Integration of Python-Based AI Models with Simulation and Hardware Deployment

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Electrical Device Development,
TS TECH Co.,Ltd.

TS TECH Co.,Ltd.

Agenda

1. Our Company
2. Products We Aim for
3. Estimation of Fatigue Level
4. Implement Algorithm in ECU
5. Conclusion

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Corporate Profile

TS TECH Co., Ltd.

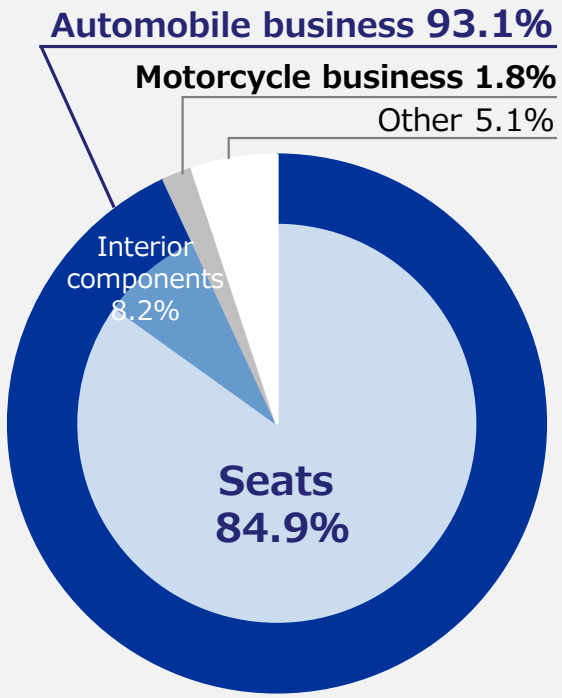
(Prime Market, Tokyo Stock Exchange
Name: TS TECH Securities Code: 7313)

- President Masanari Yasuda
- Established Dec. 5, 1960
- Head office Asaka-shi, Saitama
- Capital stock 4.7 billion yen
- Total number of shares issued 136 million
- Lines of business
  Manufacture and sale of automobile seats; automobile interiors; motorcycle seats; and resin-based products for motorcycles
- Consolidated number of employees
  14,719

FY2024 consolidated sales

Consolidated net sales **¥441.7 billion**

【Sales breakdown】



Lines of Business

	Automobile business	Motorcycle business
Business fields	 ▲Automobile seats  ▲Door trim  ▲Lighting components	 ▲▼Motorcycle seats 
Main customers	Honda Suzuki Volkswagen	Honda Suzuki Yamaha Kawasaki Harley-Davidson

Internal Structure of a Multifunction Seat

Main components

*Image of seat features

Electronic components

Safety features	Side airbag	Electronic control unit (ECU)
	Occupant posture sensor (passenger seat)	
	Occupant weight sensor (passenger seat)	
	Seat position sensor (driver's seat)	
Comfort features	Power slide	
	Power reclining	
	Power height adjuster	
	Air lumbar support	
	Ventilation system	

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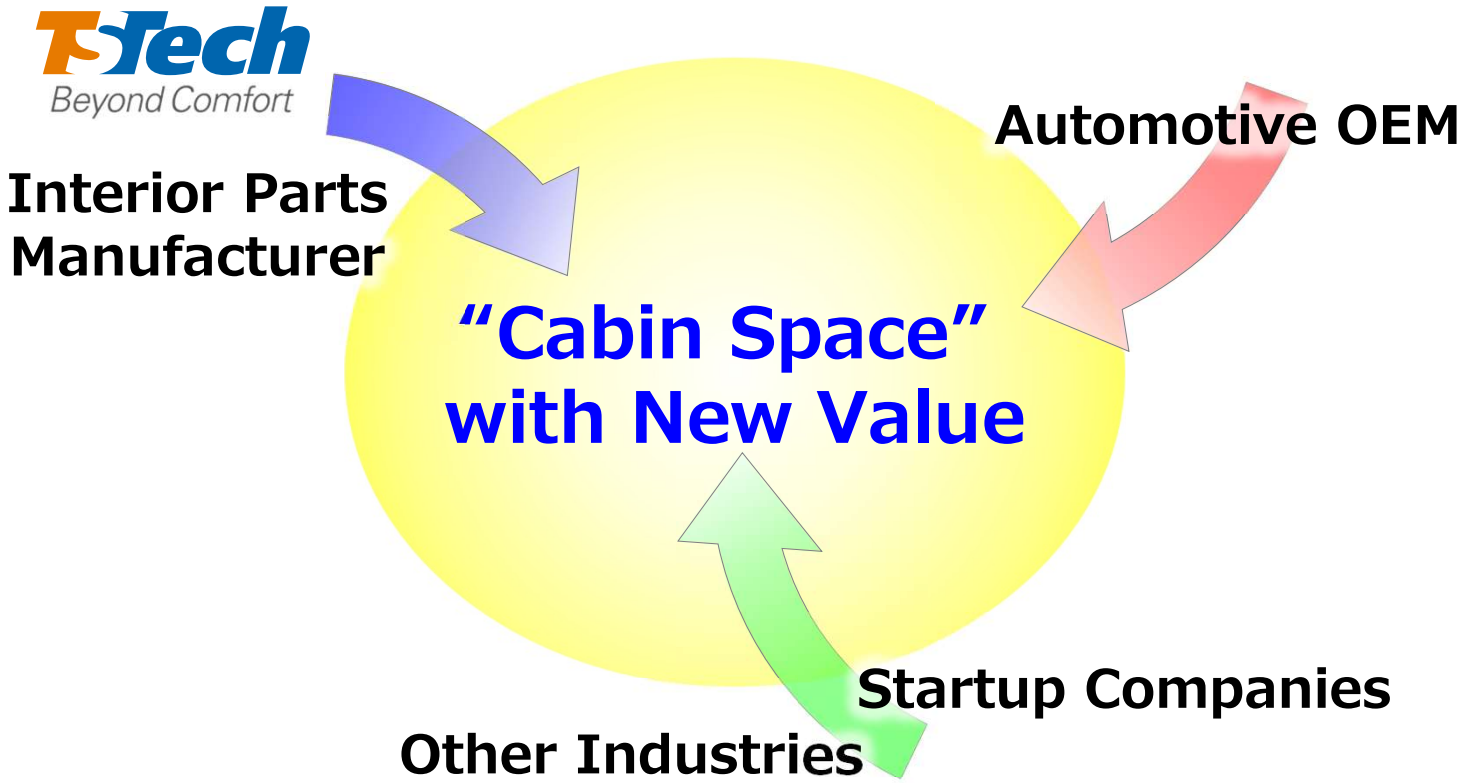
Proposing New Value for Cabin Space

Pursue "Human-centered" comfortable and attractive spaces

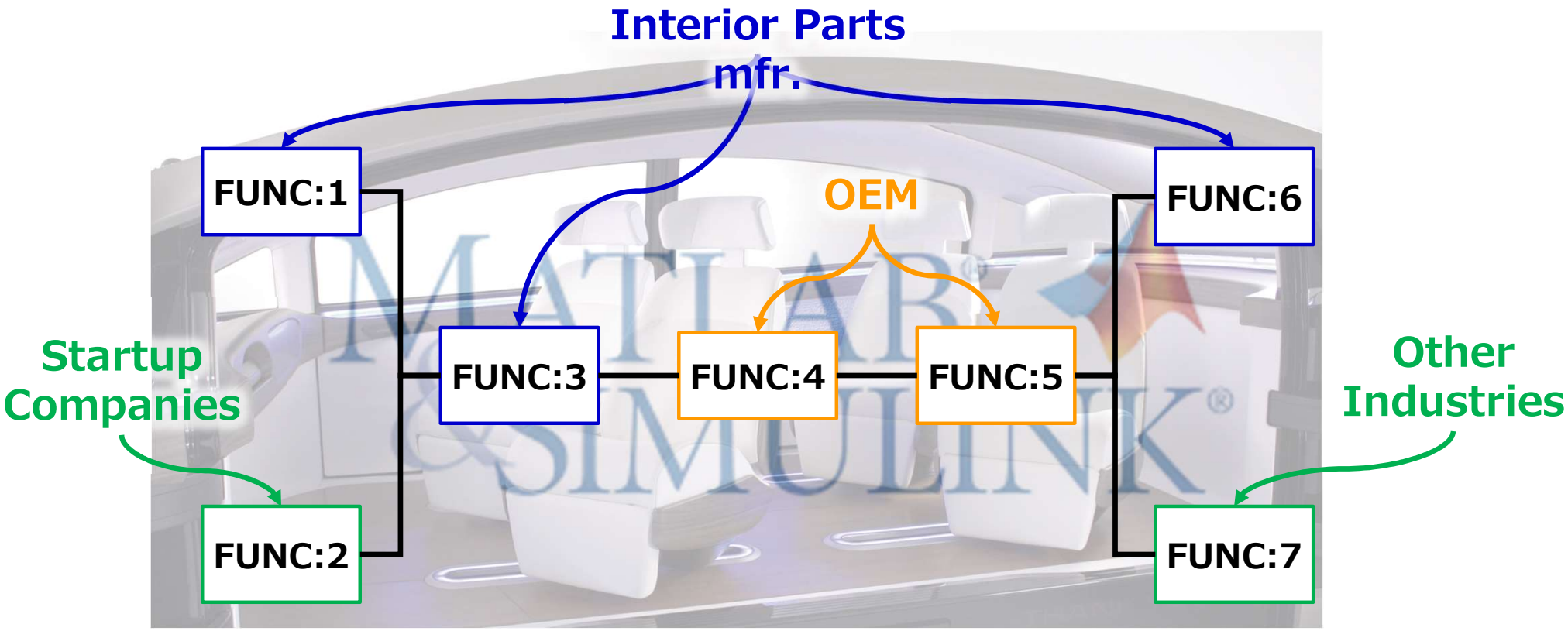
Challenges for New Value



We need …

Cooperation with companies with diverse development cultures

Integrate functionality using MATLAB®/Simulink®



MATLAB®/Simulink® = environment for the integration of "functions"

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Development Background

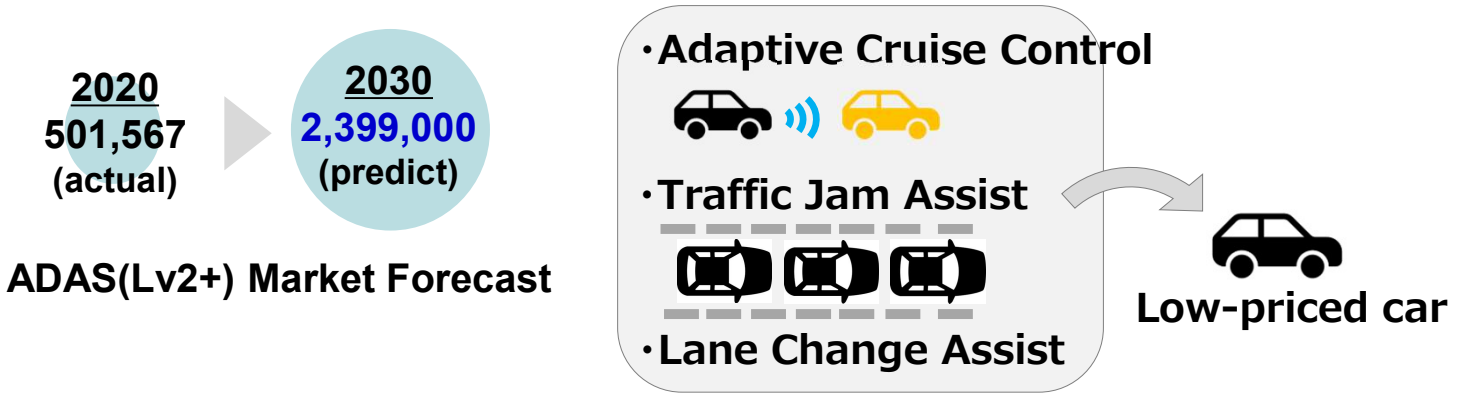
We need …

technology to know the state of human

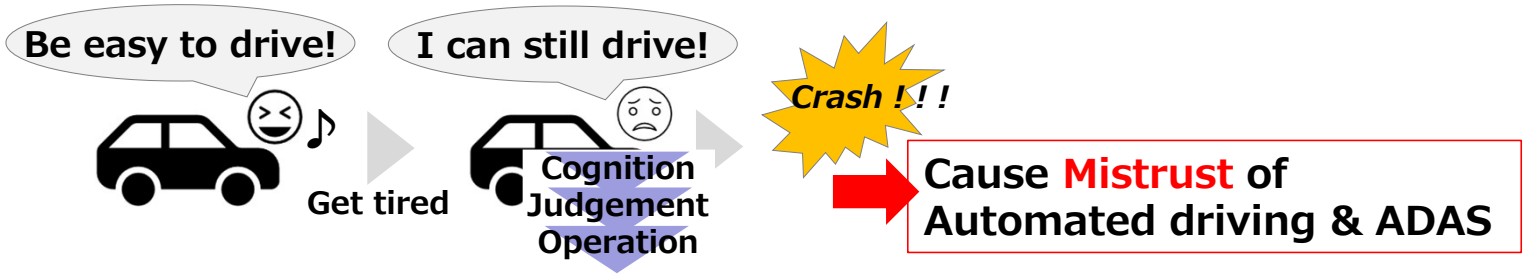
“Human-centered” comfortable and attractive spaces

Need for Driver Fatigue Estimation

Development of automated driving technology

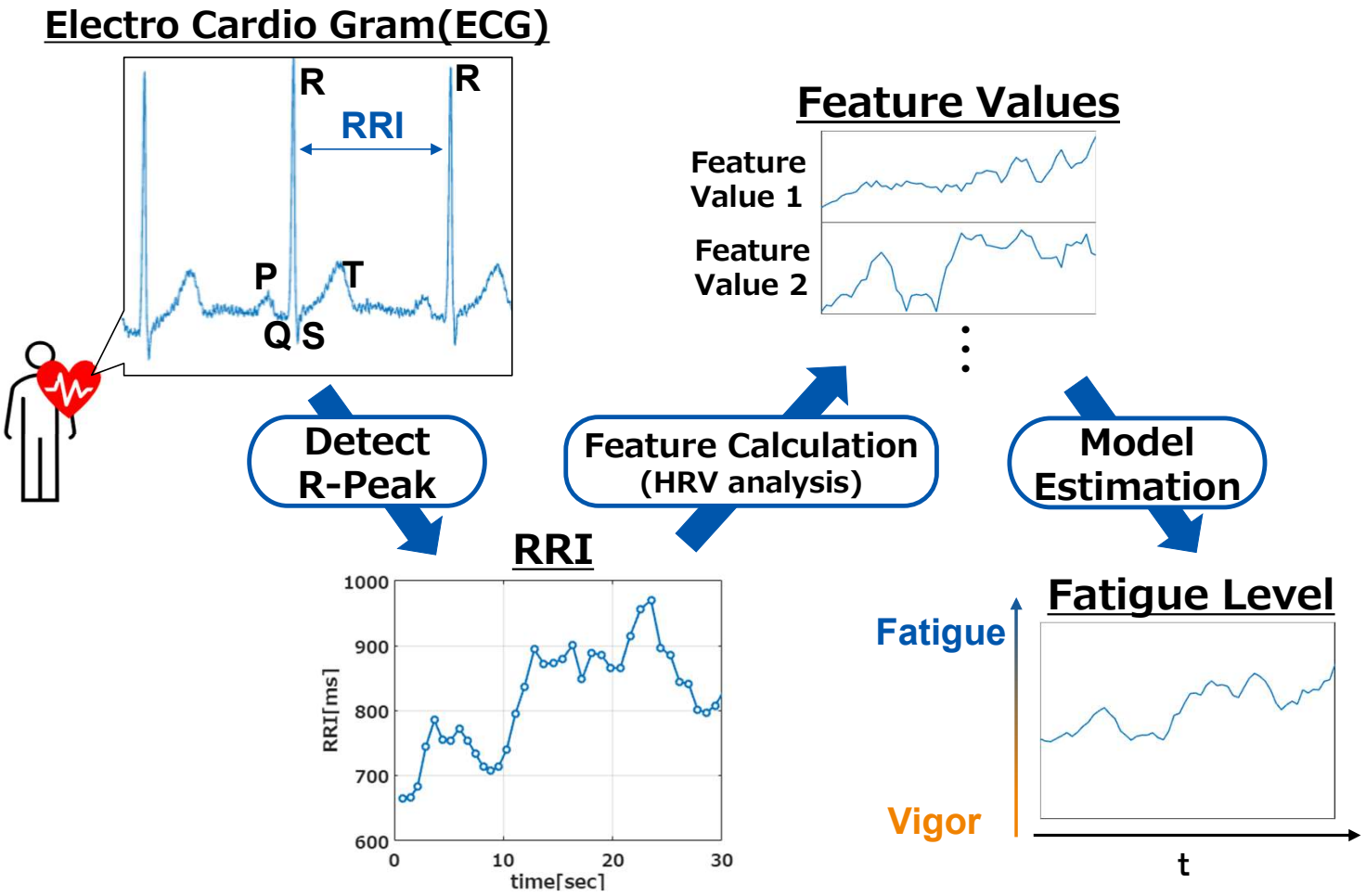


Reliance on Driver Assistance System

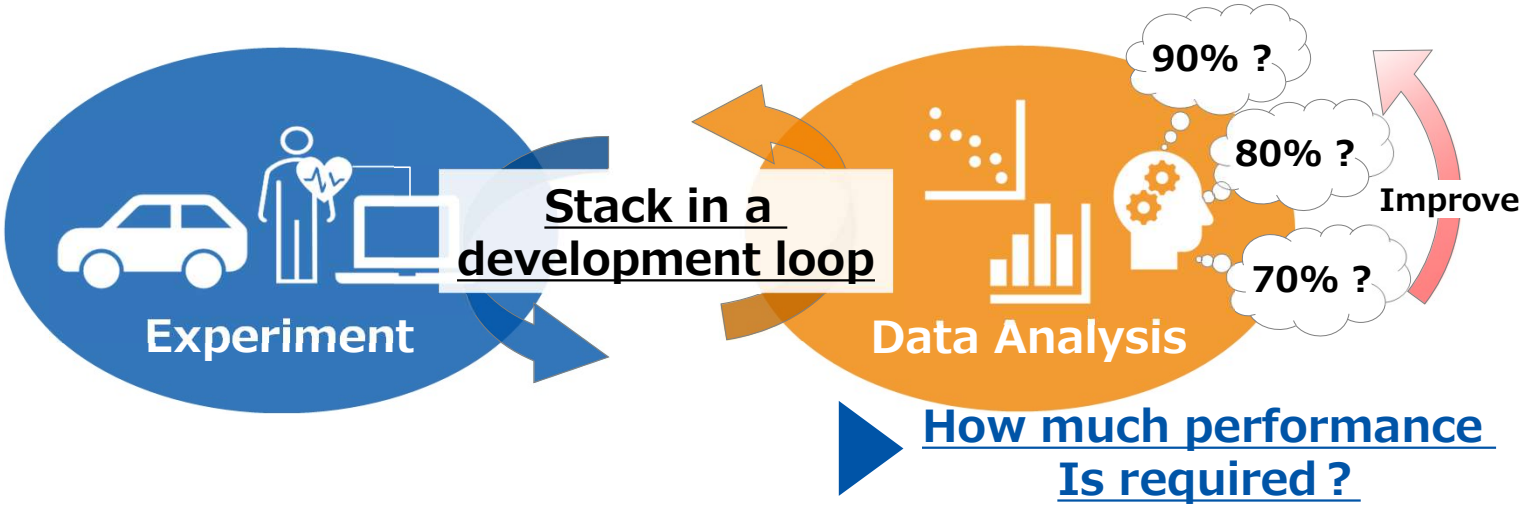


For safe driving, it is necessary to estimate fatigue and encourage rest breaks at appropriate times.

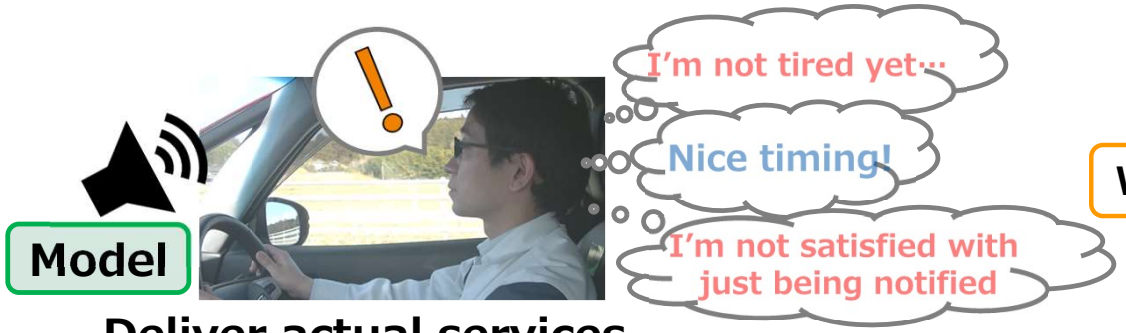
Overview of Fatigue Estimation Algorithm



Challenges in Algorithm Development



How much performance Is required ?



Deliver actual services

We need …

Run the model in real time

… Can the current model provide value ?

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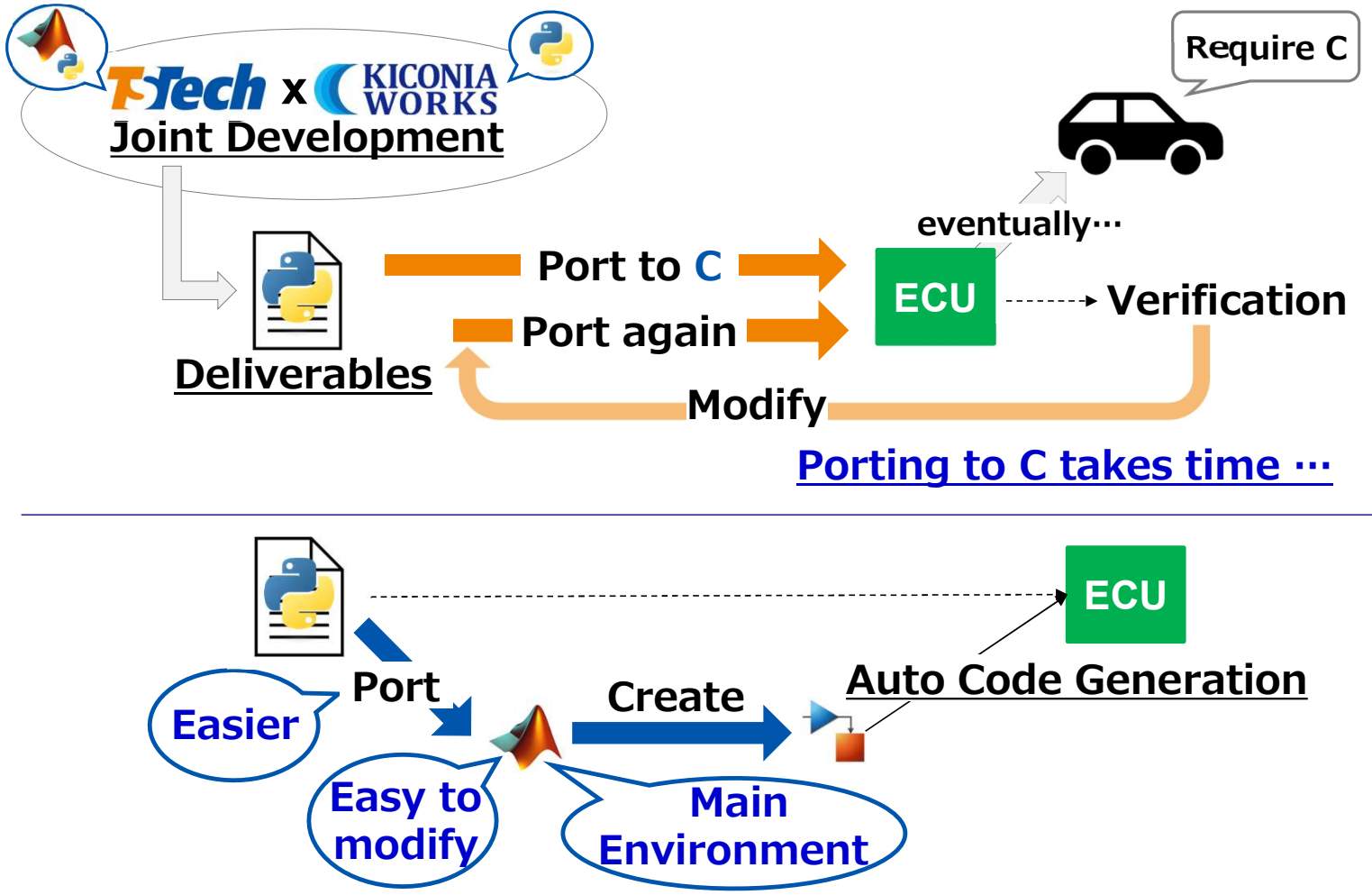
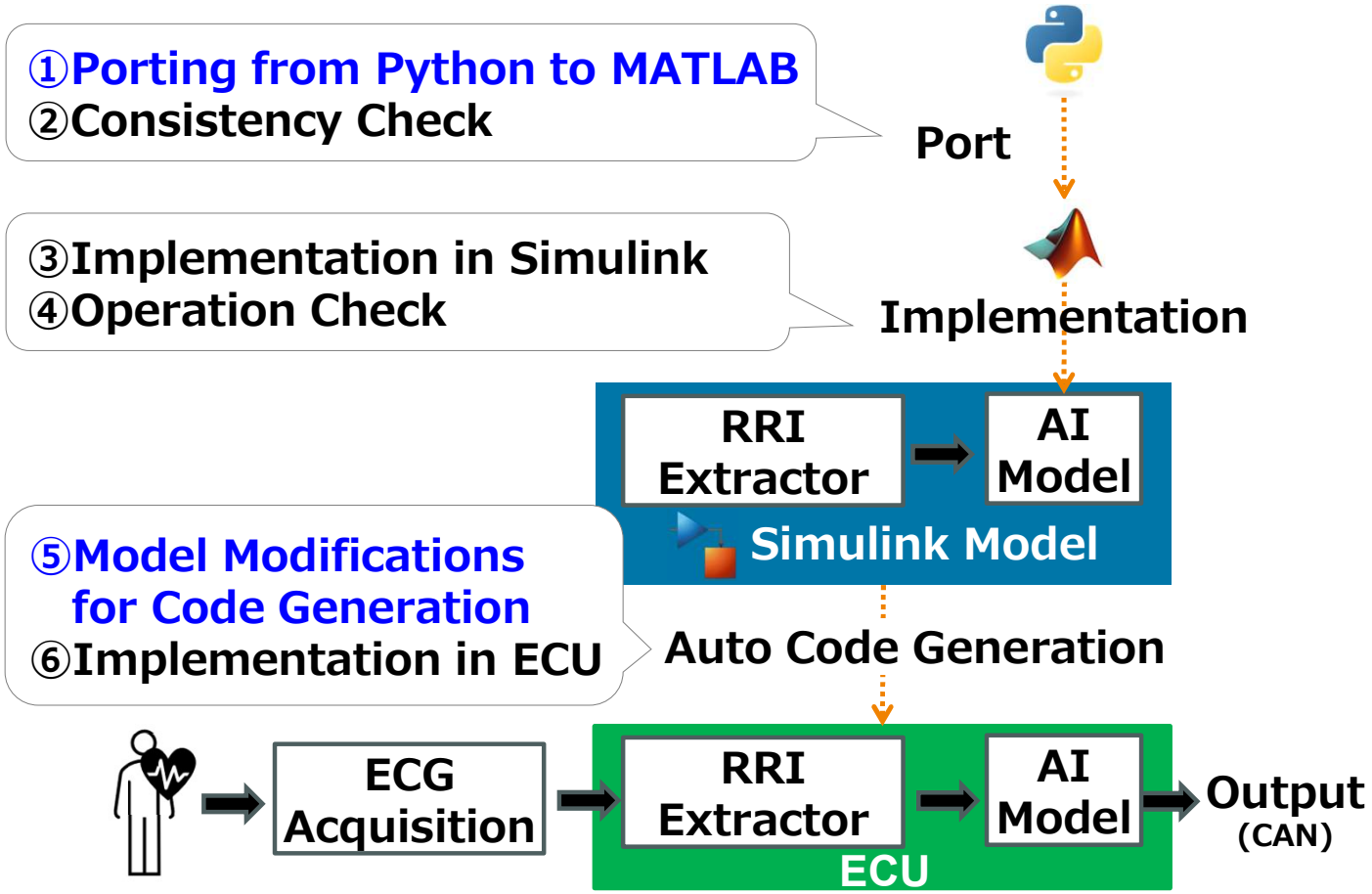
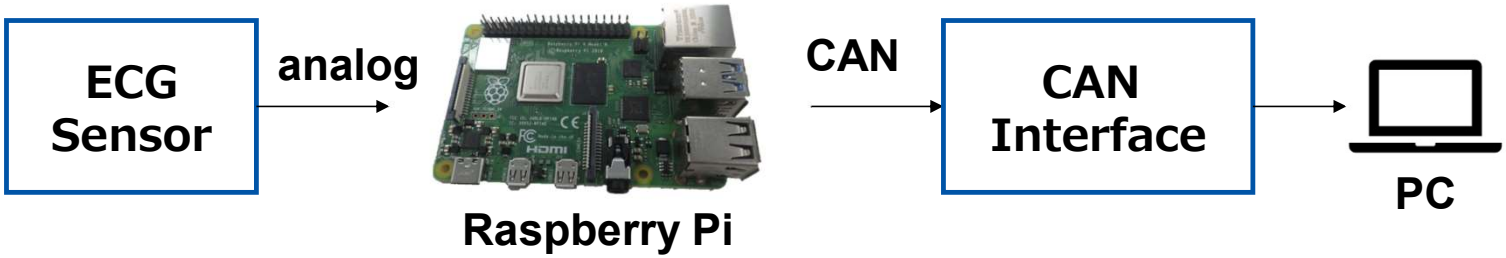
Challenges in Implementation of Real Time System



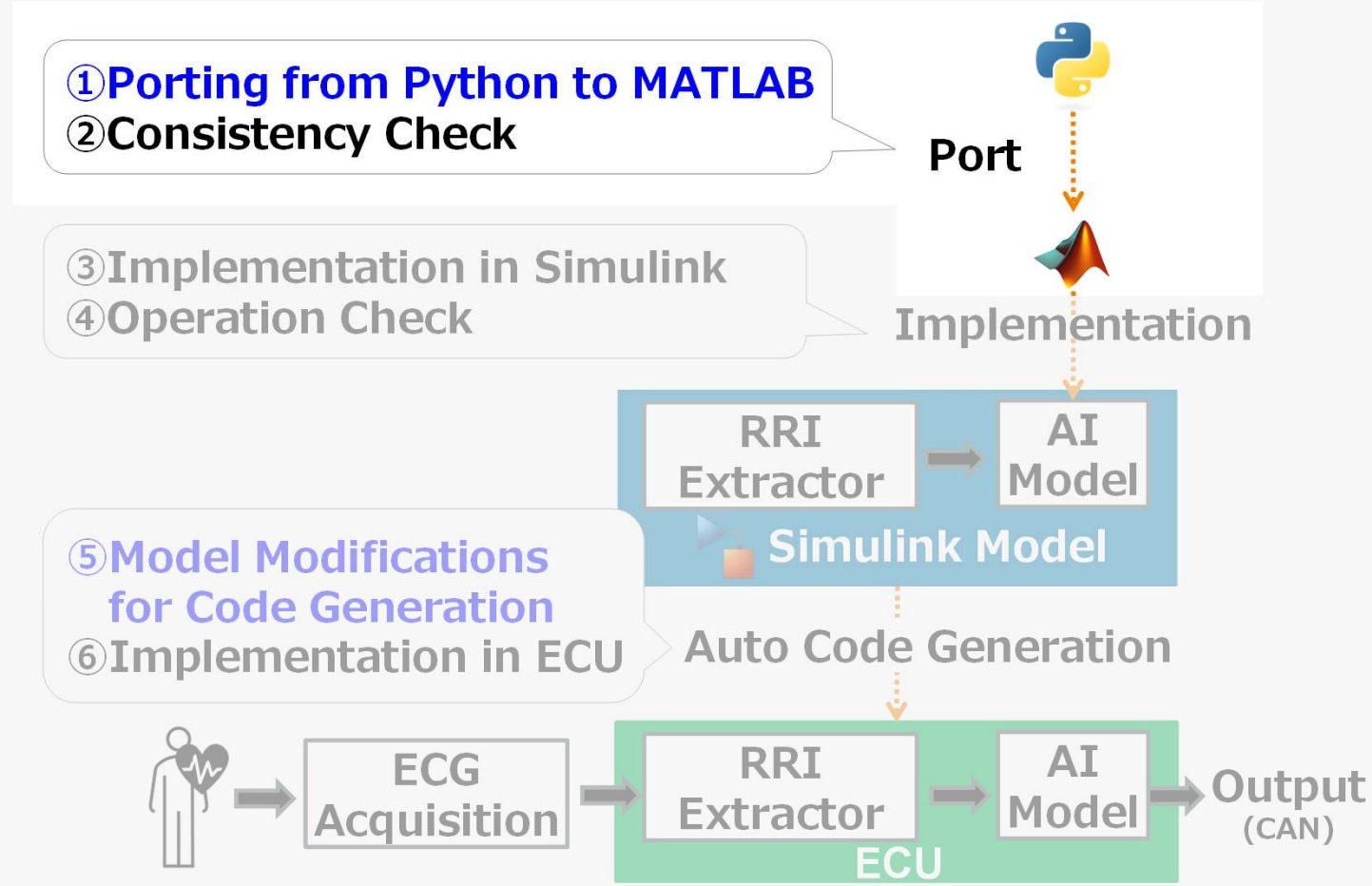
Flow to Real-time Implementation



Hardware Configuration



Flow to Real-time Implementation



Porting from Python to MATLAB

std()

```
In [1]: import numpy as np

        X = [1, 2, 3, 4, 5]

        np.std(X)
```

```
Out[1]: 1.4142135623730951
```

```
X = [1 2 3 4 5];

std(X)
```

```
ans = 1.5811
```

Same input but different output.

Why?

Differences in Default Settings

std()

$$\sigma = \sqrt{\frac{\sum(X_i - \mu)^2}{n}}$$

Standard Deviation

```
Out[1]:  1.4142135
```

$$\sigma = \sqrt{\frac{\sum(X_i - \mu)^2}{n-1}}$$

Invariant Standard Deviation

```
ans = 1.5811
```

```
std(X,1)
```

```
ans = 1.4142
```

kurtosis()

Fisher's Definition

Normal Distribution = 0

```
from scipy.stats import kurtosis

X = [1, 1, 10, 1, 1]
kurtosis(X)
```

```
0.25000000000000133
```

Pearson's Definition

Normal Distribution = 3

```
X = [1 1 10 1 1];

kurtosis(X)
```

```
ans = 3.2500
```

```
X = [1 1 10 1 1];

kurtosis(X)-3
```

```
ans = 0.2500
```

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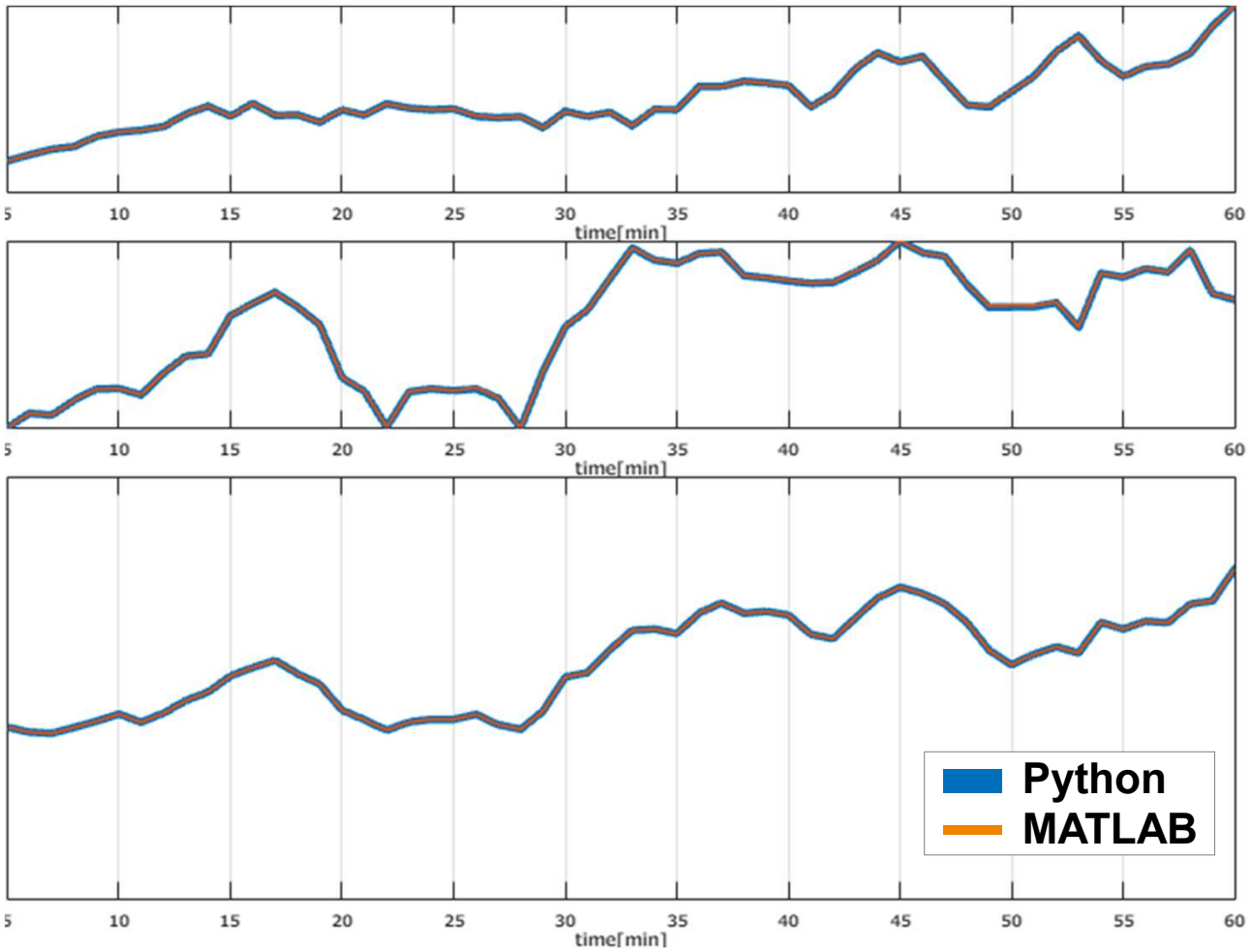
Consistency Check

Feature Value 1

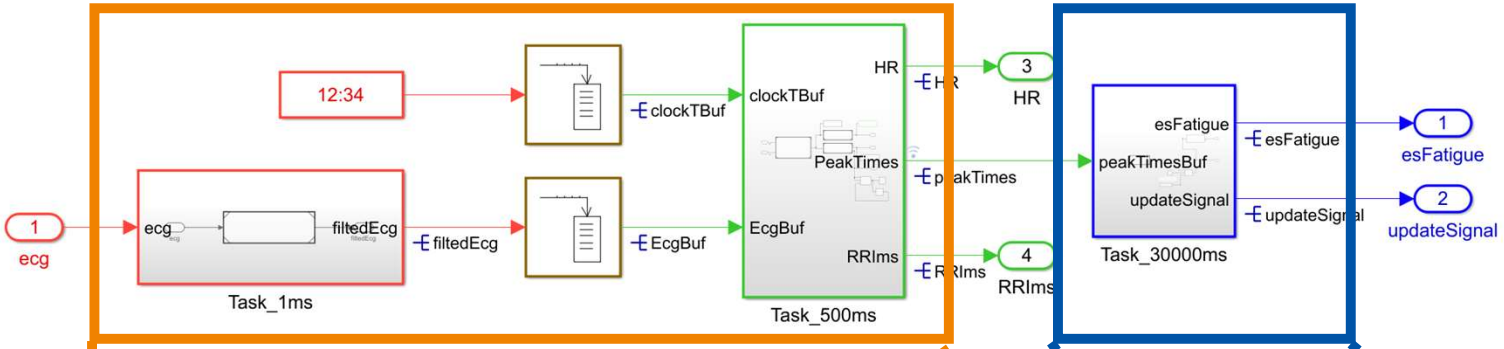
Feature Value 2

⋮

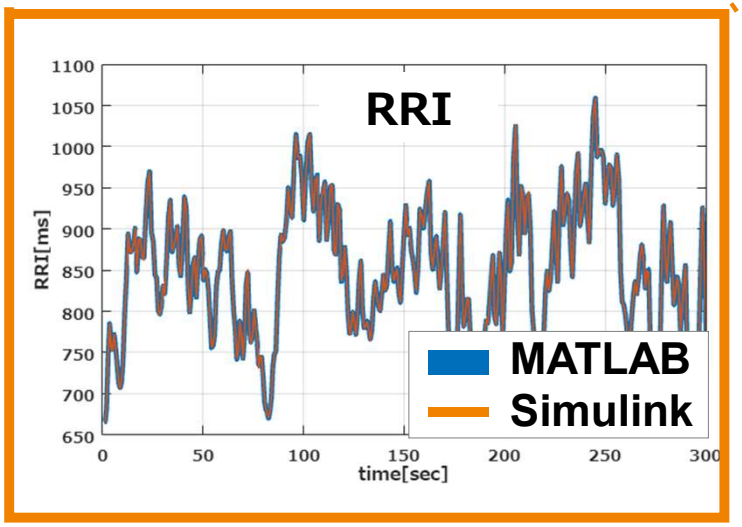
Fatigue Level



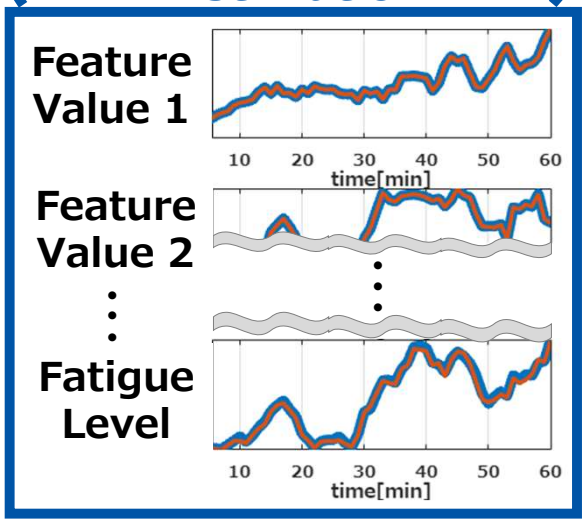
Implementation in Simulink



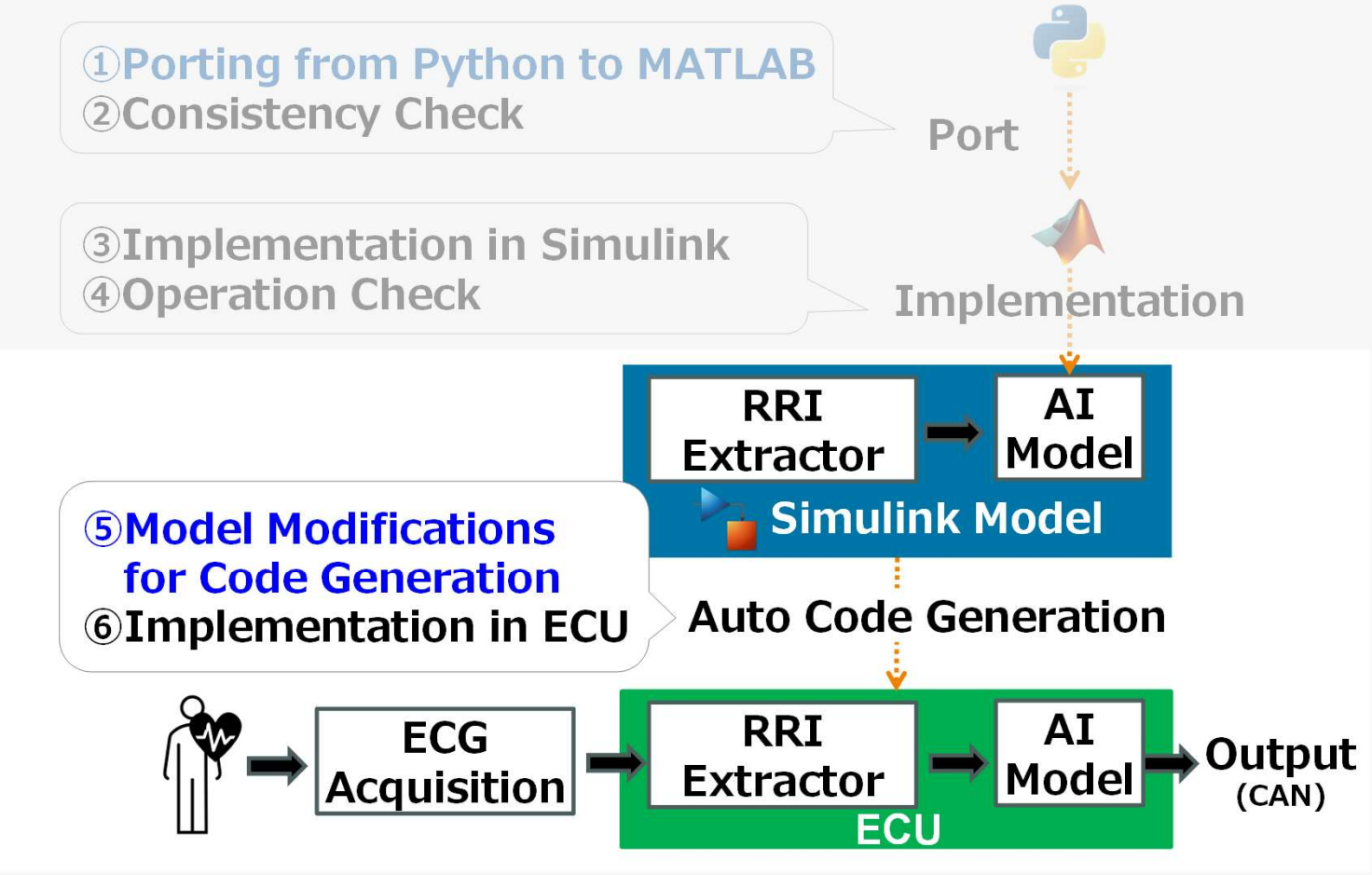
RRI Extraction



Fatigue Estimation

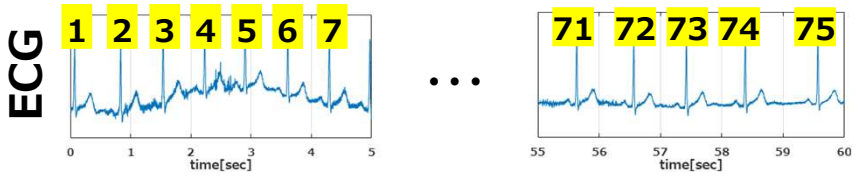


Flow to Real-time Implementation



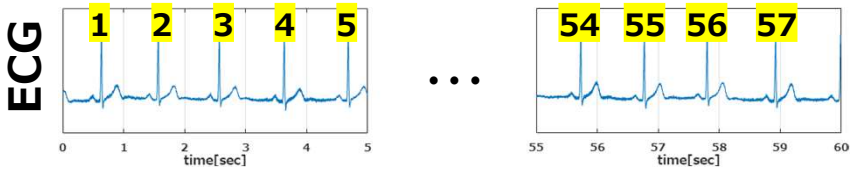
Modifying the Model – Variable-Sized Array

Heart Rate 75[bpm]



75 peaks

Heart Rate 57[bpm]



57 peaks

The # of peaks is not consistent.

Store the peak detection time. (Variable-Sized)

MATLAB Function
Simulink/User-Defined Functions

```
peakTimes = peakTimes(peakTimes~=-1);
```

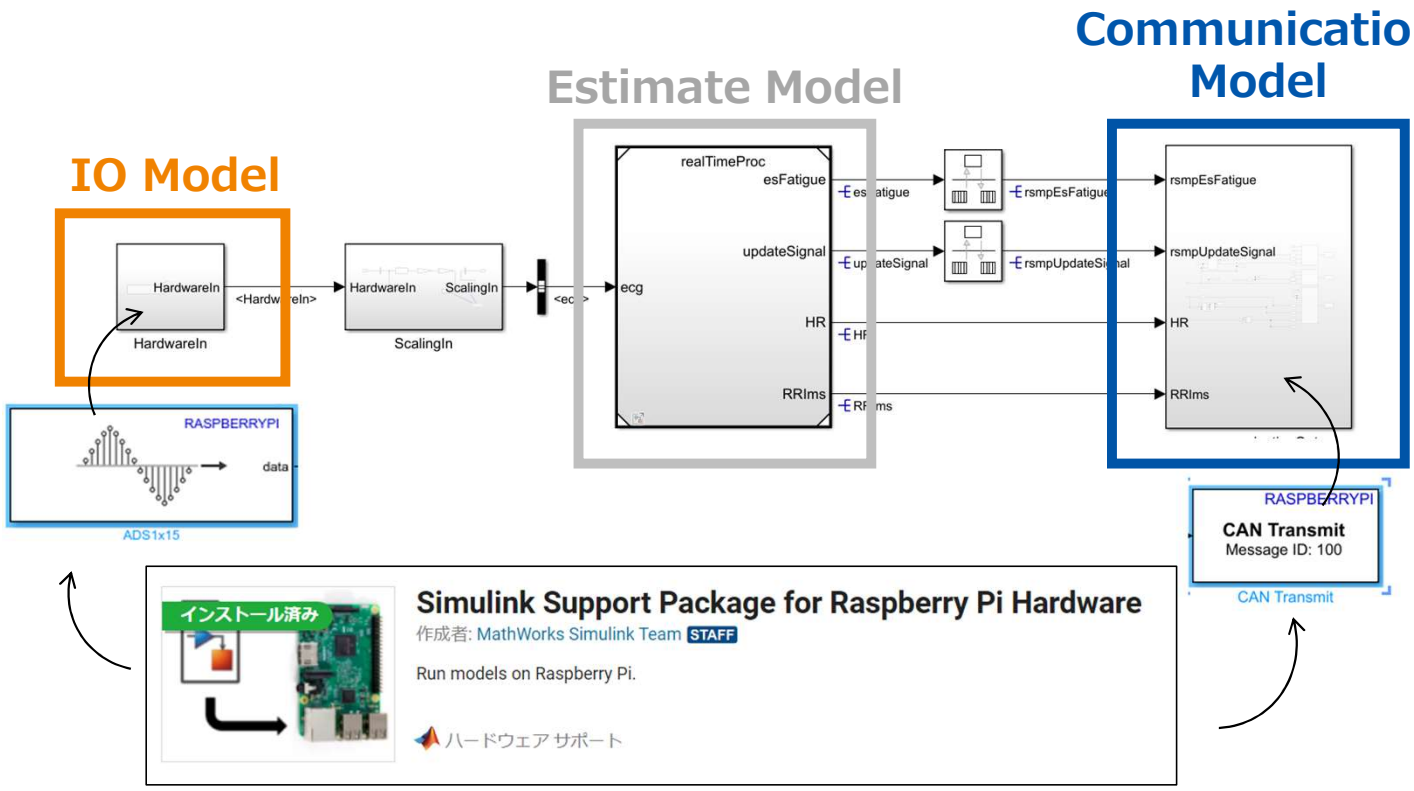
Can throw errors upon code generation

Specify Maximum array size

```
coder.varsize('peakTimes',[600 1]);

peakTimes = peakTimes(peakTimes~=-1);
```

Modifying the Model – IO/Communication Model



Add models for hardware I/O.
The package dedicated to Raspberry Pi was used for this time.

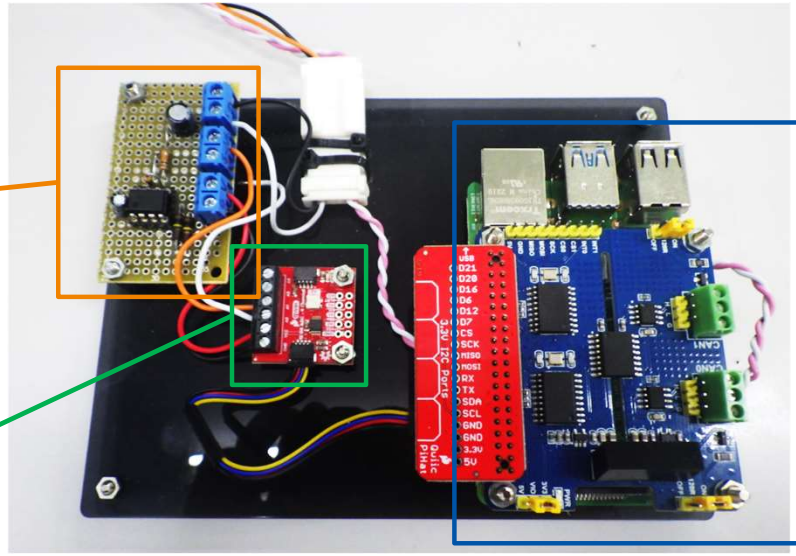
Auto Code Generation

Just Press!

C Code Generation

Analog Signal Processing

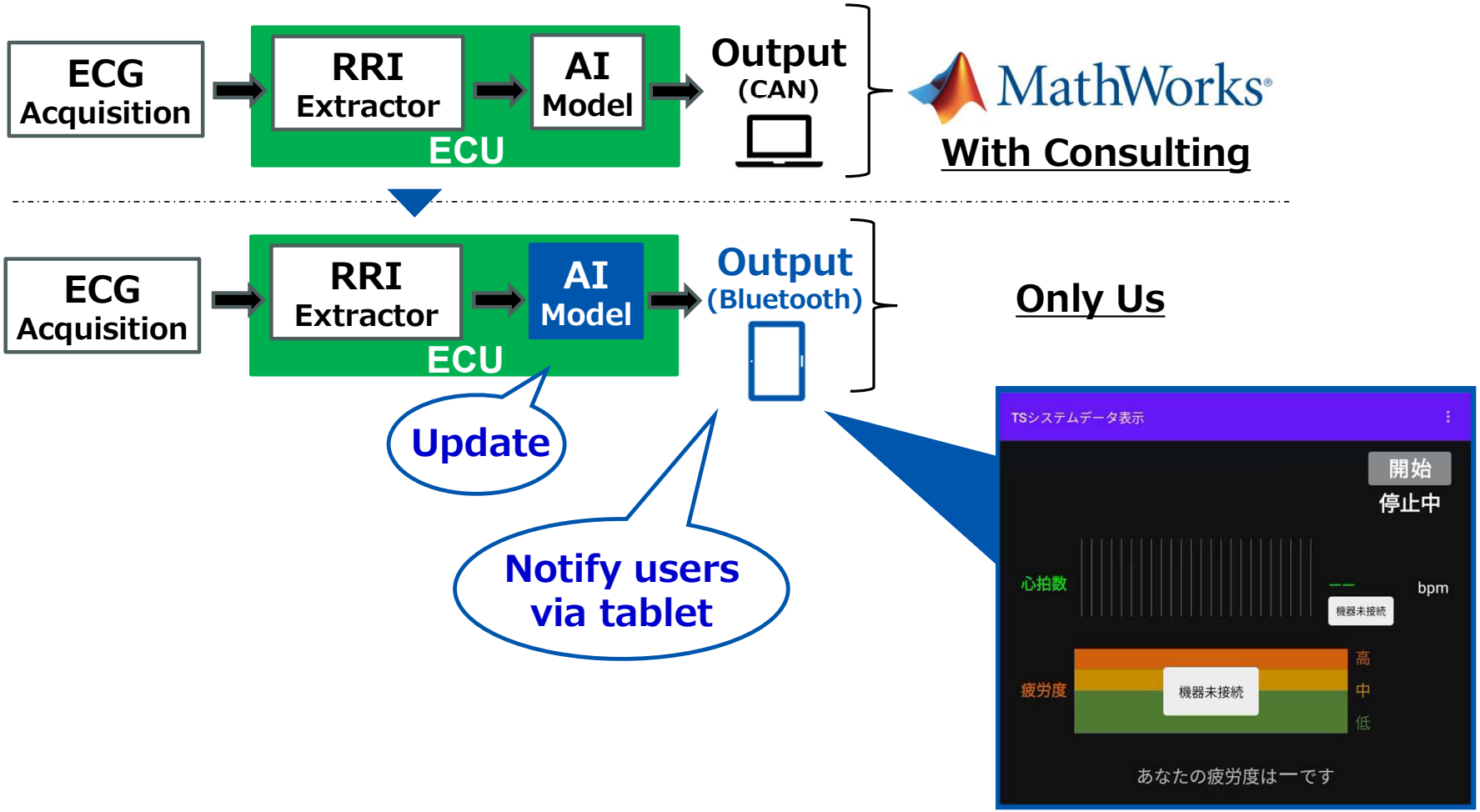
A/D Conversion



Raspberry pi + CAN HAT

ECU

Current Real-Time Estimation System



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Realize a service that combines machine learning algorithms built in Python with other functions in real-time using Simulink.

Future Work

Enhance development flow targeting vehicle OS.

MATLAB®/Simulink® Product Family Used

- MATLAB®
- Simulink®
- Statistics and Machine Learning Toolbox®
- Signal Processing Toolbox®
- DSP Toolbox®
- Wavelet Toolbox®
- Simulink Coder®
- Embedded Coder®
- Simulink Support Package for Raspberry Pi®


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