Architecture: Microservices

17-313 Fall 2024

Foundations of Software Engineering

https://cmu-17313q.github.io

Eduardo Feo Flushing

Administrivia

- Project 2C has been released
  - Due October 10th
- First Sprint Checkpoint Presentations
  - Thursday during recitation time

Smoking Section

- Last **two** full rows

Learning Goals

- Contrast the monolithic application design with a modular design based on microservices.
- Reason about tradeoffs of microservices architectures.
- Principles of microservices: how to benefit and avoid their pitfalls

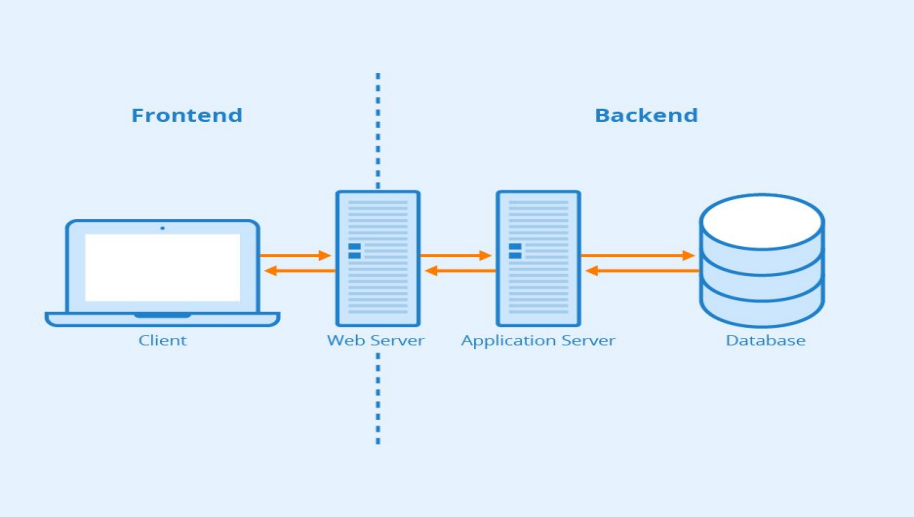
Outline

- From Monoliths to Service Oriented Architecture
  - Case Study: Chrome Web Browser
- Microservices
  - Monolith vs Microservices
  - Advantages
  - Challenges
- Microservices: Principles
- Serverless

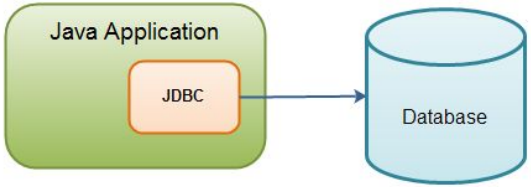
Before we get to microservices…

MONOLITHS

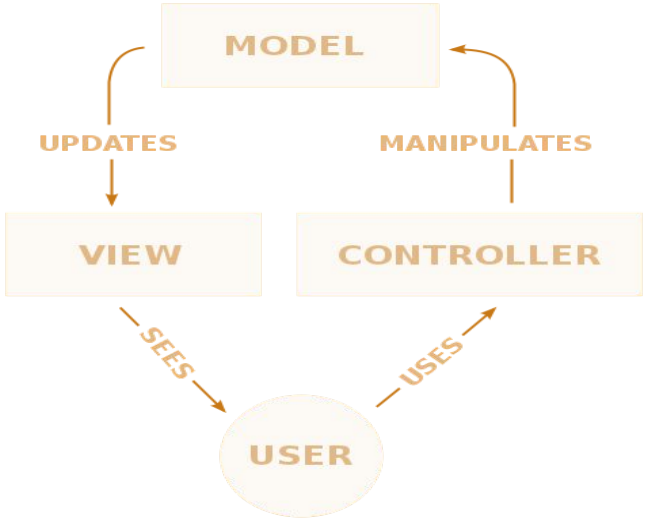
Monolithic styles



Source: https://www.seobility.net (CC BY-SA 4.0)



Monolithic styles: MVC Pattern (e.g., NodeBB)

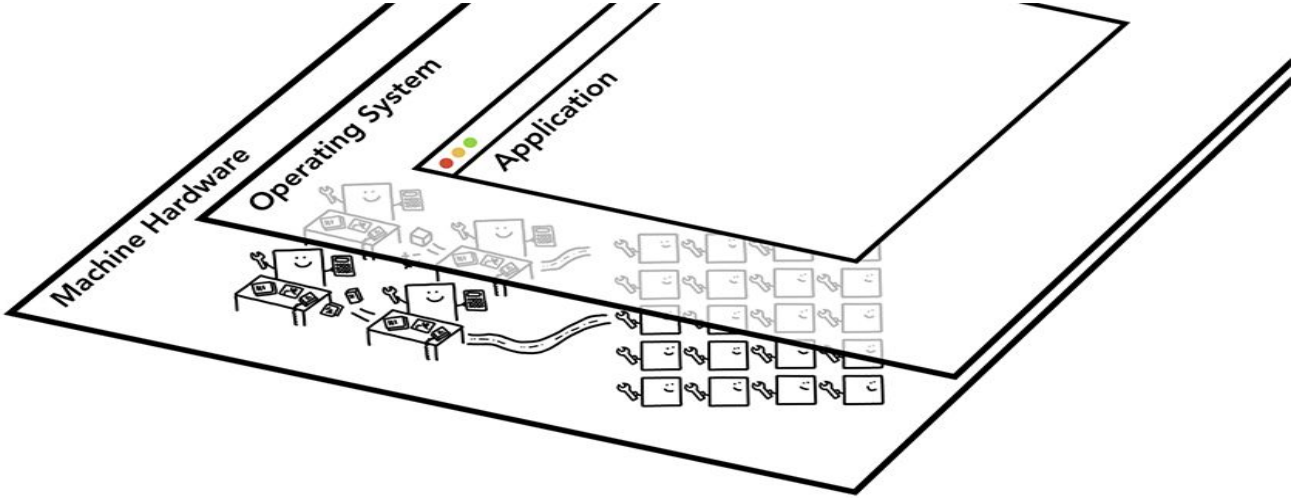


Separation of concerns

SERVICE-ORIENTED ARCHITECTURE

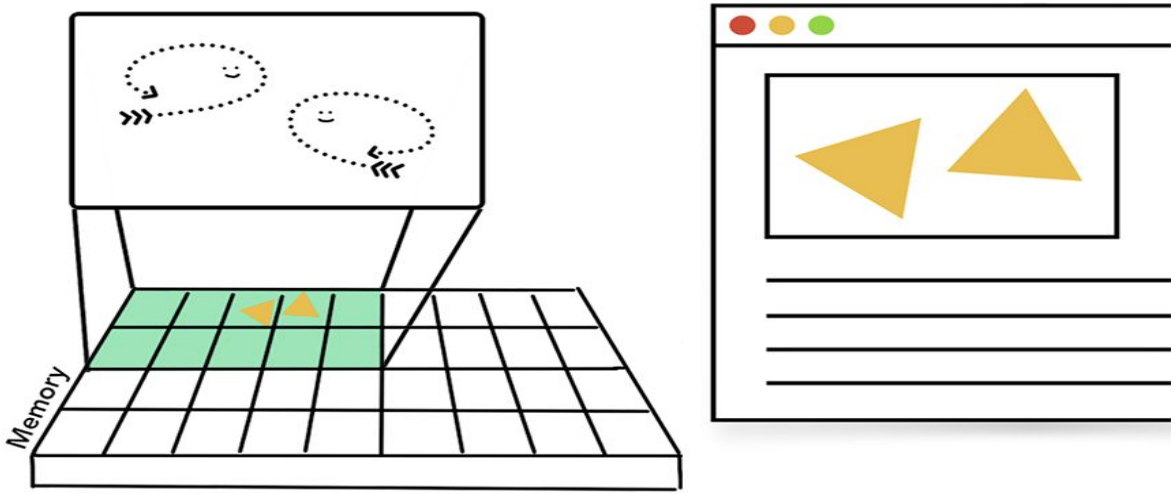
Chrome

Web Browsers



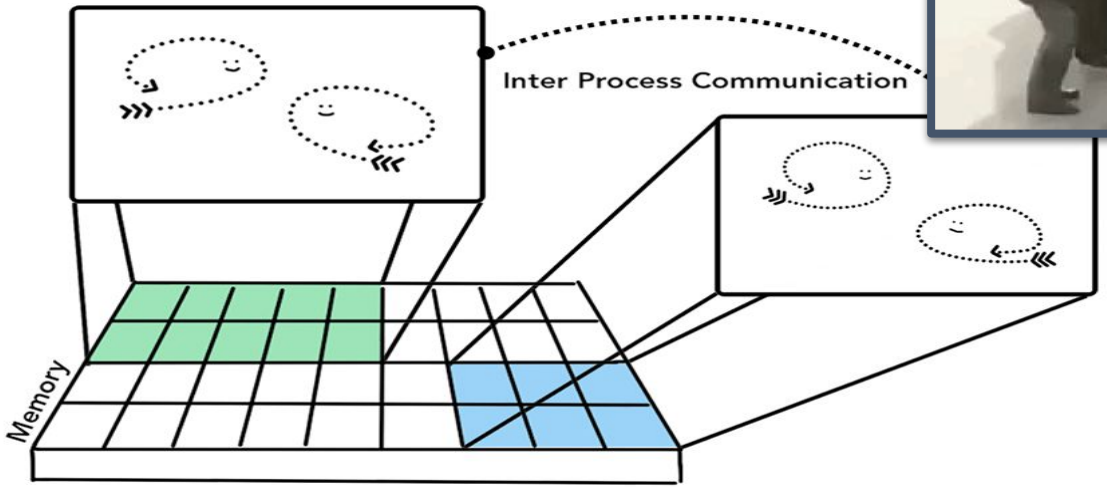
Source: https://developers.google.com/web/updates/2018/09/inside-browser-part1 (CC BY 4.0)

Browser: A multi-threaded process



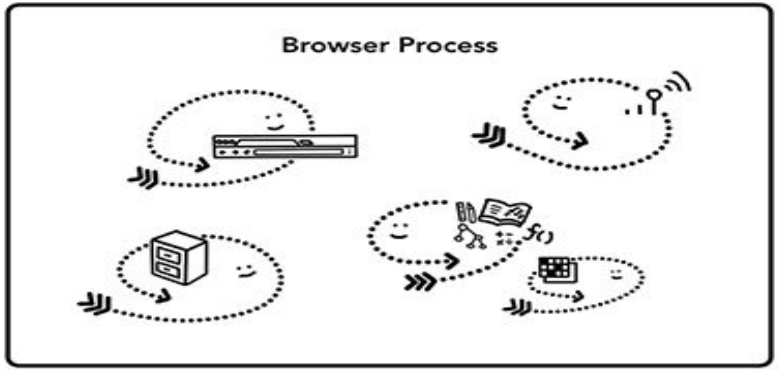
Source: https://developers.google.com/web/updates/2018/09/inside-browser-part1 (CC BY 4.0)

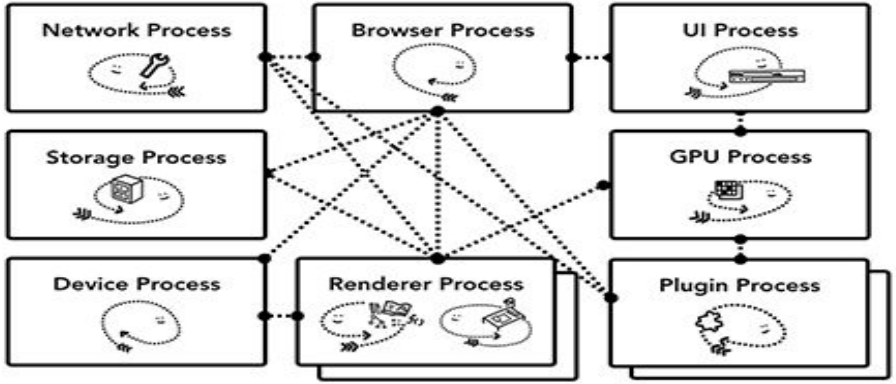
Multi-process browser with I



Source: https://developers.google.com/web/updates/2018/09/inside-browser-part1 (CC BY 4.0)

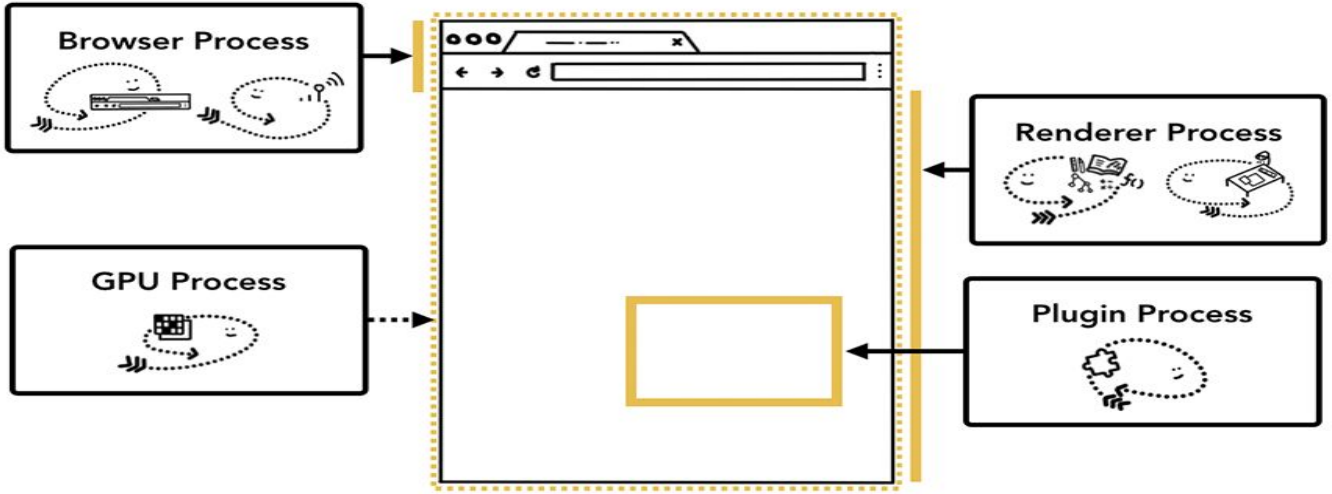
Browser Architectures





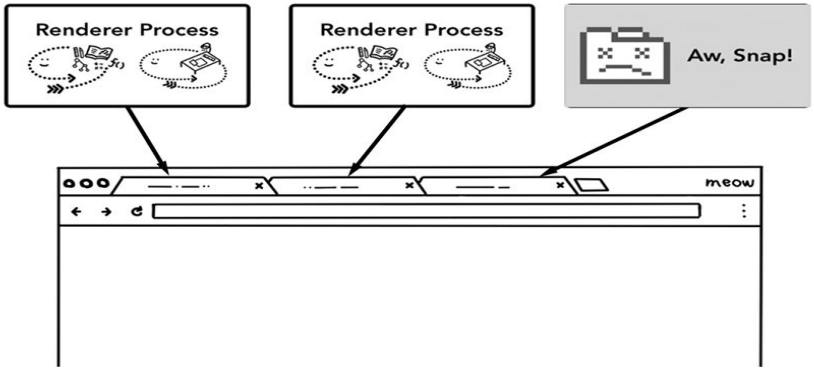
Source: https://developers.google.com/web/updates/2018/09/inside-browser-part1 (CC BY 4.0)

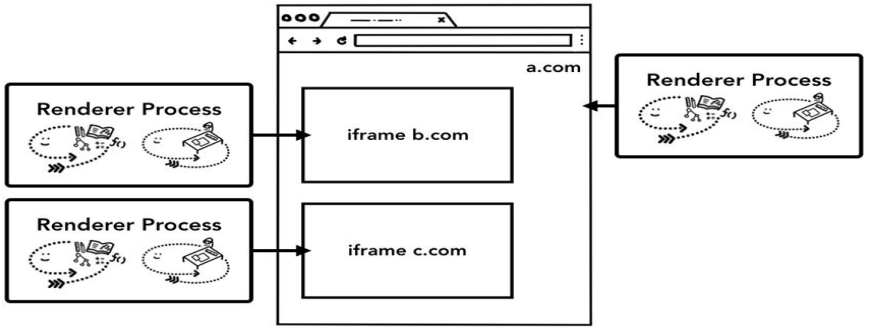
Service-oriented browser architecture



Source: https://developers.google.com/web/updates/2018/09/inside-browser-part1 (CC BY 4.0)

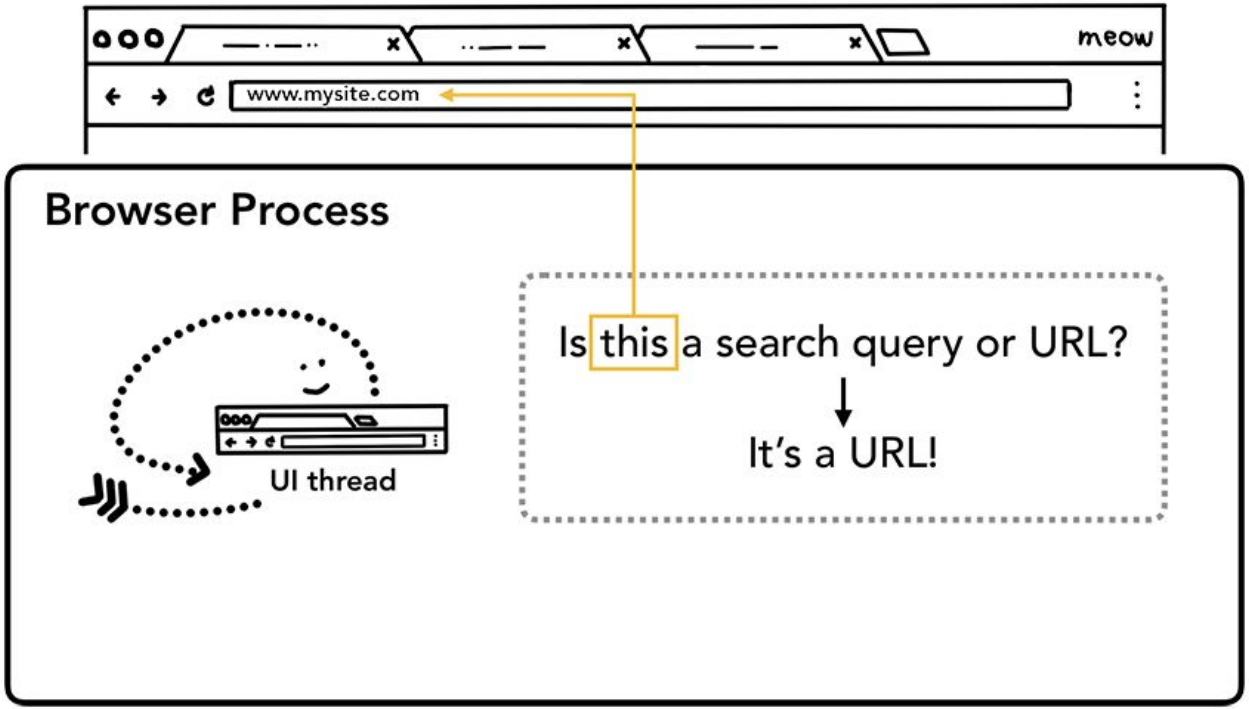
Service-oriented browser architecture





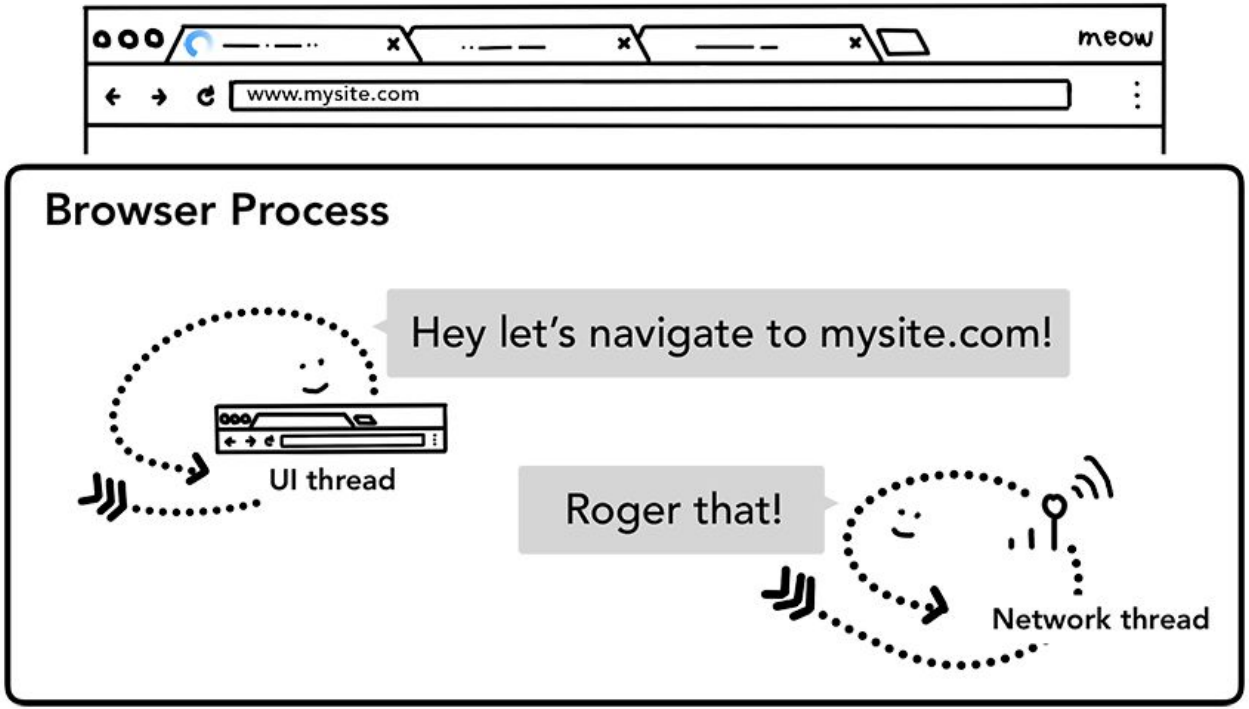
Source: https://developers.google.com/web/updates/2018/09/inside-browser-part1 (CC BY 4.0)

Navigating to a web site uses service requests



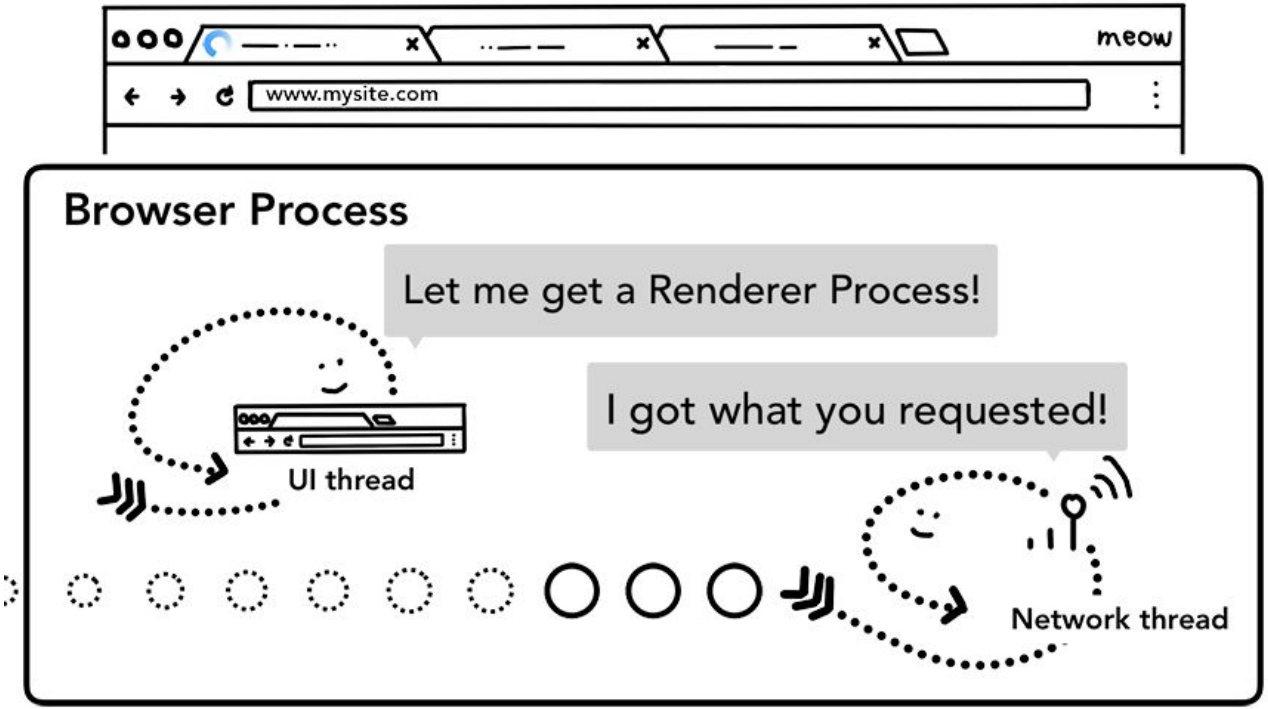
Source: https://developers.google.com/web/updates/2018/09/inside-browser-part1 (CC BY 4.0)

Navigating to a web site uses service requests



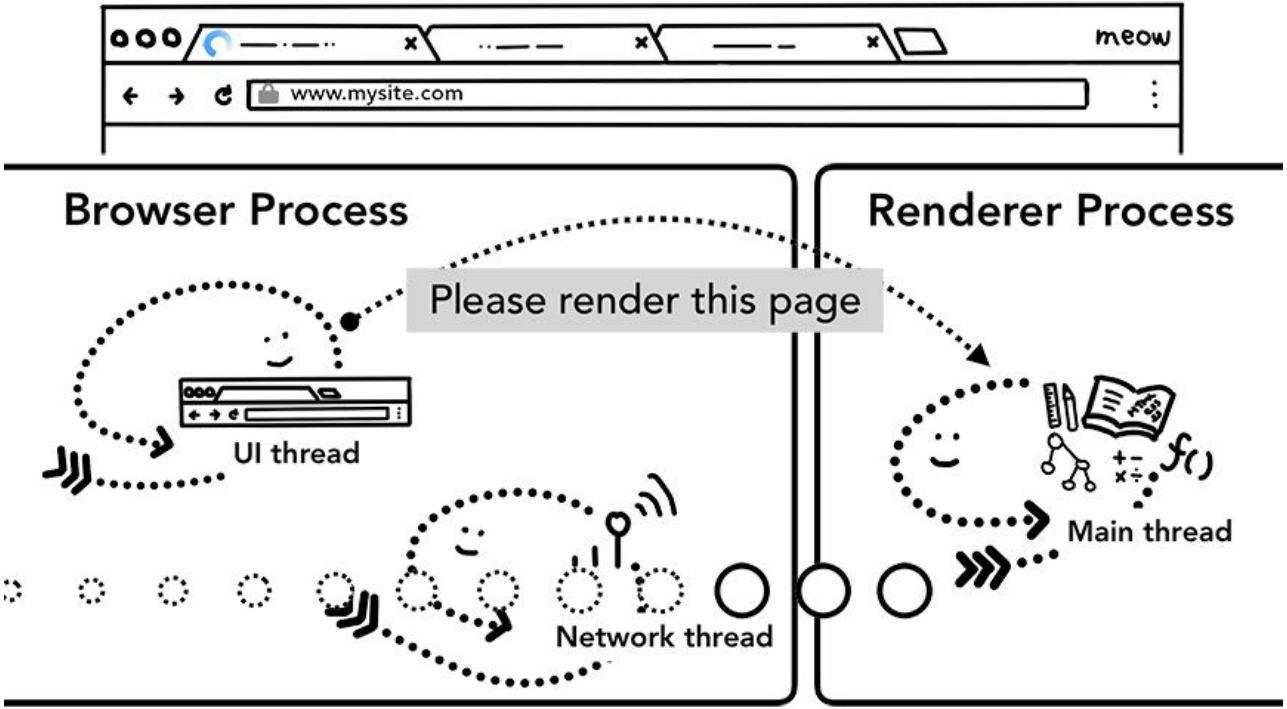
Source: https://developers.google.com/web/updates/2018/09/inside-browser-part1 (CC BY 4.0)

Navigating to a web site uses service requests



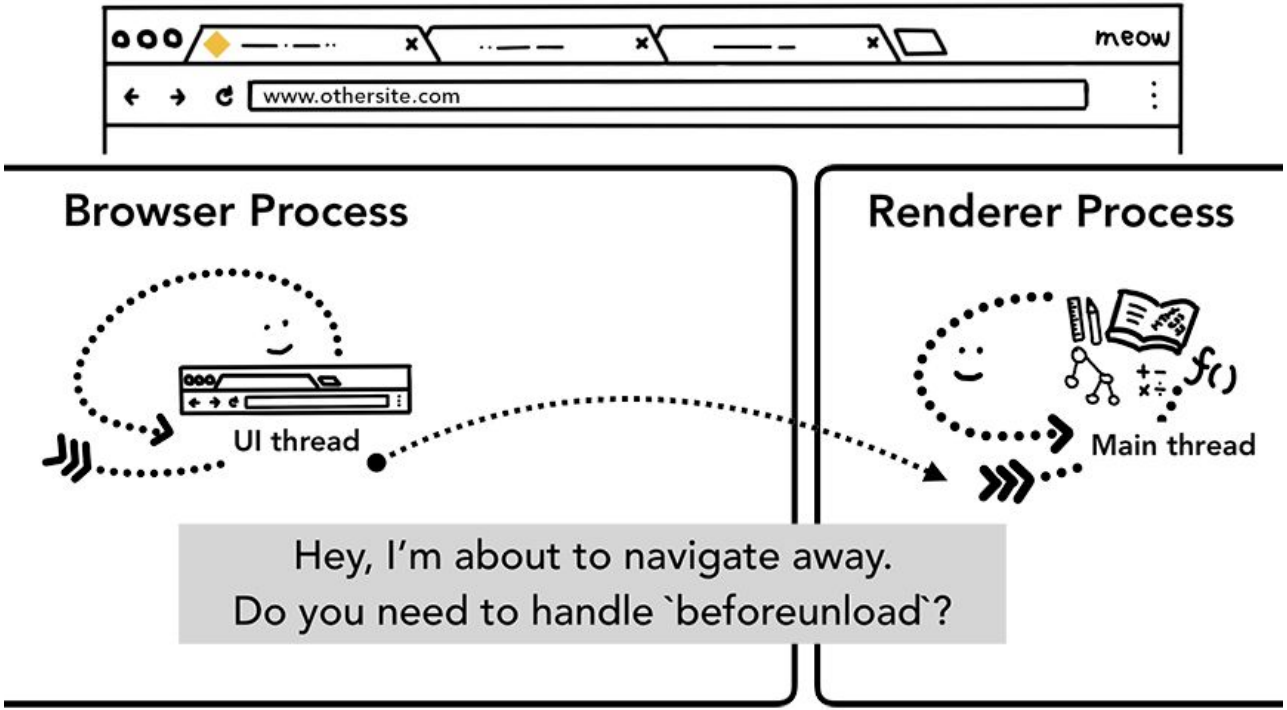
Source: https://developers.google.com/web/updates/2018/09/inside-browser-part1 (CC BY 4.0)

Navigating to a web site uses service requests



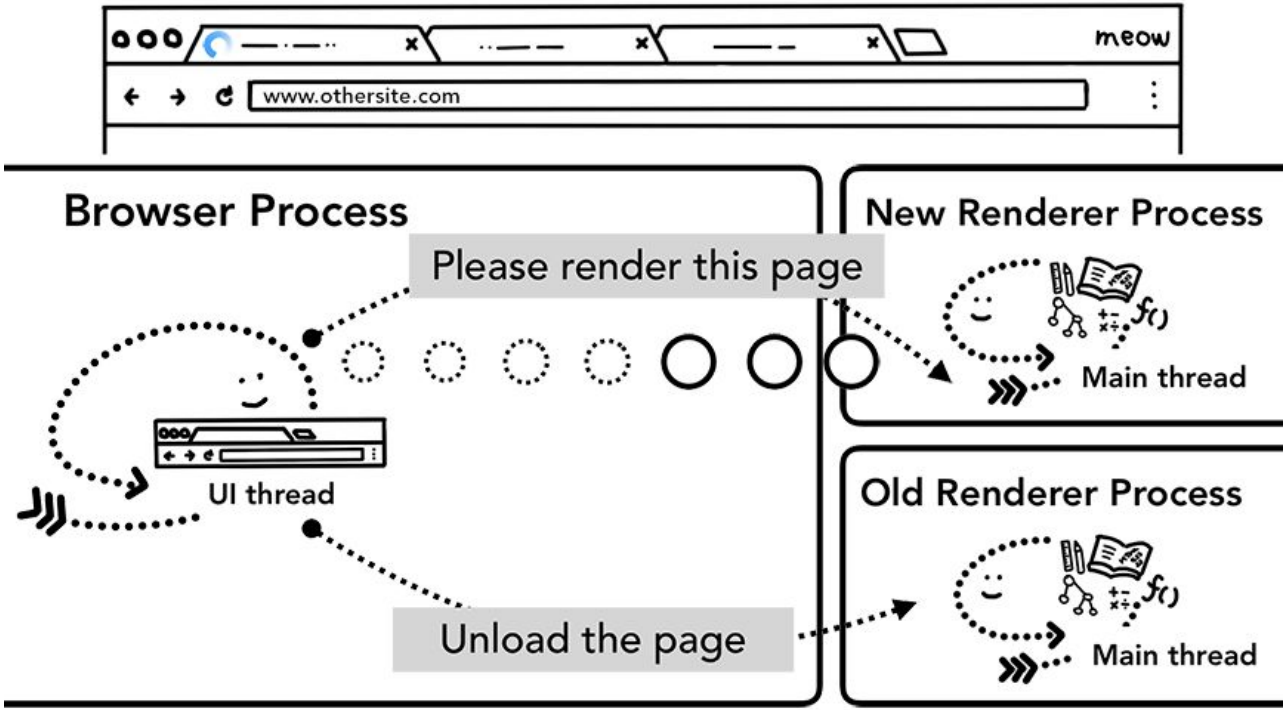
Source: https://developers.google.com/web/updates/2018/09/inside-browser-part1 (CC BY 4.0)

Navigating to a web site uses service requests

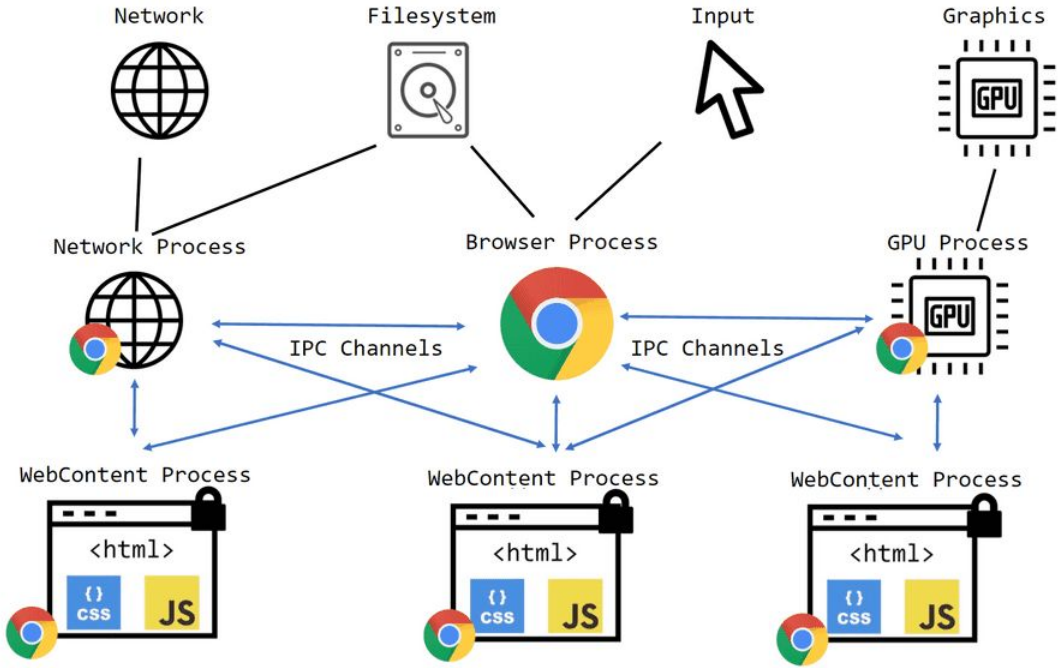


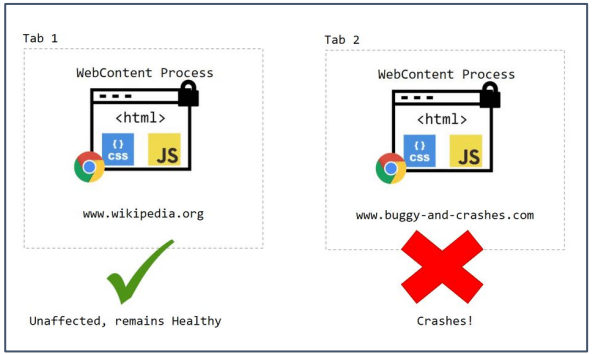
Source: https://developers.google.com/web/updates/2018/09/inside-browser-part1 (CC BY 4.0)

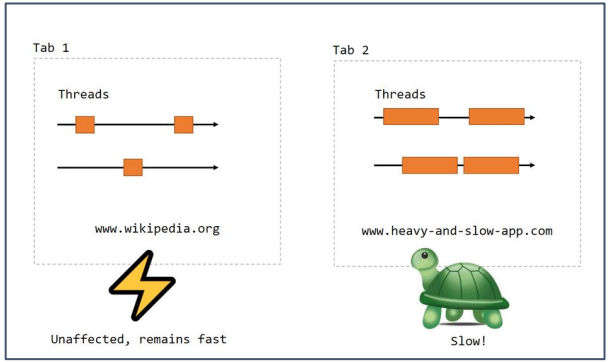
Navigating to a web site uses service requests



Source: https://developers.google.com/web/updates/2018/09/inside-browser-part1 (CC BY 4.0)







https://webperf.tips/tip/browser-process-model/

```
 303518 ?        SNl    0:00 /usr/lib/slack/chrome_crashpad_handler --monitor-self-annotation=ptype=crashpad-handler --no-upload-gzip --database=/home/eduardo/.config/Slack/Crashpad --url=https://slack.com/apps/sentryproxy/api/5277886/minidump/?sentry_key=fd30fe469dbf4aec9db40548e5acf91e --annotation=_produ
(bookworm) --annotation=plat=Linux --annotation=prod=Electron --annotation=sentry___initialScope={"release":"Slack@4.39.95","environment":"production","user":{"id":"b72f5d99-41cd-4a87-96ce-040dda56284d"},"tags":{"uuid":"b72f5d99-41cd-4a87-96ce-040dda56284d"},"extra":{"sessionId":"YjcyZjVkOTktNDFjZC00YTg3
--initial-client-fd=44 --shared-client-connection
 547177 ?        SNl   45:36 /opt/google/chrome/chrome
 547185 ?        SNl    0:00 /opt/google/chrome/chrome_crashpad_handler --monitor-self --monitor-self-annotation=ptype=crashpad-handler --database=/home/eduardo/.config/google-chrome/Crash Reports --url=https://clients2.google.com/cr/report --annotation=channel= --annotation=lsb-release=Debian GNU/Linux 12 (boo
--annotation=ver=128.0.6613.137 --initial-client-fd=5 --shared-client-connection
 547187 ?        SNl    0:00 /opt/google/chrome/chrome_crashpad_handler --no-periodic-tasks --monitor-self-annotation=ptype=crashpad-handler --database=/home/eduardo/.config/google-chrome/Crash Reports --url=https://clients2.google.com/cr/report --annotation=channel= --annotation=lsb-release=Debian GNU/Linux 12
--annotation=ver=128.0.6613.137 --initial-client-fd=4 --shared-client-connection
 547193 ?        SN     0:00 /opt/google/chrome/chrome --type=zygote --no-zygote-sandbox --crashpad-handler-pid=547185 --enable-crash-reporter=, --change-stack-guard-on-fork=enable
 547194 ?        SN     0:00 /opt/google/chrome/chrome --type=zygote --crashpad-handler-pid=547185 --enable-crash-reporter=, --change-stack-guard-on-fork=enable
 547196 ?        SN     0:04 /opt/google/chrome/chrome --type=zygote --crashpad-handler-pid=547185 --enable-crash-reporter=, --change-stack-guard-on-fork=enable
 547220 ?        SNl   48:08 /opt/google/chrome/chrome --type=gpu-process --crashpad-handler-pid=547185 --enable-crash-reporter=, --no-subproc-heap-profiling --change-stack-guard-on-fork=enable --gpu-preferences=UAAAAAAAAAAgAAAEAAAAAAAAAAAAAAAAAABgAAEAAAAAAAAAAAAAAAAAAAAAAAAAAAA
--shared-files --field-trial-handle=3,i,16924338087686289425,14108195033817998739,262144 --disable-features=EyeDropper --variations-seed-version=20240923-050122.947000
 547222 ?        SNl   21:09 /opt/google/chrome/chrome --type=utility --utility-sub-type=network.mojom.NetworkService --lang=en-US --service-sandbox-type=none --crashpad-handler-pid=547185 --enable-crash-reporter=, --no-subproc-heap-profiling --change-stack-guard-on-fork=enable --shared-files=v8_context_snapshot_
--disable-features=EyeDropper --variations-seed-version=20240923-050122.947000
 547224 ?        SNl    0:14 /opt/google/chrome/chrome --type=utility --utility-sub-type=storage.mojom.StorageService --lang=en-US --service-sandbox-type=utility --crashpad-handler-pid=547185 --enable-crash-reporter=, --no-subproc-heap-profiling --change-stack-guard-on-fork=enable --shared-files=v8_context_snapshot_d
--disable-features=EyeDropper --variations-seed-version=20240923-050122.947000
 547410 ?        SNl    2:30 /opt/google/chrome/chrome --type=renderer --crashpad-handler-pid=547185 --enable-crash-reporter=, --no-subproc-heap-profiling --change-stack-guard-on-fork=enable --lang=en-US --num-raster-threads=4 --enable-main-frame-before-activation --renderer-client-id=9 --time-ticks-at-unix-epoch=-17
--shared-files=v8_context_snapshot_data:100 --field-trial-handle=3,i,16924338087686289425,14108195033817998739,262144 --disable-features=EyeDropper --variations-seed-version=20240923-050122.947000
 547533 ?        SNl    1:23 /opt/google/chrome/chrome --type=renderer --crashpad-handler-pid=547185 --enable-crash-reporter=, --no-subproc-heap-profiling --change-stack-guard-on-fork=enable --lang=en-US --num-raster-threads=4 --enable-main-frame-before-activation --renderer-client-id=14 --time-ticks-at-unix-epoch=-1
--shared-files=v8_context_snapshot_data:100 --field-trial-handle=3,i,16924338087686289425,14108195033817998739,262144 --disable-features=EyeDropper --variations-seed-version=20240923-050122.947000
 547594 ?        SNl   10:27 /opt/google/chrome/chrome --type=utility --utility-sub-type=audio.mojom.AudioService --lang=en-US --service-sandbox-type=none --crashpad-handler-pid=547185 --enable-crash-reporter=, --no-subproc-heap-profiling --change-stack-guard-on-fork=enable --shared-files=v8_context_snapshot_data
--disable-features=EyeDropper --variations-seed-version=20240923-050122.947000
 547755 ?        SNl    0:08 /opt/google/chrome/chrome --type=renderer --crashpad-handler-pid=547185 --enable-crash-reporter=, --no-subproc-heap-profiling --change-stack-guard-on-fork=enable --lang=en-US --num-raster-threads=4 --enable-main-frame-before-activation --renderer-client-id=25 --time-ticks-at-unix-epoch=-1
--shared-files=v8_context_snapshot_data:100 --field-trial-handle=3,i,16924338087686289425,14108195033817998739,262144 --disable-features=EyeDropper --variations-seed-version=20240923-050122.947000
 554653 ?        SNl    2:43 /opt/google/chrome/chrome --type=renderer --crashpad-handler-pid=547185 --enable-crash-reporter=, --extension-process --no-subproc-heap-profiling --change-stack-guard-on-fork=enable --lang=en-US --num-raster-threads=4 --enable-main-frame-before-activation --renderer-client-id=65 --time-ti
--shared-files=v8_context_snapshot_data:100 --field-trial-handle=3,i,16924338087686289425,14108195033817998739,262144 --disable-features=EyeDropper --variations-seed-version=20240923-050122.947000
 554722 ?        SNl    0:11 /opt/google/chrome/chrome --type=renderer --crashpad-handler-pid=547185 --enable-crash-reporter=, --no-subproc-heap-profiling --change-stack-guard-on-fork=enable --lang=en-US --num-raster-threads=4 --enable-main-frame-before-activation --renderer-client-id=69 --time-ticks-at-unix-epoch=-1
--shared-files=v8_context_snapshot_data:100 --field-trial-handle=3,i,16924338087686289425,14108195033817998739,262144 --disable-features=EyeDropper --variations-seed-version=20240923-050122.947000
.....
1500520 ?        SNl    0:00 /opt/google/chrome/chrome --type=utility --utility-sub-type=data_decoder.mojom.DataDecoderService --lang=en-US --service-sandbox-type=service --crashpad-handler-pid=547185 --enable-crash-reporter=, --no-subproc-heap-profiling --change-stack-guard-on-fork=enable --shared-files=v8_contex
--field-trial-handle=3,i,16924338087686289425,14108195033817998739,262144 --disable-features=EyeDropper --variations-seed-version=20240923-050122.947000
1500532 ?        SNl    0:00 /opt/google/chrome/chrome --type=renderer --crashpad-handler-pid=547185 --enable-crash-reporter=, --no-subproc-heap-profiling --change-stack-guard-on-fork=enable --lang=en-US --num-raster-threads=4 --enable-main-frame-before-activation --renderer-client-id=2231 --time-ticks-at-unix-epoch
--shared-files=v8_context_snapshot_data:100 --field-trial-handle=3,i,16924338087686289425,14108195033817998739,262144 --disable-features=EyeDropper --variations-seed-version=20240923-050122.947000
1505970 ?        SNl    0:01 /opt/google/chrome/chrome --type=renderer --crashpad-handler-pid=547185 --enable-crash-reporter=, --no-subproc-heap-profiling --change-stack-guard-on-fork=enable --lang=en-US --num-raster-threads=4 --enable-main-frame-before-activation --renderer-client-id=2241 --time-ticks-at-unix-epoch
--shared-files=v8_context_snapshot_data:100 --field-trial-handle=3,i,16924338087686289425,14108195033817998739,262144 --disable-features=EyeDropper --variations-seed-version=20240923-050122.947000
1506177 ?        SNl    0:00 /opt/google/chrome/chrome --type=utility --utility-sub-type=data_decoder.mojom.DataDecoderService --lang=en-US --service-sandbox-type=service --crashpad-handler-pid=547185 --enable-crash-reporter=, --no-subproc-heap-profiling --change-stack-guard-on-fork=enable --shared-files=v8_contex
--field-trial-handle=3,i,16924338087686289425,14108195033817998739,262144 --disable-features=EyeDropper --variations-seed-version=20240923-050122.947000
1506231 ?        SNl    0:00 /opt/google/chrome/chrome --type=renderer --crashpad-handler-pid=547185 --enable-crash-reporter=, --no-subproc-heap-profiling --change-stack-guard-on-fork=enable --lang=en-US --num-raster-threads=4 --enable-main-frame-before-activation --renderer-client-id=2249 --time-ticks-at-unix-epoch
--shared-files=v8_context_snapshot_data:100 --field-trial-handle=3,i,16924338087686289425,14108195033817998739,262144 --disable-features=EyeDropper --variations-seed-version=20240923-050122.947000
1506253 ?        SNl    0:19 /opt/google/chrome/chrome --type=renderer --crashpad-handler-pid=547185 --enable-crash-reporter=, --no-subproc-heap-profiling --change-stack-guard-on-fork=enable --lang=en-US --num-raster-threads=4 --enable-main-frame-before-activation --renderer-client-id=2250 --time-ticks-at-unix-epoch
--shared-files=v8_context_snapshot_data:100 --field-trial-handle=3,i,16924338087686289425,14108195033817998739,262144 --disable-features=EyeDropper --variations-seed-version=20240923-050122.947000
1508636 ?        SNl    0:00 /opt/google/chrome/chrome --type=renderer --crashpad-handler-pid=547185 --enable-crash-reporter=, --extension-process --no-subproc-heap-profiling --change-stack-guard-on-fork=enable --lang=en-US --num-raster-threads=4 --enable-main-frame-before-activation --renderer-client-id=2257 --tim
--shared-files=v8_context_snapshot_data:100 --field-trial-handle=3,i,16924338087686289425,14108195033817998739,262144 --disable-features=EyeDropper --variations-seed-version=20240923-050122.947000
1511269 ?        SNl    0:01 /opt/google/chrome/chrome --type=renderer --crashpad-handler-pid=547185 --enable-crash-reporter=, --extension-process --no-subproc-heap-profiling --change-stack-guard-on-fork=enable --lang=en-US --num-raster-threads=4 --enable-main-frame-before-activation --renderer-client-id=2259 --time
--shared-files=v8_context_snapshot_data:100 --field-trial-handle=3,i,16924338087686289425,14108195033817998739,262144 --disable-features=EyeDropper --variations-seed-version=20240923-050122.947000
1511299 ?        SNl    0:00 /opt/google/chrome/chrome --type=renderer --crashpad-handler-pid=547185 --enable-crash-reporter=, --extension-process --no-subproc-heap-profiling --change-stack-guard-on-fork=enable --lang=en-US --num-raster-threads=4 --enable-main-frame-before-activation --renderer-client-id=2260 --time
--shared-files=v8_context_snapshot_data:100 --field-trial-handle=3,i,16924338087686289425,14108195033817998739,262144 --disable-features=EyeDropper --variations-seed-version=20240923-050122.947000
1511309 ?        SNl    0:00 /opt/google/chrome/chrome --type=renderer --crashpad-handler-pid=547185 --enable-crash-reporter=, --no-subproc-heap-profiling --change-stack-guard-on-fork=enable --lang=en-US --num-raster-threads=4 --enable-main-frame-before-activation --renderer-client-id=2261 --time-ticks-at-unix-epoch
--shared-files=v8_context_snapshot_data:100 --field-trial-handle=3,i,16924338087686289425,14108195033817998739,262144 --disable-features=EyeDropper --variations-seed-version=20240923-050122.947000
1511340 ?        SNl    0:00 /opt/google/chrome/chrome --type=renderer --crashpad-handler-pid=547185 --enable-crash-reporter=, --no-subproc-heap-profiling --change-stack-guard-on-fork=enable --lang=en-US --num-raster-threads=4 --enable-main-frame-before-activation --renderer-client-id=2262 --time-ticks-at-unix-epoch
--shared-files=v8_context_snapshot_data:100 --field-trial-handle=3,i,16924338087686289425,14108195033817998739,262144 --disable-features=EyeDropper --variations-seed-version=20240923-050122.947000
```

Service-oriented Architecture

- Ability to change components independently
- Independent processes (Isolation, Security)
- Focusing on doing one thing well

MICROSERVICES

Microservices
Microservices Everywhere

"*Small autonomous services that work well together*"

Sam Newman

Microservices

COMCAST

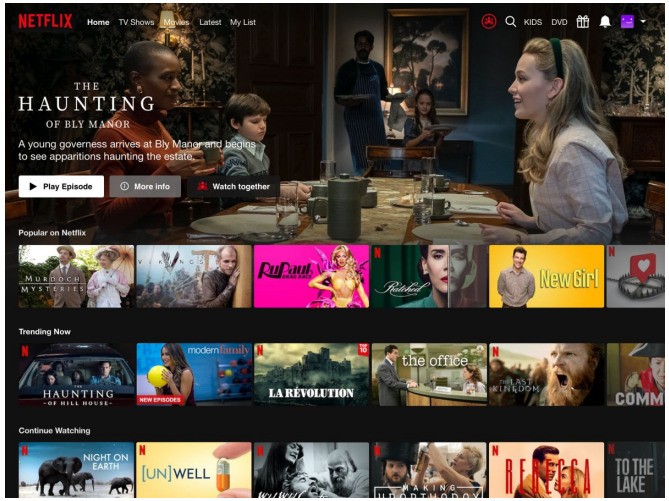
NETFLIX

ebay

UBER

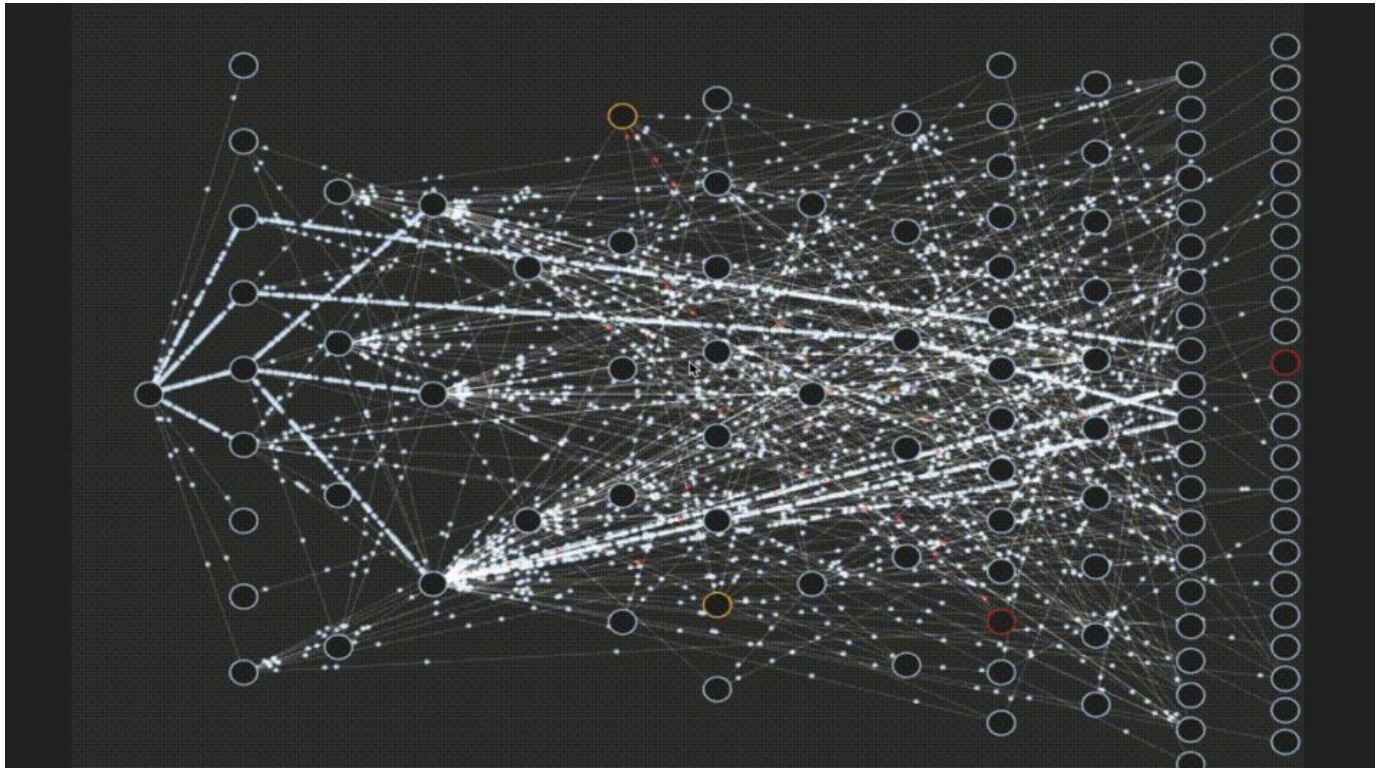
GROUPON

Netflix Microservices – App Boot



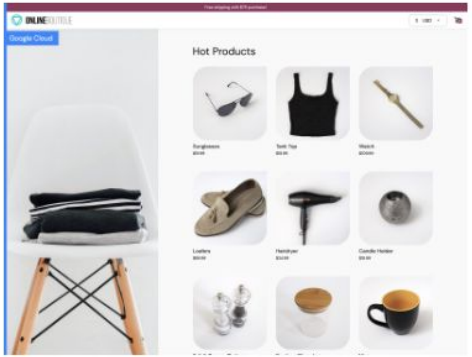
- Recommendations
- Trending Now
- Continue Watching
- My List
- Metrics

(as of 2016)

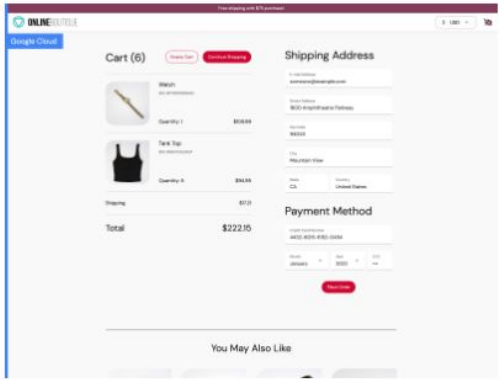


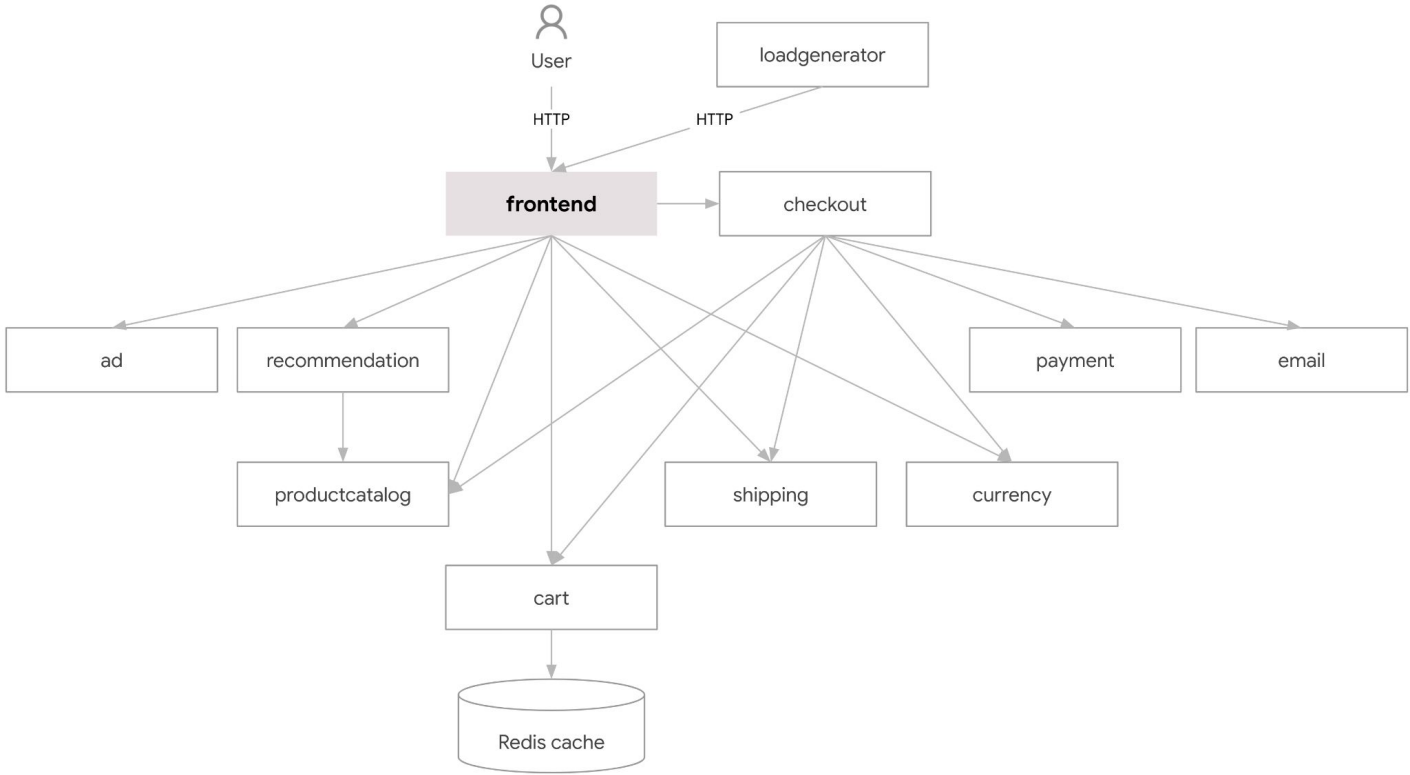
Service	Description
frontend	Exposes an HTTP server to serve the website. Does not require signup/login and generates session IDs for all users automatically.
cartservice	Stores the items in the user's shopping cart in Redis and retrieves it.
productcatalogservice	Provides the list of products from a JSON file and ability to search products and get individual products.
currencyservice	Converts one money amount to another currency. Uses real values fetched from European Central Bank.
paymentservice	Charges the given credit card info (mock) with the given amount and returns a transaction ID.
shippingservice	Gives shipping cost estimates based on the shopping cart. Ships items to the given address (mock)
checkoutservice	Retrieves user cart, prepares order and orchestrates the payment, shipping and the email notification.

Home Page



Checkout Screen





Monoliths vs Microservices

Activity: In teams of 3-4

What are the consequences of this architecture? On:

- Scalability
- Reliability
- Performance
- Development
- Maintainability
- Testability
- Ownership

Advantages of Microservices

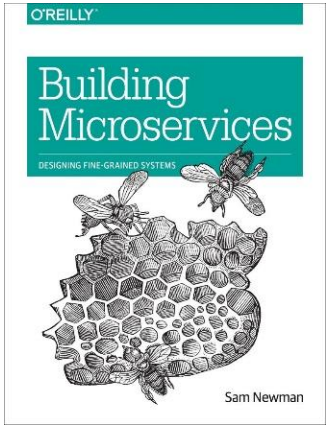
- Ship features faster and safer
- Scalability
- Target security concerns
- Allow the interplay of different systems and languages, no commitment to a single technology stack
- Easily deployable and replicable
- Embrace uncertainty, automation, and faults

Microservice challenges

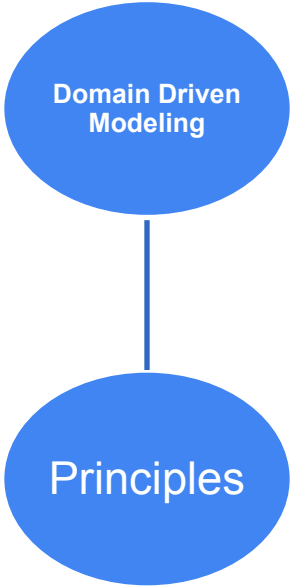
- Too many choices
- Delay between investment and payback
- Complexities of distributed systems
  - network latency, faults, inconsistencies
  - testing challenges
- Monitoring is more complex
- More system states
- More points of failure
- Operational complexity
- Frequently adopted by breaking down a monolithic application

MICROSERVICES: PRINCIPLES

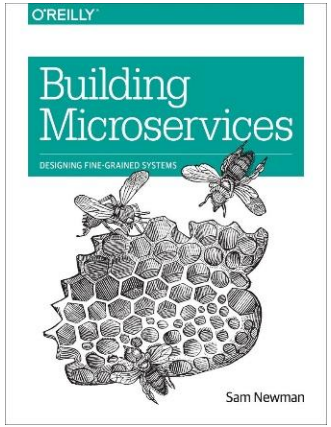
Principles

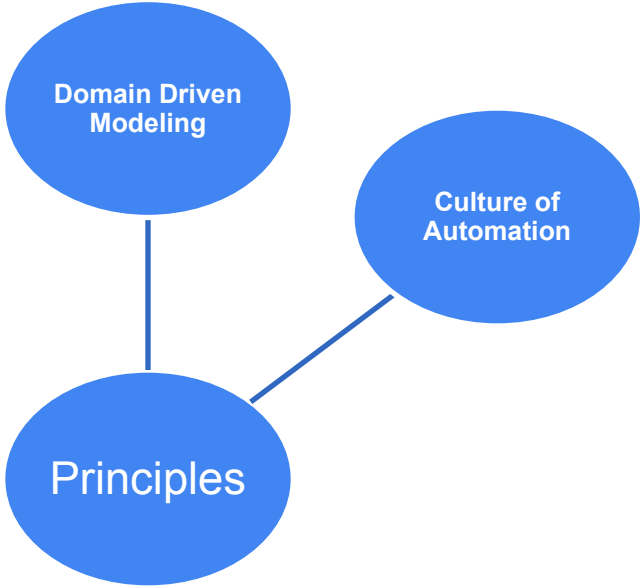


Sam Newman's Principles of Microservices

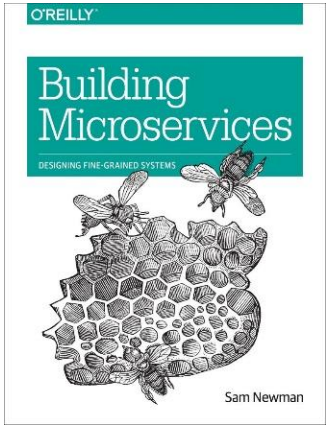


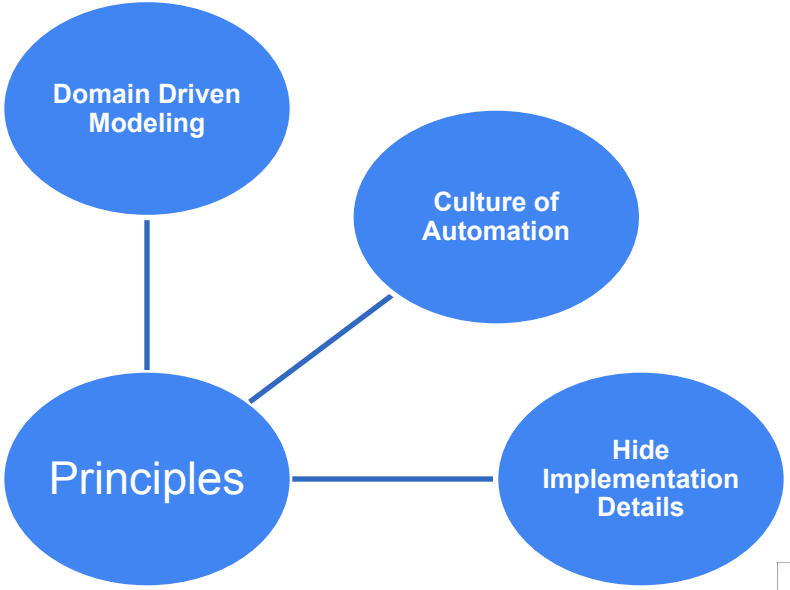
Sam Newman's Principles of Microservices



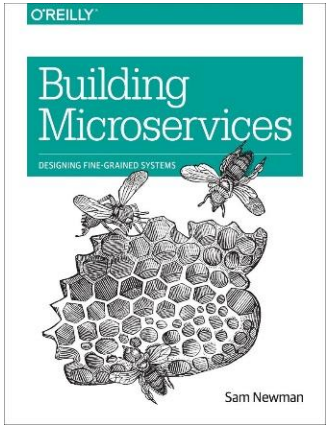


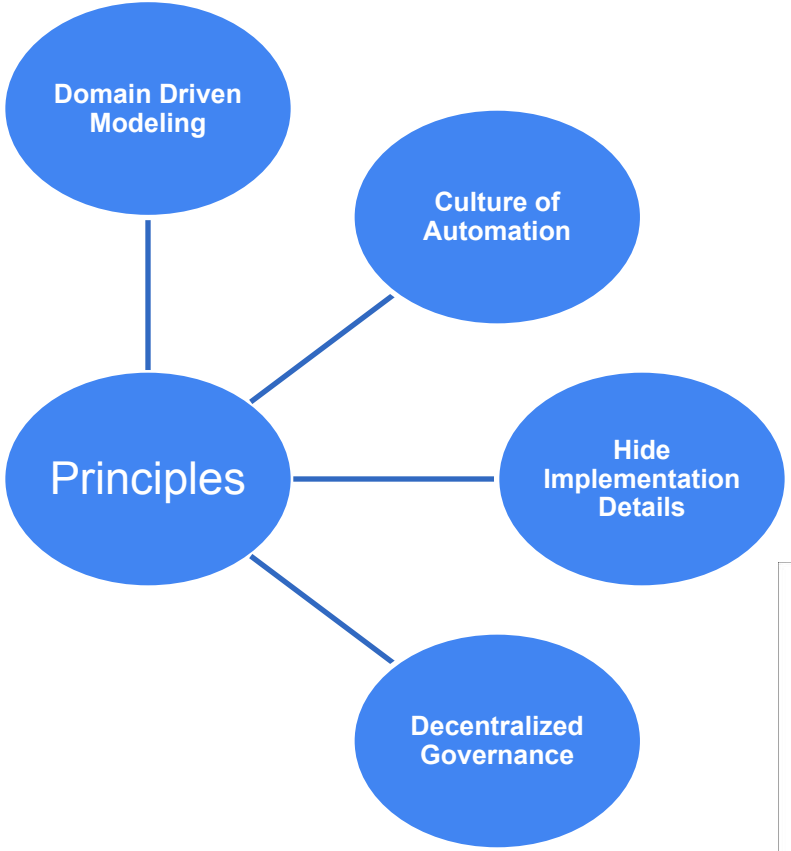
Sam Newman's Principles of Microservices



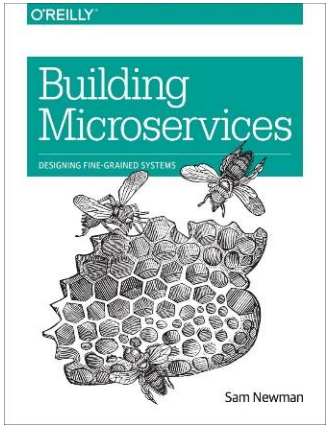


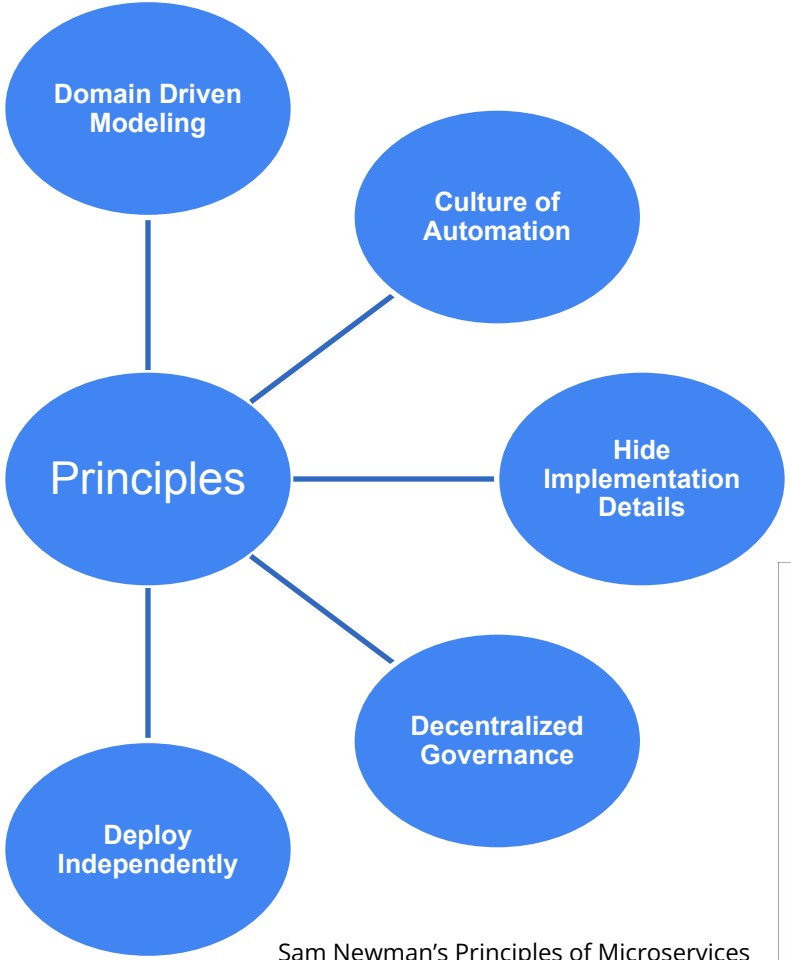
Sam Newman's Principles of Microservices



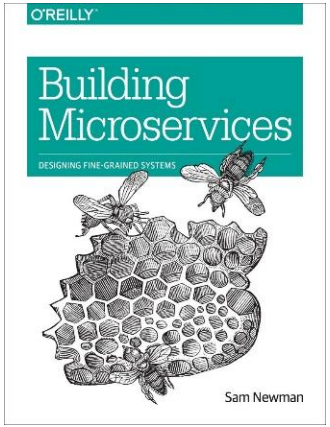


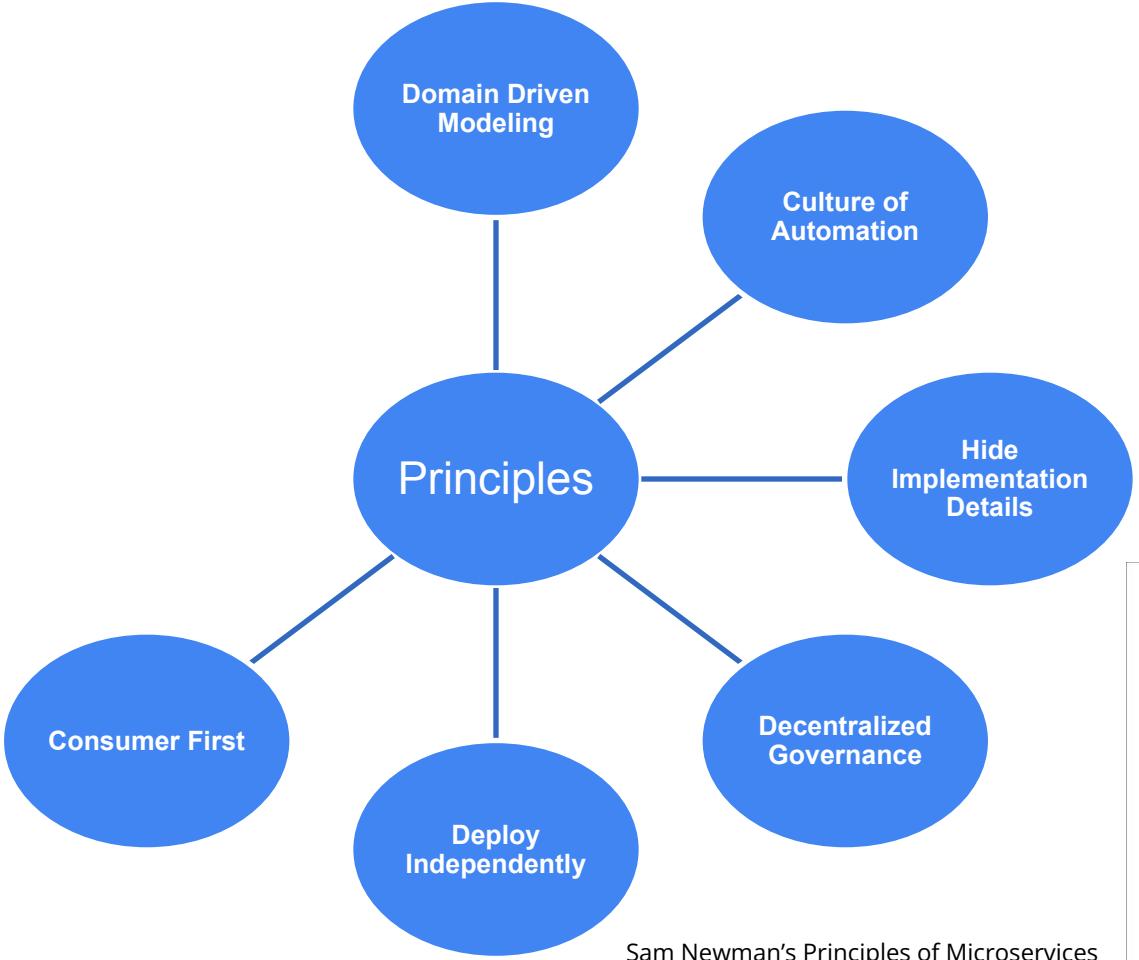
Sam Newman's Principles of Microservices



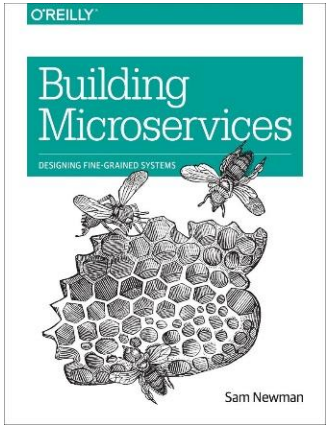


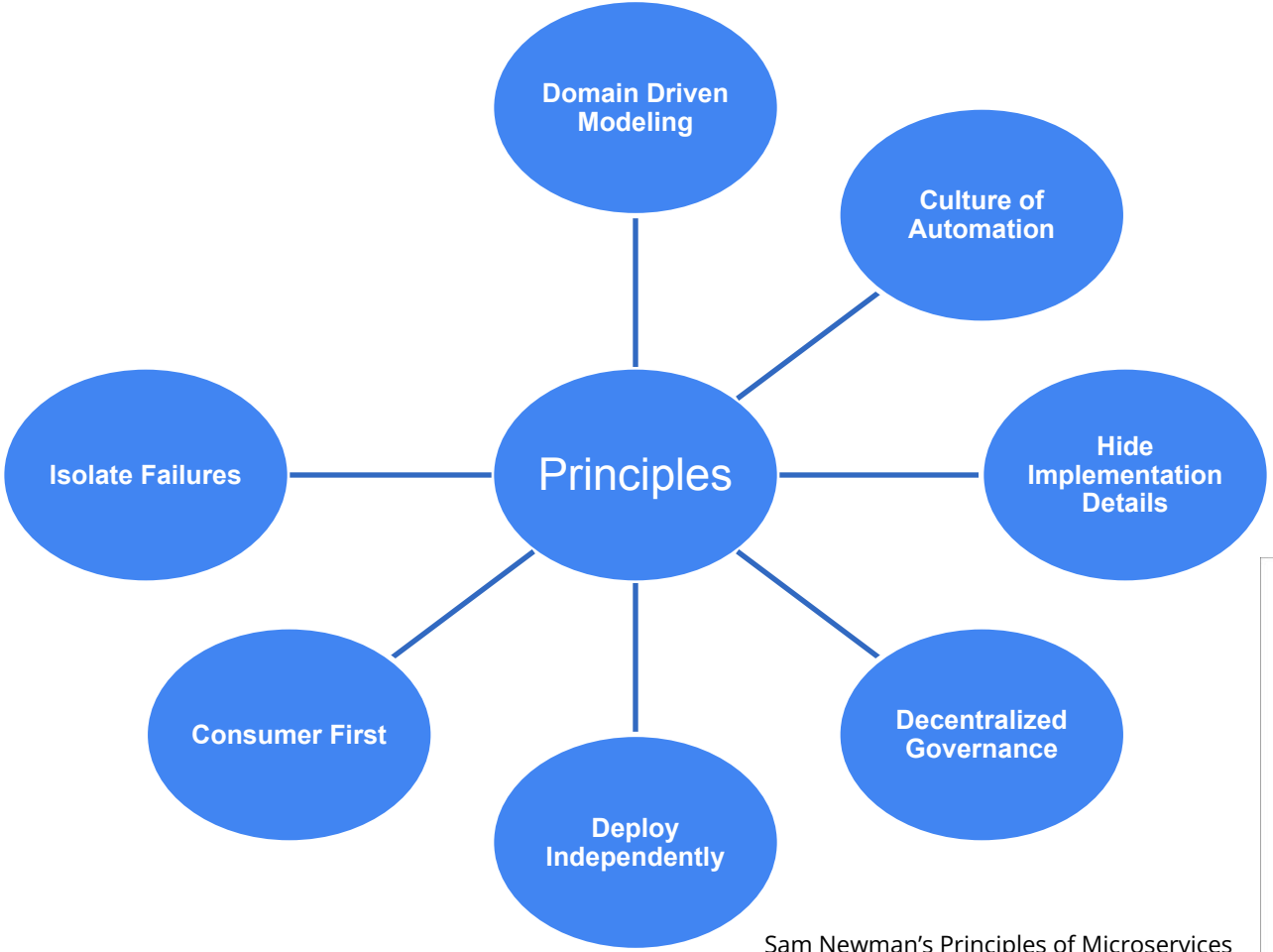
Sam Newman's Principles of Microservices



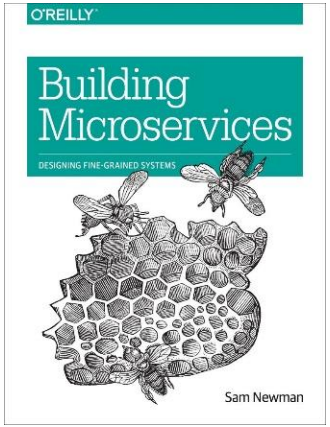


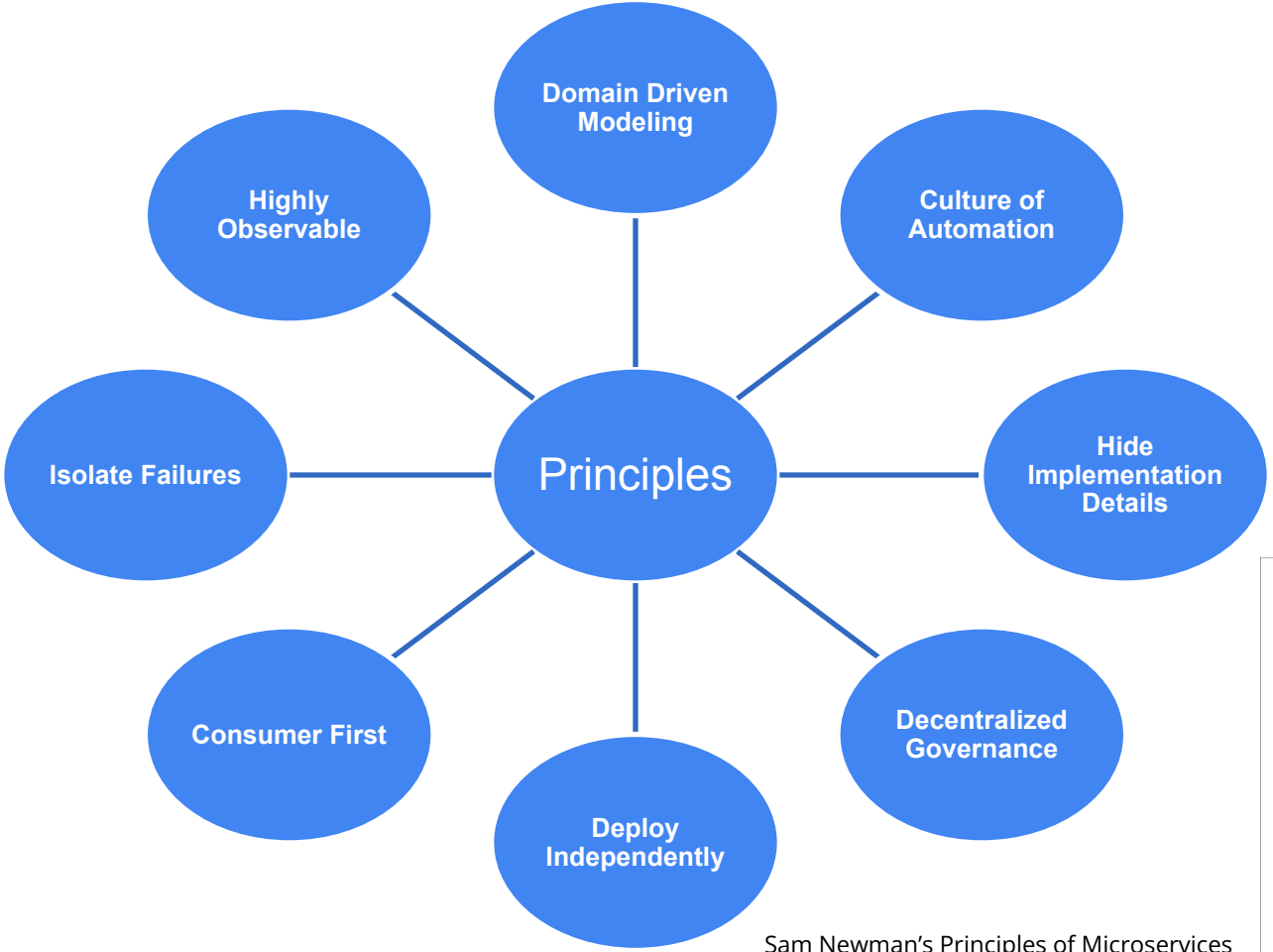
Sam Newman's Principles of Microservices



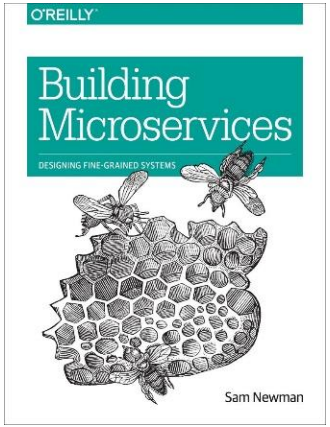


Sam Newman's Principles of Microservices



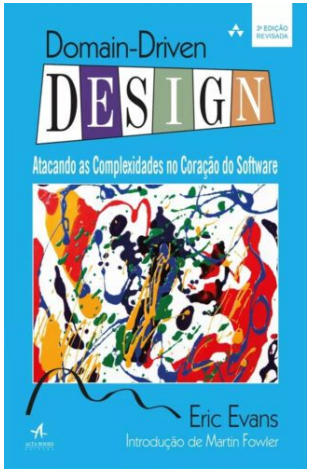


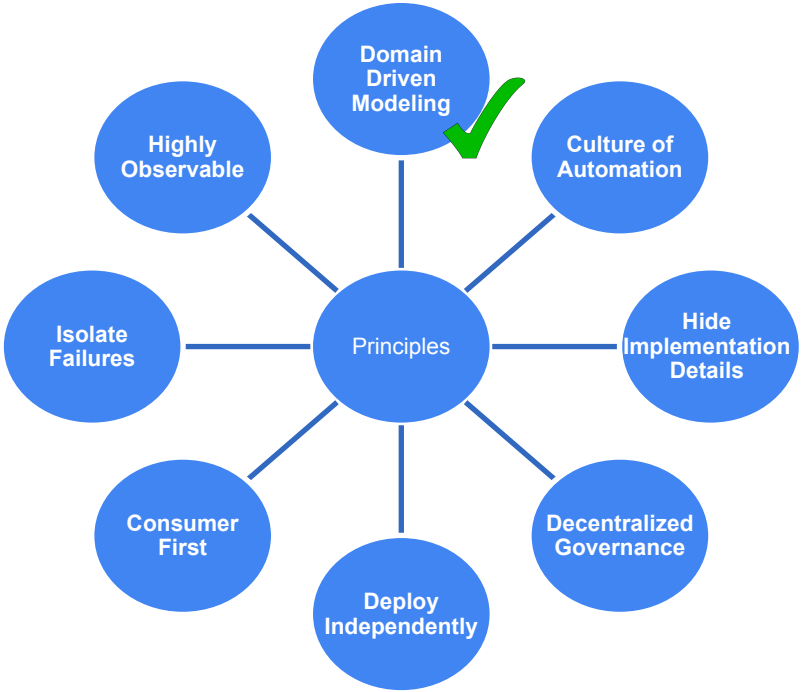
Sam Newman's Principles of Microservices



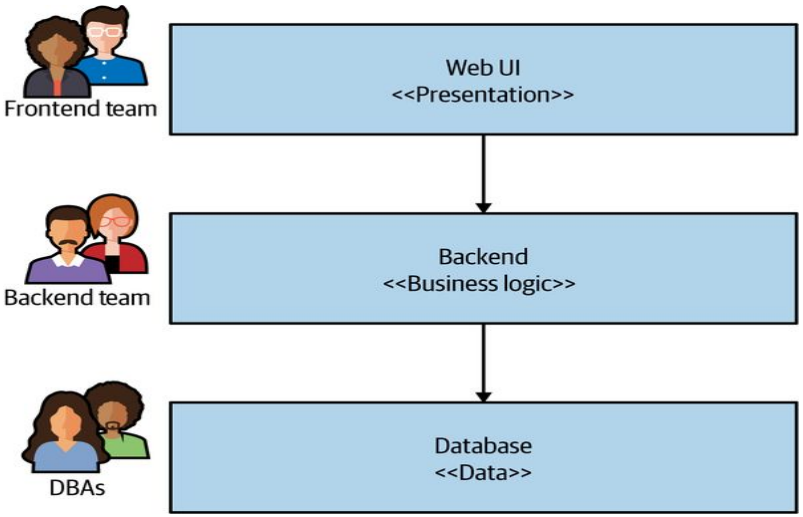
Principle 1: Domain-driven modeling

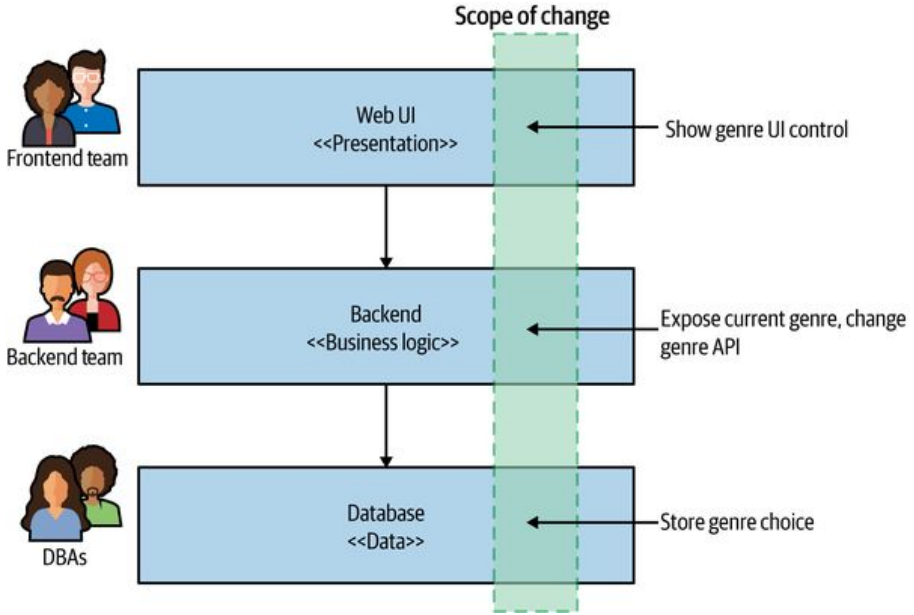
- Model services around business capabilities



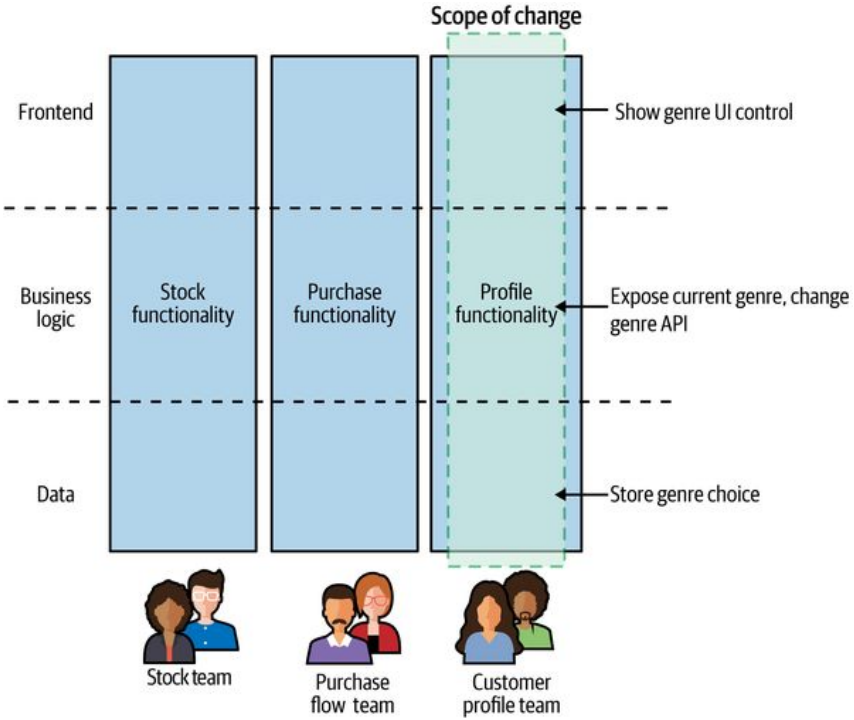


Principle 1: Domain-driven modeling



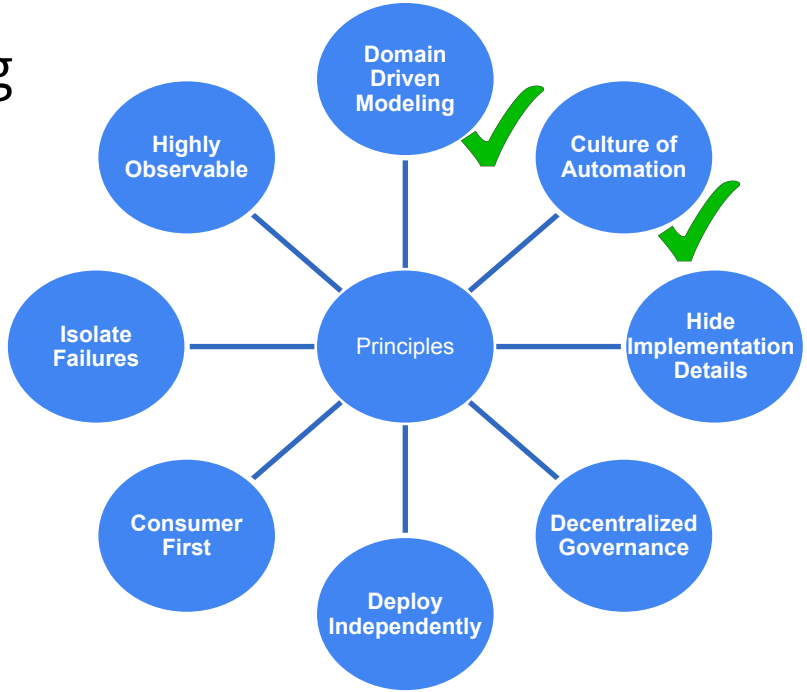


Principle 1: Domain-driven modeling



Principle 2: Culture of Automation

- API-Driven Machine Provisioning
- Continuous Delivery
- Automated Testing



API-Driven Machine Provisioning

Example: Infrastructure as code (IaC)

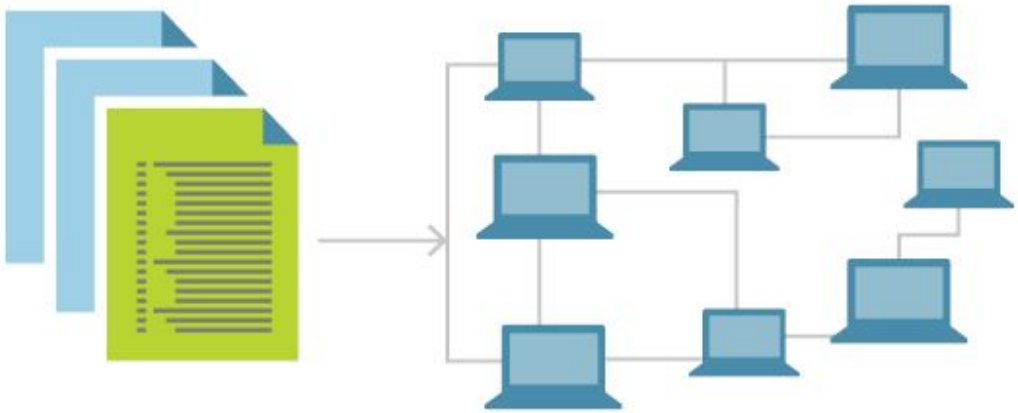
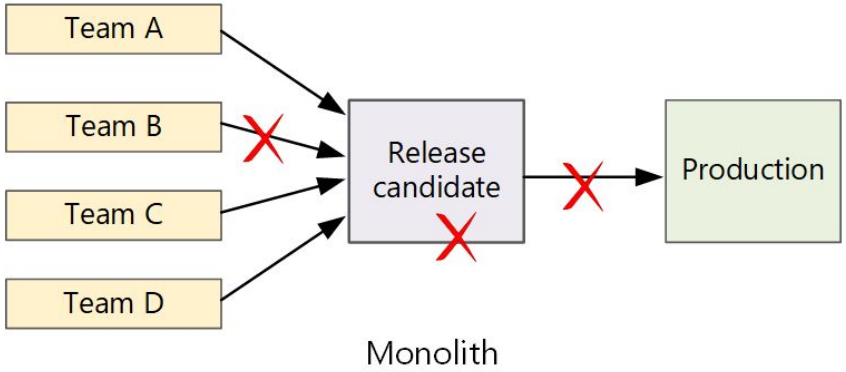


Image source: https://learn.microsoft.com/en-us/devops/deliver/what-is-infrastructure-as-code

Continuous Delivery



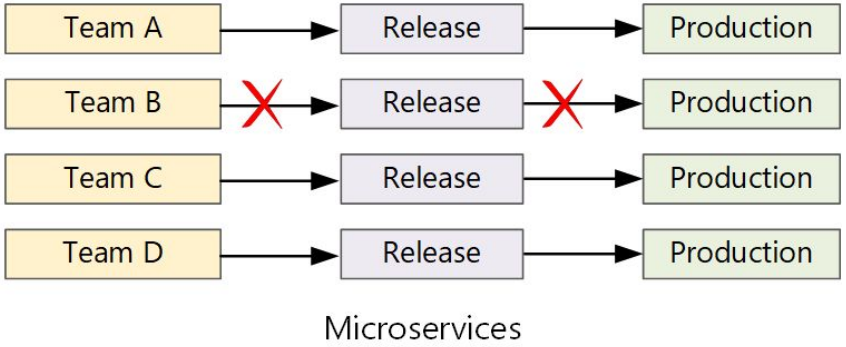
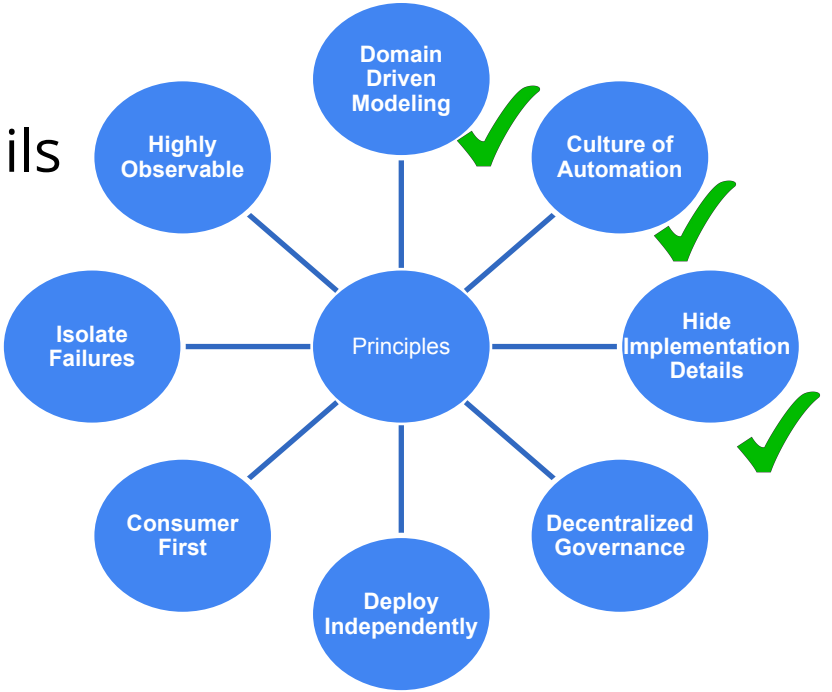


Image Source: https://learn.microsoft.com/en-us/azure/architecture/microservices/ci-cd

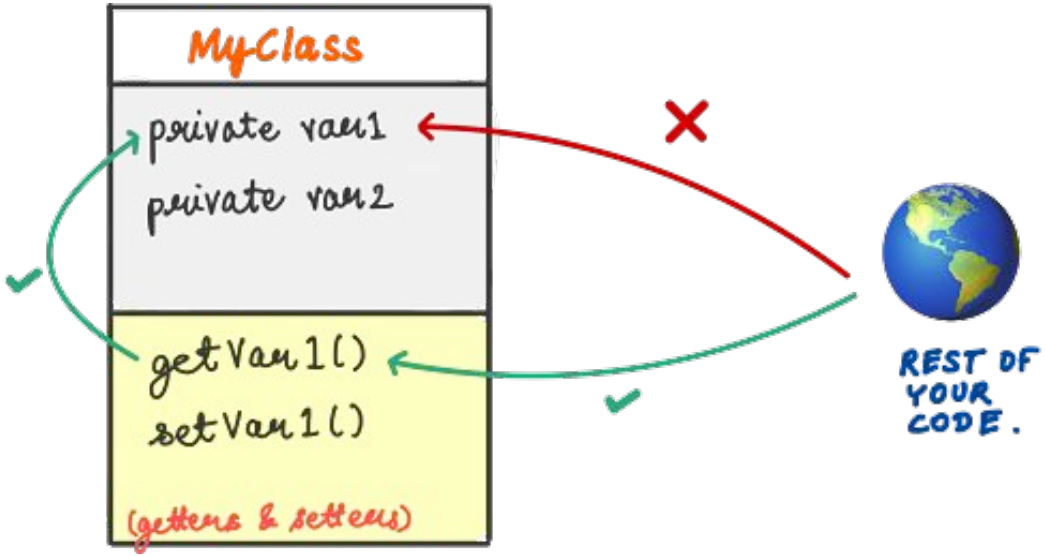
Principle 3: Hide implementation details

- Design carefully your APIs
- It’s easier to expose some details later than hide them
- Do not share your database!

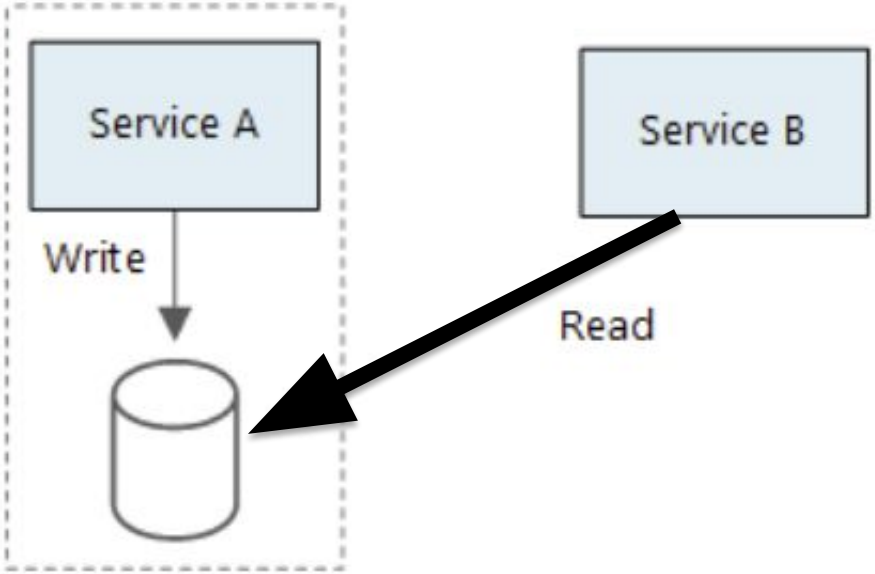


Principle 3: Hide implementation details

Recall: Encapsulation in OOP

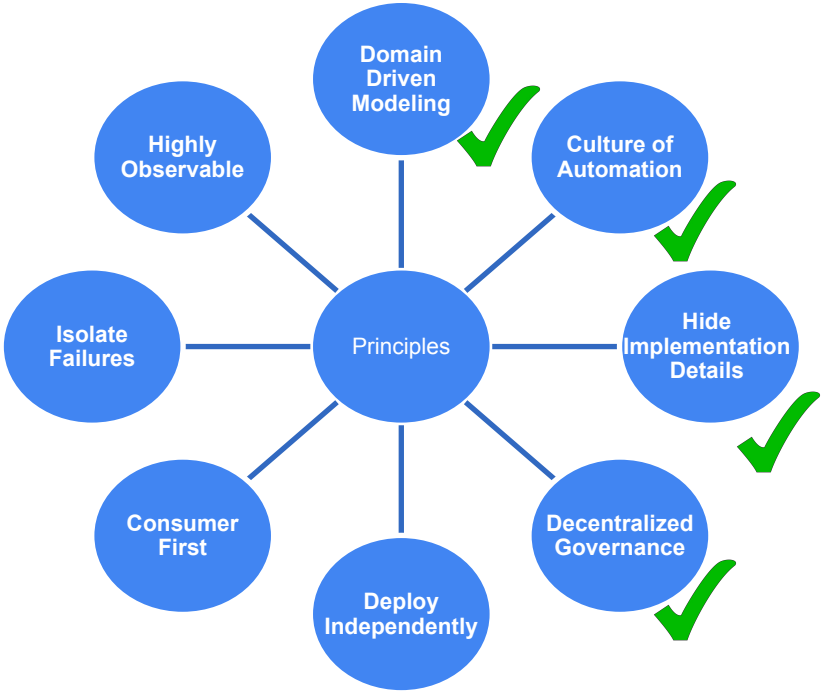


Sharing database: Anti-pattern

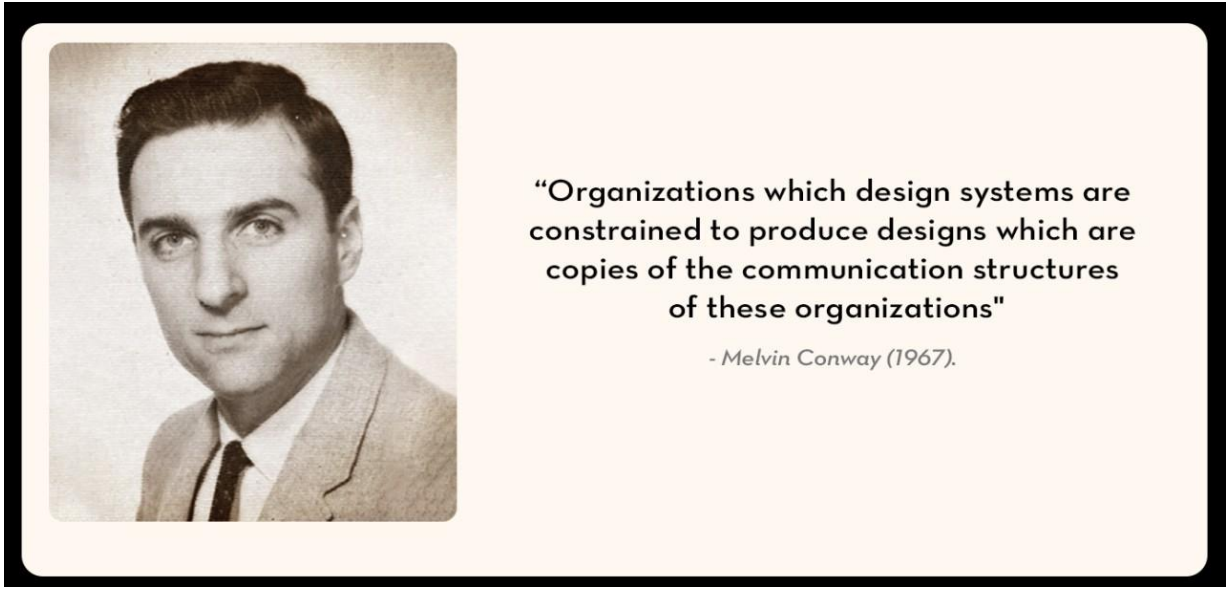


Principle 4: Decentralized Governance

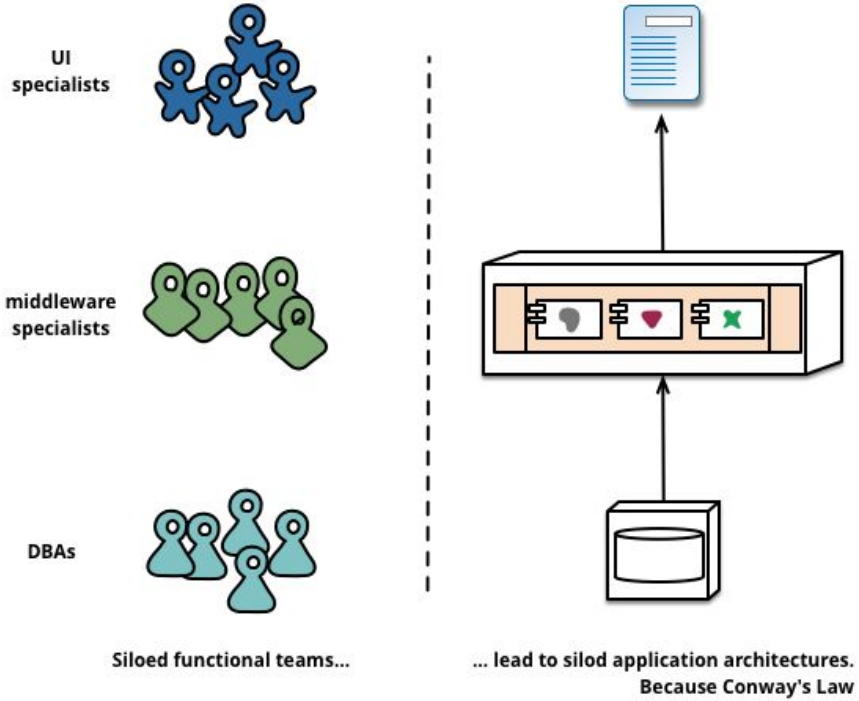
- Mind Conway's Law
- You Build It, You Run It
- Embrace team autonomy
- Internal Open Source Model

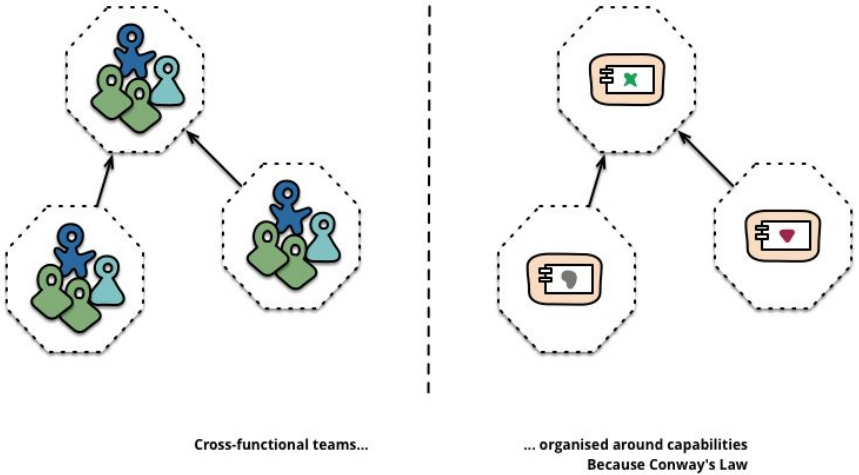


Mind Conway's Law



Mind Conway's Law





"Products" not "Projects"

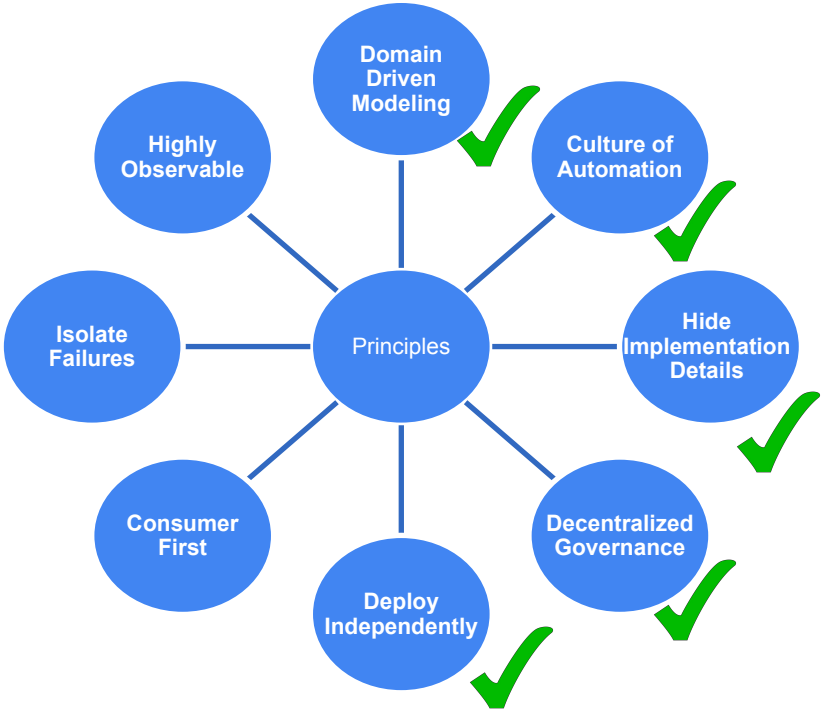
YOU BUILD IT
YOU RUN
AWAY IT

"The traditional model is that you take your software to the wall that separates development and operations, and throw it over and then forget about it. Not at Amazon. You build it, you run it. This brings developers into contact with the day-to-day operation of their software. It also brings them into day-to-day contact with the customer. This customer feedback loop is essential for improving the quality of the service."

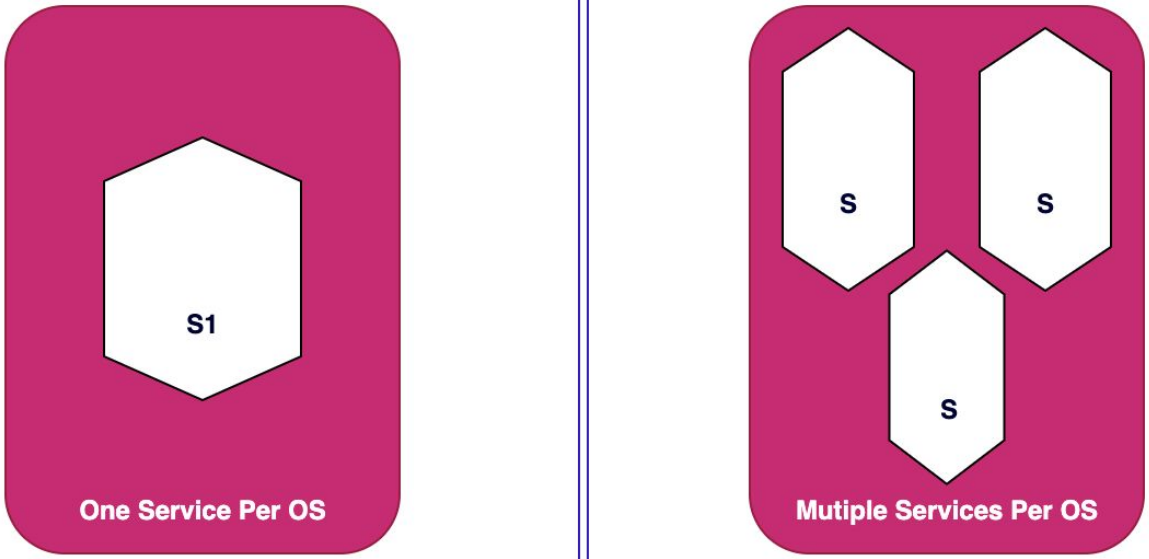
-- Werner Vogels in "A conversation with Werner Vogels" in ACM Queue, May 2006

Principle 5: Deploy Independently

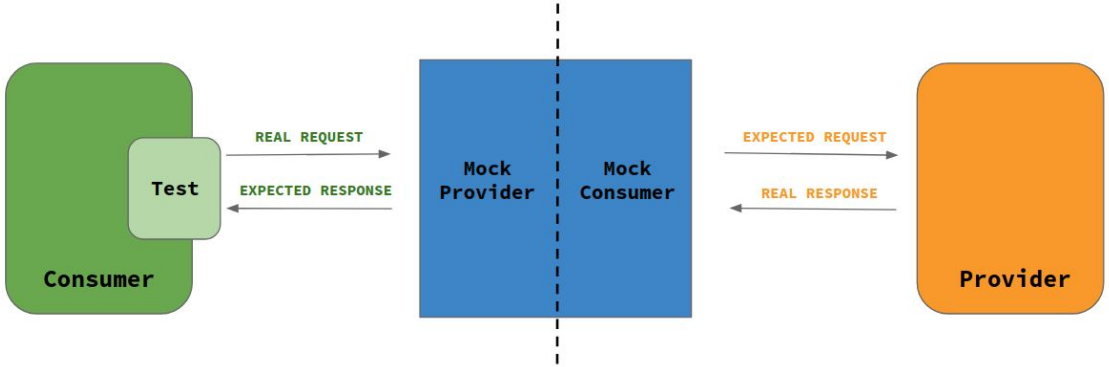
- One Service Per OS
- Consumer-Driven Contracts
- Multiple coexisting versions



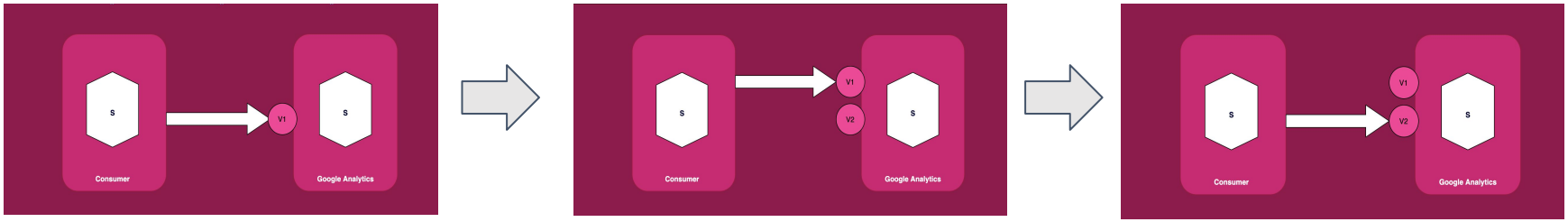
One Service Per OS



Consumer-Driven Contracts

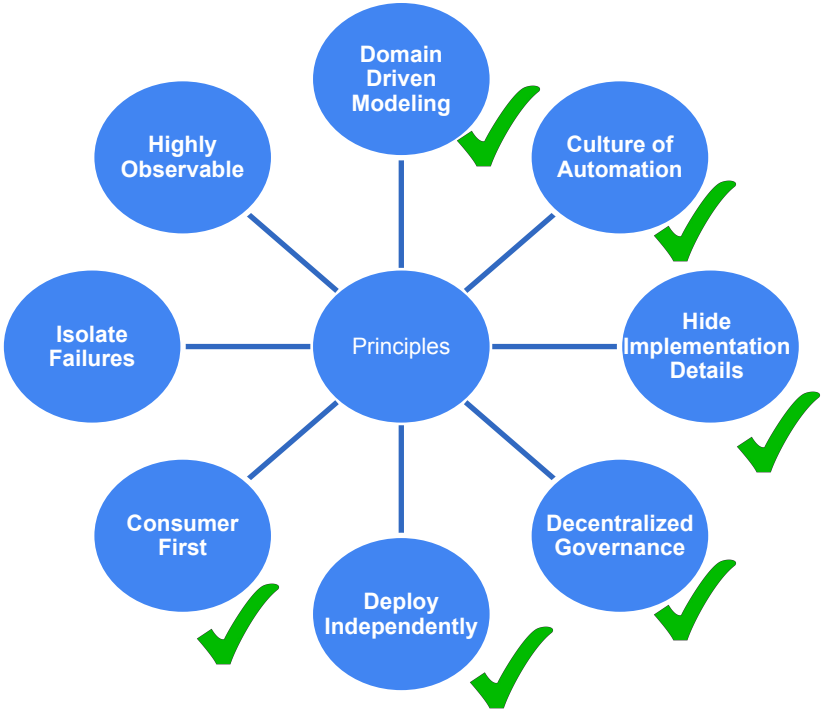


Multiple coexisting versions



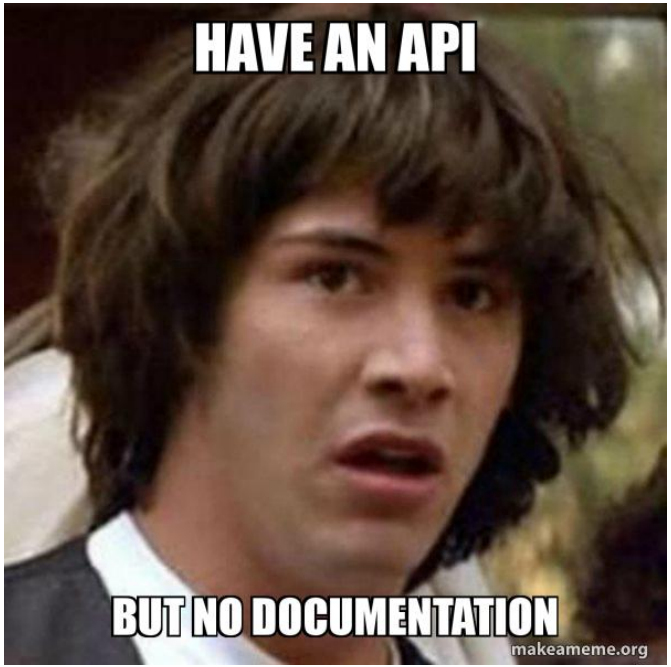
Principle 6: Consumer First

- Encourage conversations
- API Documentation
- Service Discovery



Encourage conversations

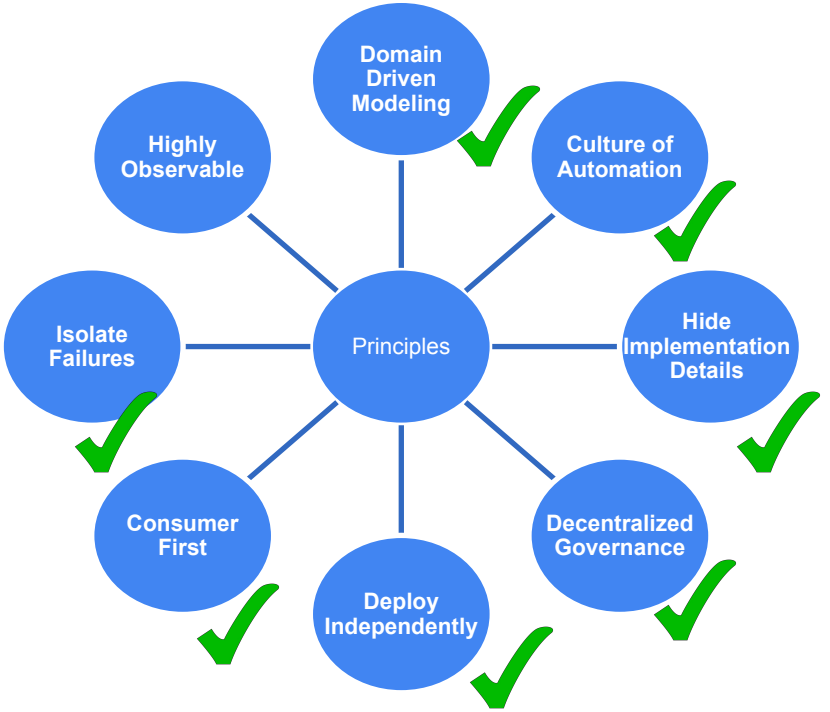
API Documentation

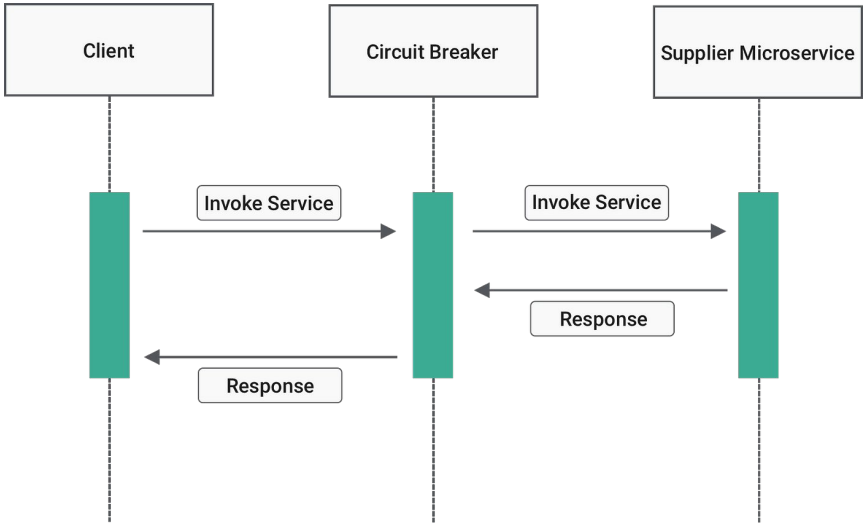


Swagger™

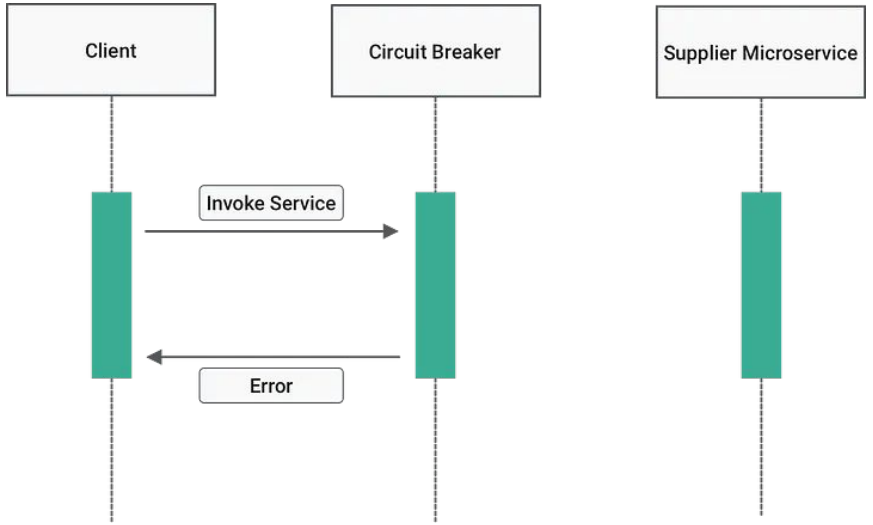
Principle 7: Isolate Failure

- Avoid cascading failures
- Timeouts between components
- **Fail fast** aka *Design for Failure*
  - Bulkheading / Circuit breakers





Closed circuit

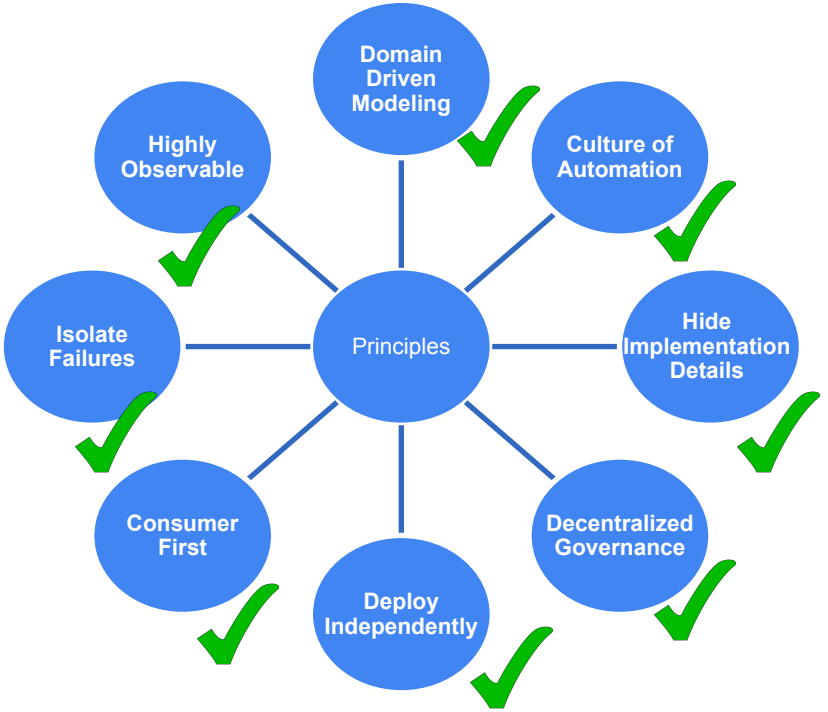


Open circuit

Image source: blogs.halodoc.io

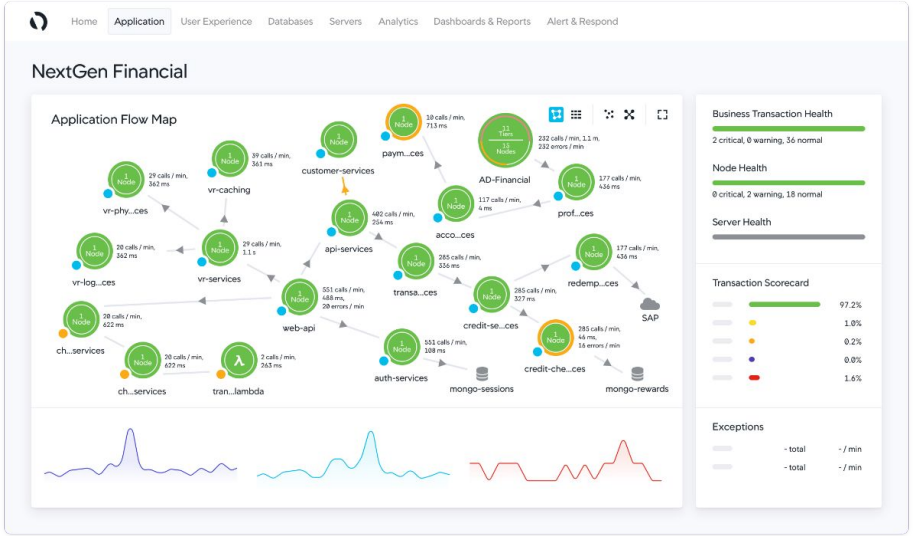
Principle 8: Highly Observable

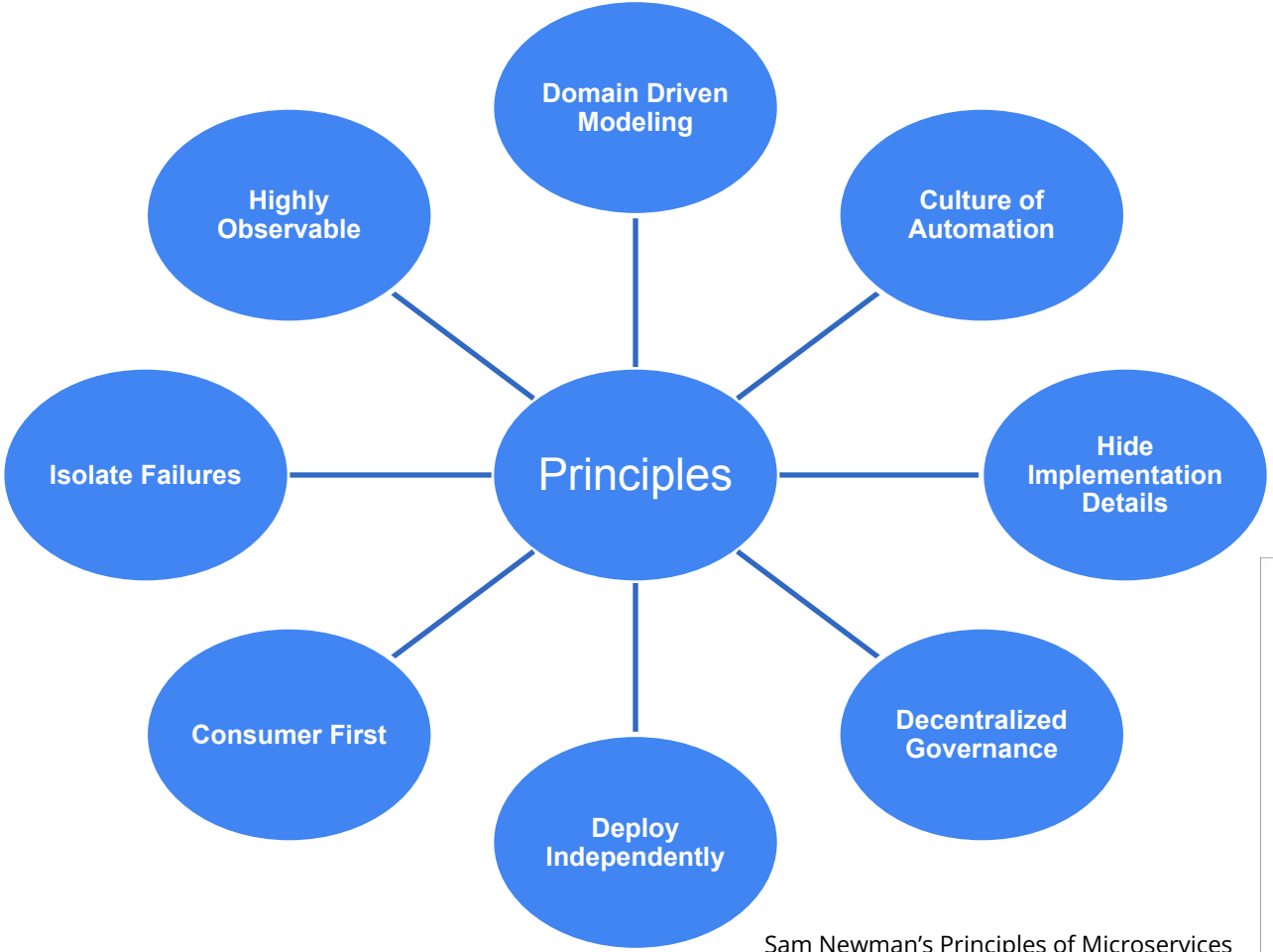
- Standard Monitoring
- Health-Check Pages
- Log and Stats aggregation
- Downstream monitoring



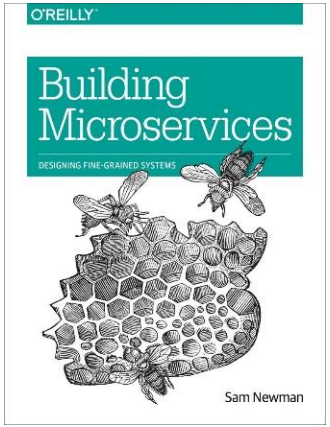
Principle 8: Highly Observable

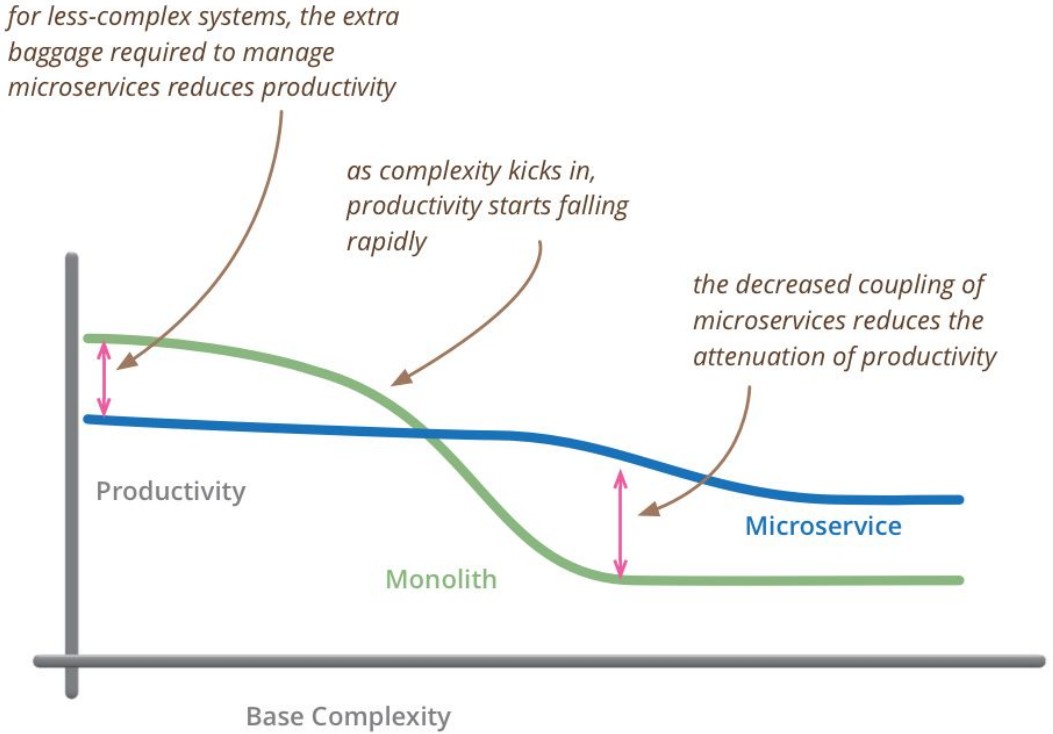
- Standard Monitoring
- Health-Check Pages
- Log and Stats aggregation
- Downstream monitoring





Sam Newman's Principles of Microservices



Are microservices always the right choice?

Microservices overhead