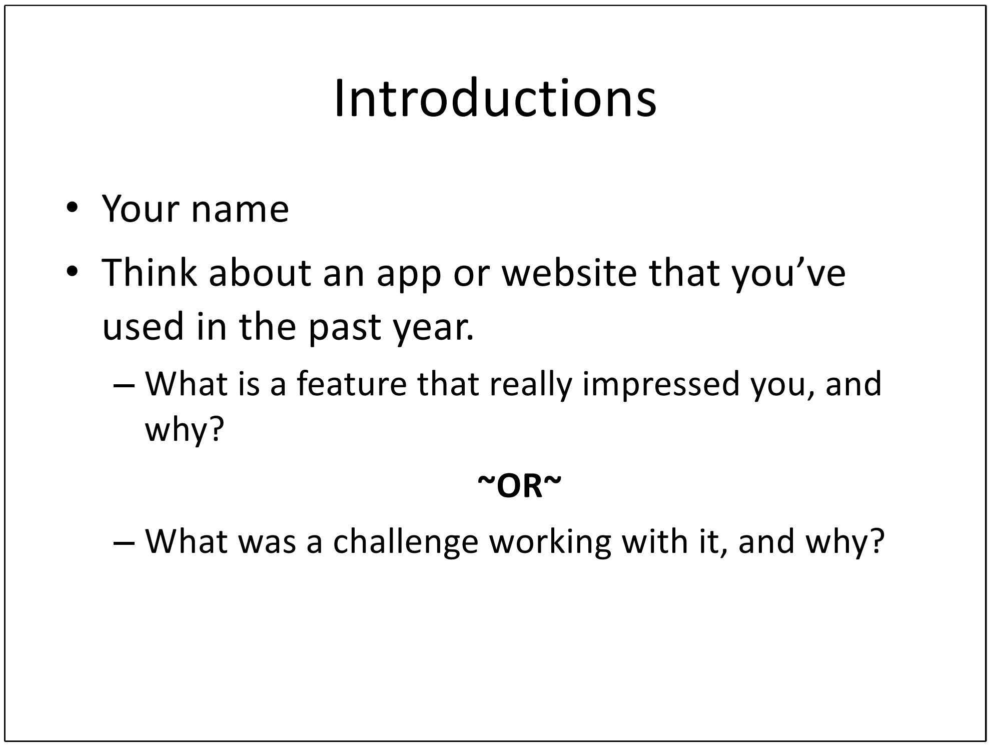
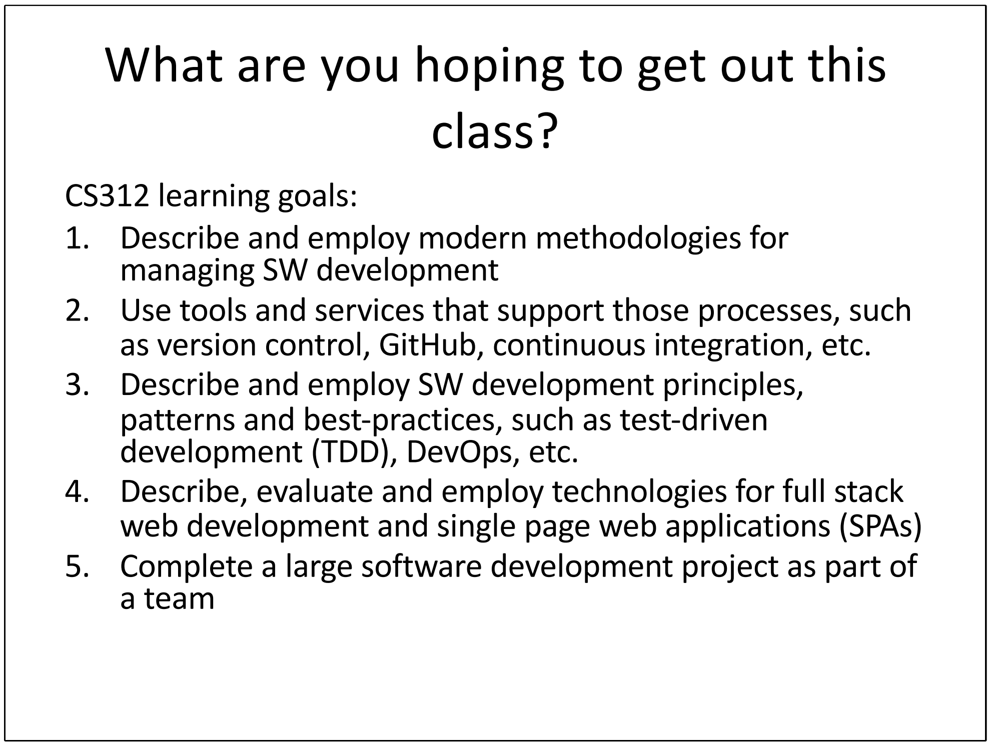


Introductions

- Your name
- Think about an app or website that you've used in the past year.
  – What is a feature that really impressed you, and why?

  ~OR~

  – What was a challenge working with it, and why?

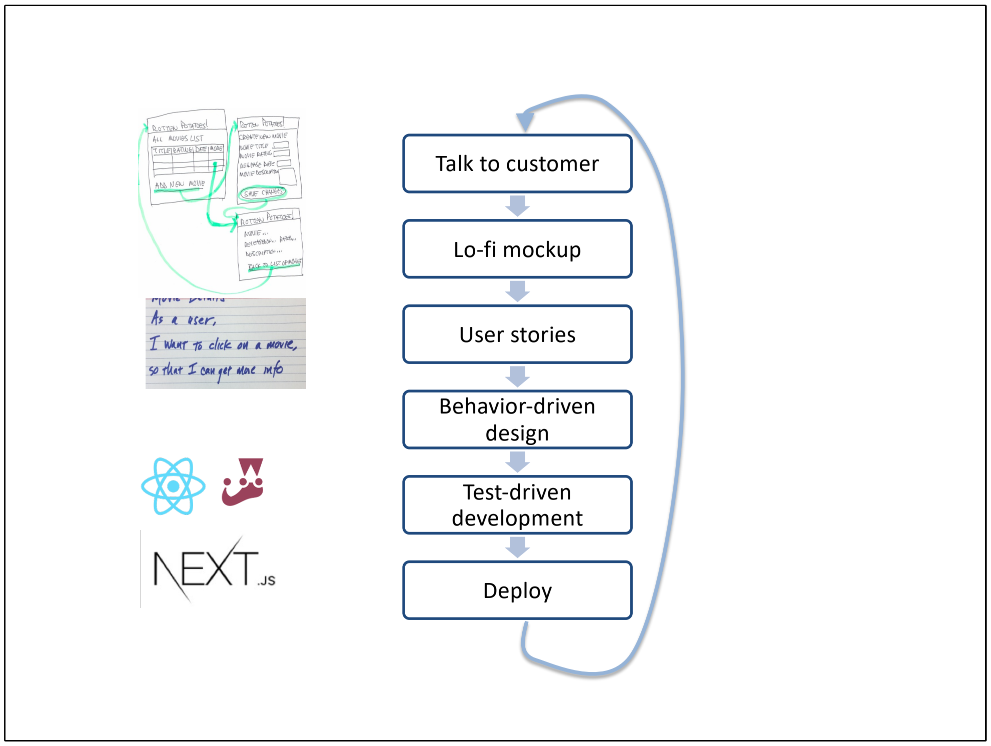


What are you hoping to get out this class?

CS312 learning goals:

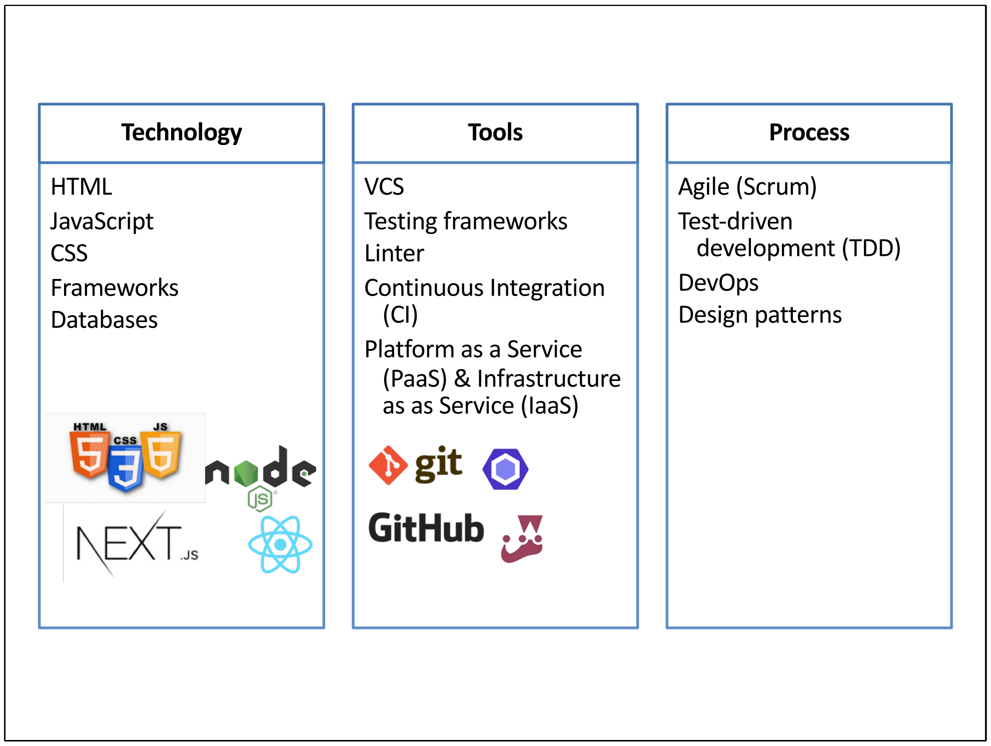
1. Describe and employ modern methodologies for managing SW development
2. Use tools and services that support those processes, such as version control, GitHub, continuous integration, etc.
3. Describe and employ SW development principles, patterns and best-practices, such as test-driven development (TDD), DevOps, etc.
4. Describe, evaluate and employ technologies for full stack web development and single page web applications (SPAs)
5. Complete a large software development project as part of a team

Alongside the more formal learning goals I hope you will gain some important development skills that are not necessarily are part of your other courses, such as working with non-technical customers and more.



The workflow we will implement has some key “technical” steps, but also some ”non-technical” steps that are equally important for ensuring that we develop the right software, i.e., software that solves the user’s actual problem, not just software that works correctly. Unlike a class assignment, where there is (often) a very clear task and problem to solve, in the project (and any real-world situation) you will need to figure out the problem too! That is figure out what you should be building!

Adapted from Armando Fox and David Patterson (Berkeley cs169) under CC-BY-SA-NC license



Technology

- HTML
- JavaScript
- CSS
- Frameworks
- Databases

Tools

- VCS
- Testing frameworks
- Linter
- Continuous Integration (CI)
- Platform as a Service (PaaS) & Infrastructure as as Service (IaaS)

Process

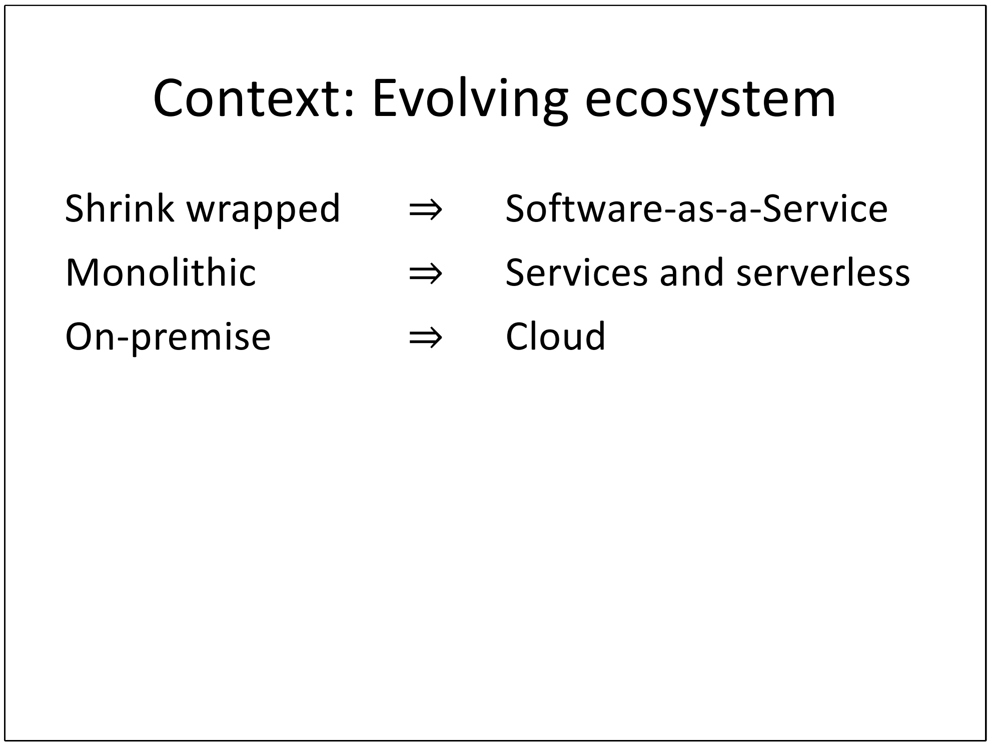
- Agile (Scrum)
- Test-driven development (TDD)
- DevOps
- Design patterns

HTML
CSS
JS
node
JS
NEXT.JS
git
GitHub

Here are some of the tools and technologies we will use. These specific tools and technologies are a means to an end. I care more that you learn the “why” for these tools than the ”how” of any particular technology or framework.

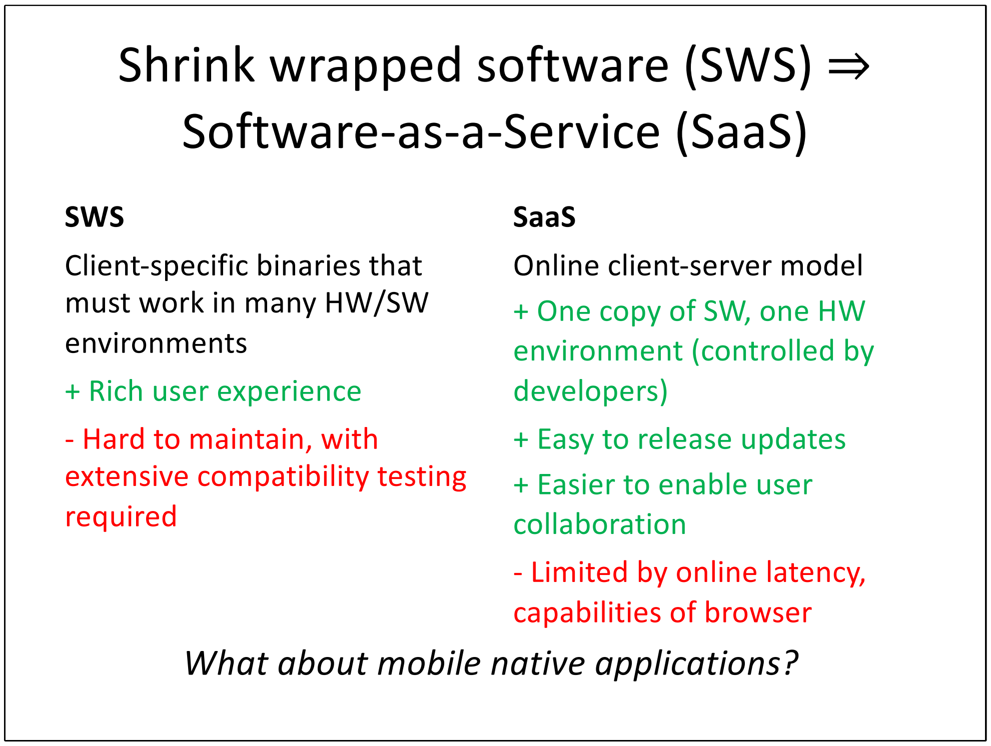
This class has a lot of moving parts. And I have made many choices for tools, techniques, methodologies. In some cases, it is a choice among many similar alternatives where there is no "right" answer. I don't want you to get bogged down in questions of whether any particular tool or technology is the best in a technical or other sense (we often are optimizing for the best class experience, not the best tool). You may be more familiar with the alternatives. As we will discuss later, I ask you to "do the class" with the class tools. Doing so will make your teams more efficient. At the same time, if our approach seems to conflict with best practices, don't hesitate to ask me about it - we will both get a lot out of the ensuing discussion.

Why this set of tools? Let’s talk a little bit about the context we are working in…



Context: Evolving ecosystem

Shrink wrapped	⇒	Software-as-a-Service
Monolithic	⇒	Services and serverless
On-premise	⇒	Cloud


Shrink wrapped software (SWS) ⇒ Software-as-a-Service (SaaS)

SWS

Client-specific binaries that must work in many HW/SW environments

+ Rich user experience

- Hard to maintain, with extensive compatibility testing required

SaaS

Online client-server model

+ One copy of SW, one HW environment (controlled by developers)

+ Easy to release updates

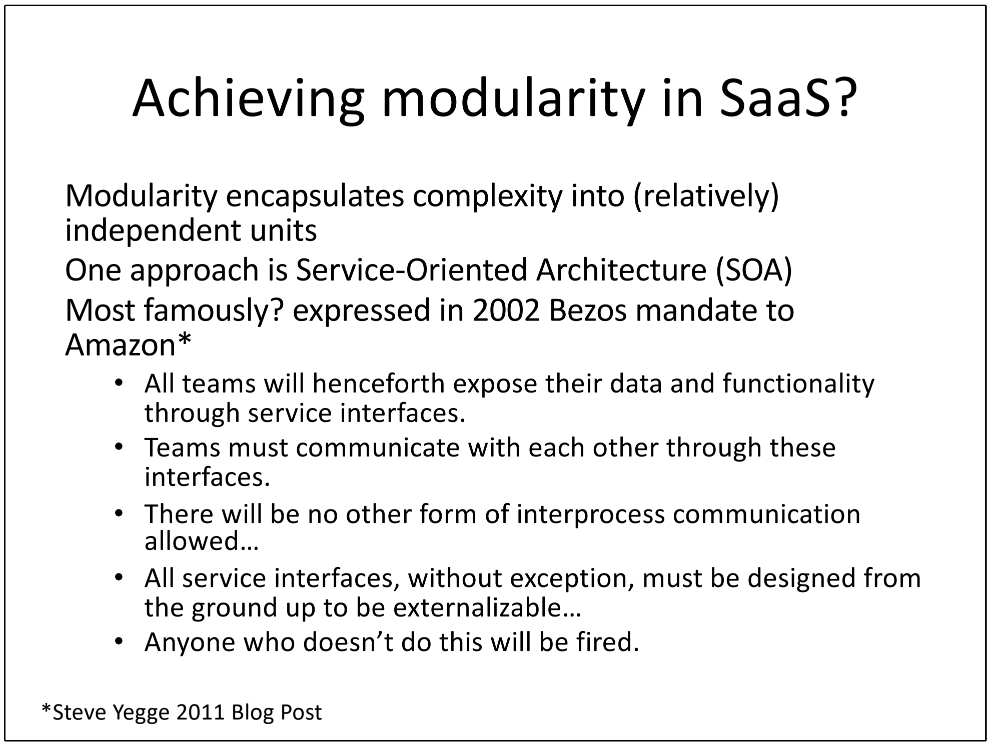
+ Easier to enable user collaboration

- Limited by online latency, capabilities of browser

What about mobile native applications?

SaaS tools are now so integral to how we work we don't really think about it (till we have to deal with Internet service in rural VT…), but it wasn't/isn't always this way.

What about mobile native applications? A counter example for this trend?
+ Use HW features unavailable in HTML5
+ *May* be faster…or not (many just HTML5 apps in native "container")
+ Your brand is on user's home screen (though can get this in other ways)
- Harder to maintain with multiple platforms to support
- Upgrades now once again user's problem (although app stores mitigate some of that…)



Achieving modularity in SaaS?

Modularity encapsulates complexity into (relatively) independent units

One approach is Service-Oriented Architecture (SOA)

Most famously? expressed in 2002 Bezos mandate to Amazon*

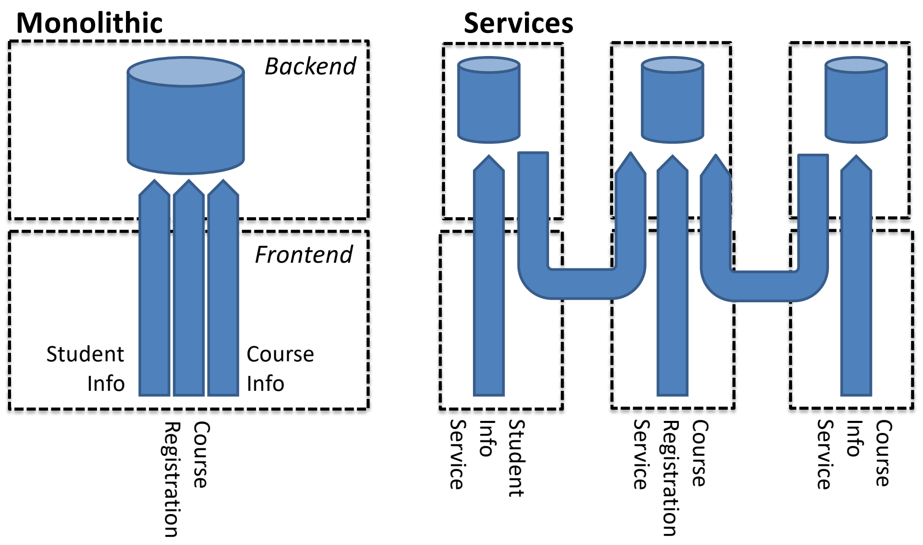
- All teams will henceforth expose their data and functionality through service interfaces.
- Teams must communicate with each other through these interfaces.
- There will be no other form of interprocess communication allowed…
- All service interfaces, without exception, must be designed from the ground up to be externalizable…
- Anyone who doesn’t do this will be fired.

*Steve Yegge 2011 Blog Post

SOA: An architecture that focuses on discrete services instead of a “monolithic” design (where components are part of the same application and can often directly access all of the application’s data).

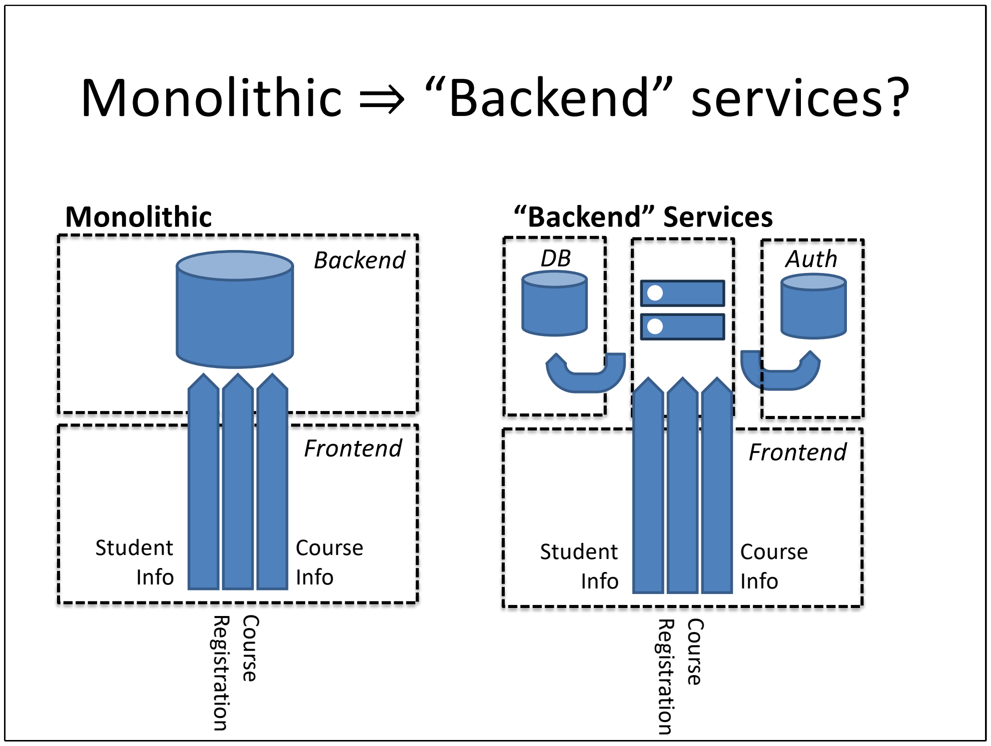
https://courses.cs.washington.edu/courses/cse452/23wi/papers/yegge-platform-rant.html

Monolithic ⇒ Multiple services?



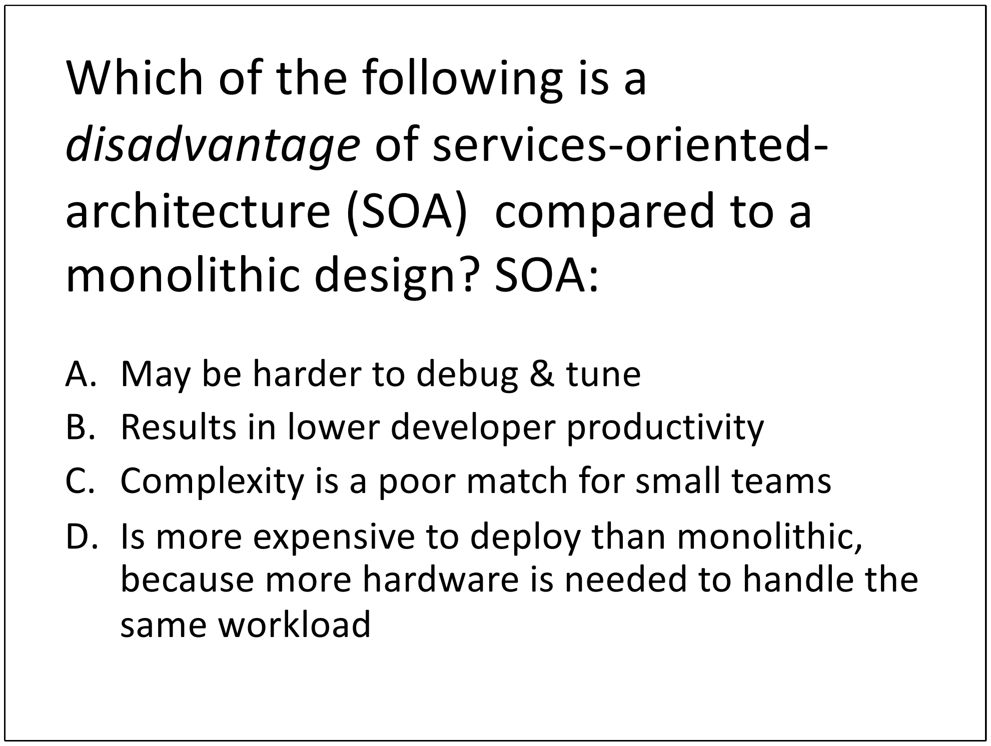
What do we mean by services and service-oriented architecture (also sometimes called microservices). As described in Bezos mandate, the system is decomposed into independent services. Each can be developed/deployed independently. In the ideal case the complexity of the system only "scales" with the most complex modules (not the system as a whole). In practice that ideal is not achievable. And as you might image, this approach introduces its own challenges, e.g., debugging, coordination/collaboration across service boundaries. So why this mandate? In part it was to turn Amazon into a platform, not just an ”application”, and to do so they were going to “eat their own dogfood”, i.e., use their internal tools like a customer.

Absolutes rarely work (moderation in all things). Services are not always appropriate and the trends towards SOA has in some cases swing back towards more monolithic applications. For example, part of Amazon Prime described how transforming their application back to a more monolithic approach substantially reduced costs: https://www.primevideotech.com/video-streaming/scaling-up-the-prime-video-audio-video-monitoring-service-and-reducing-costs-by-90



Monolithic ⇒ “Backend” services?

That trend back to monoliths, is sometimes only monolithic in a sense. A common approach today is not to decompose an application into multiple discrete services, but to build an application using multiple external services. That is use a separate “third party” service for authentication, for images, for real-time chat, etc. An extreme version of this are “serverless” architectures – a terrible name – in which the backend code you write is not stateful. Instead, it is interacting with multiple stateful services… but more on that in the future.



Which of the following is a *disadvantage* of services-oriented-architecture (SOA) compared to a monolithic design? SOA:

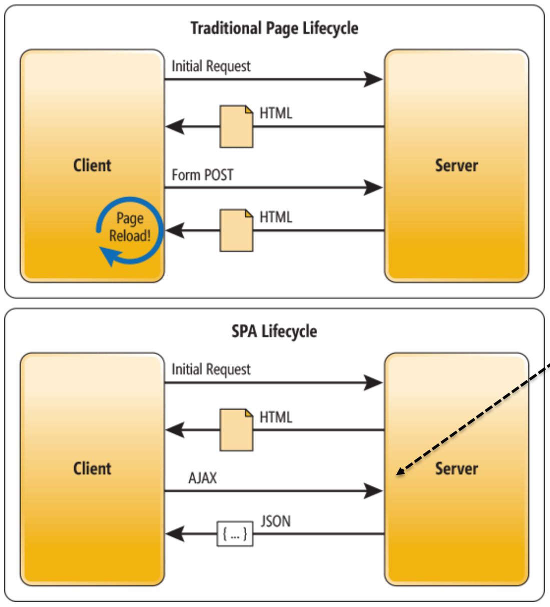
A. May be harder to debug & tune
B. Results in lower developer productivity
C. Complexity is a poor match for small teams
D. Is more expensive to deploy than monolithic, because more hardware is needed to handle the same workload

Correct: A.

Microservices can trade application complexity for system complexity. A microservice-based architecture can be more difficult to design and maintain at a system level, but each individual component of the system is greatly simplified. (https://www.sitepen.com/blog/2017/02/20/microservices-and-spas/)

I should note that pendulum might be swinging back the other direction (towards more monolithic systems). Why? Decomposing systems too much can introduce additional overhead and friction. And often that decomposition is not a function of separate functionality, but often separate parts of an organization (i.e., different teams).

Single Page Applications (SPA)



Server now mostly provides data, making SPAs natural consumers of services

Wasson, Microsoft

Traditional "thin client" model

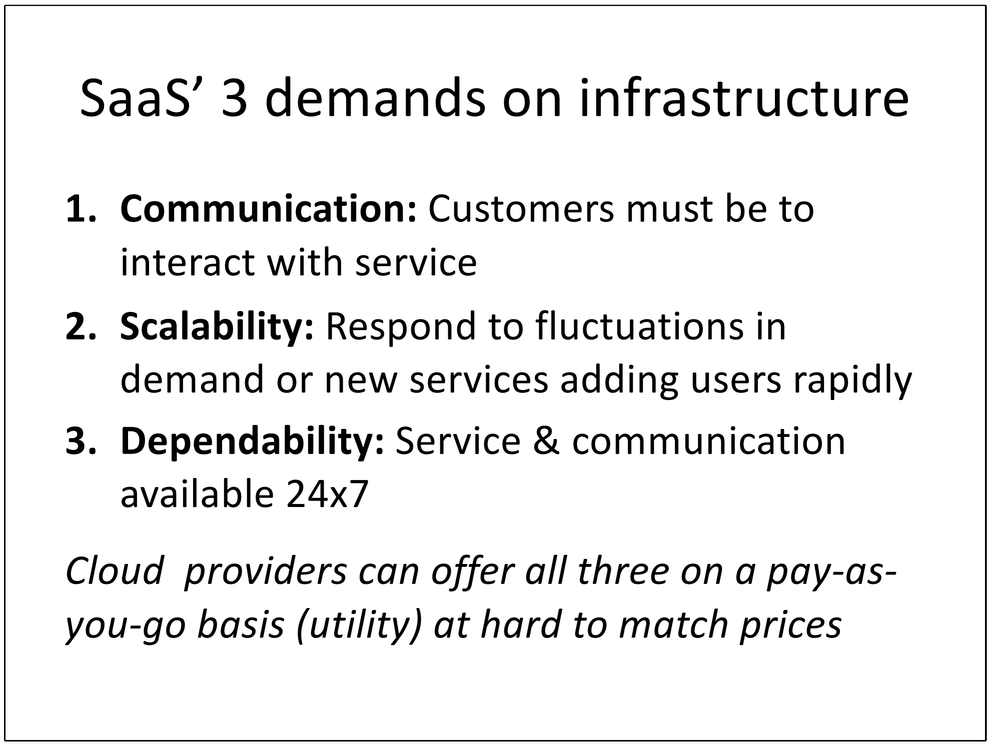
1. User enters an address
2. Browser requests a resource from the address
3. Server at that address returns the resource
4. Browser renders the resource
5. User clicks link or fills in form
6. Browser makes new request to server
7. Server returns _new_ resource
8. Browser loads new resource and displays it

This is a "thin client" model in which all the real work is happening and all state is maintained on the server. JavaScript may be used, but only for simple tasks: form validation, layout tricks, and interactive - but stateless - features like an accordion.

Single page application or "thick" client

Google (with the help of some Microsoft technology) upturned this model with the introduction of Google maps. Prior maps applications, e.g., Mapquest, would request a new page from the server when you wanted to navigate. In contrast Google used an MS technology called AJAX which allows JavaScript to make requests to the server without loading a new page in the browser. In this "thick client" approach, much of the application functionality is implemented in the browser with communication happening behind the scenes. The result was (is) an experience much closer to a desktop application. While this approach is commonplace now, it was revolutionary at the time.

We would choose such an approach when we need to implement an application with extensive user interaction that primarily interacts with an API, i.e., an application programming interface intended for use by other computational components (not people). Such APIs are what (micro)services typically expose, making these kind of applications natural consumer of/fit with service-oriented architectures.



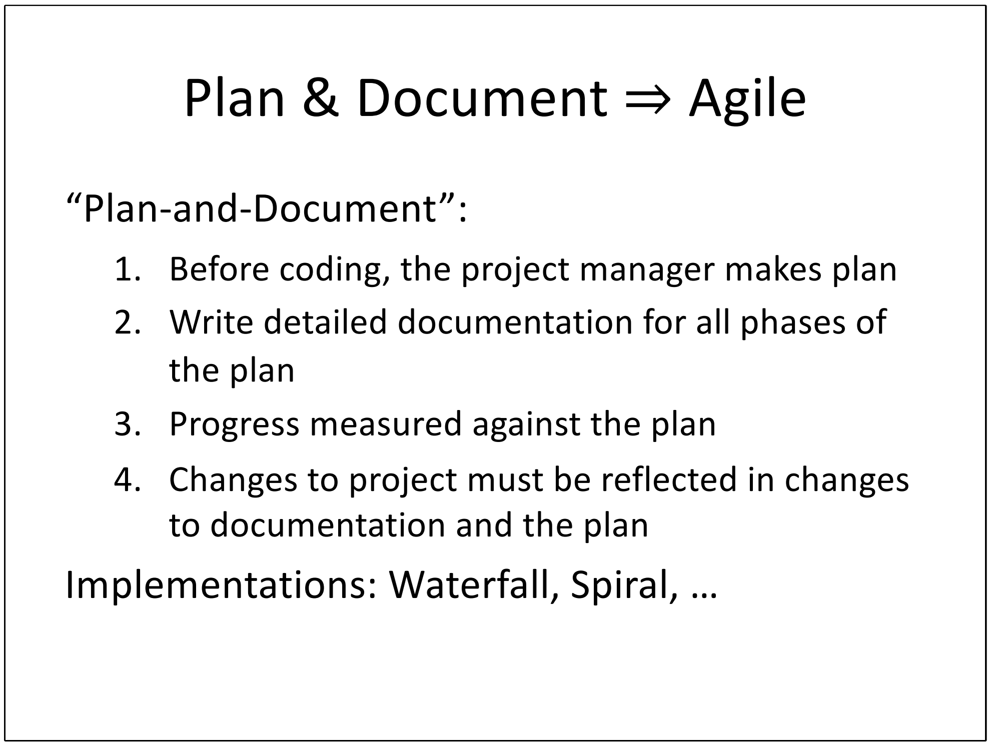
SaaS’ 3 demands on infrastructure

1. **Communication:** Customers must be to interact with service
2. **Scalability:** Respond to fluctuations in demand or new services adding users rapidly
3. **Dependability:** Service & communication available 24x7

Cloud providers can offer all three on a pay-as-you-go basis (utility) at hard to match prices

Below a certain scale, it is hard to compete on price with experienced data center operators building warehouse-scale computers. Economies of scale and relentless optimization pushed down cost of largest datacenters many fold (estimates of 3-8×). Remember when thinking about cost, it is not just the cost to purchase the machine, but the cost to manage the space, power the machine, maintain it, etc. The actual hardware itself is only a part…

The barrier to entry is now very low (don’t need to buy HW up front) and individual developers have access to same computing power as the big players. Infrastructure-as-a-service (IaaS), e.g., the ”original” AWS, are increasingly becoming platform-as-a-services, PaaS. With a PaaS, the developer connects many “higher-level” services instead of provisioning the underlying servers, storage, etc.

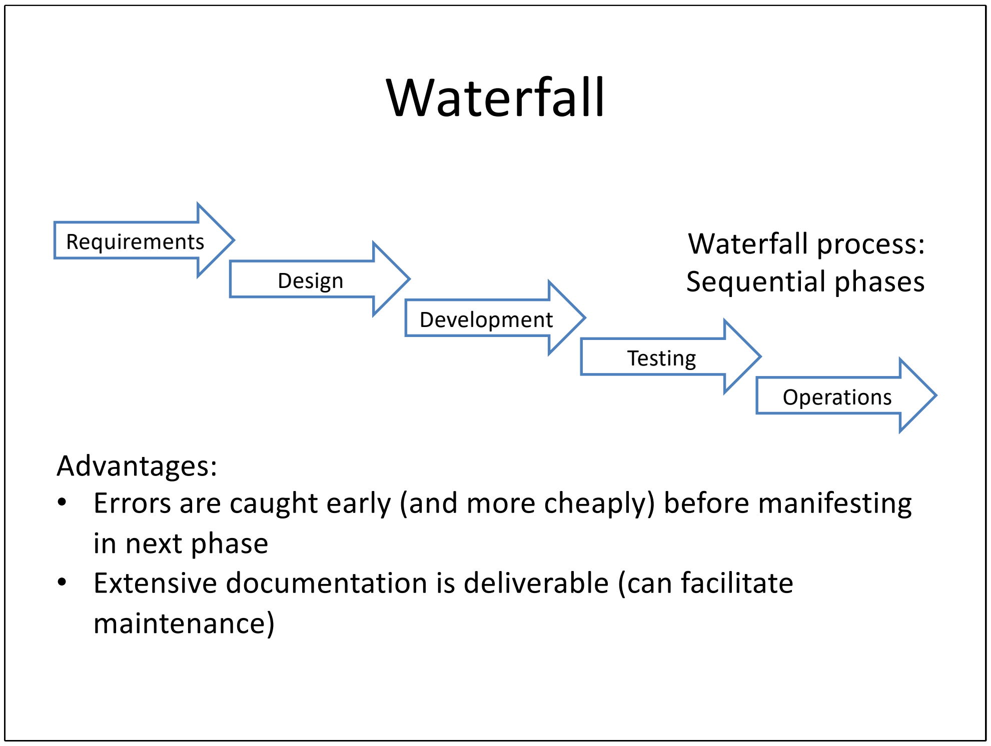


Plan & Document ⇒ Agile

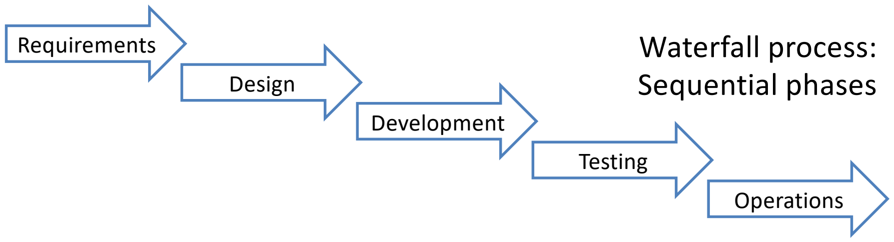
“Plan-and-Document”:

1. Before coding, the project manager makes plan
2. Write detailed documentation for all phases of the plan
3. Progress measured against the plan
4. Changes to project must be reflected in changes to documentation and the plan

Implementations: Waterfall, Spiral, …



Waterfall

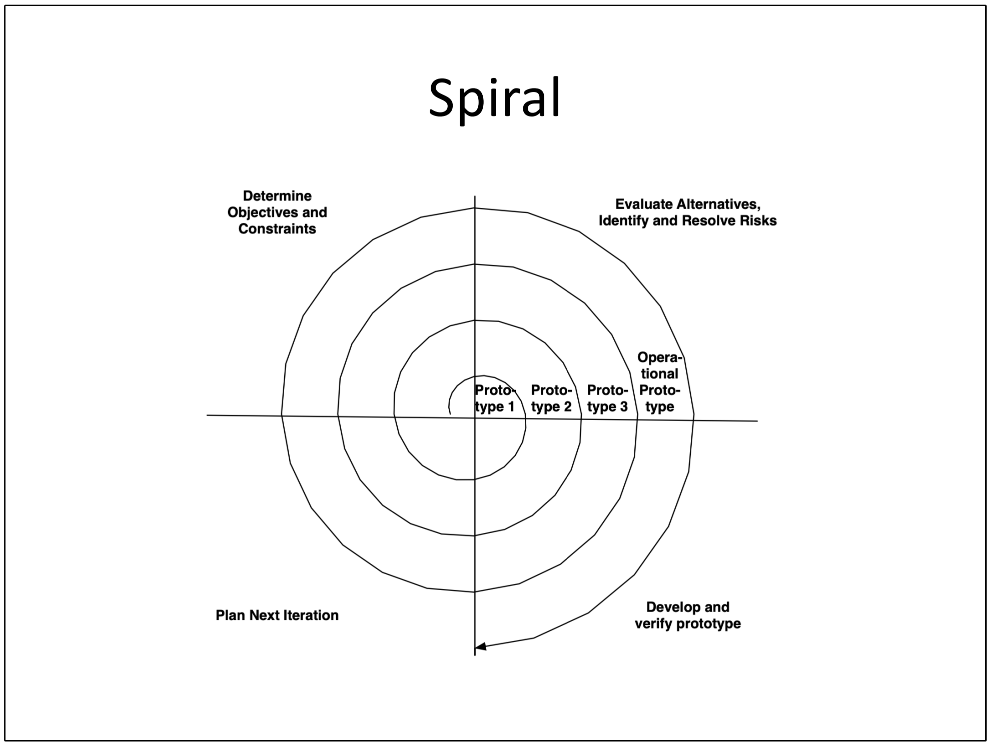


Waterfall process:
Sequential phases

Advantages:

- Errors are caught early (and more cheaply) before manifesting in next phase
- Extensive documentation is deliverable (can facilitate maintenance)

Waterfall: Sequential phases of project (like a cascading waterfall).



Spiral

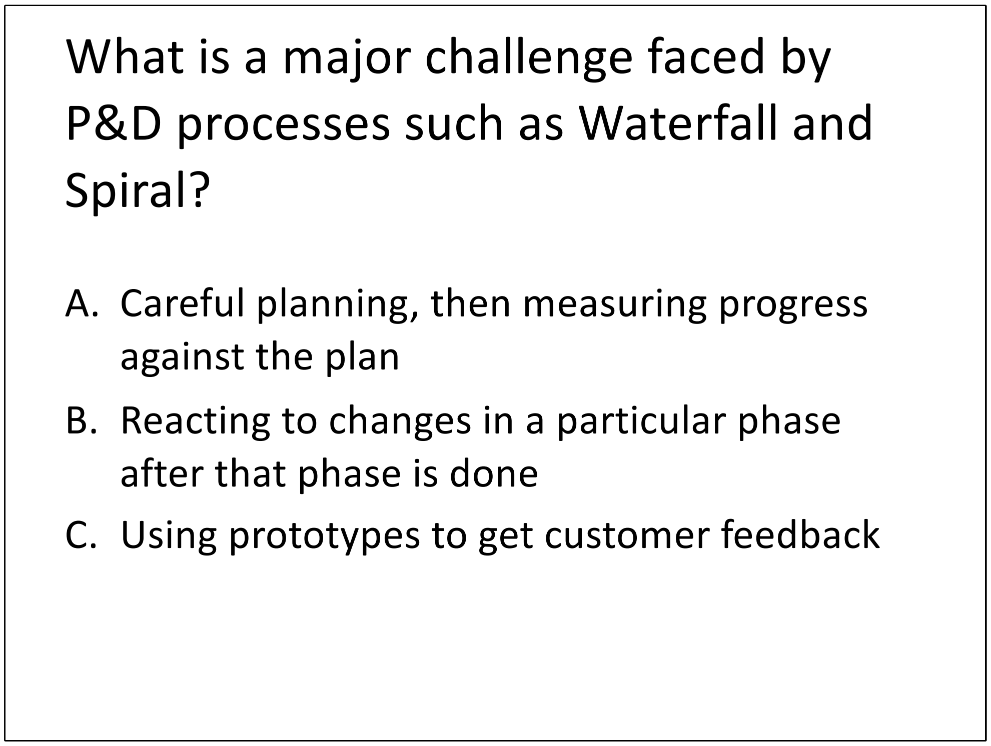
Determine Objectives and Constraints
Evaluate Alternatives, Identify and Resolve Risks
Opera-tional Proto-type
Proto-type 1
Proto-type 2
Proto-type 3
Plan Next Iteration
Develop and verify prototype

Spiral: ”Spiralling” iterations of:
Determine objectives and contraints
Evaluate alternatives and identify and resolve risks
Develop and verify prototype
Plan next iterations

Spiral could be described as Waterfall with prototyping. Both involve a lot of planning and long phase changes (i.e., iterations can be long)

“However, as originally envisioned, these iterations were 6 to 24 months long, so there is plenty of time for customers to change their minds during an iteration! Thus, Spiral still relies on planning and extensive documentation, but the plan is expected to evolve on each iteration. “

Adapted from Armando Fox and David Patterson (Berkeley cs169) under CC-BY-SA-NC license

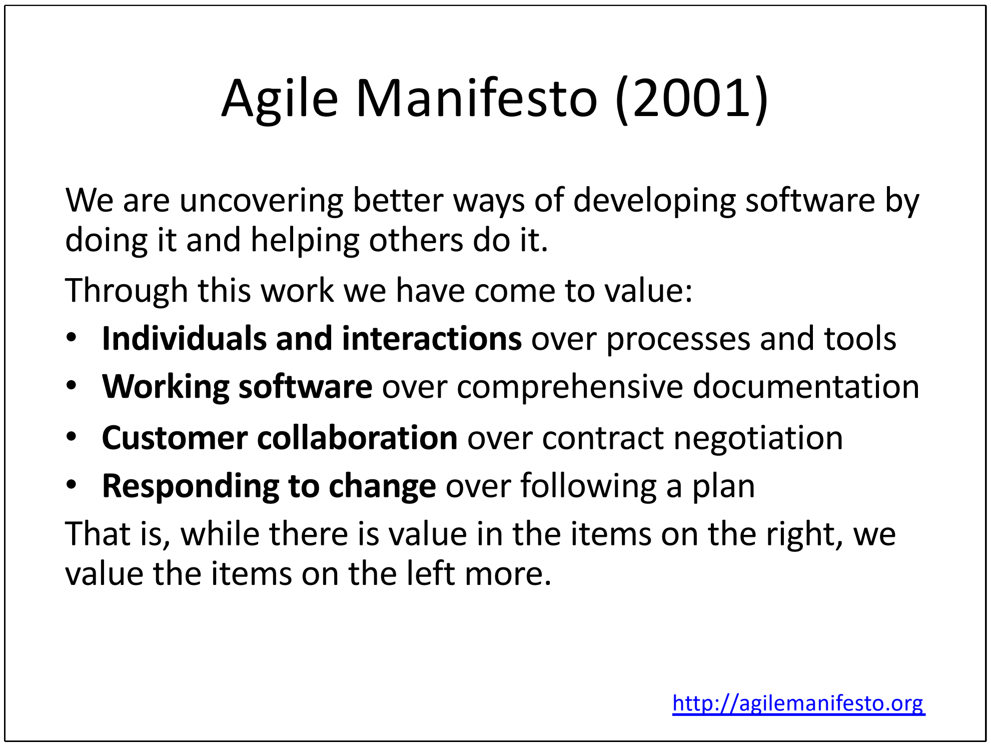


What is a major challenge faced by P&D processes such as Waterfall and Spiral?

A. Careful planning, then measuring progress against the plan
B. Reacting to changes in a particular phase after that phase is done
C. Using prototypes to get customer feedback

Answer: B

P&D assumes a phase is done once we move on. But we can imagine that during development, testing, deployment, etc. we observe we need to change the design. Revisiting the design process can be challenging at that point in these processes.



Agile Manifesto (2001)

We are uncovering better ways of developing software by doing it and helping others do it.

Through this work we have come to value:

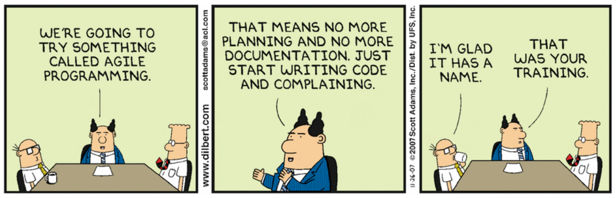
- **Individuals and interactions** over processes and tools
- **Working software** over comprehensive documentation
- **Customer collaboration** over contract negotiation
- **Responding to change** over following a plan

That is, while there is value in the items on the right, we value the items on the left more.

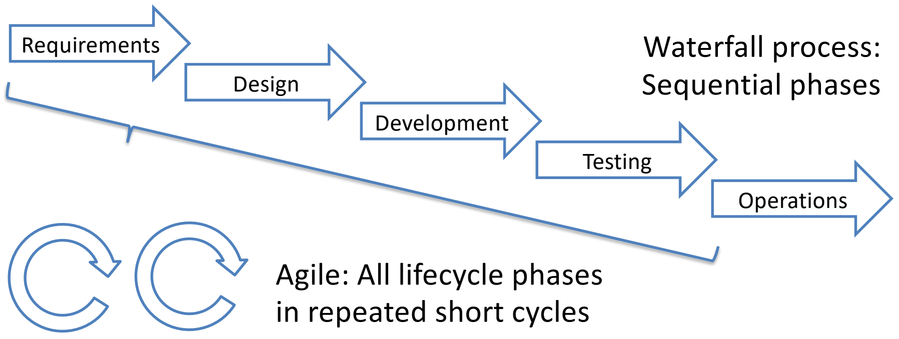
http://agilemanifesto.org

http://agilemanifesto.org

Plan & Document ⇒ Agile


WE'RE GOING TO TRY SOMETHING CALLED AGILE PROGRAMMING.
THAT MEANS NO MORE PLANNING AND NO MORE DOCUMENTATION. JUST START WRITING CODE AND COMPLAINING.
I'M GLAD IT HAS A NAME.
THAT WAS YOUR TRAINING.

Dilbert 11/26/17



Waterfall process:
Sequential phases

Agile: All lifecycle phases
in repeated short cycles

Waterfall: Sequential phases of project (like a cascading waterfall).

In contrast Agile, implements multiple iterations of those lifecycles in short repeated cycles. Embraces change as a fact of life: continuous improvement instead of a single planning planning phase. Team continuously improves working but incomplete prototype until customer satisfied (with customer feedback after each 1-2 week iteration).

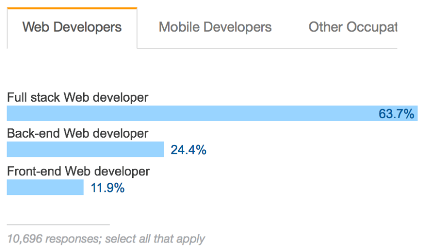
Note that when we talk about agile, we are talking as a project management "philosophy" (like P&D is a description of more than just Waterfall). Scrum, Extreme Programming (XP) are specific methodologies guided by the Agile philosophy.

In class we will implement one version of agile, in a way thar is tailored to a class. Our approach is not the only one (or necessarily the best – a matter of opinion) or even appropriate for all applications/industries. But it will give us hands-on experience with these approaches to project management.

Agile is also a "brand" with consultants, etc. We are really aiming to be "lowercase a" agile, that is demonstrate agility, as opposed to the "capital A" Agile, the formal process that someone might want to sell you.

Adapted from Armando Fox and David Patterson (Berkeley cs169) under CC-BY-SA-NC license.

“Full-Stack”, “DevOps” and other buzzwords…



[StackOverflow 2017 developer survey](https://insights.stackoverflow.com/survey/2017)

"A Full-Stack Web Developer is someone who is able to work on both the front-end and back-end portions of an application.”[1]

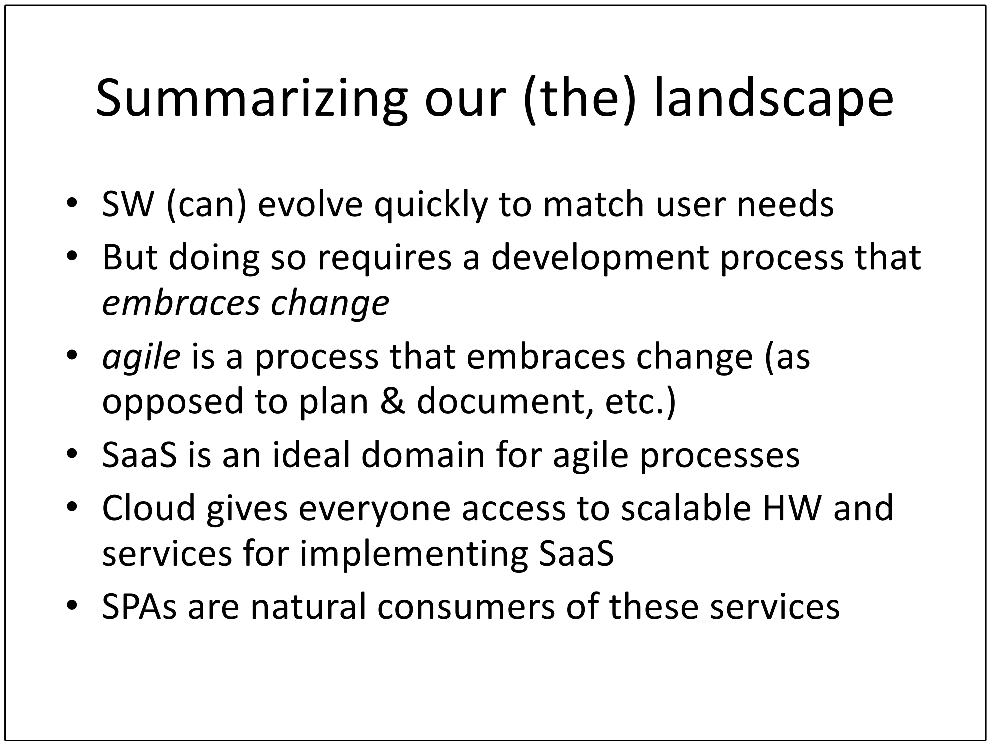
DevOps? Cross-functional (no more silos) teams that:

- Apply “development” practices to operations, e.g., infrastructure as code
- Automate everything
- Integrate operations into developer role

The front-end is typically the portion of the application the user interacts with directly (and runs in the browser), while the back-end is the portion of the application that provides resources (data) to the front-end (e.g., implements persistent datastores, business logic, etc.).

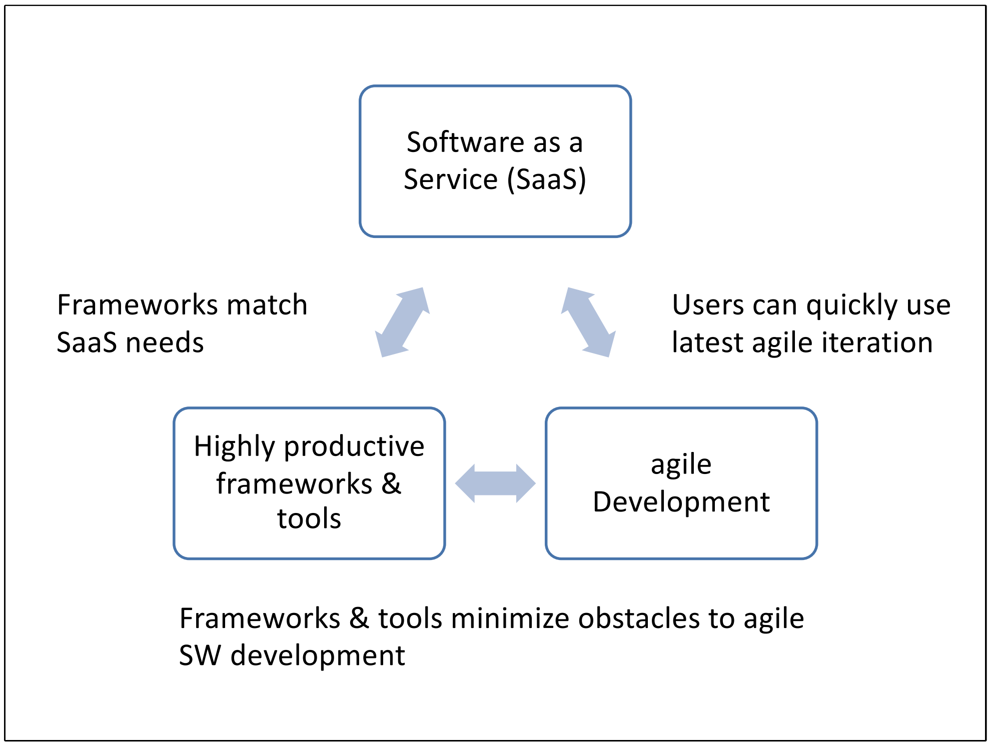
"Being a Full-Stack Developer doesn't mean that you have necessarily mastered everything required to work with the front-end or back-end, but it means that you are able to work on both sides and understand what is going on when building an application.”
[1](https://medium.com/coderbyte/a-guide-to-becoming-a-full-stack-developer-in-2017-5c3c08a1600c)

“DevOps essentially extends the continuous development goals of the Agile movement to continuous integration and continuous delivery.”
https://www.ansible.com/blog/confessions-of-a-full-stack-devop
https://newrelic.com/devops/what-is-devops



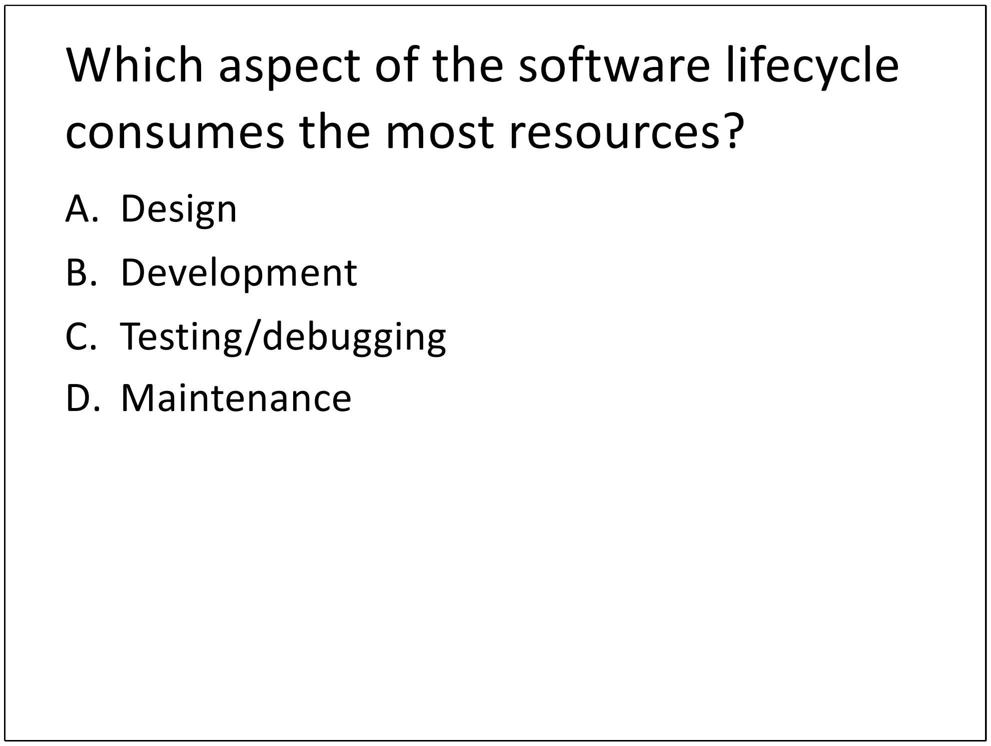
Summarizing our (the) landscape

- SW (can) evolve quickly to match user needs
- But doing so requires a development process that *embraces change*
- *agile* is a process that embraces change (as opposed to plan & document, etc.)
- SaaS is an ideal domain for agile processes
- Cloud gives everyone access to scalable HW and services for implementing SaaS
- SPAs are natural consumers of these services


Software as a Service (SaaS)
Frameworks match SaaS needs
Users can quickly use latest agile iteration
Highly productive frameworks & tools
agile Development
Frameworks & tools minimize obstacles to agile SW development

Synergistic methods (deliver software as a service), tools (frameworks, etc.) and processes

Adapted from Armando Fox and David Patterson (Berkeley cs169) under CC-BY-SA-NC license.

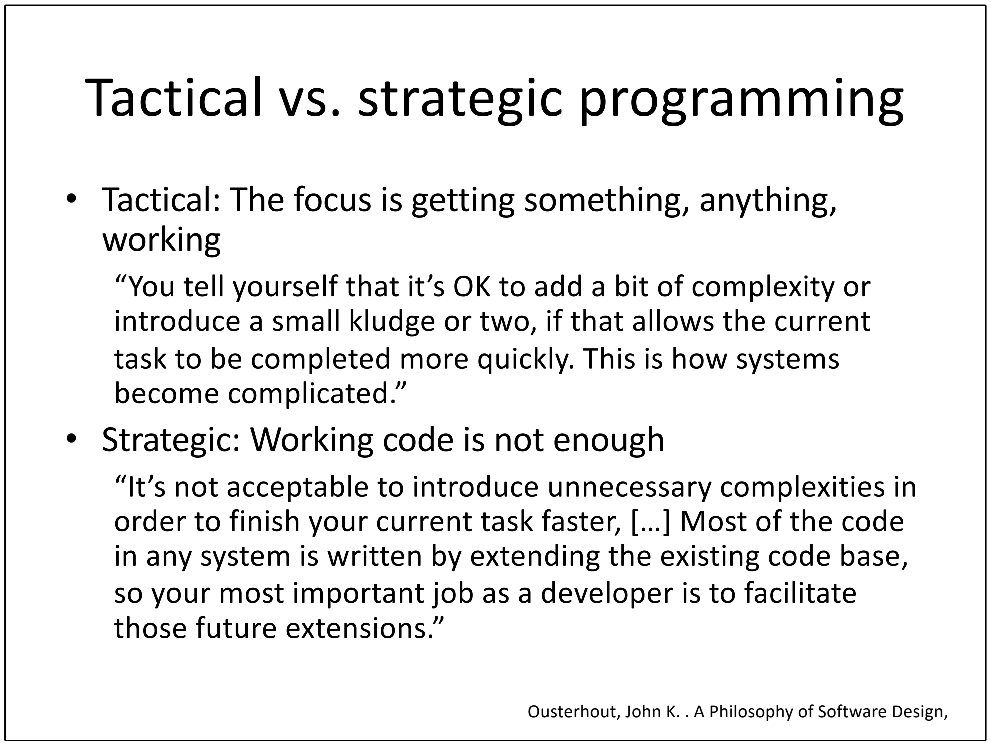


Which aspect of the software lifecycle consumes the most resources?

A. Design
B. Development
C. Testing/debugging
D. Maintenance

Correct: D.

We will do a lot of ”greenfield” development in class but that is not necessarily true of your future tasks. A lot of code has already been written, and SW maintenance (adding new features to legacy SW) is ~60% of SW costs. Working with “legacy code” matters. Part of what we will learn is how to write code that is maintainable, and by virtue of working with large teams, how to work with code others have written. Whenever you are about to disregard legacy SW, remember that legacy code is successful code, otherwise it wouldn’t still be around.



Tactical vs. strategic programming

- Tactical: The focus is getting something, anything, working

  "You tell yourself that it's OK to add a bit of complexity or introduce a small kludge or two, if that allows the current task to be completed more quickly. This is how systems become complicated."

- Strategic: Working code is not enough

  "It's not acceptable to introduce unnecessary complexities in order to finish your current task faster, […] Most of the code in any system is written by extending the existing code base, so your most important job as a developer is to facilitate those future extensions."

Ousterhout, John K. . A Philosophy of Software Design,

"All programming requires is a creative mind and the ability to organize your thoughts. If you can visualize a system, you can probably implement it in a computer program. This means that the greatest limitation in writing software is our ability to understand the systems we are creating."

Complexity is our enemy. The tools and processes we will learn about are designed to help minimize and/or overcome complexity. But tools alone are not enough. We have to design software to be simple or at least simpler. How can we do so? 1) Actively try at each moment to make our code simpler and more obvious, 2) encapsulate the complexity we can't eliminate (by providing a simple interface). We will see and do both this semester.

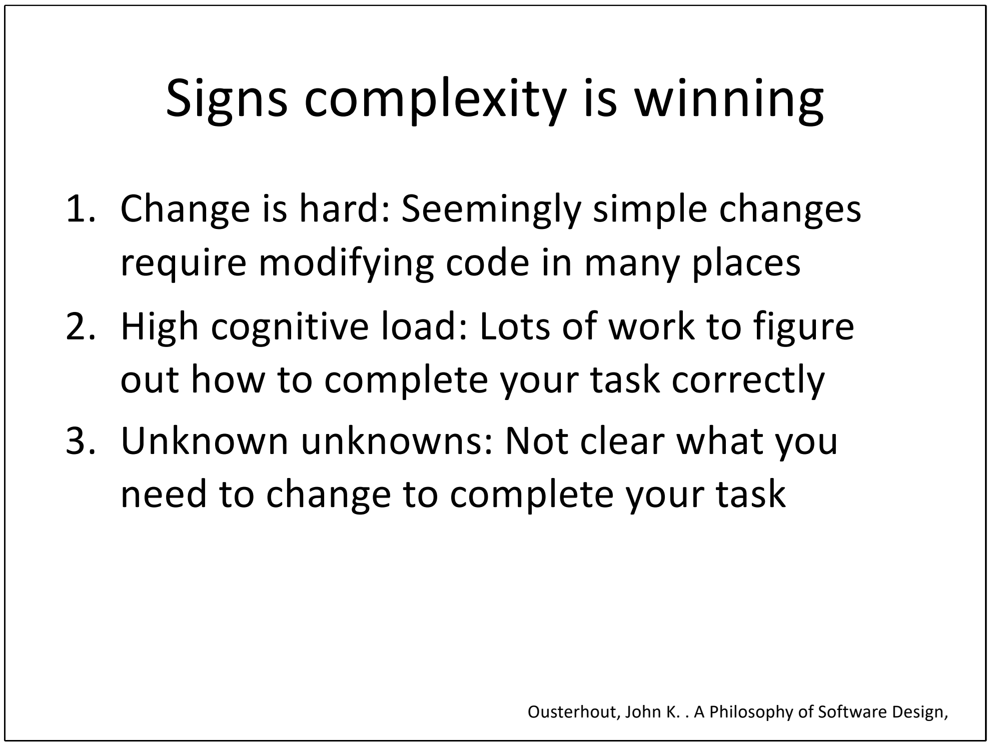
[click]

We have all done this (I am doubtful of anyone who says otherwise…) And the structure of most courses actually encourages "tactical programming". Most programming assignments are "green field" (you start from scratch), there are often hard deadlines, and you rarely need to use the code you write in the future, so there is minimal cost to introducing complexity.

"Almost every software development organization has at least one developer who takes tactical programming to the extreme: a tactical tornado. The tactical tornado is a prolific programmer who pumps out code far faster than others but works in a totally tactical fashion. When it comes to implementing a quick feature, nobody gets it done faster than the tactical tornado. In some organizations, management treats tactical tornadoes as heroes. However, tactical tornadoes leave behind a wake of destruction. They are rarely considered heroes by the engineers who must work with their code in the future. Typically, other engineers must clean up the messes left behind by the tactical tornado, which makes it appear that those engineers (who are the real heroes) are making slower progress than the tactical tornado."

There are no absolutes – moderation in all things. We don't to spend so much time coming up the "best" design that we don't accomplish anything. We should think about this from an investment perspective. We are continually making small investment (say 10-20% of our time) make the system better. This may be proactive – spending a little more time up front to improve our design, or reactive – fixing a design problem instead of working around it.

Ousterhout, John K. . A Philosophy of Software Design, 2nd Edition



Signs complexity is winning

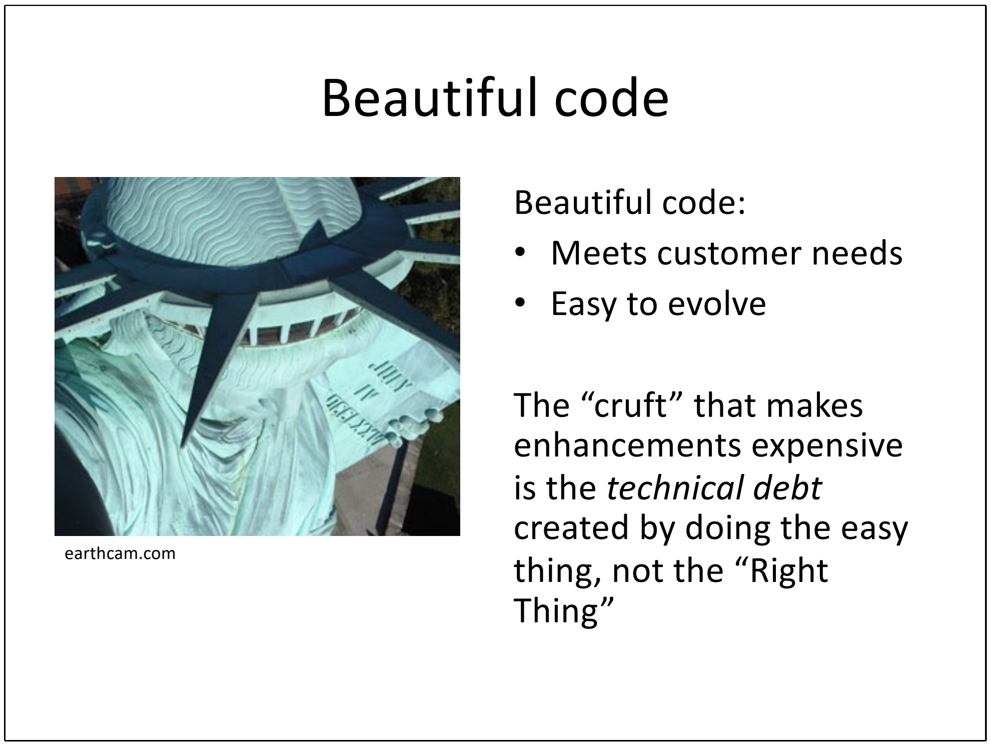
1. Change is hard: Seemingly simple changes require modifying code in many places
2. High cognitive load: Lots of work to figure out how to complete your task correctly
3. Unknown unknowns: Not clear what you need to change to complete your task

Ousterhout, John K. . A Philosophy of Software Design,

“Of the three manifestations of complexity, unknown unknowns are the worst. An unknown unknown means that there is something you need to know, but there is no way for you to find out what it is, or even whether there is an issue. You won’t find out about it until bugs appear after you make a change. Change amplification (change is hard) is annoying, but as long as it is clear which code needs to be modified, the system will work once the change has been completed. Similarly, a high cognitive load will increase the cost of a change, but if it is clear which information to read, the change is still likely to be correct. With unknown unknowns, it is unclear what to do or whether a proposed solution will even work.”

More generally we will see this warning signs in slightly different forms – different people use different descriptions, but there are crosscutting ideas about the difficulty of making changes/improvements.

Ousterhout, John K. . A Philosophy of Software Design, 2nd



Beautiful code

earthcam.com

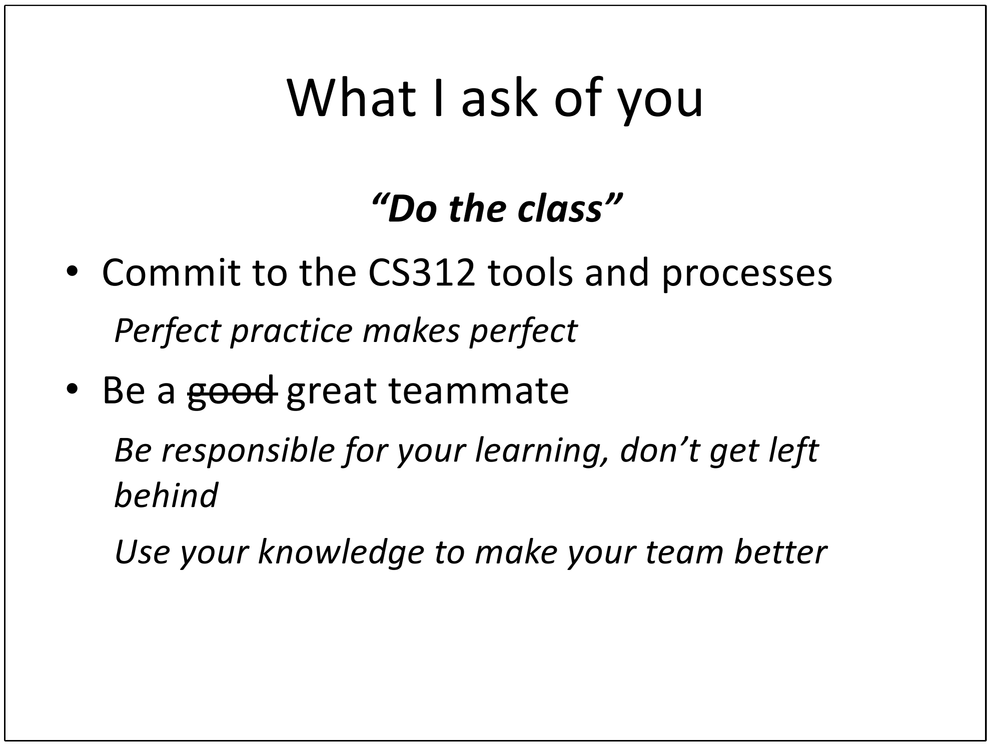
Beautiful code:

- Meets customer needs
- Easy to evolve

The “cruft” that makes enhancements expensive is the *technical debt* created by doing the easy thing, not the “Right Thing”

The only people that can see the Statue of Liberty’s hair are those that climb up the torch. Yet the artist(s) included hair anyway!

Adapted from Armando Fox and David Patterson (Berkeley cs169) under CC-BY-SA-NC license.



What I ask of you

"Do the class"

- Commit to the CS312 tools and processes

  Perfect practice makes perfect

- Be a ~~good~~ great teammate

  Be responsible for your learning, don't get left behind

  Use your knowledge to make your team better

One goal of this course is to practice effective SW development methodologies. That is the process itself is important. Our goal is to practice strategic programming, i.e., working code is not our only goal. Recall that *perfect* practice makes perfect. I want you to "slow down" and make those investments and the structure of the course is intended to enable you to do so!

We have a wide variety of backgrounds:

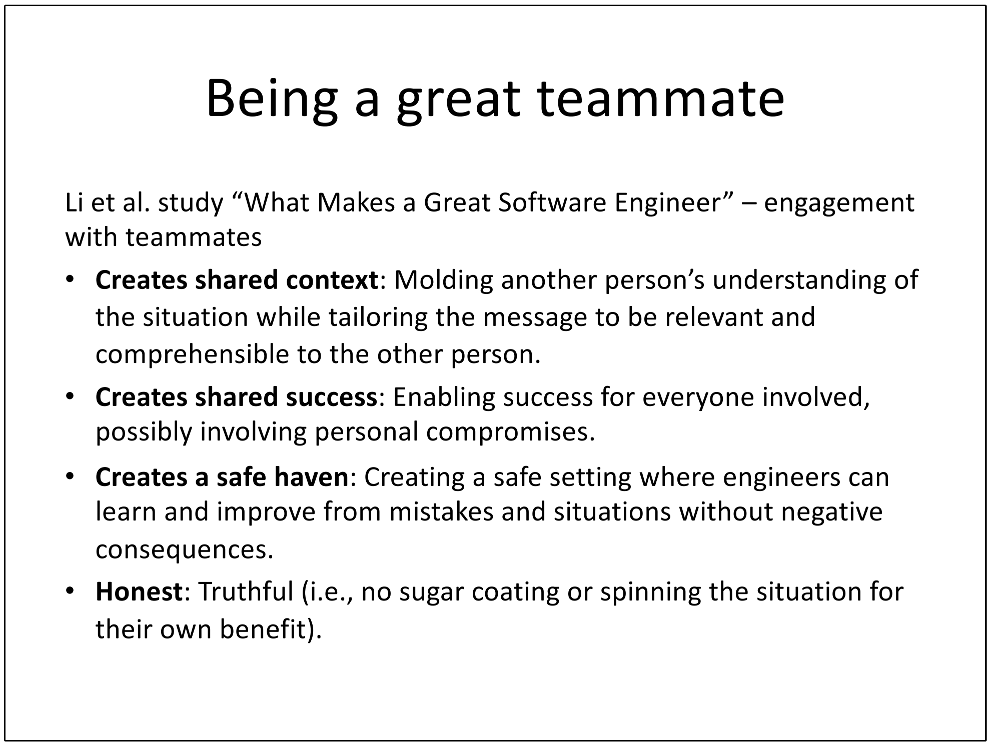
- Some of you have learned these technologies in/for another class
- Some of you have used these technologies in an internship or summer research, and
- Some of you have never touched these technologies before…

In some of these aspects, CS312 will be similar to your future working environments but more challenging (a company doesn't usually create a team of composed only of new developers). To overcome these challenges, I expect you to:

* Be responsible for independently picking up the details of unfamiliar tools or technologies.
* Put in the effort to make sure you don't get left behind. Use the resources on the course page (and others) and make sure to ask me and others for help when you need it. Don't be the teammate that can't contribute because you don't know what is going on!

If you have prior experience, we expect you to:

* Use your knowledge to actively make your team better, not to sit back in judgement or frustration. Recall the often the best way to learn is to teach (e.g., "see one, do one, teach one"); you will get more out of the class if you actively engage with all of your classmates, including those with less experience.
* Understand you can't do it alone. It may seem like you can do the project better or faster by yourself, but the end product will actually be worse if the whole team can't (or doesn't) contribute.



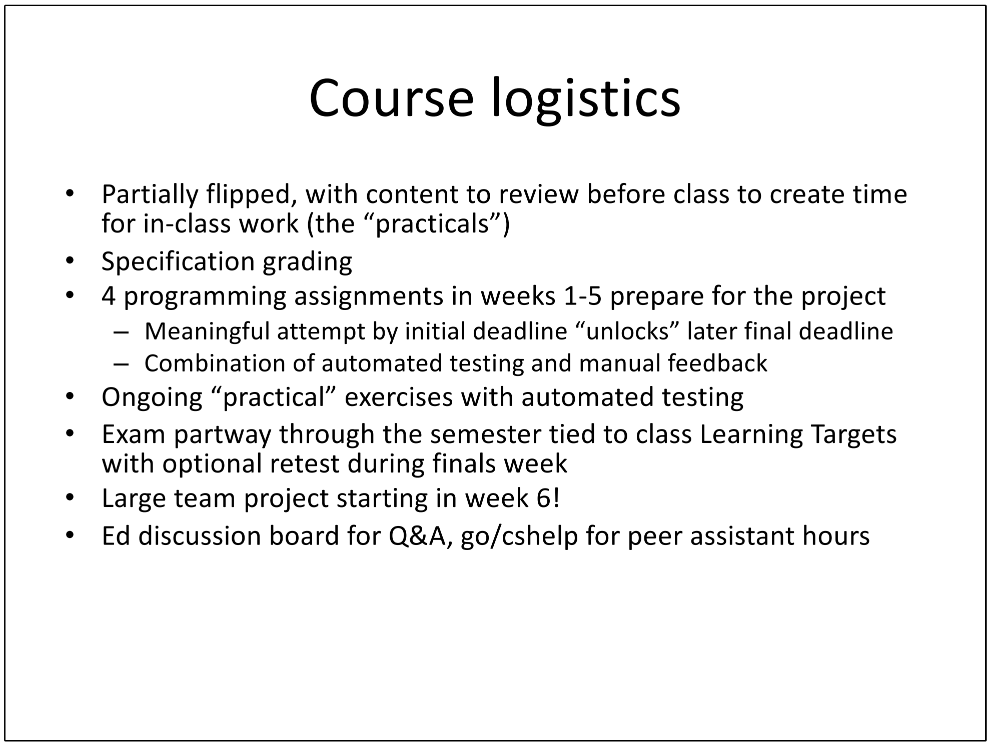
Being a great teammate

Li et al. study “What Makes a Great Software Engineer” – engagement with teammates

- **Creates shared context**: Molding another person’s understanding of the situation while tailoring the message to be relevant and comprehensible to the other person.
- **Creates shared success**: Enabling success for everyone involved, possibly involving personal compromises.
- **Creates a safe haven**: Creating a safe setting where engineers can learn and improve from mistakes and situations without negative consequences.
- **Honest**: Truthful (i.e., no sugar coating or spinning the situation for their own benefit).

Remember – you are all learning!

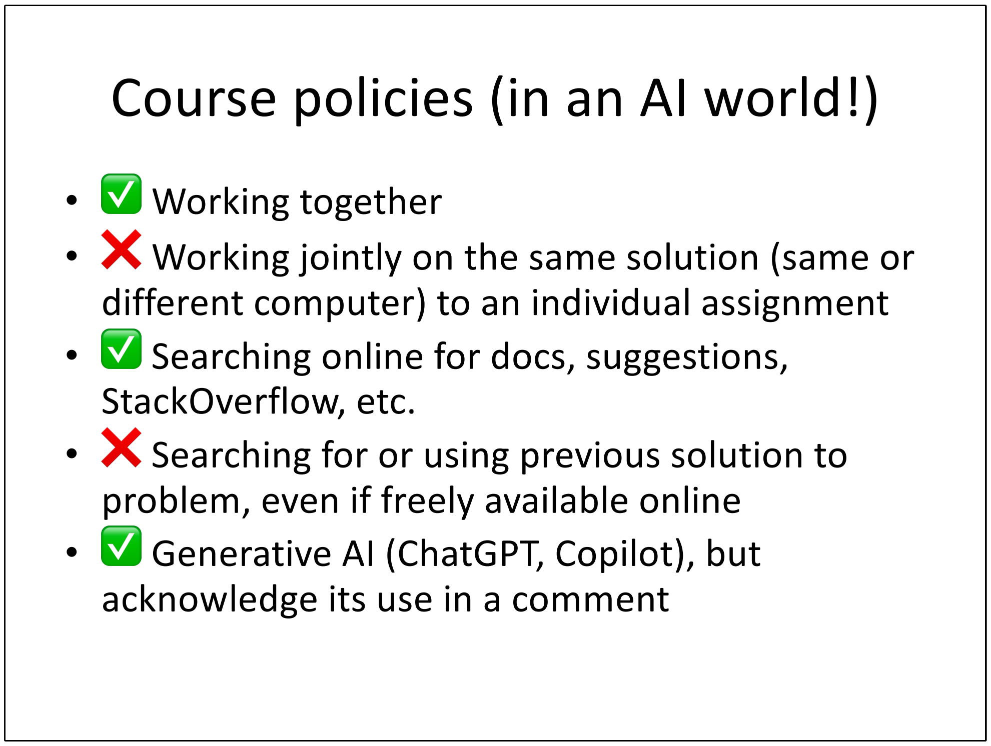
Being a great teammate is a skill in its own right that can be developed and honed (like any other skill).


Course logistics

- Partially flipped, with content to review before class to create time for in-class work (the “practicals”)
- Specification grading
- 4 programming assignments in weeks 1-5 prepare for the project
  - Meaningful attempt by initial deadline “unlocks” later final deadline
  - Combination of automated testing and manual feedback
- Ongoing “practical” exercises with automated testing
- Exam partway through the semester tied to class Learning Targets with optional retest during finals week
- Large team project starting in week 6!
- Ed discussion board for Q&A, go/cshelp for peer assistant hours

Experiment with Specification grading. No “points” or partial credit. Everything is graded on a form of satisfactory/not yet satisfactory. All elements have an opportunity to receive feedback and resubmit (for programming assignments, project) or retake a similar problem (exams). Final grade is determined by the bundles described in the syllabus. Why? A grade should reflect your demonstrated understanding of the material at the end of the course. Assessing your work is a necessary but imperfect proxy for assessing understanding. My goal and responsibility is to create the best structures possible for you to demonstrate your true understanding. And your corresponding responsibility is to do everything you can to make your work accurately reflect your true understanding. Note that is an ongoing experiment. It will almost certainly require tweaking. I welcome your feedback and am ready to change any aspects that are not working.

There is extensive ”Getting Started” page with software to install. Please “get started” so you are ready to go for next class and we can resolve any setup problems.



Course policies (in an AI world!)

- ✅ Working together
- ❌ Working jointly on the same solution (same or different computer) to an individual assignment
- ✅ Searching online for docs, suggestions, StackOverflow, etc.
- ❌ Searching for or using previous solution to problem, even if freely available online
- ✅ Generative AI (ChatGPT, Copilot), but acknowledge its use in a comment

Our goal in this course it maximize our productivity by using professional tools and practices (of which generative AI, is definitely one!). As an experiment I used GitHub copilot all summer and continue to have it turned on. I use it and ChatGPT to help assemble materials for this course. You are welcome and even encourage to experiment with those tools in this course. Here, as in any professional situation, you are responsible for the code that you submit/commit. That AI generated the code it is not an excuse for code that doesn't work.

That said, I would encourage you to not just dump the assignments into ChatGPT, et al. In many cases you are learning to use Javascript et al. for the first time. Finding/generating code that seems to work but you don't know why doesn't help build the understanding you need to tackle these problems in the future. The analogy you might hear a lot is it like it is like working out by lifting weights with a forklift. You lifted a lot of weight, but to what end… In our programming assignments there are lots of tests and other feedback to know if the code works. But in the projects and elsewhere, that isn't the case. You are responsible for both writing the code and ensuring it works. Magic code only makes that harder…