Advanced Cloud Computing

Container Virtualization

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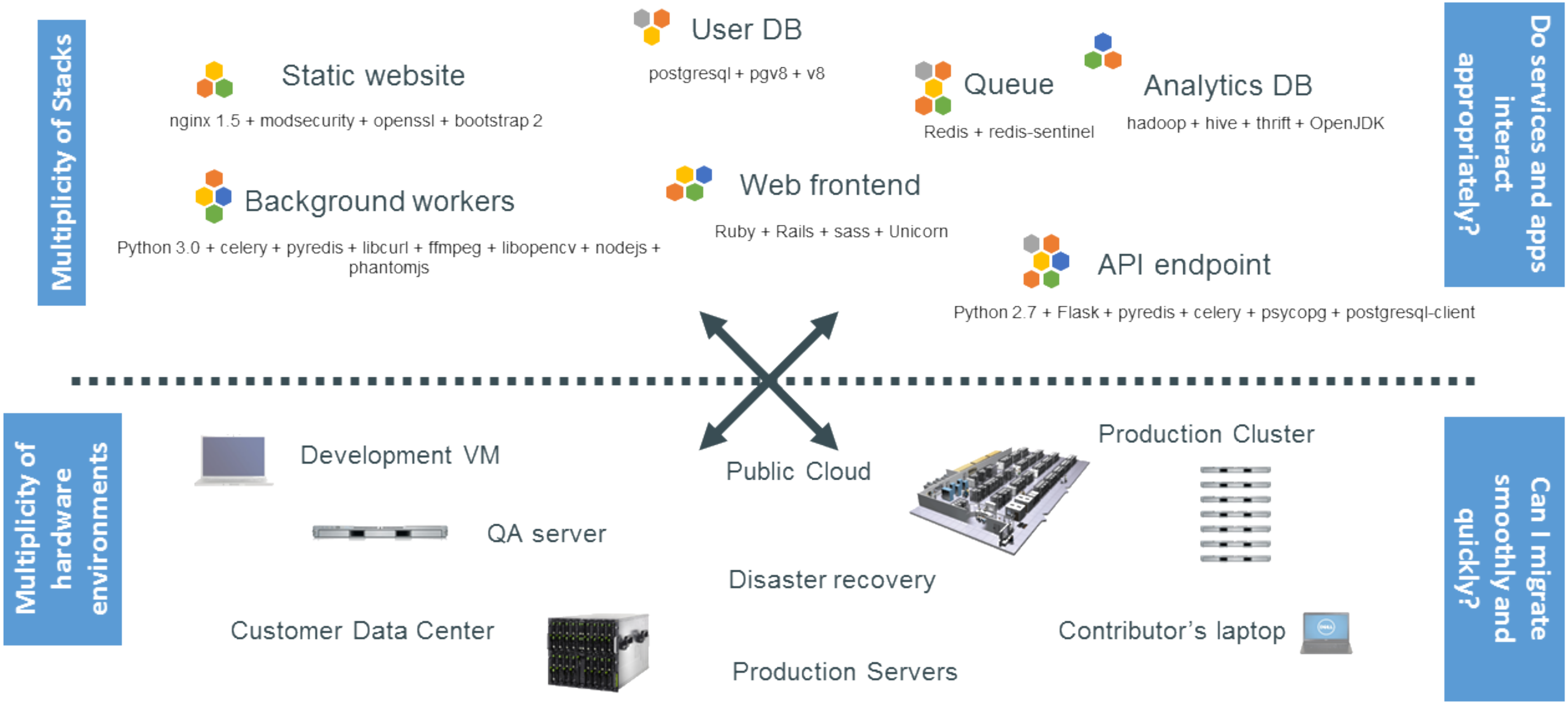
Why container?

The challenge



Multiplicity of Stacks

Static website

nginx 1.5 + modsecurity + openssl + bootstrap 2

User DB

postgresql + pgv8 + v8

Queue

Redis + redis-sentinel

Analytics DB

hadoop + hive + thrift + OpenJDK

Background workers

Python 3.0 + celery + pyredis + libcurl + ffmpeg + libopencv + nodejs + phantomjs

Web frontend

Ruby + Rails + sass + Unicorn

API endpoint

Python 2.7 + Flask + pyredis + celery + psycopg + postgresql-client

Do services and apps interact appropriately?

Multiplicity of hardware environments

Development VM

QA server

Customer Data Center

Public Cloud

Disaster recovery

Production Servers

Production Cluster

Contributor's laptop

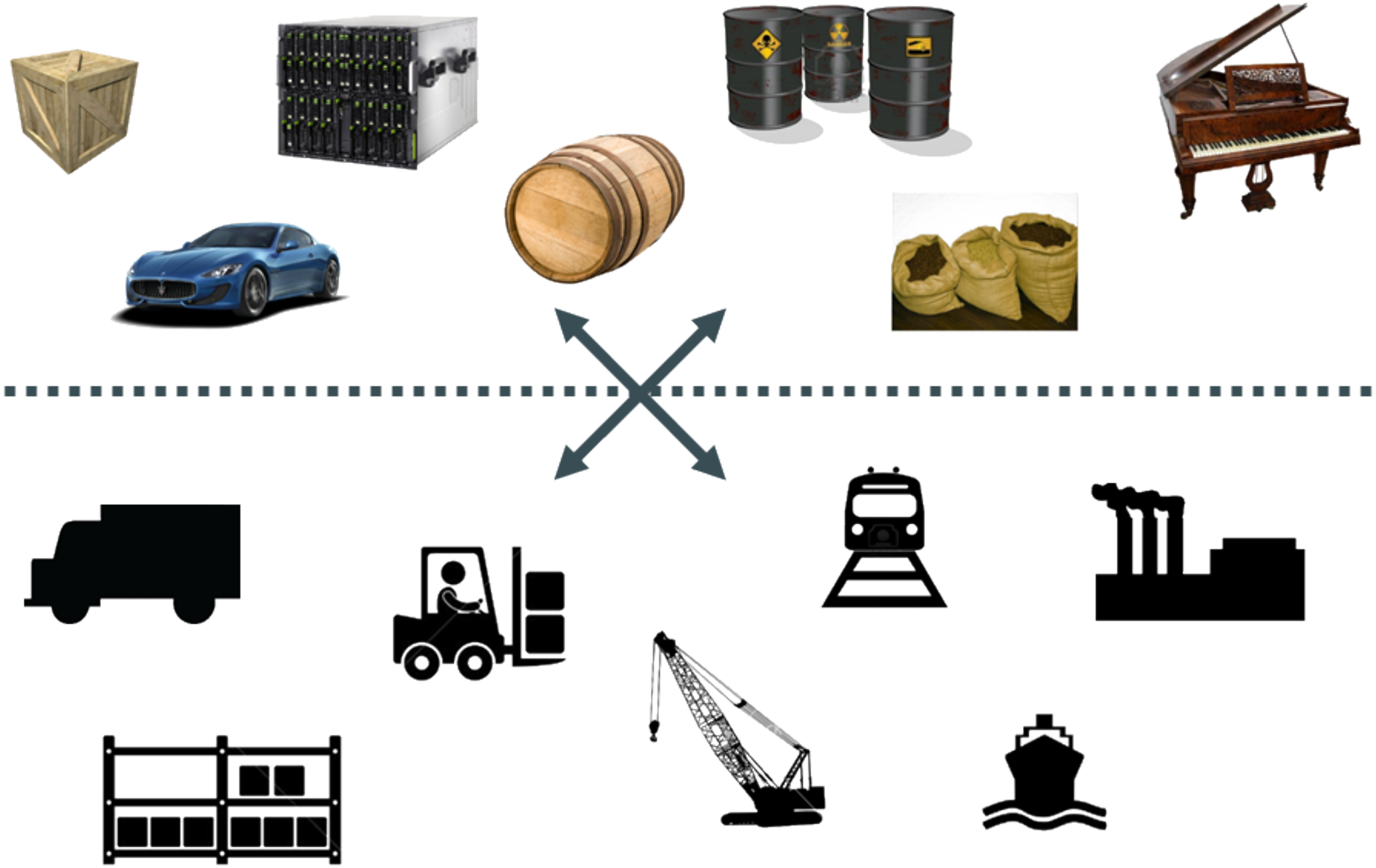
Can I migrate smoothly and quickly?

The Matrix from hell

	Development VM	QA Server	Single Prod Server	Onsite Cluster	Public Cloud	Contributor's laptop	Customer Servers
Static website	?	?	?	?	?	?	?
Web frontend	?	?	?	?	?	?	?
Background workers	?	?	?	?	?	?	?
User DB	?	?	?	?	?	?	?
Analytics DB	?	?	?	?	?	?	?
Queue	?	?	?	?	?	?	?

Cargo transport pre-1960

Multiplicity of Goods

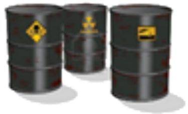
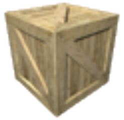
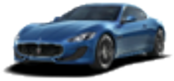
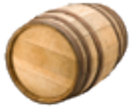
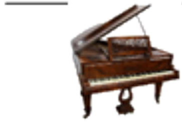
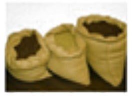
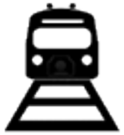
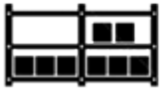
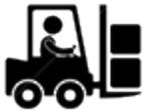
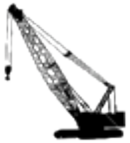
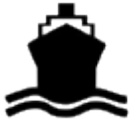
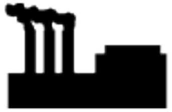
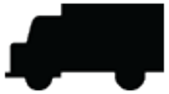


Do I worry about how goods interact (e.g. coffee beans next to spices)

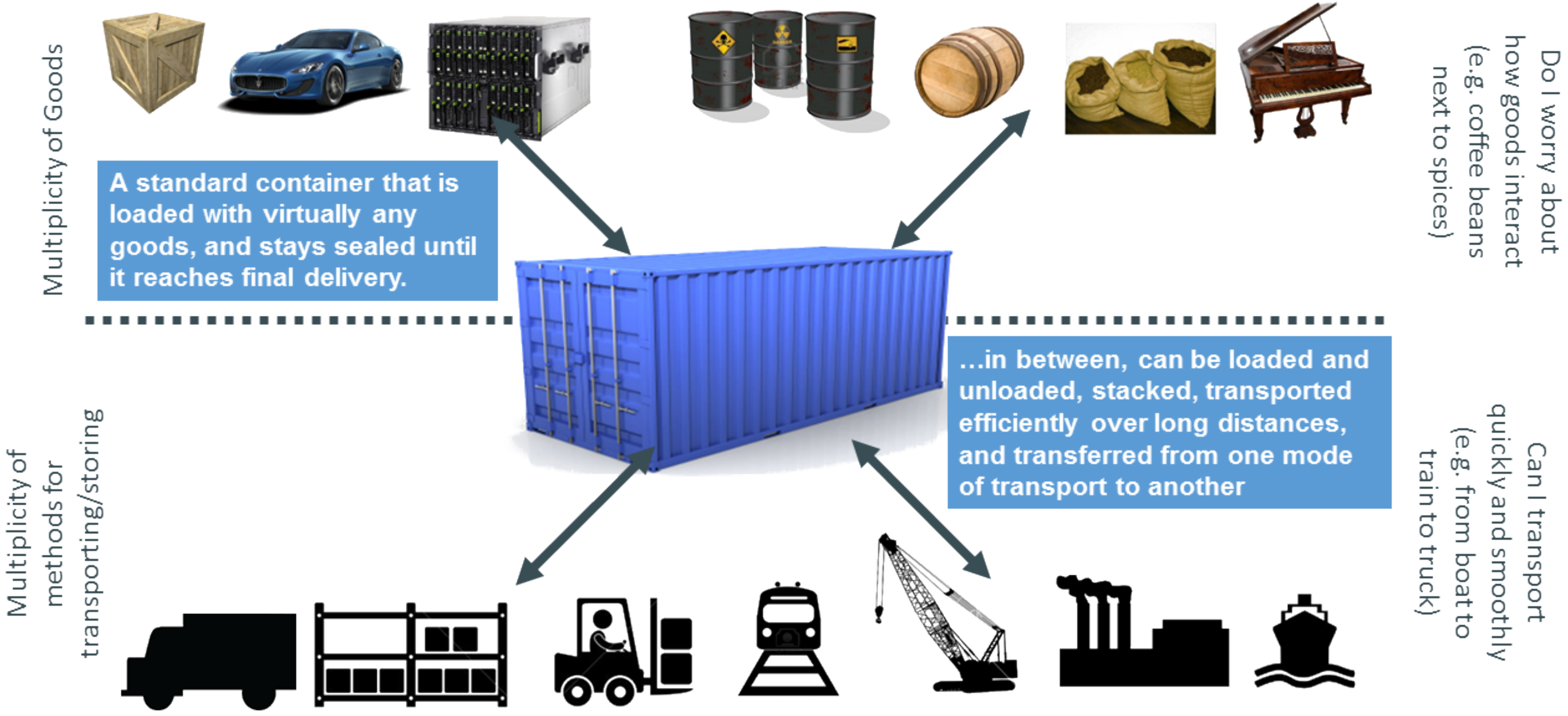
Multiplicity of methods for transporting/storing

Can I transport quickly and smoothly (e.g. from boat to train to truck)

Also a matrix from hell

	?	?	?	?	?	?	?
	?	?	?	?	?	?	?
	?	?	?	?	?	?	?
	?	?	?	?	?	?	?
	?	?	?	?	?	?	?
	?	?	?	?	?	?	?
							

Intermodal shipping container



Multiplicity of Goods

A standard container that is loaded with virtually any goods, and stays sealed until it reaches final delivery.

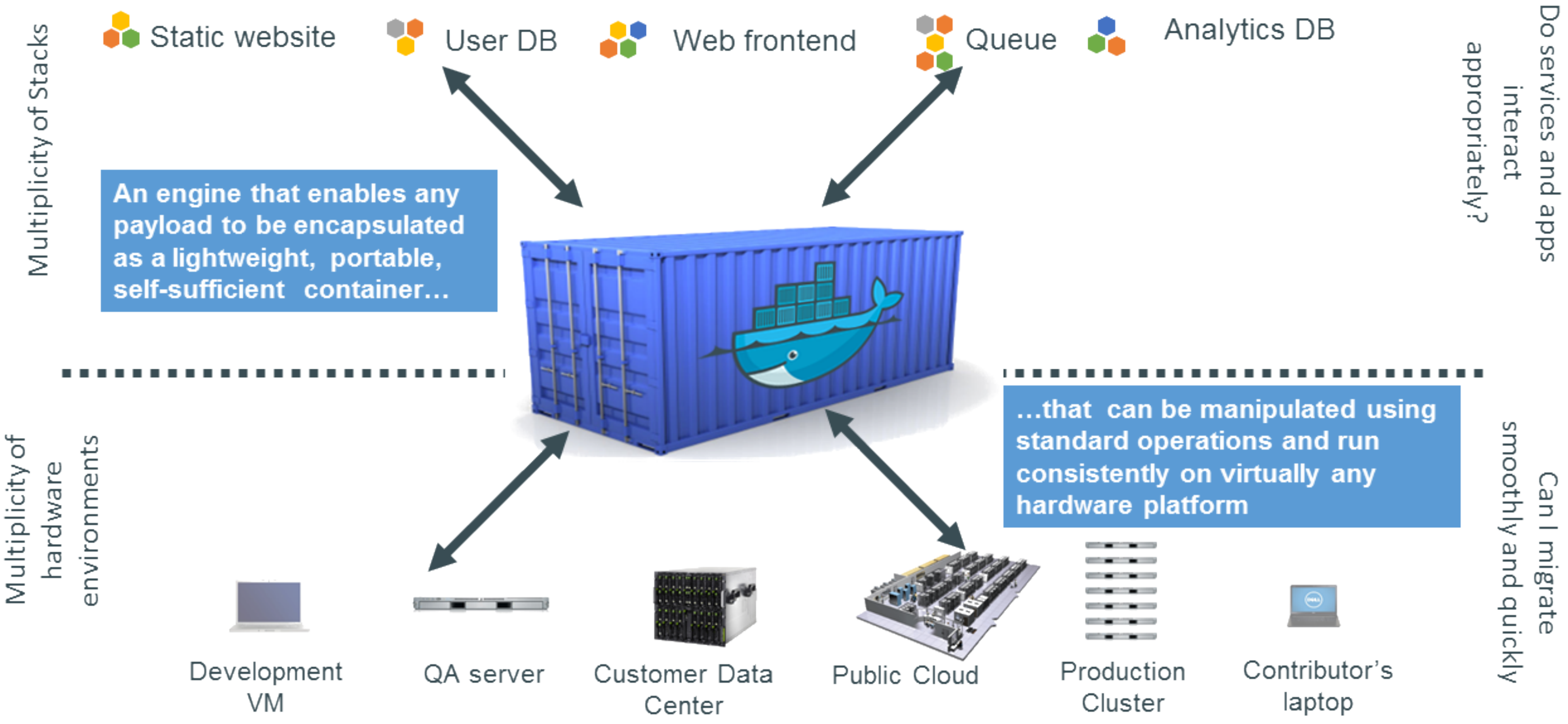
Do I worry about how goods interact (e.g. coffee beans next to spices)

…in between, can be loaded and unloaded, stacked, transported efficiently over long distances, and transferred from one mode of transport to another

Multiplicity of methods for transporting/storing

Can I transport quickly and smoothly (e.g. from boat to train to truck)

A container system for code



Multiplicity of Stacks

Static website

User DB

Web frontend

Queue

Analytics DB

Do services and apps interact appropriately?

An engine that enables any payload to be encapsulated as a lightweight, portable, self-sufficient container…

…that can be manipulated using standard operations and run consistently on virtually any hardware platform

Multiplicity of hardware environments

Development VM

QA server

Customer Data Center

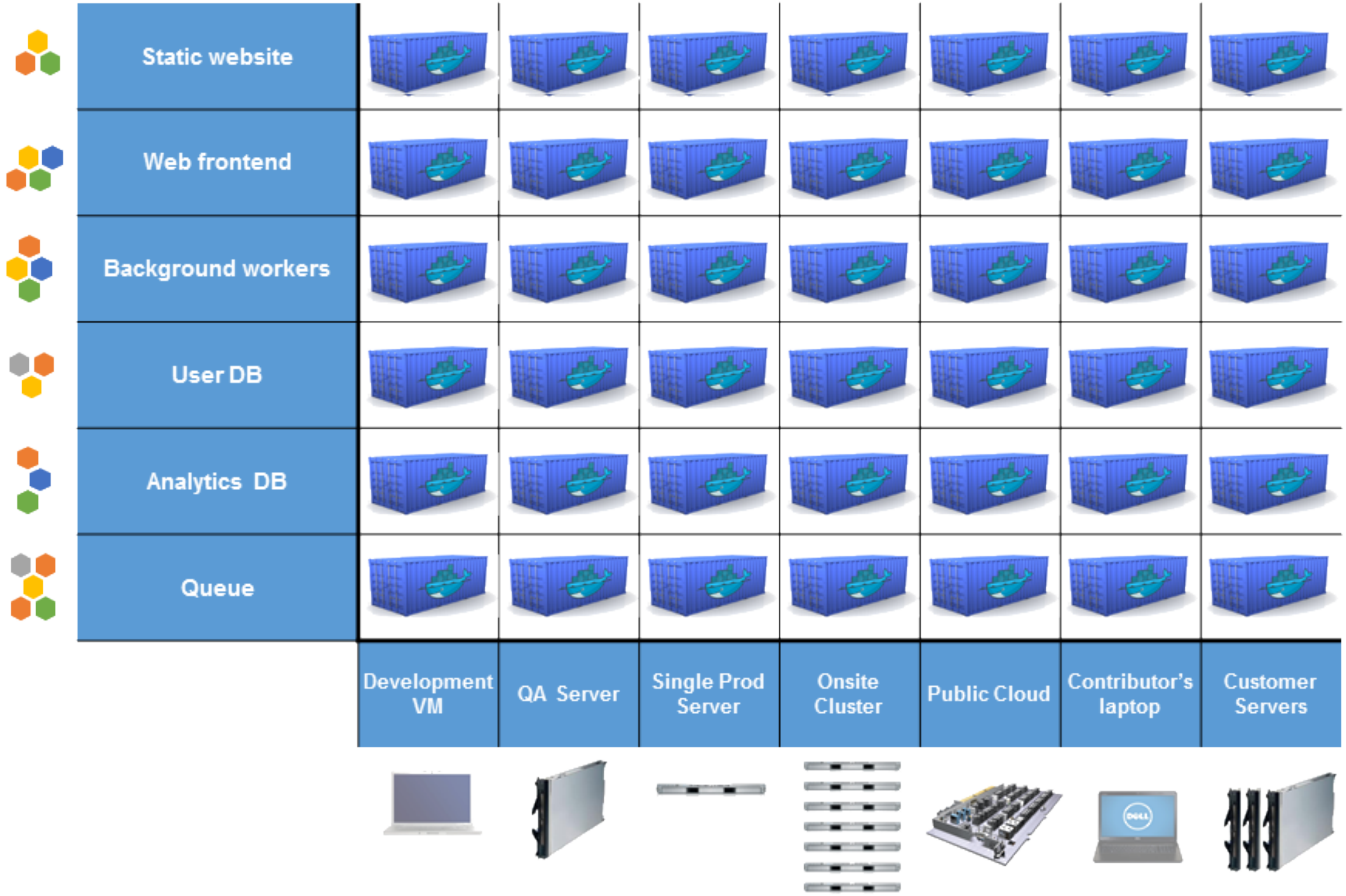
Public Cloud

Production Cluster

Contributor's laptop

Can I migrate smoothly and quickly

Eliminates the matrix from hell



Static website

Web frontend

Background workers

User DB

Analytics DB

Queue

Development VM

QA Server

Single Prod Server

Onsite Cluster

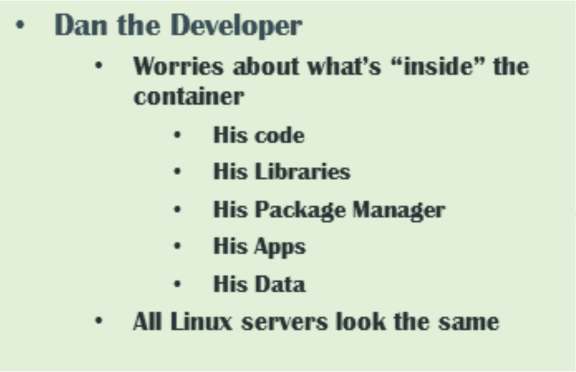
Public Cloud

Contributor's laptop

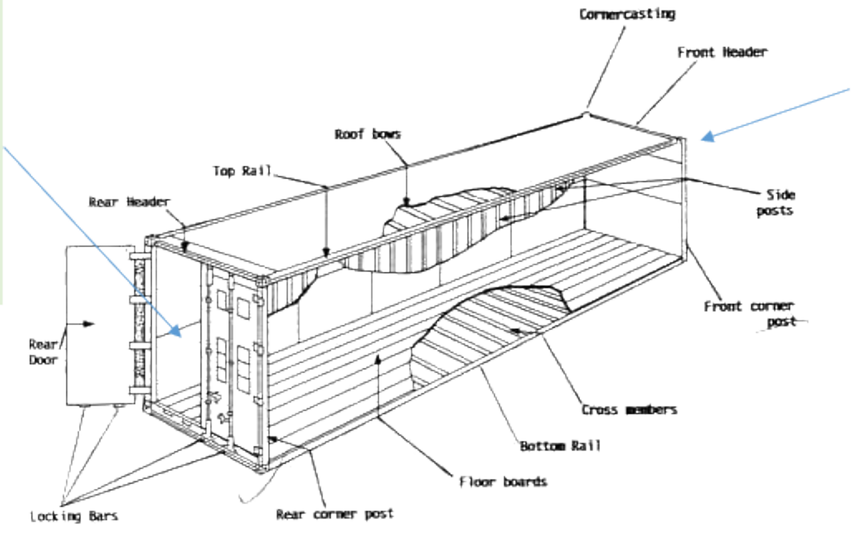
Customer Servers

Configure once, run anything

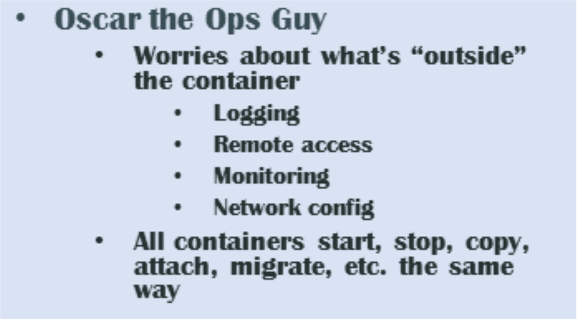
Separation of concerns



- Dan the Developer
  - Worries about what's "inside" the container
    - His code
    - His Libraries
    - His Package Manager
    - His Apps
    - His Data
  - All Linux servers look the same



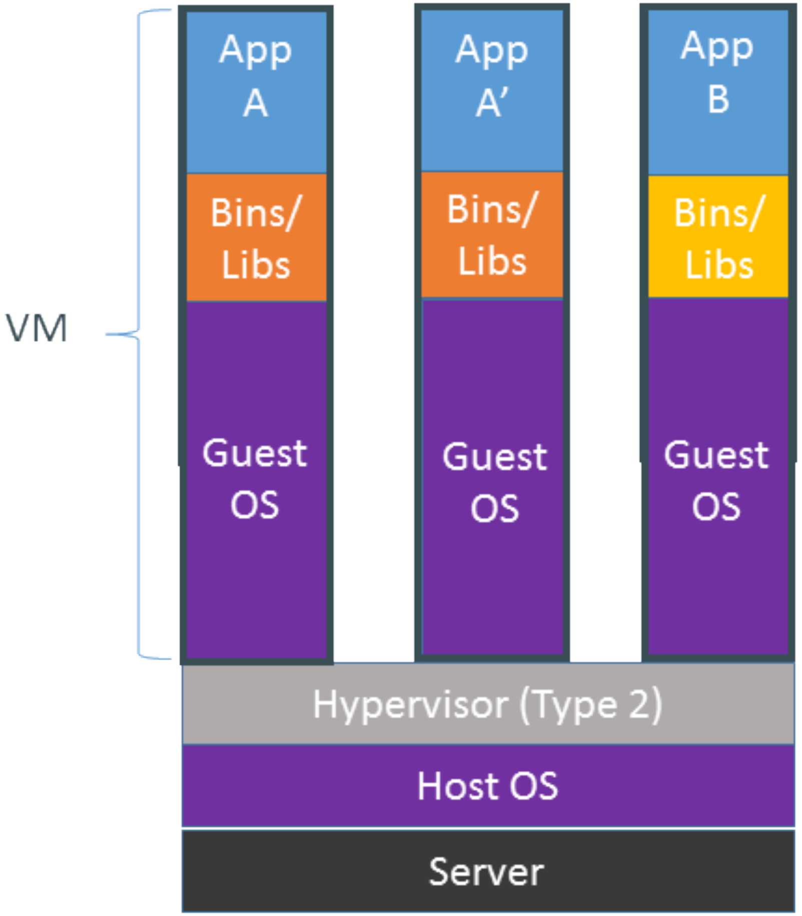
Major components of the container:



- Oscar the Ops Guy
  - Worries about what's "outside" the container
    - Logging
    - Remote access
    - Monitoring
    - Network config
  - All containers start, stop, copy, attach, migrate, etc. the same way

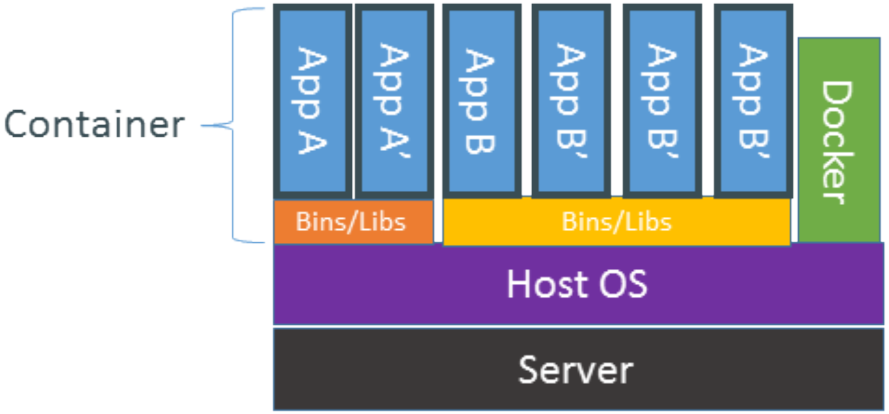
Configure once, run anything anywhere

VM vs. Containers



Containers are isolated, but share OS and, where appropriate, bins/libraries

...result is significantly faster deployment, much less overhead, easier migration, faster restart



VM vs. Container

VM system call path

- application inside the VM makes a system call
- trap to the hypervisor (or host OS)
- hand trap back to the guest OS

Container virtualization system call path

- application inside the container makes a system call
- trap to the OS
- OS returns the results to application

No binary translation,
no emulation

More technical details

High level: a lightweight "VM"

- own process space
- own network interface
- can run stuffs as root
- can have its own /sbin/init (different from host)
- <<machine container>>

Low level: `chroot` on steroids

- Container = isolated process: <<application container>>

Container implementation

Leveraging Linux kernel mechanisms

- namespaces: per process resource isolation
- cgroups: manage resources for groups of processes
- seccomp: limit available system calls
- capabilities: limit available privileges
- CRIU: checkpoint/restore (w/ kernel support)

What names must be virtualized?

Process IDs

- top inside the container shows only processes running inside it
- top outside the container may show processes inside the container, but with different process IDs

File names

- processes inside the container may have a limited different view of the mounted file system
- File names may resolve to different names - and some file names outside the container may be removed

What names must be virtualized?

User names

- containers may have different users w/ different roles
- **root** inside the container should not be the same as **root** outside it

Host name and IP addresses

- processes inside the container may use a different host name and IP addresses when performing network operations

namespaces

Limit the scope of kernel-side names and data structures at process granularity

mnt	(mount points, filesystems)	*CLONE_NEWNS*
pid	(processes)	*CLONE_NEWPID*
net	(network stack)	*CLONE_NEWNET*
ipc	(System V IPC)	*CLONE_NEWIPC*
uts	(unix timesharing - domain name, etc)	*CLONE_NEWUTS*
user	(UIDs)	*CLONE_NEWUSER*

Three system calls for management

`clone()` new process, new namespace, attach process to ns

`unshare()` new namespace, attach current process to it

`setns(int fd, int nstype)` join an existing namespace

Resource control

The OS may want to ensure that the entire container — or everything that runs inside it — cannot consume more than a certain amount of

- CPU time
- memory
- disk or network bandwidth

cgroups: Linux control groups

- control group subsystem offering a resource management solution for a group of processes
- Each subsystem has a ***hierarchy*** **(a tree)**
  - separate hierarchies for CPU, memory, block I/O
  - each process is in a node in each hierarchy
  - each node = a group of processes sharing the same resources

cgroup hierarchies

cgroup hierarchies ← each subsystem can be used at most once* **subsystems (controllers)**

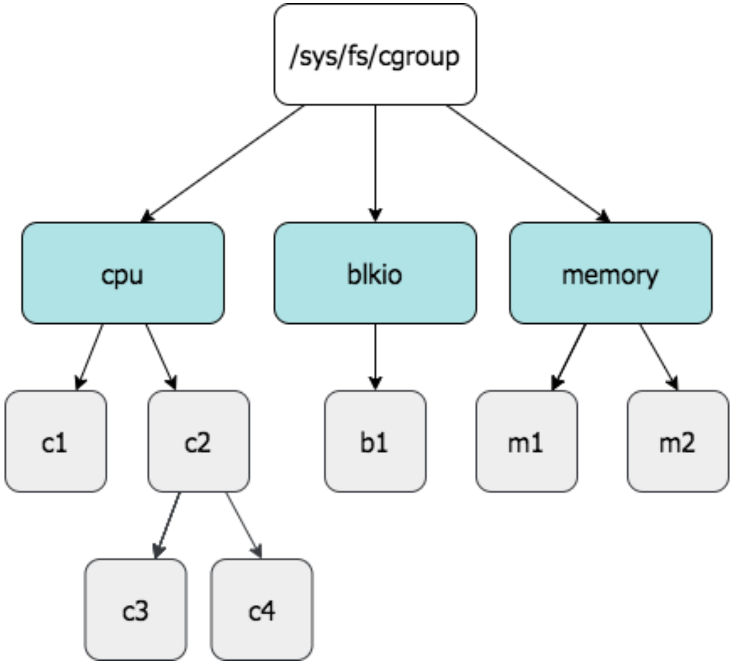
```
   /sys/fs/cgroup
TL /cpu  cpu  cpuacct
      /high-priority
      /normal
      /experiment_1
TL /mem  memory
      /opus
      /normal
      /experiment_1
```

cpuset cpu cpuacct

memory hugetbl

devices blkio net_cls ▲ net_prio ▲

freezer perf

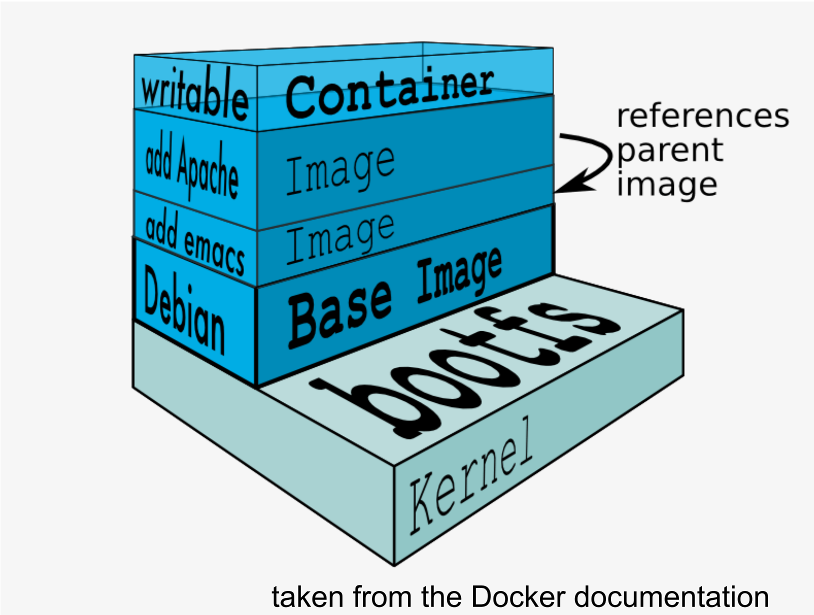


▲ built as kernel module

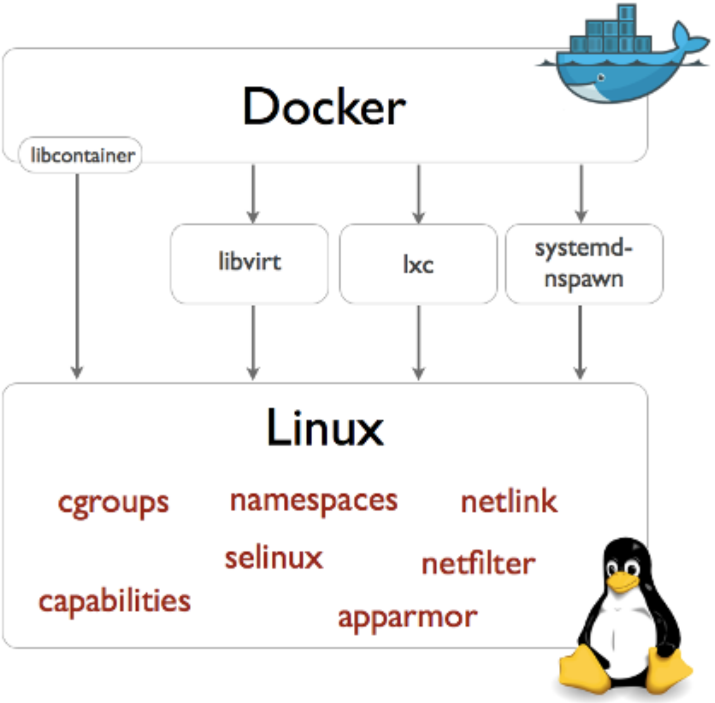
TL top level cgroup (mount)

Containers

- A light form of resource virtualization based on kernel mechanisms like **cgroups** and **namespaces**
  - Multiple containers run on the same kernel with the illusion that they are the only one using resources

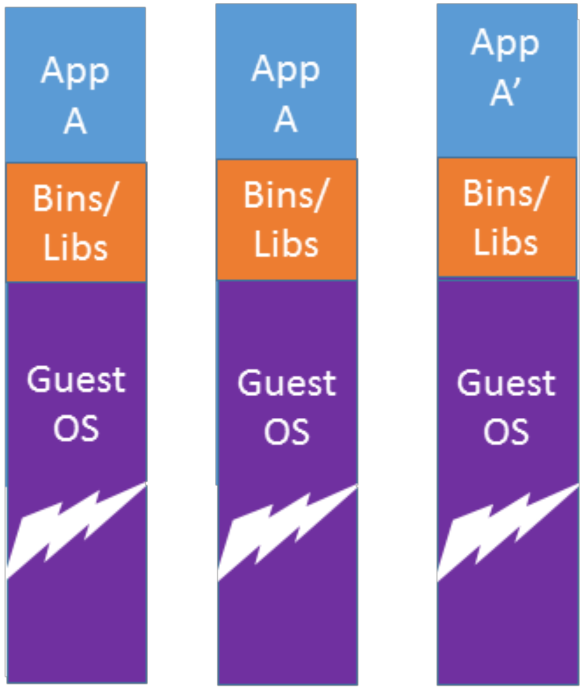


taken from the Docker documentation



Containers are lightweight

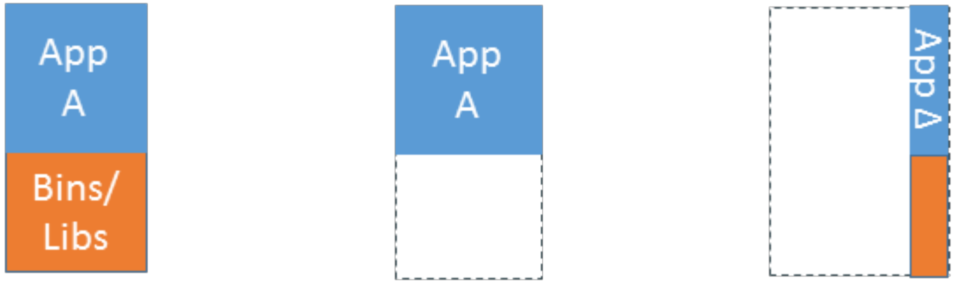
VMs



VMs

Every app, every copy of an app, and every slight modification of the app requires a new virtual server

Containers



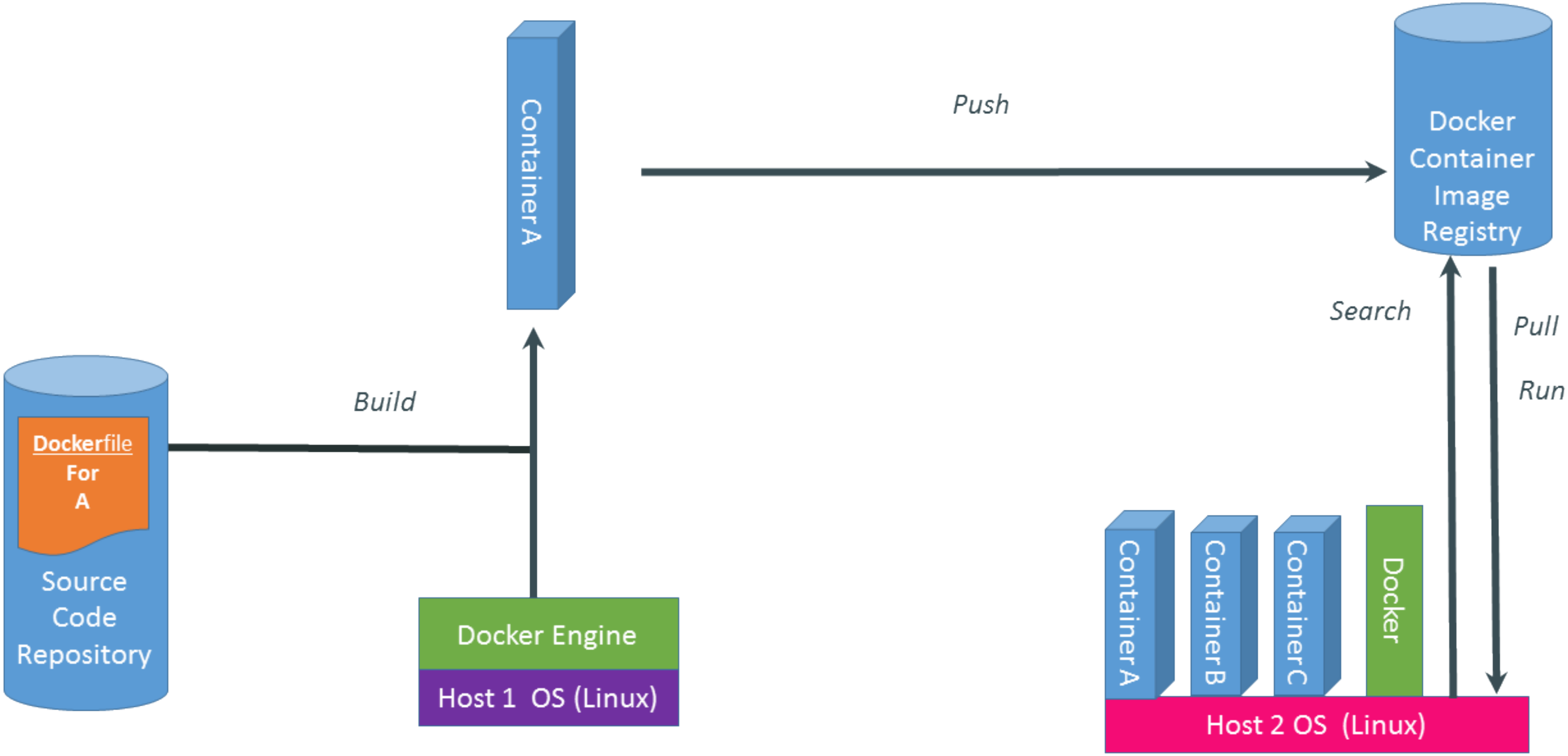
Original App
(No OS to take up space, resources, or require restart)

Copy of App
No OS. Can Share bins/libs

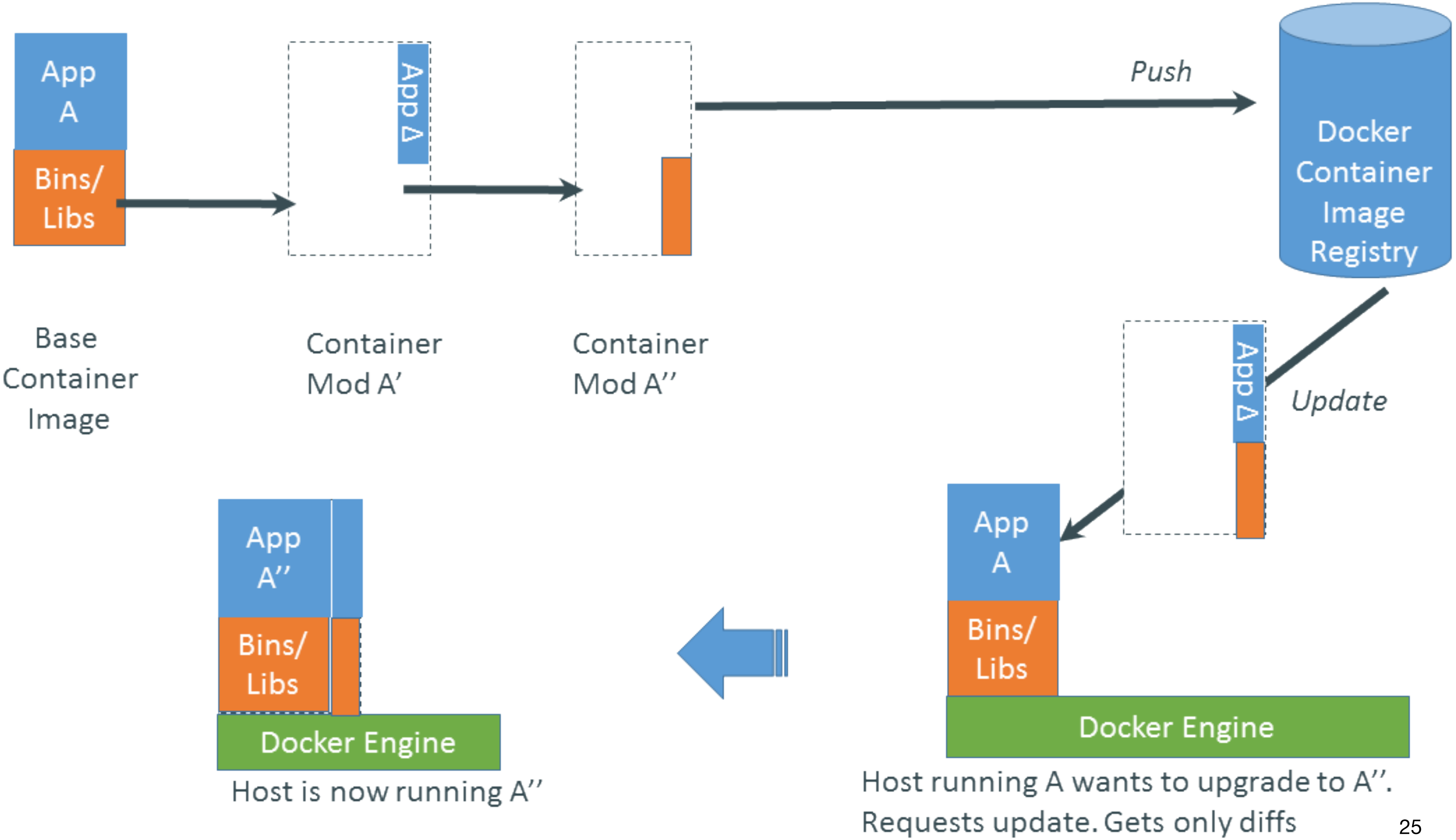
Modified App

Copy on write capabilities allow us to only save the diffs Between container A and container A'

Basics of a Docker system



Changes and updates



Credits

Slides are adapted from the community repository (CNCF) of presentations about Docker.