectations

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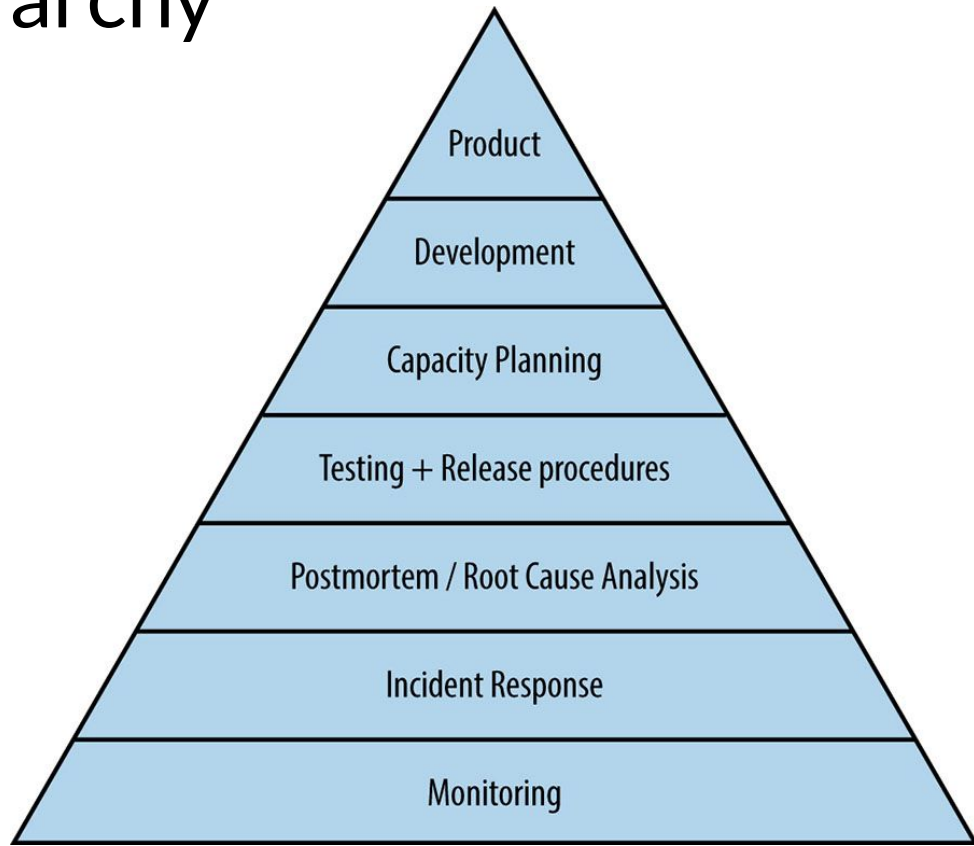
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- How do we think about how to do this?
 - **insight:** there is a **hierarchy** of system components that need to be working well in order to meet an SLA

Service Reliability Hierarchy

- analogy to Maslow's "Hierarchy of Needs" for humans



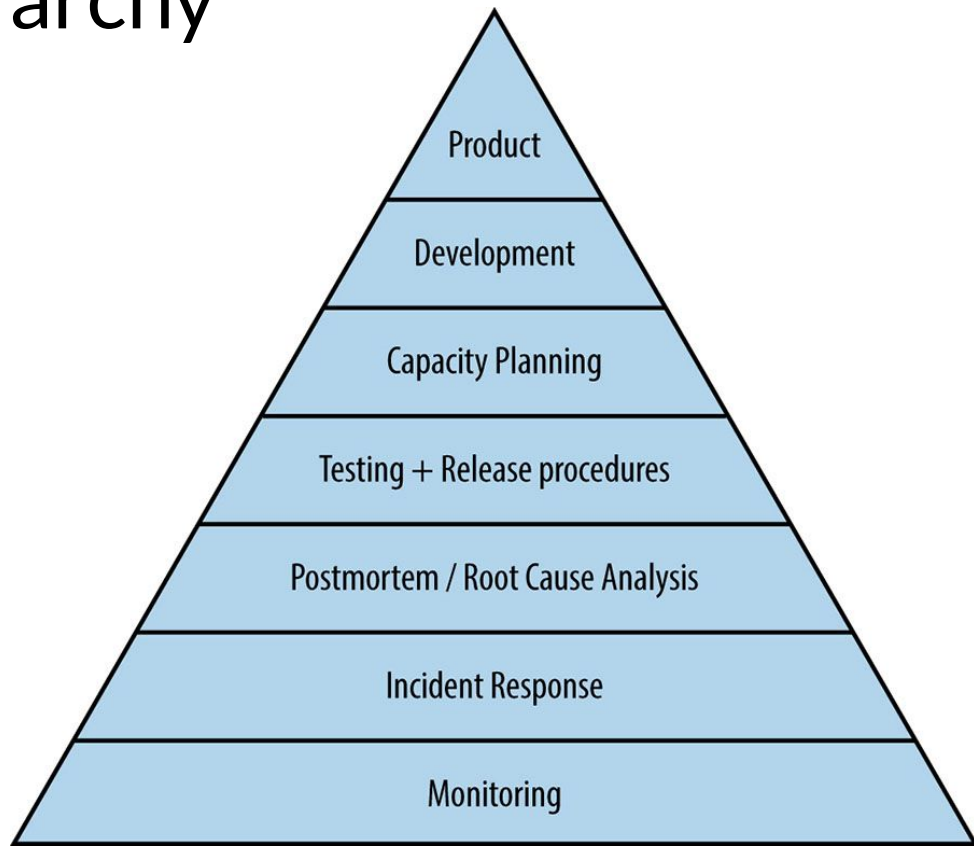
Maslow's Hierarchy of Needs



Maslow's hierarchy of needs

Service Reliability Hierarchy

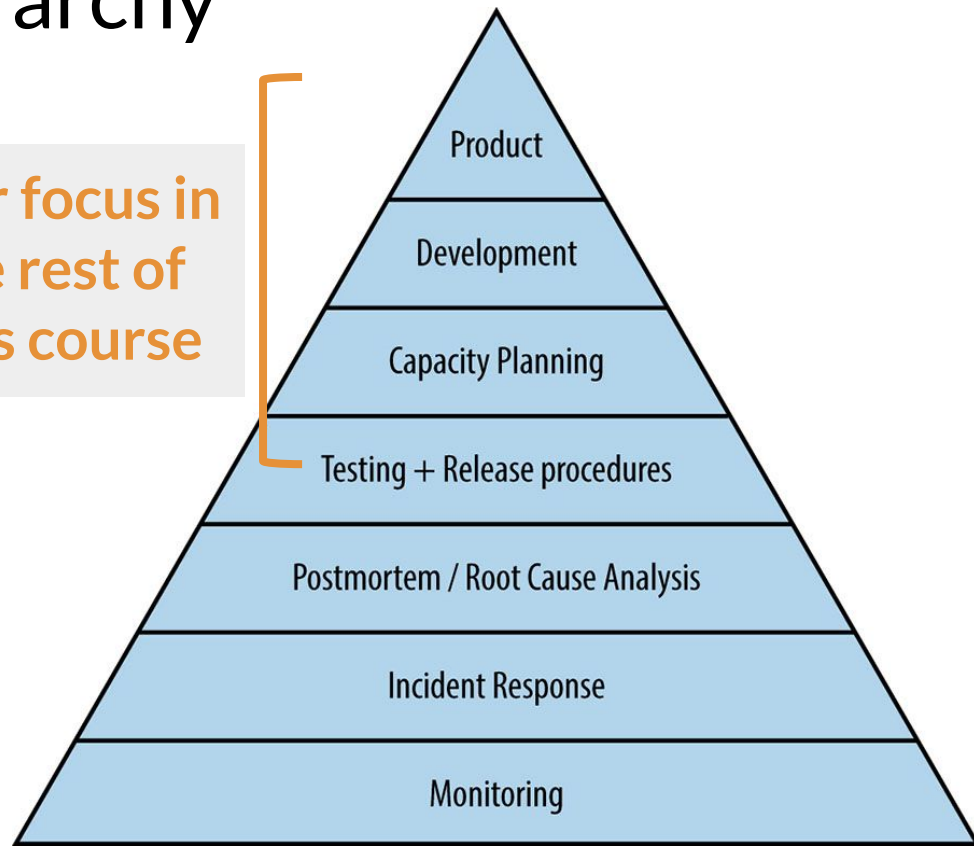
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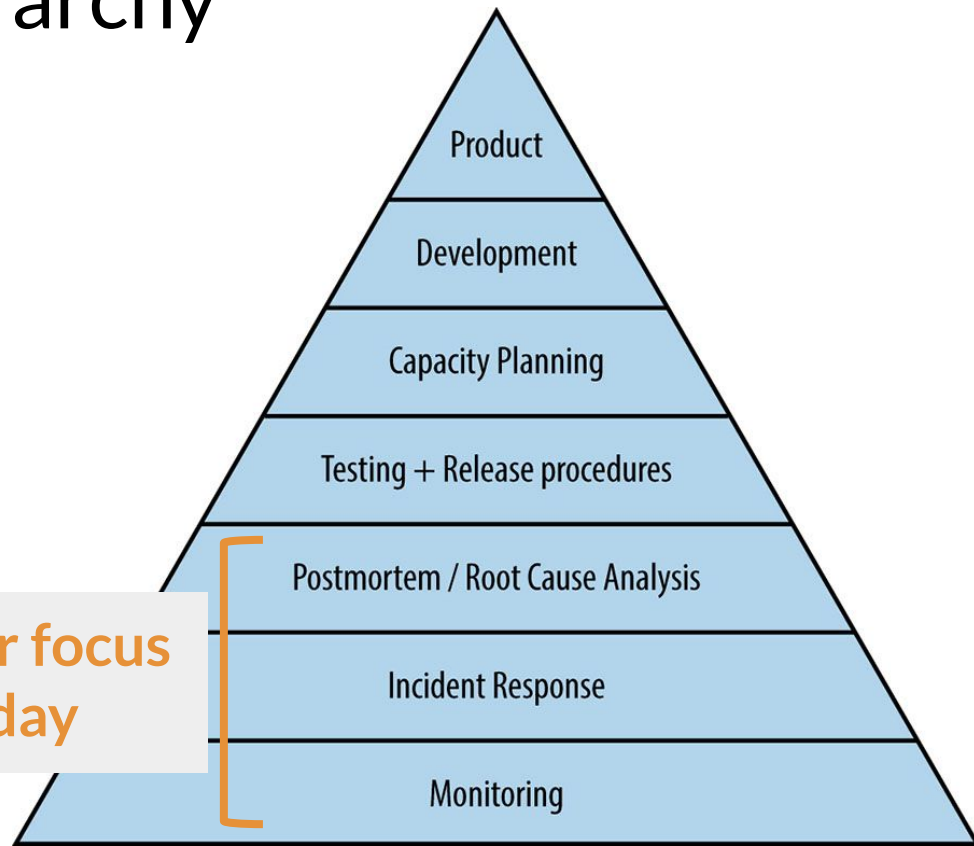
our focus in
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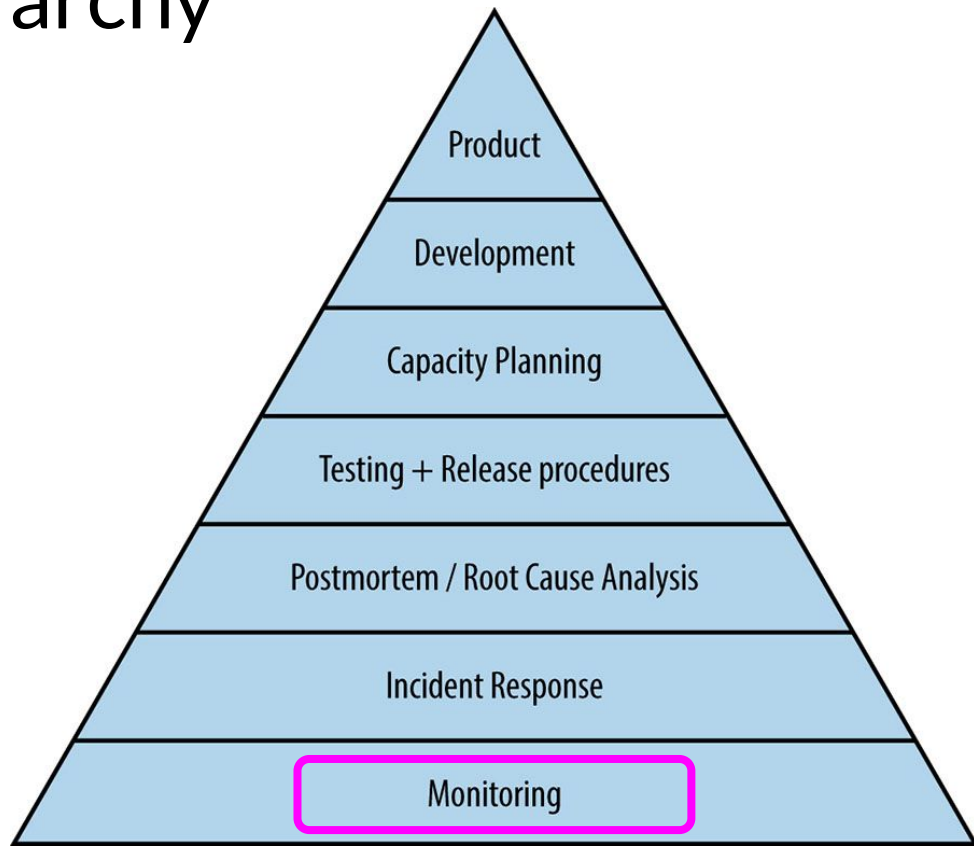
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DevOps

Today's agenda:

- Operations, Toil, and the DevOps philosophy
- Ops challenge example: deployment
- Achieving reliability
 - the service reliability hierarchy + SLAs/targets
 - **monitoring**
 - incident/emergency response
 - post-mortems + learning from failure

Monitoring

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Monitoring is why **logging** is so important in practice: if your monitoring depends on your logging framework, it is a very important component of your service!

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- **page** = alert send directly to a human (via a pager)

Monitoring: being on-call

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DevOps (2/2)

Martin Kellogg

Reading quiz: DevOps (2)

Q1: Which of these is a role-playing exercise to train new SREs on incident management?

- A. Failure Dice
- B. DevOps and Dragons
- C. Outage Roulette
- D. Wheel of Misfortune

Q2: **TRUE** or **FALSE**: Luu argues that “high risk protocols” for humans to follow during high-risk operations are an “ops smell”, because humans shouldn’t carry out high-risk operations manually at all.

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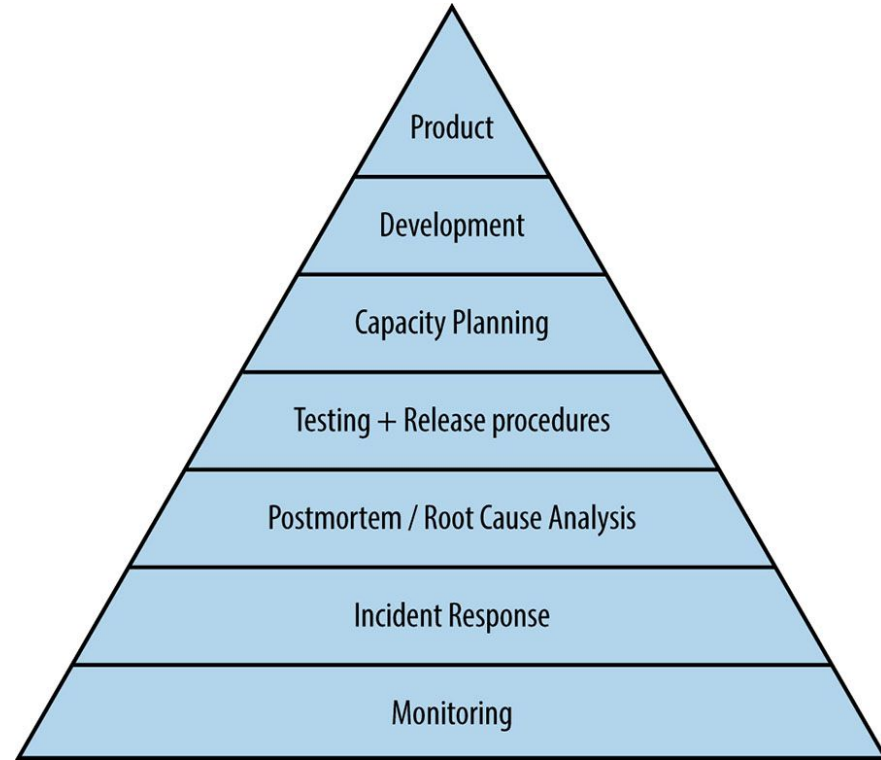
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Announcements

- Team survey #2 is open. Please fill it out before you leave for Thanksgiving break.
- No class on Wednesday
 - University has declared it to be a Friday
- Enjoy your break!

Review: Service Reliability Hierarchy

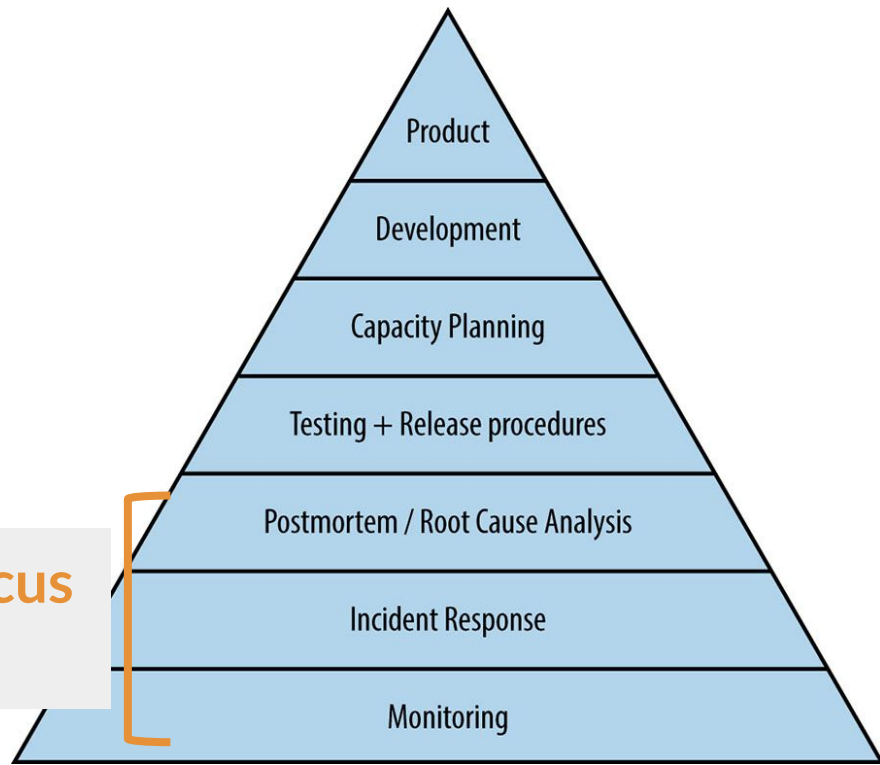
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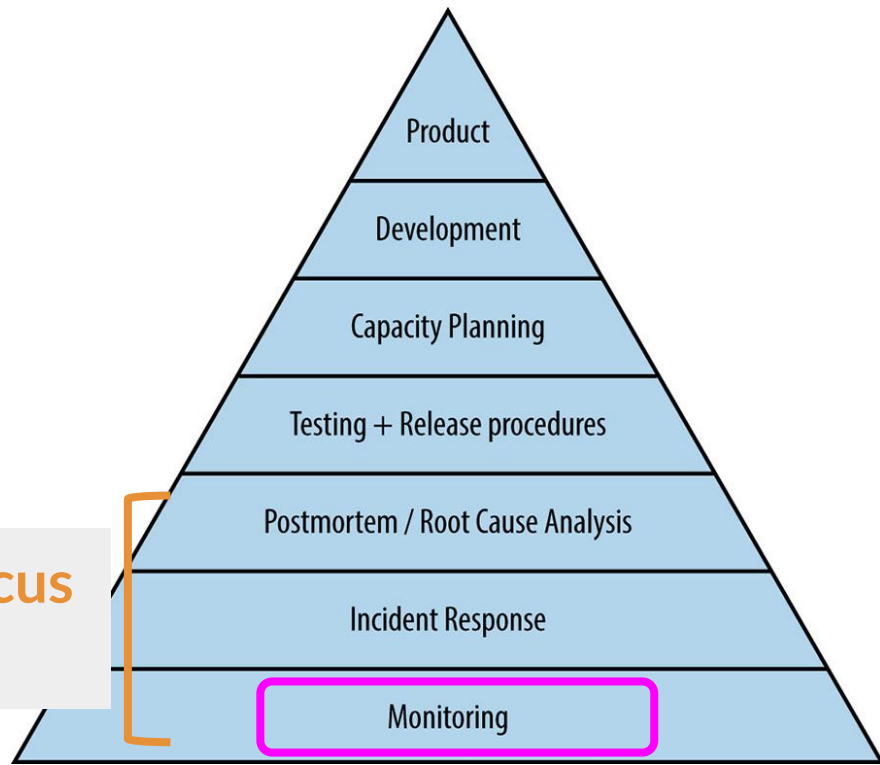
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 - Or it might be a **page** to the on-call engineer, if the problem needs to be investigated right away

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- Example from Monday: “cleaning up a service’s alerting config” = fixing **what corresponds** to pages vs email alerts vs tickets

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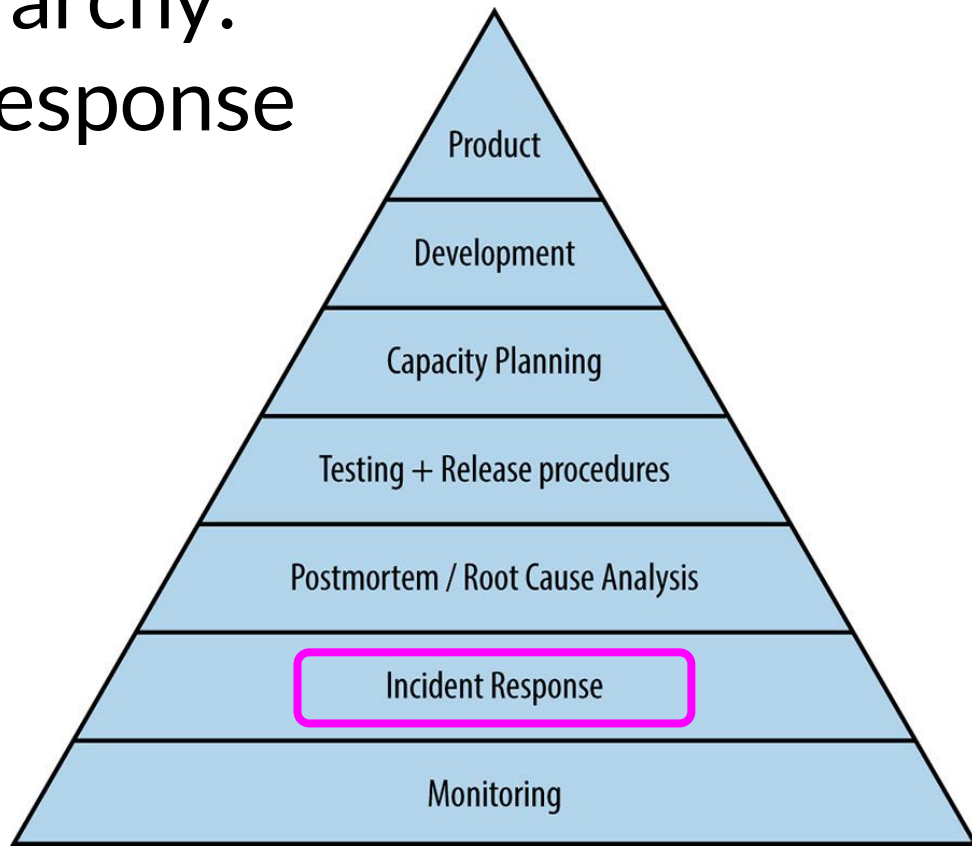
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 - but can (**and should**) page other team members in an emergency

DevOps

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- Operations, Toil, and the DevOps philosophy
- Achieving reliability
 - the service reliability hierarchy + SLAs/targets
 - monitoring and reliability testing
 - **incident/emergency response**
 - preventing problems before they occur
 - post-mortems + learning from failure

Service Reliability Hierarchy: Incident/Emergency Response



Emergency Response

- So you're the on-call, and you get a page. What happens next?

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 - “**emergency response**”
 - as the on-call, **you are in charge** in an emergency by default
- What constitutes an emergency?
 - depends on your service, but typically these qualify:
 - big % of user requests aren't getting responses
 - big % of user requests have really high latency
 - lots of your servers are unavailable/down (even if users aren't yet impacted)

Emergency Response: causes of emergencies

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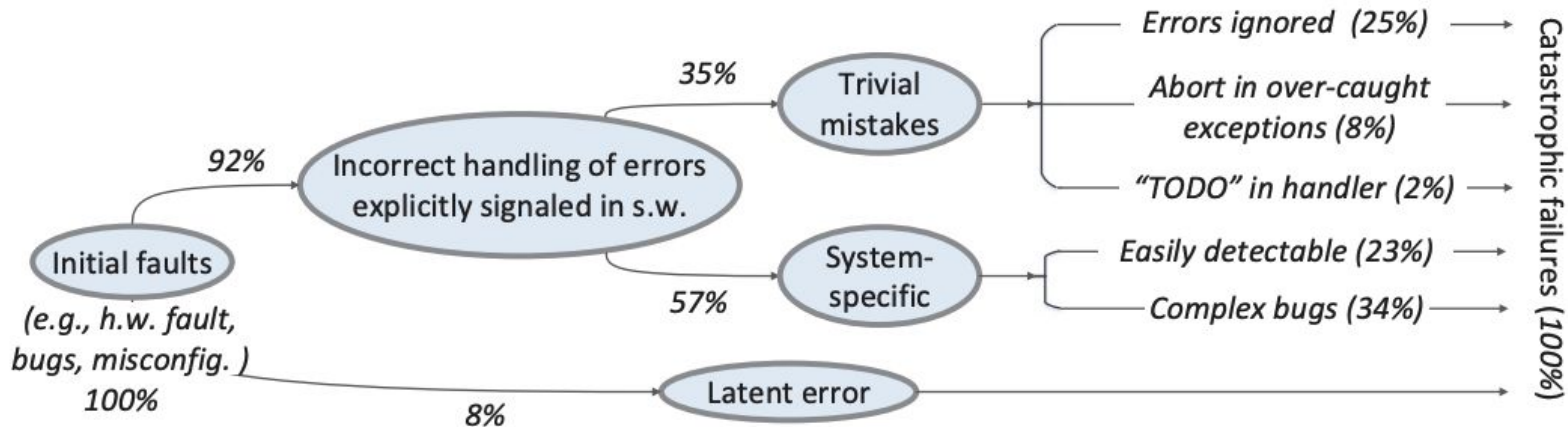
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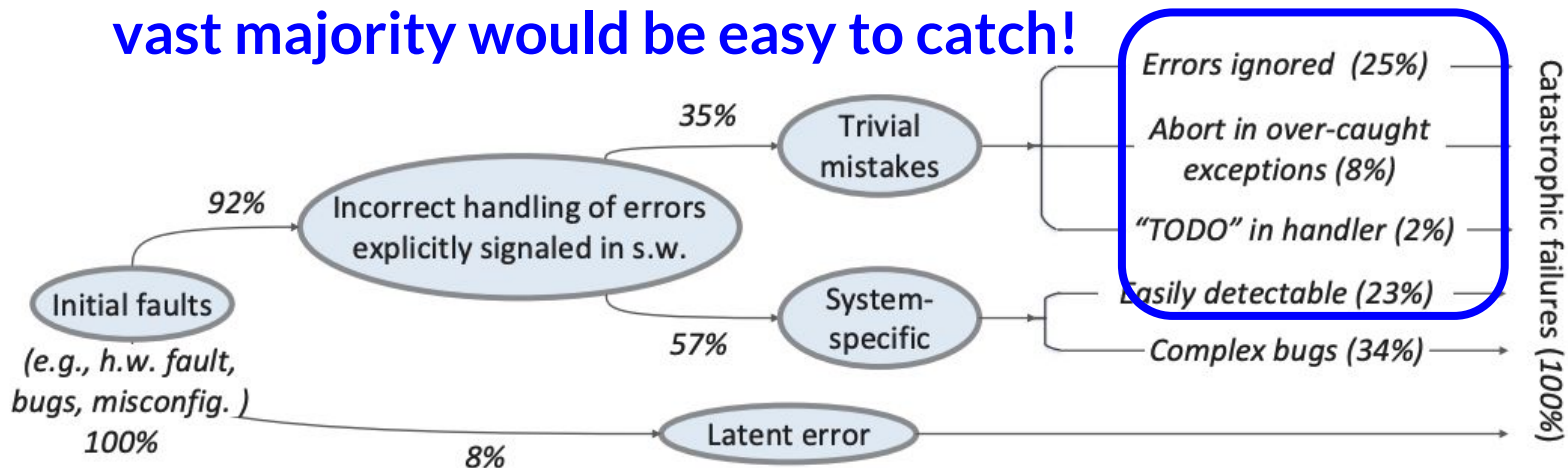
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Emergency Response: causes of emergencies

- **configuration changes:**
 - especially for services, how the servers that run the system are configured is often as important as the code itself
 - changes to the infrastructure (e.g., adding or removing servers) are just as risky as changes to the code
 - but testing them is harder!

Emergency Response: causes of emergencies

- hardware:
 - pop quiz: how long does an average hard disk last?

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- **almost 100%!**
 - each disk lasts $365 \times 5 = 1825$ days. 10k disks = **~5 fail/day**

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Implication: in large systems, you
must plan for hardware failures,
because they **will occur**

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 - of course you have! we all make mistakes sometimes!
 - it is a mistake for a human to repeatedly perform a task that could lead to catastrophic failure if it is not done perfectly
 - computers are good at this!
 - analogy: just like hardware components sometimes fail, any step carried out by humans should be assumed to have a non-zero failure rate

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 - playbooks also have a psychological function: **prevent panic**

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 - **preserve evidence**: save logs, etc., for post-mortem analysis
- **Practice** makes perfect
 - don't wait for an actual emergency to find out if your playbook works: simulate one instead!

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- The need to roll back has important implications:

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 - key idea: most emergencies are caused by some **change**
 - so, to fix the incident, we should **undo** the change
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Easy rollbacks are one motivation for “**infrastructure-as-code**”: if your infrastructure configuration is in version control, it’s easy to go back to the last working one!

- The need to roll back has important implications:

- avoid changes that **cannot be undone** (“two-way doors”)
- your version control system is your friend here!

- make sure to commit things that might cause incidents if they change to version control, e.g., your **config files**

DevOps

Today's agenda:

- Operations, Toil, and the DevOps philosophy
- Achieving reliability
 - the service reliability hierarchy + SLAs/targets
 - monitoring and reliability testing
 - incident/emergency response
 - **preventing problems before they occur**
 - post-mortems + learning from failure

Preventing Problems

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Preventing Problems

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 - we can use many of the techniques that we discussed in this class to help prevent emergencies!
- however, there are some **DevOps-specific** testing and deployment strategies that can help:
 - integrating testing and monitoring
 - stress testing services
 - canaries and “baking the binary”

Integrating Testing and Monitoring

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- If we view our monitoring system this way, we can **apply many testing techniques** to monitoring
 - for example, should there be a **relationship** between a pair of metrics that we’re collecting? (= **metamorphic testing**)
 - if so, we can define an alert that goes off if that relationship is ever violated

Stress Testing

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 - “How many queries a second can be sent to an application server before it becomes overloaded, causing requests to fail?”
- **Chaos Monkey** is one example of a stress testing technique
 - Others include intentionally *scaling up* another service
 - i.e., simulate a spike in demand with artificial traffic

Stress Testing: Chaos Monkey

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- *"Imagine a monkey entering a "data center", these "farms" of servers that host all the critical functions of our online activities. The monkey **randomly** rips cables, destroys devices and returns everything that passes by the hand. The challenge for IT managers is to **design the** information **system** they are responsible for **so that it can work despite these monkeys**, which no one ever knows when they arrive and what they will destroy."*

– Antonio Martinez, Chaos Monkey

Stress Testing: Chaos Monkey

- *“We have created Chaos Monkey, a program that randomly chooses a server and disables it during its usual hours of activity. Some will find that crazy, but we could not depend on the random occurrence of an event to test our behavior in the face of the very consequences of this event.”*
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 - cascading failures are typically much harder to recover from
 - many parts of the system have failed, not just one!
 - one of the goals of Chaos Monkey is to detect such cascading failures before they actually happen in production

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 - this part of the fleet is monitored for failures, and if none occur then **more and more** of the fleet is updated

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 - the blast radius is how many users/requests are impacted
- An important technique for limiting blast radius is **staged deployment**, which is also called **canary deployment**.
 - in a staged deployment, a small **percentage** of the active fleet is upgraded
 - this part of the fleet is monitored for failures, and if none occur then **more and more** of the fleet is updated

This incubation period while the fleet is partially upgraded is sometimes called “**baking the binary**”.

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 - R = the rate of reports

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Staged Deployment: concrete example

- Consider a given underlying fault that:

Note that C , R , and K should all be **measurable** by your monitoring system. But that is **exponential**

- We would expect a growing cumulative number of reported variances, governed by the equation $C^U = RK$, where:
 - C = cumulative number of reports
 - U = order of the fault (see next slide)
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Observe that *order* here is like big-O notation:

- $U=1$ means that only the request itself is impacted
- $U=2$ means that a linear-ish number of other requests will be impacted
- $U=3$ means exponentially more requests will be impacted
- etc.

know

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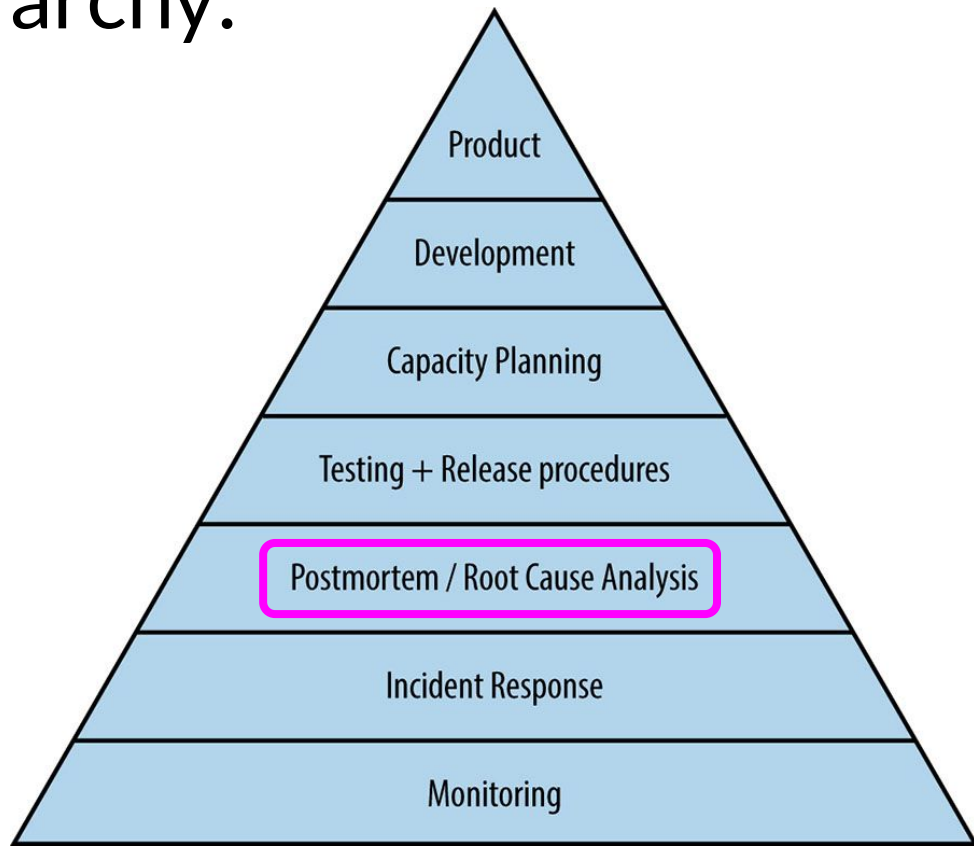
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 - this might involve writing automation to trace all requests that hit the bug, restoring from a backup, etc.
- As we do all of this, it's important to **keep records**
 - they'll be useful later for **writing the post-mortem** (next topic!)

DevOps

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 - preventing problems before they occur
 - **post-mortems + learning from failure**

Service Reliability Hierarchy: Post-mortems



Post-mortems

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- good postmortems are **blameless** and **actionable**:
 - “**blameless**” = find the faults in the process, not the people
 - “**actionable**” = give specific guidance for how to avoid the problem in the future (these become tickets)

Post-mortems: blameless

- Why not assign blame after an incident?
 - After all, **someone** should be responsible, right?

Post-mortems: blameless

- Why not assign blame after an incident?
 - After all, **someone** should be responsible, right?
- Some reasons:
 - Gives people **confidence to escalate** issues without fear
 - Avoids creating a culture in which incidents and issues are **swept under the rug** (which is worse long-term!)
 - **Learning experience**: engineers who have experienced an incident won't make the same mistakes again
 - You can't "fix" people, but you can fix **systems and processes**

Post-mortems: blameless

- Why not assign blame?
 - After all, **some** people do make mistakes
- Some reasons:
 - Gives people **confidence** to speak up
 - Avoids creating **blame culture** where mistakes are **swept under the rug**
 - **Learning experience**: engineers who have experienced an incident won't make the same mistakes again
 - You can't "fix" people, but you can fix **systems and processes**

Historically, software engineering adopted a lot of "blameless culture" from **aviation and medicine**, where mistakes can be fatal! We might not have the same stakes, but **all complex systems are similar** in a lot of ways.

Post-mortems: peer review

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- Peer review **raises the bar**: senior engineers on other teams will expect you to **explain and justify** the changes you are proposing in response to an incident
 - leads to more actionable takeaways and better understanding of what went wrong
 - also enables engineers on different teams to learn from each others' mistakes

Post-mortems: example

Shakespeare Sonnet++ Postmortem (incident #465)

Date: 2015-10-21

Authors: jennifer, martym, agoogler

Status: Complete, action items in progress

Summary: Shakespeare Search down for 66 minutes during period of very high interest in Shakespeare due to discovery of a new sonnet.

Impact:¹⁶³ Estimated 1.21B queries lost, no revenue impact.

Root Causes:¹⁶⁴ Cascading failure due to combination of exceptionally high load and a resource leak when searches failed due to terms not being in the Shakespeare corpus. The newly discovered sonnet used a word that had never before appeared in one of Shakespeare's works, which happened to be the term users searched for. Under normal circumstances, the rate of task failures due to resource leaks is low enough to be unnoticed.

Trigger: Latent bug triggered by sudden increase in traffic.

[source: <https://sre.google/sre-book/example-postmortem/>]

Post-mortems: example

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Date: 2015-10-21

Authors: jennifer, martym, agoogler

Status: Completed

Summary: Shakespeare Sonnet++
a new sonnet.

Impact:¹⁶³ Estimated 1.2M queries lost, no revenue impact.

Resolution: Directed traffic to sacrificial cluster and added 10x capacity to mitigate cascading failure. Updated index deployed, resolving interaction with latent bug. Maintaining extra capacity until surge in public interest in new sonnet passes. Resource leak identified and fix deployed.

Detection: Borgmon detected high level of HTTP 500s and paged on-call.

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Post-mortems: example

Action Item	Type	Owner	Bug
Update playbook with instructions for responding to cascading failure	mitigate	jennifer	n/a DONE
Use flux capacitor to balance load between clusters	prevent	martym	Bug 5554823 TODO
Schedule cascading failure test during next DiRT	process	docbrown	n/a TODO
Investigate running index MR/fusion continuously	prevent	jennifer	Bug 5554824 TODO

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Plug file descriptor leak in search ranking

prevent

agoogle

Bug 5554825 **DONE**

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and 5 more...

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Plug file descriptor leak in search ranking prevent

agoogle

Bug 5554825 **DONE**

Post-mortems: example

Lessons Learned

What went well

- Monitoring quickly alerted us to high rate (reaching ~100%) of HTTP 500s
- Rapidly distributed updated Shakespeare corpus to all clusters

What went wrong

- We're out of practice in responding to cascading failure
- We exceeded our availability error budget (by several orders of magnitude) due to the exceptional surge of traffic that essentially all resulted in failures

Where we got lucky¹⁶⁶

- Mailing list of Shakespeare aficionados had a copy of new sonnet available
- Server logs had stack traces pointing to file descriptor exhaustion as cause for crash
- Query-of-death was resolved by pushing new index containing popular search term

[source: <https://sre.google/sre-book/example-postmortem/>]

Post-mortems: example

Timeline¹⁶⁷

2015-10-21 (all times UTC)

- 14:51 News reports that a new Shakespearean sonnet has been discovered in a DeLorean's glove compartment
- 14:53 Traffic to Shakespeare search increases by 88x after post to **/r/shakespeare** points to Shakespeare search engine as place to find new sonnet (except we don't have the sonnet yet)
- 14:54 **OUTAGE BEGINS** — Search backends start melting down under load
- 14:55 docbrown receives pager storm, **ManyHttp500s** from all clusters
- 14:57 All traffic to Shakespeare search is failing: see **<https://monitor>**
- 14:58 docbrown starts investigating, finds backend crash rate very high
- 15:01 **INCIDENT BEGINS** docbrown declares incident #465 due to cascading failure, coordination on **#shakespeare**, names jennifer incident commander
- 15:02 someone coincidentally sends email to **shakespeare-discuss@** re sonnet discovery, which happens to be at top of martym's inbox

Post-mortems: example

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this goes on for several pages!

- shows importance of keeping records

opens to be at

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DevOps: takeaways

- Many modern engineering organizations prefer to combine, rather than separate, development and operations
 - this works best when most systems are services
- Major benefit of DevOps approach is elimination of toil
 - developers are best at building automation
- Planning for incidents/emergencies is critical
 - Monitoring allows on-call to quickly identify problems
 - Have a plan (ideally, in a playbook) for incidents
 - Use post-mortems to learn from prior emergencies
 - not to blame people for causing them!

