



# Scaling Vehicle Simulations

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# Who We Are

Founded: 2009, known as Rivian from 2011

Founder & CEO: RJ Scaringe

Employees: 10000+

Locations: USA and Europe

IPO: November 2021

## Keep the world adventurous forever



Rivian R1T



Rivian R1S



Electric Delivery Van  
(Powered by Rivian)





# Agenda

- Physical Testing vs Simulations
- Simulation Stakeholders
- Simulations for Everyone
- Defining a Simulation Run
- Vehicle Simulation Interface Tool
- Backend: Simulation Objects
- Parallel Simulations
- Use Case
- Benchmarking
- MATLAB at Rivian



# The Basics

# Physical Testing vs Simulations



Range



Acceleration



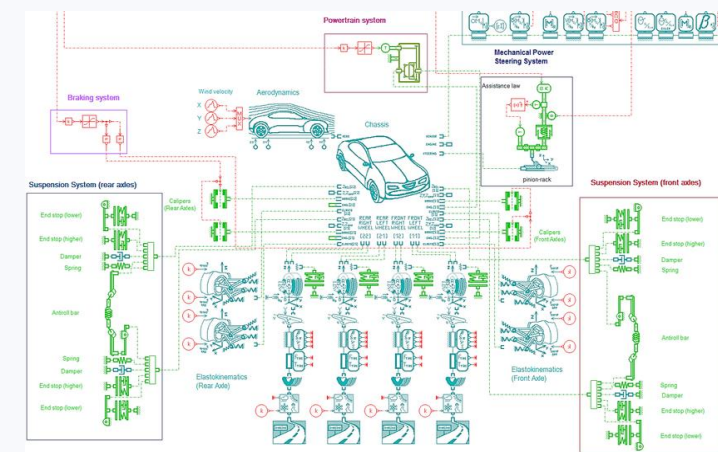
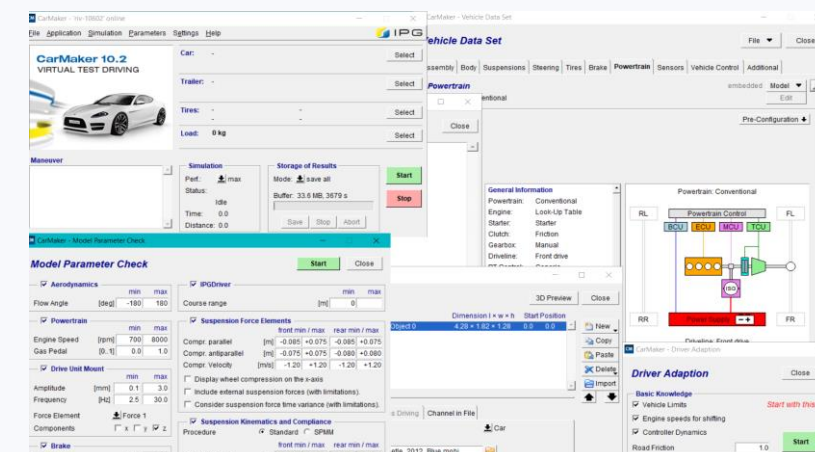
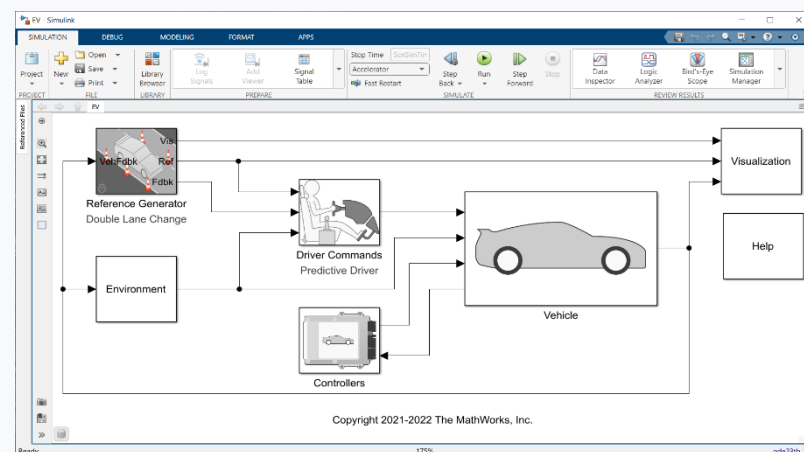
Off Roding



Handling

\$\$\$\$\$\$\$ 🕒

Spec and build an actual vehicle  
 Transport vehicle to different locations  
 Run tests in real time



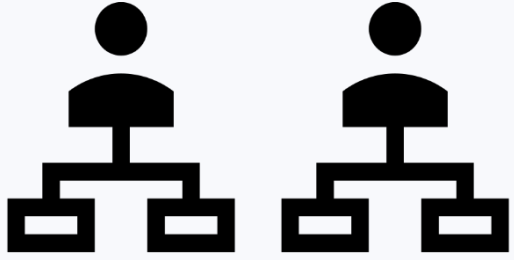
  
 Commercial software

\$\$\$ 🕒

Configure a virtual vehicle in seconds  
 Design testing conditions as needed  
 10x real time speeds

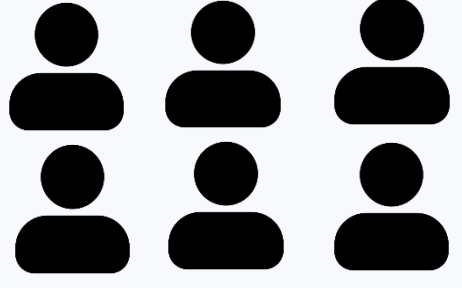
In the last 6 months, Rivian users have run 9000+ full vehicle simulations equivalent to about 2 million simulation miles

# Simulation Stakeholders



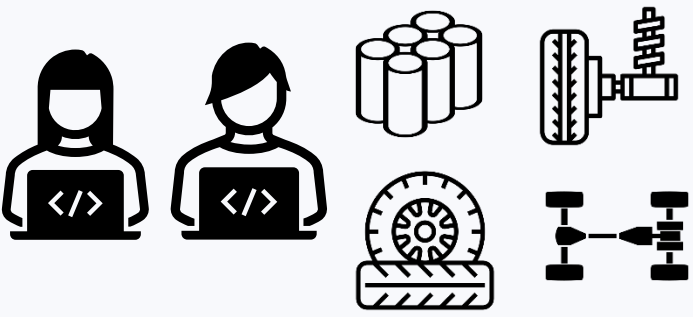
Leaders

VP, Directors, Principal Engineers, Sr. Managers take product/program level decisions and provide attribute targets



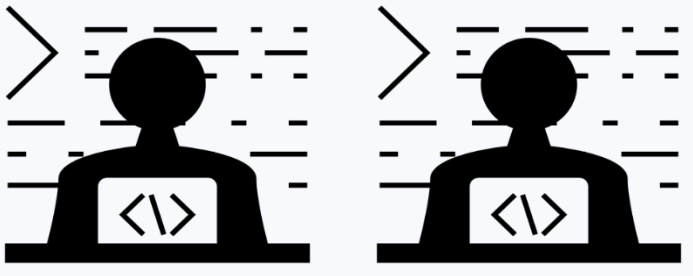
Attribute Engineer

System owners of vehicle attributes. Includes Performance Engineers, Range & Efficiency Engineers, Dynamics Engineers etc.



Modeling Engineer

Development of component models like battery, tire, propulsion etc.

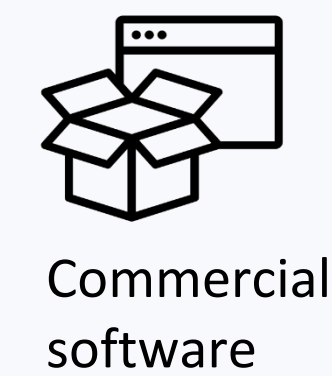
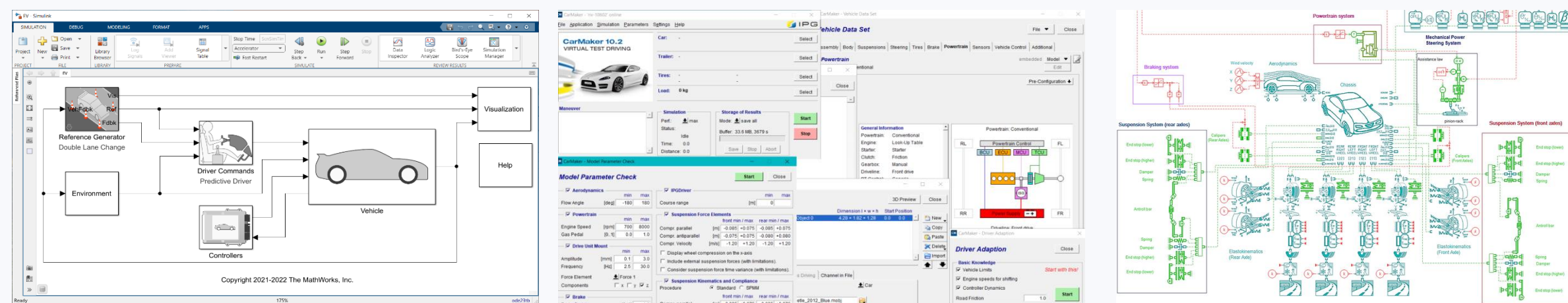
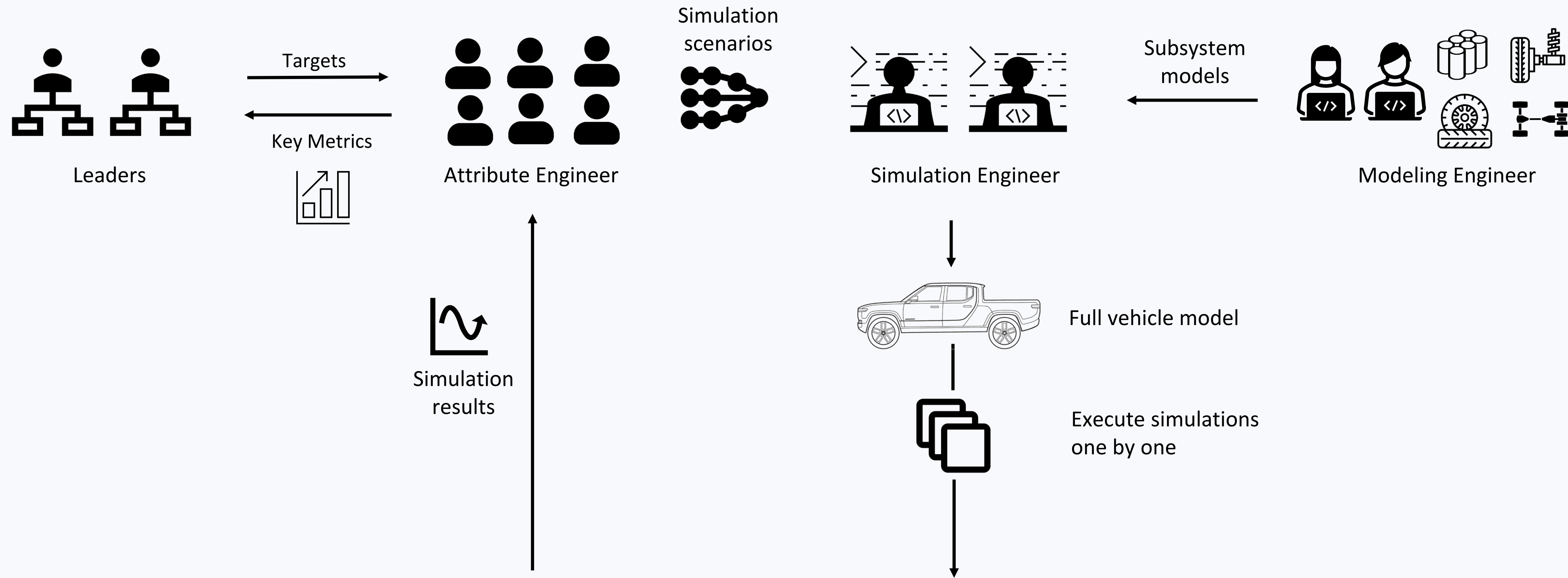


Simulation Engineer

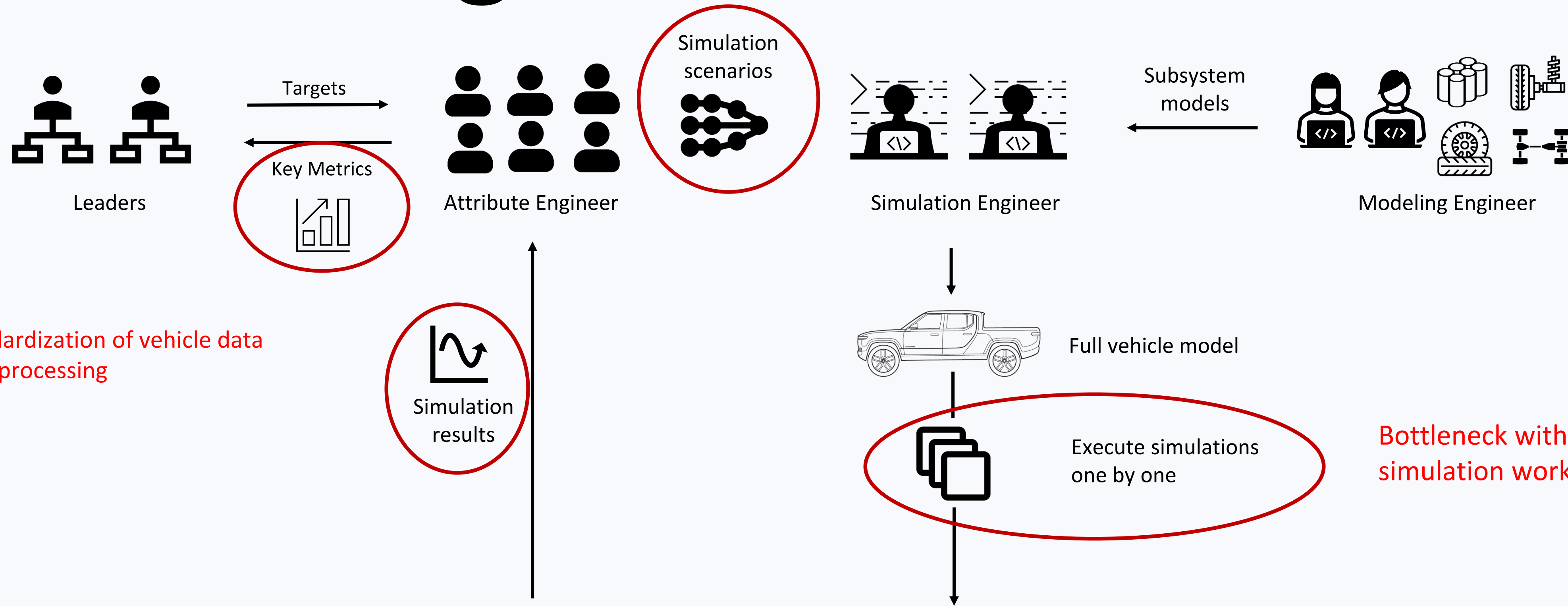
Create full vehicle models from component models and run simulations



# Simulation Workflow

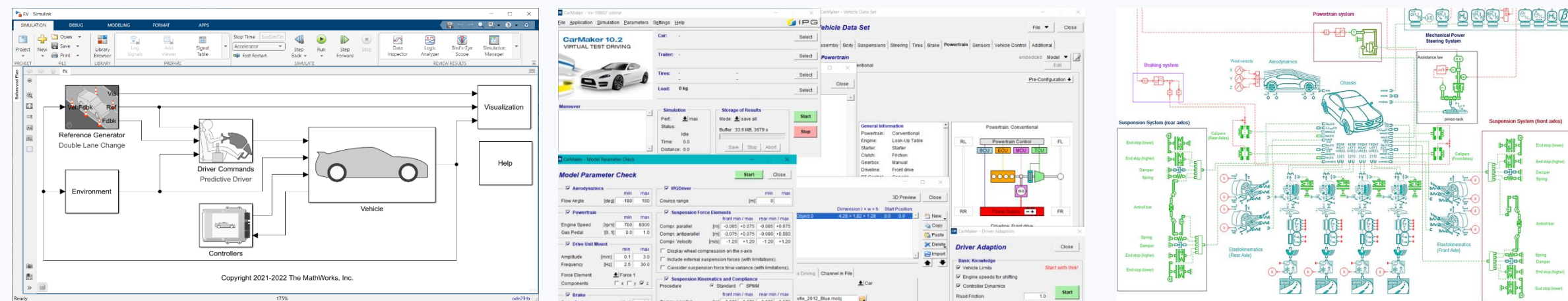


# The Challenge



- Lack of standardization of vehicle data
- Ad hoc post-processing

Bottleneck with sequential simulation workflow

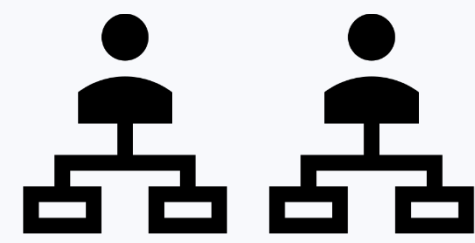


Commercial software

Complexity of running simulations for non-simulation engineers



# Simulations for Everyone



Leaders



Range & Efficiency Engineer



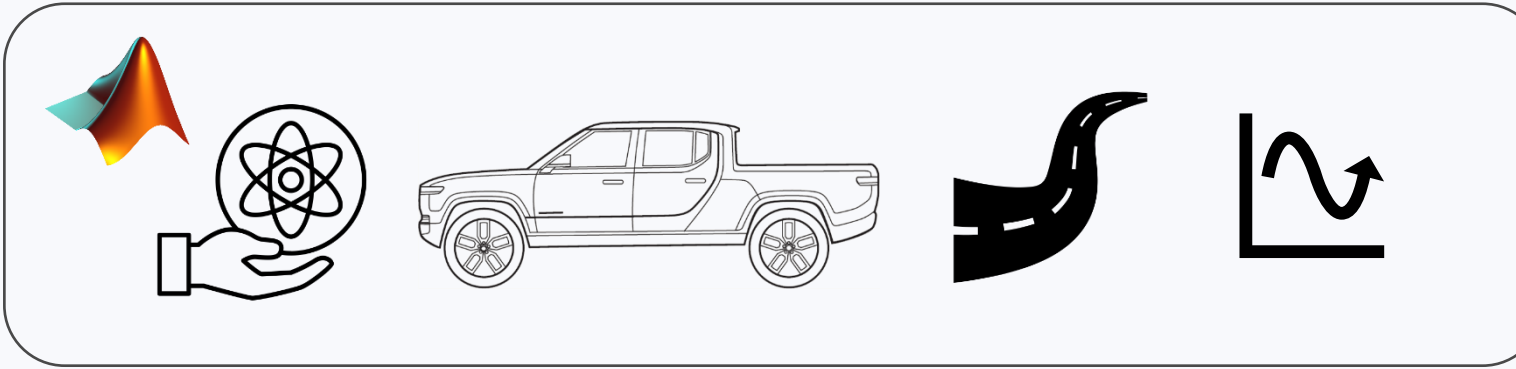
Performance Engineer



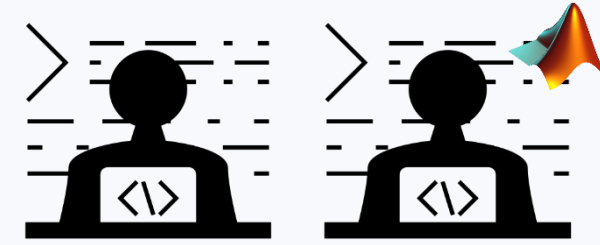
Dynamics Engineer



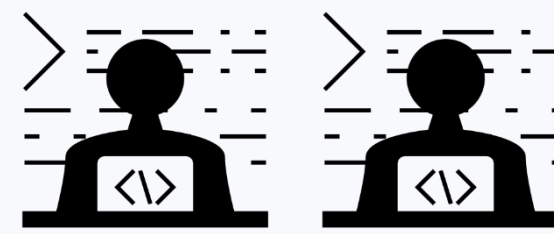
Weight Management Engineer



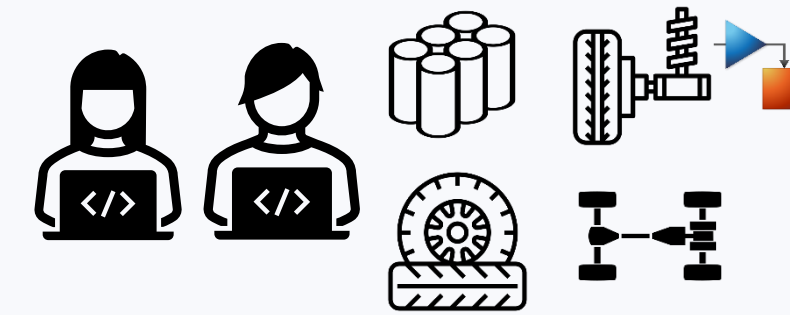
Scalable, easy-to-use tool to configure, run and post-process large number of simulations



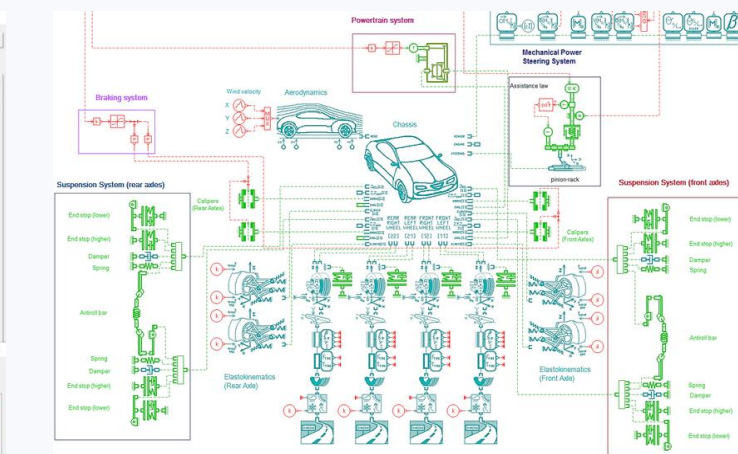
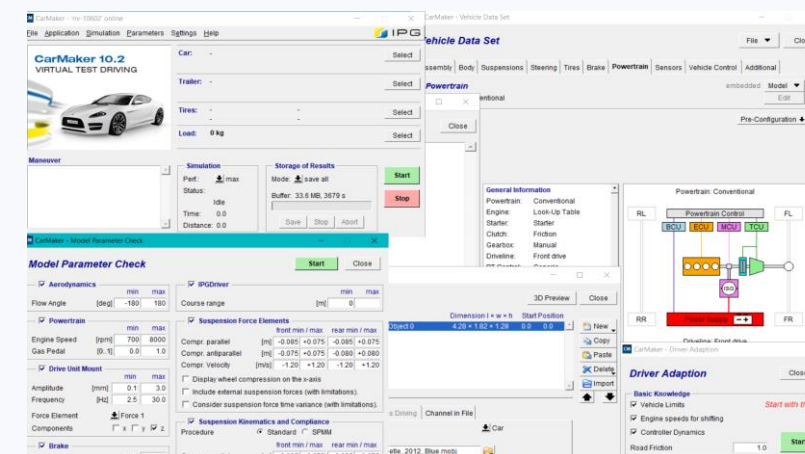
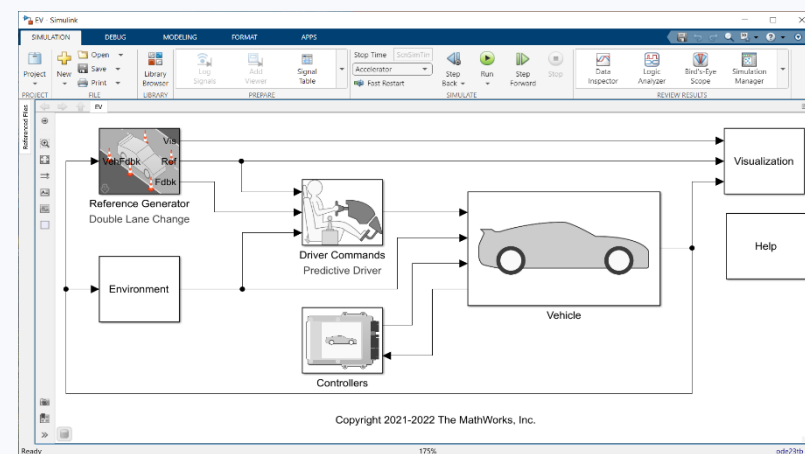
Toolset Engineer



Simulation Engineer



Modeling Engineer



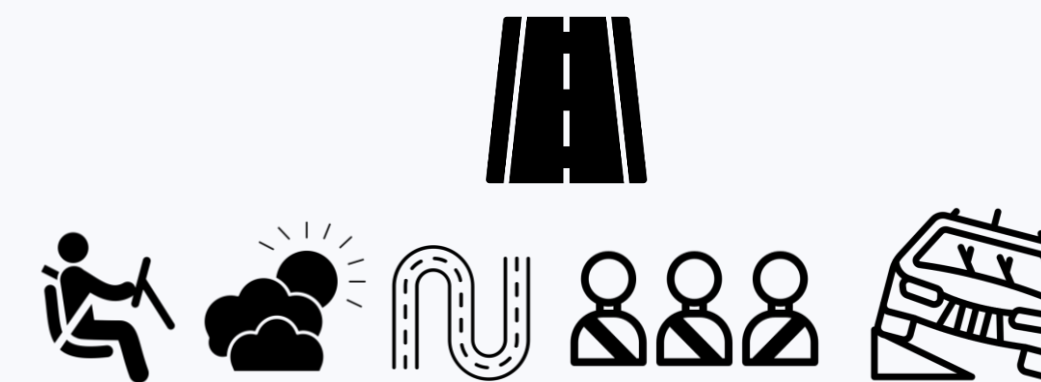
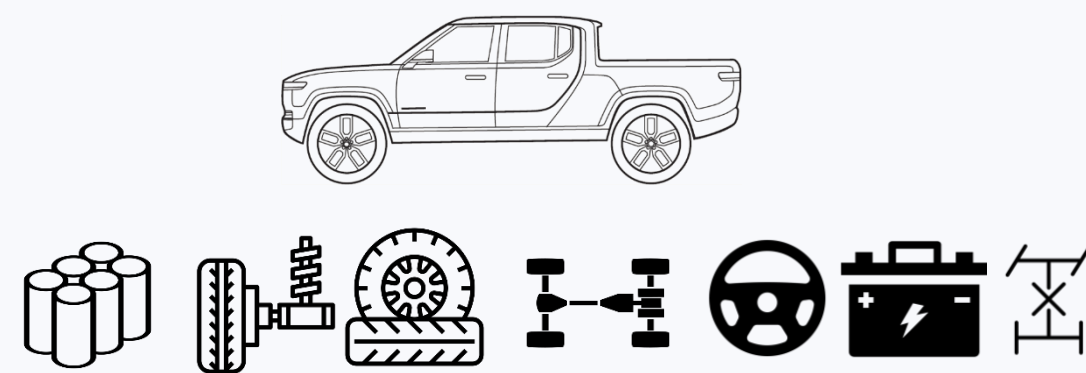
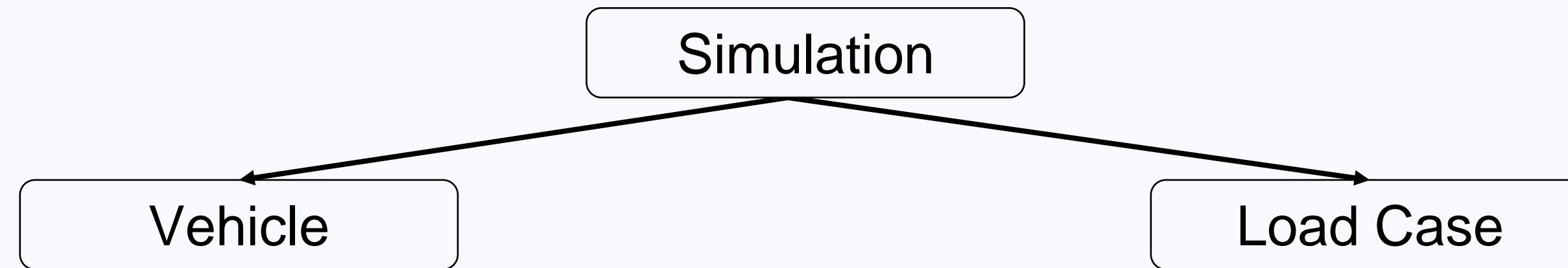
Commercial software



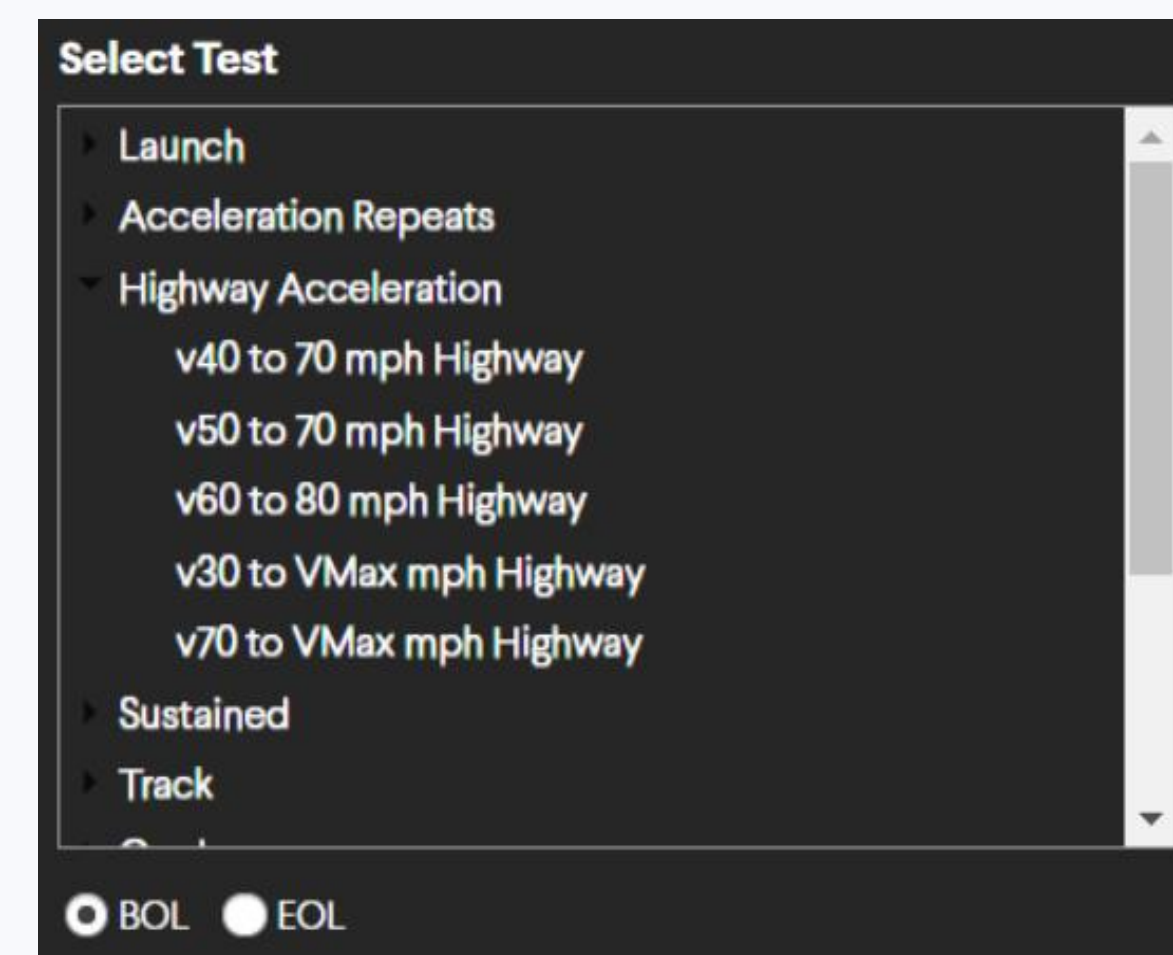
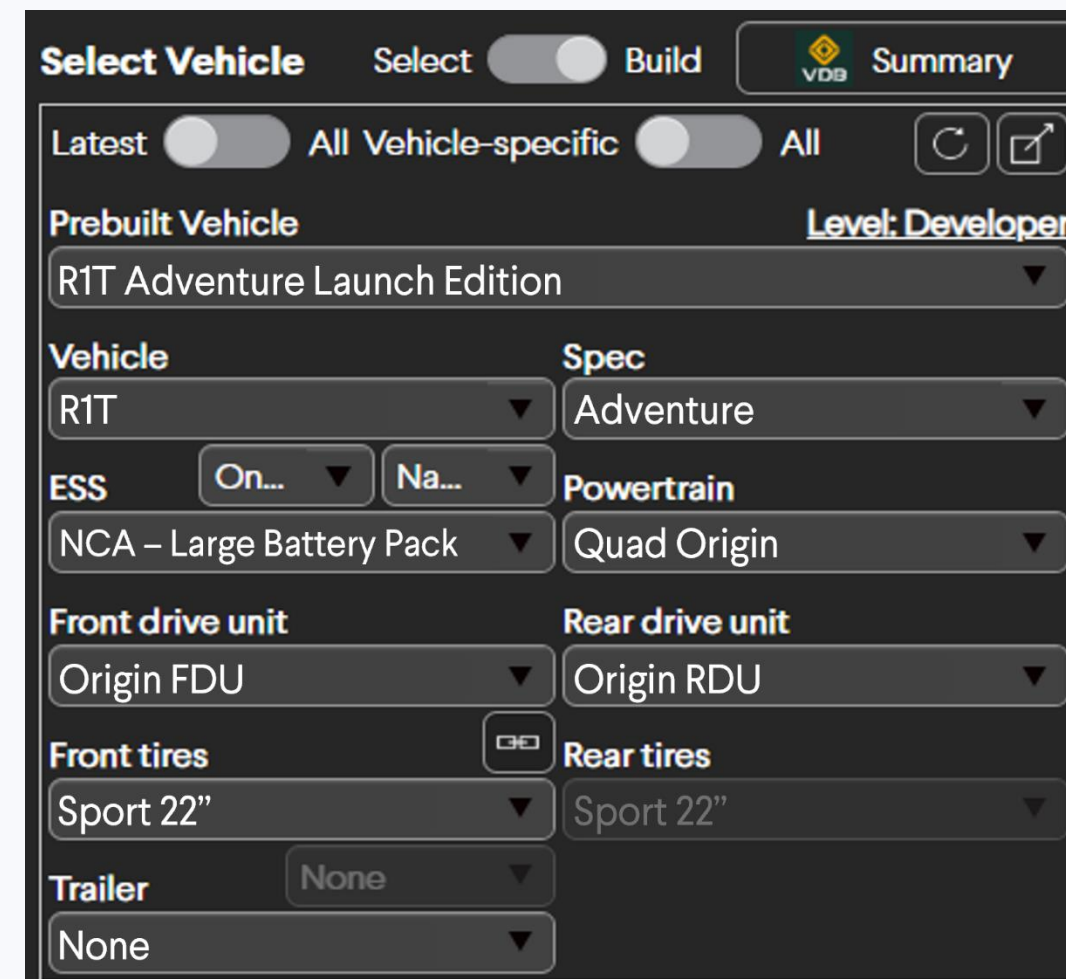
# Vehicle Simulation Interface



# Defining a Simulation Run



- Vehicle Database:**
- Object-oriented
  - Assemble a “virtual” vehicle from components
  - Version controlled



- Pre-defined load cases:**
- Ambient conditions
  - Driver model
  - Speed Profile
  - ...

**Note on simulation duration:**

- A typical “short” simulation (ex. Acceleration repeats) takes about **3-4 simulation minutes** to complete
- A typical “long” simulation (ex. durability cycles) takes about **60 simulation minutes** to complete



# Vehicle Simulation Interface (VSI)

VSI UI built in App Designer deployed as a MATLAB toolbox or a compiled app

**Vehicle Database**

**Test run/load case selection**

**Simulations**

	Vehicle	VDB File	Test Run Name	Test Run File	Vehicle Settings	Test Run Settings	Description	Status
<b>RIT</b>								
1	RIT Adventure Launch Edition	\\rai.com\Shares...	Launch Acceleration -BOL	\\rai.com\Shares...	default	default	RIT	Amber
2	RIT Adventure Launch Edition	\\rai.com\Shares...	v40 to 70 mph Highway-B...	\\rai.com\Shares...	default	default	RIT	Green
3	RIT Adventure Launch Edition	\\rai.com\Shares...	v60 mph Regen Repeats...	\\rai.com\Shares...	default	default	RIT	Amber
4	RIT Adventure Launch Edition	\\rai.com\Shares...	Ramp Steer LiftOff LH 45...	\\rai.com\Shares...	{"XMM": {"DriveMode": "E...	default	RIT	Red
<b>RIS</b>								
5	RIS Adventure Launch Edition	\\rai.com\Shares...	Launch Acceleration -BOL	\\rai.com\Shares...	default	["BatteryTemp": "20"]	RIS	Green
6	RIS Adventure Launch Edition	\\rai.com\Shares...	v40 to 70 mph Highway-B...	\\rai.com\Shares...	default	default	RIS	Green
7	RIS Adventure Launch Edition	\\rai.com\Shares...	v60 mph Regen Repeats...	\\rai.com\Shares...	{"XMM": {"RideHeight": "Lo...	default	RIS	Red
8	RIS Adventure Launch Edition	\\rai.com\Shares...	Ramp Steer LiftOff LH 45...	\\rai.com\Shares...	default	default	RIS	Green
<b>EDV</b>								
9	Electric Delivery Van	\\rai.com\Shares...	Launch Acceleration -BOL	\\rai.com\Shares...	default	default	EDV	Amber
10	Electric Delivery Van	\\rai.com\Shares...	v40 to 70 mph Highway-B...	\\rai.com\Shares...	{"UserSetting": {"MassCon...	default	EDV	Red
11	Electric Delivery Van	\\rai.com\Shares...	v60 mph Regen Repeats...	\\rai.com\Shares...	default	default	EDV	Green
12	Electric Delivery Van	\\rai.com\Shares...	Vegas Traffic Flat-BOL	\\rai.com\Shares...	{"UserSetting": {"MassCon...	default	EDV	Red
13								
14								
15								
16								
17								
18								

**Run & Post-Process**

Run Simulations

Context menu options to copy/paste, modify vehicle, test run etc.

Load saved studies | Browse previous simulations

Run & Post-Process

Parallel, PNG, Excel, TBX, Create Reports

Total: 12, Done: 0, Failed: 0

Busy

Simulations grouped by vehicle platform. Each row is a unique simulation. Black rows are "sections" and grey rows are "simulations".

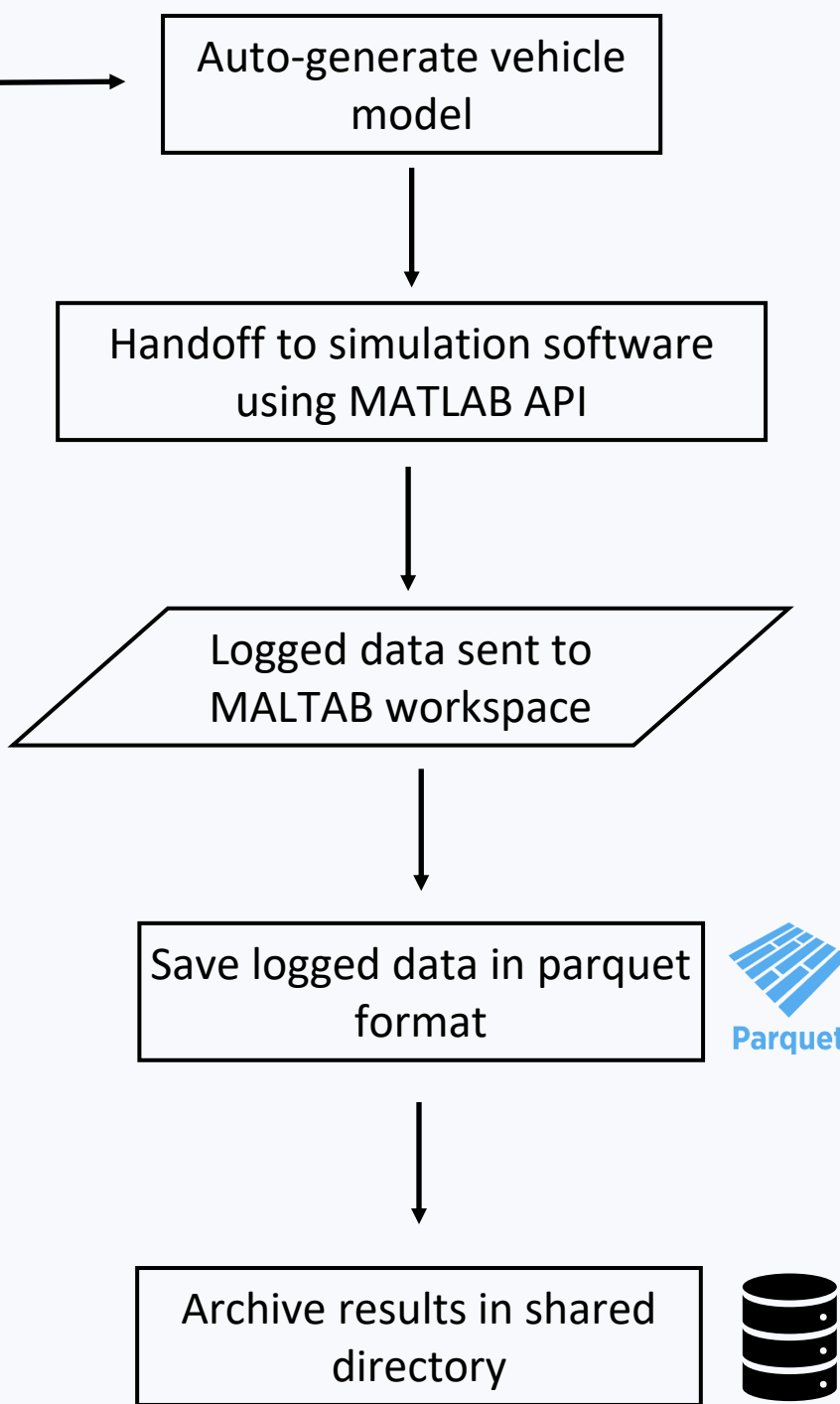
**Red:** Yet to be simulated  
**Green:** Completed simulation  
**Amber:** Completed simulation, results out-of-date



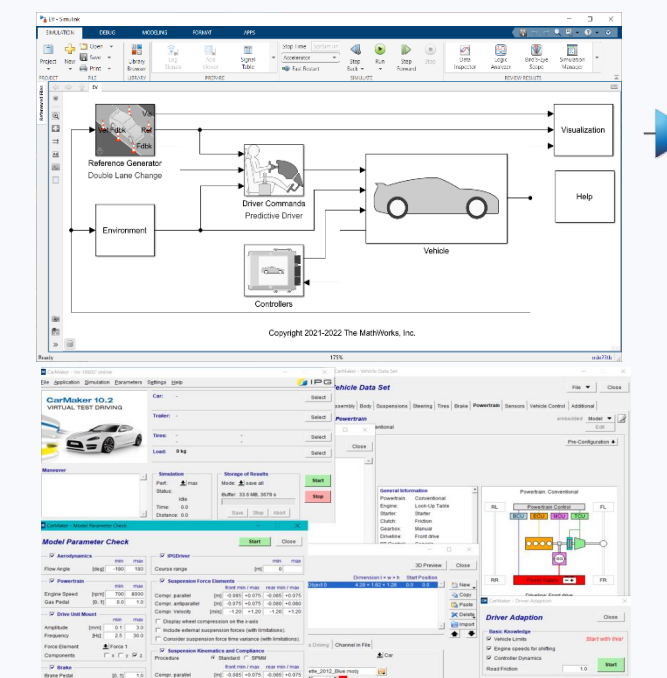
# Running Simulations

Blue rows are rows selected by user to simulate  
 Purple status indicates simulations running in the background

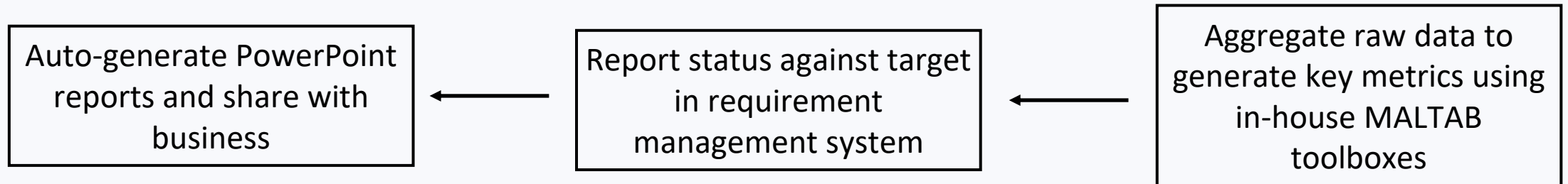
Simulations								
	Vehicle	VDB File	Test Run Name	Test Run File	Vehicle Settings	Test Run Settings	Description	Status
	<i>RIT</i>							
1 ✓	RTT Adventure Launch Edition	\\rai.com\Shares...	Launch Acceleration -BOL	\\rai.com\Shares...	{"UserSetting":{"MassCon...	default	RIT	Purple
2	RTT Adventure Launch Edition	\\rai.com\Shares...	v40 to 70 mph Highway-B...	\\rai.com\Shares...	default	default	RIT	Green
3	RTT Adventure Launch Edition	\\rai.com\Shares...	v60 mph Regen Repeats...	\\rai.com\Shares...	default	default	RIT	Green
4 ✓	RTT Adventure Launch Edition	\\rai.com\Shares...	Ramp Steer LiftOff LH 45...	\\rai.com\Shares...	{"ModelFidelity":{"Suspen...	default	RIT	Red
	<i>RIS</i>							
5	RIS Adventure Launch Edition	\\rai.com\Shares...	Launch Acceleration -BOL	\\rai.com\Shares...	default	[{"BatteryTemp":"20"}]	RIS	Green
6 ✓	RIS Adventure Launch Edition	\\rai.com\Shares...	v40 to 70 mph Highway-B...	\\rai.com\Shares...	{"ModelFidelity":{"Suspen...	default	RIS	Red
7	RIS Adventure Launch Edition	\\rai.com\Shares...	v60 mph Regen Repeats...	\\rai.com\Shares...	default	default	RIS	Green
8 ✓	RIS Adventure Launch Edition	\\rai.com\Shares...	Ramp Steer LiftOff LH 45...	\\rai.com\Shares...	{"ModelFidelity":{"Suspen...	default	RIS	Red
	<i>EDV</i>							
9	Electric Delivery Van	\\rai.com\Shares...	Launch Acceleration -BOL	\\rai.com\Shares...	default	default	EDV	Green
10 ✓	Electric Delivery Van	\\rai.com\Shares...	v40 to 70 mph Highway-B...	\\rai.com\Shares...	{"ModelFidelity":{"Suspen...	default	EDV	Red
11	Electric Delivery Van	\\rai.com\Shares...	v60 mph Regen Repeats...	\\rai.com\Shares...	default	default	EDV	Green
12	Electric Delivery Van	\\rai.com\Shares...	Vegas Traffic Flat-BOL	\\rai.com\Shares...	default	default	EDV	Green
13								
14								
15								
16								
17								
18								



\*Simulations run on Simulink + commercial software using MATLAB API. Uses base workspace.

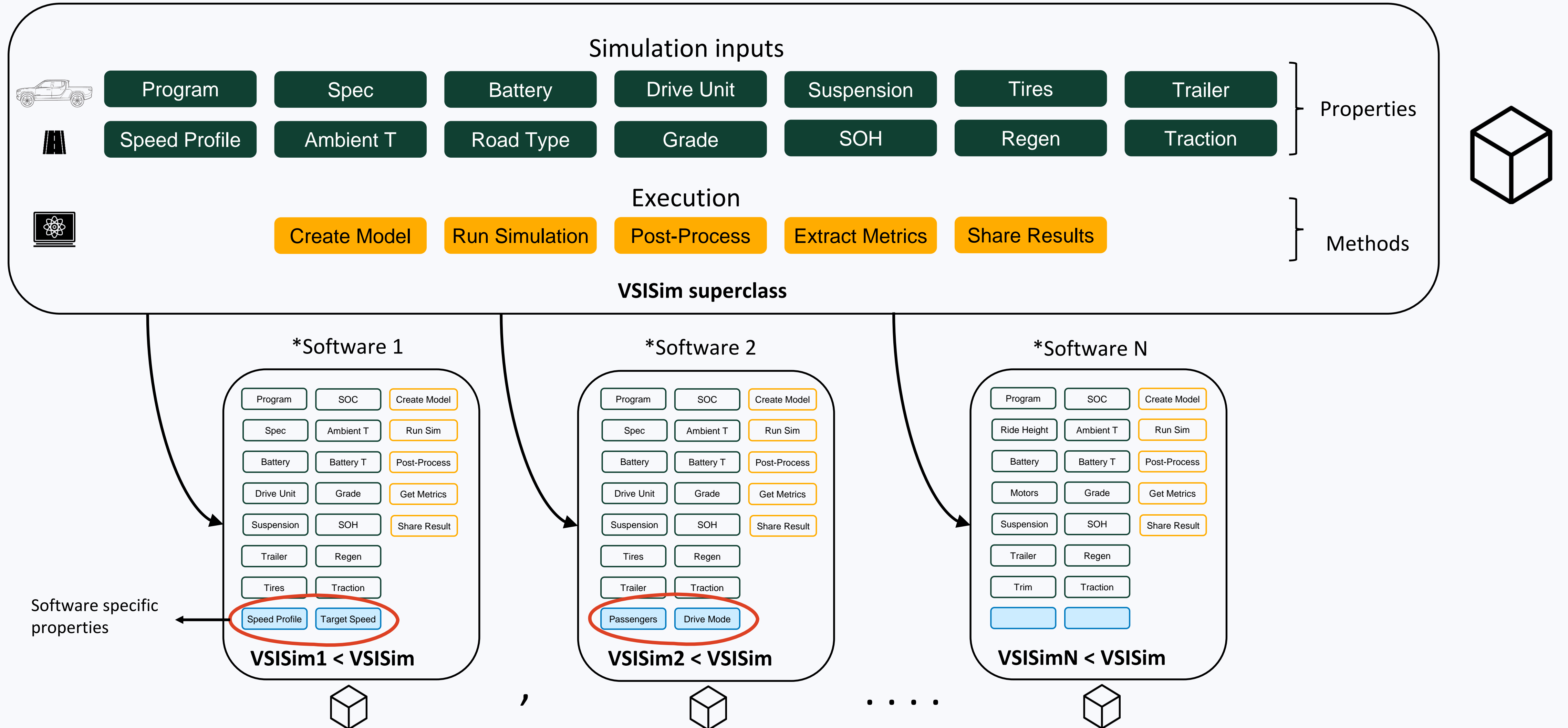


Time	Vehicle Speed (kph)	SOC (%)	Front Left Torque (Nm)
11.1 s	88.6	75	788
11.2 s	87.5	75	787
11.3 s	86.2	74.9	765





# Simulation Objects



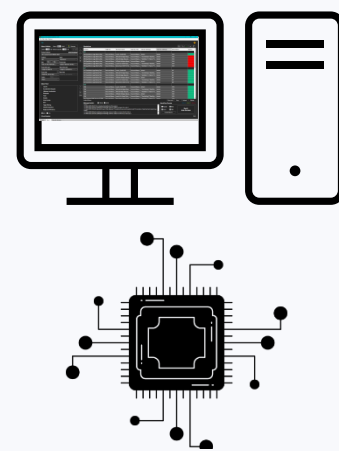


# Parallel Simulations



# Types of Parallel Simulations

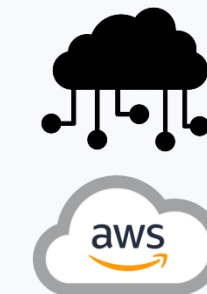
## Parallel Local



- 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

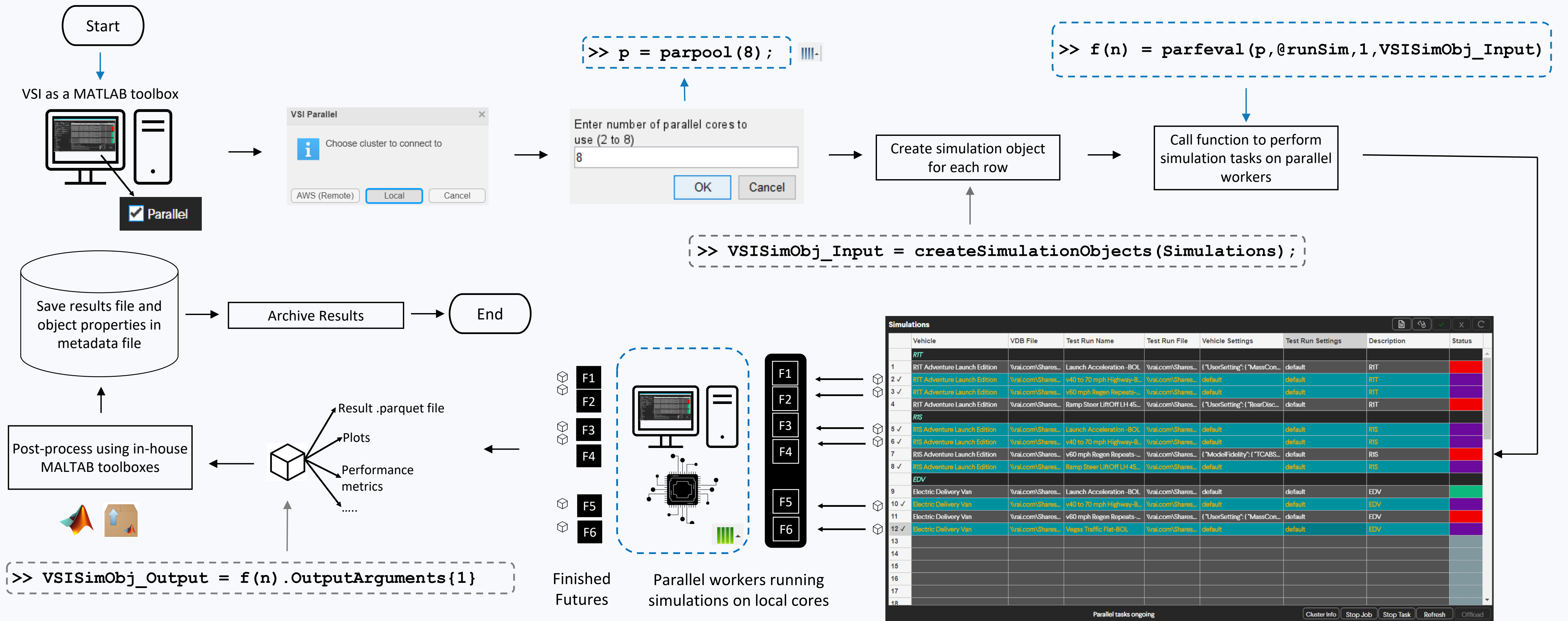
AWS EC2 Instance  
Running MPS / MJS



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



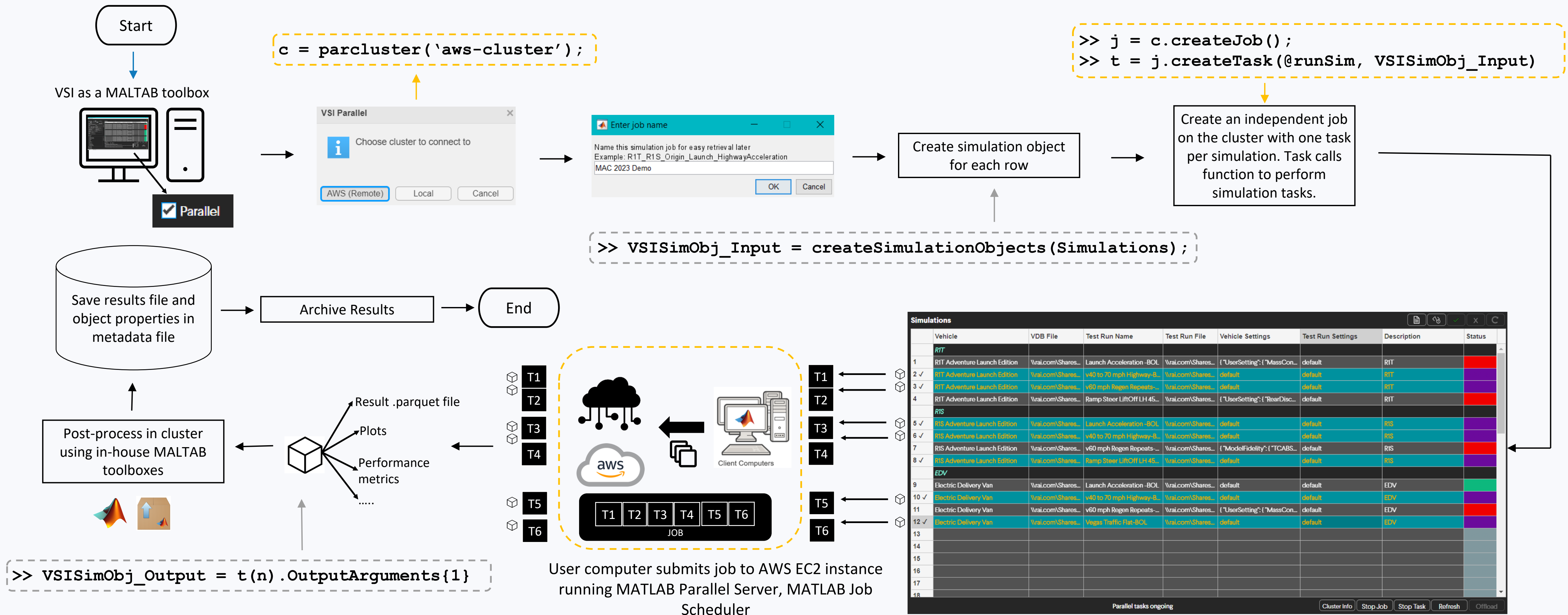
# Parallel Simulations (Local)



Each simulation is a "future". Each future runs a simulation.



# Parallel Simulations (Cluster)



Each simulation is a "task". A collection of simulations is a "job".



# Use Case



User A (GMT)



User B (EST)



User C (PST)

- Users A, B and C are engineers from different time zones on different teams.
- They are working on a tight schedule to simulate various vehicle-drive cycle combinations for an upcoming design review in a couple of days.
- While they work on different attribute parameters, some of their simulation cycles overlap. The simulations take a long time to run, so users must get on with their simulations ASAP.



# Simulation Piggybacking

User A creates a simulation "study" and notices that some simulations have already been run.

Simulations								
	Vehicle	VDB File	Test Run Name	Test Run File	Vehicle Settings	Test Run Settings	Description	Status
	<i>RIT</i>							
1	RIT Adventure Launch Edition	\\rai.com\Shares...	Launch Acceleration -BOL	\\rai.com\Shares...	{"UserSetting": {"MassCon...	default	RIT	Orange
2	RIT Adventure Launch Edition	\\rai.com\Shares...	v40 to 70 mph Highway-B...	\\rai.com\Shares...	default	default	RIT	Green
3	RIT Adventure Launch Edition	\\rai.com\Shares...	v60 mph Regen Repeats...	\\rai.com\Shares...	default	default	RIT	Orange
4	RIT Adventure Launch Edition	\\rai.com\Shares...	Ramp Steer LiftOff LH 45...	\\rai.com\Shares...	{"ModelFidelity": {"Suspen...	default	RIT	Red
	<i>RIS</i>							
5	RIS Adventure Launch Edition	\\rai.com\Shares...	Launch Acceleration -BOL	\\rai.com\Shares...	default	[{"BatteryTemp": "20"}]	RIS	Orange
6	RIS Adventure Launch Edition	\\rai.com\Shares...	v40 to 70 mph Highway-B...	\\rai.com\Shares...	{"ModelFidelity": {"Suspen...	default	RIS	Red
7	RIS Adventure Launch Edition	\\rai.com\Shares...	v60 mph Regen Repeats...	\\rai.com\Shares...	default	default	RIS	Green
8	RIS Adventure Launch Edition	\\rai.com\Shares...	Ramp Steer LiftOff LH 45...	\\rai.com\Shares...	{"ModelFidelity": {"Suspen...	default	RIS	Red
	<i>EDV</i>							
9	Electric Delivery Van	\\rai.com\Shares...	Launch Acceleration -BOL	\\rai.com\Shares...	default	default	EDV	Green
10	Electric Delivery Van	\\rai.com\Shares...	v40 to 70 mph Highway-B...	\\rai.com\Shares...	{"ModelFidelity": {"Suspen...	default	EDV	Red
11	Electric Delivery Van	\\rai.com\Shares...	v60 mph Regen Repeats...	\\rai.com\Shares...	default	default	EDV	Green
12	Electric Delivery Van	\\rai.com\Shares...	Vegas Traffic Flat-BOL	\\rai.com\Shares...	default	default	EDV	Green
13								
14								

User A only runs the red and amber simulations from this study

Simulations								
	Vehicle	VDB File	Test Run Name	Test Run File	Vehicle Settings	Test Run Settings	Description	Status
	<i>RIT</i>							
1 ✓	RIT Adventure Launch Edition	\\rai.com\Shares...	Launch Acceleration -BOL	\\rai.com\Shares...	{"UserSetting": {"MassCon...	default	RIT	Orange
2	RIT Adventure Launch Edition	\\rai.com\Shares...	v40 to 70 mph Highway-B...	\\rai.com\Shares...	default	default	RIT	Green
3 ✓	RIT Adventure Launch Edition	\\rai.com\Shares...	v60 mph Regen Repeats...	\\rai.com\Shares...	default	default	RIT	Orange
4 ✓	RIT Adventure Launch Edition	\\rai.com\Shares...	Ramp Steer LiftOff LH 45...	\\rai.com\Shares...	{"ModelFidelity": {"Suspen...	default	RIT	Red
	<i>RIS</i>							
5 ✓	RIS Adventure Launch Edition	\\rai.com\Shares...	Launch Acceleration -BOL	\\rai.com\Shares...	default	[{"BatteryTemp": "20"}]	RIS	Orange
6 ✓	RIS Adventure Launch Edition	\\rai.com\Shares...	v40 to 70 mph Highway-B...	\\rai.com\Shares...	{"ModelFidelity": {"Suspen...	default	RIS	Red
7	RIS Adventure Launch Edition	\\rai.com\Shares...	v60 mph Regen Repeats...	\\rai.com\Shares...	default	default	RIS	Green
8 ✓	RIS Adventure Launch Edition	\\rai.com\Shares...	Ramp Steer LiftOff LH 45...	\\rai.com\Shares...	{"ModelFidelity": {"Suspen...	default	RIS	Red
	<i>EDV</i>							
9	Electric Delivery Van	\\rai.com\Shares...	Launch Acceleration -BOL	\\rai.com\Shares...	default	default	EDV	Green
10 ✓	Electric Delivery Van	\\rai.com\Shares...	v40 to 70 mph Highway-B...	\\rai.com\Shares...	{"ModelFidelity": {"Suspen...	default	EDV	Red
11	Electric Delivery Van	\\rai.com\Shares...	v60 mph Regen Repeats...	\\rai.com\Shares...	default	default	EDV	Green
12	Electric Delivery Van	\\rai.com\Shares...	Vegas Traffic Flat-BOL	\\rai.com\Shares...	default	default	EDV	Green
13								
14								

User A saves time taken to run 5 out of 12 simulations in his study that were previously simulated by other users.

User B works in EST. User B configures a study and notices that most of the simulations have been simulated by User A. User B creates two additional simulations for towing studies.

Simulations								
	Vehicle	VDB File	Test Run Name	Test Run File	Vehicle Settings	Test Run Settings	Description	Status
	<i>RIT</i>							
1	RIT Adventure Launch Edition	\\rai.com\Shares...	Launch Acceleration -BOL	\\rai.com\Shares...	{"UserSetting": {"MassCon...	default	RIT	Green
2	RIT Adventure Launch Edition	\\rai.com\Shares...	v40 to 70 mph Highway-B...	\\rai.com\Shares...	default	default	RIT	Green
	<i>RIS</i>							
3	RIS Adventure Launch Edition	\\rai.com\Shares...	Launch Acceleration -BOL	\\rai.com\Shares...	default	[{"BatteryTemp": "20"}]	RIS	Green
4	RIS Adventure Launch Edition	\\rai.com\Shares...	v40 to 70 mph Highway-B...	\\rai.com\Shares...	default	default	RIS	Green
	<i>RIT/RIS Towing</i>							
5 ✓	RIT Adventure + 11000 lb Trailer	\\rai.com\Shares...	v50 to 70 mph Highway-B...	\\rai.com\Shares...	{"XMM": {"DriveMode": "E...	default		Red
6 ✓	RIS + 7700 lb Trailer	\\rai.com\Shares...	v50 to 70 mph Highway-B...	\\rai.com\Shares...	default	default		Red

User B saves time taken to run 4 out of 6 simulations in his study that were previously simulated by other users including user A.

User C works in PST. User C configures a study and finds that ALL simulations have been completed. User C goes ahead with analyzing the data and creating reports.

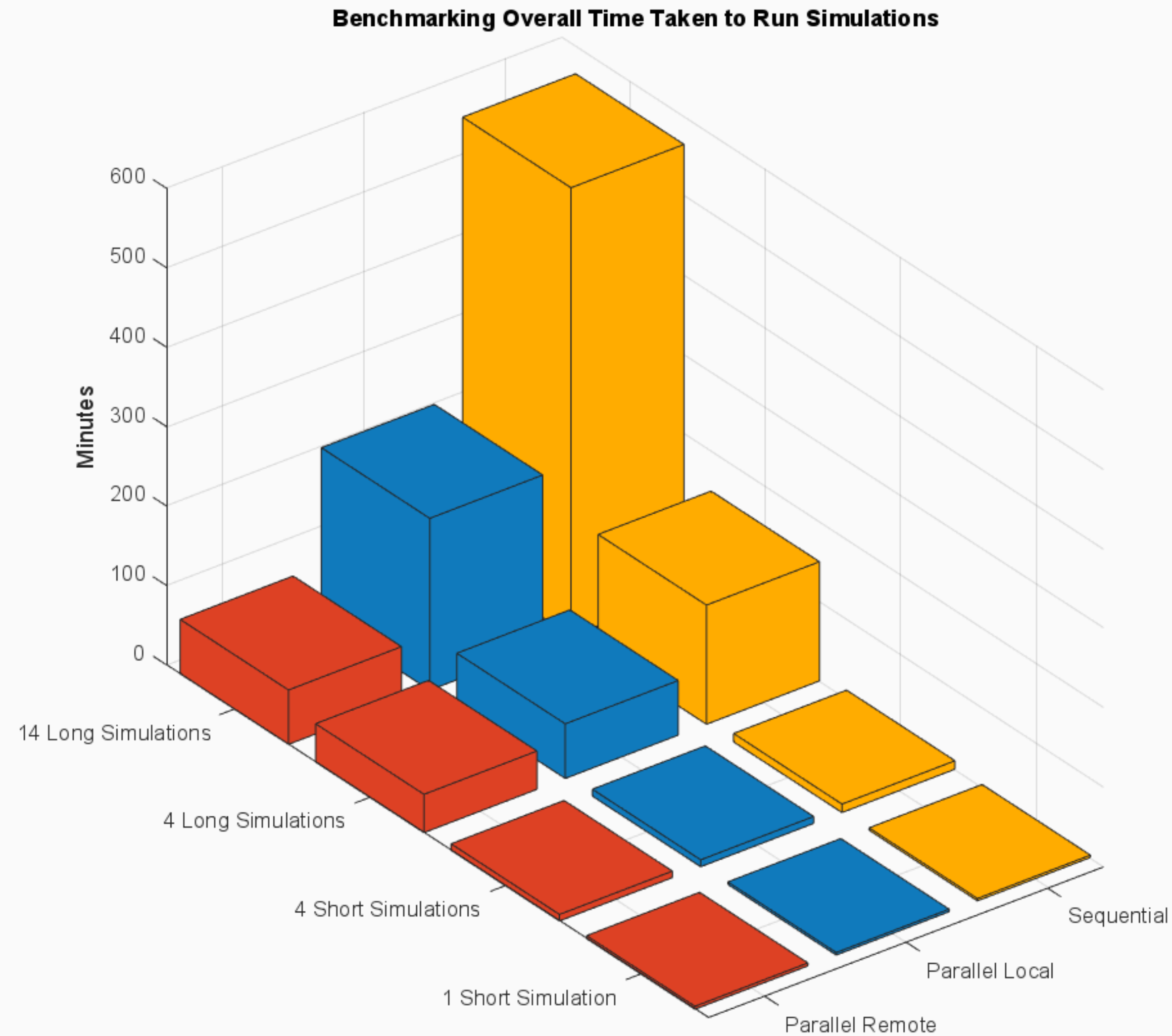
Simulations								
	Vehicle	VDB File	Test Run Name	Test Run File	Vehicle Settings	Test Run Settings	Description	Status
	<i>RIT</i>							
1	RIT Adventure Launch Edition	\\rai.com\Shares...	Launch Acceleration -BOL	\\rai.com\Shares...	{"UserSetting": {"MassCon...	default	RIT	Green
2	RIT Adventure Launch Edition	\\rai.com\Shares...	v40 to 70 mph Highway-B...	\\rai.com\Shares...	default	default	RIT	Green
3	RIT Adventure Launch Edition	\\rai.com\Shares...	v60 mph Regen Repeats...	\\rai.com\Shares...	default	default	RIT	Green
4	RIT Adventure + 11000 lb Trailer	\\rai.com\Shares...	v50 to 70 mph Highway-B...	\\rai.com\Shares...	default	default	RIT	Green
5								
6								
7								
8								
9								

User A does not run any new simulations. Uses existing results and post-processes.



# Benchmarking Simulation Speeds

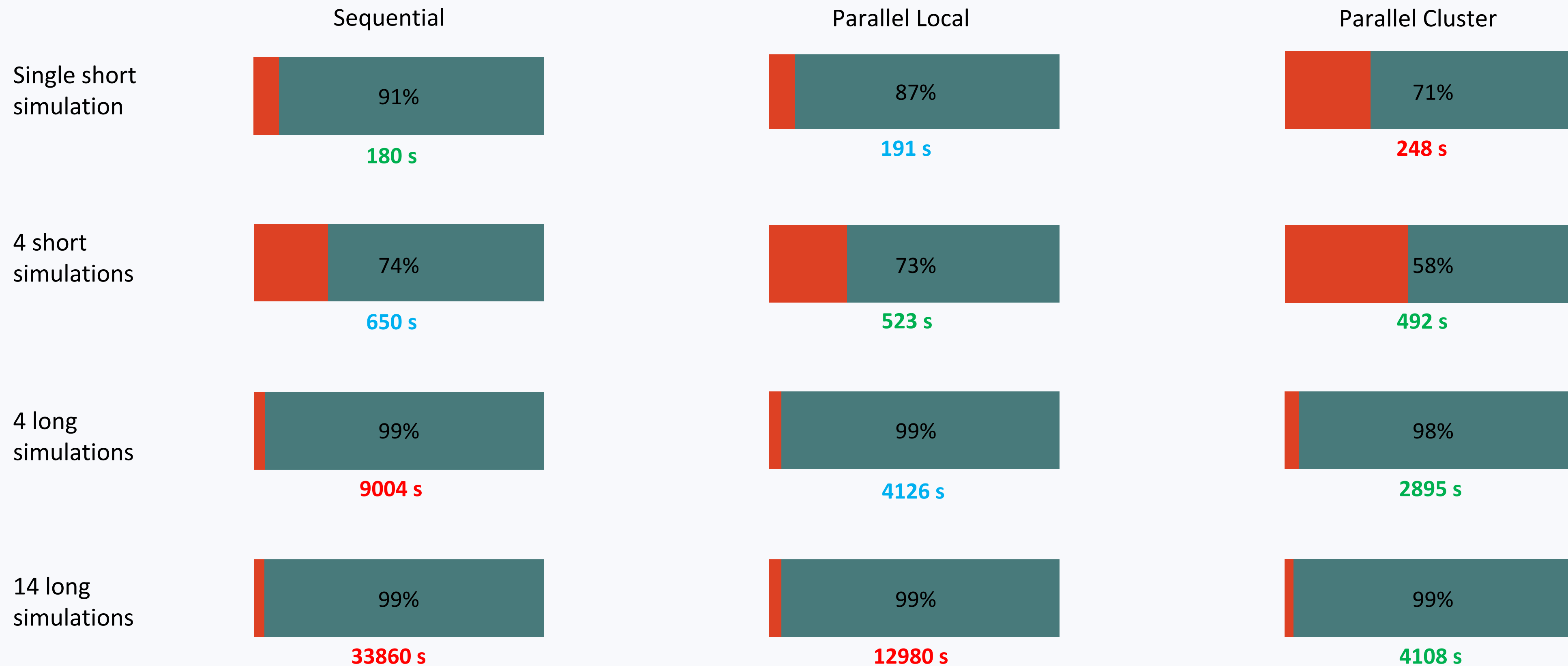
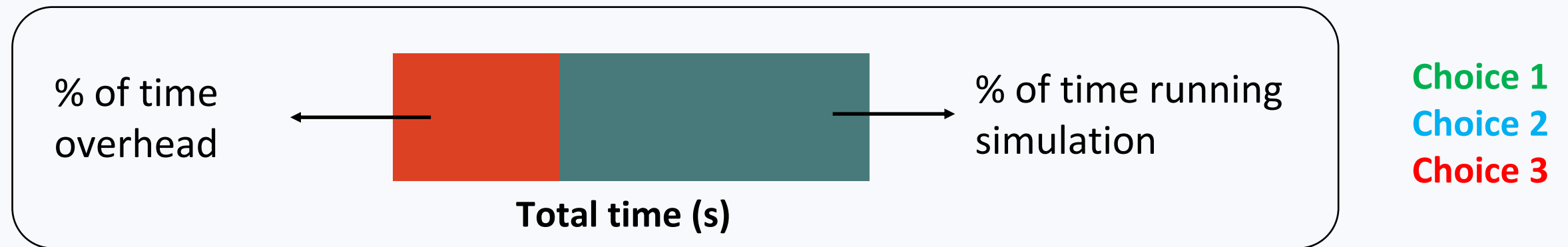
# Time Taken to Run Simulations



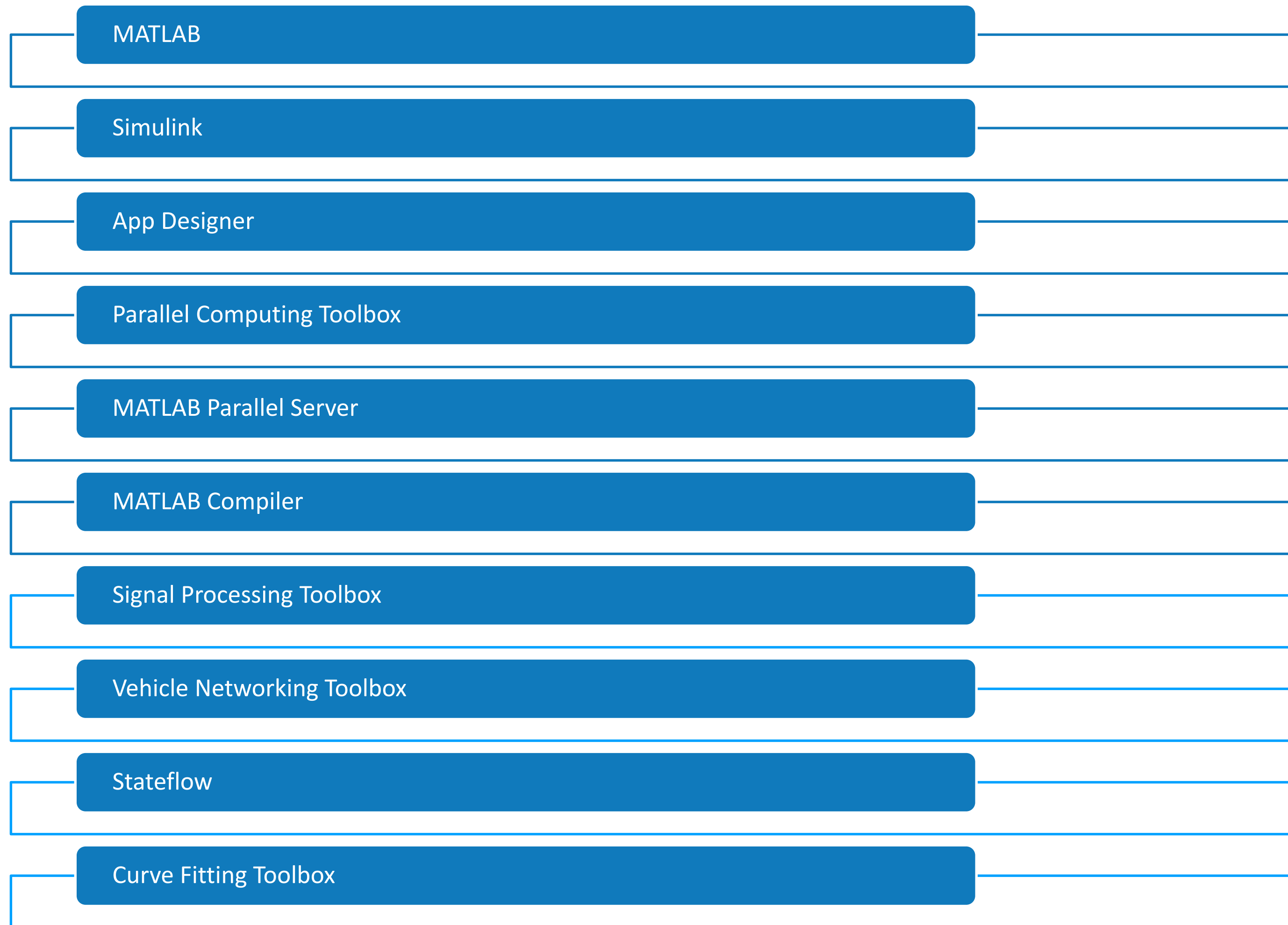
- Sequential is fastest for single short simulations
- Parallel simulations on cluster is best when running multiple long simulations
- Parallel local is best suited for developers testing changes to models



# Overhead vs Simulation Time



# MathWorks Products in VSI





# Closing Points

## What we have achieved with this toolchain:

- **Single platform** for users to run simulations, post-process and create reports
- **“Simulations for Everyone”** – accessibility to vehicle simulations for non-simulation users
- Eliminated **simulation request bottleneck**
- **Reduced redundancy** in simulation tasks
- **Simulation reuse**
- Maximized throughput with **parallel simulations**

## What's next:

- VSI as a web app
- Move from EC2 instances to clusters for “unlimited” computing power
- Enhanced simulation data management
- Dashboard for KPIs

# Rivian MATLAB Minimart

A store for in-house MATLAB toolboxes at Rivian with version control and auto-update capabilities

- **Auxiliary Tools** – Supporting Functions
- **Data Converter** – Convert different data files to a common format
- **Dynamics Tools** – Functions for the dynamics team
- **Launch Toolbox** – Automated launch analysis toolbox
- **Rivian Data Viewer**
- **Rivian Toolbox Viewer**
- **Range & Efficiency Toolbox** – toolbox for processing step steer maneuvers
- **VehicleDB** – Vehicle Database for simulation data

and more..



Rivian Data Viewer



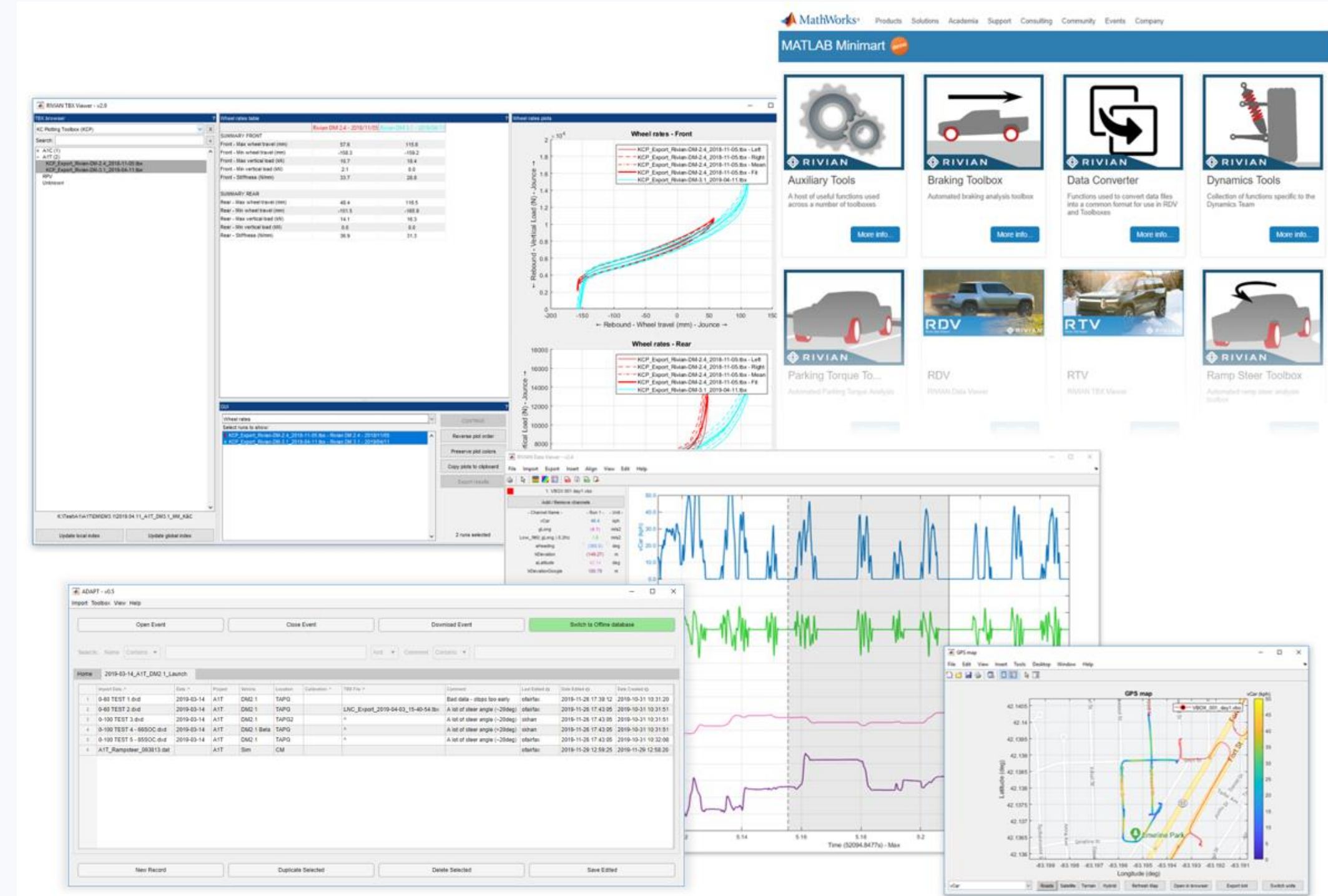
Rivian Toolbox Viewer



Vehicle Database



Vehicle Simulation Interface





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# Thank you

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