

Enabling MATLAB and Simulink for Use in the Cloud

Loren Dean, MathWorks



- Senior director of MATLAB development. ~30 years with MathWorks
- Responsibilities include
 - Parallel computing, controls and test and measurement
 - Online Products Development: MATLAB Online, MATLAB Mobile, Cloud Platform integration and general infrastructure
- B.S. and an M.S. in aeronautical engineering from Purdue University and an M.B.A. from Northeastern University.

Leslie Mehrez, MathWorks



- Senior manager, technical marketing. 15+ years with MathWorks
- Responsibilities include
 - Technical marketing of online products
 - Bringing MATLAB and Simulink products to cloud, web and mobile platforms
- B.S.E.E. from Lafayette College and an M.B.A. from Babson College

MathWorks
**AUTOMOTIVE
CONFERENCE 2024**
North America

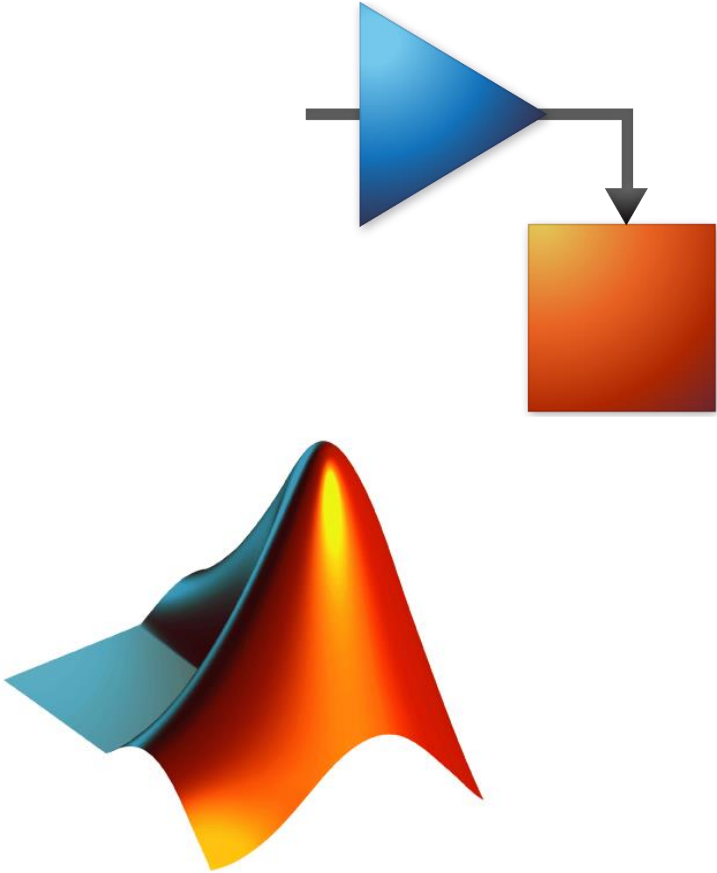
Enabling MATLAB and Simulink for use in the cloud

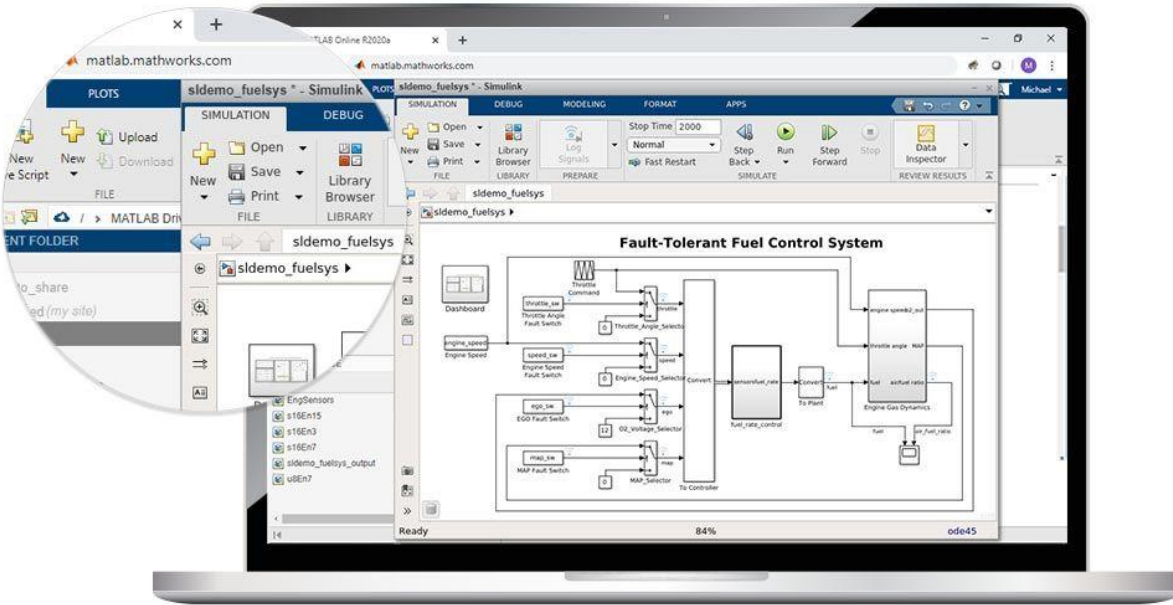
Leslie Mehrez
Sr. Manager Technical Marketing
Online Products



Loren Dean
Senior Director of Engineering,
Online Products and Technical Computing







**MATLAB Online
(2010)**



Containers



Cloud Center



**Cloud Data
Services**



**Cloud Marketplace
Offerings**



**Reference
Architectures**



**Infrastructure
as Code**

Cloud Plays a Critical Role in Automotive Transformations

Software complexity and data growth

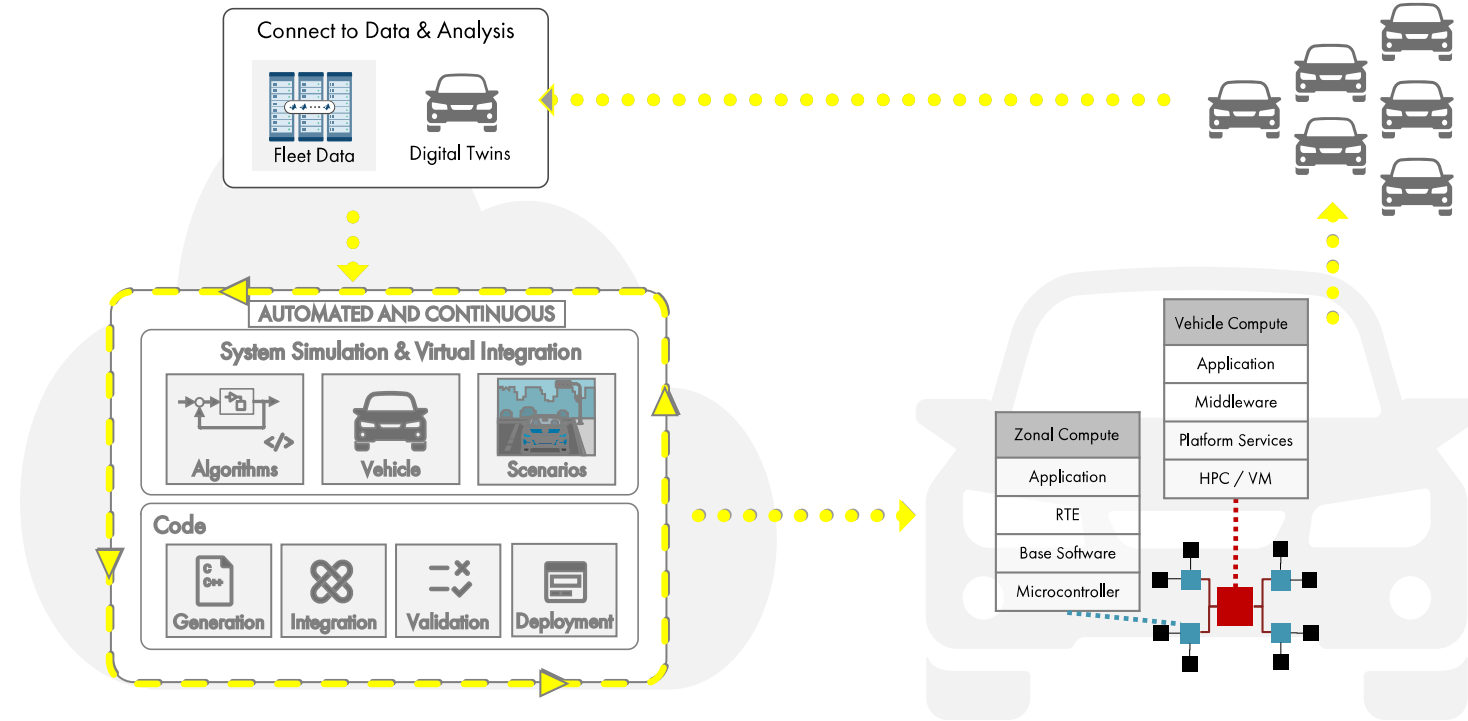
- Connectivity V2X (Vehicle to Infrastructure, Vehicle to Vehicle, etc.)

Shorter development times

- New models every 2 years vs 5 years

Consumer expectations

- Digital continuity from phone to car, Immediate OTA (Over the Air) fixes



MathWorks
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CONFERENCE 2024**
North America

Enabling MATLAB and Simulink for use in the cloud

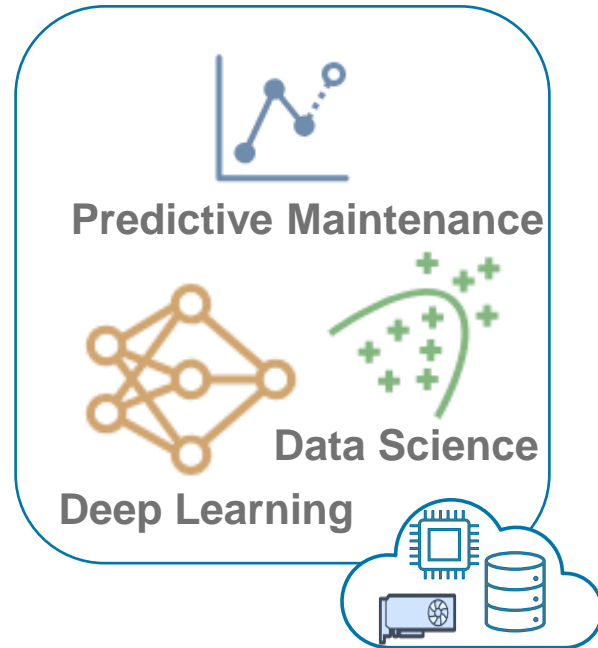
Leslie Mehrez
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Senior Director of Engineering,
Online Products and Technical Computing



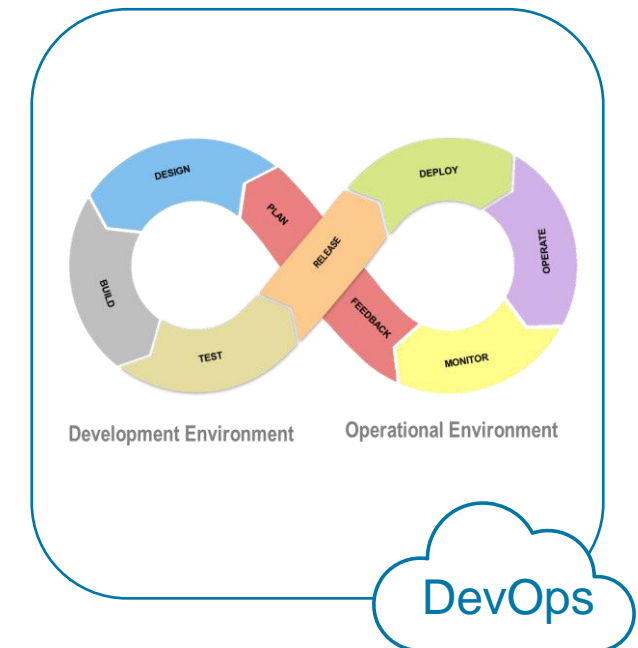
Key reasons engineering workflows move to the Cloud



Data Growth



IT Evolution



Operationalize Code
and Realize Value

Start with the Cloud Usage Framework

Interactive Design & Development



Scale



CI & Test



Deploy & Operate




Start with the Cloud Usage Framework

Interactive Design & Development



Scale



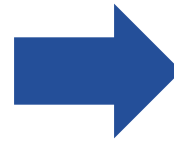
CI & Test



Deploy & Operate



Run MATLAB & Simulink in any Cloud Context



Google Cloud Platform



databricks



Run MATLAB & Simulink in any cloud context

MATLAB Online for your organization

The screenshot displays the MATLAB Online web interface. At the top, a browser window shows the URL 'https://matlab.acme.com'. Below it, the MATLAB Online toolbar is visible, including options for 'New Variable', 'Open Variable', 'Favorites', 'Clear Commands', 'Simulink', 'Layout', 'Set Path', 'Add-Ons', 'Preferences', 'Help', and 'Community'. The main workspace area shows a Simulink model titled 'sldemo_fuelsys - Simulink'. The workspace pane on the left lists files such as 'ModelingAFaultTolerantFuelControl', 'sld_FuelModes.m', 'sldemo_fuelsys_data.m', and 'sldemo_fuelsys.slx'. The Simulink model canvas displays a 'Fault-Tolerant Fuel Control System' block diagram. The diagram includes a 'Dashboard' block, 'Throttle Command' block, 'Throttle Angle Fault Switch', 'Throttle_Angle_Selector', 'Engine Speed' block, 'speed_sw' block, 'Engine Speed Fault Switch', 'Engine_Speed_Selector', 'Convert' block, 'sensorfuel_rate (g/s)' block, 'To Plant' block, 'fuel_rate_control', 'fuel' block, 'air/fuel ratio (l)' block, 'Engine Gas Dynamics', 'fuel' block, 'air_fuel_ratio', and 'MAP' block. A text box at the bottom of the diagram reads: 'Open the Dashboard subsystem to simulate any combination of sensor failures.'

Private Hosting

Your corporate file system

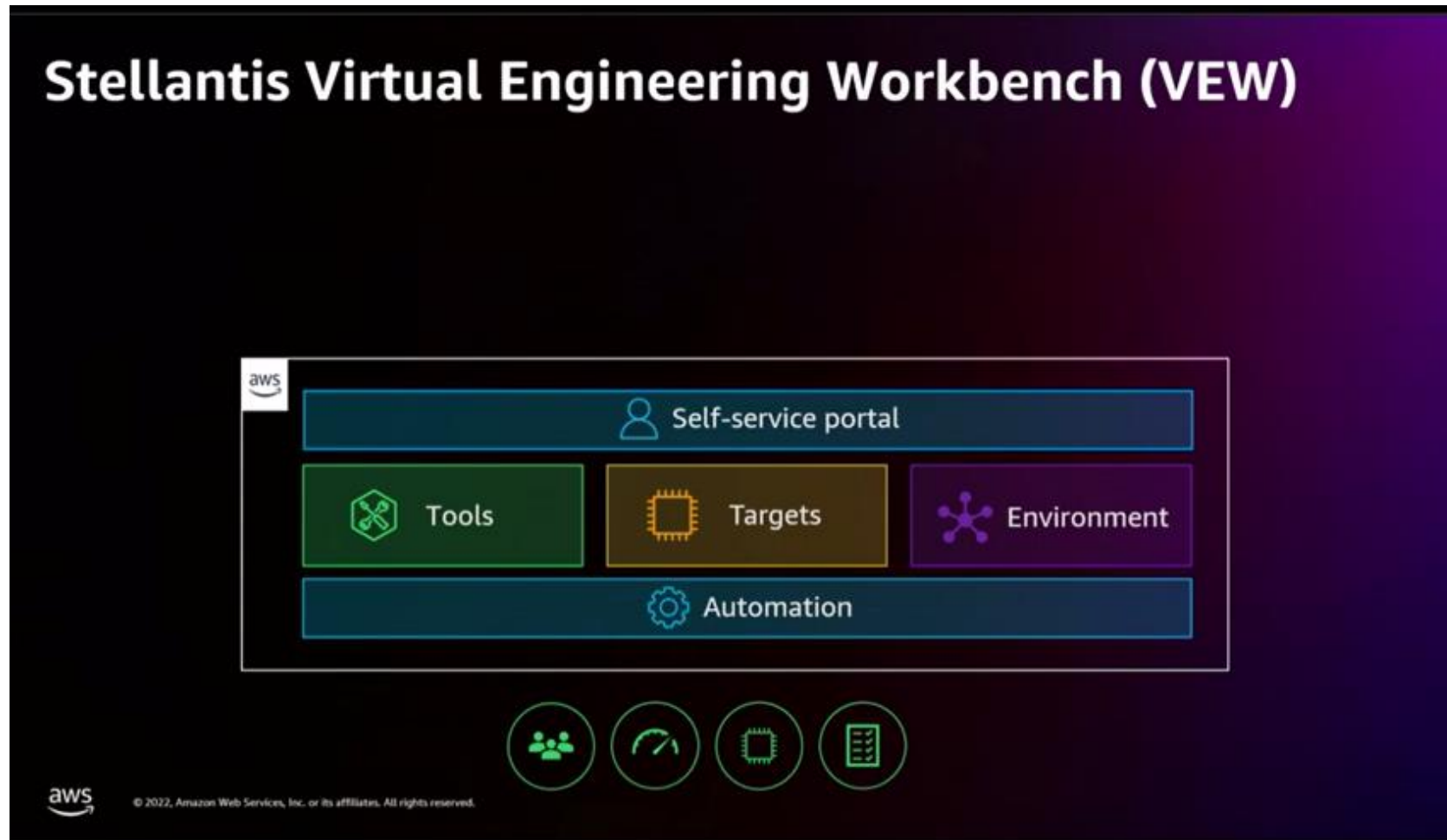
Run MATLAB & Simulink in any Cloud Context

MATLAB in a Virtual Machine or container



The screenshot displays the MATLAB R2023b interface within a cloud environment. The main window shows a Simulink model titled "Friction Model with Hard Stops". The model includes a "Friction Model" block, a "Stuck" block, and a "Velocity to Position" block. The simulation is running, and a "Scope" window is open, showing a plot of position (X) over time (t). The plot shows a signal that starts at 0, rises to a peak of approximately 5.5, then falls to a trough of approximately -3.5, and finally settles near 0. The simulation parameters are set to "Sample based" with a sampling time (T) of 2.000. The workspace window shows a variable named "out" with a value of "1x1 SimulationO...". The MATLAB interface includes a menu bar, a toolbar, and a command window. The system tray at the bottom shows the taskbar with icons for the Software Updater, MATLAB R2023b, the Simulink model, and the Scope window. The system clock indicates the time is 18:29.

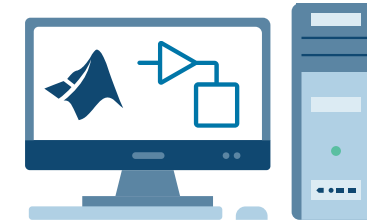
Stellantis Virtual Engineering Workbench Will Streamline Software Development Workflows



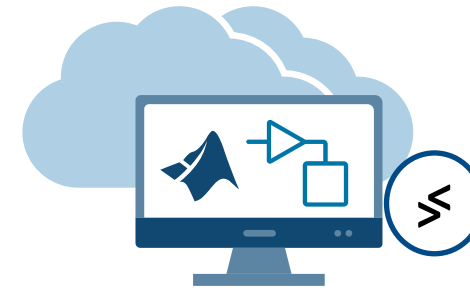
Presented at AWS Re:Invent 2023

New Considerations for Interactive Design and Development on the Cloud

- MathWorks
 - Common user experience for all contexts
- You
 - What is the right cloud context?
 - Control and flexibility



Local PC



Virtual Desktop



Browser-based

MATLAB and Simulink Cloud Usage Framework

Interactive Design & Development



Scale



CI & Test



Deploy & Operate



Scaling Compute and Data



Compute



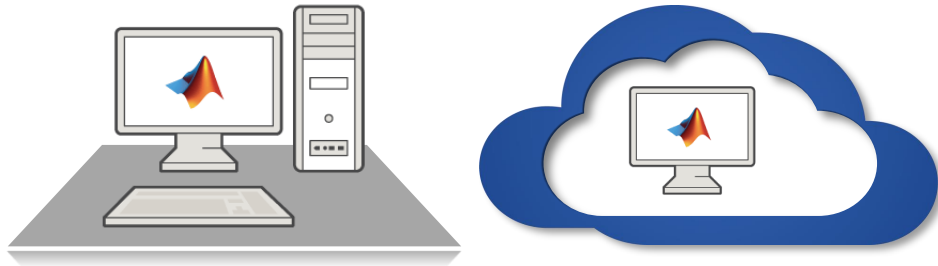
Scale locally with GPU or multi-core

Data

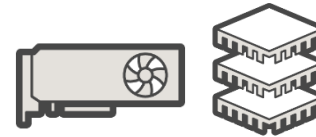


Connect to cloud data

Scaling Compute and Data



Compute



Scale locally with GPU or multi-core

Data

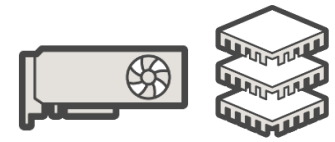


Connect to cloud data

Scaling Compute and Data



Compute



Scale locally with GPU or multi-core

Data



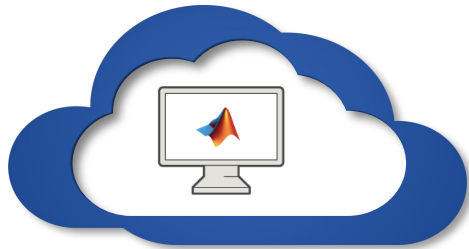
Connect to cloud data



Access more capable compute resources at scale

Connect to cloud data

Scaling Compute and Data



Compute



Scale locally with GPU or multi-core

Data



Connect to cloud data



Access more capable compute resources at scale

Connect to cloud data

Orchestration required

Scaling Vehicle Simulations




Scaling Vehicle Simulations

Adithya Vignesh Jayaraman
Senior Toolset Engineer, Attributes & Performance

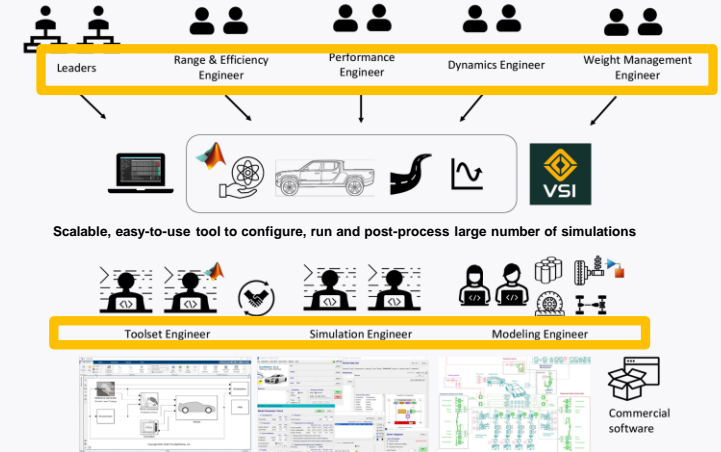
25th April 2023

RIVIAN Scaling Vehicle Simulations



MathWorks Automotive Conference 2023

Simulations for Everyone



Types of Parallel Simulations

Parallel Local



- Run simulations of local cores of user's machine
- Used for testing model updates and changes
- Uses **Parallel Computing Toolbox**
- Limited by physical cores
- parpool and parfeval

Parallel Remote



- Run simulations of a remote cluster
- Used to run simulations with released models
- Uses **MATLAB Parallel Server/MATLAB Job Scheduler**
- Limited by cluster resources and MPS licenses
- parcluster

New Requirements for Scaling



Parallel Computing Toolbox Plugin for Kubernetes

Version 2.0.2.0 (41.2 KB) by MathWorks Parallel Computing Toolbox Team **STAFF**

Submit jobs to MATLAB Parallel Server with Kubernetes

<https://github.com/mathworks/matlab-parallel-kubernetes-plugin>

- MathWorks
 - Building tools that can scale on any cloud environment while providing a common user experience
 - Parallel Language for end users
 - Technology and licensing to scale

10,000 Workers with 64
Threads each – 640,000
cores of computation

R2023a

 A screenshot of the MathWorks Cloud Center web interface. The browser address bar shows 'cloudcenter.mathworks.com/resource/'. The page title is 'Cloud Center'. Below the title, there are tabs for 'Cloud Resources' and 'Cloud Accounts'. The main content area shows a section for 'MATLAB' with a '+ Create' button. Below this is a table of MATLAB cloud resources.

Name	Release	IP Address	Operating System	Provider
MATLAB R2021b AWS	R2021b	10.0.0.250	Linux	Amazon AWS
MATLAB R2022a AWS	R2022a	10.0.0.209	Linux	Amazon AWS

 Below the table, there is a section for 'MATLAB Parallel Server' with another '+ Create' button. The bottom of the screenshot shows the start of another table with columns for 'Name', 'Release', 'Operating System', and 'Provider'.

New Requirements for Scaling



Parallel Computing Toolbox Plugin for Kubernetes

Version 2.0.2.0 (41.2 KB) by MathWorks Parallel Computing Toolbox Team **STAFF**

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- MathWorks
 - Building tools that can scale on any cloud environment while providing a common user experience
 - Parallel Language for end users
 - Technology and licensing to scale
- You
 - Running at scale is a journey, not a “one and done” activity.
 - Building processes that let you scale from desktop to cloud
 - Working across the organization with other teams, including IT, and departments

10,000 Workers with 64
Threads each – 640,000
cores of computation

R2023a

Cloud Center

cloudcenter.mathworks.com/resource/

Cloud Resources | Cloud Accounts

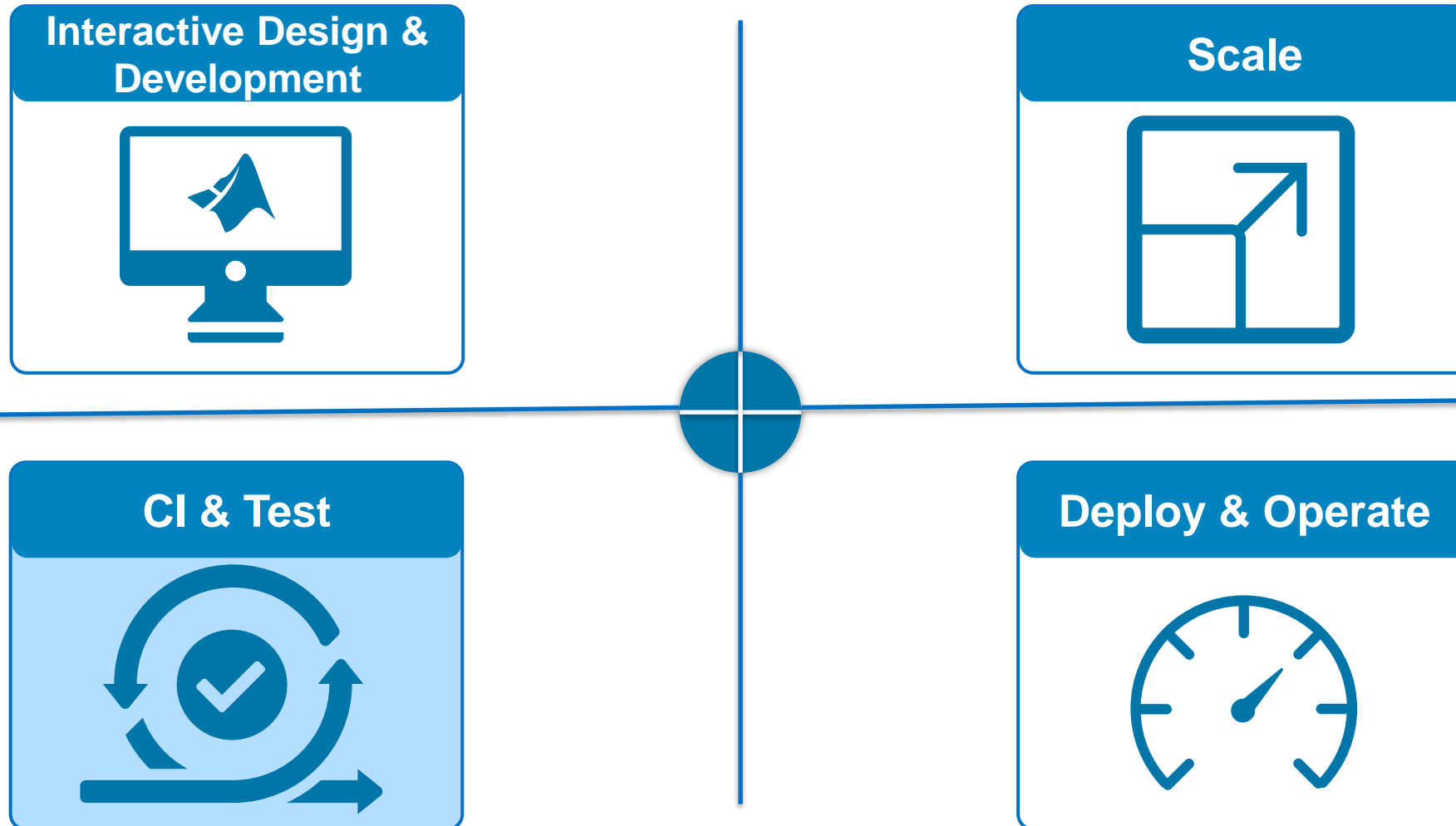
MATLAB [+ Create](#)

Name	Release	IP Address	Operating System	Provider
MATLAB R2021b AWS	R2021b	10.0.0.250	Linux	Amazon AWS
MATLAB R2022a AWS	R2022a	10.0.0.209	Linux	Amazon AWS

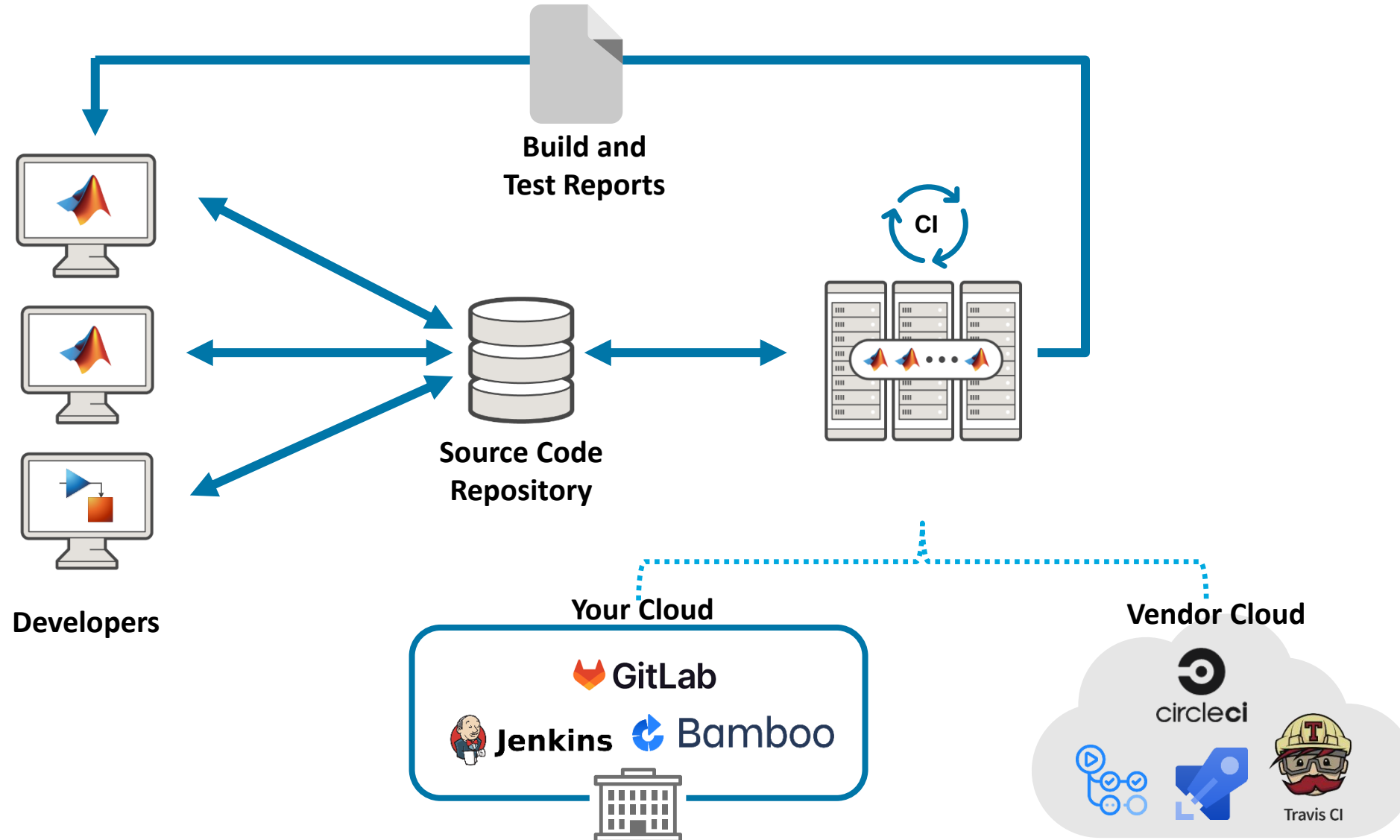
MATLAB Parallel Server [+ Create](#)

Name	Release	Operating System	Provider
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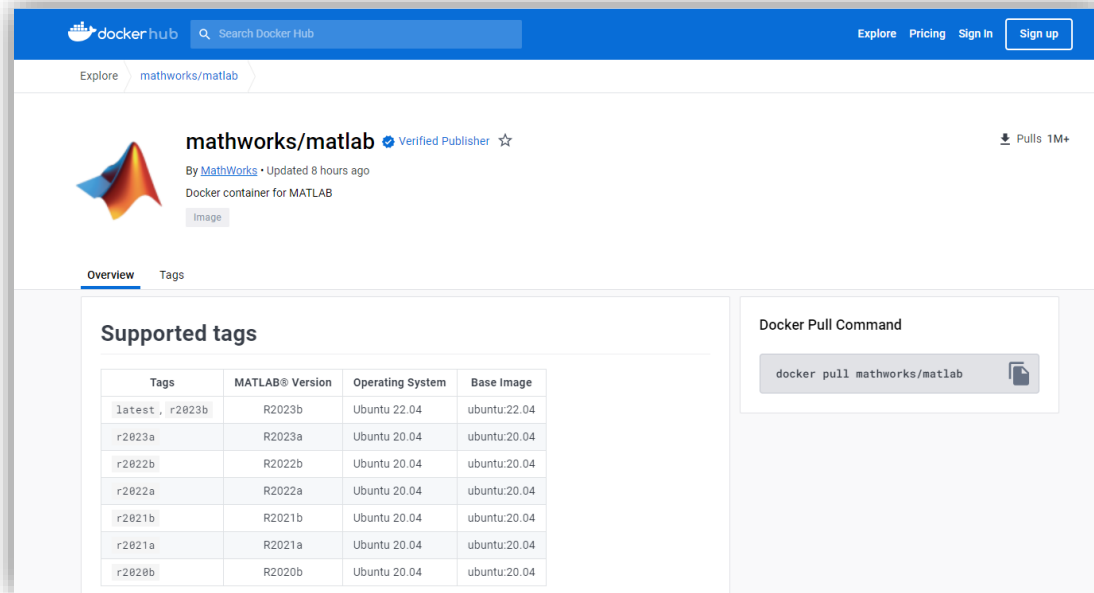
MATLAB and Simulink Cloud Usage Framework



CI & Test involves automating the build and test of MATLAB code and Simulink models

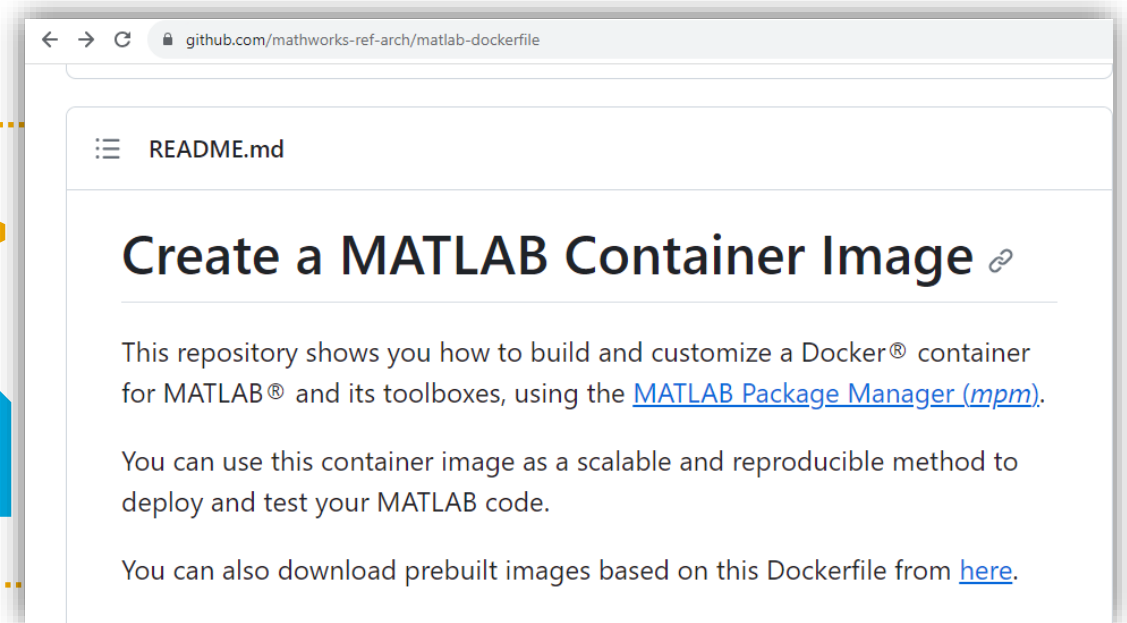


Containers are the basis for CI build agents and environments



The screenshot shows the Docker Hub page for the `mathworks/matlab` image. It includes a search bar, navigation links, and a table of supported tags. The table lists various versions of MATLAB (R2023b, R2023a, R2022b, R2022a, R2021b, R2021a, R2020b) and their corresponding operating systems (Ubuntu 22.04, 20.04) and base images (ubuntu:22.04, ubuntu:20.04).

Tags	MATLAB® Version	Operating System	Base Image
latest, r2023b	R2023b	Ubuntu 22.04	ubuntu:22.04
r2023a	R2023a	Ubuntu 20.04	ubuntu:20.04
r2022b	R2022b	Ubuntu 20.04	ubuntu:20.04
r2022a	R2022a	Ubuntu 20.04	ubuntu:20.04
r2021b	R2021b	Ubuntu 20.04	ubuntu:20.04
r2021a	R2021a	Ubuntu 20.04	ubuntu:20.04
r2020b	R2020b	Ubuntu 20.04	ubuntu:20.04



The screenshot shows the README for the `github.com/mathworks-ref-arch/matlab-dockerfile` repository. The title is "Create a MATLAB Container Image". The text describes how to build and customize a Docker container for MATLAB and its toolboxes using the MATLAB Package Manager (`mpm`). It also mentions that prebuilt images can be downloaded from a link.

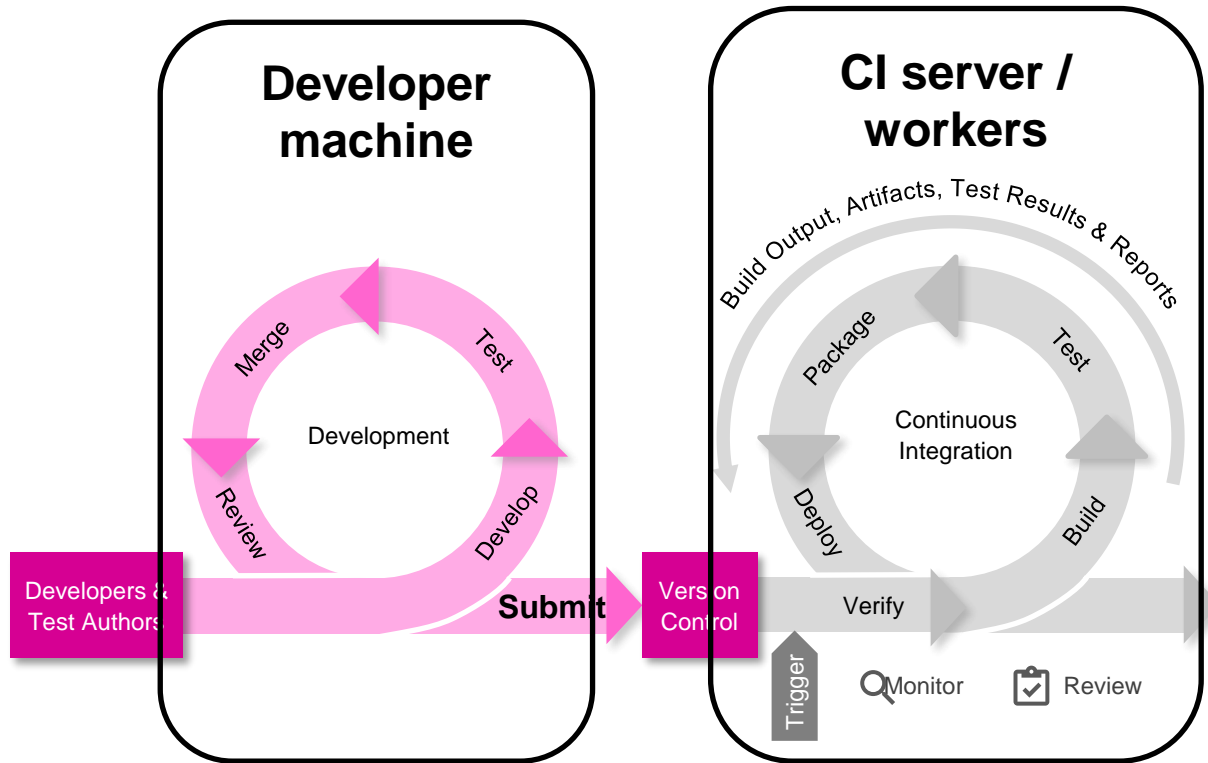
A container is an executable package

application and all its

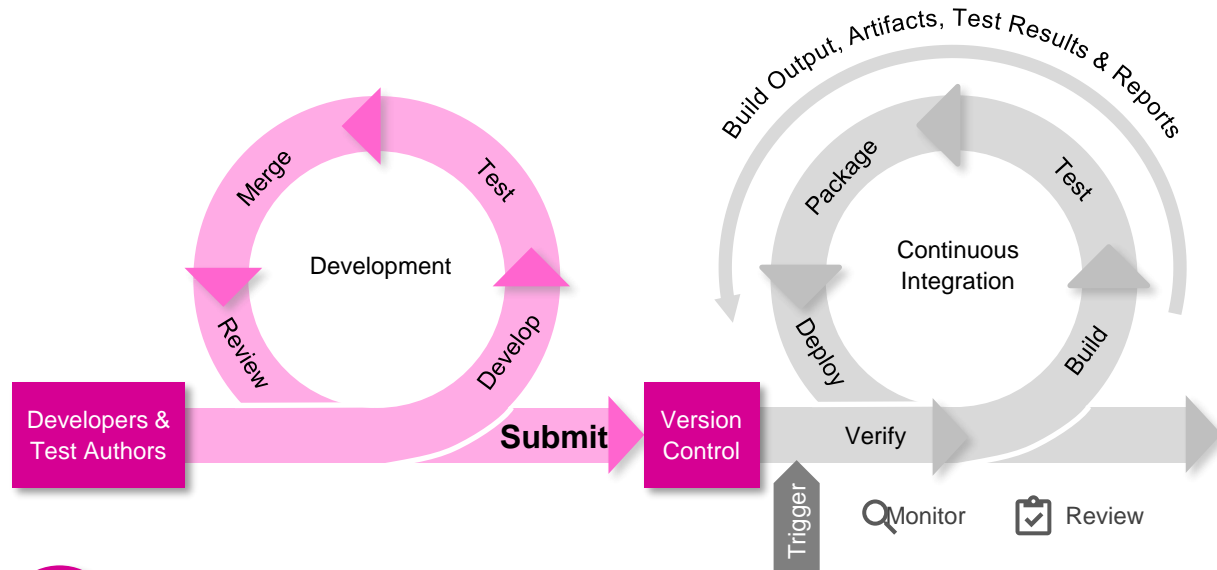
MATLAB & Simulink Containers on Dockerhub

Docker files on GitHub

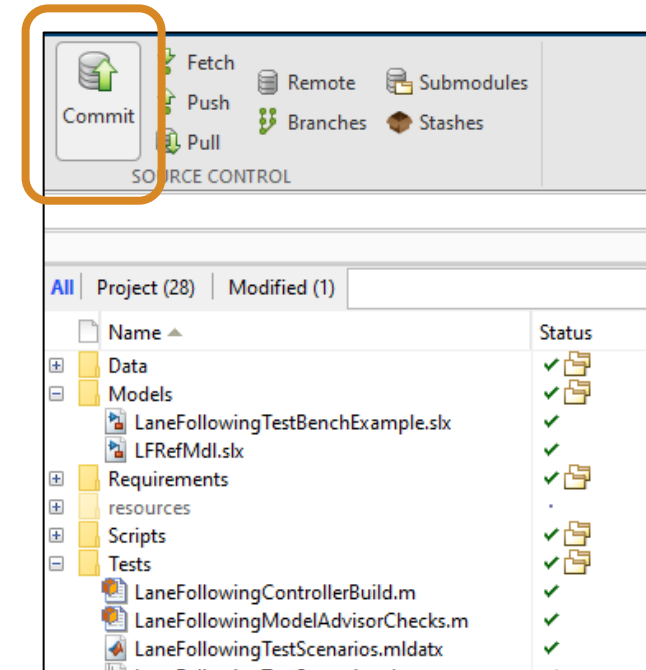
Continuous Integration workflow with Model-Based Design



Continuous Integration workflow with Model-Based Design

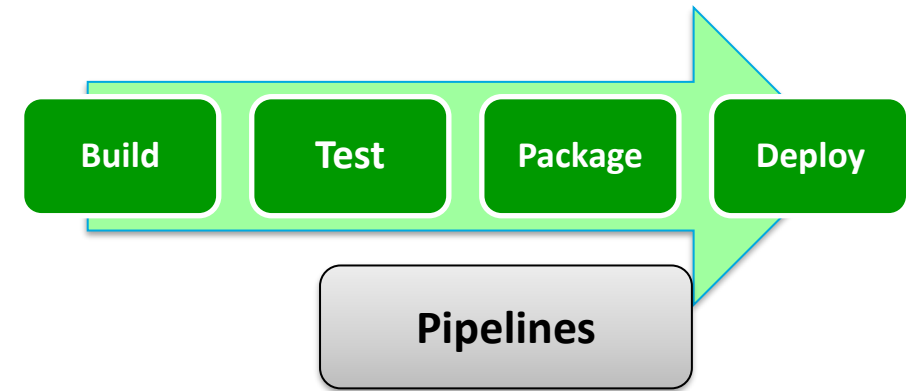
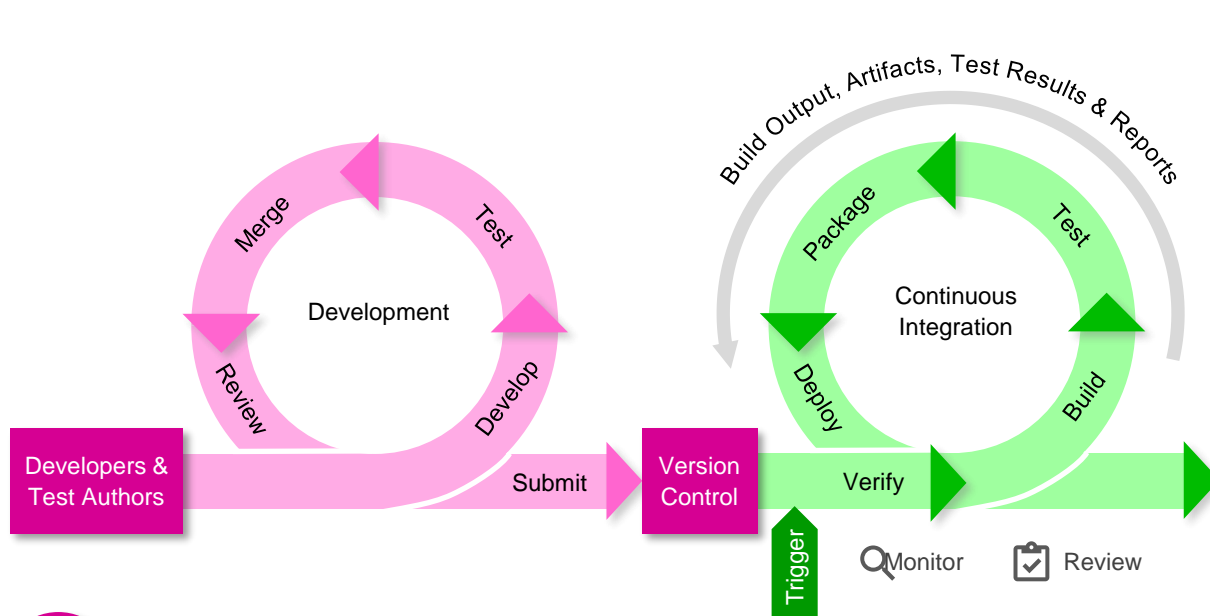


1 Development

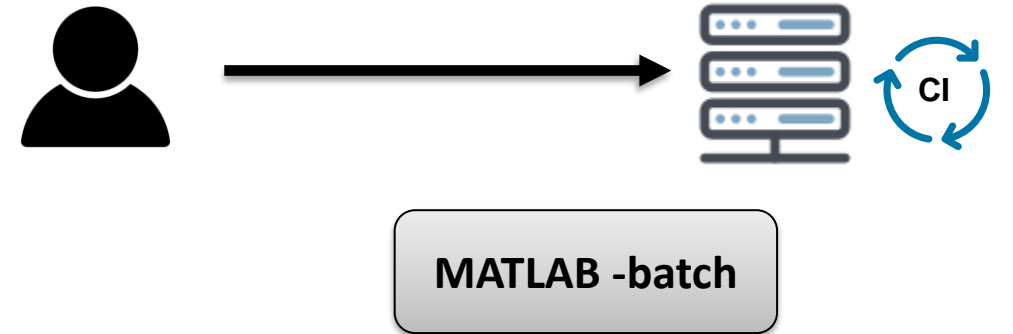


Manage using Projects

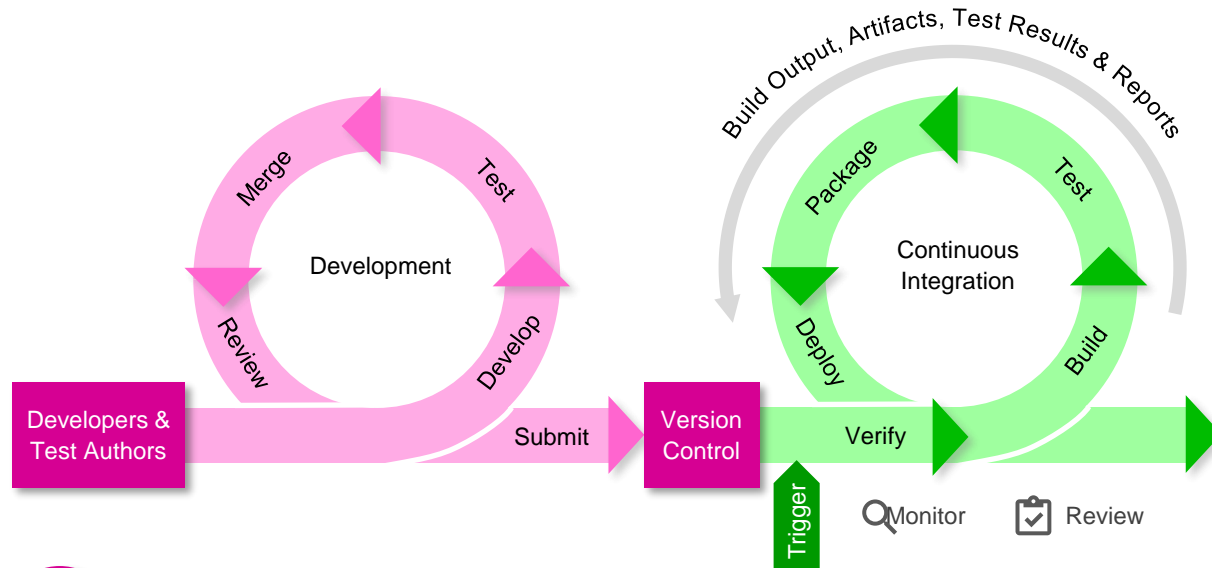
Continuous Integration workflow with Model-Based Design



- 1** Development
- 2** Continuous Integration

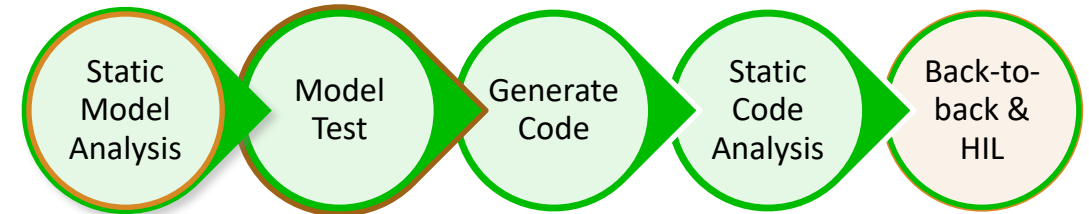


Continuous Integration workflow with Model-Based Design



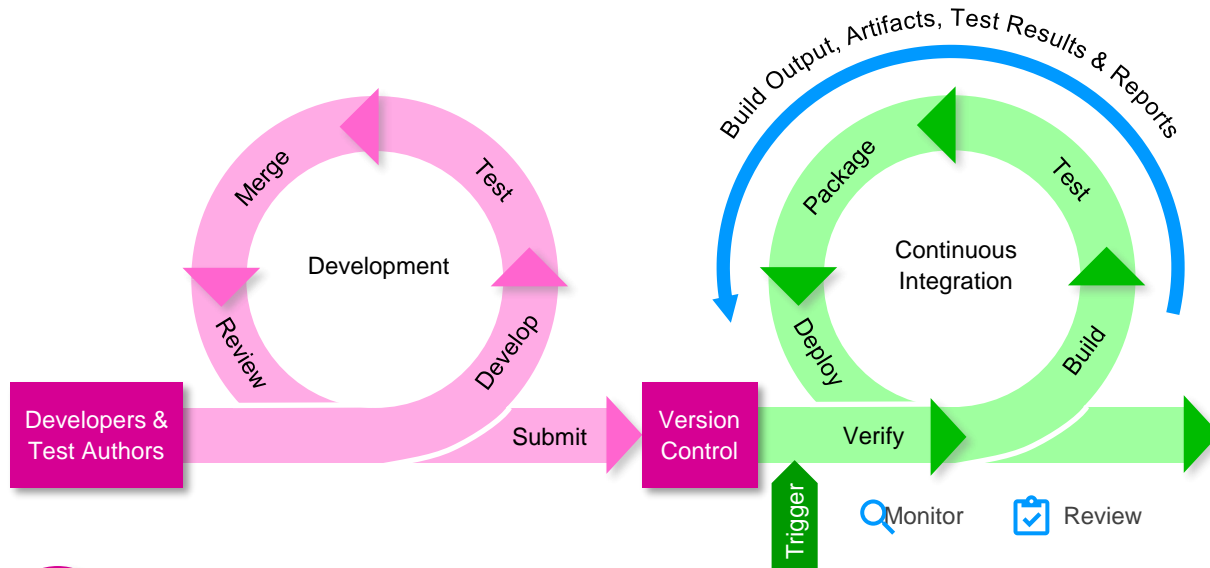
1 Development

2 Continuous Integration



Verification, Build, and Test

Continuous Integration workflow with Model-Based Design



Results: 2017-Jan-19 13:34:39
 Result Type: Result Set
 Parent: None
 Start Time: 2017-Jan-19 13:34:39
 End Time: 2017-Jan-19 13:34:39
 Outcome: Total: 2

Aggregated Coverage Results
 Analyzed Model: Sim Mode: Comp
[AHRS_voter](#) ModelRef: SLDV_32
[Back to Report Summary](#)

AHRS_voter_SLDV_Test
 Test Result Information
 Result Type: Test File
 Parent: Results
 Start Time: 2017-Jan-19 13:34:39
 End Time: 2017-Jan-19 13:34:39
 Outcome: Total: 2

Test Suite Information
 Name: AHRS_voter_SLDV_Test
[Back to Report Summary](#)

MATLAB® Test Report
 Timestamp: 04-Feb-2021 20:27:27
 Host: SEBDEERAZER
 Platform: win64
 MATLAB Version: 9.9.0.1570001 (R2020b) Update 4

Test Manager interface showing a test result plot. The plot shows a 'Fail' state with a red vertical bar at approximately x=10. The y-axis ranges from 0 to 12. The plot title is 'Test Assessments/GlobalAssessments/verify(duration(time_gap < 1.5, sec) < 2)'. The plot area also shows 'Pass' and 'Unlabeled' regions.

**Test and Code Coverage Reports
 Simulink Test Results**

- 1 Development**
- 2 Continuous Integration**
- 3 Results Monitor and Review**

ISO 26262

Functional Safety

ISO/SAE 21434

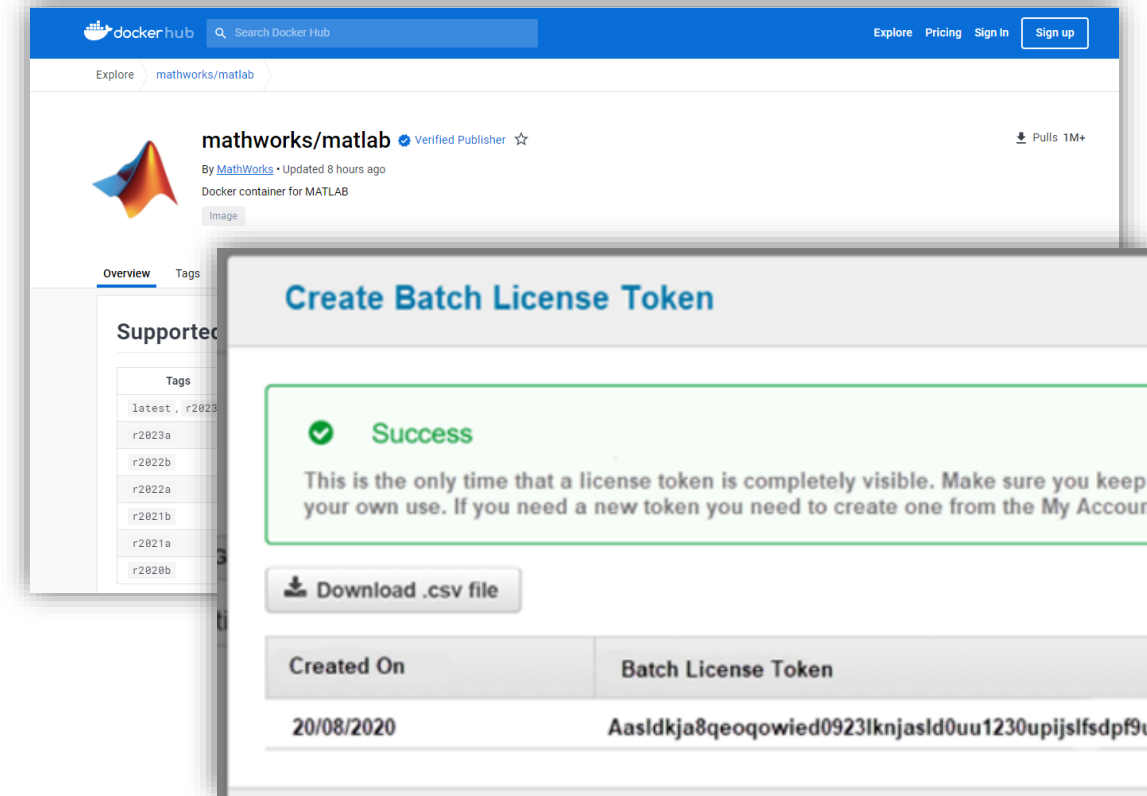
Cybersecurity for Road Vehicles

ISO 21448

Safety of the intended functionality (SOTIF)

Considerations for CI and Test on the Cloud

- MathWorks
 - Container ecosystem
 - Batch (non-interactive) licensing
- You
 - Evolving software development practices



The image shows a screenshot of the Docker Hub interface for the `mathworks/matlab` repository. The repository page displays the MathWorks logo, the name `mathworks/matlab`, and a 'Verified Publisher' badge. Below the repository name, there is a 'Supported' section with a list of tags: `latest`, `r2023a`, `r2022b`, `r2022a`, `r2021b`, `r2021a`, and `r2020b`. Overlaid on the right side of the screenshot is a 'Create Batch License Token' dialog box. The dialog box has a green success message: 'Success' and a warning: 'This is the only time that a license token is completely visible. Make sure you keep your own use. If you need a new token you need to create one from the My Account'. Below the message is a 'Download .csv file' button. At the bottom of the dialog box is a table with two columns: 'Created On' and 'Batch License Token'. The table contains one row with the date '20/08/2020' and a long alphanumeric string: 'Aasldkja8qeoqowied0923lknjasld0uu1230upijlsfspf9u'.

Created On	Batch License Token
20/08/2020	Aasldkja8qeoqowied0923lknjasld0uu1230upijlsfspf9u

MATLAB and Simulink Cloud Usage Framework

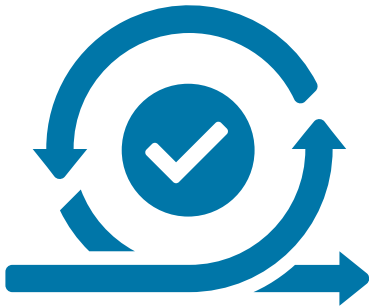
Interactive Design & Development



Scale



CI & Test



Deploy & Operate

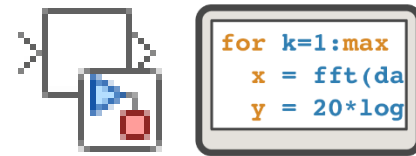


What is a microservice?

“Microservices are an architectural and organizational approach to software development where software is composed of **small independent services that communicate over well-defined APIs.**”

aws.amazon.com/microservices

Creating a microservice from MATLAB/Simulink in 2 steps



1

Compile your code/model
into a **CTF archive**



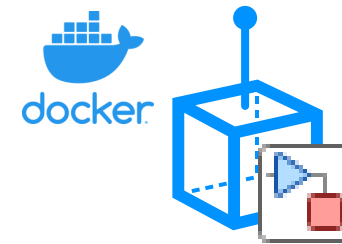
2

Create a **Docker container** that has:

1. Ubuntu
2. MATLAB Runtime (optimized for size)
3. Your code
4. An HTTP server to respond to the API



HTTP RESTful Endpoint

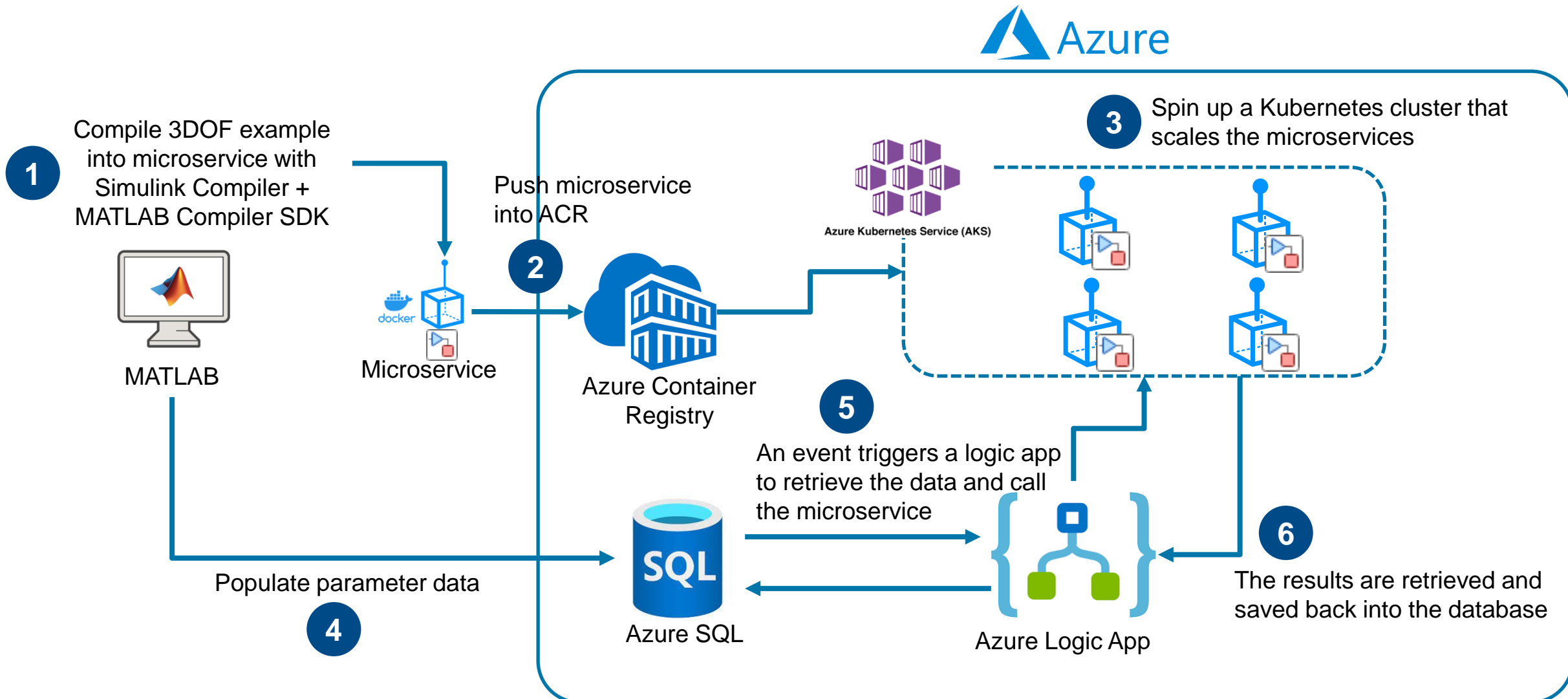


Microservice container can
be shared/hosted royalty-free

```
>> compiler.build.productionServerArchive
```

```
>> compiler.package.microserviceDockerImage
```

Using a Simulink microservice



New Requirements for Deploying and Operating MATLAB/Simulink Models on the Cloud

- MathWorks

- Enabling MATLAB and Simulink code/models as microservices
- Integration with Cloud technologies like Docker/Kubernetes
- Logging/monitoring for observability
- Footprint reduction

- You

- Working with IT and others in the organization to build the right architecture and infrastructure or learning how you plug into what exists
- Learning how to do 24x7 operation and to meet SLAs
- Building observability into your applications
- Measuring reliability and responding to outages (DORA, etc.)

MATLAB and Simulink Cloud Usage Framework

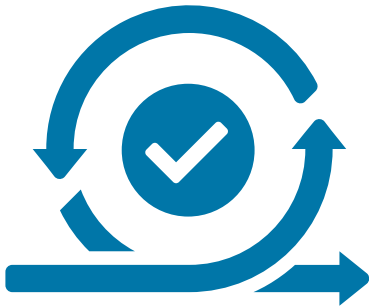
Interactive Design & Development



Scale



CI & Test



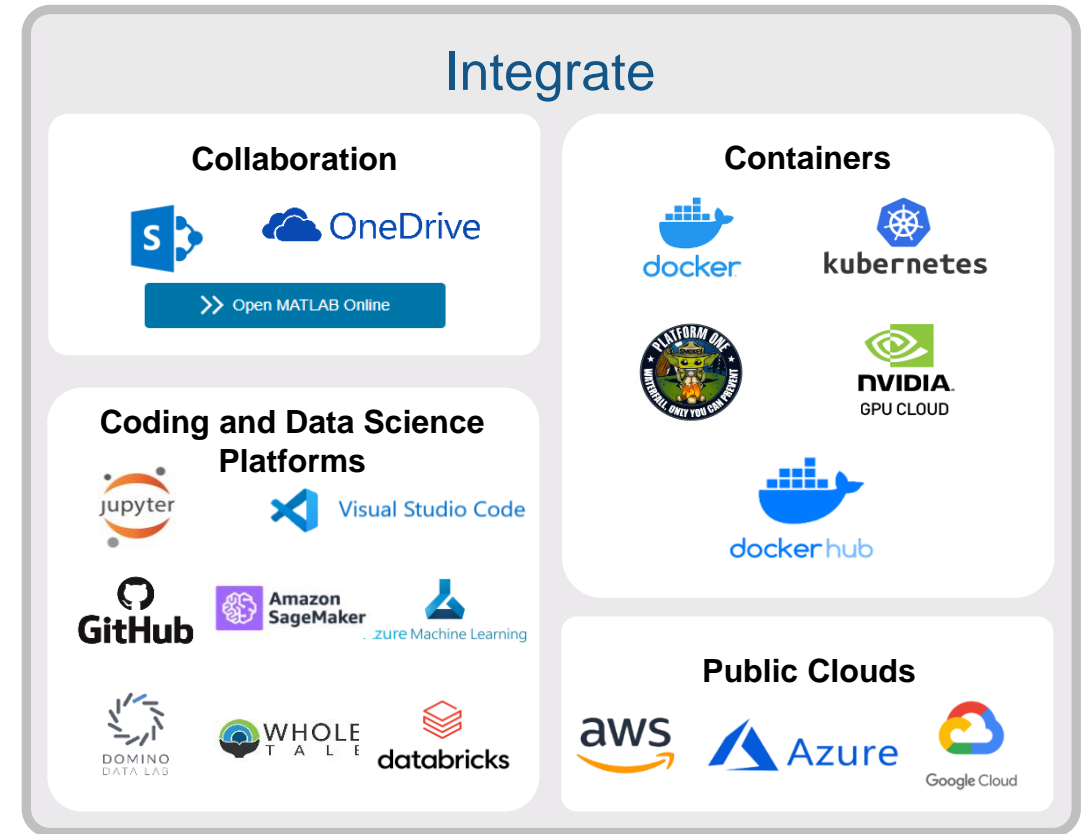
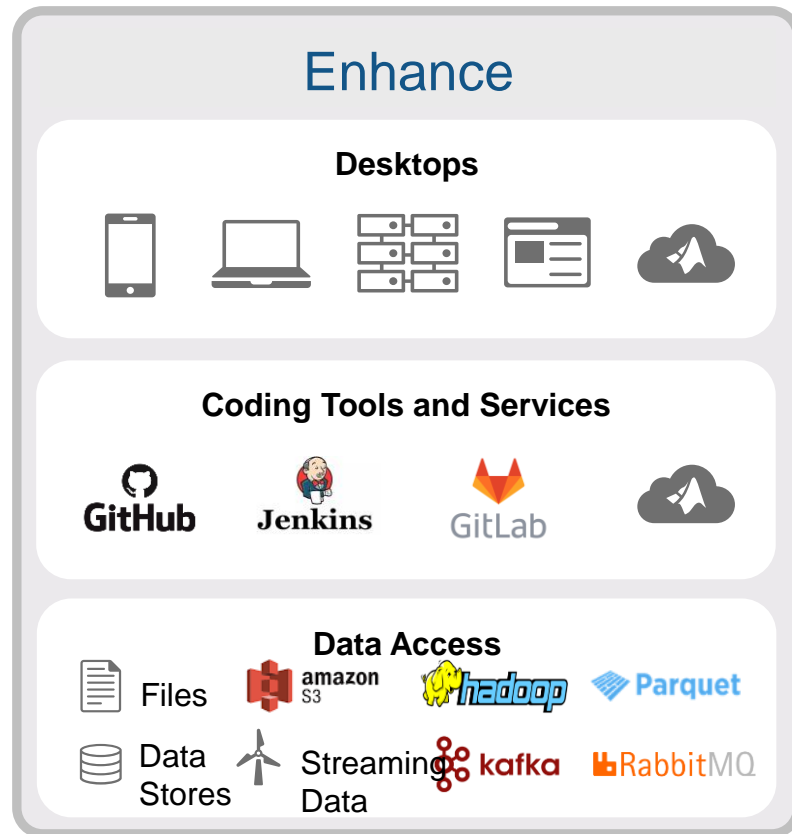
Deploy & Operate



Our Cloud Philosophies

- Enhancing and integrating are equally important
- Cloud represents a new platform (like Win/Mac/Linux)
- Evolving our own software for cloud involves significant evolution of MATLAB/Simulink
- Evolving MATLAB to support your online workflows

Enhancing and Integrating are equally Important



Usage starts from MATLAB
 MATLAB needs to be *enhanced* to access
 online technologies

MATLAB is started by somebody else
 MATLAB needs to be *integrated into these
 environments*

Integrating four widely used toolchains for SDV

MathWorks®

aws FOR AUTOMOTIVE

SYNOPSYS®

Elektrobit

Automotive Software Development in the Cloud powered by aws

MathWorks
Virtual Vehicle Simulation in MATLAB & Simulink

Application Code from Model

Elektrobit
Road-ready Automotive Software

Infotainment (Android Automotive OS)

Vehicle Control Unit (Adaptive AUTOSAR)

```

[205.18] Adaptive AUTOSAR HPC - received discharge current limit: -310.00 charge current limit: 102.30 charge: 0.75
[206.18] Adaptive AUTOSAR HPC - received discharge current limit: -310.00 charge current limit: 102.30 charge: 0.75
[207.19] Adaptive AUTOSAR HPC - received discharge current limit: -310.00 charge current limit: 102.30 charge: 0.75
[208.20] Adaptive AUTOSAR HPC - received discharge current limit: -310.00 charge current limit: 102.30 charge: 0.75
[209.20] Adaptive AUTOSAR HPC - received discharge current limit: -310.00 charge current limit: 102.30 charge: 0.75
[210.21] Adaptive AUTOSAR HPC - received discharge current limit: -310.00 charge current limit: 102.30 charge: 0.75
[211.21] Adaptive AUTOSAR HPC - received discharge current limit: -310.00 charge current limit: 102.30 charge: 0.75
[212.22] Adaptive AUTOSAR HPC - received discharge current limit: -310.00 charge current limit: 102.30 charge: 0.75
[213.23] Adaptive AUTOSAR HPC - received discharge current limit: -310.00 charge current limit: 102.30 charge: 0.75
[214.23] Adaptive AUTOSAR HPC - received discharge current limit: -310.00 charge current limit: 102.30 charge: 0.75
[215.24] Adaptive AUTOSAR HPC - received discharge current limit: -310.00 charge current limit: 102.30 charge: 0.75
[216.24] Adaptive AUTOSAR HPC - received discharge current limit: -310.00 charge current limit: 102.30 charge: 0.75
[217.25] Adaptive AUTOSAR HPC - received discharge current limit: -310.00 charge current limit: 102.30 charge: 0.75
                
```

Battery Management System (Classic AUTOSAR)

```

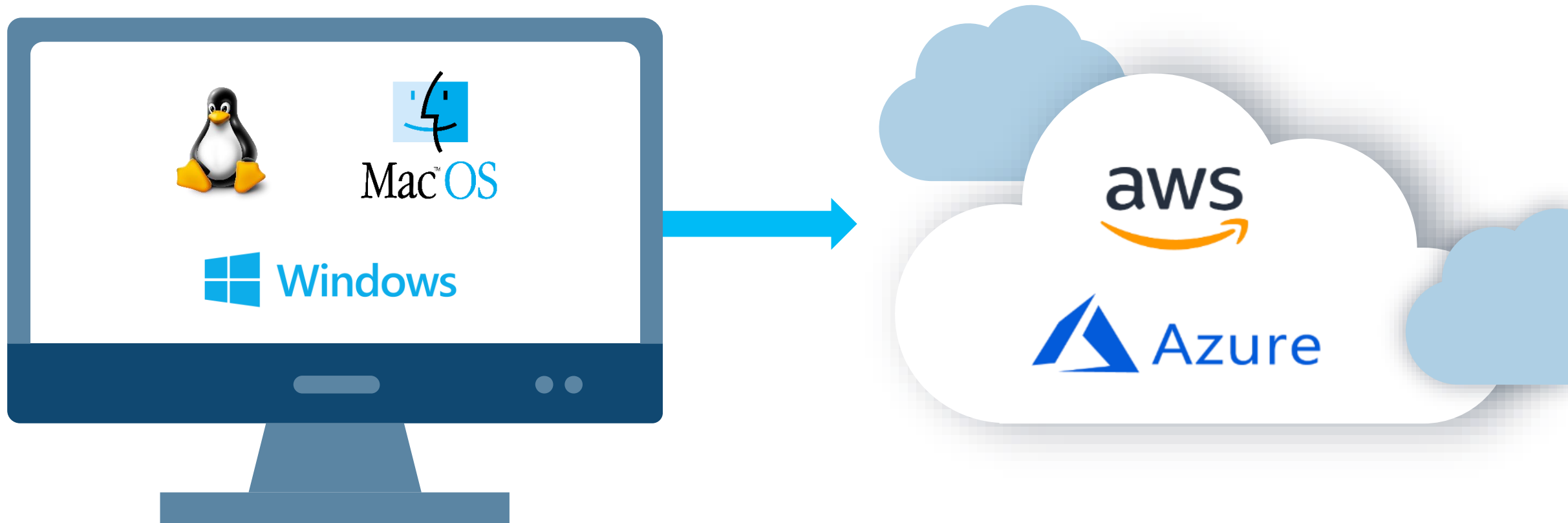
[281.02] Classic AUTOSAR ECU - sending discharge current limit: -310.00 charge current limit: 102.30 charge: 0.75
[282.02] Classic AUTOSAR ECU - sending discharge current limit: -310.00 charge current limit: 102.30 charge: 0.75
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[285.02] Classic AUTOSAR ECU - sending discharge current limit: -310.00 charge current limit: 102.30 charge: 0.75
[286.02] Classic AUTOSAR ECU - sending discharge current limit: -310.00 charge current limit: 102.30 charge: 0.75
[287.02] Classic AUTOSAR ECU - sending discharge current limit: -310.00 charge current limit: 102.30 charge: 0.75
[288.02] Classic AUTOSAR ECU - sending discharge current limit: -310.00 charge current limit: 102.30 charge: 0.75
[289.02] Classic AUTOSAR ECU - sending discharge current limit: -310.00 charge current limit: 102.30 charge: 0.75
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[291.02] Classic AUTOSAR ECU - sending discharge current limit: -310.00 charge current limit: 102.30 charge: 0.75
[292.02] Classic AUTOSAR ECU - sending discharge current limit: -310.00 charge current limit: 102.30 charge: 0.75
                
```

ECU Simulation

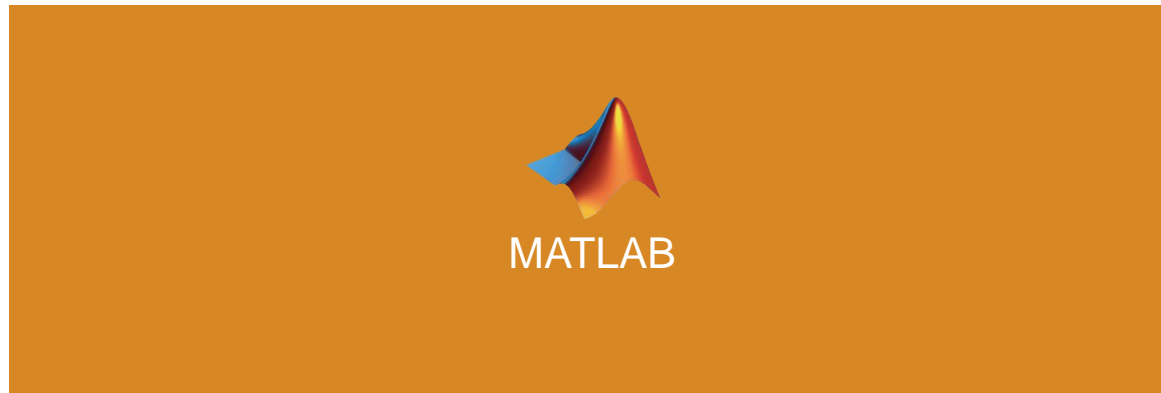
SYNOPSYS
Virtual ECUs in Synopsys Silver

Stop by the booth to see it in action!

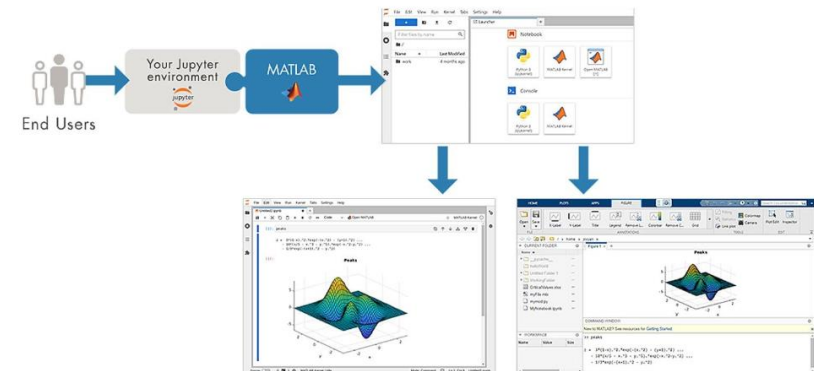
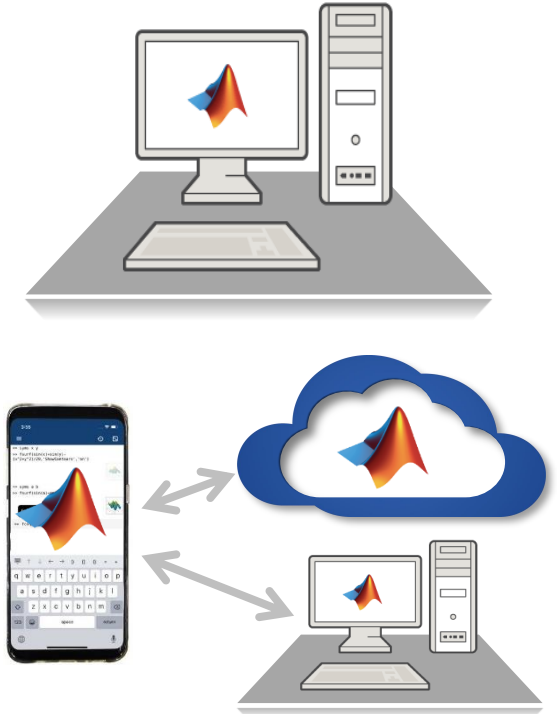
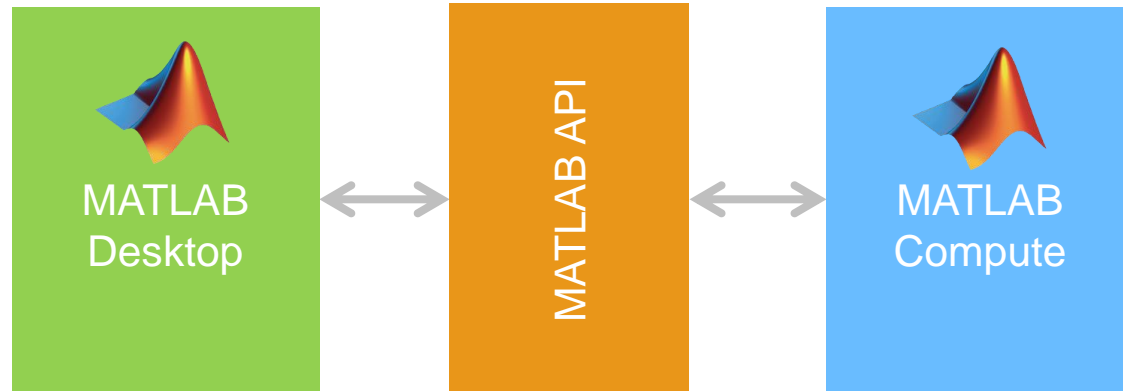
Cloud represents a new platform (like Win/Mac/Linux)
and should be treated like one



Evolving our own software for cloud involves significant evolution of MATLAB/Simulink



Evolving our own software for cloud involves significant evolution of MATLAB/Simulink



Evolving MATLAB to support your online workflows

Collaboration and Integration	Cloud Center	Docker / Kubernetes	VS Code	MATLAB Production Server
	MATLAB Online Server	Connected Desktop	JupyterHub	MATLAB Parallel Server
Software Development Workflows	MATLAB Test	MATLAB / Simulink Compiler	MATLAB / Simulink Coder	GitHub / GitLab
	Build Tool	MATLAB / Simulink Projects	Toolbox Standards	Package Management
Foundations	Modular Execution	Code Analysis	Extension Points	Apps
	Performance	Desktop and Editor	Language	Graphics

Our Cloud Philosophies

- Enhancing and integrating are equally important
- Cloud represents a new platform (like Win/Mac/Linux)
- Evolving our own software for cloud involves significant evolution of MATLAB/Simulink
- Evolving MATLAB to support your online workflows

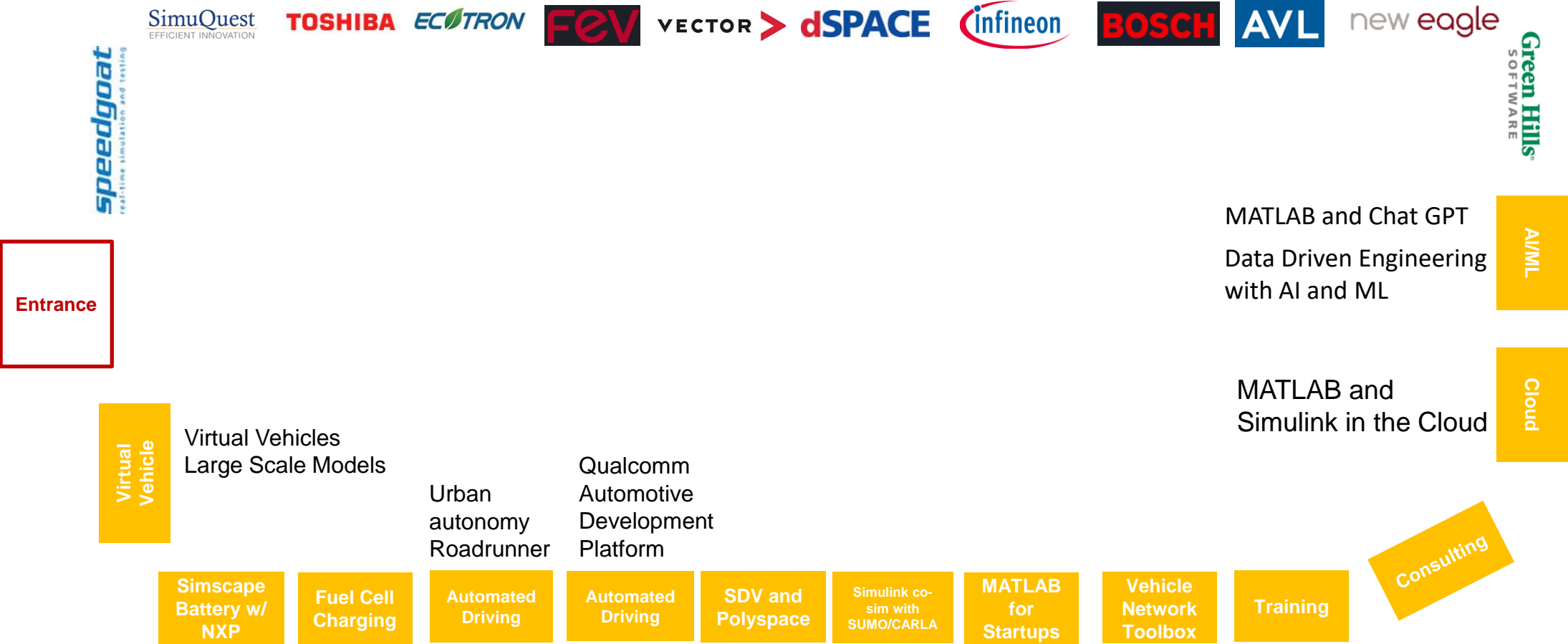
We're Ready When You Are....

- Not sure where to start?
 - Cloud usage framework
 - mathworks.com/cloud
- We can help
 - Account team
 - cloud@mathworks.com
- Tech showcase
- Soft Dev Session at 4:15
 - “How Cloud-Based Virtual Vehicles Can Help You Build Your Next-Gen Software”



The screenshot shows the MathWorks website interface. At the top right is the MathWorks logo. Below it is a navigation bar with "MATLAB in the Cloud" and a search box labeled "Search MathWorks.com". Underneath are tabs for "Overview" and "Resources". A large blue banner reads "Resources for Using MATLAB and Simulink in the Cloud". On the left, a "CATEGORY" section lists four topics: "Interactive Design and Development Using MATLAB and Simulink", "Simulation and Design Exploration at Scale with MATLAB and Simulink", "Integrate MATLAB and Simulink into CI and Automated Test Systems", and "Deploy and Operationalize MATLAB Code and Simulink Models into Production". On the right, text states "There are many ways to use MATLAB and Simulink in the cloud. Visit one of the pages below." followed by a heading "Interactive Design and Development Using MATLAB and Simulink" and the text "Hosted by MathWorks". Below this, it says "Access MATLAB in your web browser without needing to install software locally." and lists "MATLAB Online" and "Simulink Online" as bullet points.

Technology Showcase



Next presentation starts at 10:30 AM

MathWorks
**AUTOMOTIVE
CONFERENCE 2024**
North America

Enabling MATLAB and Simulink for use on the cloud

Leslie Mehrez
Sr. Manager Technical Marketing
Online Products



Loren Dean
Senior Director of Engineering,
Online Products and Technical Computing

