MATLAB EXPO

国六车辆的预测性健康检查- 数字孪生的产品化落地

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MathWorks

THE POWER OF CUMMINS

- The world’s largest independent engine manufacturer, found in 1919
- 23Bil USD revenue in 2018
- Global manufacturing & distribution in 190+ countries and territory, with over 60,000 employees
- China business started in 1975. 30+ manufacturing & distribution locations with over 10,000 China employees






DIGITAL TO ENABLE CUMMINS TRANSFORMATION

Cummins is not just an engine company…

Cummins is a technology company with a broad range of power solutions

Cummins digital mandate:

We will leverage Digital technologies to **transform customers' experience with Cummins products & services**.

- Smart device
- Connected solutions
- Big Data driven operations

什么是预测性健康检查

预测性健康检查是数字孪生产品生命周期管理中的重要技术。

<u>什么是预测性健康检查?</u>

- 一种预测技术
- 数据驱动
- 基于机器学习模型
- 差异化/定制化服务战略

为什么选 MATLAB?

数据处理

- **MATLAB 基础信号处理** 为我们带来更多挖掘数据价值的机会，提高工作效率，开发数据科学相关产品。

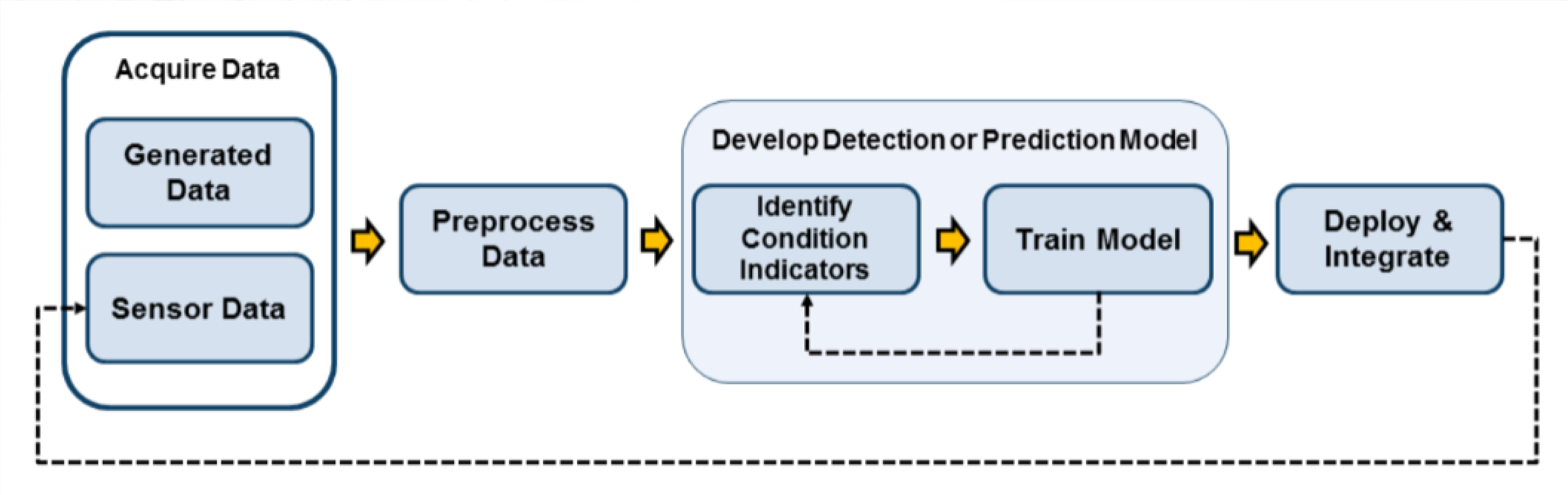
机器学习

- **MATLAB Statistics and Machine Learning Toolbox** 加快了模型选择处理的速度。

机理模型

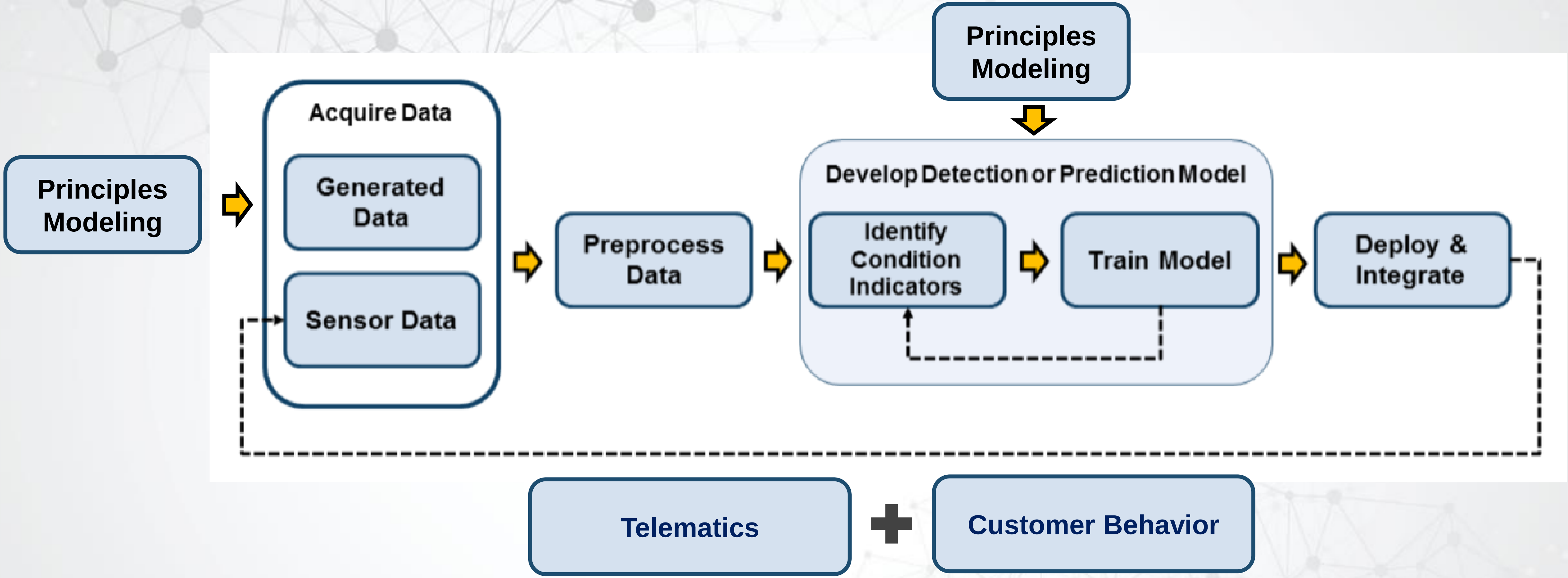
- **Simulink** 帮助将原理模型和机器学习耦合在一起，包括建立调优数据集，在线实时运行。

概念 - 基于模型的预测



* Overcoming Four Common Obstacles to Predictive Maintenance with MATLAB and Simulink White Paper

概念 - 基于模型的预测



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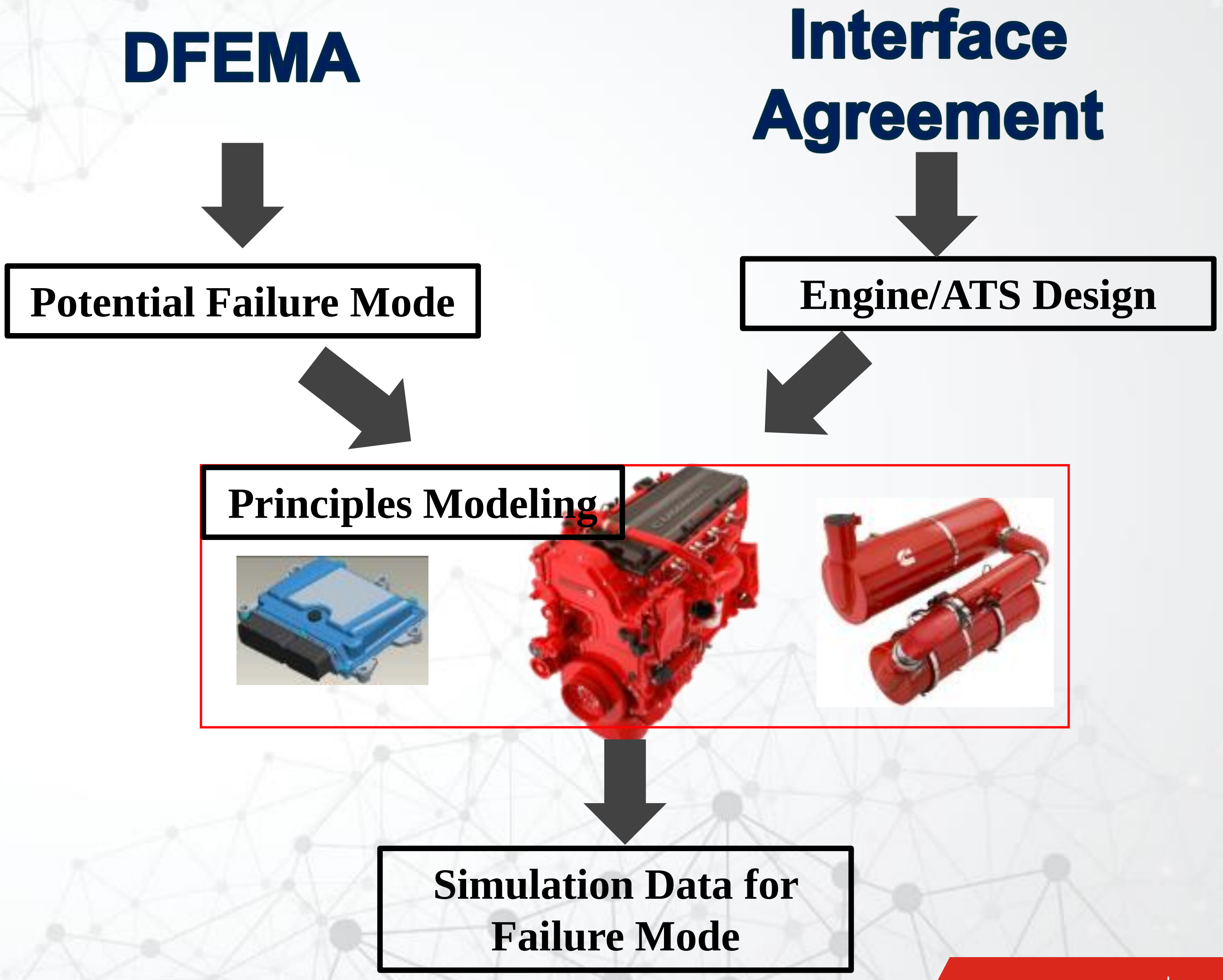
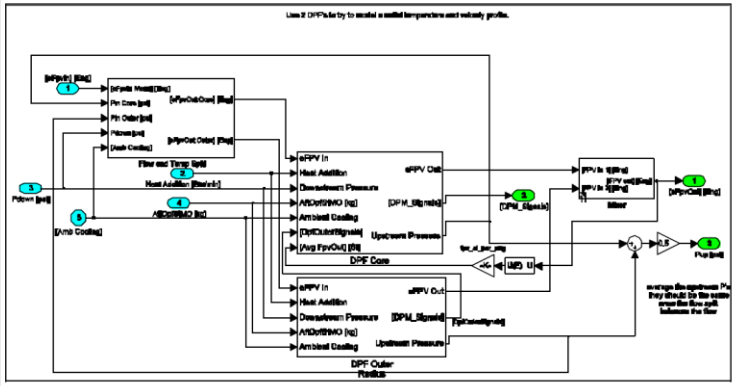
基于Simulink使用DFEMA和机理建模

- 根据DFEMA和服务数据估计发动机相关故障模式。
- 以原理建模为基础，建立提案产品的模型。
- 运行原理模型与控制模型收集数据
- 利用故障数据、历史测试数据和模拟数据来调整数据科学模型。

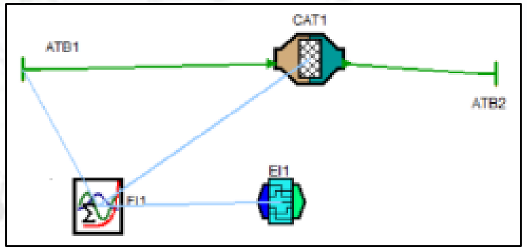


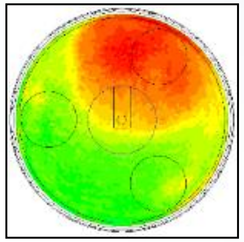
MATLAB&Simulink为基础 使用DFEMA和原理建模

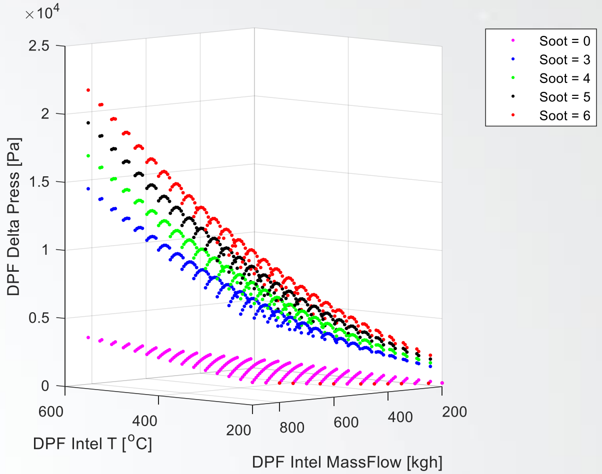
Simulink Platform



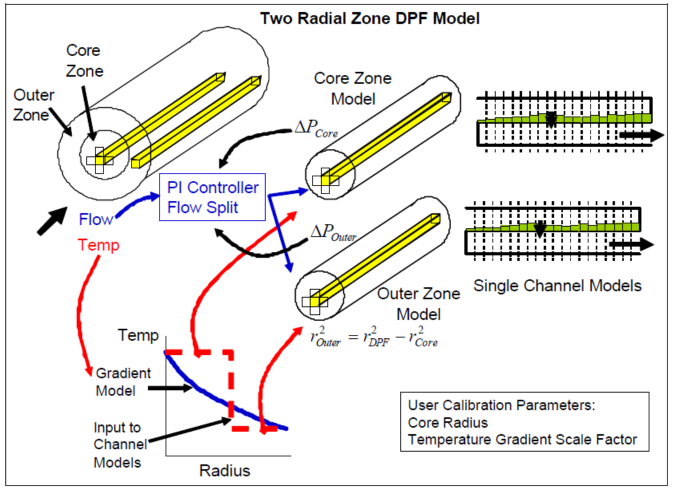
0D & 1D & 3D Coupling Simulation

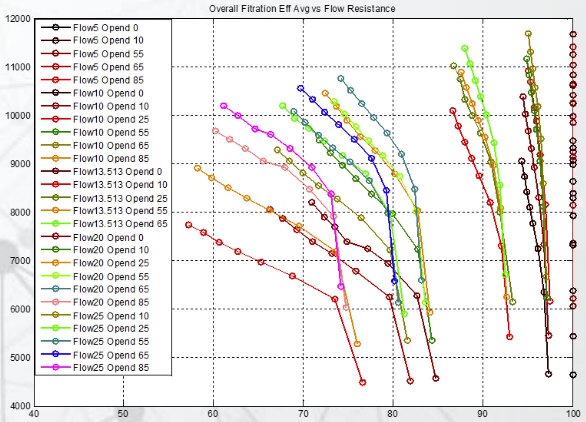






Failure Simulation for Parallel Zone Model





特征工程 - MATLAB信号分析

Porous Media Princely Formula – Ergun

$$\frac{\Delta P}{L}=\frac{150(1-\varepsilon)^2}{d^2\varepsilon^3}\mu u+\frac{7(1-\varepsilon)}{4d\varepsilon^3}\rho u^2$$

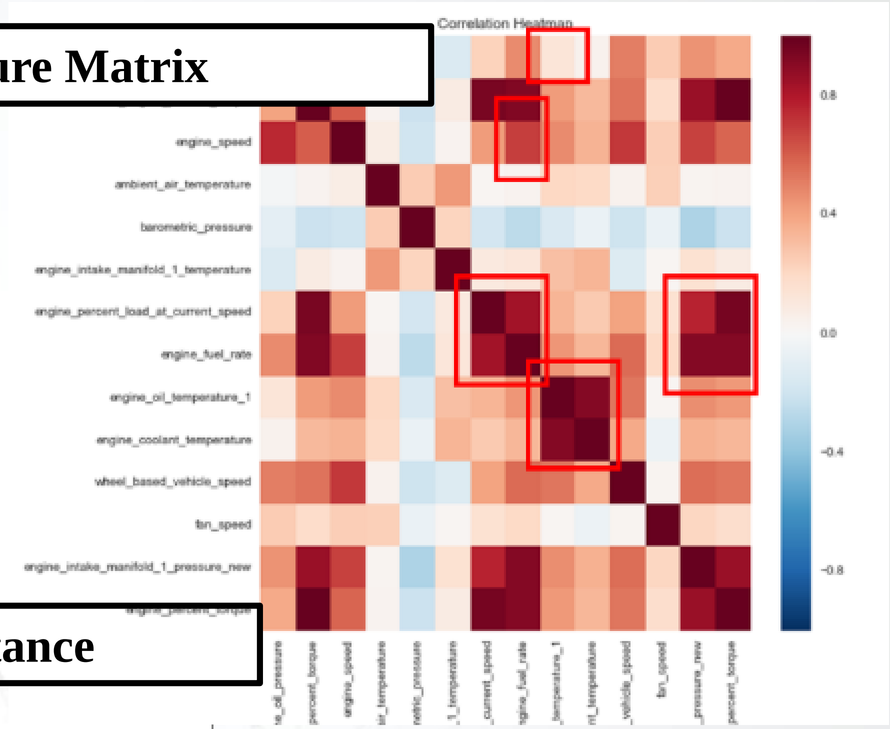
$$u=\frac{Q}{\rho A}=\frac{4Q}{\rho\pi d_c^2}$$

$$\frac{\mu}{\mu_0}=\left(\frac{T}{288.15}\right)^{1.5}\frac{288.15+B}{T+B}$$

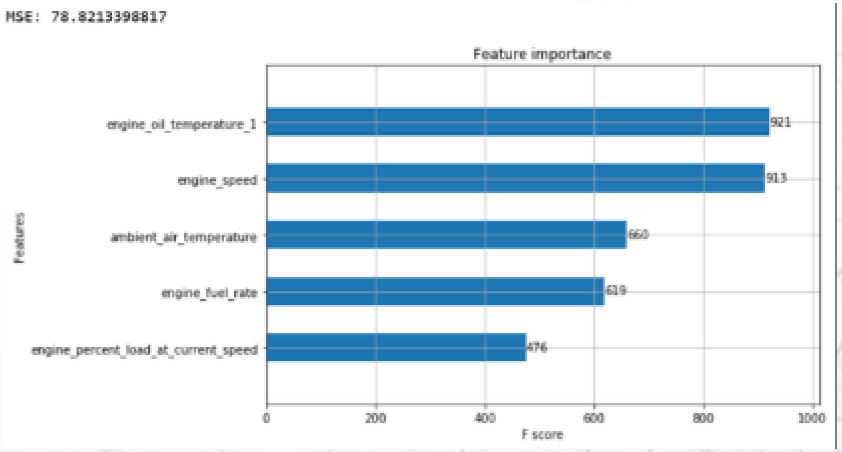
Air B=110.4 K

$$\Delta P=L\left(\frac{600(1-\varepsilon)^2}{\rho\pi d^2 d_c^2}\mu Q+\frac{28(1-\varepsilon)}{\rho d\varepsilon^3\pi^2 d_c^4}Q^2\right)$$

Feature Matrix

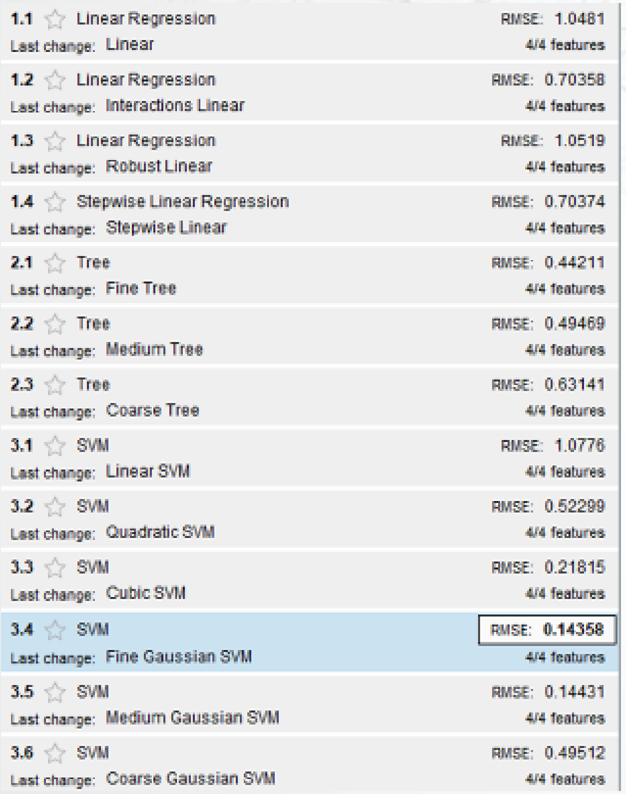


Feature Importance

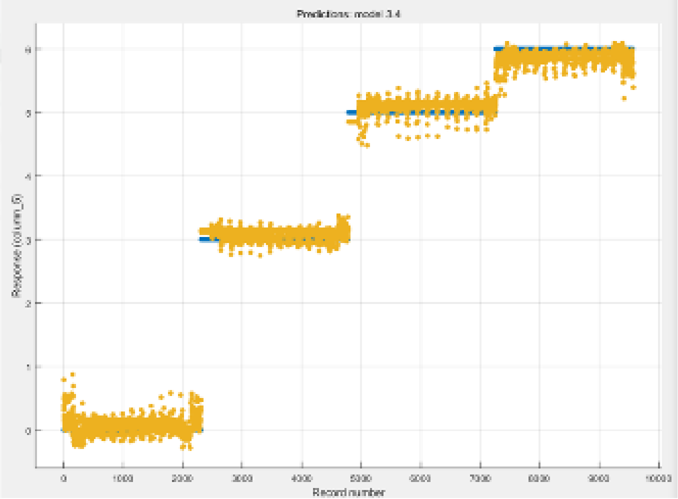


模型开发 - MATLAB机器学习

模型选择

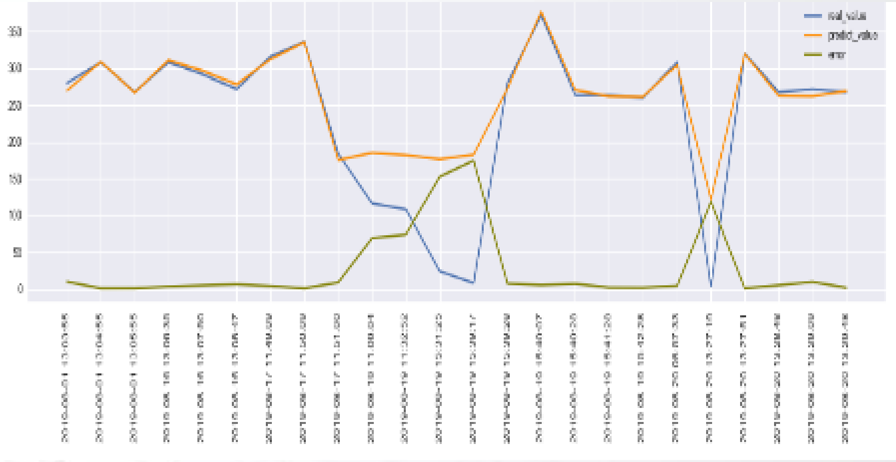


模型校验



MATLAB的工具包 在模型选择方面加速了过程。

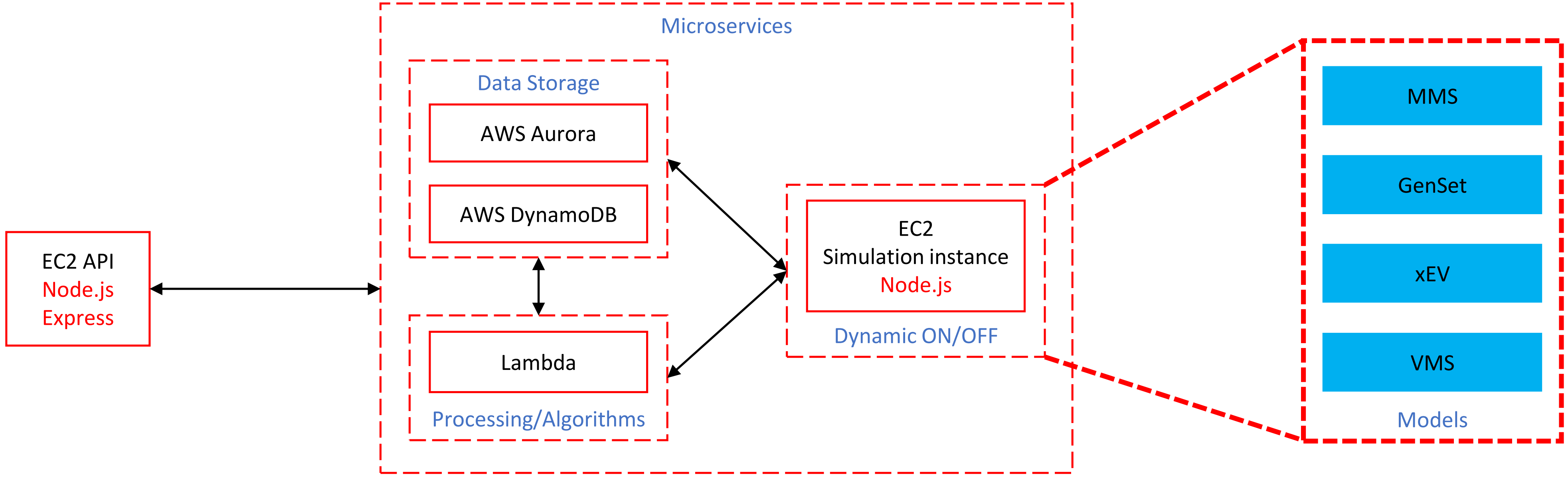
模型验证



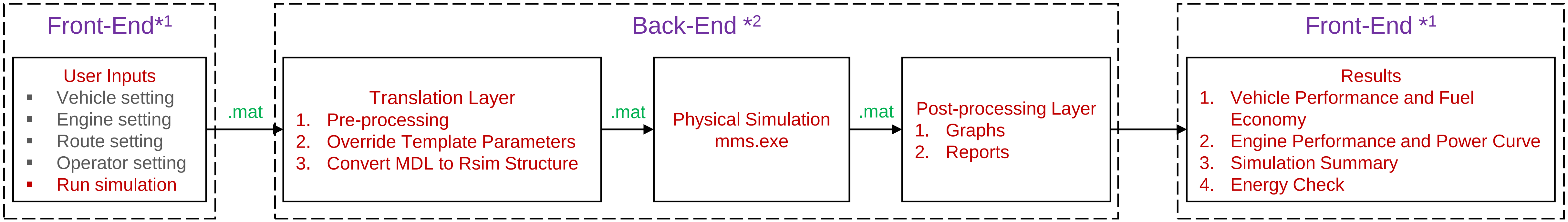
基于失效数据，建立云端数学模型.

云端仿真

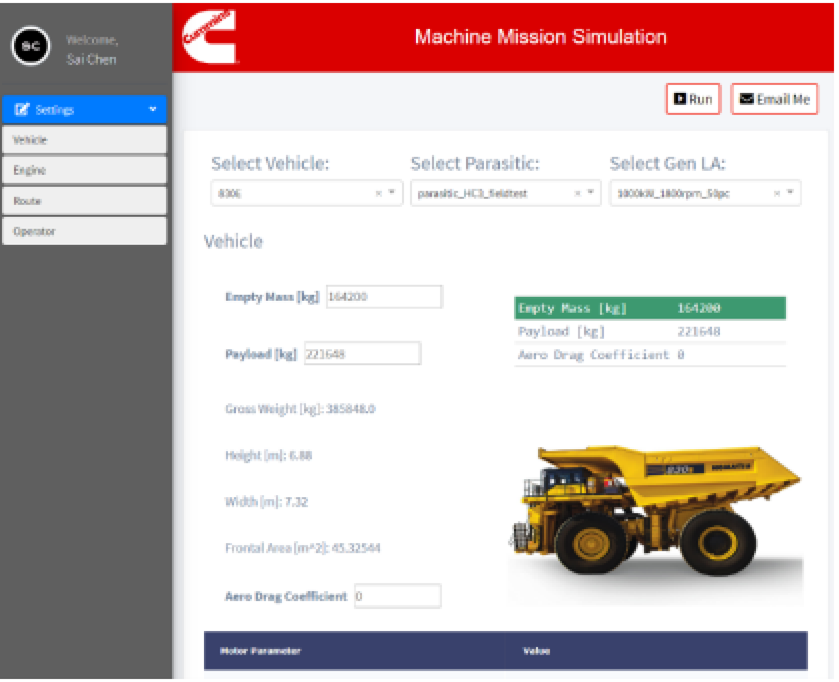
微服务



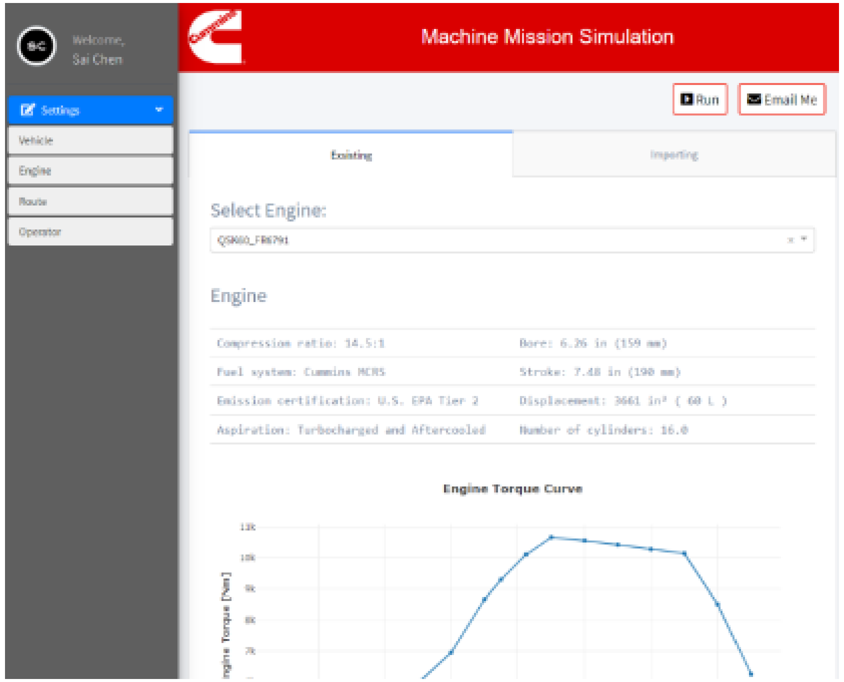
云端仿真模型



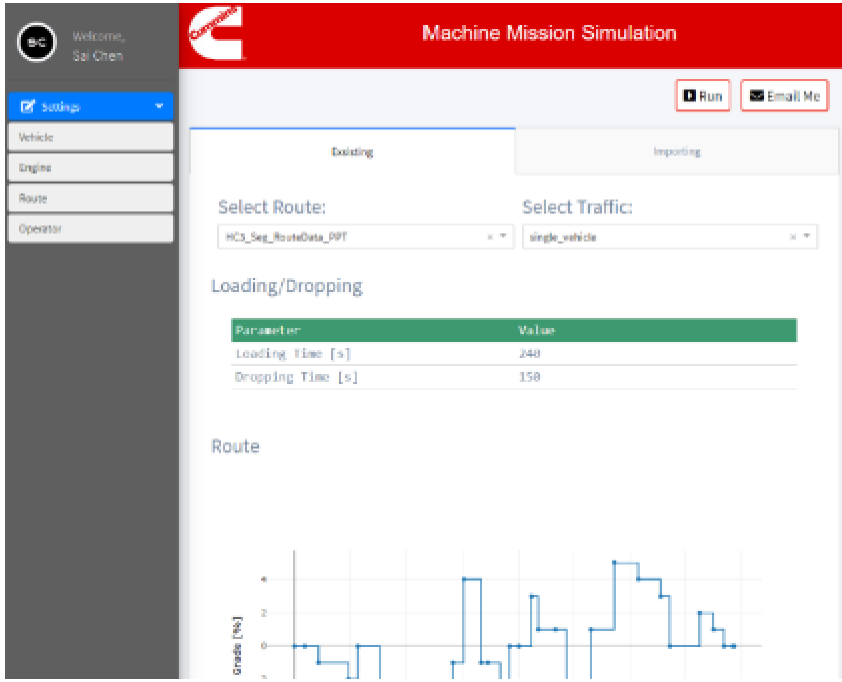
模型运算结果展示



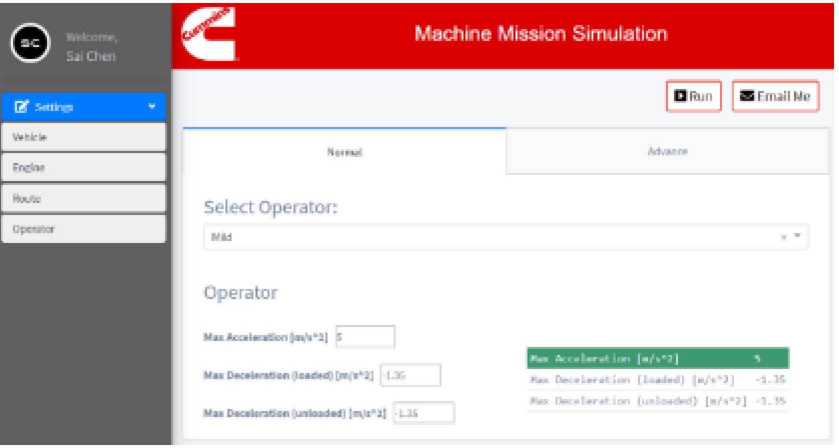
Welcome,
Sai Chen
Settings
Vehicle
Engine
Route
Operator
Machine Mission Simulation
Run
Email Me
Select Vehicle:
Select Parasitic:
Select Gen LA:
Vehicle
Empty Mass [kg]
Payload [kg]
Aero Drag Coefficient
Motor Parameter
Value



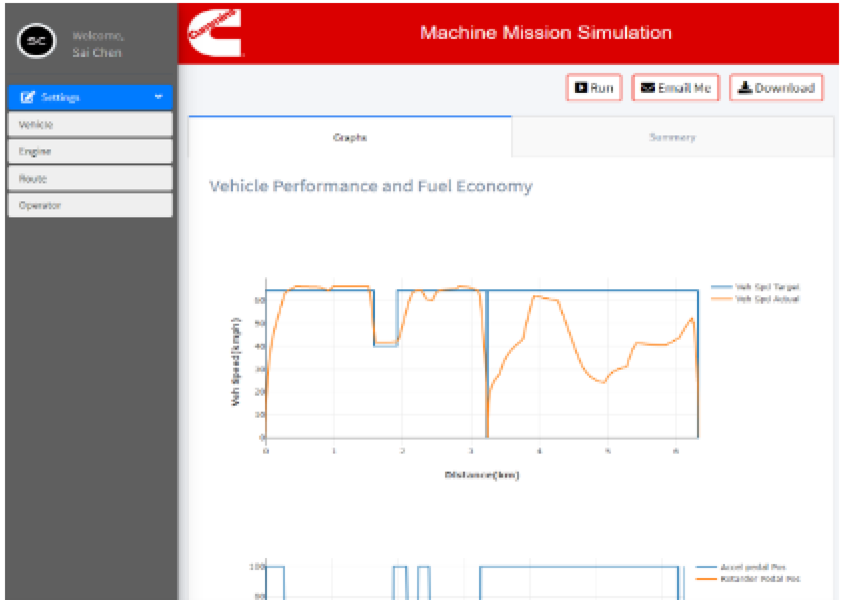
Welcome,
Sai Chen
Settings
Vehicle
Engine
Route
Operator
Machine Mission Simulation
Run
Email Me
Existing
Importing
Select Engine:
Engine
Engine Torque Curve



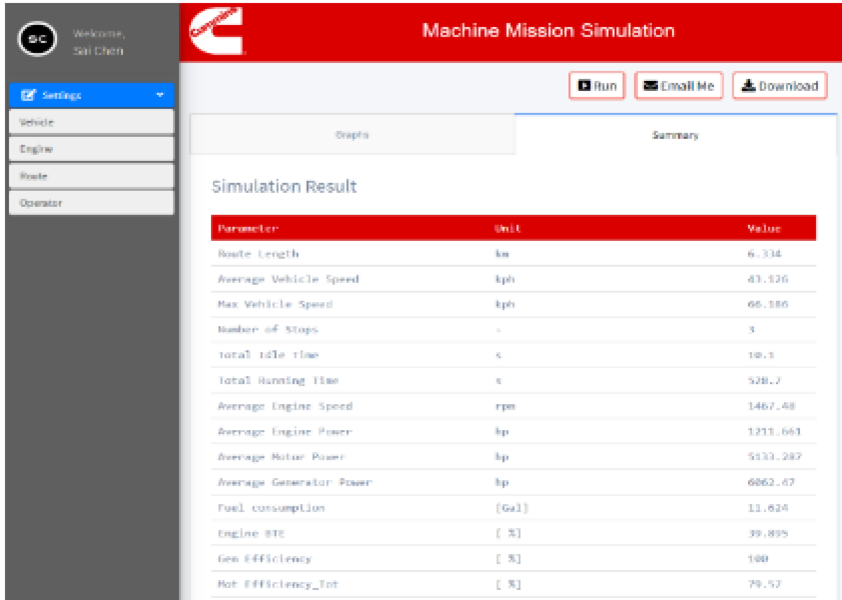
Welcome,
Sai Chen
Settings
Vehicle
Engine
Route
Operator
Machine Mission Simulation
Run
Email Me
Existing
Importing
Select Route:
Select Traffic:
Loading/Dropping
Parameter
Value
Loading Time [s]
240
Dropping Time [s]
150
Route



Welcome,
Sai Chen
Settings
Vehicle
Engine
Route
Operator
Machine Mission Simulation
Run
Email Me
Normal
Advance
Select Operator:
Operator



Welcome,
Sai Chen
Settings
Vehicle
Engine
Route
Operator
Machine Mission Simulation
Run
Email Me
Download
Graphs
Summary
Vehicle Performance and Fuel Economy
Distance(km)



Welcome,
Sai Chen
Settings
Vehicle
Engine
Route
Operator
Machine Mission Simulation
Run
Email Me
Download
Graphs
Summary
Simulation Result
Parameter
Unit
Value

CHALLENGES AND REFLECTION

1

Data Availability

- Data engineering capability
- Enterprise data lake

2

Value Creation

- Value engineering capability
- Business ownership
- Change management

3

Talent Pipeline

- Prepare for competition
- Inclusive and diversity

Demanding that everything we do leads to a cleaner, healthier, safer environment.

我们致力于构建一个更清洁、更健康、更安全的环境

Thank You!

谢谢!

Email：Seth.S.Sun@hotmail.com

Q+A