



From Data to Action

Data & Telemetry **BOOTCAMP**

Marco Schmid
CEO and Head of R&D
Schmid Elektronik



Shell Eco-marathon Partner

10.4.2026, SEM Indianapolis



Marco Schmid



Thank you
Shell Eco
official p

Technical Team
Marco



telemetry

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10 System Settings - Internal Configuration Page

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Schmid Elektronik is Shell Eco-marathon Partner



About Shell Eco-marathon

For over 40 years, since 1985, the programme has consistently brought to life Shell's mission of Powering Progress together by providing more and cleaner energy solutions.

[Watch the NEW film to learn more about Shell Eco-marathon'](#)

[Read more →](#)



2026 Programme

The season opens a new chapter that reflects the changing face of STEM and introduces a comprehensive competition experience, leading to a truly Global Championship.

[Learn more about the 2026 Programme here](#)

[Read more →](#)



Partners

Our partners are essential to Shell Eco-marathon. Not only do we work together, but we combine resources and share ideas and innovations to help build a lower-carbon future.



Shell Eco-marathon Partner

[Read more →](#)

NEW
2026



Shell Eco-marathon **Telemetry System**

**NEW
2026**



NEW
2026



Logistics Nightmare

10 Years → OBC NXG

~~One Size fits all?~~

 Shell Eco-marathon **Telemetry System**



Changes of Telemetry Focus: all Teams equal

All Energy Types

- ICE
- H2
- BE



For both Vehicle Categories



Data & Telemetry **Off-Track Award:** Developing a Strategy that:

- #1** Accounts for the straights, slopes, crests and corners of a track
- #2** Balances maximum energy efficiency with competitive lap times
- #3** Ensures driver safety in all conditions, including rain and wind.



A **Sixth** OTA-Question

**NEW
2026**

- 1 **Data Strategy** to Achieve the Three Goals
- 2 Capturing Data with a **Telemetry** System
- 3 Gaining **Knowledge** from Race Data
- 4 Data-driven **Race Strategy** Development
- 5 **Driver** performance on Track
- 6 Qualitative and Quantitative **Results Improvement**

Publishing the OTA-Winners



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Celebrating 40 years of innovation by the world's best and brightest young minds



Shell Eco-marathon Europe and Africa 2025

Regional Competition / June 10 to 15, 2025

Silesia Ring, Kamień Śląski, Poland

[Read more about Shell Eco-marathon Europe and Africa 2025](#)

**NEW
2026**

Publishing the OTA-Winners

**NEW
2026**

Data and Telemetry Award sponsored by Schmid Elektronik

The Data and Telemetry Award celebrates teams that harness the power of data to optimise vehicle performance and enhance overall strategy.

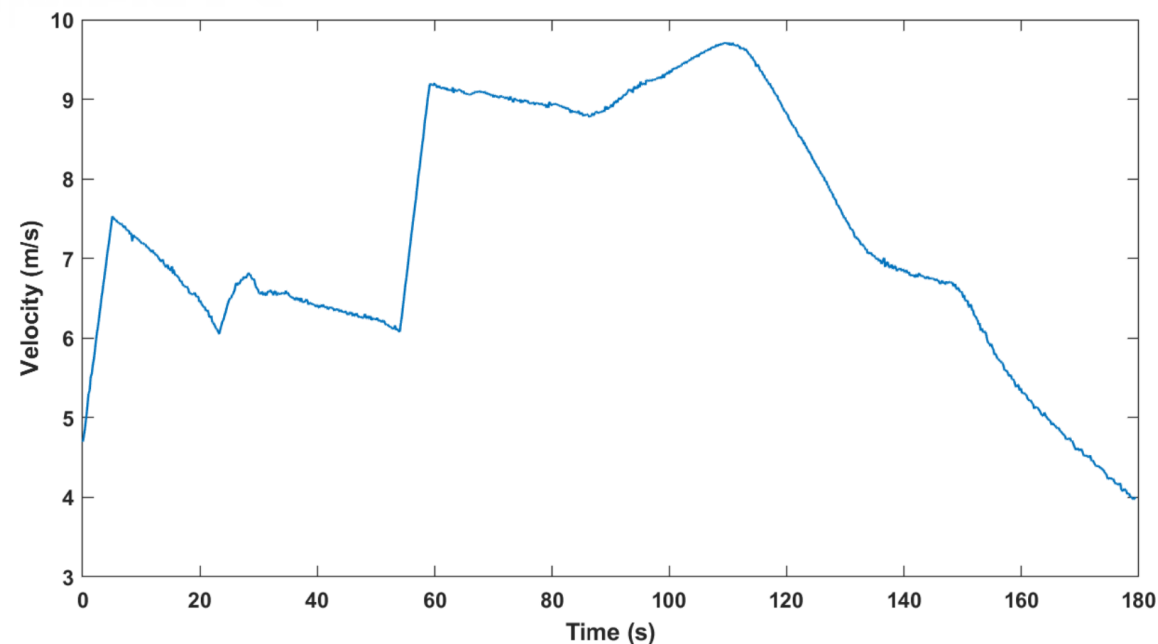
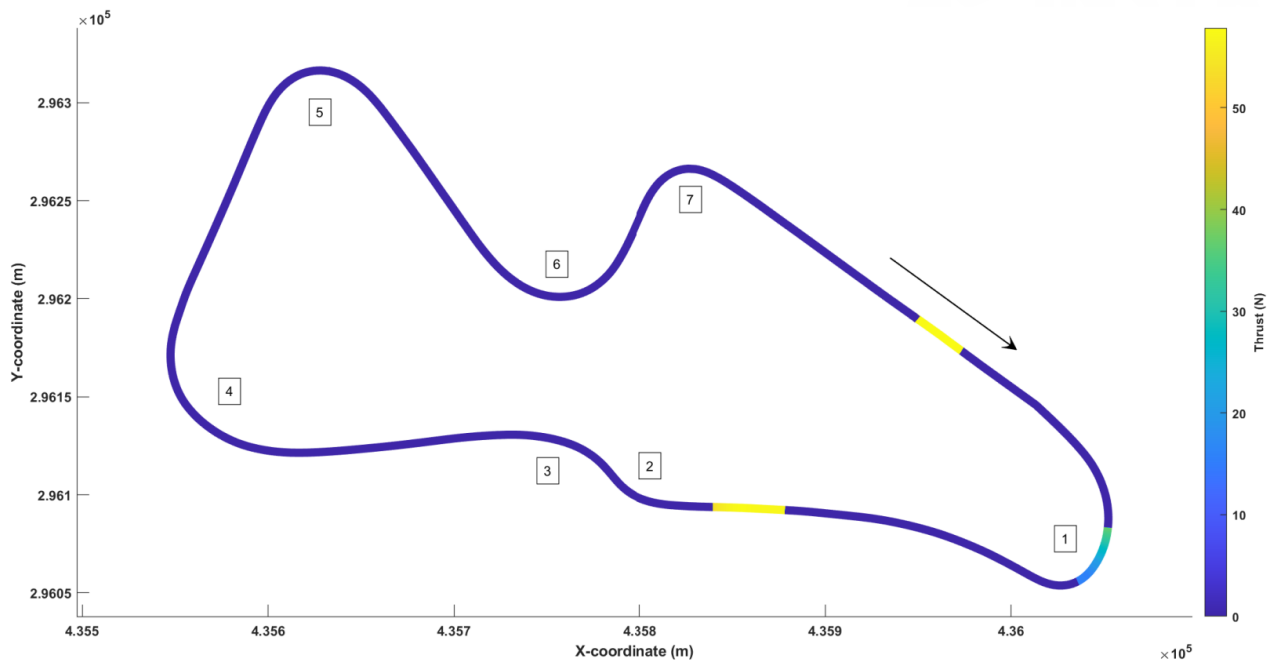
Winner: Imperial Eco-Marathon, Imperial College London, United Kingdom

Judges' Remarks: Rigorously engineered telemetry and simulation underpin this entry. Instead of chasing a single perfect lap, the team optimizes the entire multi-lap attempt, preventing over-tuning of a single lap. A predictive throttle map and speed profile give the driver foresight, while live telemetry refines tactics in real time—a holistic, adaptive and data-driven masterclass!

Runner-Up: PROMETHEUS ECO RACING NTUA, National Technical University of Athens, Greece

[Read Imperial Eco-Marathon's winning entry \(PDF, 4 MB\)](#)

Judges' Remarks: Rigorously engineered telemetry and simulation underpin this entry. Instead of chasing a single perfect lap, the team optimizes the entire multi-lap attempt, preventing over-tuning of a single lap. A predictive throttle map and speed profile give the driver foresight, while live telemetry refines tactics in real time - a holistic, adaptive and data-driven masterclass!



A large, vibrant phoenix with orange and yellow flames for feathers is shown in flight over a racetrack. The phoenix is positioned on the left side of the frame, with its wings spread wide. The racetrack below is a dark asphalt track with green and red markings, curving into the distance. In the background, there are green hills and a clear sky. The overall scene is dynamic and energetic.

Changes to the Data & Telemetry **Bootcamp**

Level ⑤

Holistic: Advanced Data-Driven Racing

Level ④

Modelling: Maintain physics based Digital Twin

Level ③

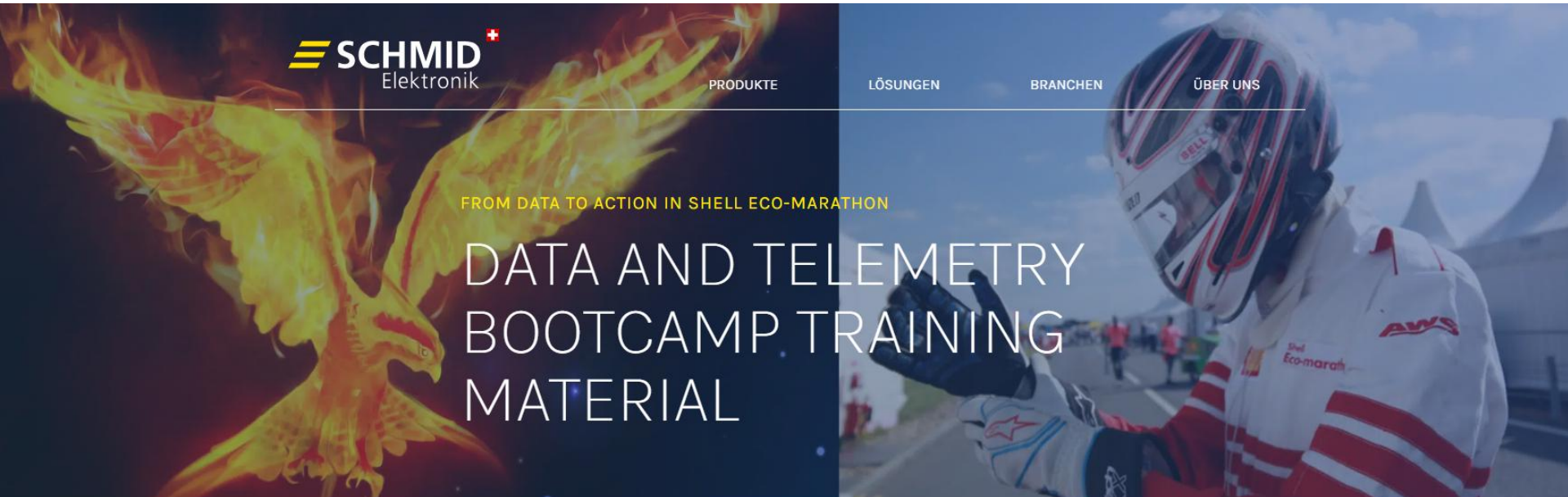
Live Data: Send Data from the Track to the IoT

Level ②

Data Analytics: Recognize Correlations and Patterns

Level ①

Telemetry: How to create relevant Race Data on Track?



Bootcamp Structure

YOU PROGRESS FROM LEVEL TO LEVEL, JUST LIKE IN A GAME.

In five steps, you will learn how data turns into knowledge and knowledge turns into action.

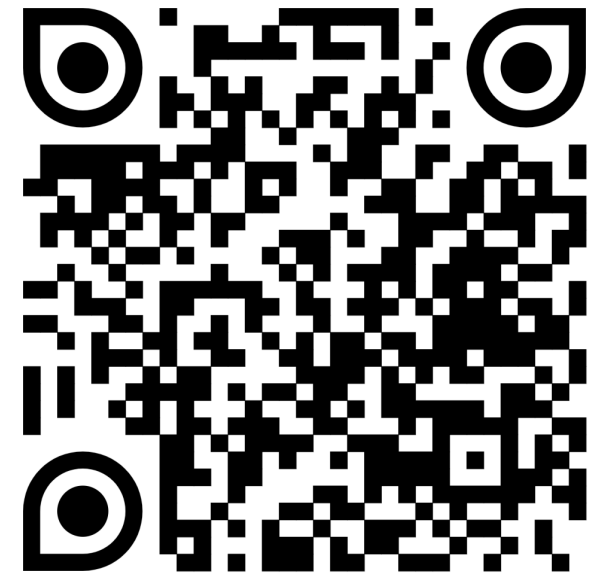
Level 1 | Telemetry: How to Create relevant Race Data on Track?

Level 2 | Data Analytics: Recognize Correlations and Patterns

Level 3 | Live Data: Send Data from the Track to the IoT

Level 4 | Modelling: Maintain Physics Based Digital Twin

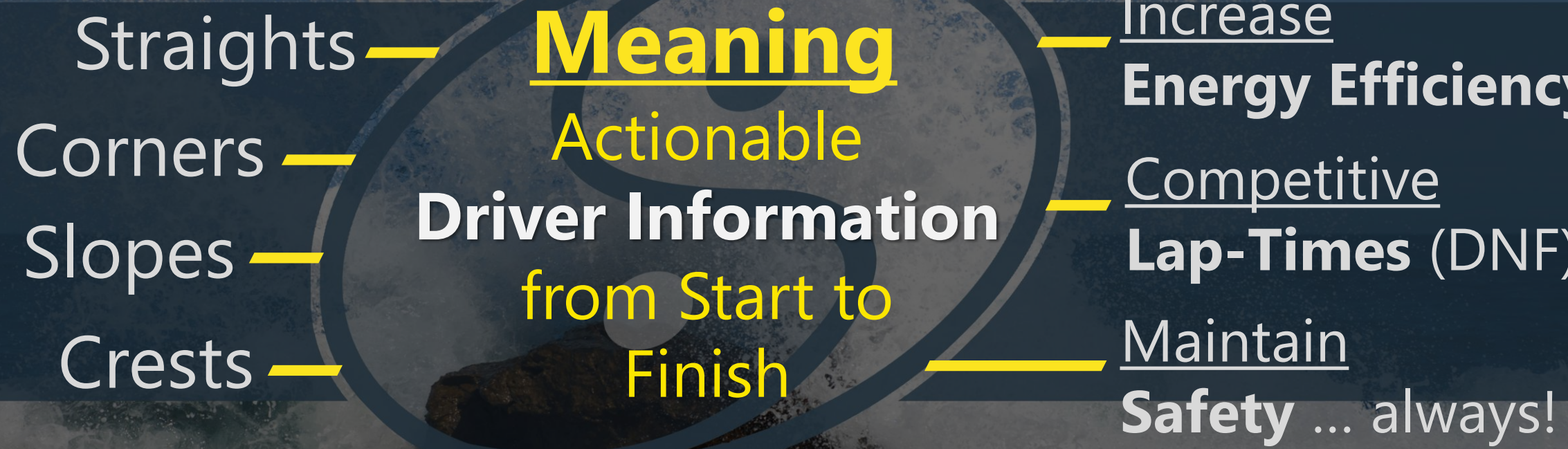
Level 5 | Holistic: Advanced Data-Driven Racing



**Why move from intuitive
to data-driven Racing?**

≡ Classic Multigoal-Problem & Global Optimum

Environmental Influence



Vehicle Characteristics

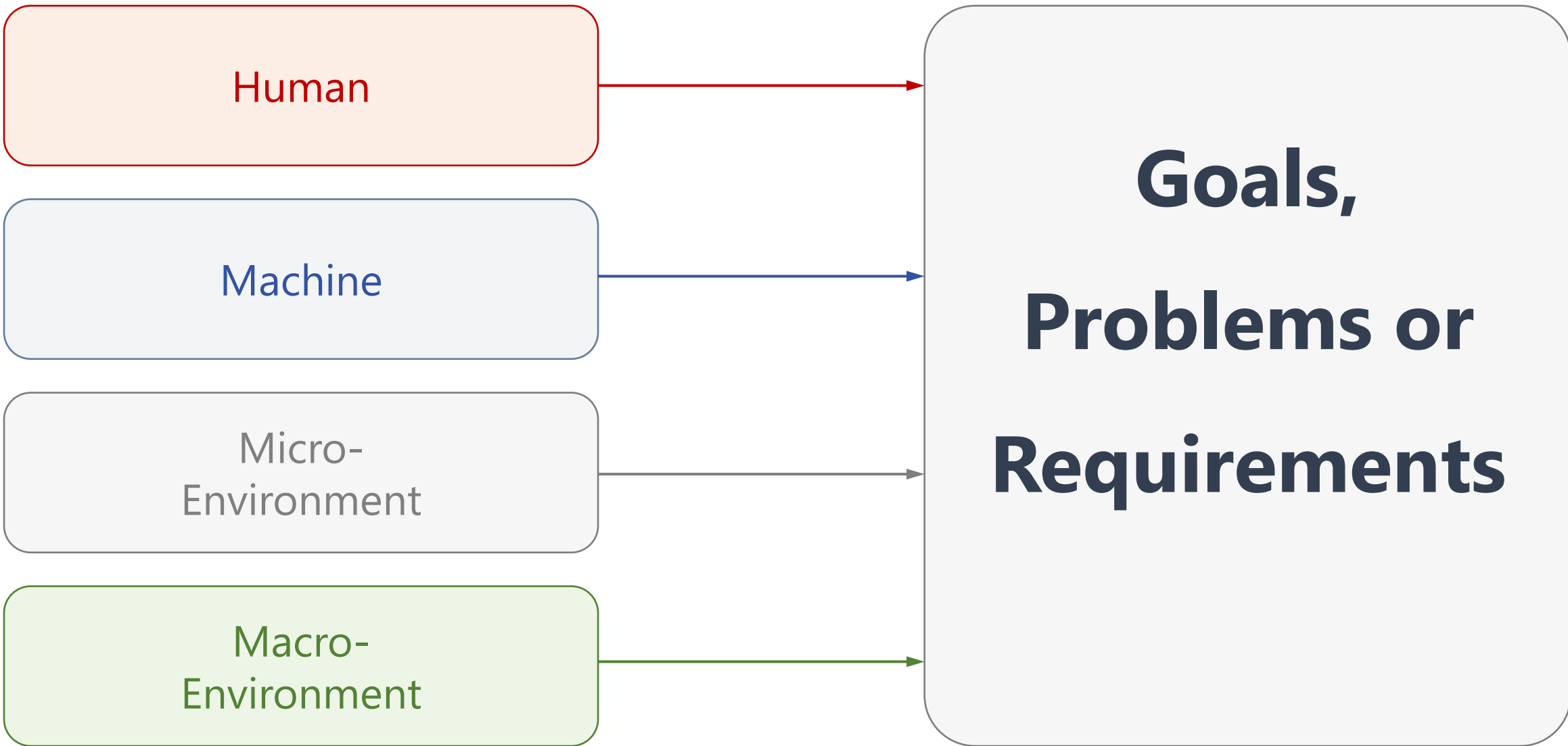
A large, vibrant phoenix made of fire is flying over a race track. The phoenix is bright orange and yellow, with its wings spread wide. The race track is dark asphalt with a red and white striped curb on the right. In the background, there are green hills and a blue sky with some clouds. The overall scene is dynamic and energetic.

Telemetry

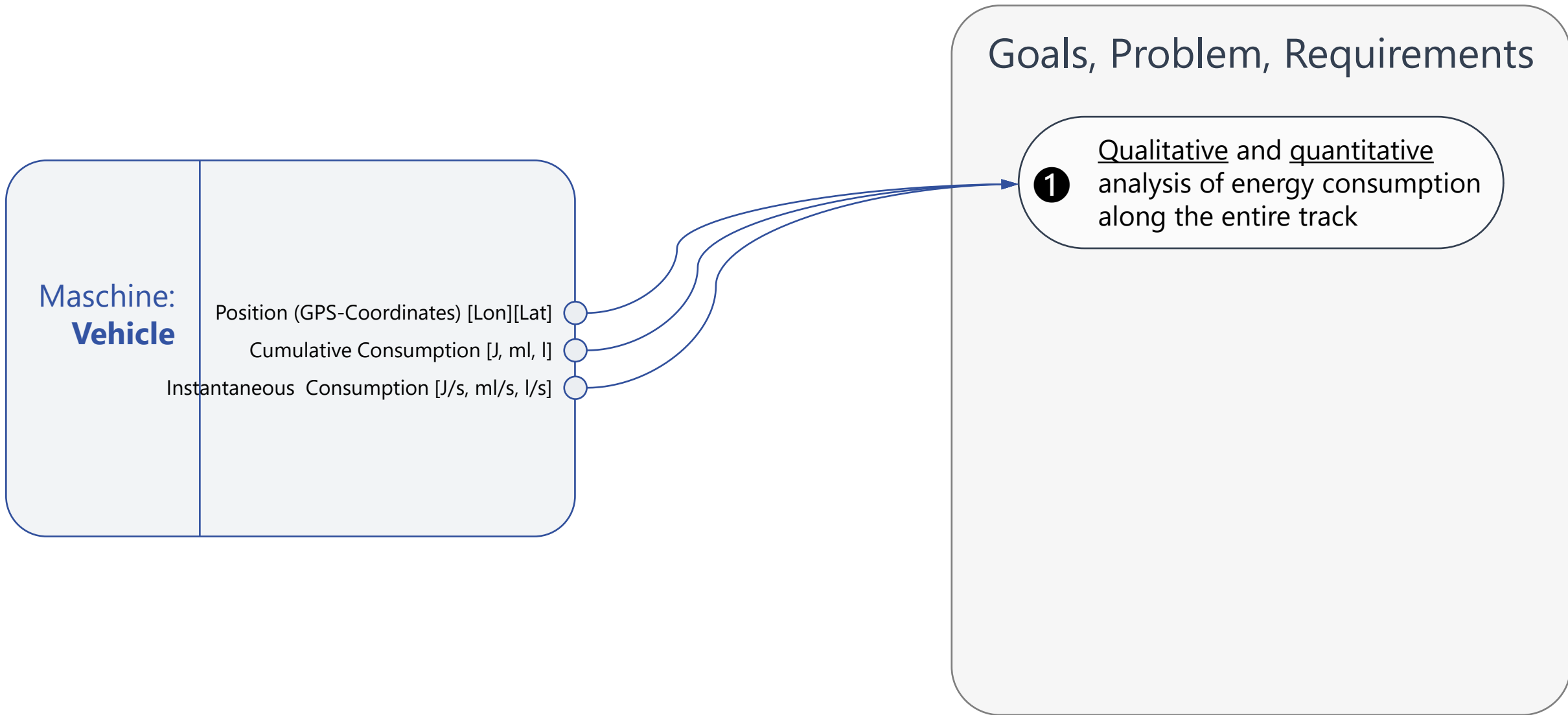
How to identify and create relevant
race data on the track?

Level 1

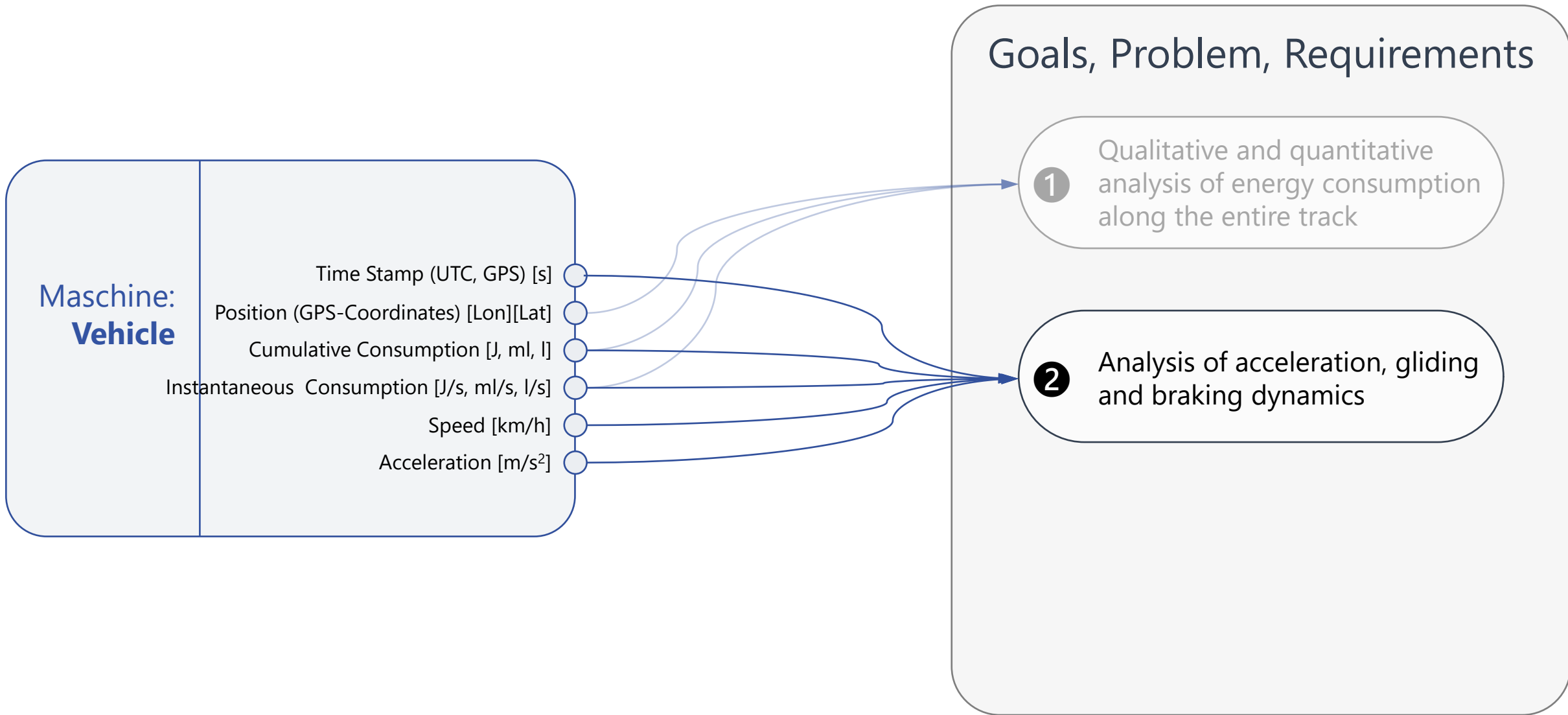
≡ What is your **Data Strategy** + relevant Data?



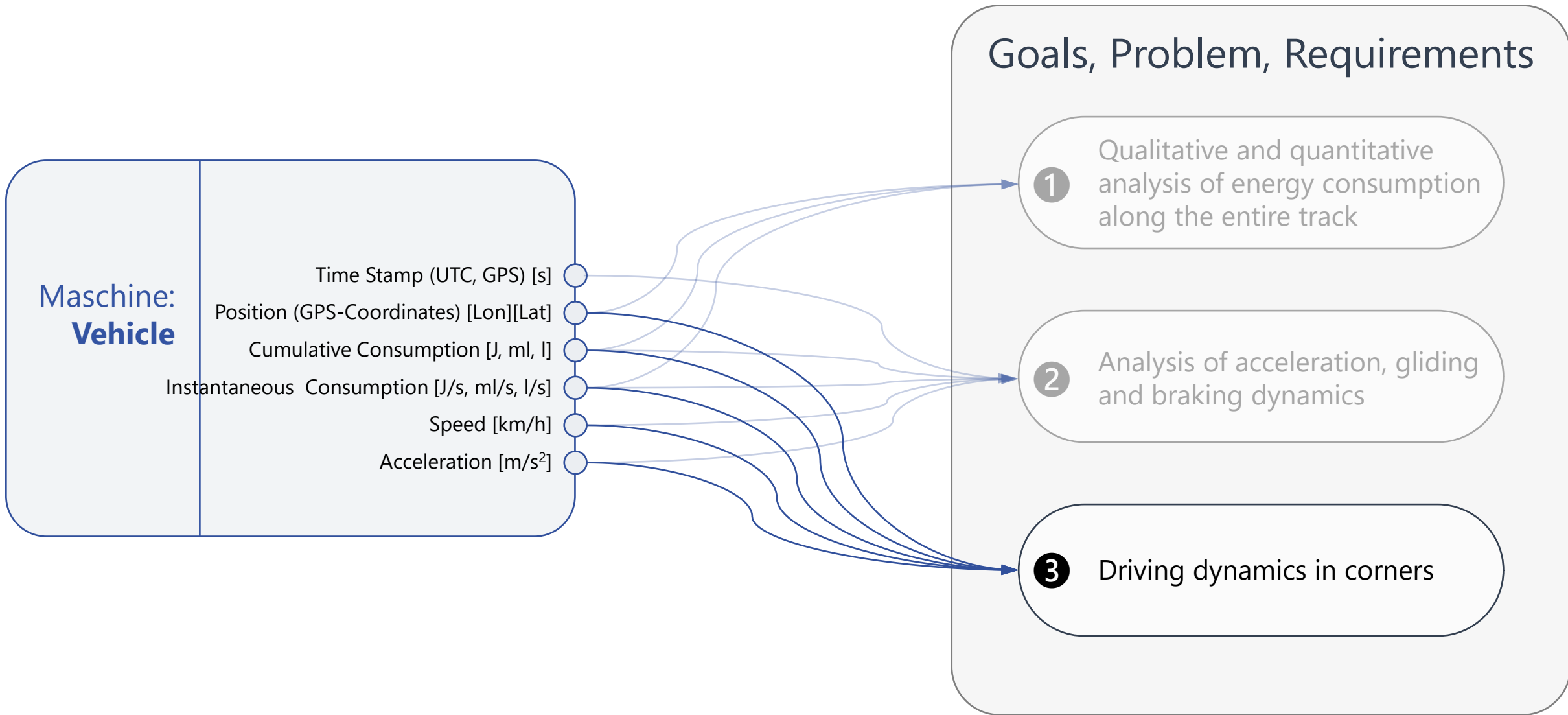
≡ What is your **Data Strategy** + relevant Data?



≡ What is your **Data Strategy** + relevant Data?



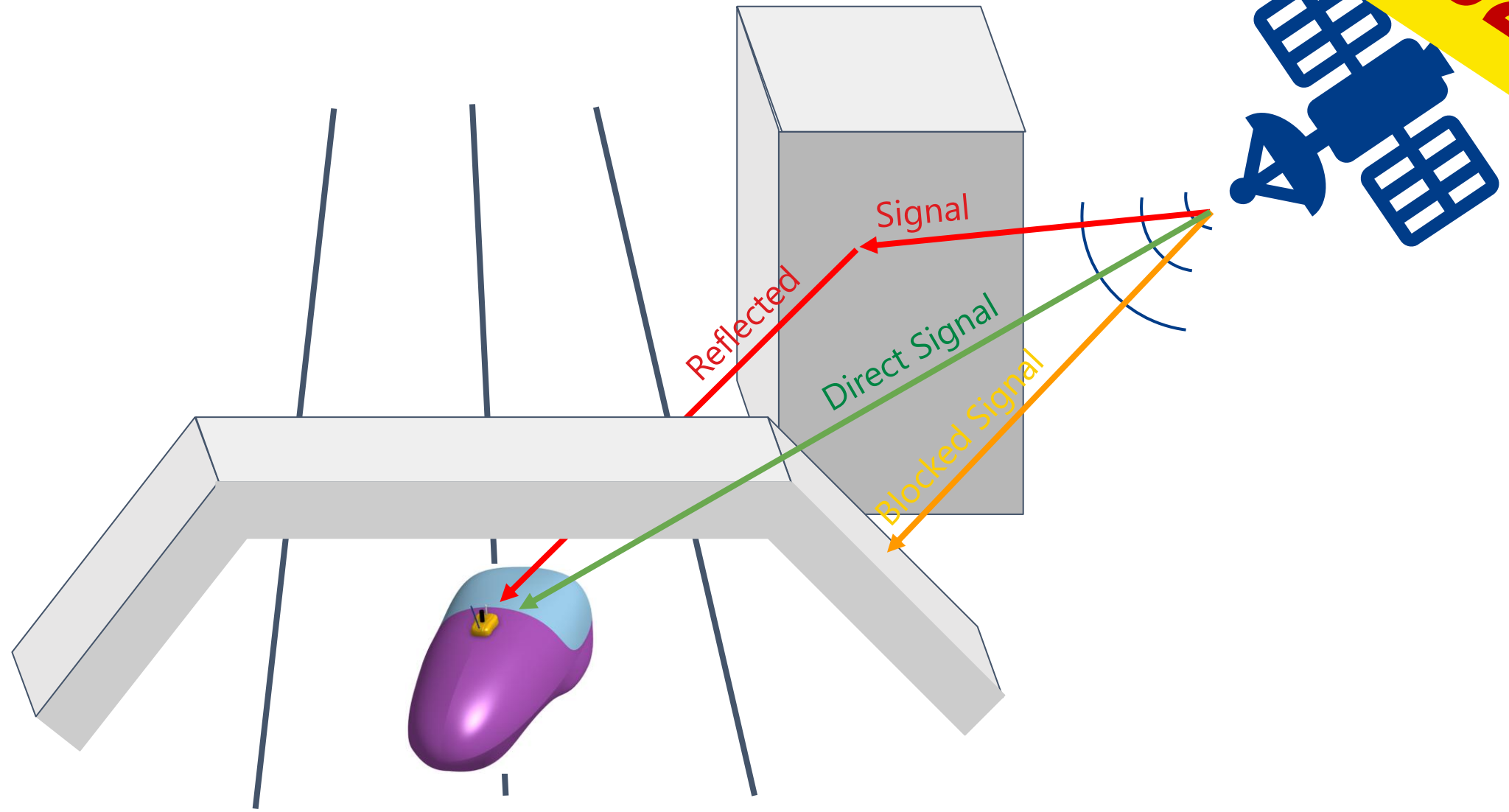
≡ What is your **Data Strategy** + relevant Data?

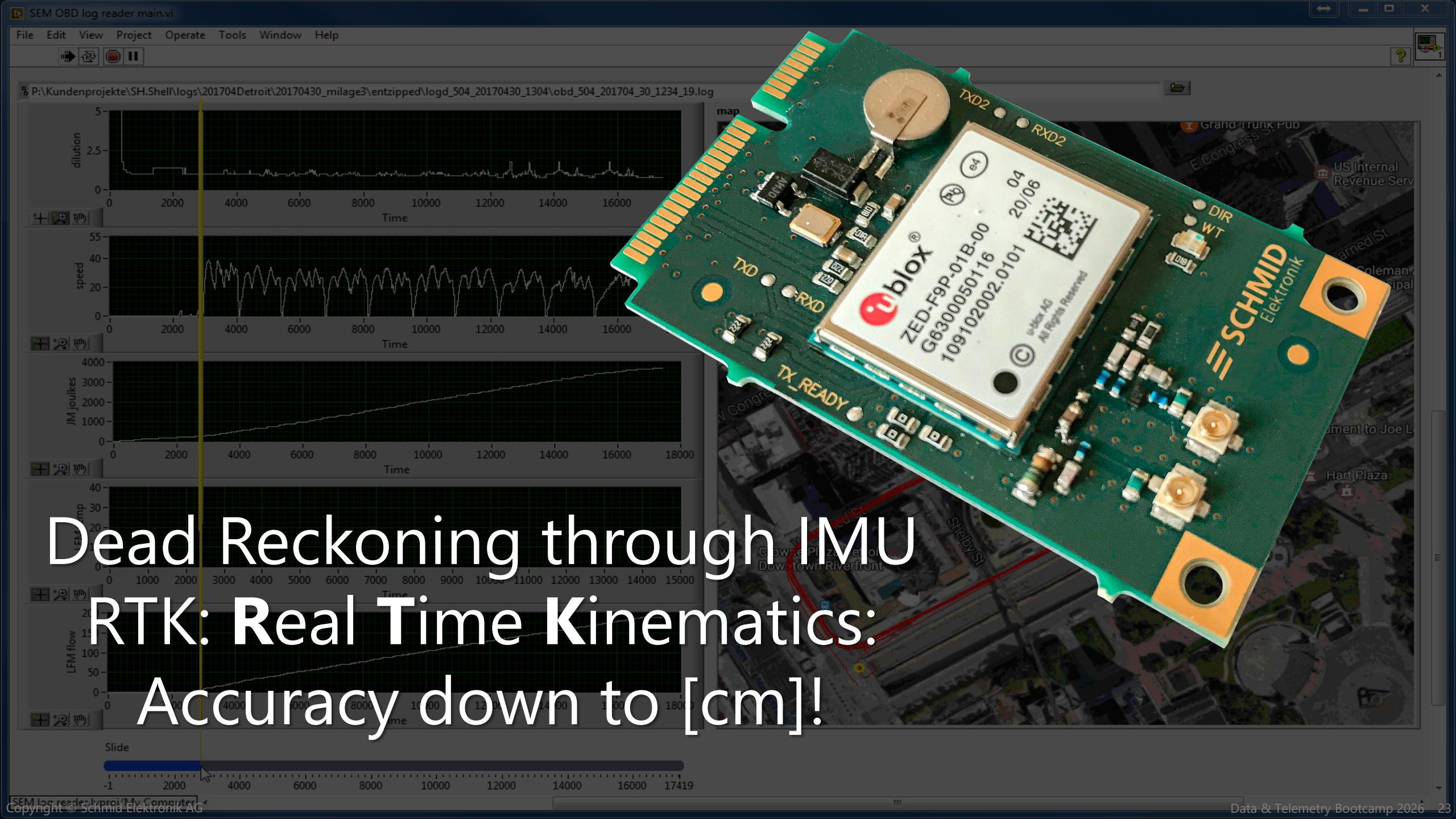




GPS Data and it's Challenge

**NEW
2026**





Dead Reckoning through IMU
RTK: Real Time Kinematics:
Accuracy down to [cm]!



Passive Helix-Antenna and GPS RTK

Maxtena

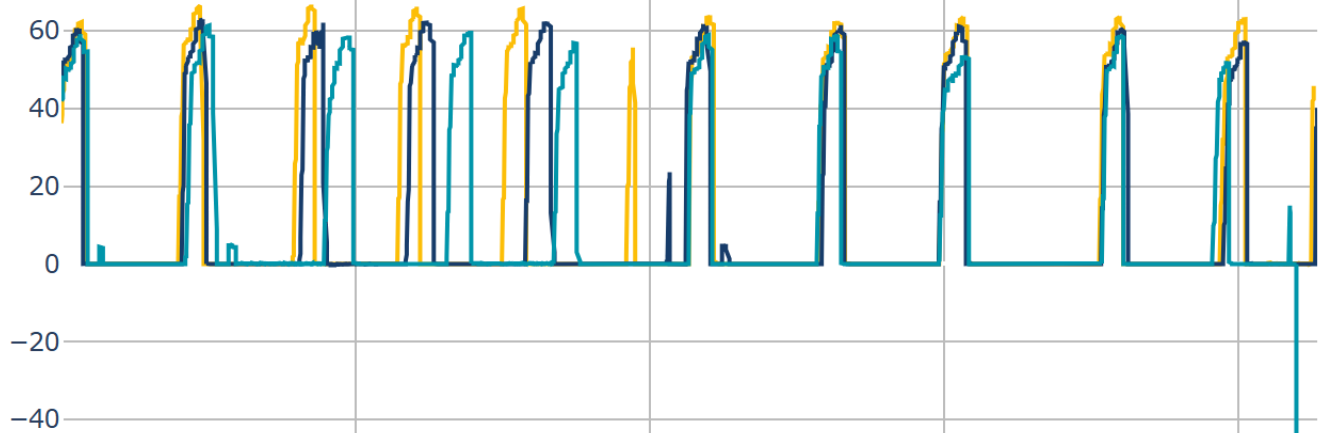
M1621HCT-P-SMA



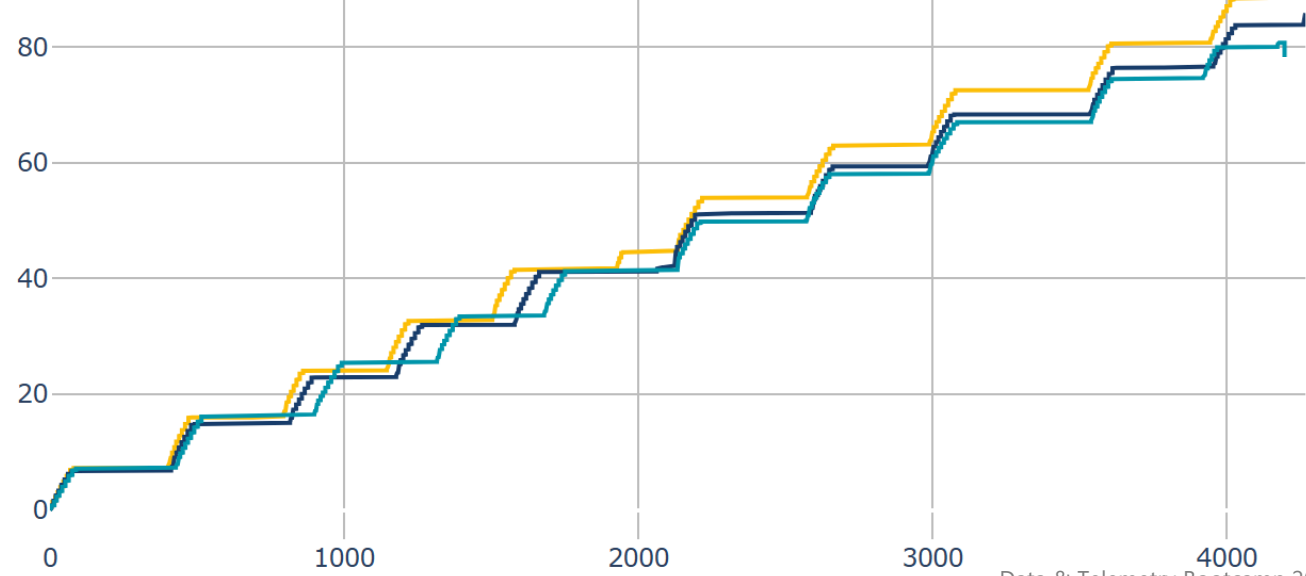
Joulemeter for Electrical Energy



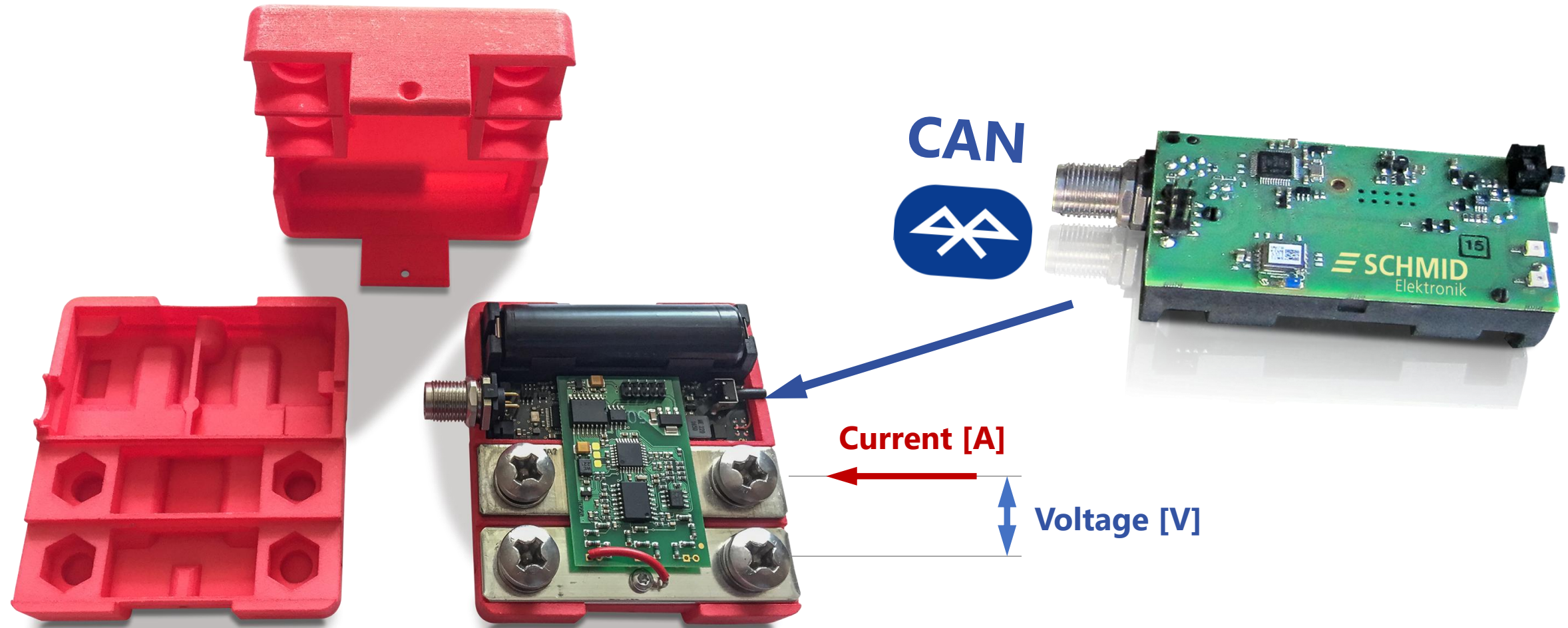
Instantaneous Energy Use



Cumulative Energy use



Electrical Energy: Sensorfusion



Measures electrical Energy in Joules [J]

$$1 \text{ Joule [J]} = 1 \text{ Wattsecond [Ws]} = 1 \text{ VA} = 1 \text{ N m} = 1 \text{ kg m}^2 \text{ s}^{-2}$$

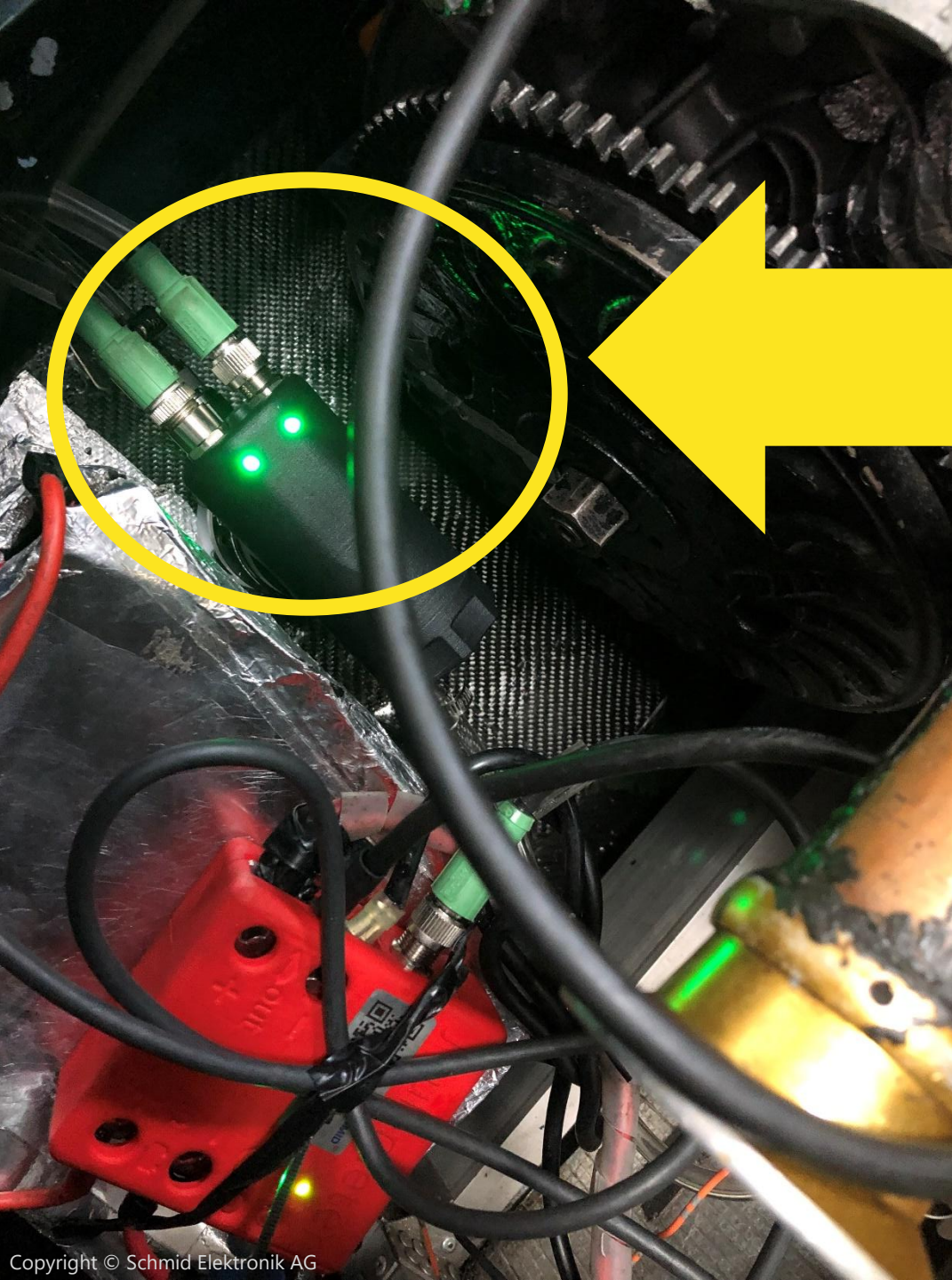
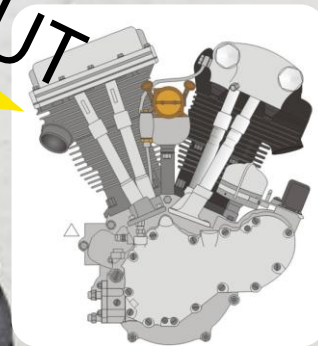
**NEW
2026**

Liquids
in milli-liters [ml]
e.g 12.5ml



IN

OUT



Gasflow Meter for **Hydrogen**

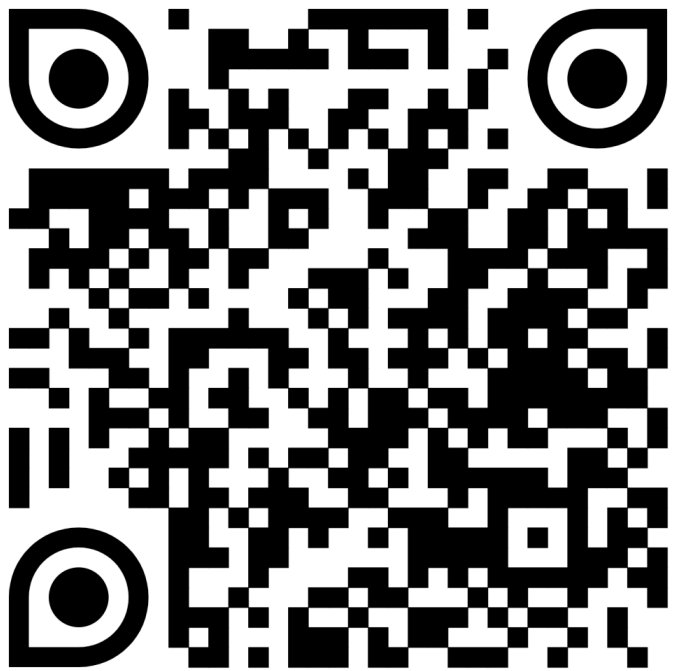


Hydrogen in
normalized Liters [l], e.g 0.534l

Shell Eco-marathon Data & Telemetry Portal

You are here: Home » **Student Documentation**

- Home
- Student Documentation**
- Track Coordinates
- Contact



Student Documentation

Select your category/class from the following:

		Prototypes P	Urban Concepts UC
	ICE	Prototype Internal Combustion Engine	Urban Concept Internal Combustion Engine
Hybrid	ICE	Prototype Internal Combustion Hybrid Engine	Urban Concept Internal Combustion Hybrid Engine
	BE	Prototype Battery Electric	Urban Concept Battery Electric
	H2	Prototype Hydrogen without Supercapacitor	Urban Concept Hydrogen without Supercapacitor
Supercap	H2	Prototype Hydrogen with Supercapacitor	Urban Concept Hydrogen with Supercapacitor

CAN

GPS Receiver

4G/5G Modem

WIFI

Digital I/O

9x IMU

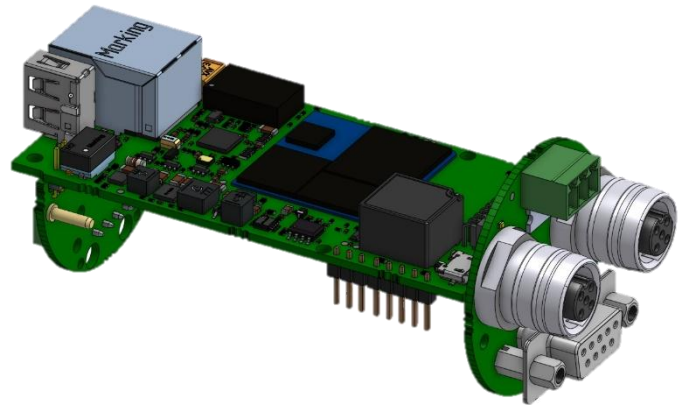
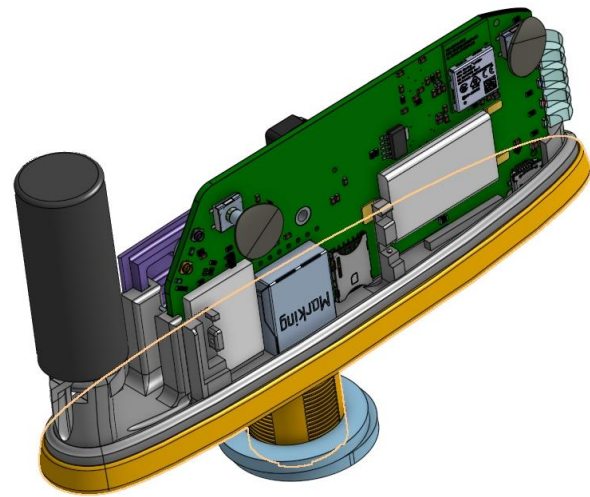
Battery Mgmt

SIM Card

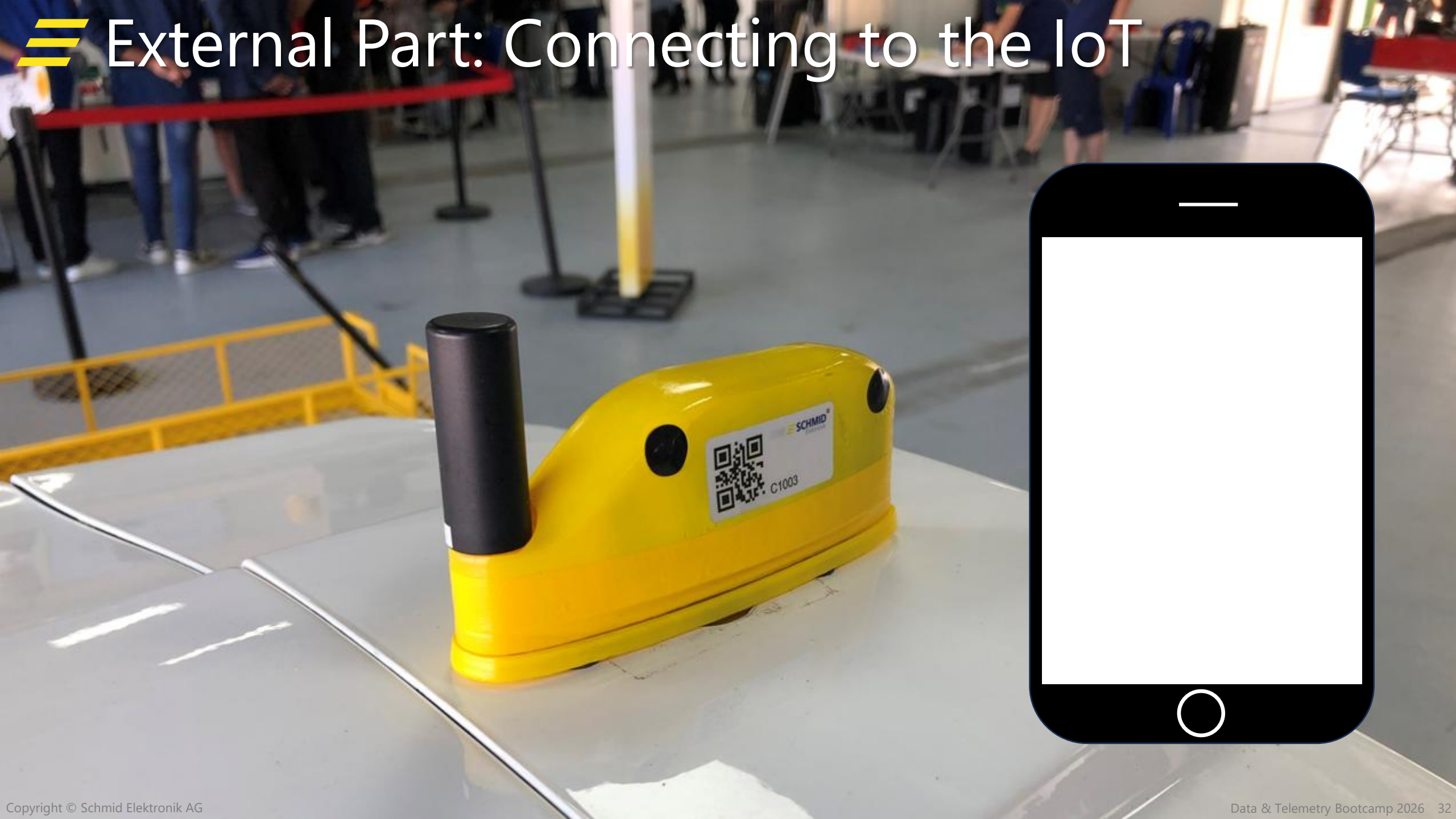
μSD

Blue Tooth

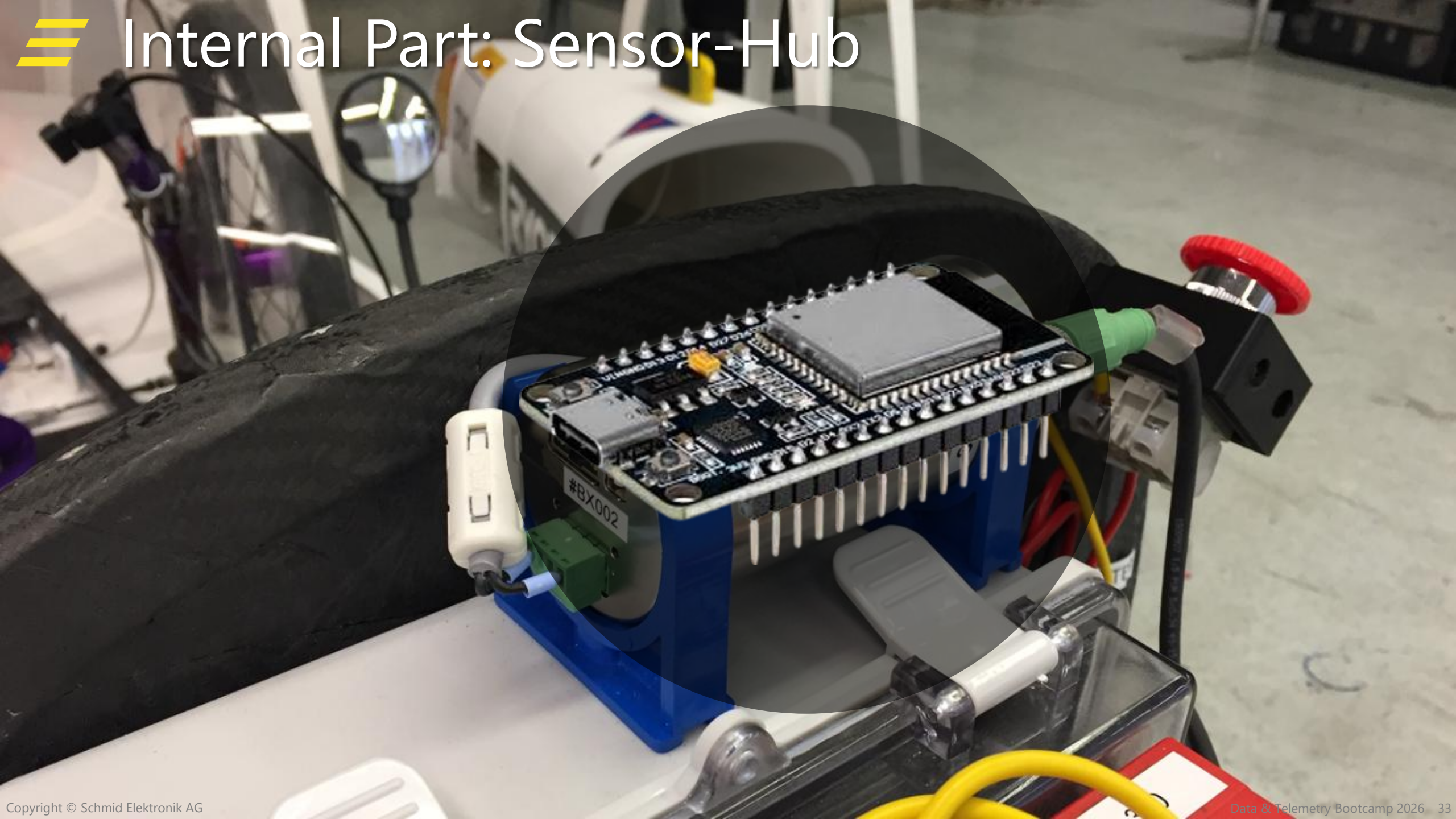
1x ARM **Cortex-A7** Cores and 1x **Cortex-M4** Core



External Part: Connecting to the IoT



Internal Part: Sensor-Hub

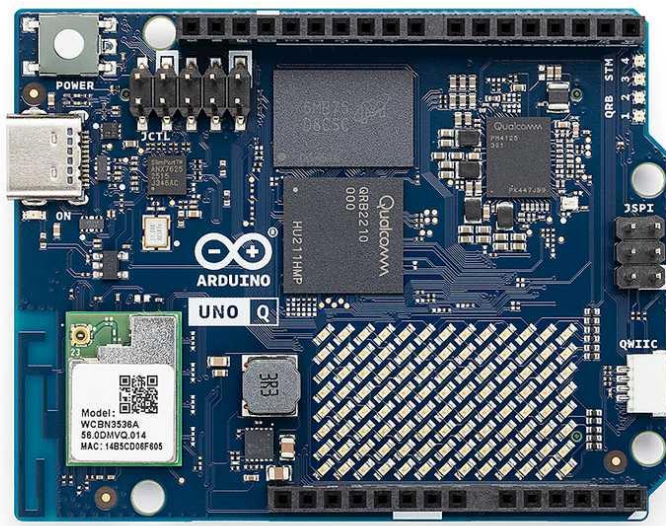


≡ Alternatives that I have seen in OTA-Papers

ESP32



Arduino



Raspi

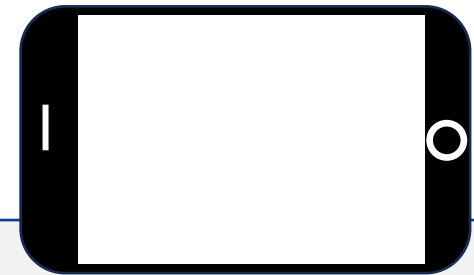
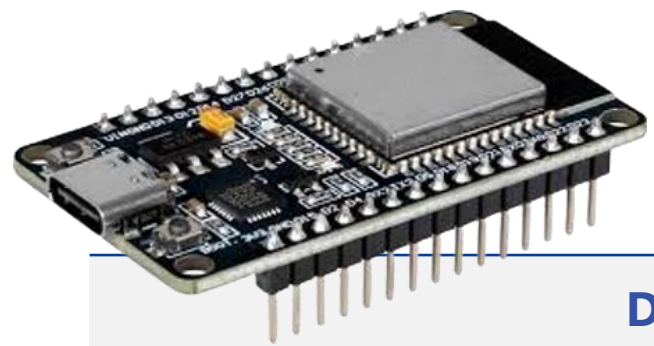


Your Phone





Empowering you to create **your own Telemetry**



Data-API (Application Programming Interface)



Joulemeter



Liquid Flowmeter



Gas Flowmeter

A large, vibrant phoenix made of fire is flying across the top left of the image. The background is a high-angle view of a racetrack with grandstands filled with spectators. The sky is blue with some clouds. The text 'Data Analytics' is written in a large, bold, yellow font with a yellow underline. Below it, the text 'Recognise Correlations and Patterns' is written in a white font. At the bottom, 'Level 2' is written in a yellow font with the number 2 inside a yellow circle.

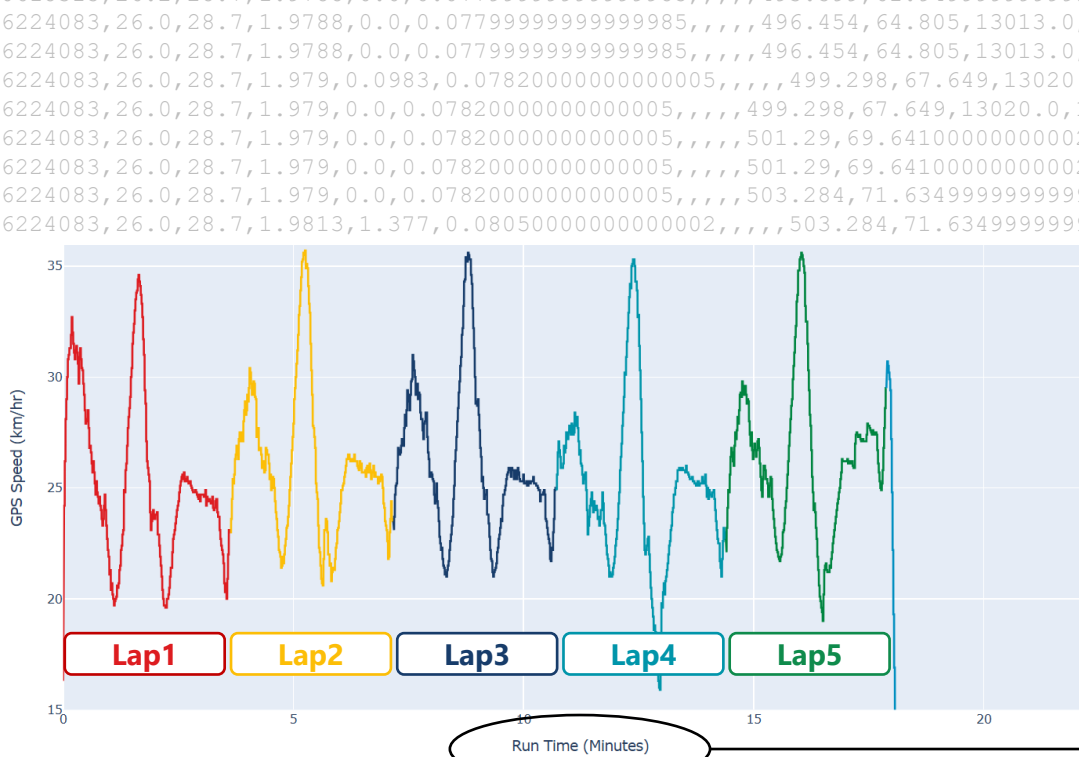
Data Analytics

Recognise Correlations
and Patterns

Level 2

Time-Based «Chunk» to distance based Lap-to-Lap Data

NEW
2026



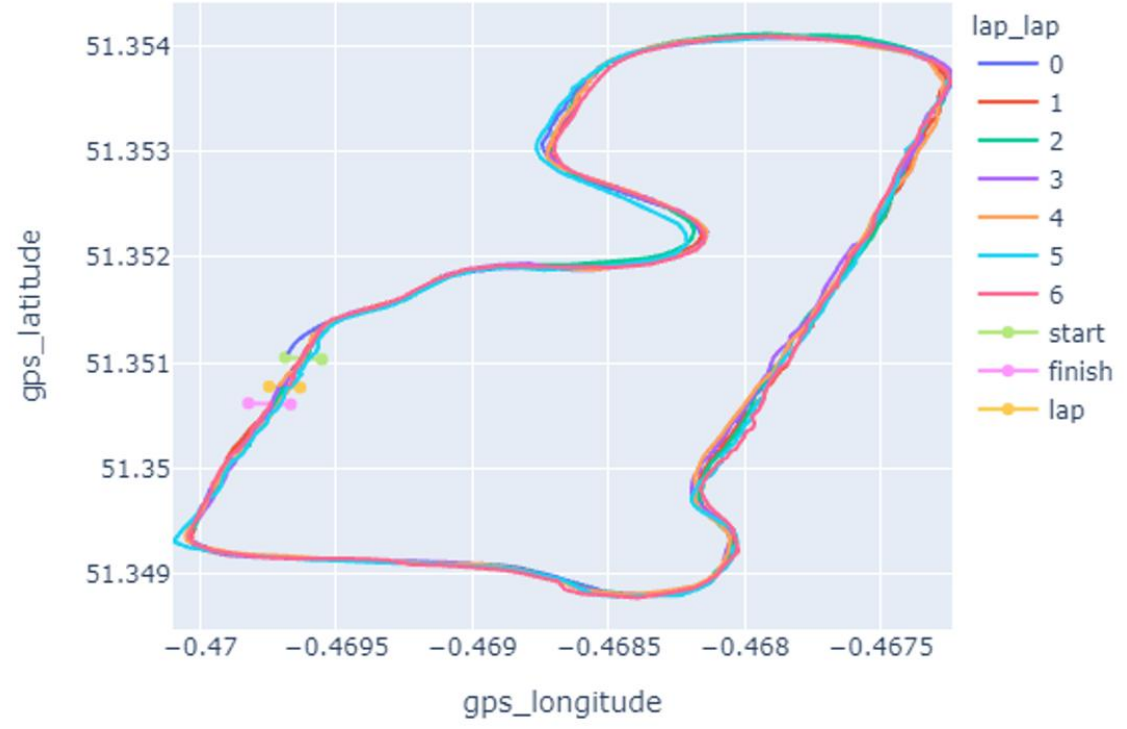
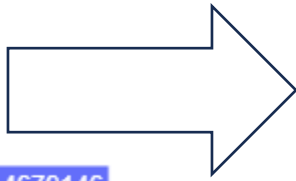
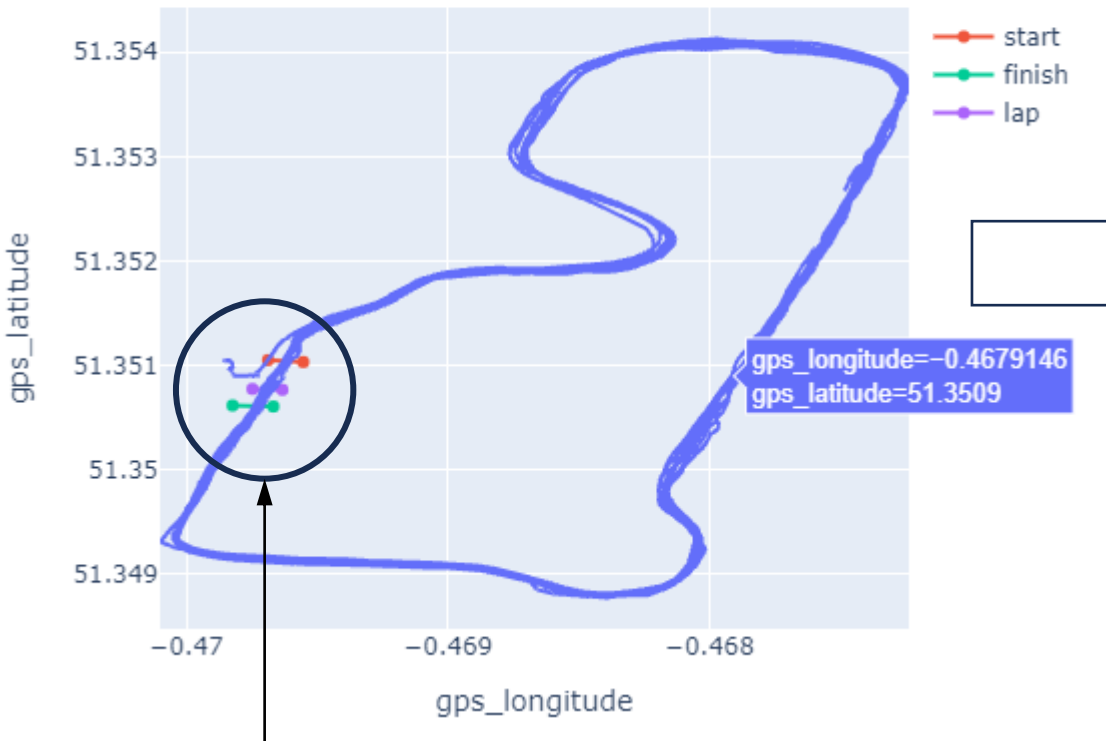
t=0 min

t=17 min



Time-Based «Chunk» to distance based Lap-to-Lap Data

```
fig = df.plot(x='gps_longitude', y='gps_latitude')
for name, points in lines.items():
    fig.add_trace(go.Scatter(x=points[0], y=points[1], name=name))
fig.show()
```



```
lines = {
    'start': ((-0.469553367, -0.4696881), (51.35103562, 51.3510535)),
    'finish': ((-0.469667683, -0.469823533), (51.35060957, 51.35061913)),
    'lap': ((-0.469633117, -0.46974765), (51.35076913, 51.35077756))
}
```



Time-Based «Chunk» to distance based Lap-to-Lap Data

```

for line, points in lines.items():
    x1 = points[0][0]
    y1 = points[1][0]
    x2 = points[0][1]
    y2 = points[1][1]
    x3 = df.gps_longitude
    y3 = df.gps_latitude
    x4 = df.gps_longitude.shift(-1)
    y4 = df.gps_latitude.shift(-1)

    denom = ((x1 - x2) * (y3 - y4)) - ((y1 - y2) * (x3 - x4))
    t = round((((x1 - x3) * (y3 - y4)) - ((y1 - y3) * (x3 - x4))) / denom, 1)
    u = round((((x1 - x2) * (y1 - y3)) - ((y1 - y2) * (x1 - x3))) / denom, 1)

    df[f'{line}_cross'] = (t >= 0) & (t <= 1) & (u >= 0) & (u <= 1)
    df[f'{line}_lap'] = df[f'{line}_cross'].cumsum()

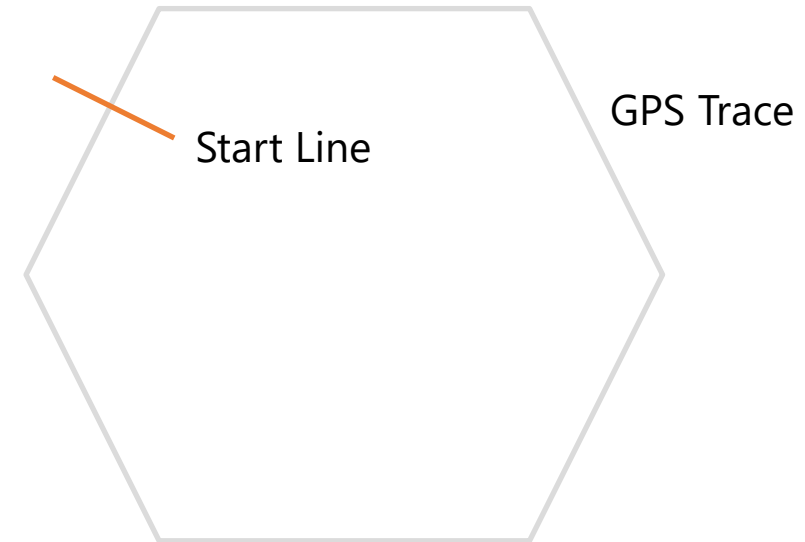
```

```

df.drop(index=df.loc[df.start_lap < 1].index, inplace=True)
df.drop(
    index=df.loc[df.finish_lap >= df.finish_lap.max()].index,
    inplace=True
)

```

- Efficiently calculate when a vehicle has crossed one of the three lines entered previously: Line-segment intersection



- Data at beginning and end of logfile is dropped

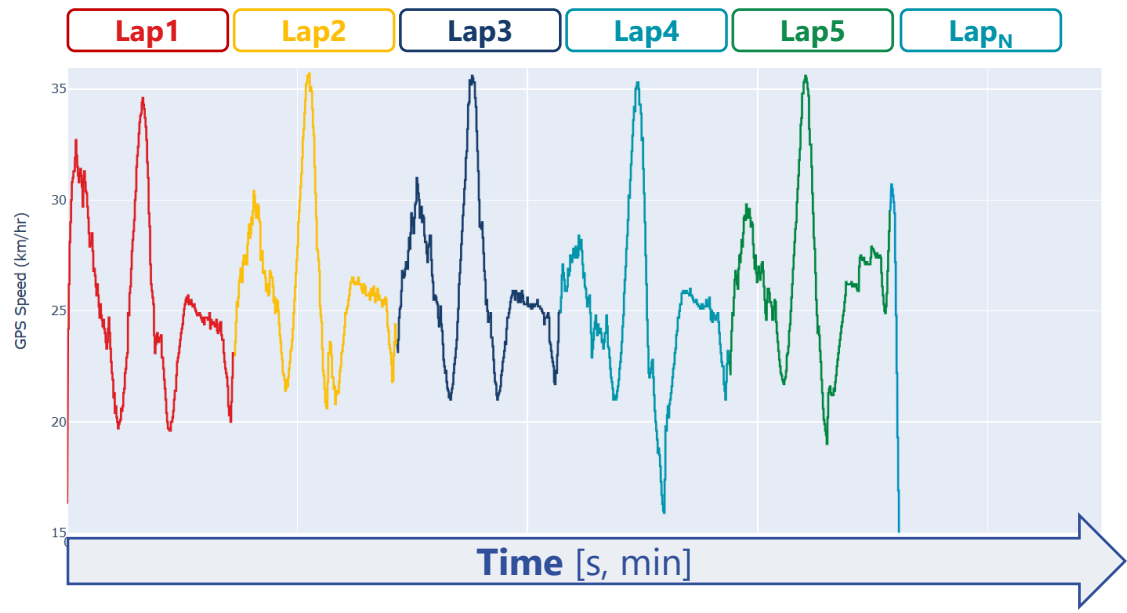
Formula: WIKIPEDIA „Line-Line-Intersection“

$$t = \frac{\begin{vmatrix} x_1 - x_3 & x_3 - x_4 \\ y_1 - y_3 & y_3 - y_4 \end{vmatrix}}{\begin{vmatrix} x_1 - x_2 & x_3 - x_4 \\ y_1 - y_2 & y_3 - y_4 \end{vmatrix}} = \frac{(x_1 - x_3)(y_3 - y_4) - (y_1 - y_3)(x_3 - x_4)}{(x_1 - x_2)(y_3 - y_4) - (y_1 - y_2)(x_3 - x_4)}$$

$$u = \frac{\begin{vmatrix} x_1 - x_2 & x_1 - x_3 \\ y_1 - y_2 & y_1 - y_3 \end{vmatrix}}{\begin{vmatrix} x_1 - x_2 & x_3 - x_4 \\ y_1 - y_2 & y_3 - y_4 \end{vmatrix}} = -\frac{(x_1 - x_2)(y_1 - y_3) - (y_1 - y_2)(x_1 - x_3)}{(x_1 - x_2)(y_3 - y_4) - (y_1 - y_2)(x_3 - x_4)}$$



Time-Based «Chunk» to distance based Lap-to-Lap Data





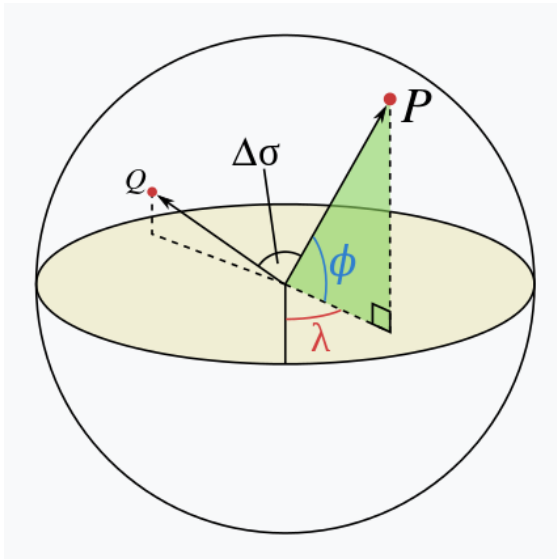
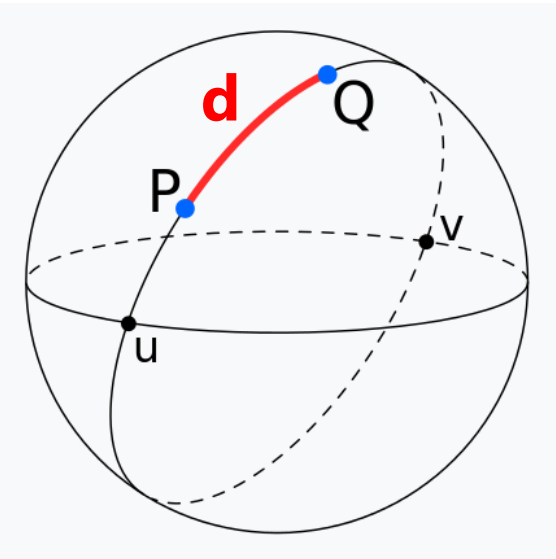
Time-Based «Chunk» to distance based Lap-to-Lap Data

The Haversine Formula:

en.wikipedia.org/wiki/Haversine_formula

$$d = 2r \arcsin\left(\sqrt{\sin^2\left(\frac{\varphi_2 - \varphi_1}{2}\right) + \cos \varphi_1 \cdot \cos \varphi_2 \cdot \sin^2\left(\frac{\lambda_2 - \lambda_1}{2}\right)}\right)$$

φ_1, φ_2 are the latitude of point 1 and latitude of point 2,
 λ_1, λ_2 are the longitude of point 1 and longitude of point 2.



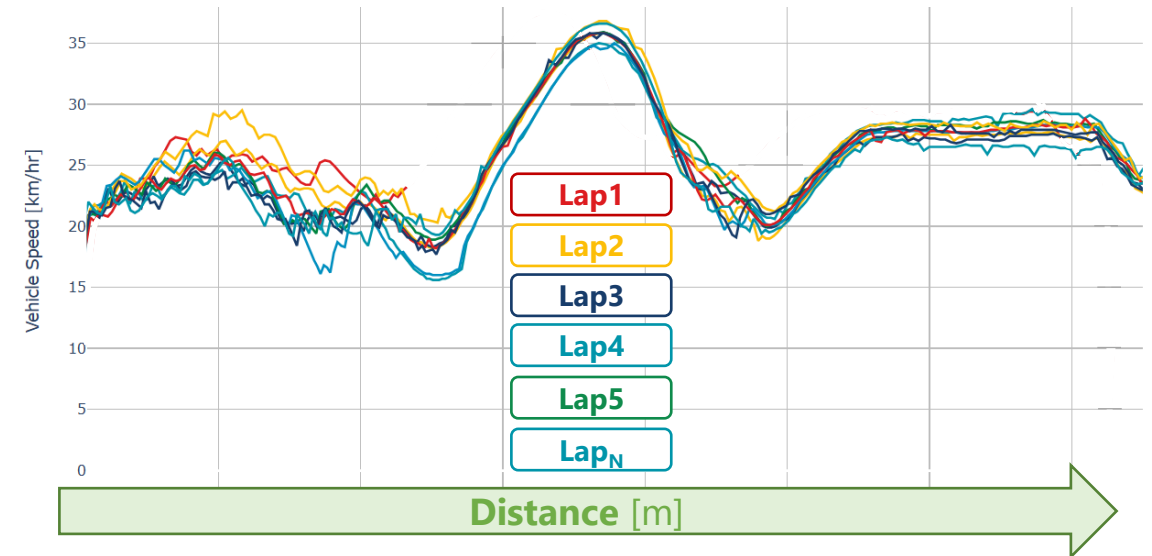
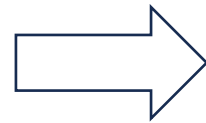
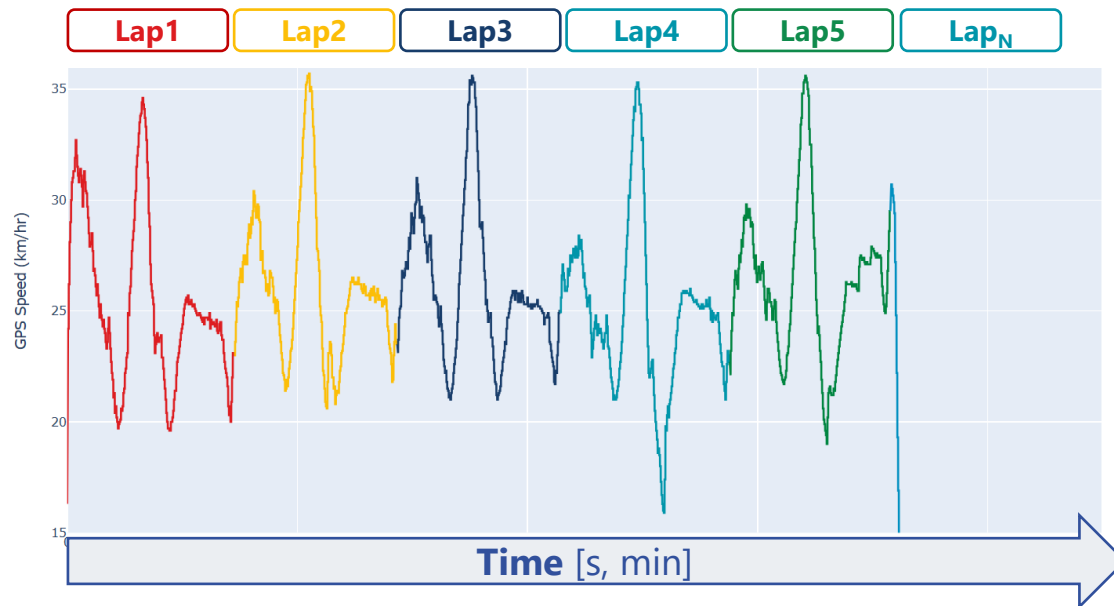
```
lon1 = df.gps_longitude / 180 * np.pi
lat1 = df.gps_latitude / 180 * np.pi
lon2 = df.gps_longitude.shift(1) / 180 * np.pi
lat2 = df.gps_latitude.shift(1) / 180 * np.pi

r = 6371000 Earth Radius in [km]

df['dist'] = (
    2
    * r
    * np.arcsin(
        (
            np.sin((lat2 - lat1) / 2) ** 2
            + np.cos(lat1) * np.cos(lat2) * np.sin((lon2 - lon1) / 2) ** 2
        )
        ** 0.5
    )
)
df['dist'] = df.dist.cumsum()
```



Time-Based «Chunk» to distance based Lap-to-Lap Data

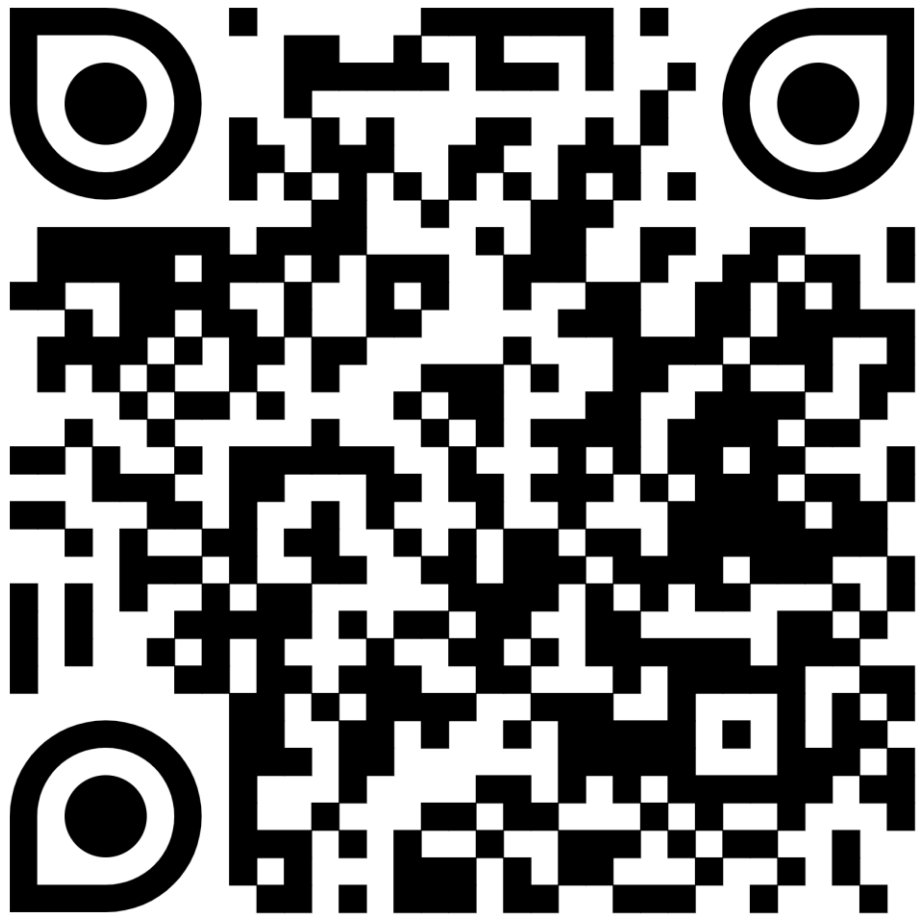


Python Code for this Transformation

OPTIONAL: DOWNLOAD PYTHON-PACKAGES FOR THE ANACONDA-SUITE

This step is optional. The three sandboxes can be conveniently run directly in your own browser (Binder) via the three links above. If you want to use these two packages (Jupyter Lab), download the **Anaconda 2.7.0** suite [here](#) at anaconda.org.

Phoenix Bootcamp Python Code Space-Time Transformation	DOWNLOAD ▾
Phoenix-Bootcamp Sandbox #1 Data Analysis	DOWNLOAD ▾
Phoenix Bootcamp Sandbox #2 and #3 Knowledge Graph and AI	DOWNLOAD ▾

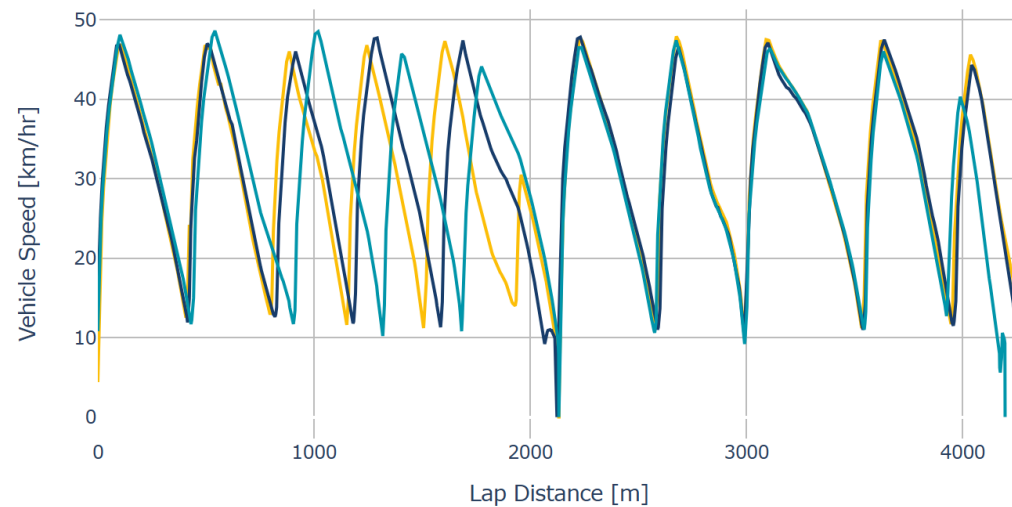




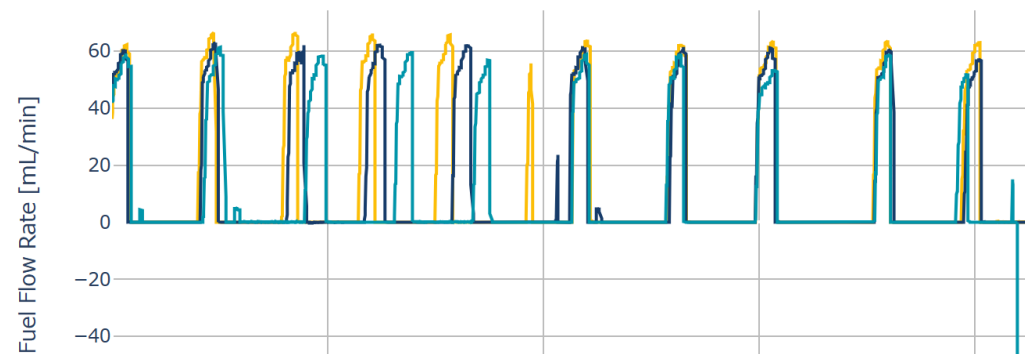
Data Correlation

Lap

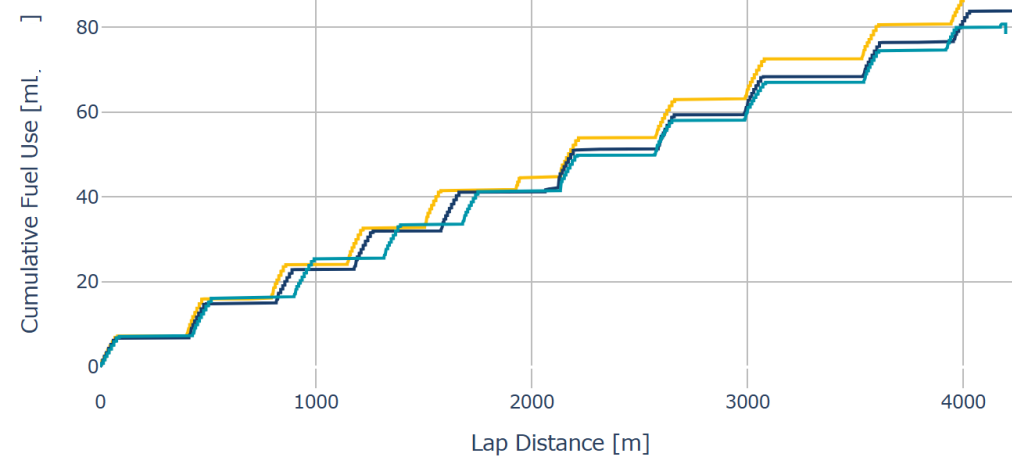
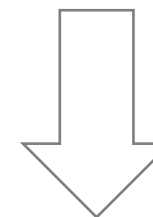
- 1
- 2
- 3



**Speed
[km/h]**



**Instantaneous
Energy Consumption
[ml/min]**

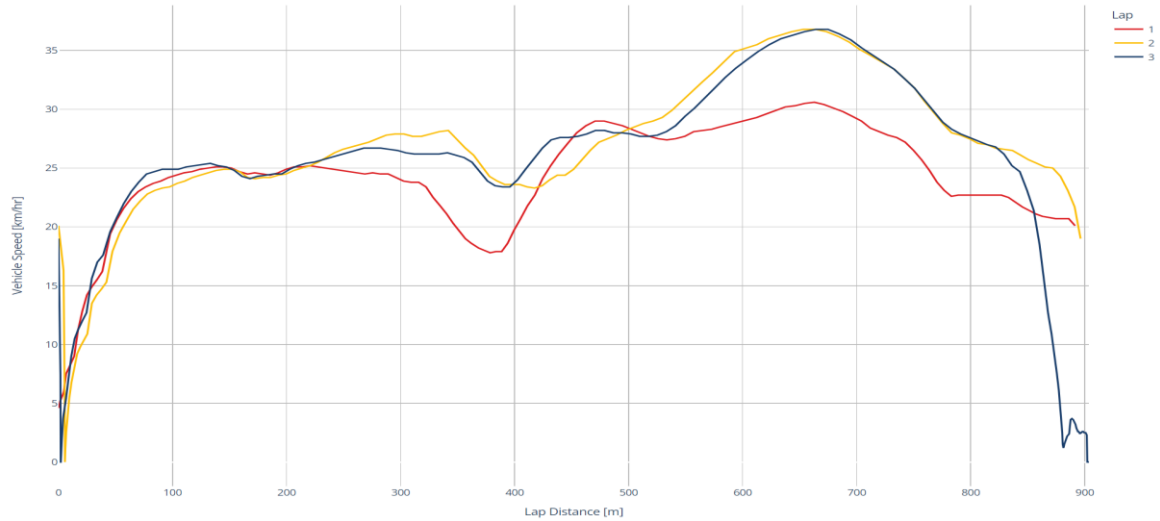


**Cumulative
Energy Consumption
[ml]**

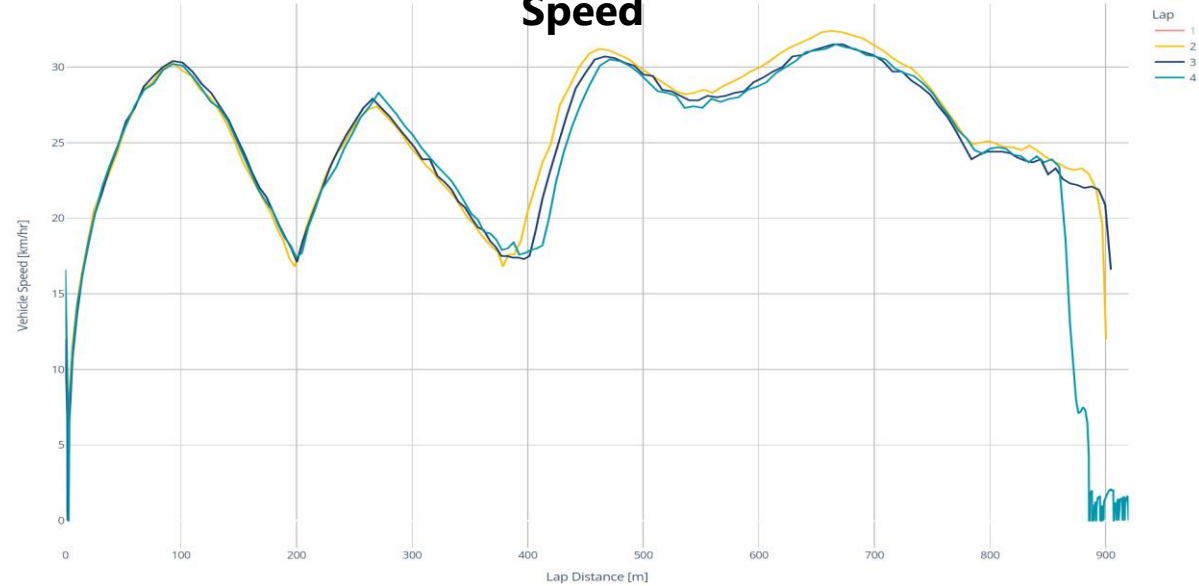


Driving Consistency!

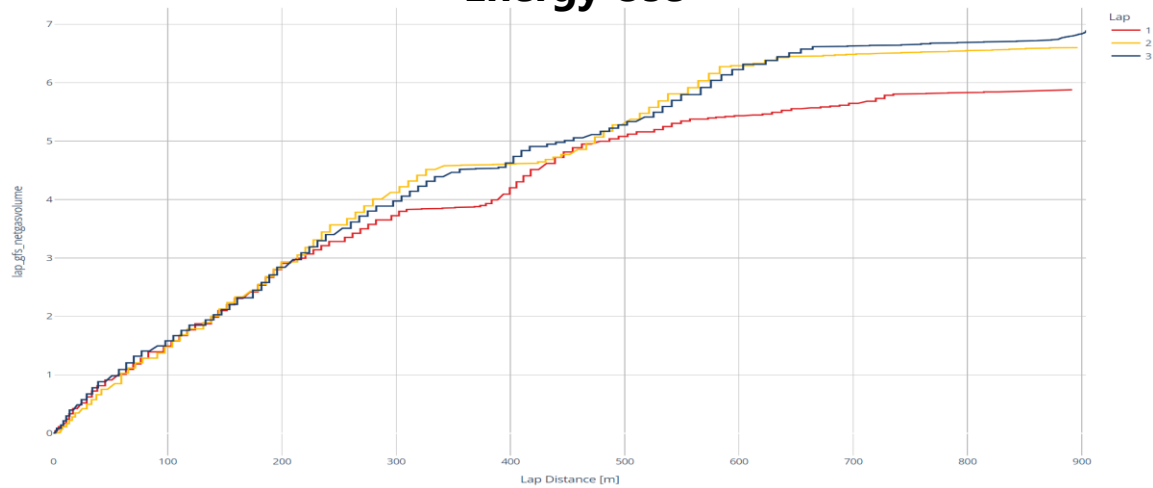
Speed



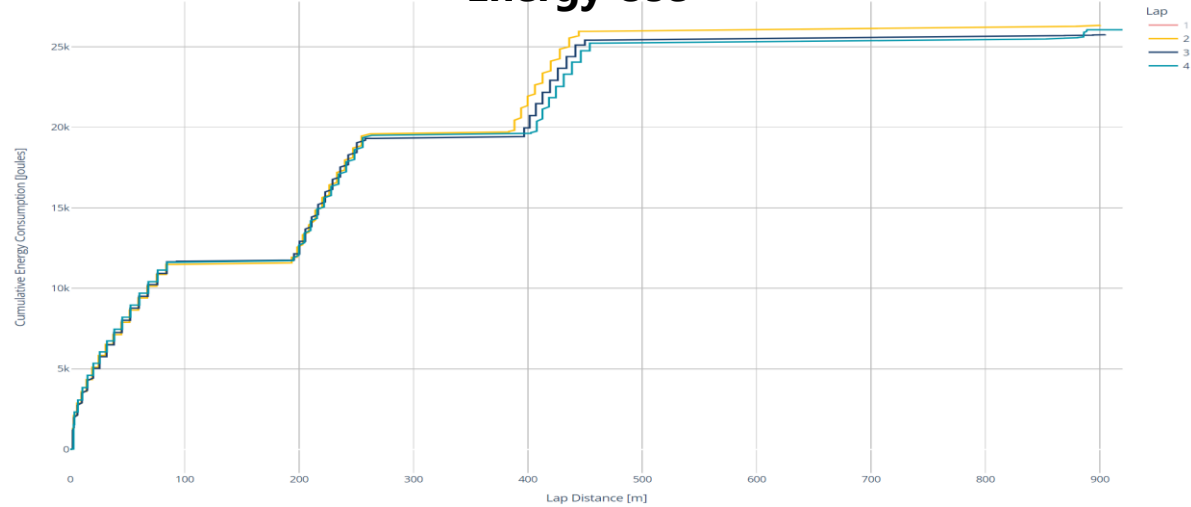
Speed



Energy Use

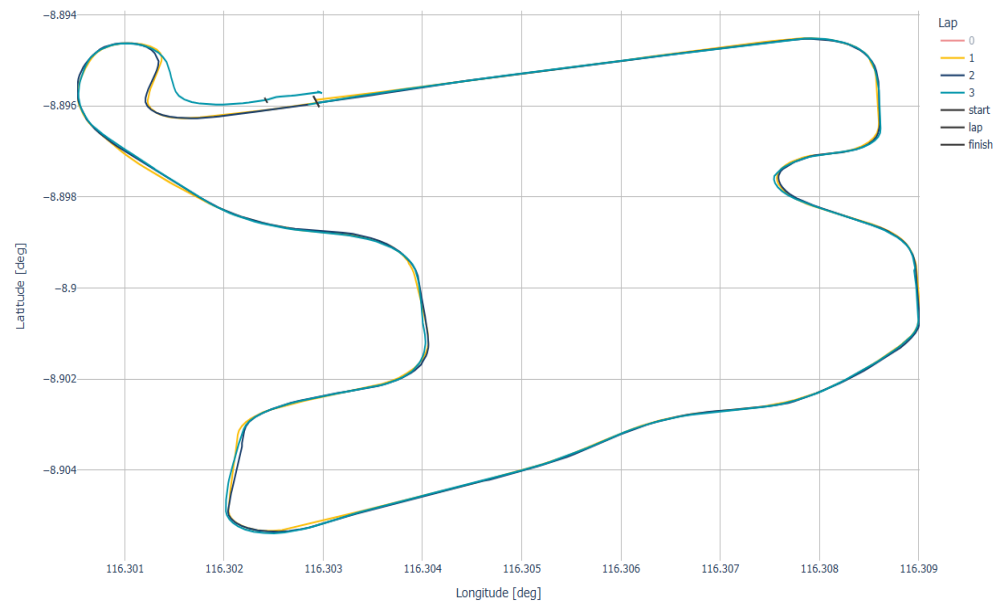
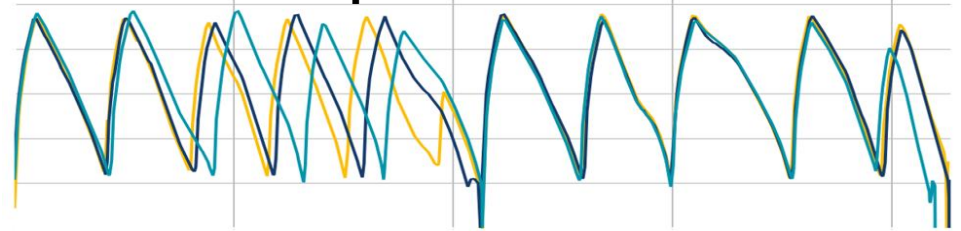


Energy Use

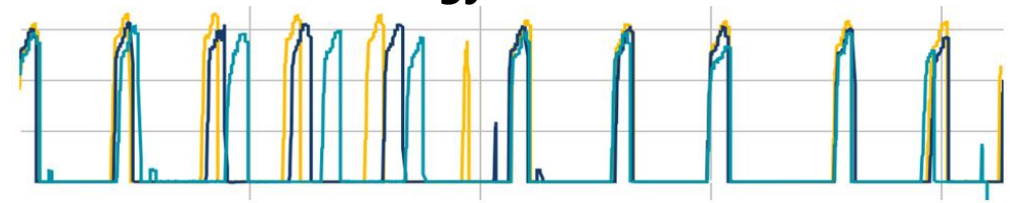


From Pattern to Meaning

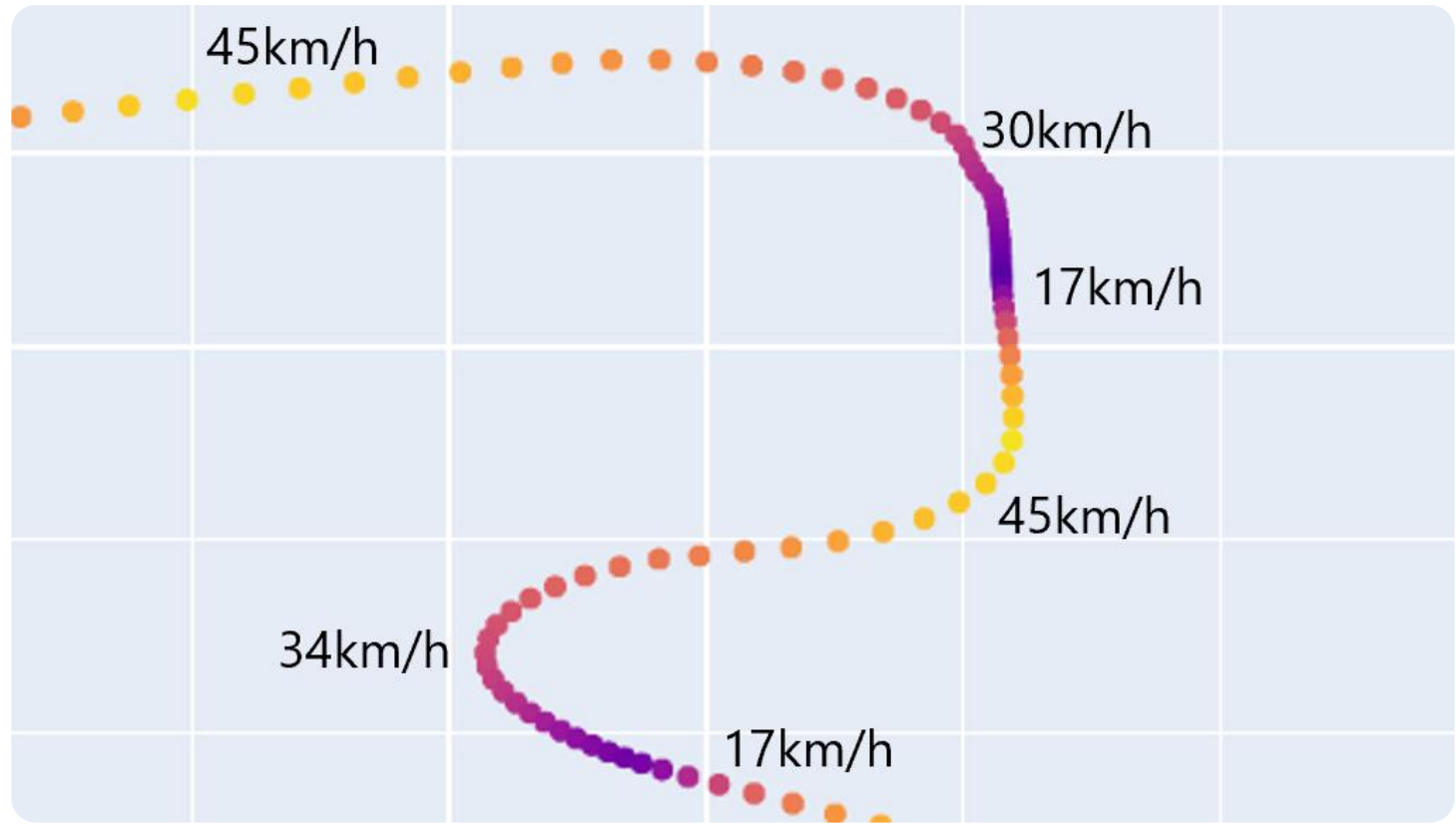
Speed



Energy Use

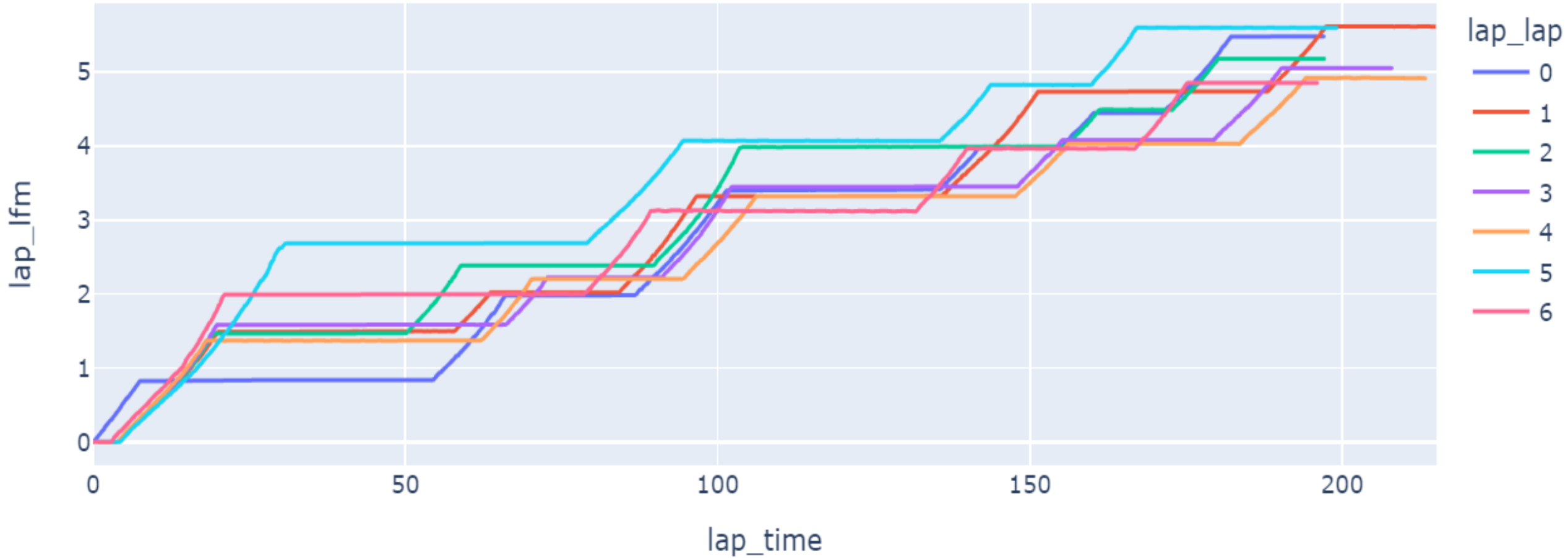


Pattern and Meaning



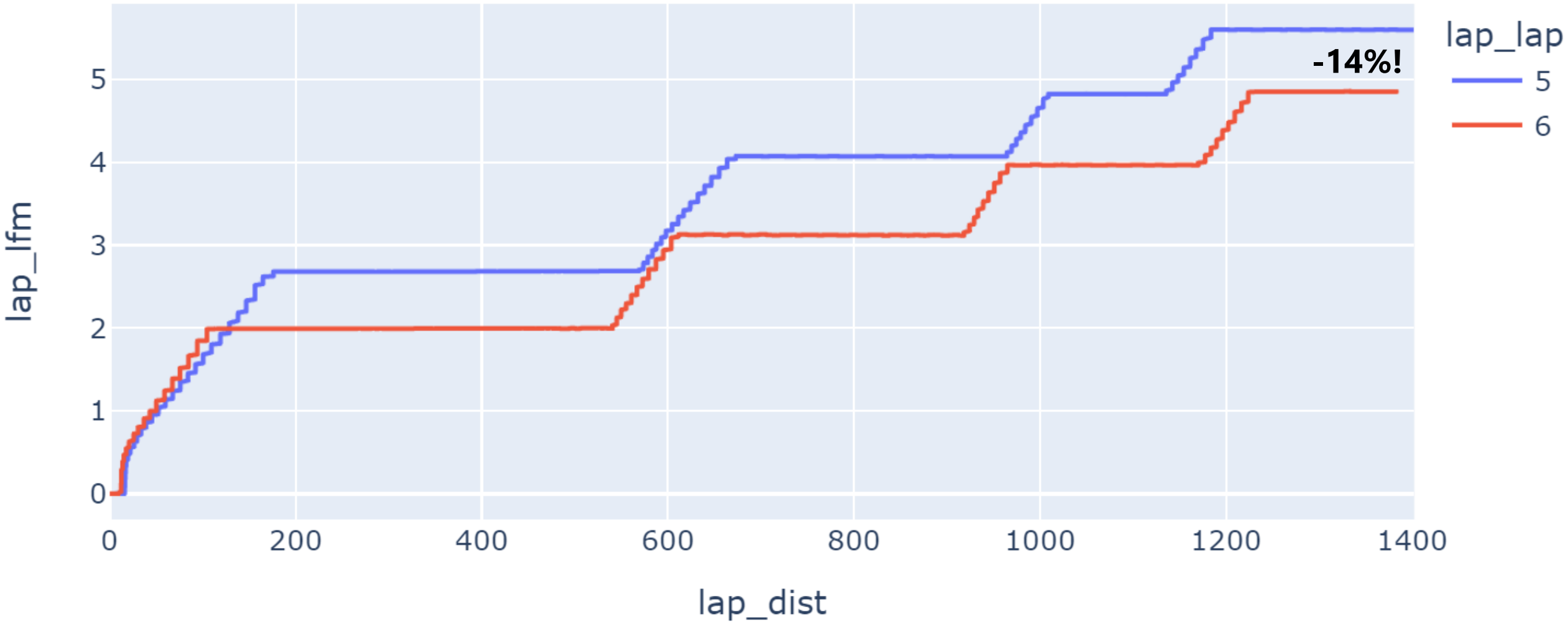


Quantitative Analysis: **Cumulative** Consumption



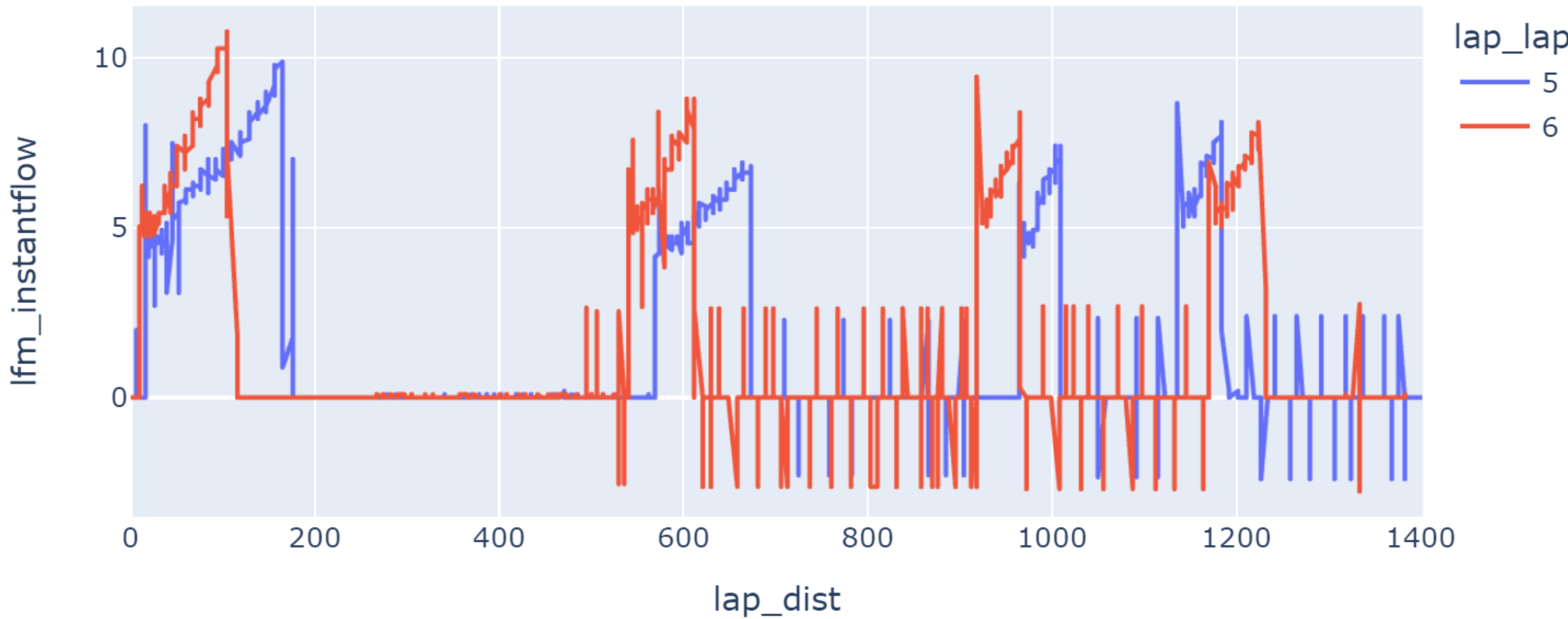


Quantitative Analysis: **Cumulative** Consumption



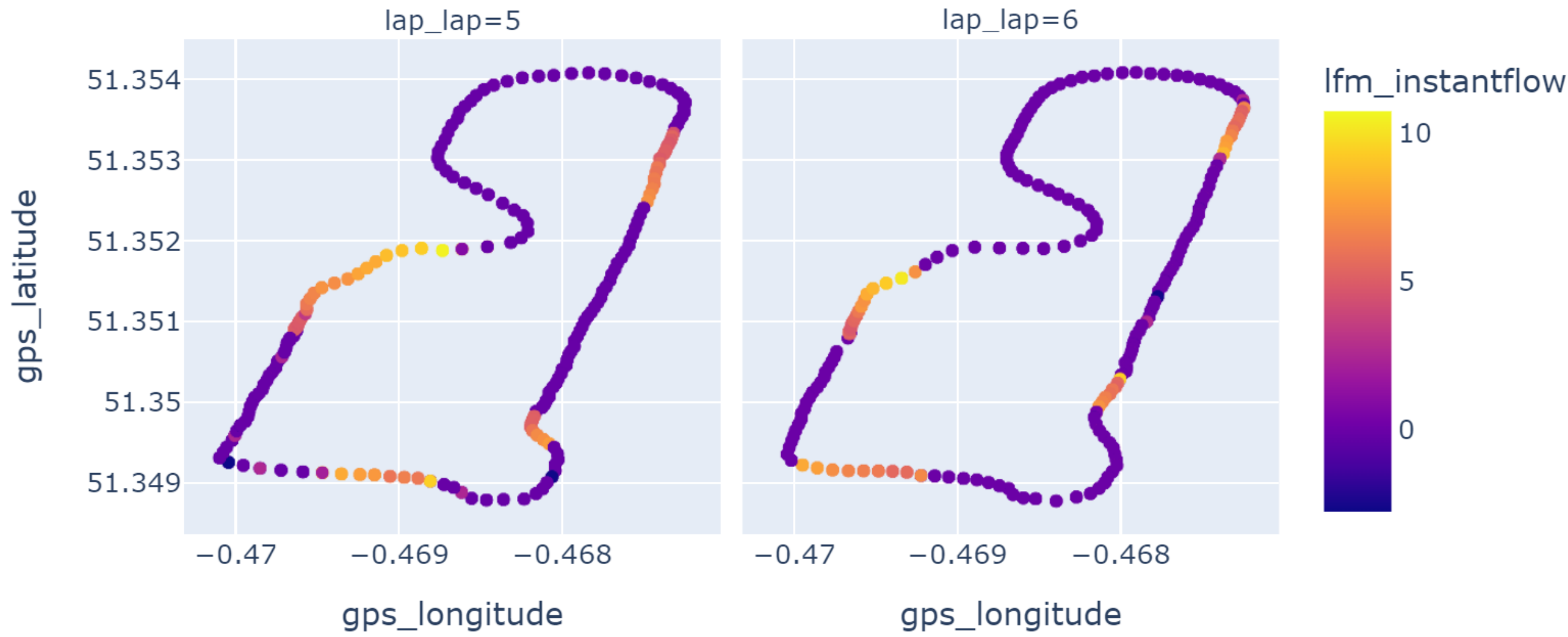


Quantitative Analysis: **Instantaneous** Consumption

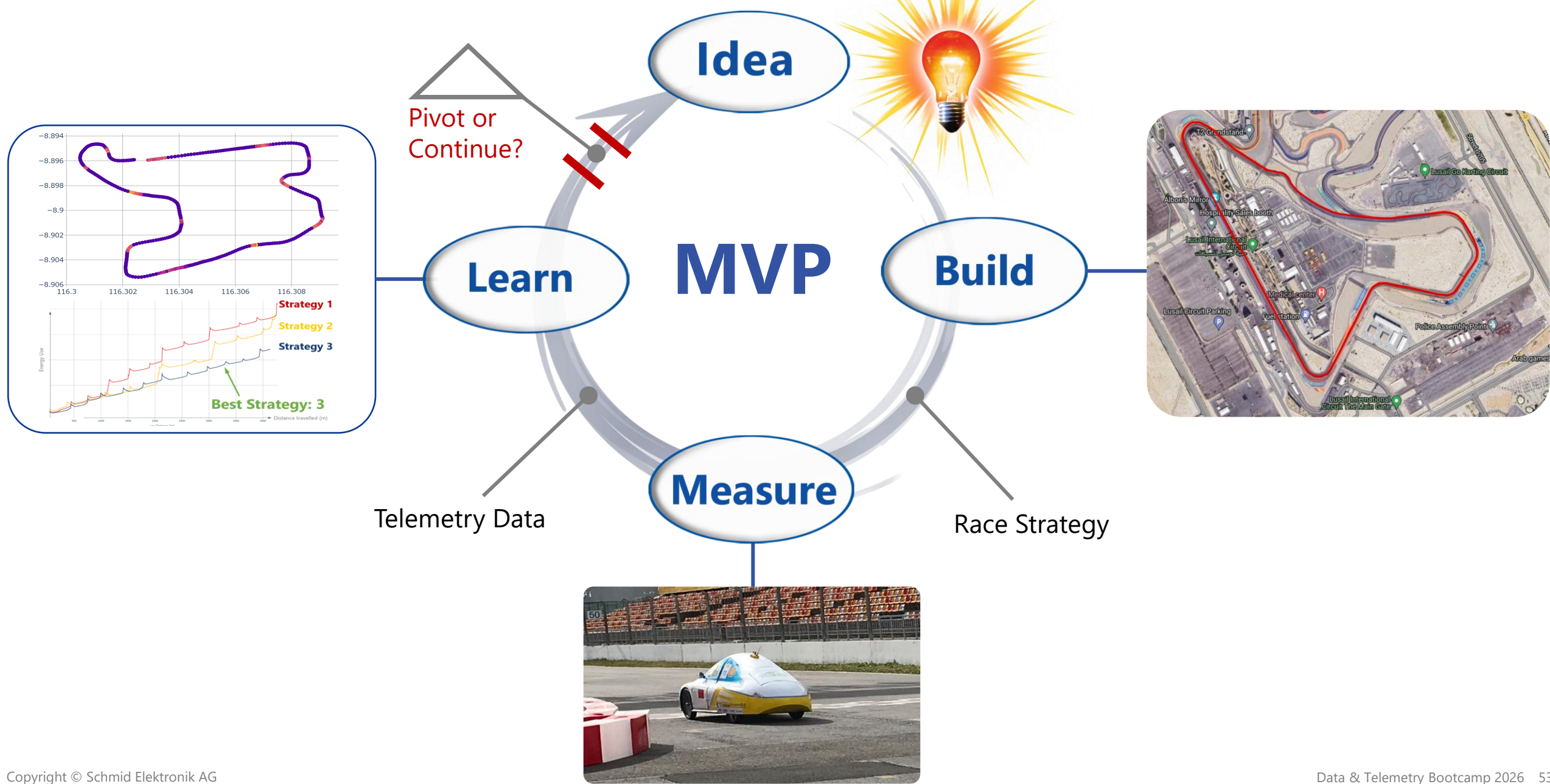




Qualitative Analysis: Burn & Coast Heatmap

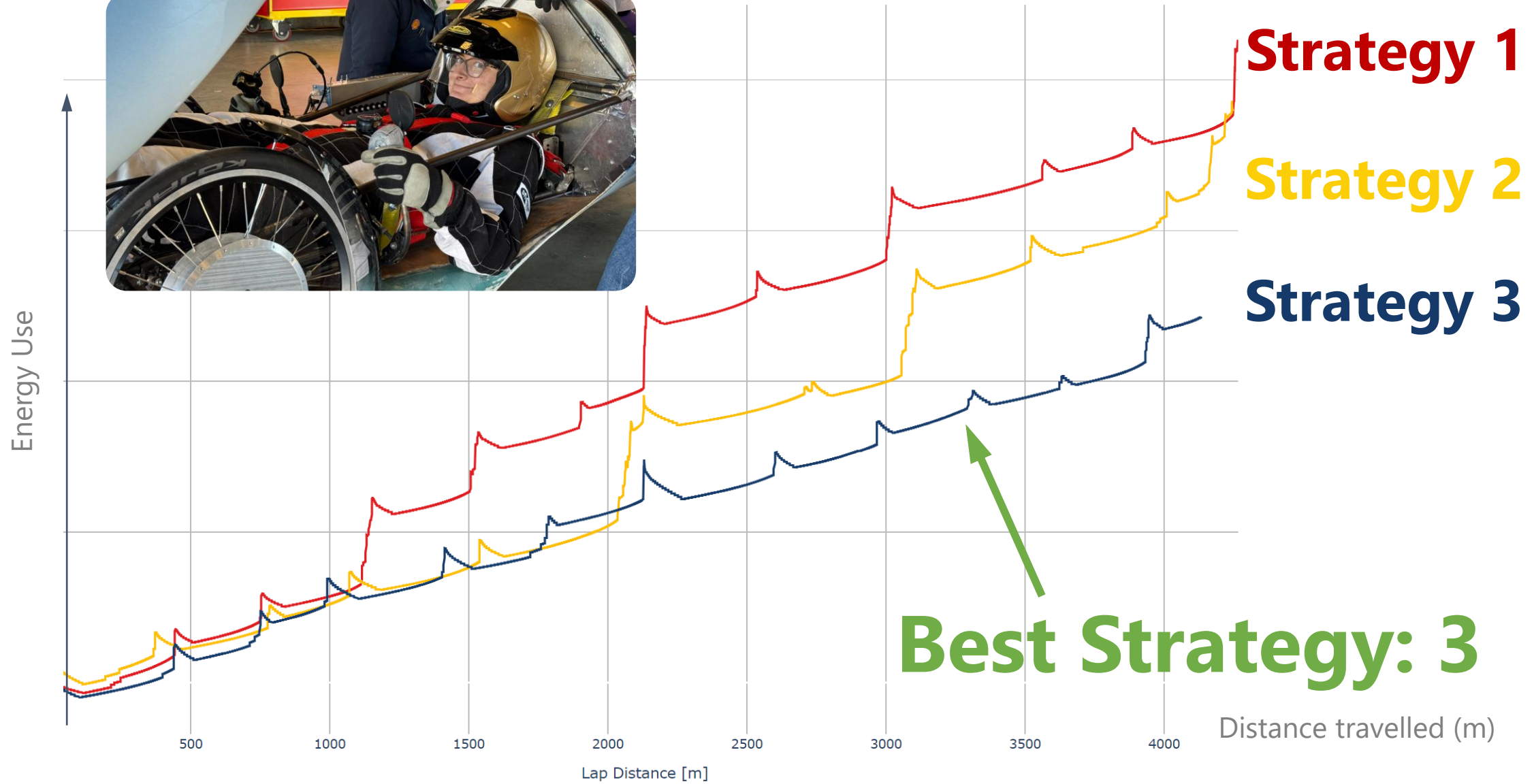


Iterative Learning based on MVP Philosophy





Learn: Quantitative Analysis of Energy Use



Strategy 1

Strategy 2

Strategy 3

Best Strategy: 3

Distance travelled (m)

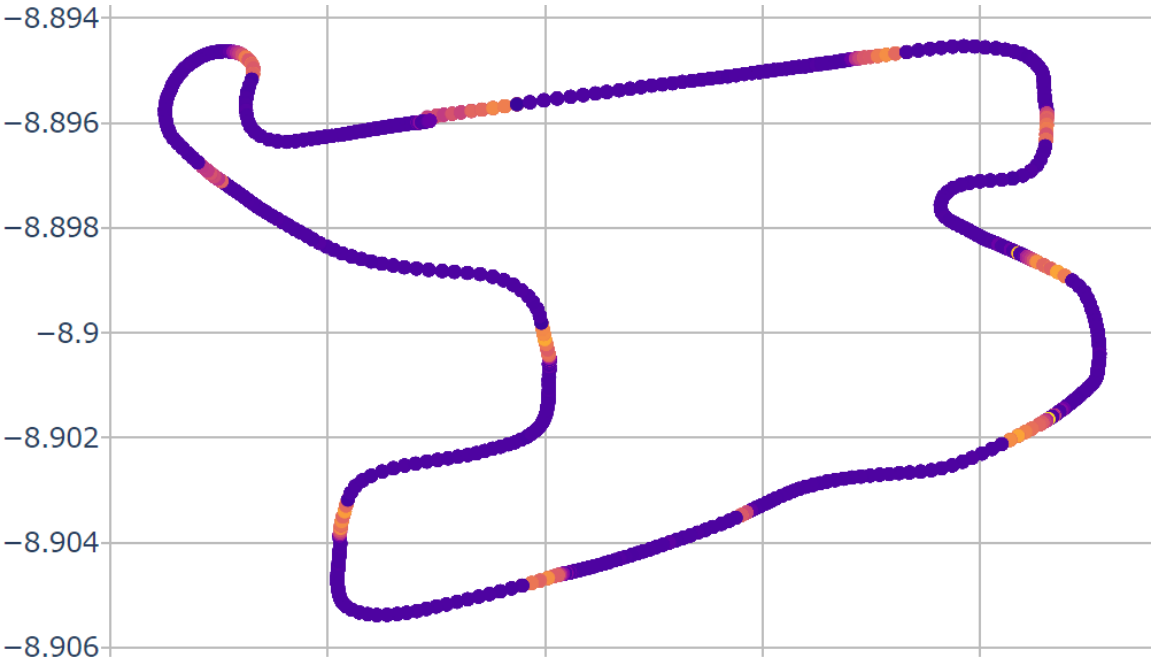
Lap Distance [m]



Learn: Qualitative Analysis of Driving Patterns

From Quantitative Analysis, we know:

Strategy 1



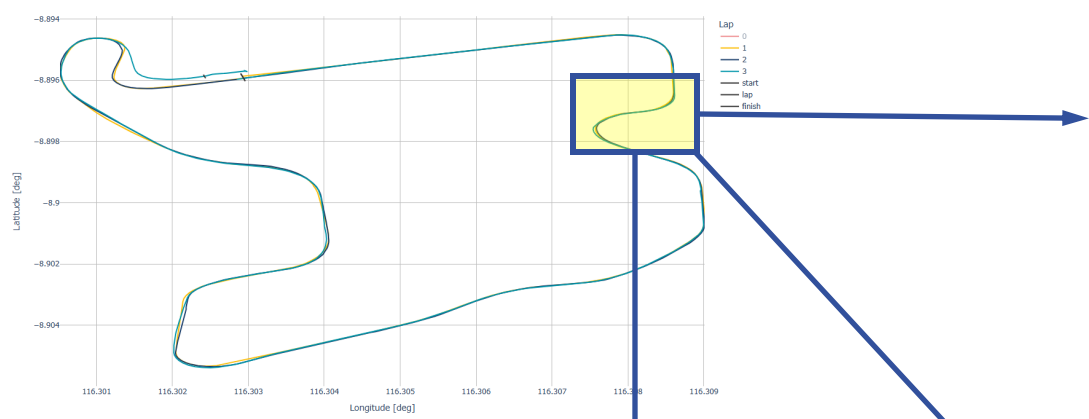
Strategy 3 (better!)



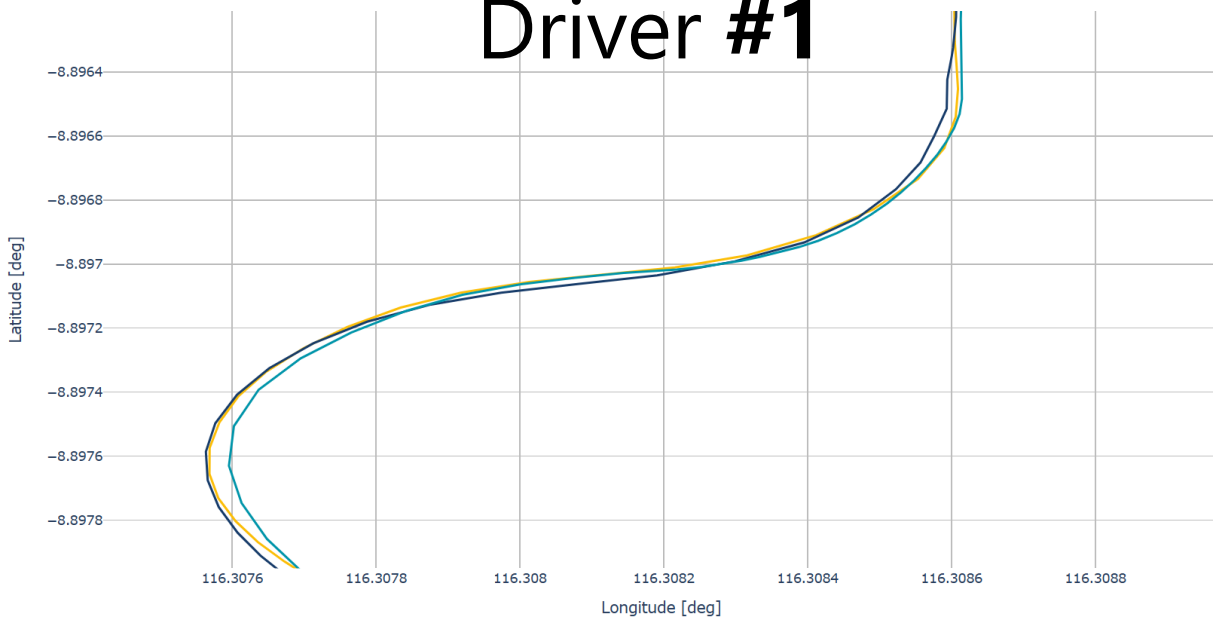
But Why?



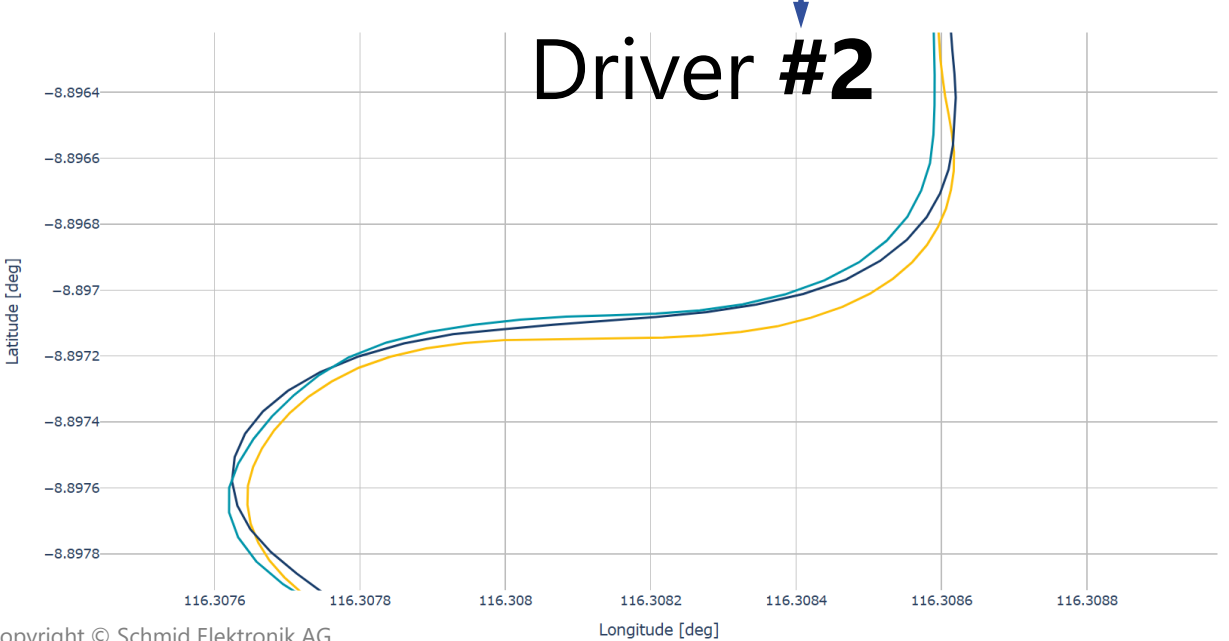
Race Lines in Corners



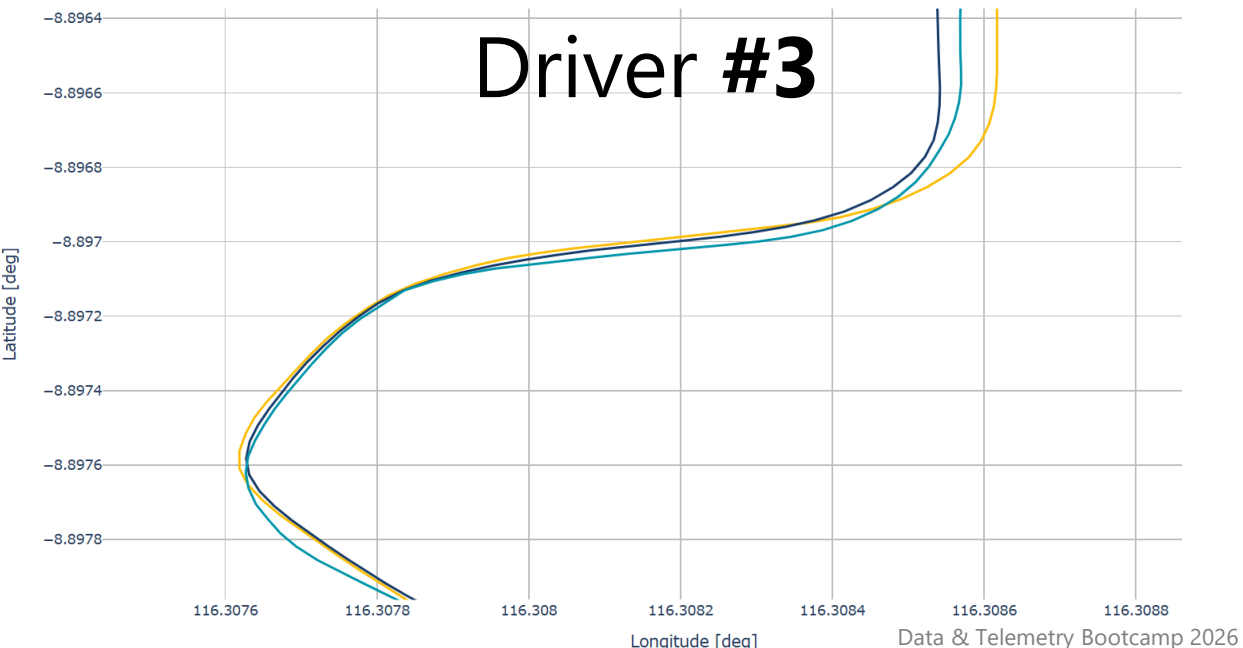
Driver #1



Driver #2



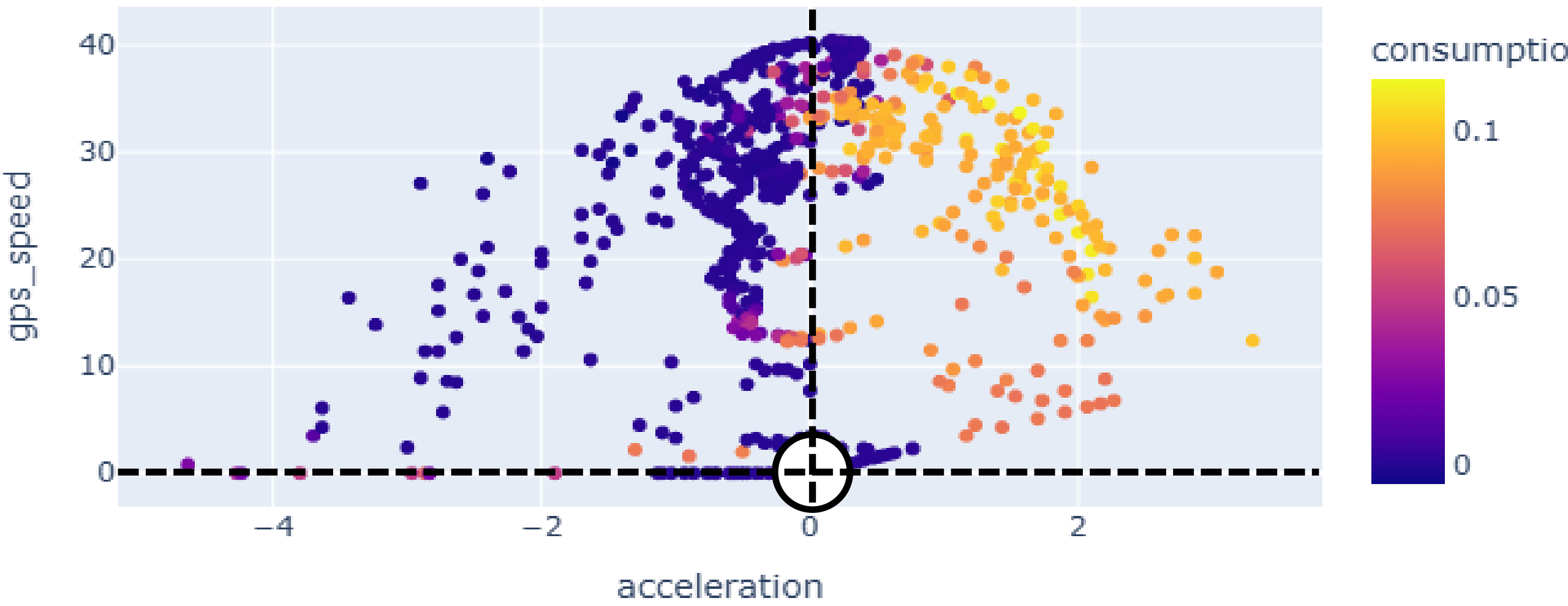
Driver #3





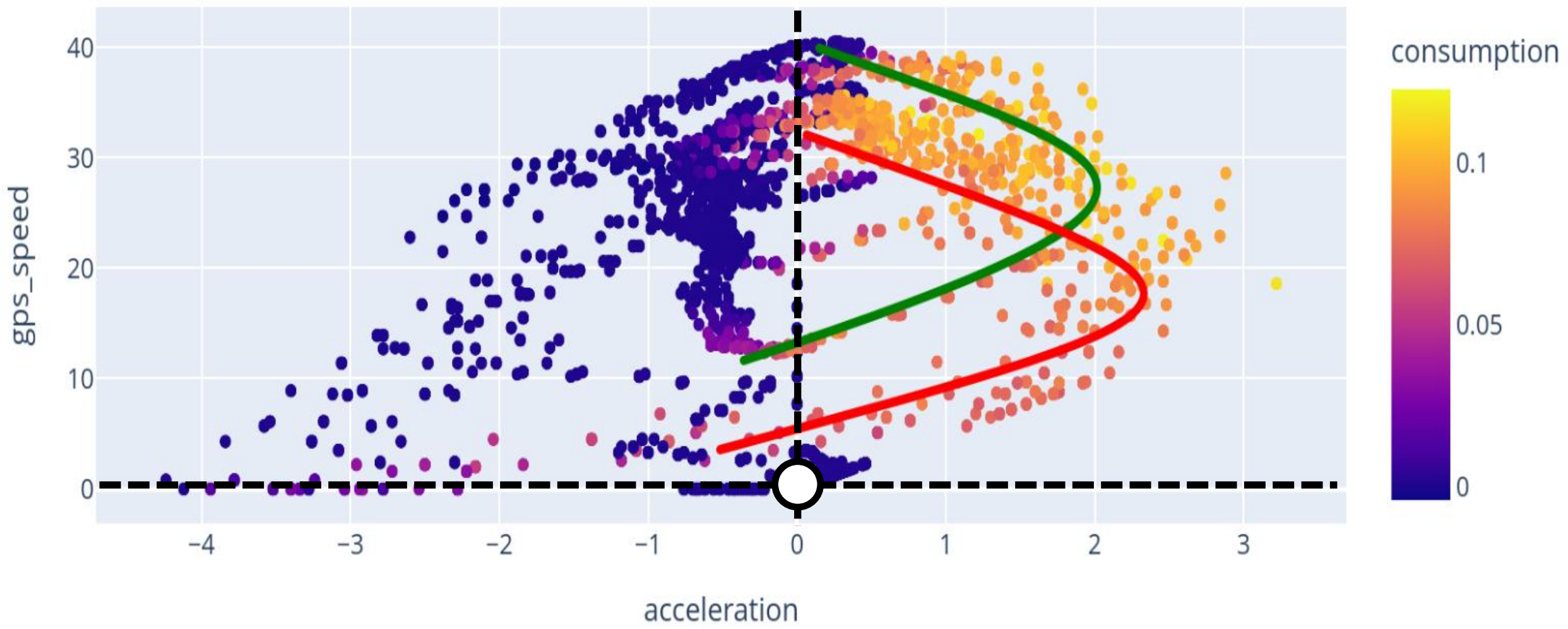
Data as a storyteller

Label	Unit	Description
acceleration	m/s ²	How much the speed changes per second
consumption	W/s	How much energy is used per second



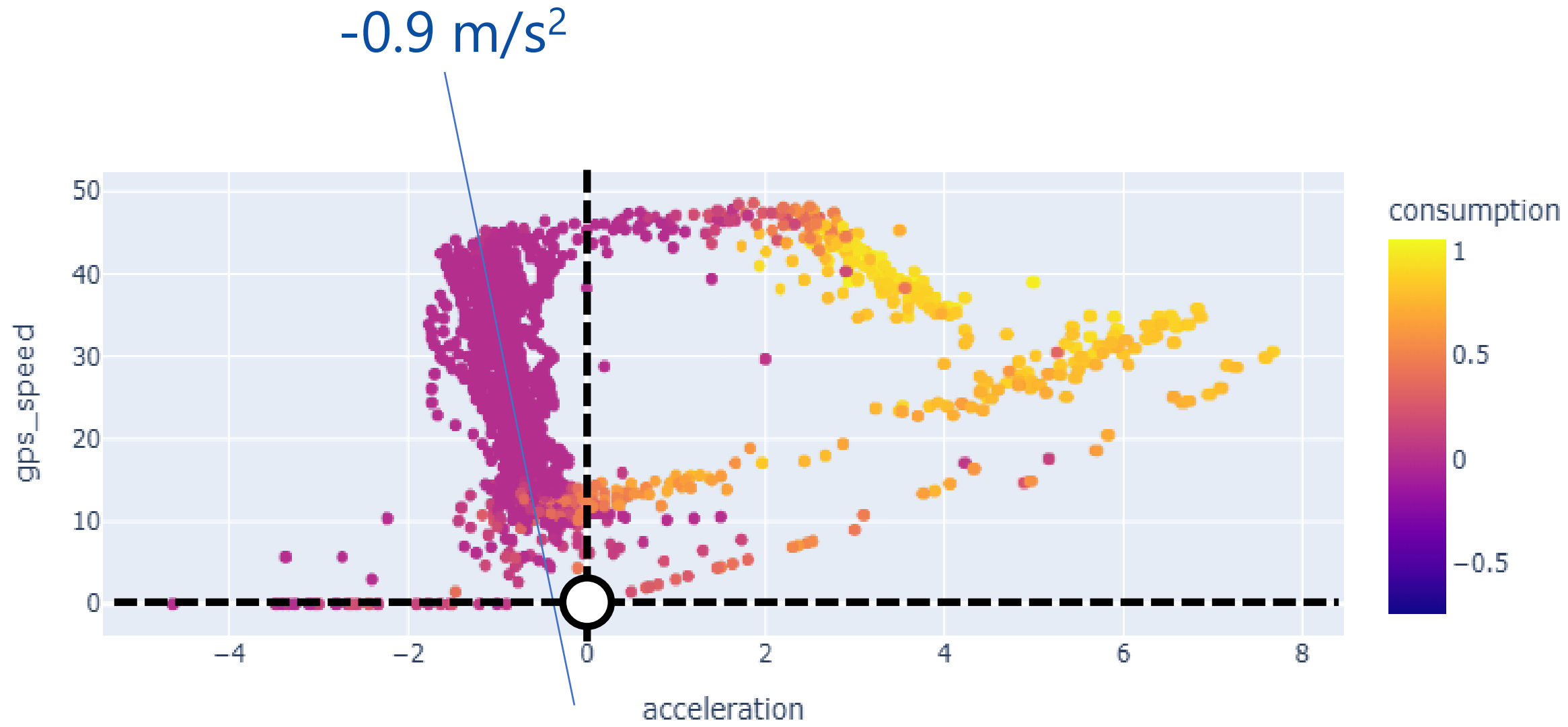


Data as a storyteller





Data as a storyteller: e.g. Coastdown-Testing





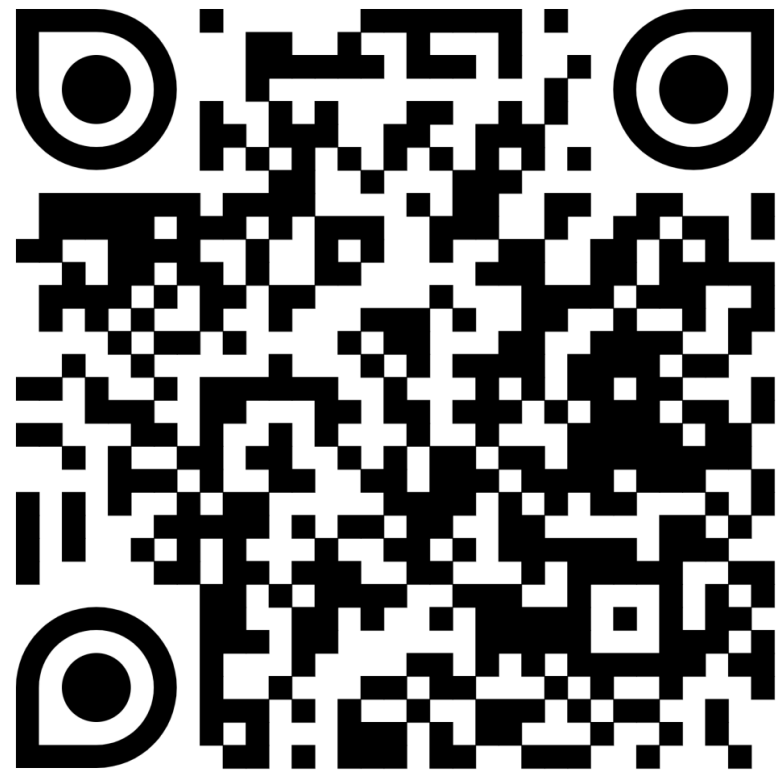
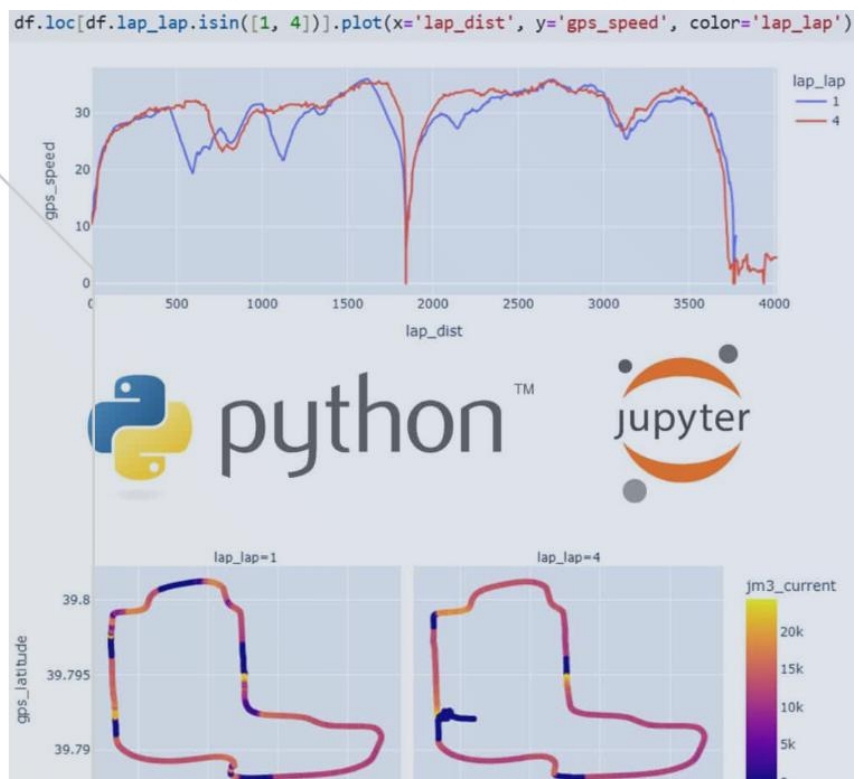
Python Sandbox #1 to understand Race Data

Programming Sandbox #1

JUPYTER NOTEBOOK UND PYTHONCODE FOR LEVEL-3

Start Jupyter Notebook in your browser (Binder, ~1-2 min.) and play with Python. Start with real race data (speed, GPS) and calculate accelerations and energy consumption. Save the source code locally, because when you close the browser, the environment will be gone.

START SANDBOX #1 IN YOUR BROWSER >



A large, vibrant phoenix made of fire is flying over a racetrack. The phoenix is bright orange and yellow, with its wings spread wide. The racetrack below is dark asphalt with white and red markings. In the background, there are green hills and a blue sky with some clouds. The overall scene is dynamic and energetic.

Live Data

Send Data from the Track
to the IoT with 4G, LoRa, ...

Level ③

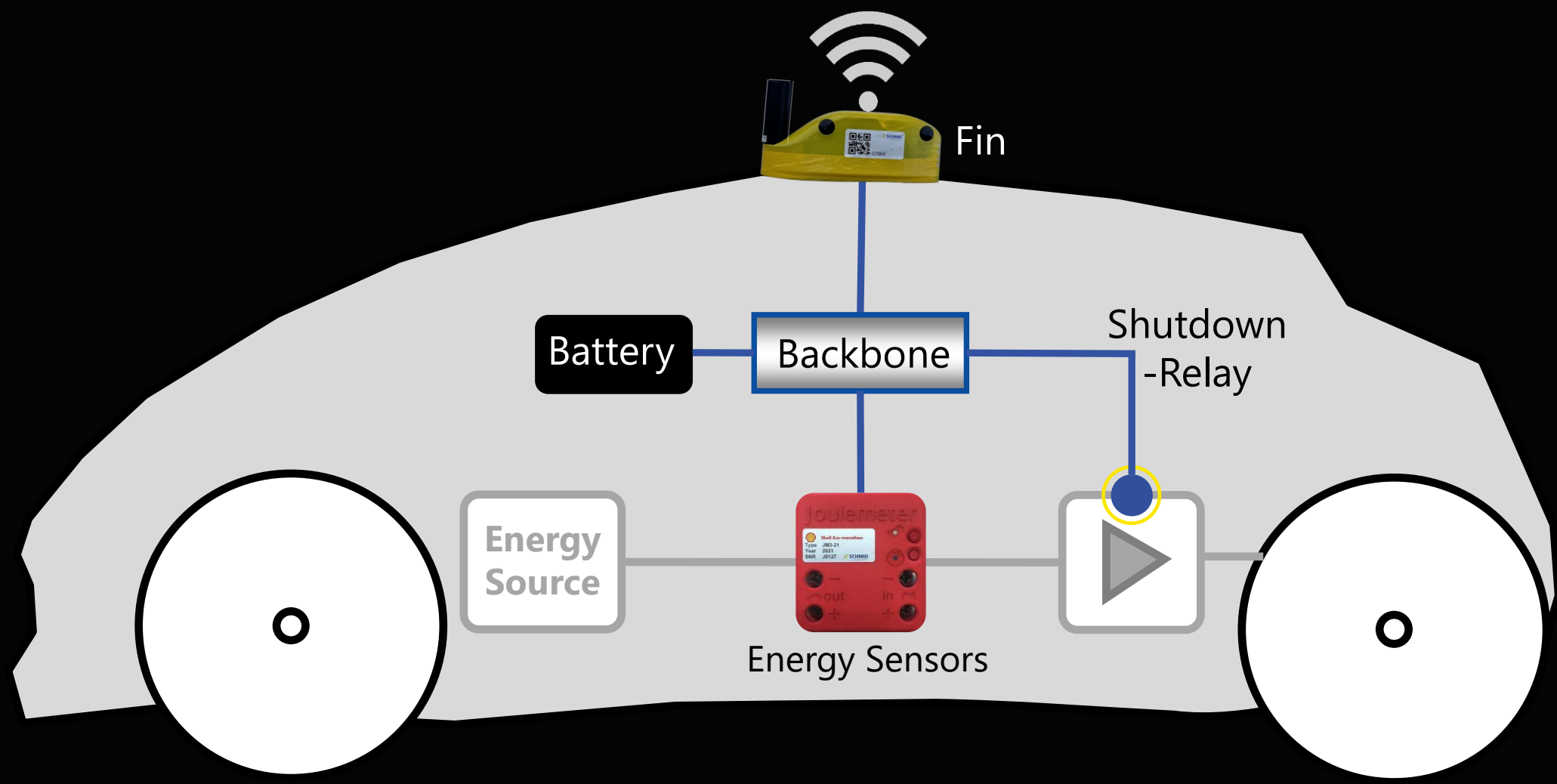


Rank	Country	#	Team Name	Energy Left	Lap
1		502	Schluckspecht Urban Conc...	96.9%	1/6
2		501	DTU Roadrunners	95.7%	1/6
3		505	H2politO - Molecule Urbane	96.7%	1/6
-		701	SZEnergy Team	100.0%	-
-		614	La Joliverie Polytech Nantes	100.0%	-
-		702	TUfast Eco Team	100.0%	-
-		703	TIM UPS INSA	100.0%	-
-		604	ENSEM Eco-Marathon	100.0%	-

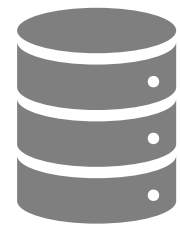
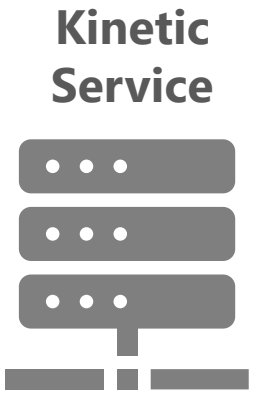
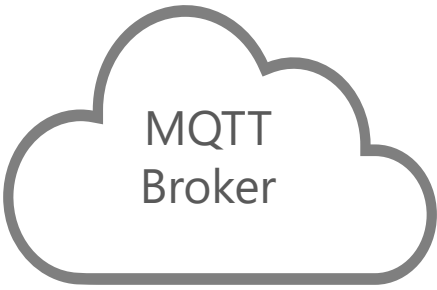
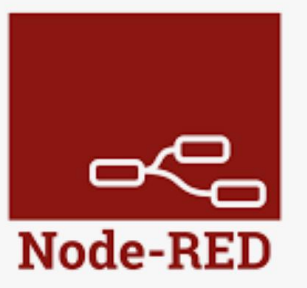
Shell Eco-marathon

Live on Track
Final Race (Replay)

```
imx6@obc:~$ mosquitto -c /etc/mosquitto/mosquitto.conf -d
imx6@obc:~$ mosquitto_sub -h localhost -v -t 'device/mqtt/data/506_data'
```



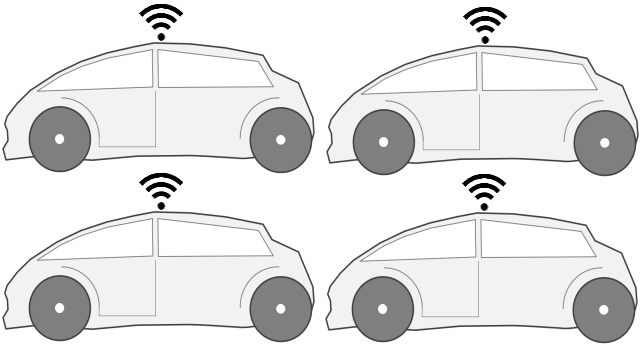
Live Dataflow in the IoT-Server



Database for Static Data (SD-Card)

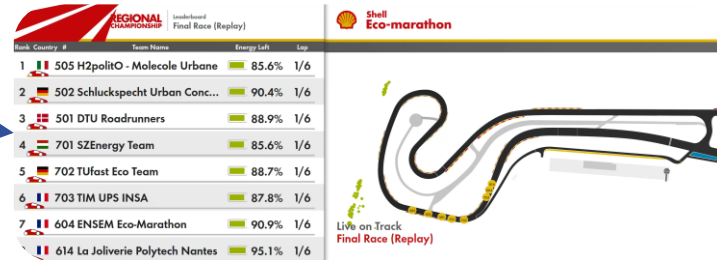


Telemetry Monitoring



Onboard Computers use **Publish/Subscribe** Messaging

Data Validation
Boundary Check
Outlier Detection
Smooth GPS-Data



Live Data Visualization

A digital rendering of a phoenix, a mythical bird that is reborn from its own ashes, depicted as a bright orange and yellow flame-like creature with large, outstretched wings. It is flying over a detailed digital model of a racetrack, complete with grandstands filled with spectators, pit buildings, and a clear sky with some clouds. The racetrack surface is dark grey with white and red markings along the edges.

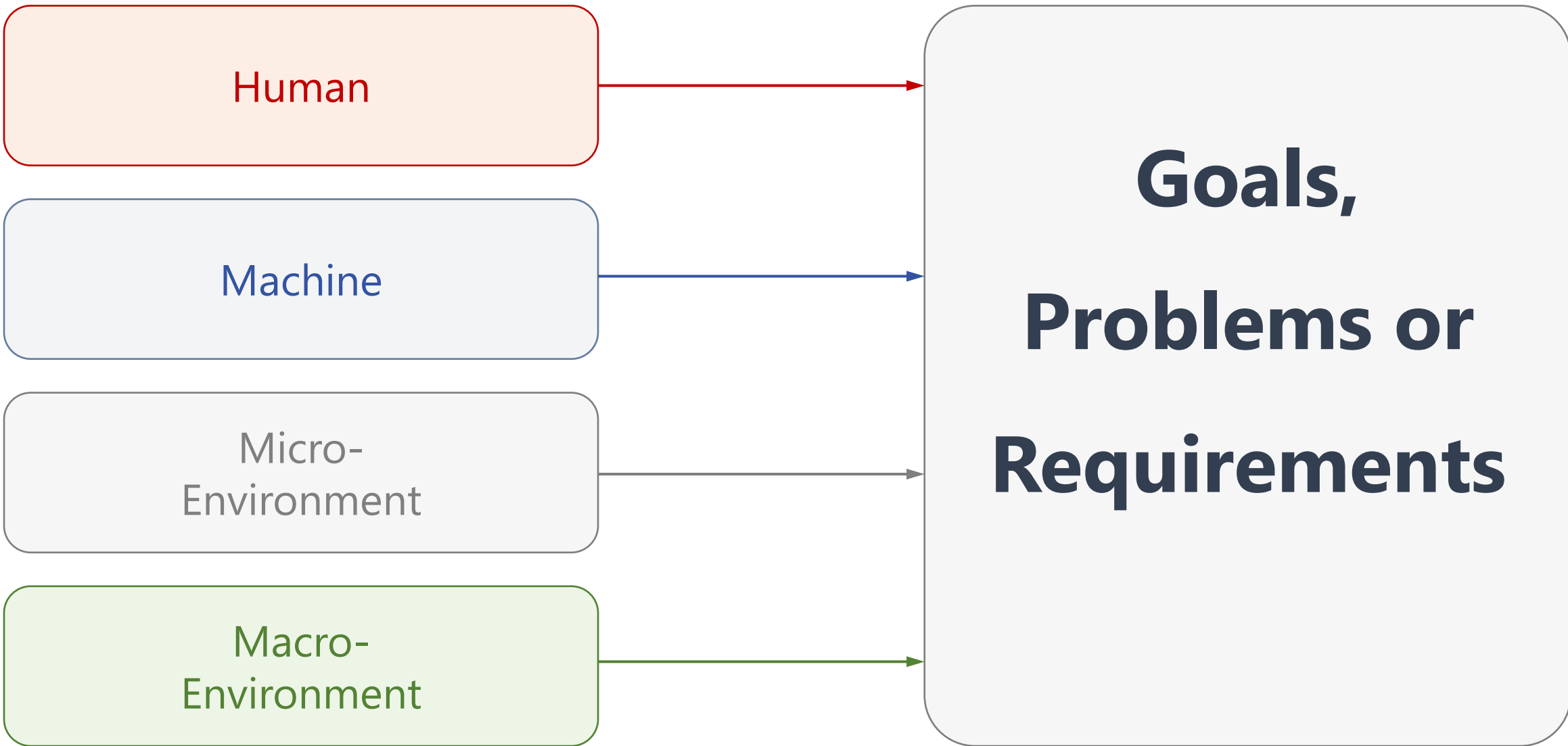
System Modelling

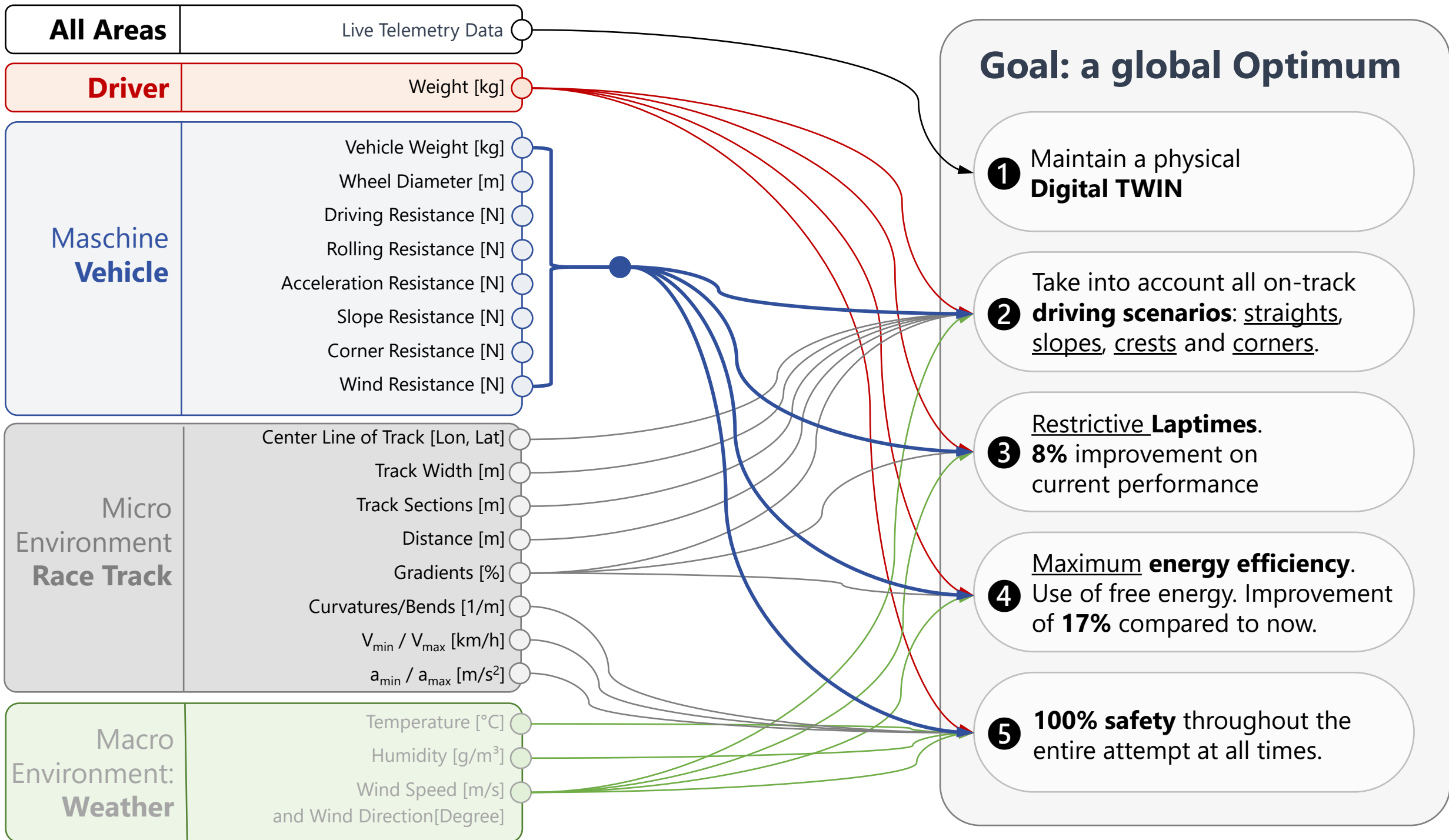
Maintain physics based

Digital Twin

Level 4

≡ Scaling the Data Strategy







Fitness

- Heartbeat
- Eye movement
- Cognitive Load

Behavior

- Throttle
- Brake
- Steering Wheel





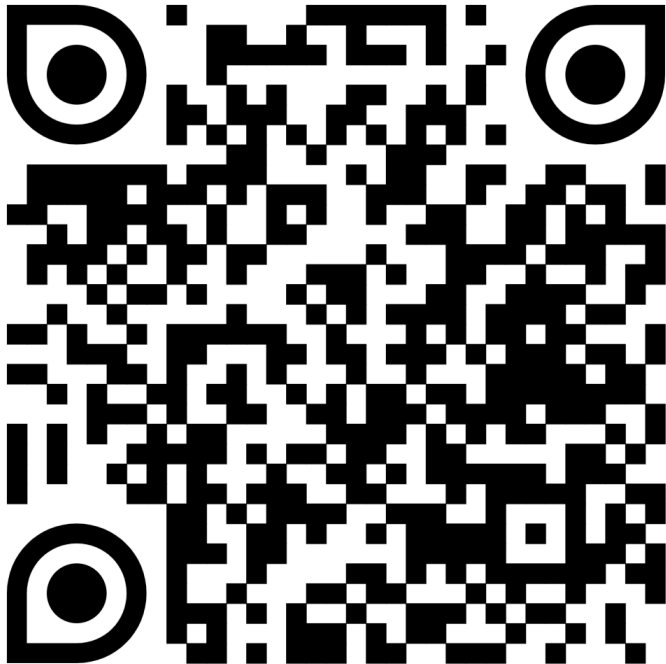
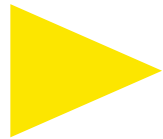
Modelling the Track

Shell Eco-marathon Data & Telemetry Portal

You are here: Home » **Student Documentation**

student_documentation:home

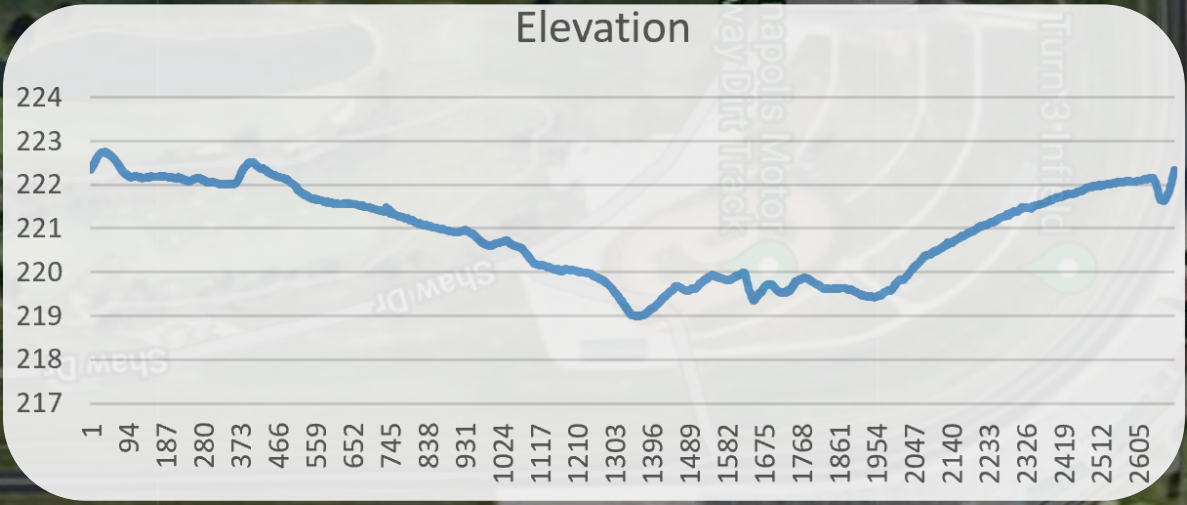
- Home
- Student Documentation**
- Track Coordinates
- Contact



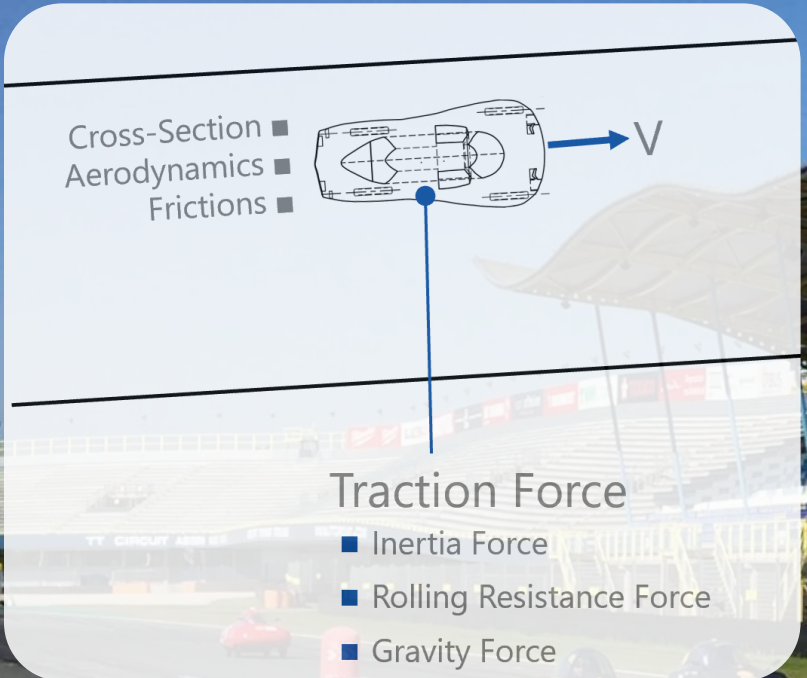
Student Documentation

Select your category/class from the following:

		Prototypes P	Urban Concepts UC
	ICE	Prototype Internal Combustion Engine	Urban Concept Internal Combustion Engine
Hybrid	ICE	Prototype Internal Combustion Hybrid Engine	Urban Concept Internal Combustion Hybrid Engine
	BE	Prototype Battery Electric	Urban Concept Battery Electric
	H2	Prototype Hydrogen without Supercapacitor	Urban Concept Hydrogen without Supercapacitor
Supercap	H2	Prototype Hydrogen with Supercapacitor	Urban Concept Hydrogen with Supercapacitor

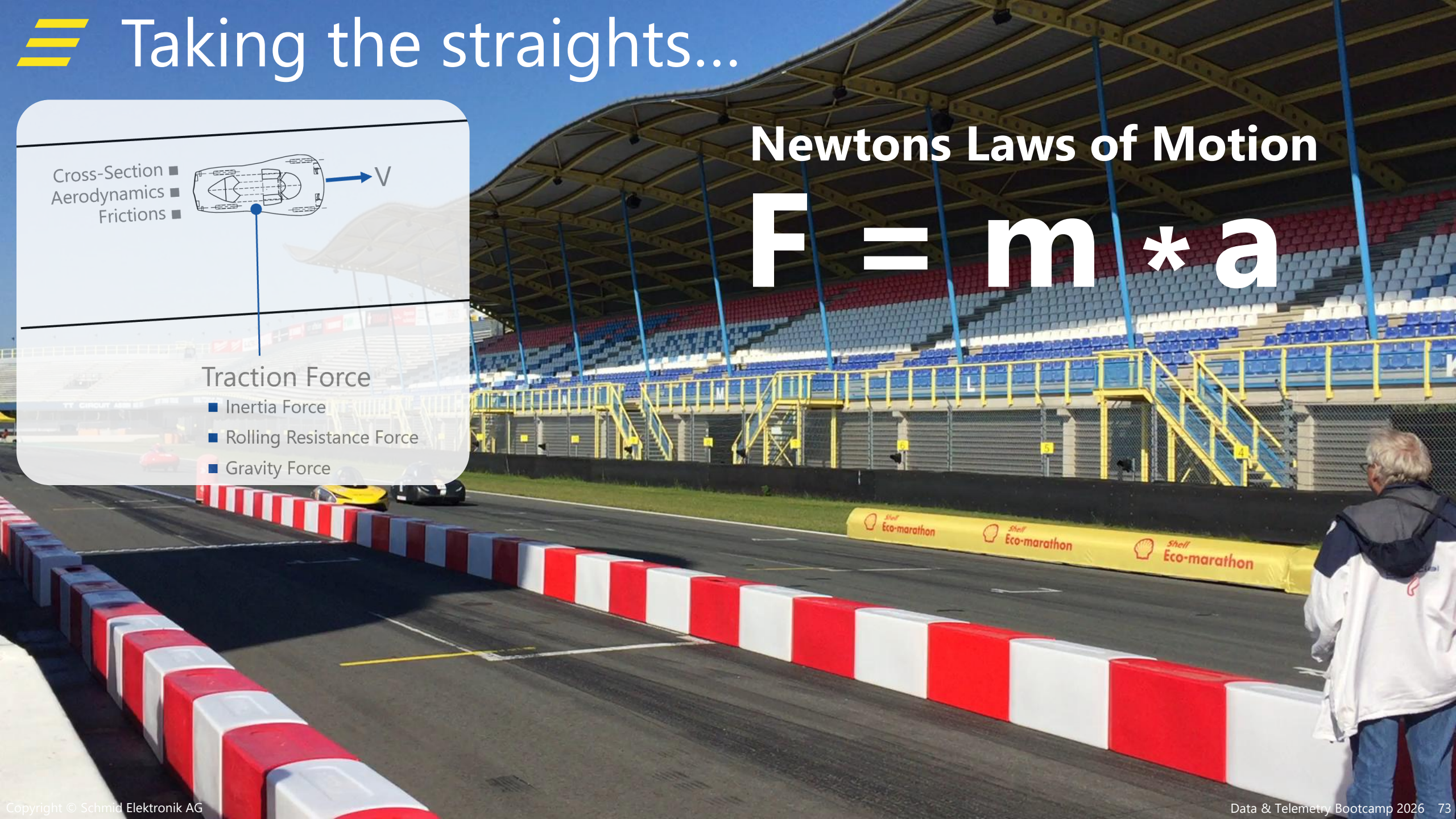


≡ Taking the straights...



Newton's Laws of Motion

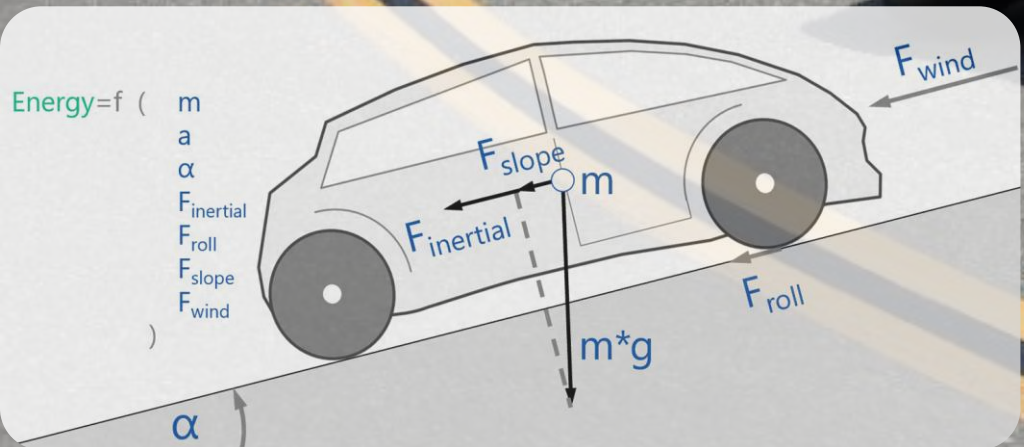
$$F = m * a$$



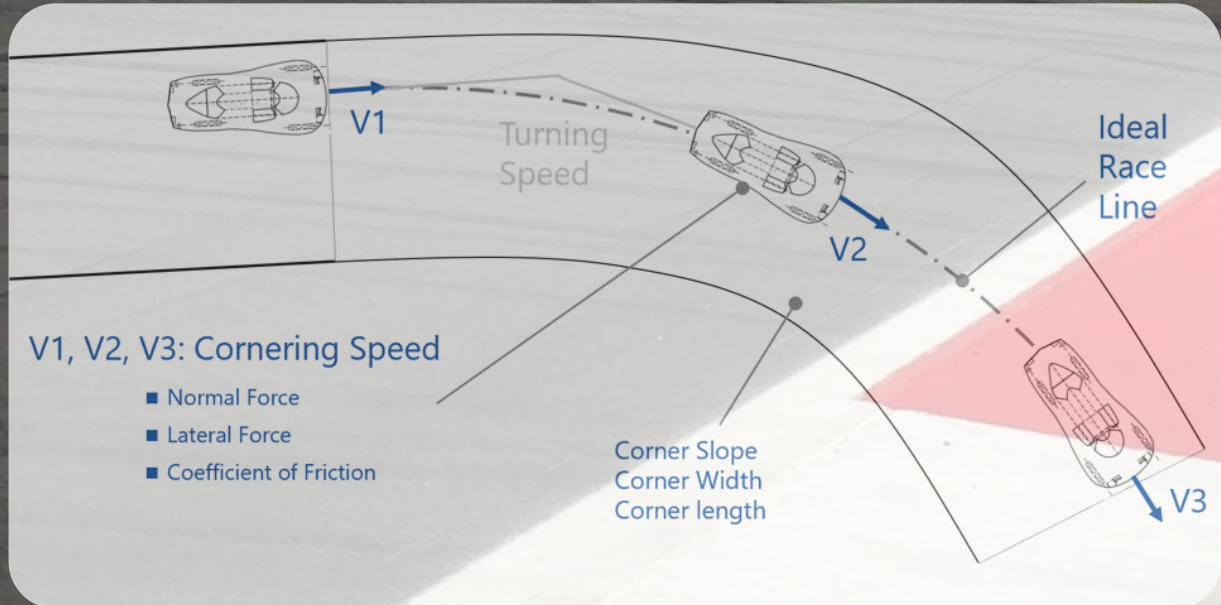
Managing the slopes ...

$$dE = \frac{1}{3600} \left[mg(f \cos \varphi + \sin \varphi) + \frac{1}{2} (\rho C_x A \frac{(v_{EV} + v_w)^2}{3.6}) + (m + m_f) \frac{dv}{dt} \right] ds$$

dE	Mechanical energy required at the wheels to drive a distance ds [kWh]
m	Total vehicle mass [kg]
m_f	Fictive mass of rolling inertia [kg]
g	Gravitational acceleration [m/s^2]
f	Vehicle coefficient of rolling resistance [-]
φ	Road gradient angle [$^\circ$]
ρ	Air density [kg/m^3]
C_x	Drag coefficient of the vehicle [-]
A	Vehicle equivalent cross section [m^2]
v_{EV}	Vehicle speed between the point i and the point j [km/h]
v_w	Wind speed projected to the opposing direction of the driving direction [km/h]
ds	Distance driven from point i to point j [km]



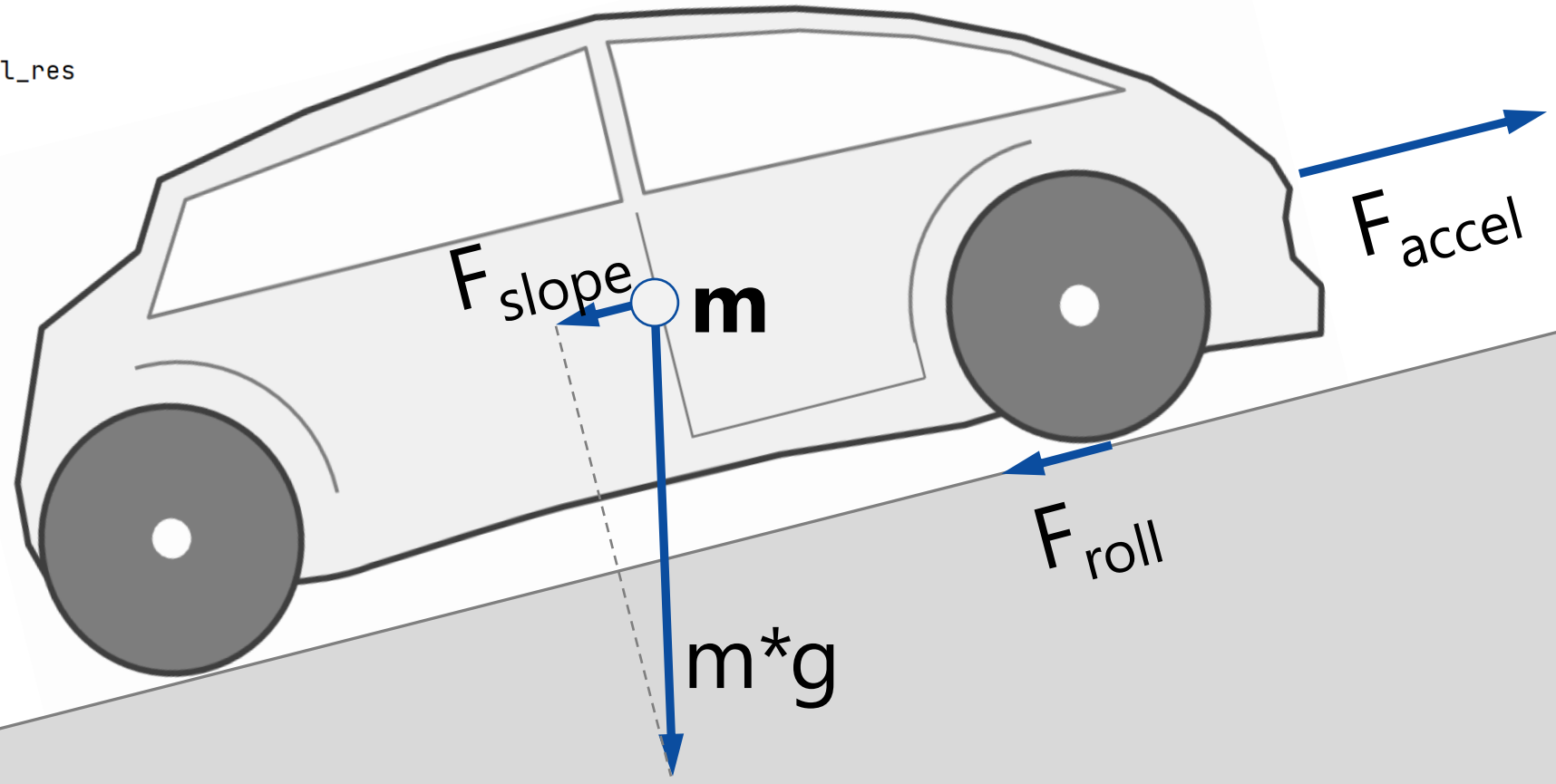
≡ The corners are the holy grail



Vehicle Model

$$F_{\text{total}} = F_{\text{roll}} + F_{\text{slope}} + F_{\text{accel}}$$

```
vold_mps = vold/3.6  
v_mps = v/3.6  
time = 2 * section_length / (v_mps + vold_mps)  
gradient_angle = math.tanh( (config.loc[x, "m above sea"]-config.loc[x-1, "m above sea"]) / section_length)  
f_roll_res = car_mass * g * math.cos(gradient_angle) * coeff_roll_res  
f_slope = car_mass * g * math.sin(gradient_angle)  
f_accel = ((v_mps-vold_mps) / time) * car_mass  
  
f_total = f_accel + f_slope + f_roll_res  
E_total = f_total * section_length
```



α

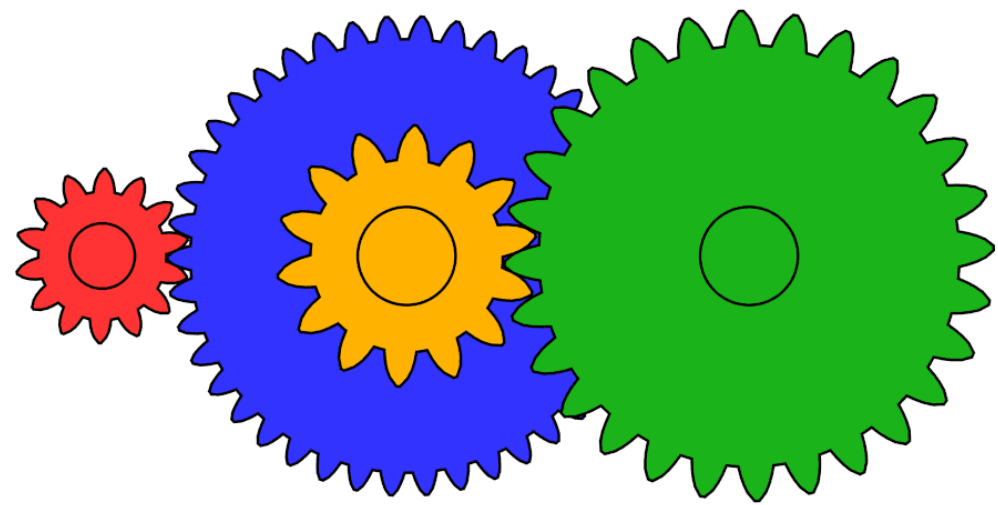
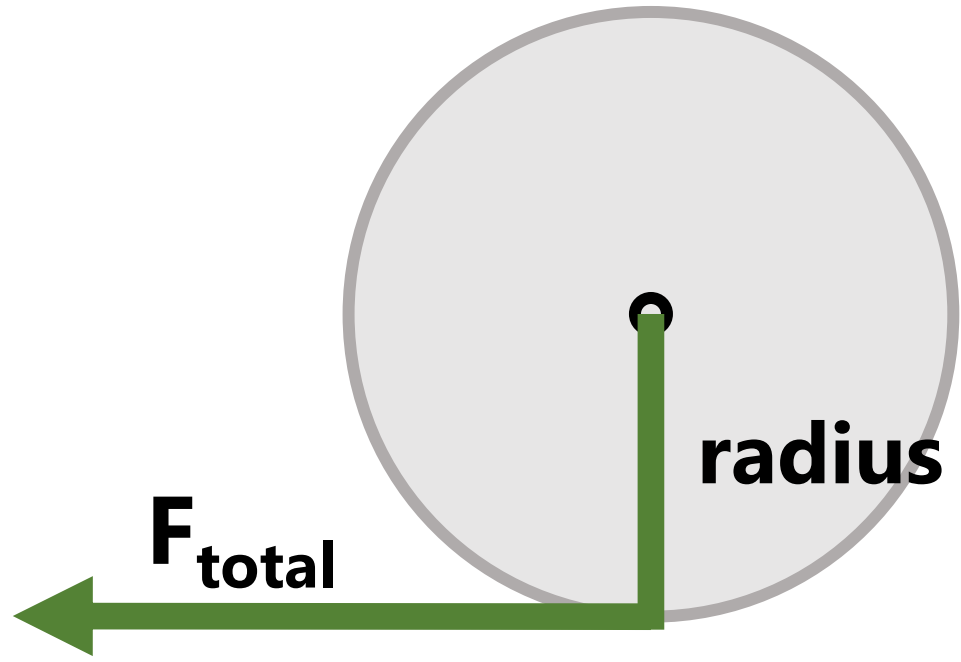


Power calculation for a series wound motor

Total Power $P = F_{total} * v$

Rotation speed $\omega = v * gear_ratio / radius$

Torque $\tau = P / \omega$



A large, vibrant phoenix made of fire is flying over a racetrack. The phoenix is bright orange and yellow, with its wings spread wide. The racetrack below is dark asphalt with green and red markings. In the background, there are hills and a cloudy sky. The text is overlaid on the right side of the image.

Holistic Racing

Conflicting Goals, Global Optimum
Advanced Data-Driven
Racing Methods

Level 5

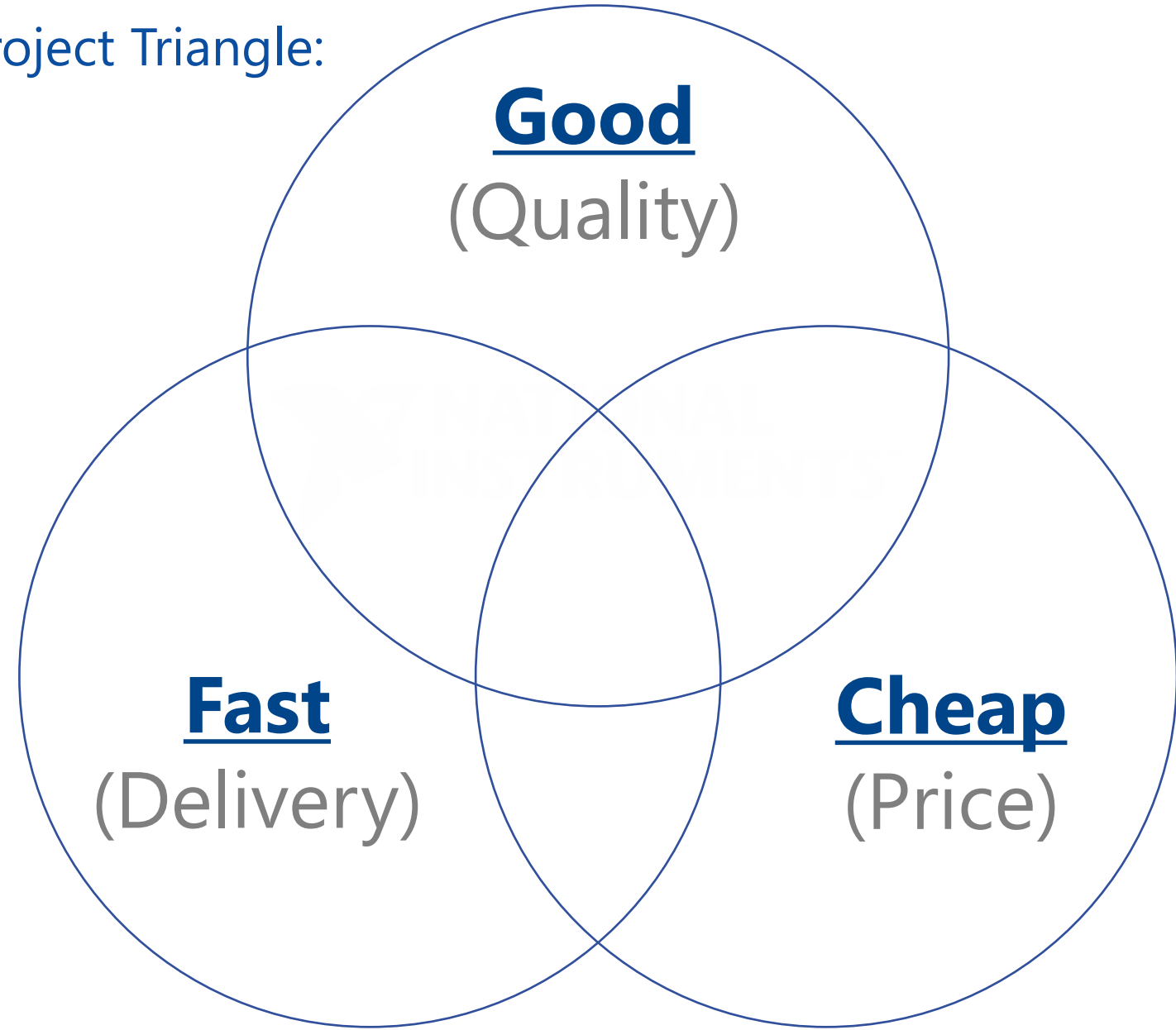
≡ What are Conflicting Goals?





Conflicting Goals in Industrial Projects

The Magic Project Triangle:



≡ Classic Multigoal-Problem & Global Optimum

Environmental Influence

Straights —
Corners —
Slopes —
Crests —

Meaning
Actionable
Speed Profile
from Start to
Finish

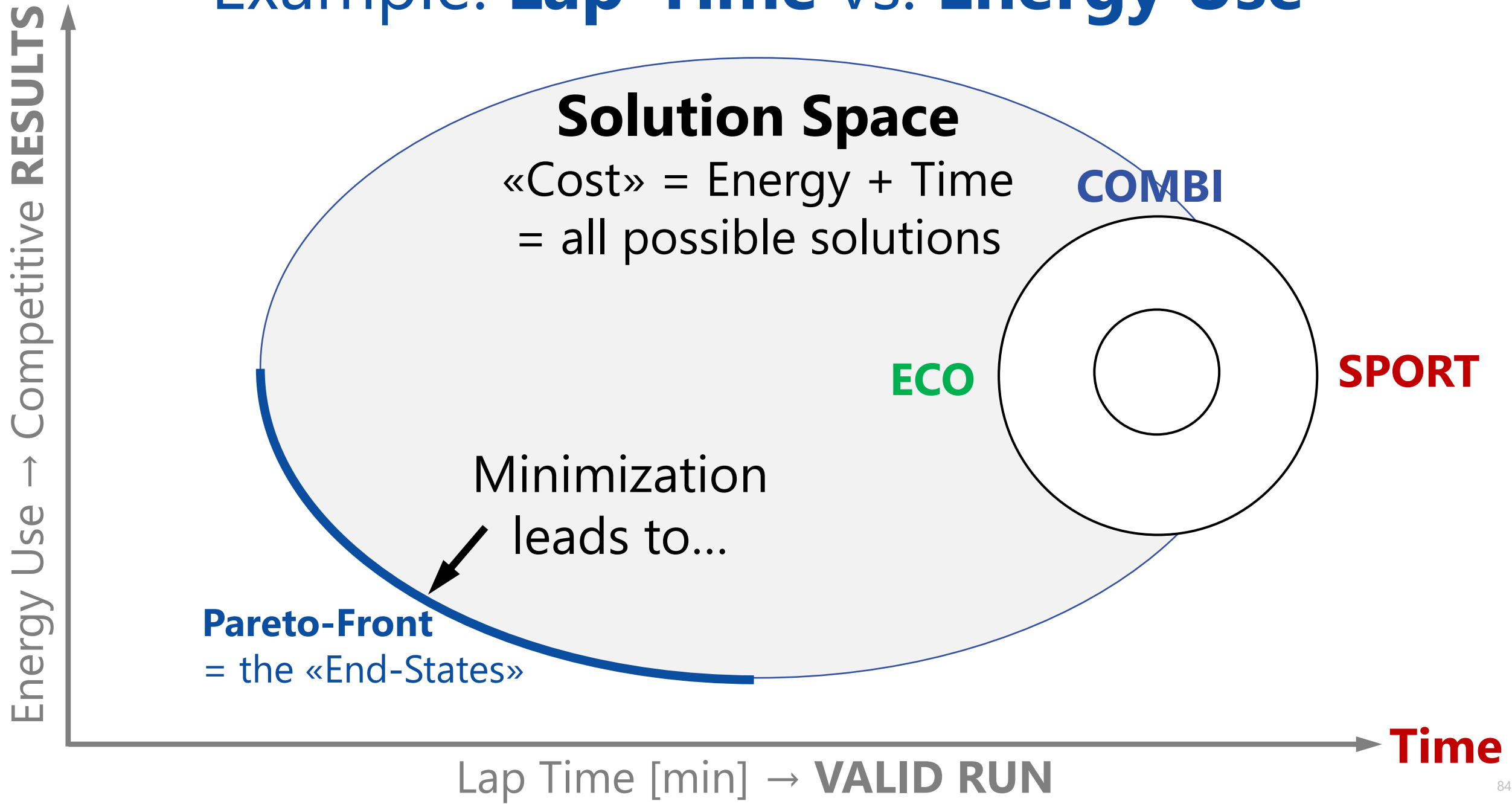
— Increase
Energy Efficiency
— Competitive
Lap-Times (DNF)
— Maintain
Safety ... always!

Vehicle Characteristics

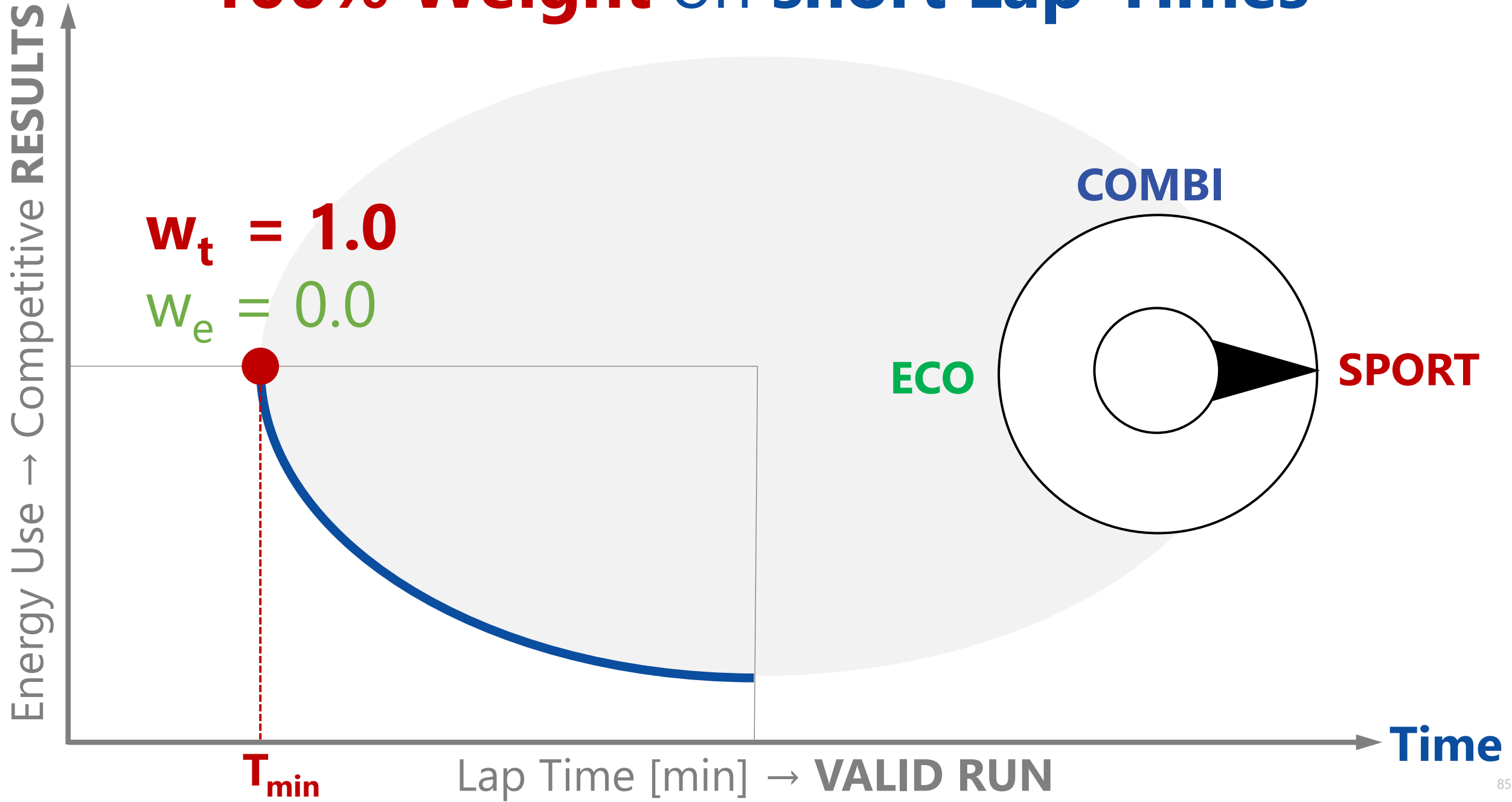


Energy

Example: Lap-Time vs. Energy Use



Energy 100% Weight on short Lap-Times



100% Weight on Fuel Economy

Energy

Energy Use → Competitive RESULTS

E_{\min}

$$W_t = 0.0$$

$$W_e = 1.0$$

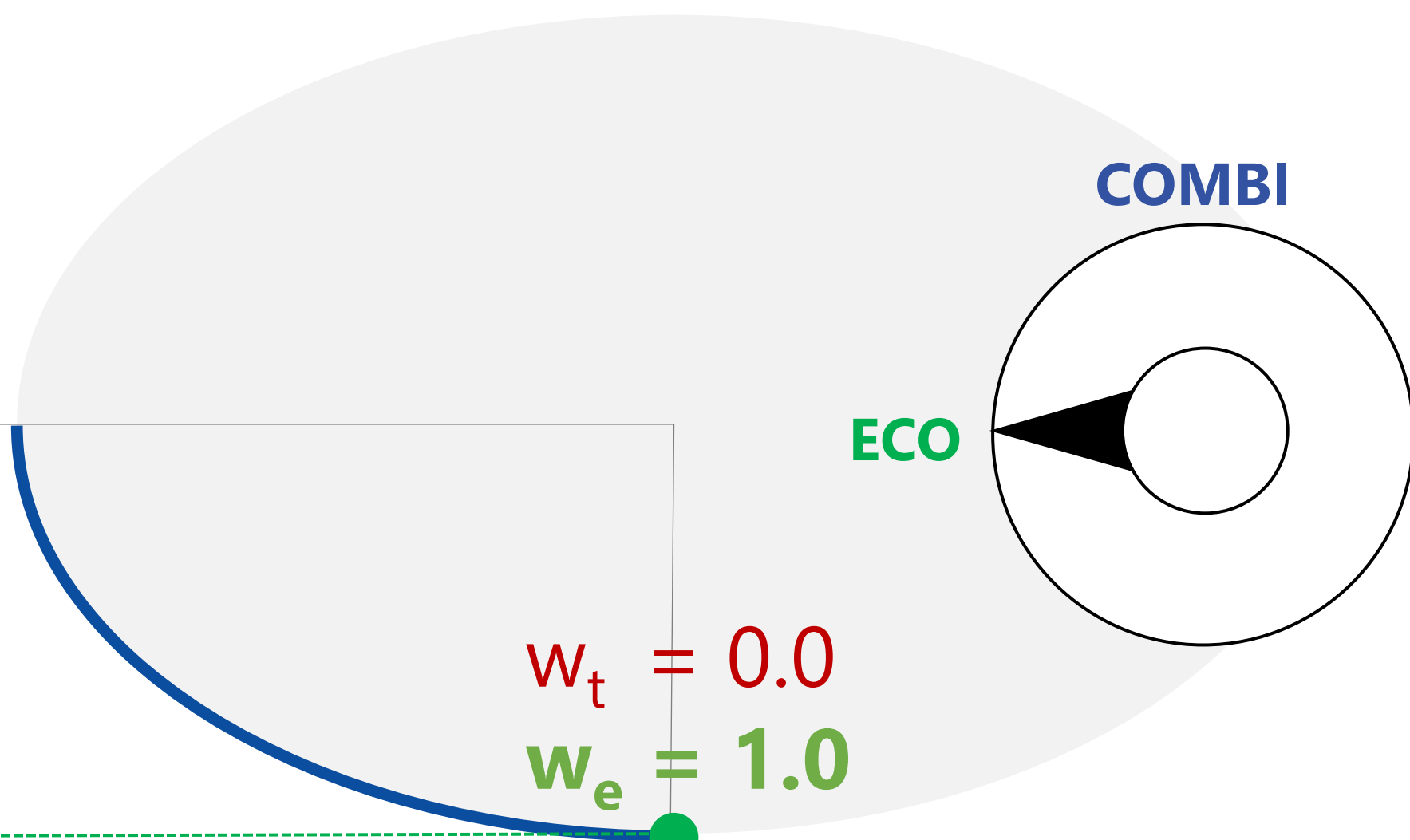
COMBI

ECO

SPORT

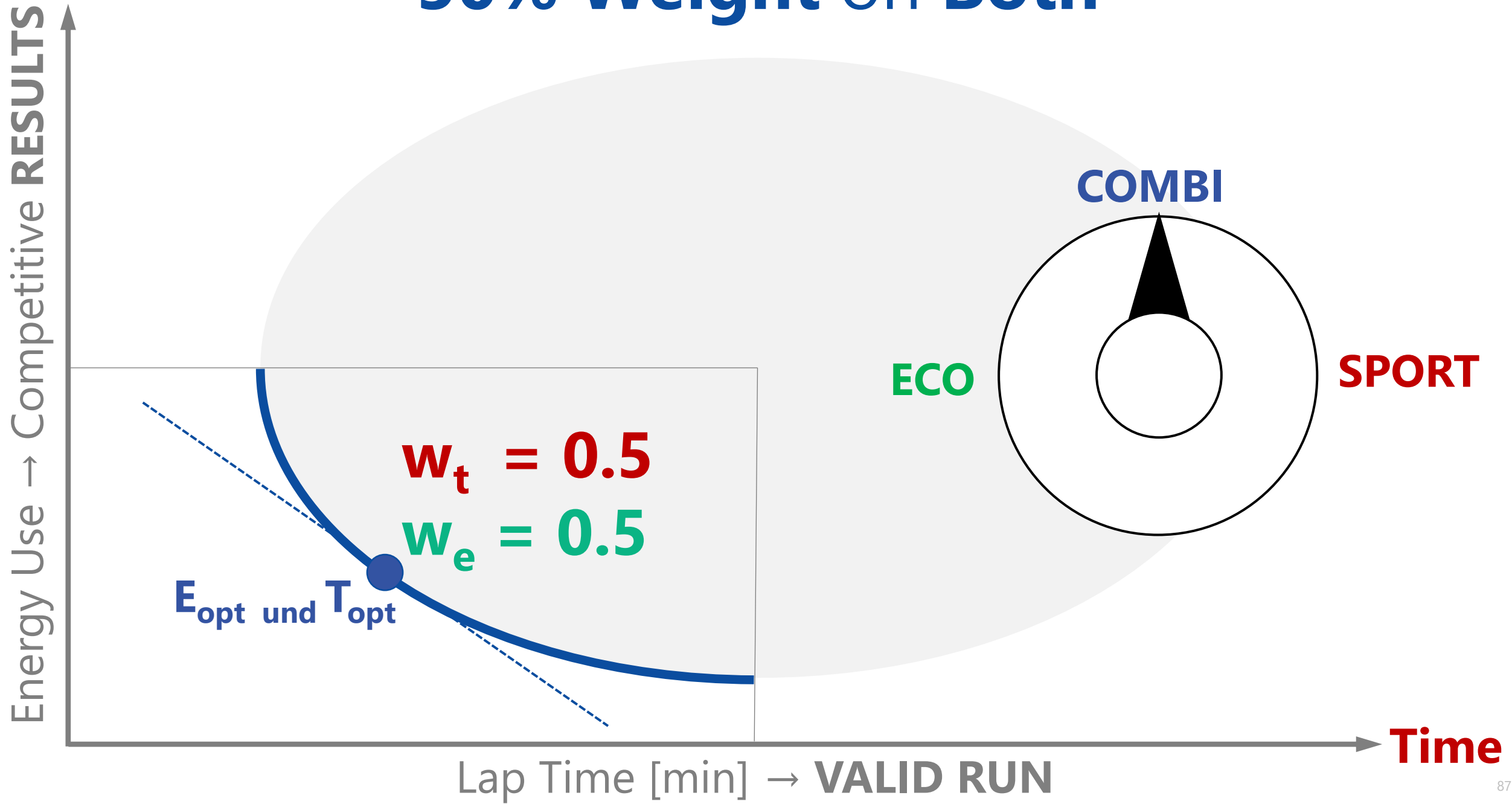
Lap Time [min] → VALID RUN

Time



Energy

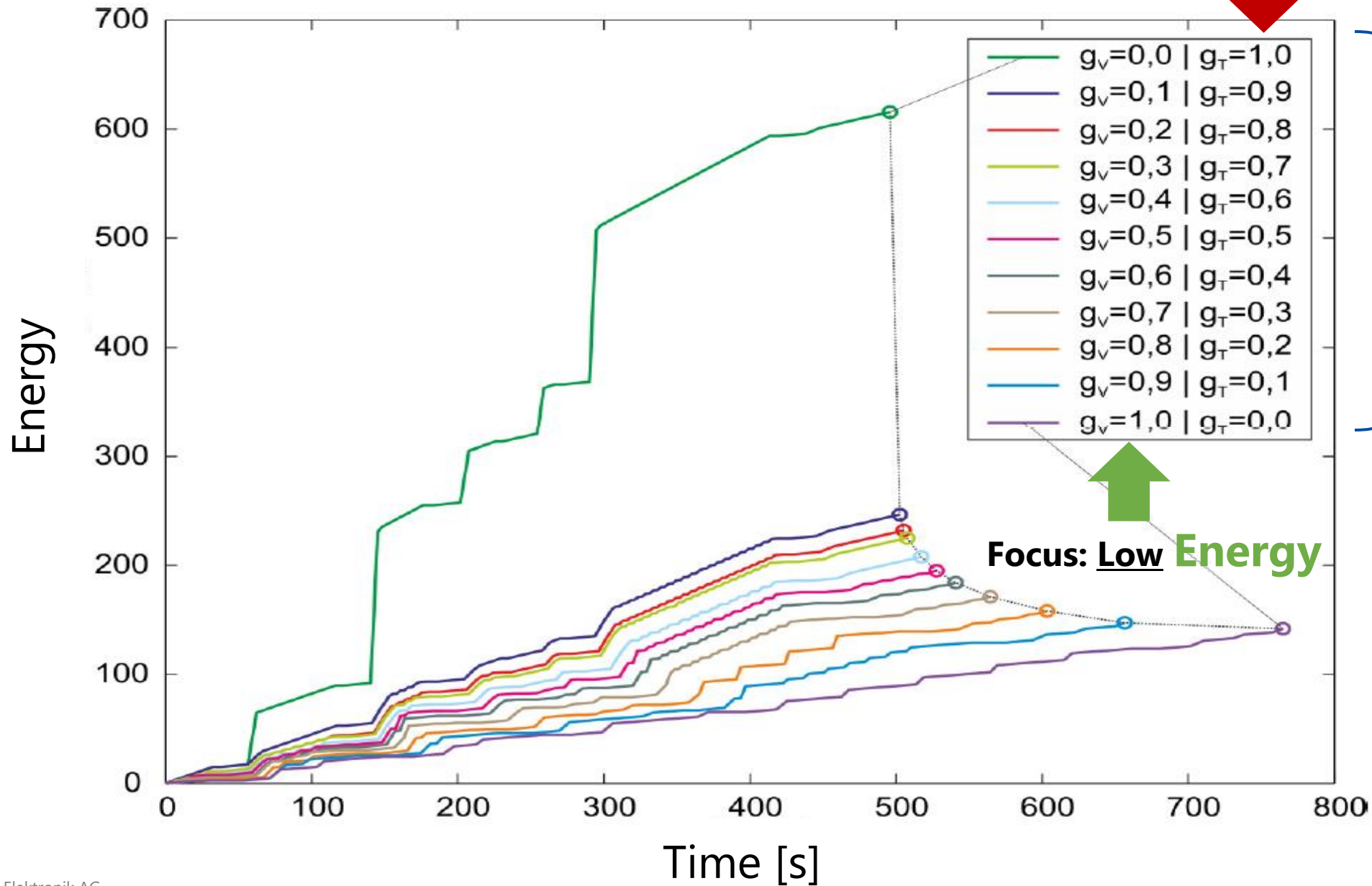
50% Weight on Both





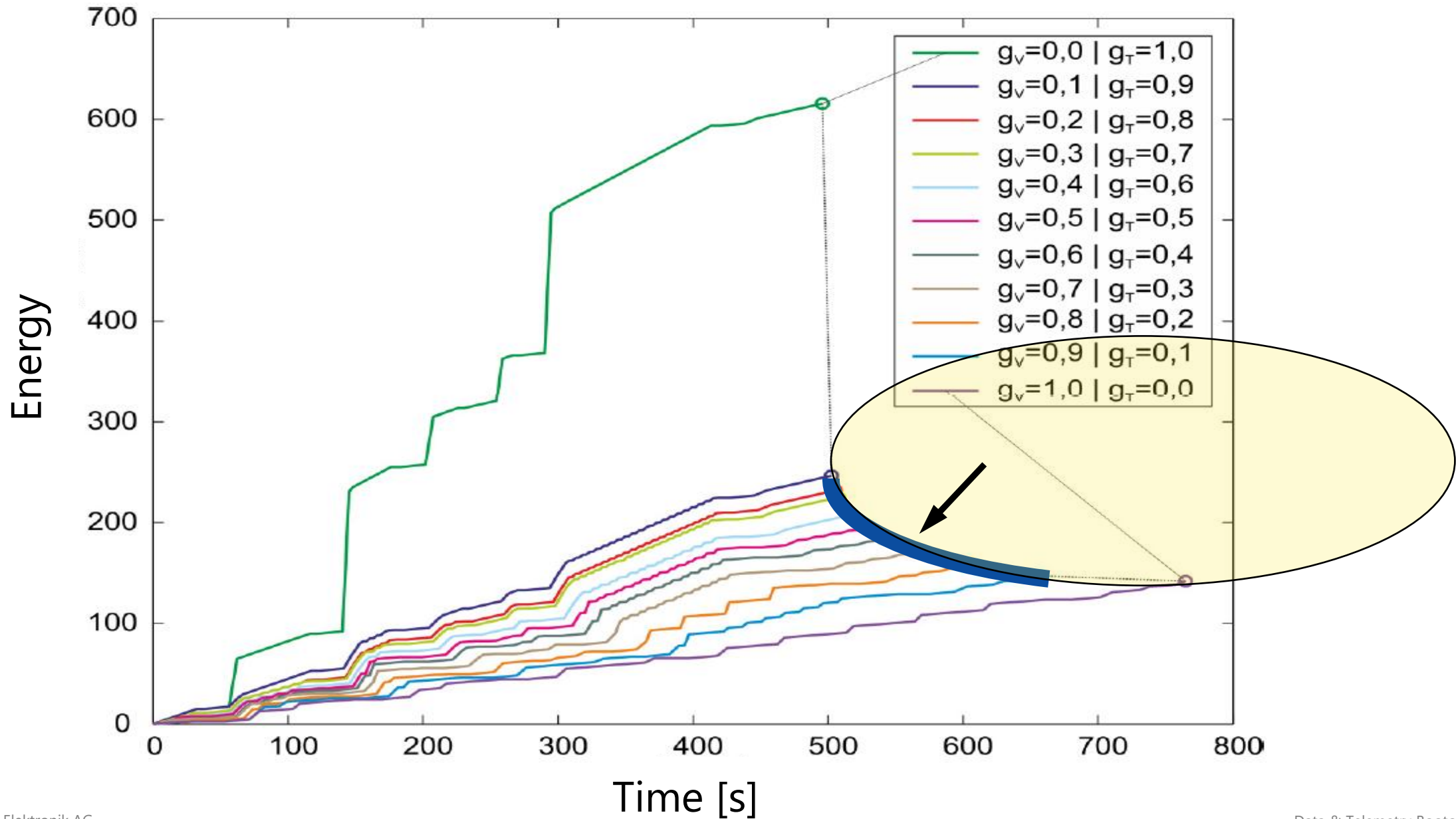
A real Pareto-Front

Focus: Short **Laptime**





A real Pareto-Front



Motorsport = solving **complex** physical Problems

Diagram of a car on a slope with forces F_{MOT} , F_{WIND} , F_S , and $m \cdot g$. The slope angle is α and the distance along the slope is d .

$$F_S = mgs \sin \alpha \approx mgd$$
$$d = f(F_a) = f(\cos \alpha)$$
$$m\ddot{x} + d\dot{x} = F_{MOT} - F_{WIND} - F_S$$
$$x_1 = x$$
$$\dot{x}_1 = x_2$$
$$\dot{x}_2 = -\frac{d}{m}x_2 + \frac{F_{MOT} - F_{WIND} - mgd}{m}$$
$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ 0 & -\frac{d}{m} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \frac{F_{MOT} - F_{WIND} - mgd}{m}$$

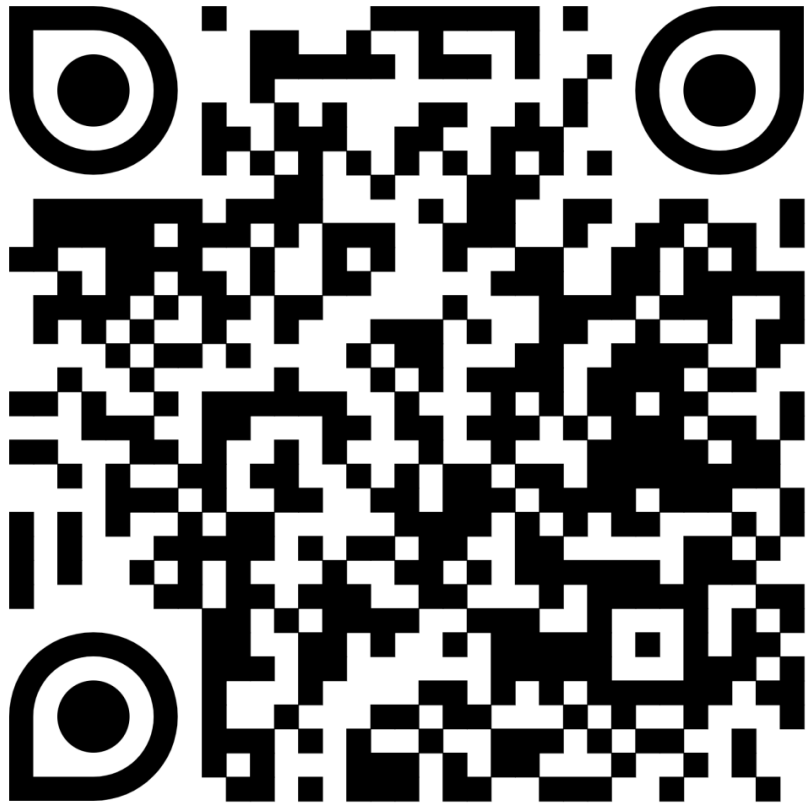
Eigenwerte

$$\text{DET} \begin{vmatrix} \lambda & -1 \\ 0 & \lambda + \frac{d}{m} \end{vmatrix} = -\lambda^2 + \frac{d}{m}\lambda = 0$$
$$\lambda_1 = 0; \lambda_2 = -\frac{d}{m}; d = f(\cos \alpha)$$

Traditional Way



Python Sandbox #2 Using Knowledge Graphs




```

nodelist = nx.dijkstra_path(G, "x0_k0", f"x{x_end}_k{k_end}")
outputlist = []
for i in range(len(config.index)):
    outputlist.append(G.nodes[nodelist[i]]["v"])

output = pd.DataFrame(outputlist)
output.rename(columns={0:"Speed optimal"}, inplace = True)
output['distance'] = output.index * section_length

```



Programming Sandbox #2

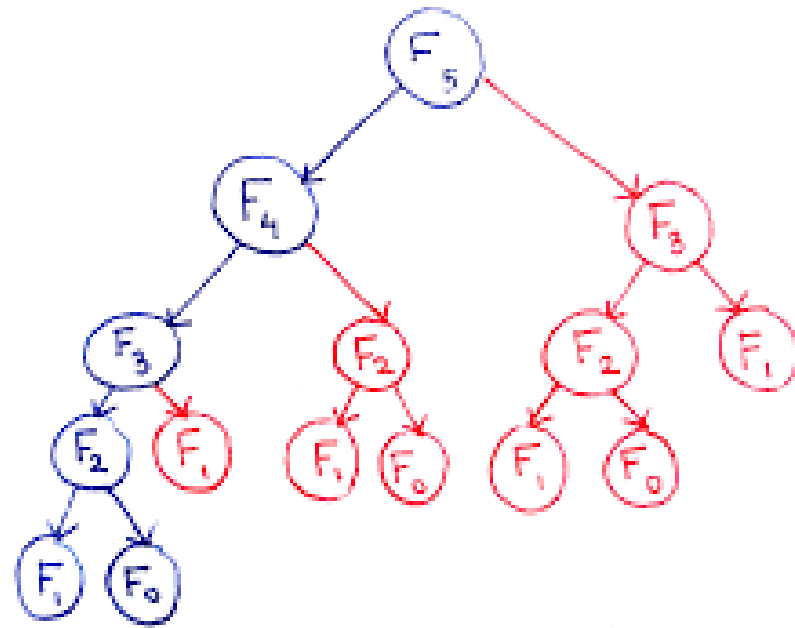
JUPYTER NOTEBOOK AND PYTHONCODE FOR LEVEL-5 (PHYSICAL MODELL)

Start up the Jupyter notebook in your browser (Binder, ~1-2 min.) and play with Python. Learn how to formulate the multigoal problem of data-driven racing with python and how to use a knowledge graph. Save the source code locally, because when you close the browser, the environment will be gone.

[START SANDBOX #2 IN YOUR BROWSER >](#)

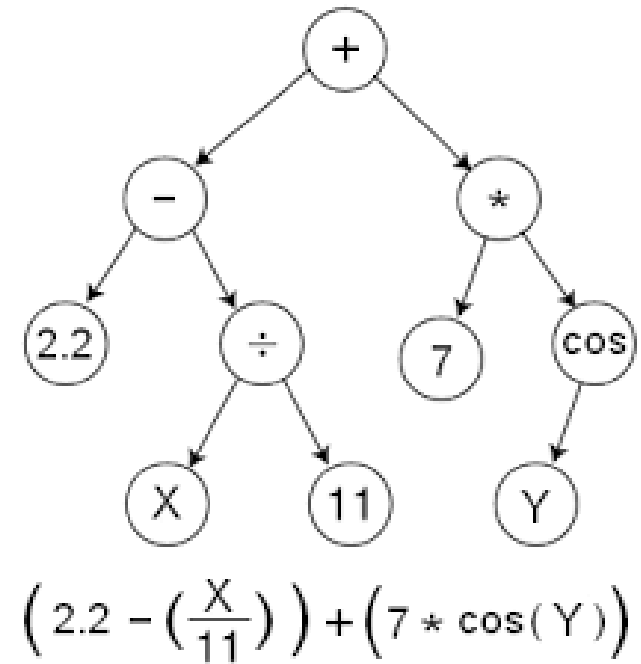
≡ Promising and well established Approaches:

Dynamic Programming



Breaking Complex Problems **down** into simpler subproblems

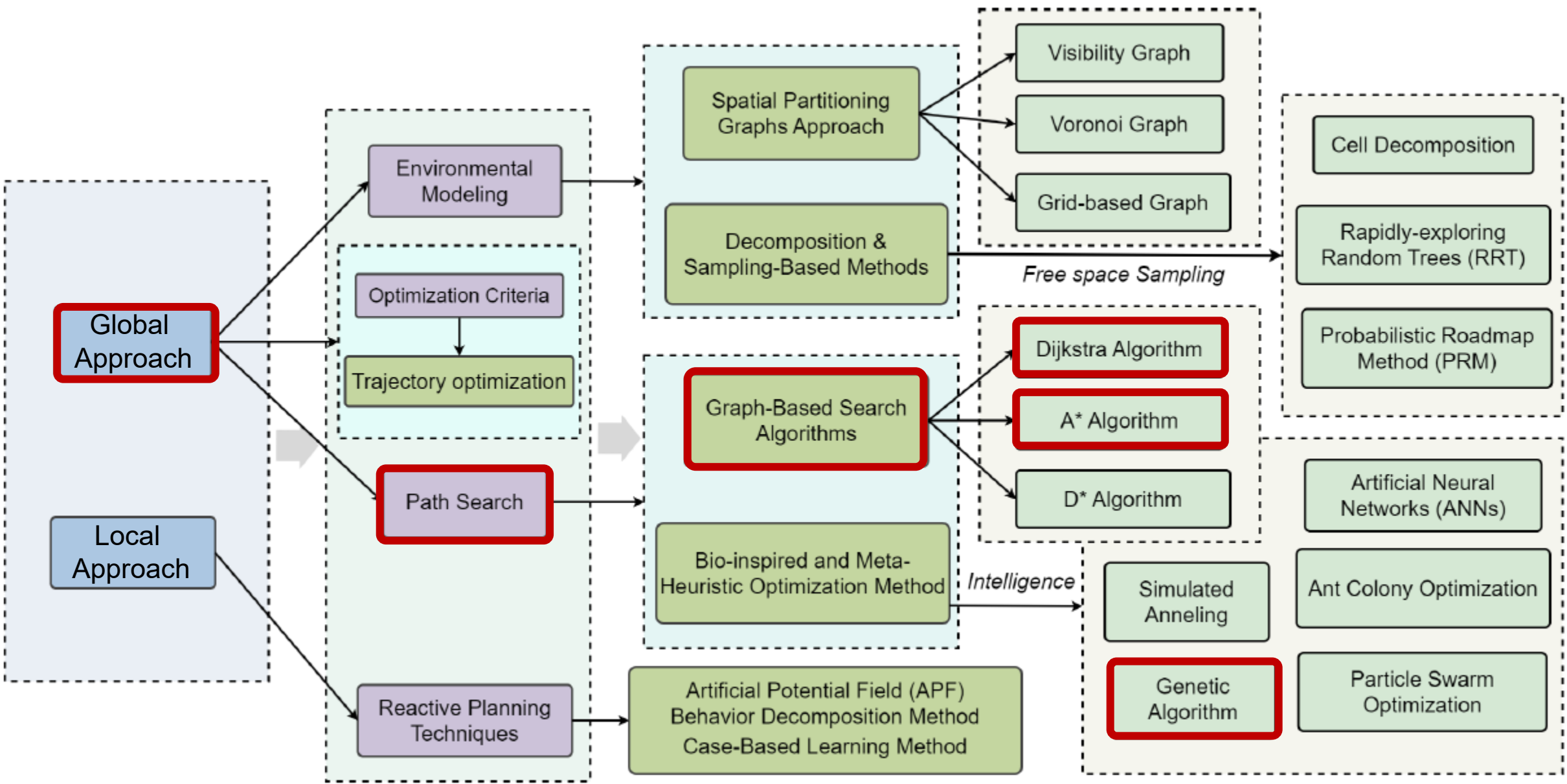
Genetic Programming



AI technique inspired by **natural evolution** that evolves computer programs to solve complex problems



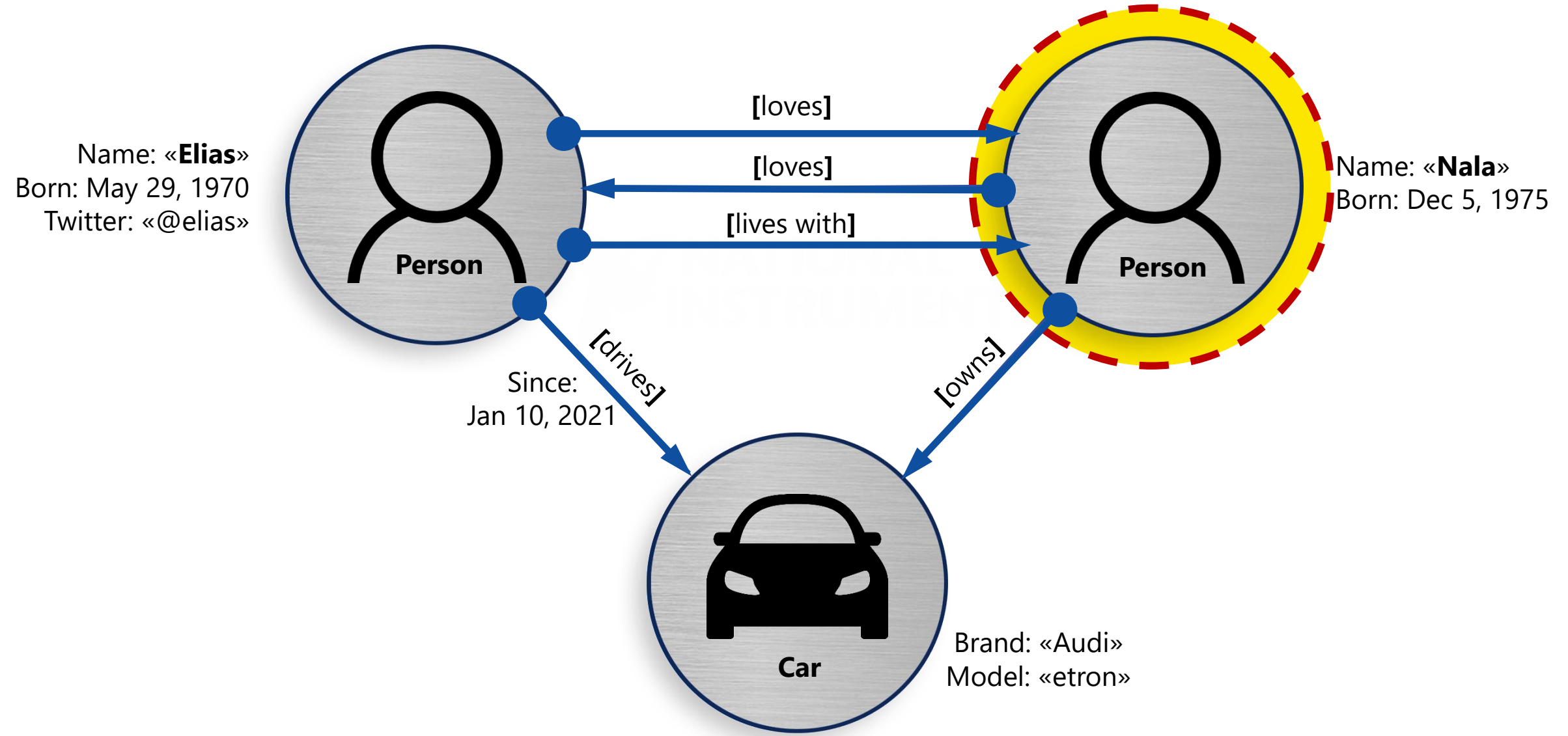
Overview How to Solve Complex Problems





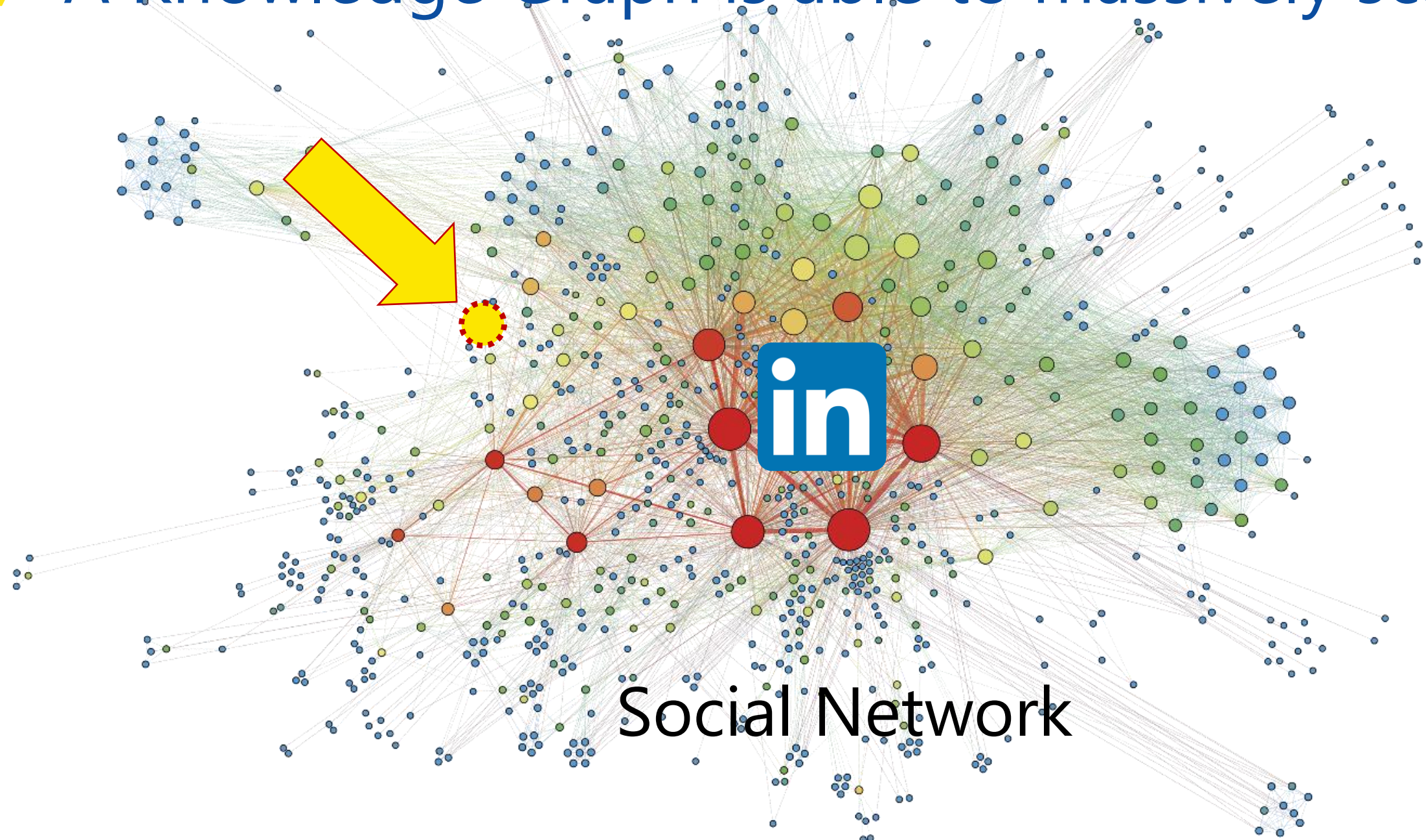
A Knowledge Graph with Nodes and Edges

Understanding the «**Essence of Things**»



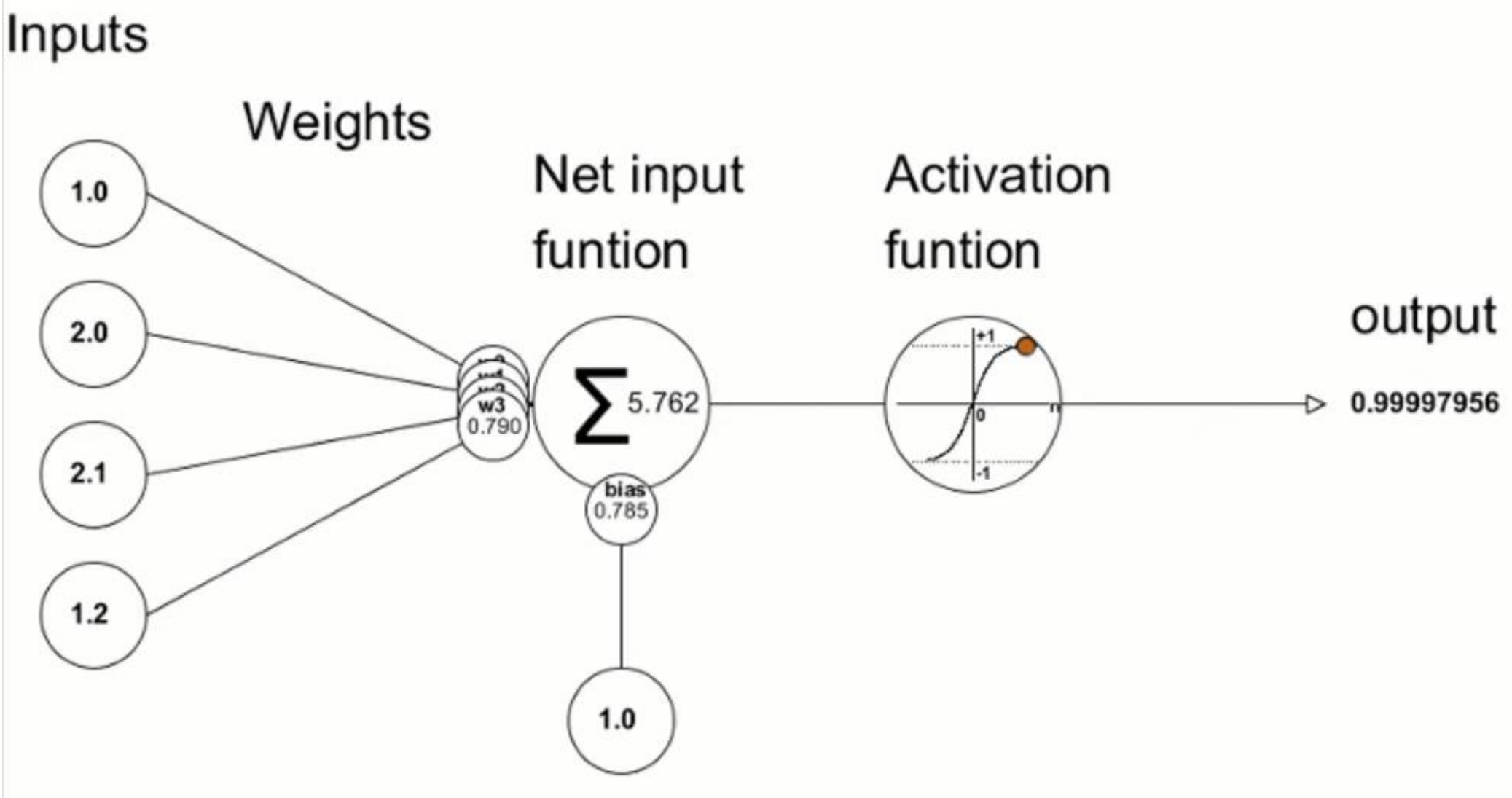


A Knowledge Graph is able to massively scale



Social Network

≡ From a single Neuron...

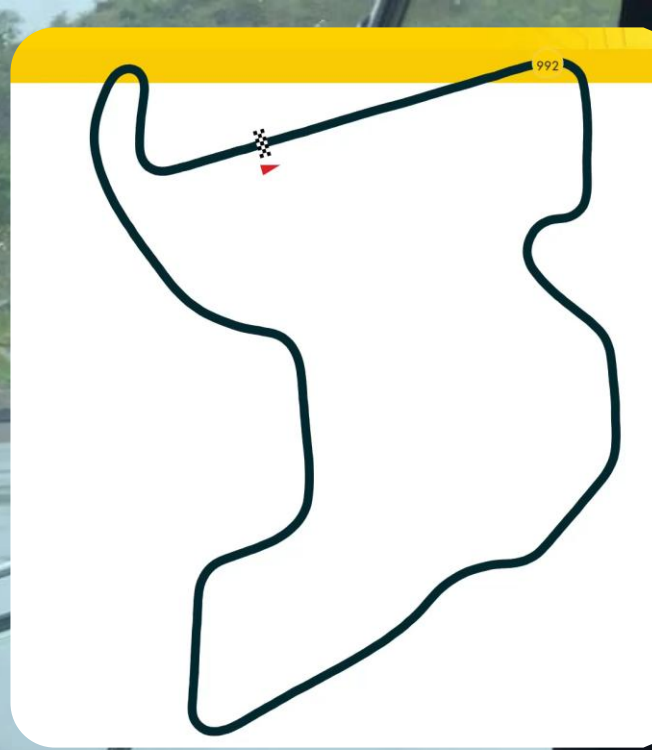


Tokens

That which does not kill you only makes you

???

≡ ...to powerful Large Language Models (LLM)

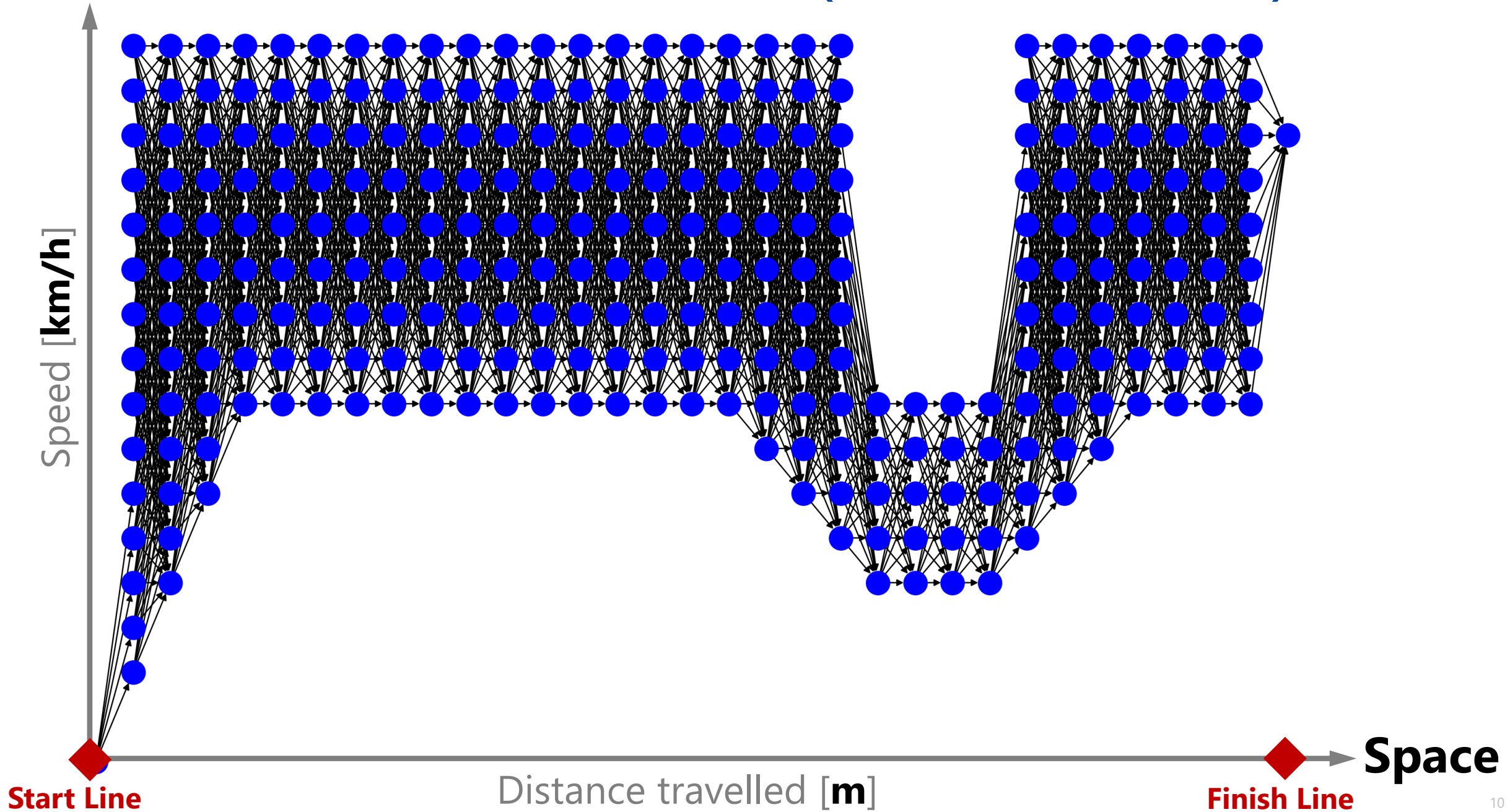


Team: 711

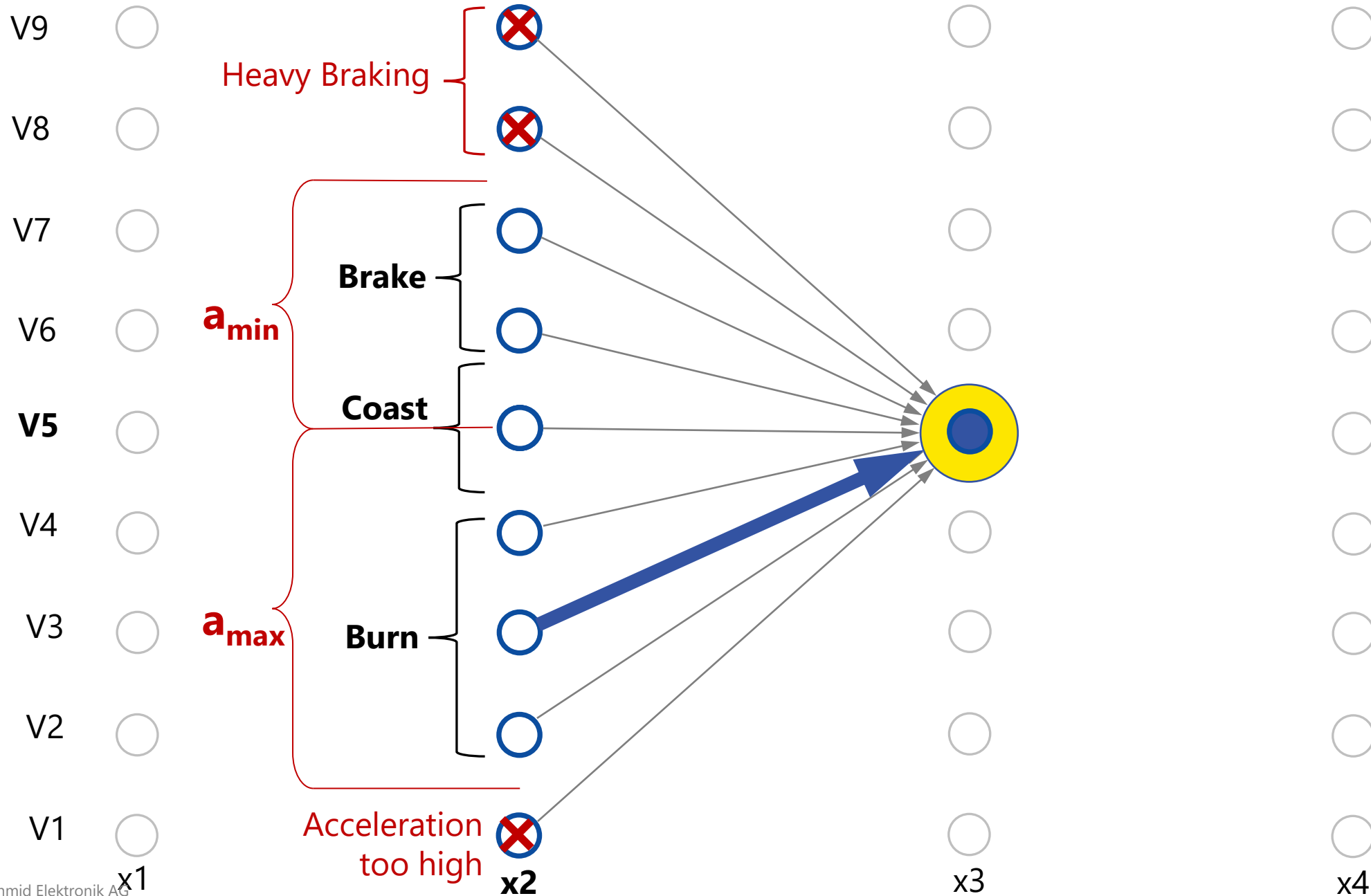


...and to our Race Use Case

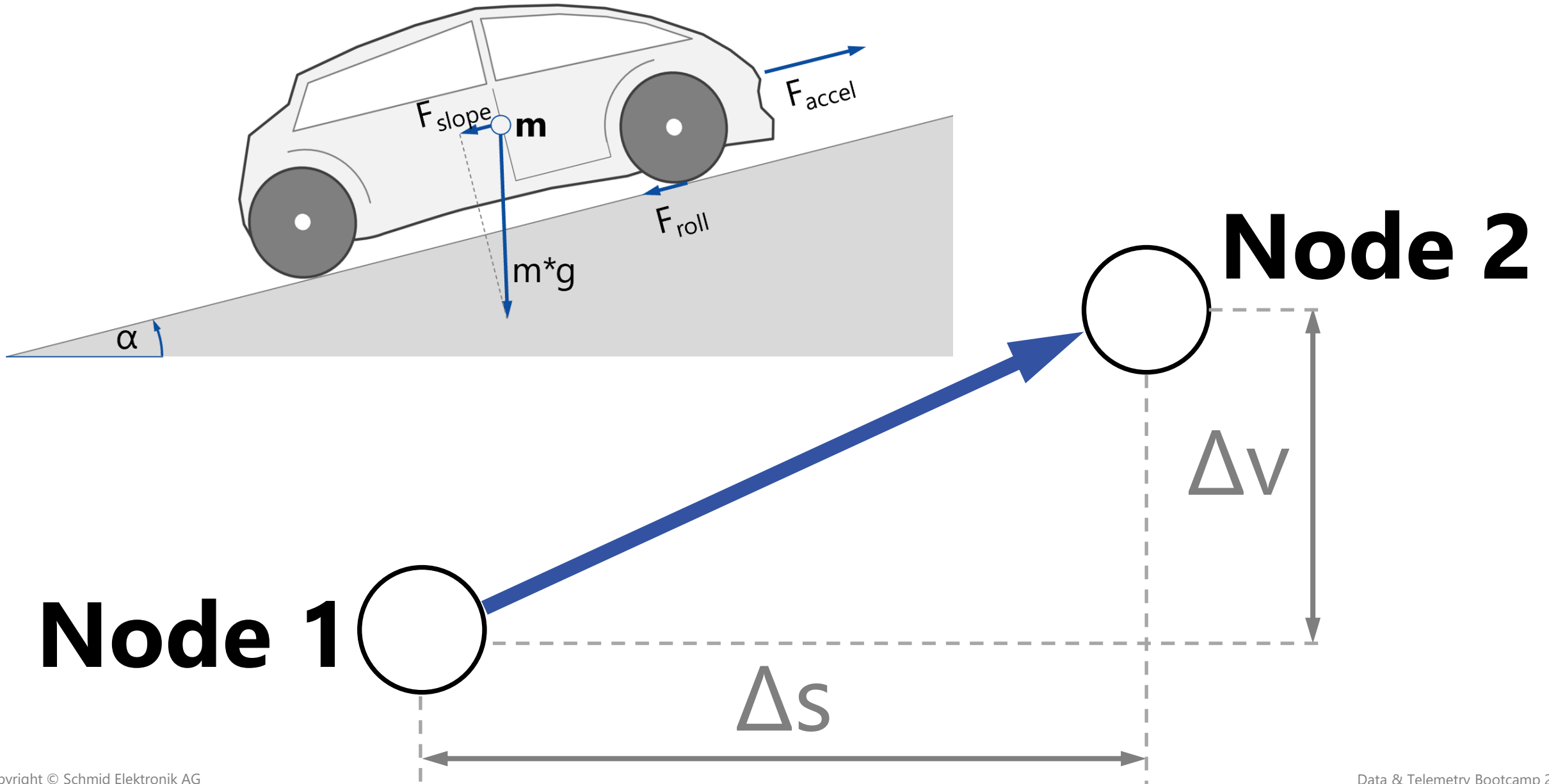
Time Define the **Nodes** (Vehicle States)



The Graphs Edges



Each **State Change** is a **Decision** with a **Cost**

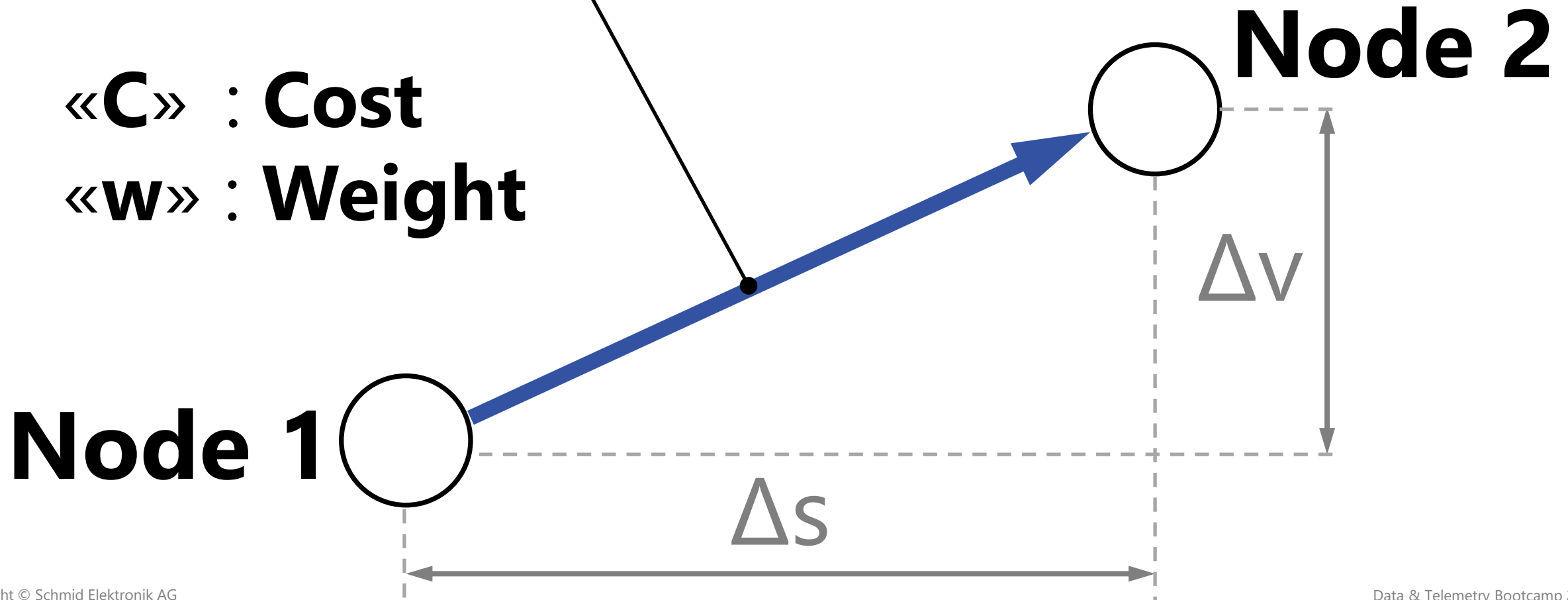


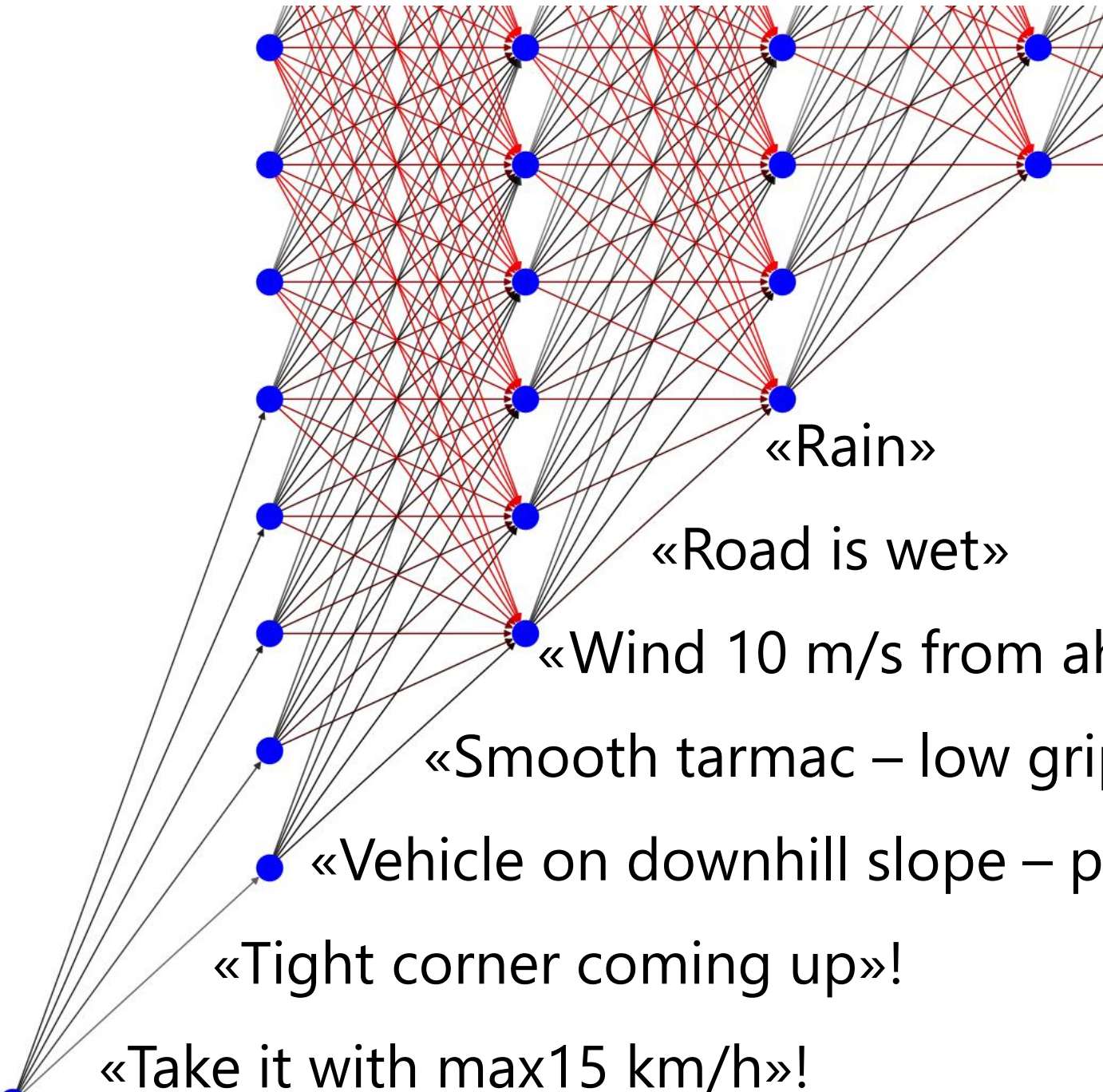
Each **State Change** is a **Decision** with a **Cost**

$$C_{\text{edge}} = C_{\text{time}} * W_{\text{time}} + C_{\text{energy}} * W_{\text{energy}} \rightarrow \text{MIN!}$$

«**C**» : **Cost**

«**w**» : **Weight**

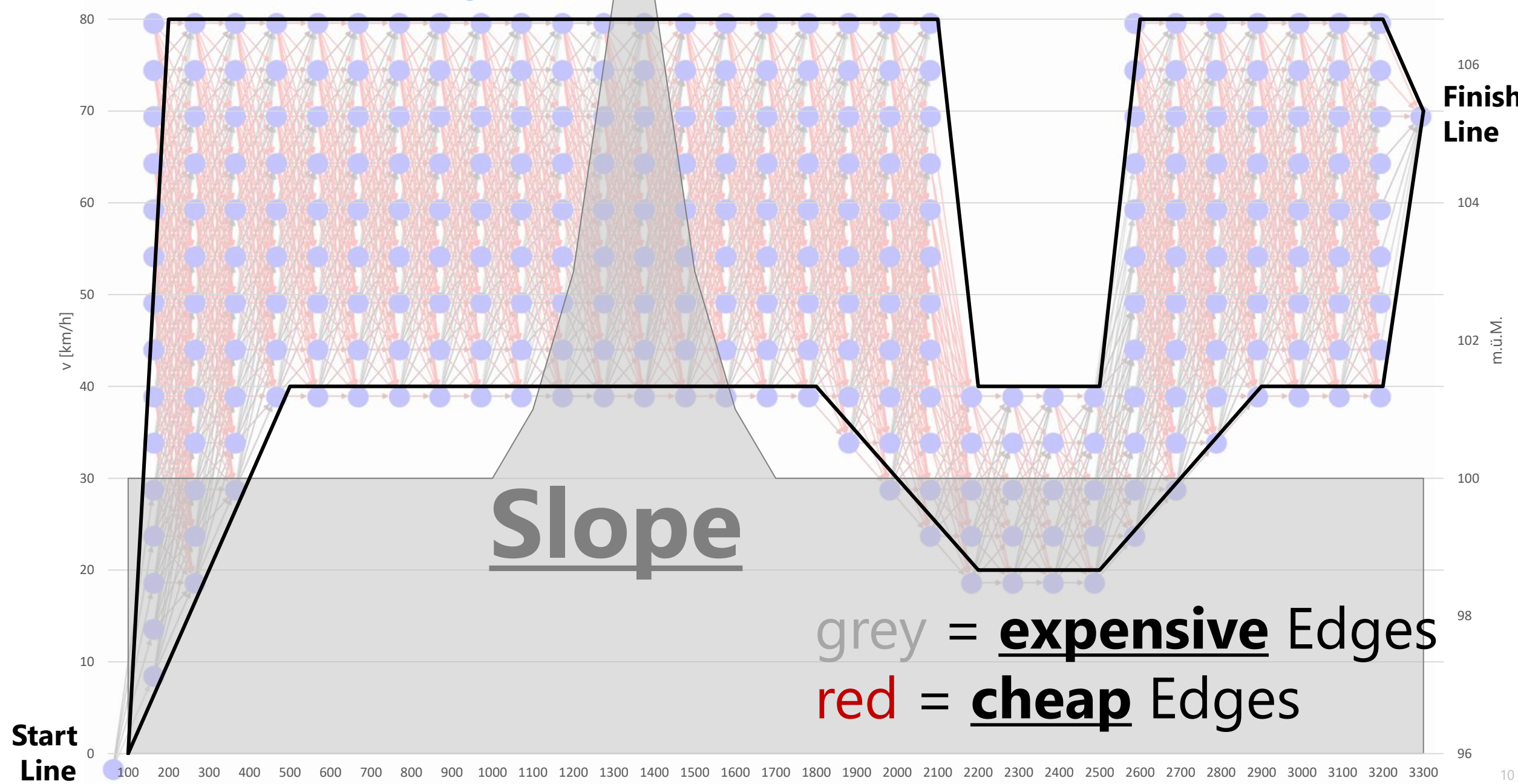




≡ Meaning

The perfect **speed profile**, balancing speed, energy efficiency, safety, vehicle characteristics and external influences

Knowledge Graph from **Start** to **Finish**



Start Line

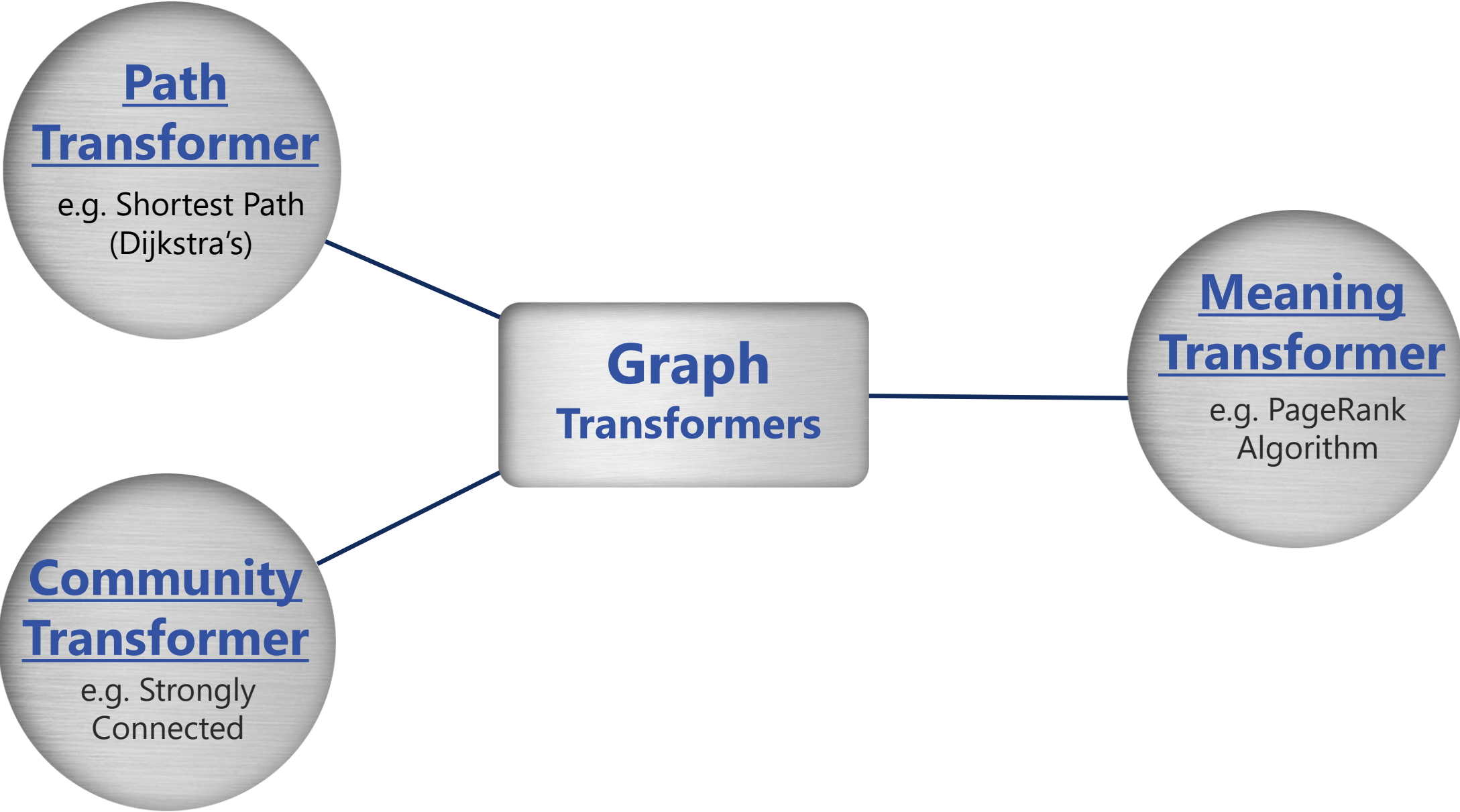
Finish Line

Slope

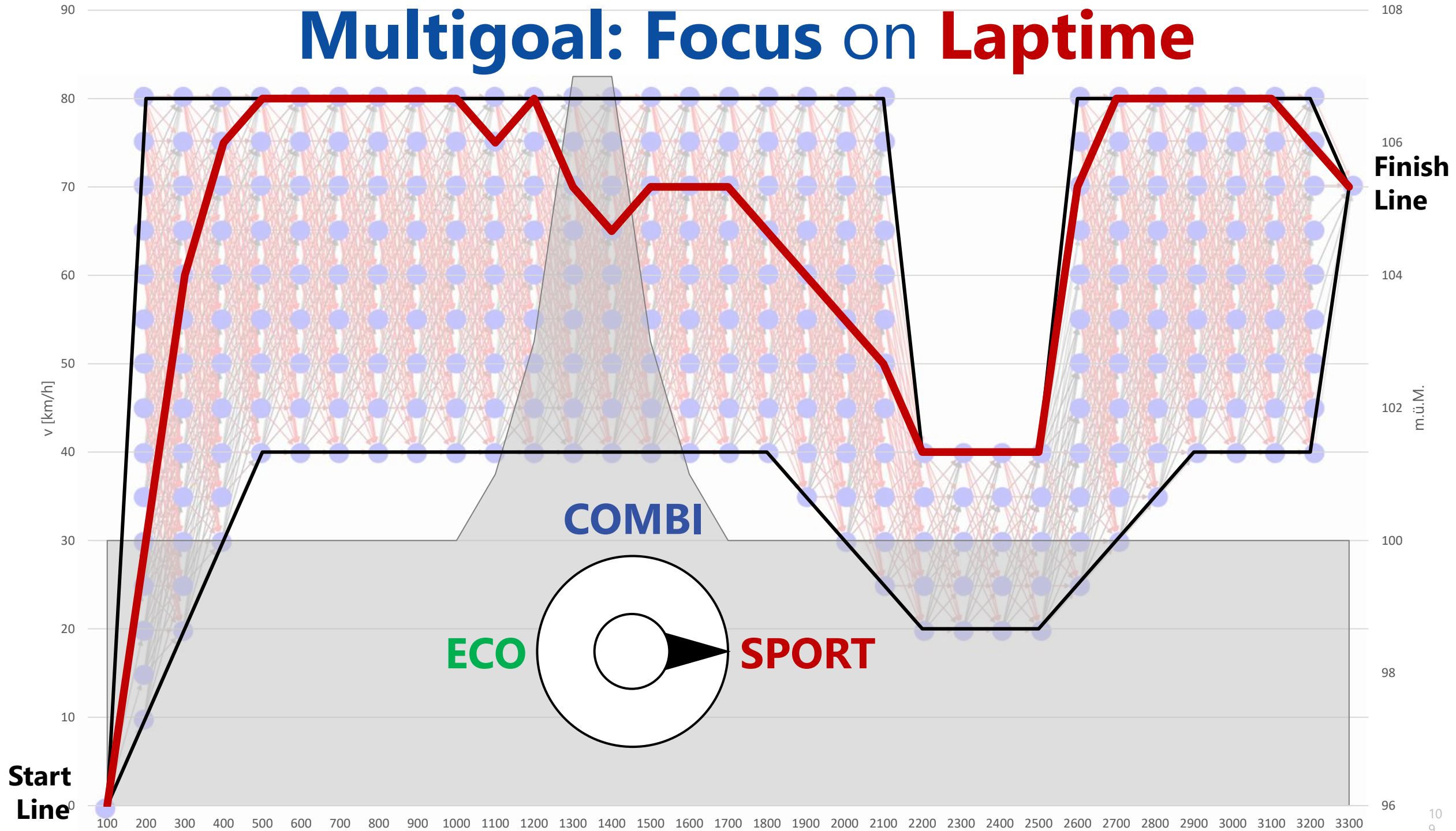
grey = **expensive** Edges

red = **cheap** Edges

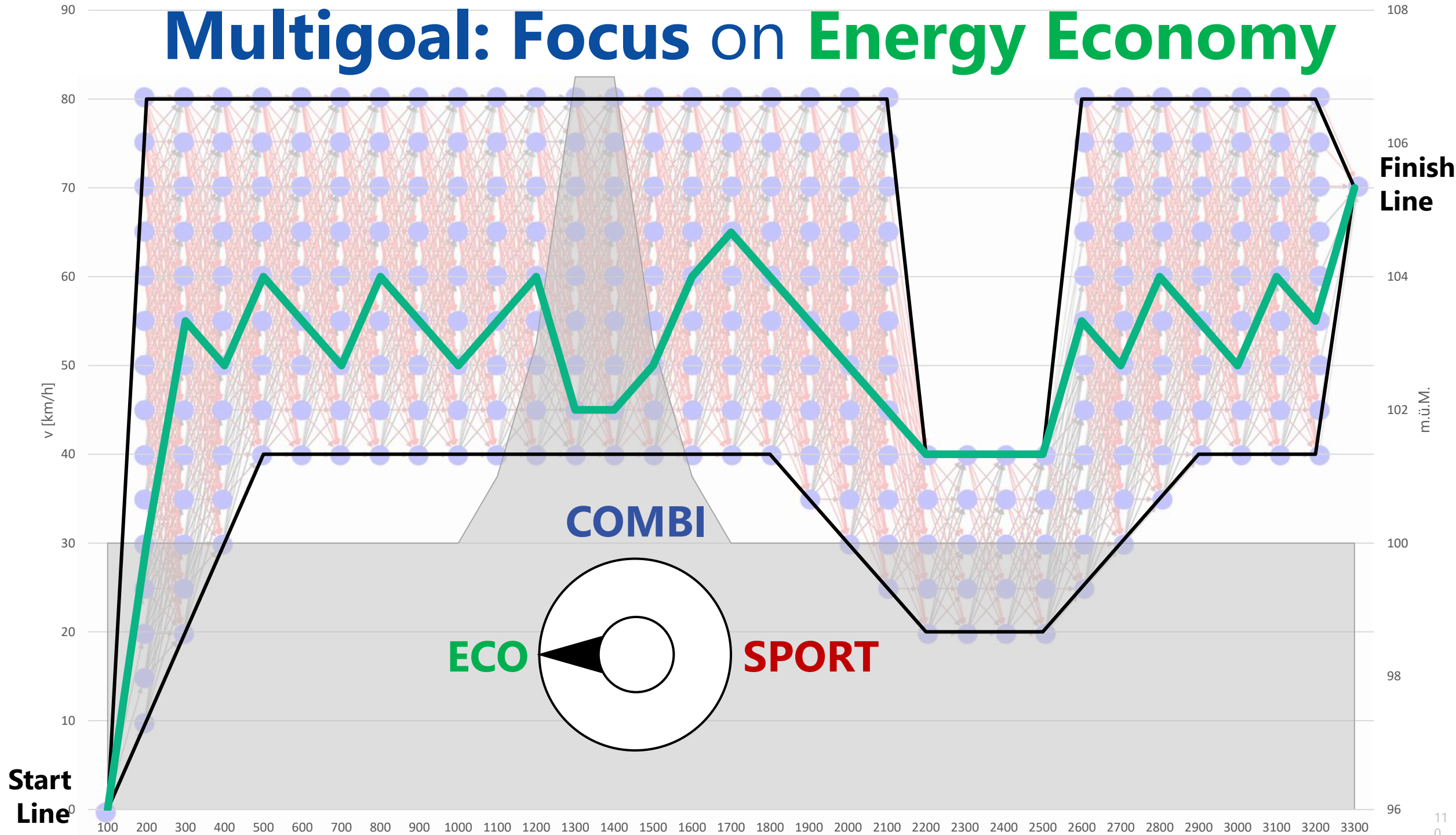
Transform a Graph into Meaning



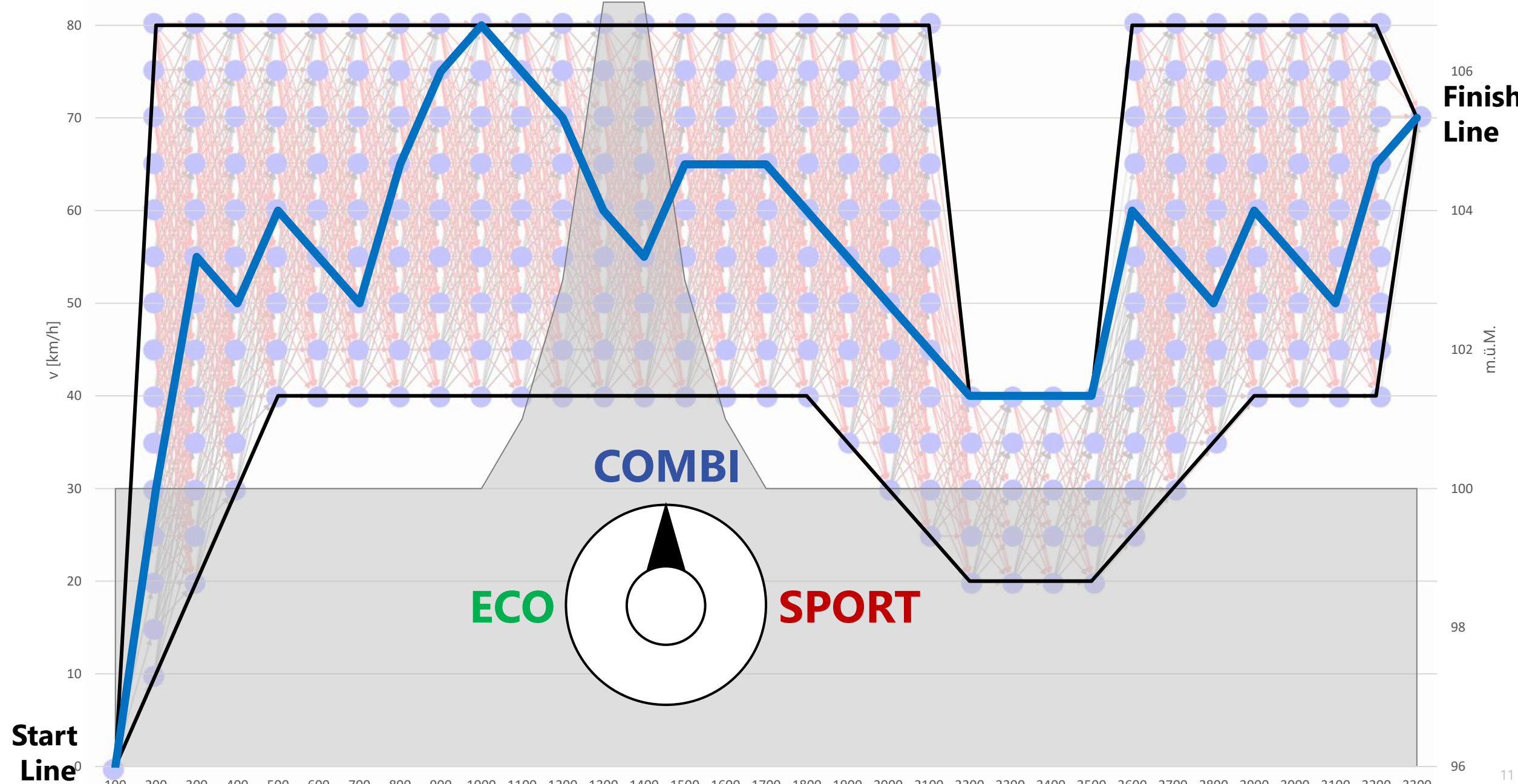
Multigoal: Focus on **Laptime**



Multigoal: Focus on Energy Economy



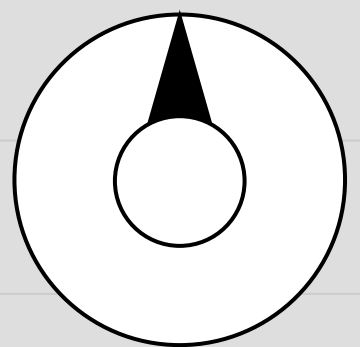
Multigoal: Focus on **Laptime** + **Energy Economy**



Start Line⁰

Finish Line

ECO

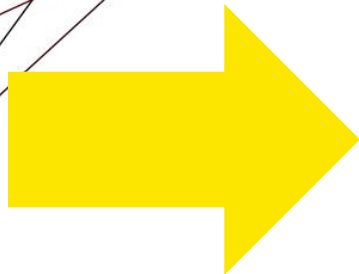
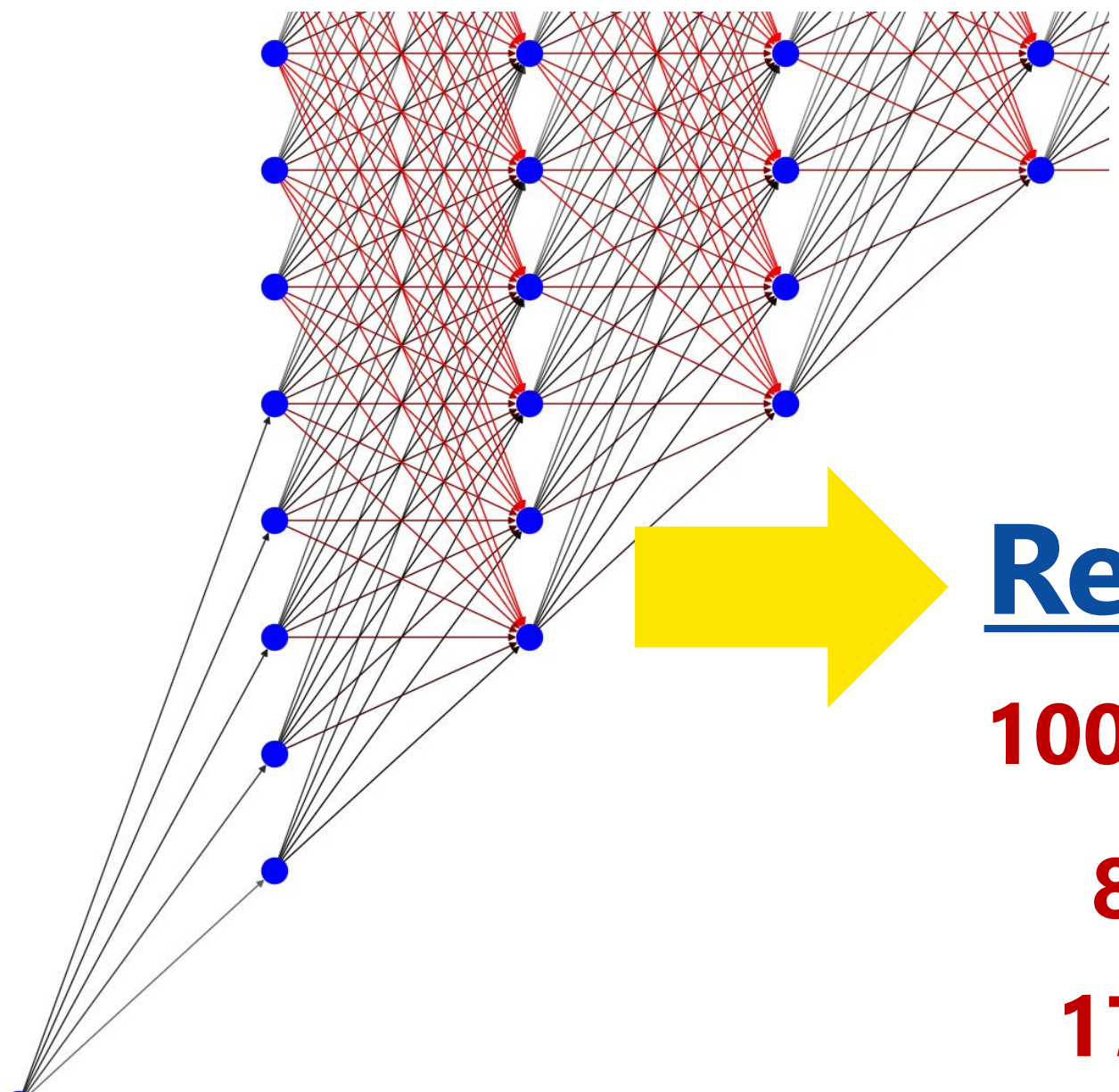


COMBI

SPORT



Collecting **Knowledge** in the Nodes and Edges



Result:

100% Accident-free Attempts

8% Shorter Lap Times

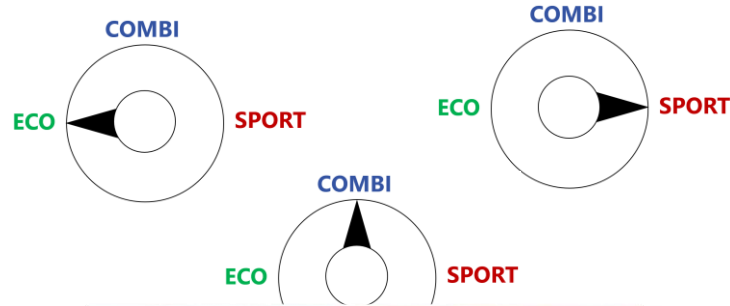
17% Higher Energy Efficiency



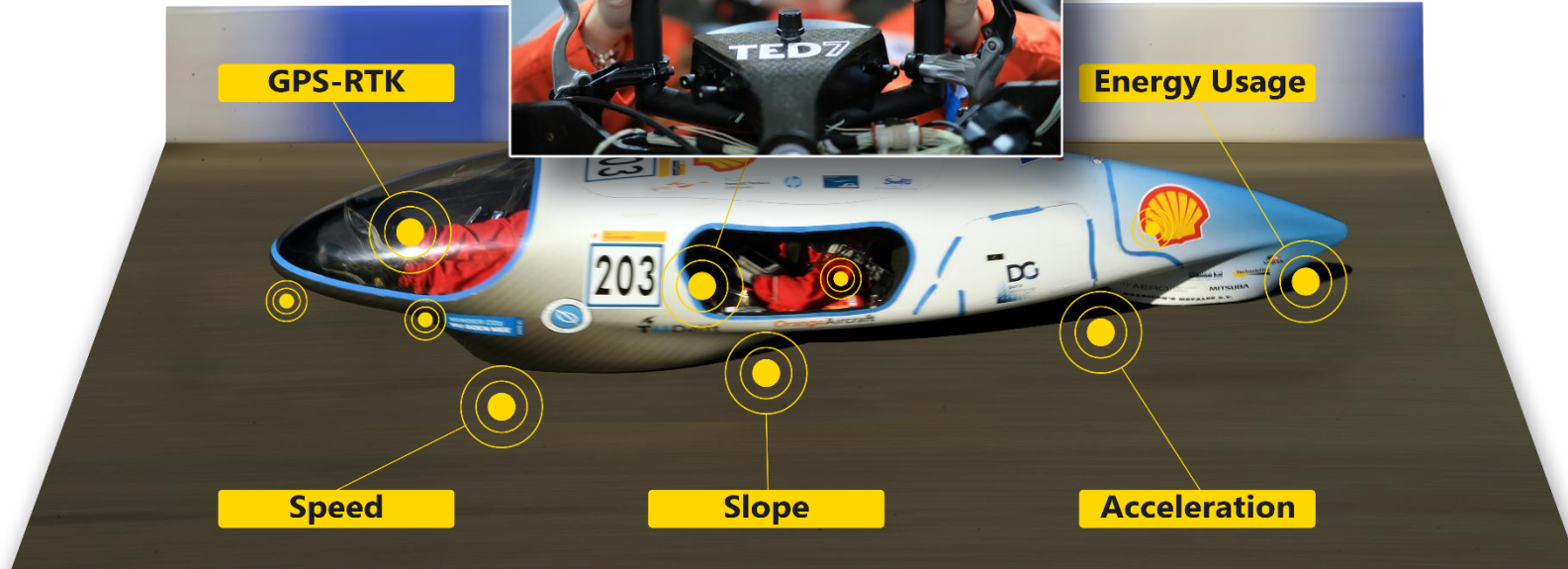
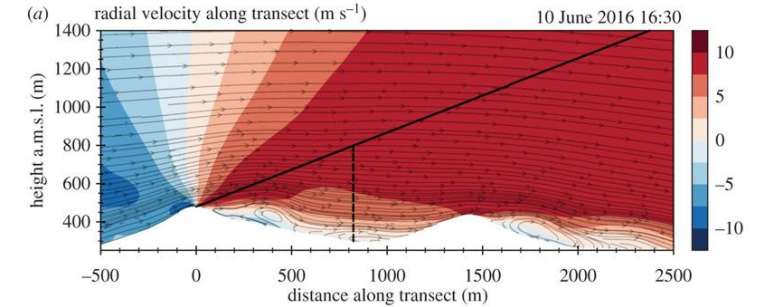
Include and adjust with Telemetry Data



Dynamically Changed Driving Patterns



Include dynamic Weather Data

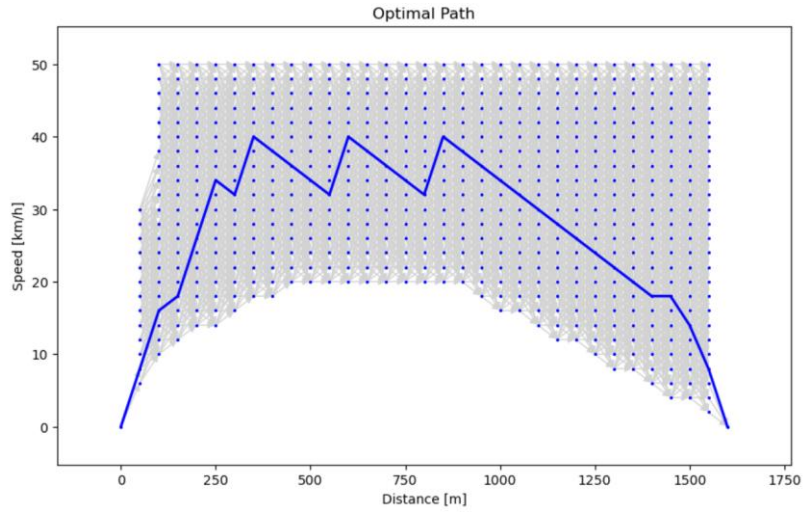
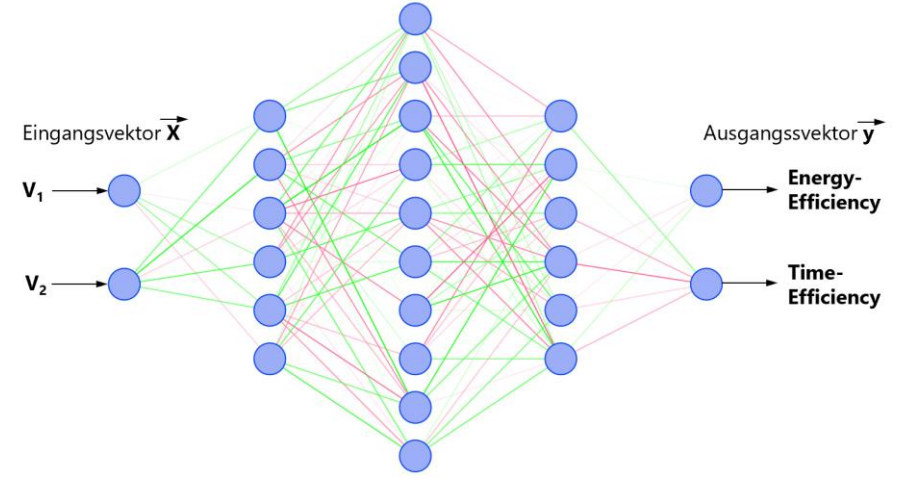




Then move to Neural Networks with DL/ML

NEW
2026

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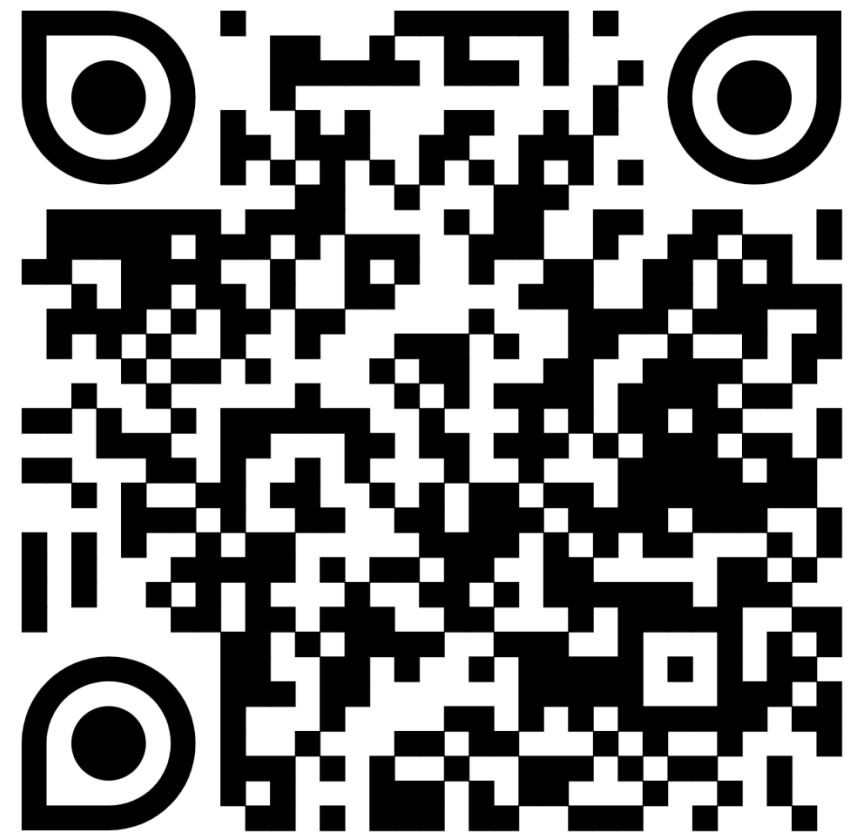
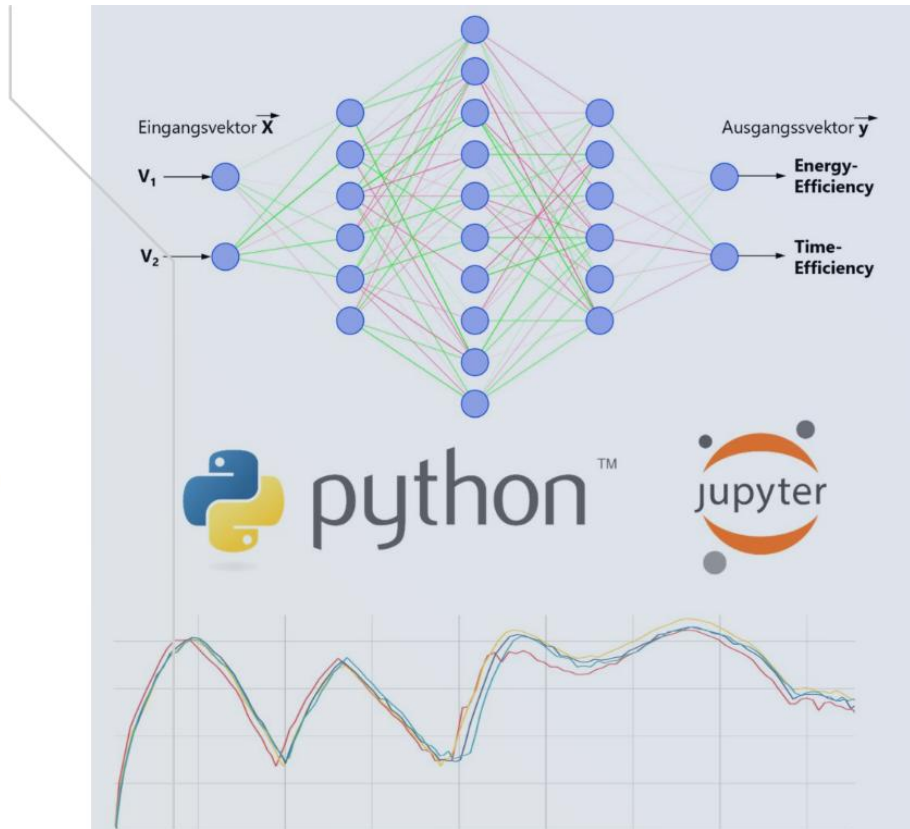
Python Sandbox #3 Use AI with real Race Data

Programming Sandbox #3

JUPYTER NOTEBOOK AND PYTHONCODE FOR LEVEL-5 (AI-APPROACH WITH NN, DL UND ML)

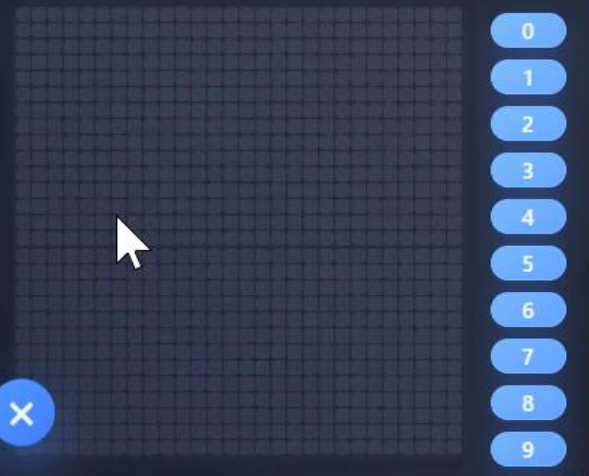
Start Jupyter Notebook in your browser (Binder, ~1-2 min.) and play with Python. There is some real race data waiting for you and you experiment with a neural network, deep learning and machine learning. Save the source code locally, because when you close the browser, the environment will be gone.

START SANDBOX #3 IN YOUR BROWSER >

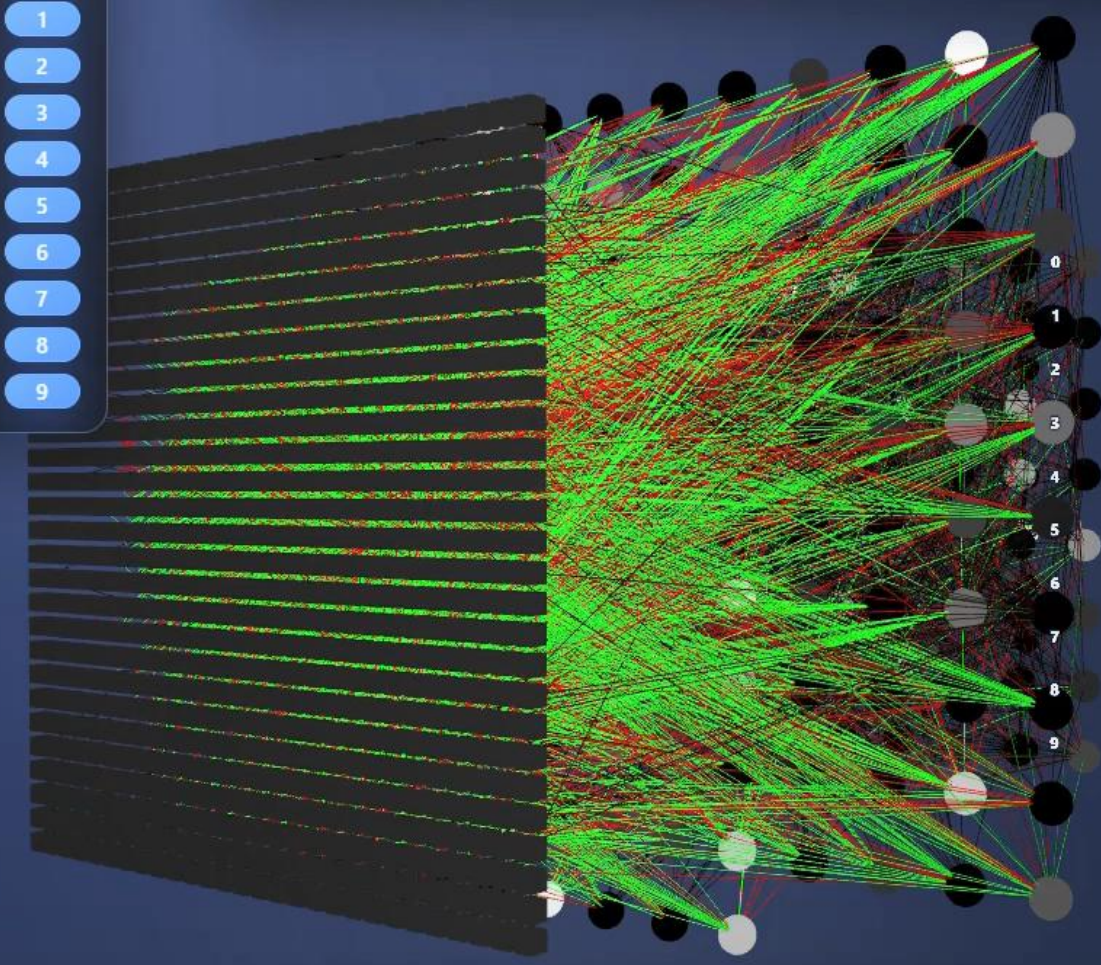


Tinker with NN: <https://nn-vis.noelith.dev/>

ZIFFER ZEICHNEN



Zeichnen: Auf dem Raster klicken und ziehen (Rechtsklick zum Löschen)
3D-Steuerung: • Linke Taste + ziehen = drehen • Rechte Taste + ziehen = verschieben • Scrollrad = zoomen



WAHRSCHEINLICHKEITEN DER ZIFFERN

0	<input type="text"/>	0.0%
1	<input type="text"/>	0.0%
2	<input type="text"/>	0.0%
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NETZWERKÜBERSICHT

Gesamtparameter	109.386
Eingabeknoten	784
Ausgabeklassen	10
Layer (inkl. Ausgaben)	3

dense 0 (relu) • 784 → 128
GEWICHTE: 100.352 BIAS: 128
SUMME: 100.480

dense 1 (relu) • 128 → 64
GEWICHTE: 8.192 BIAS: 64 SUMME: 8.256

dense 2 (linear) • 64 → 10
GEWICHTE: 640 BIAS: 10 SUMME: 650

TRAININGSVERLAUF 50x dataset

3,000,000 images • 50x dataset • 23,450 batches

Test acc: 98.16% • Avg loss: 0.0234

1 FPS ⚙️ ⓘ

The Sky is the Limit...

Train LLMs &
Race Agents

Vehicle Health
Monitoring

Efficiency
Prediction

Collision Warning

ADAS

Use

Driver Training
(Simulator)

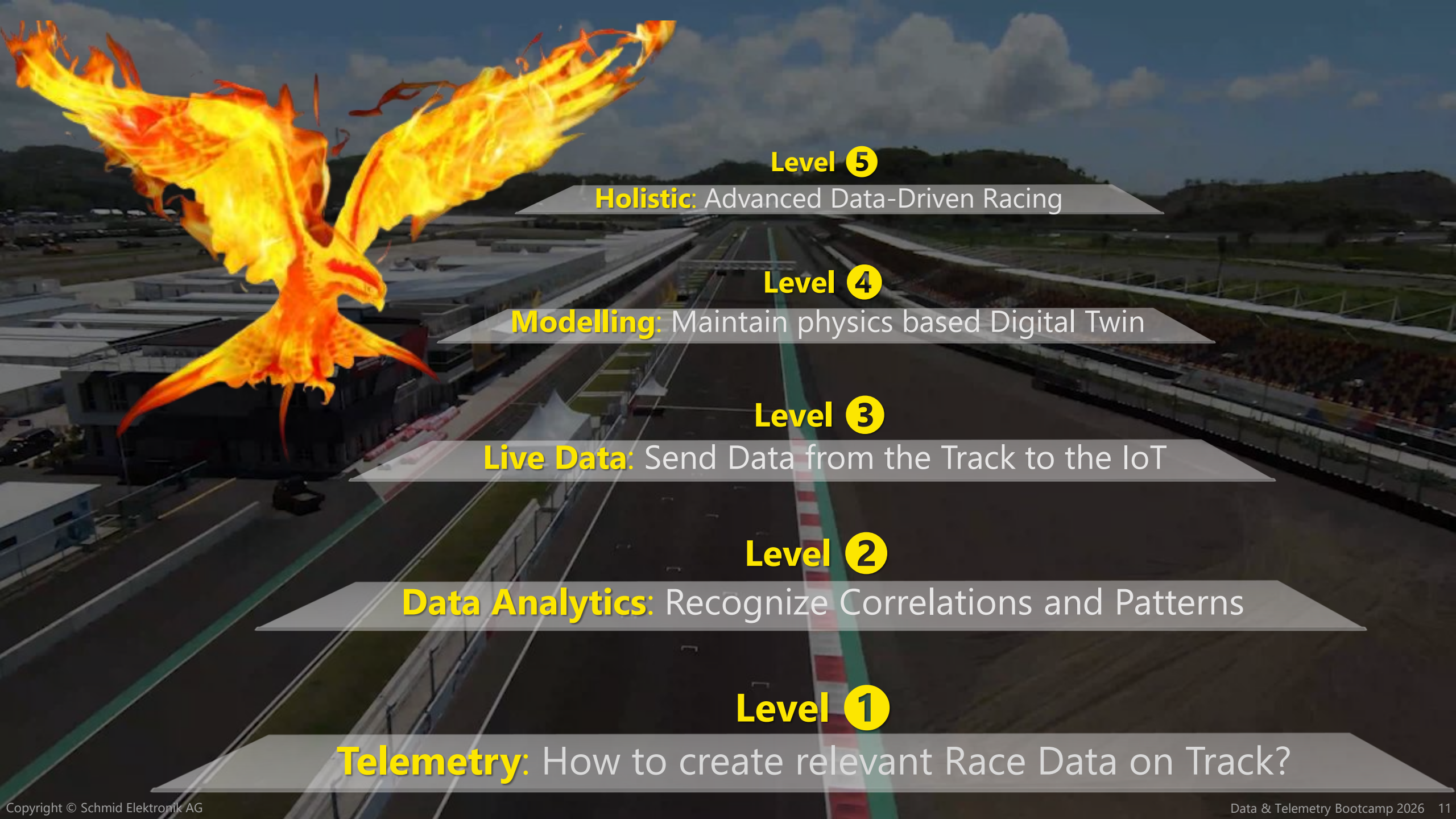
Oponents

Environment

- Wind
- Rain

etc, etc, etc

Gameification



Level ⑤

Holistic: Advanced Data-Driven Racing

Level ④

Modelling: Maintain physics based Digital Twin

Level ③

Live Data: Send Data from the Track to the IoT

Level ②

Data Analytics: Recognize Correlations and Patterns

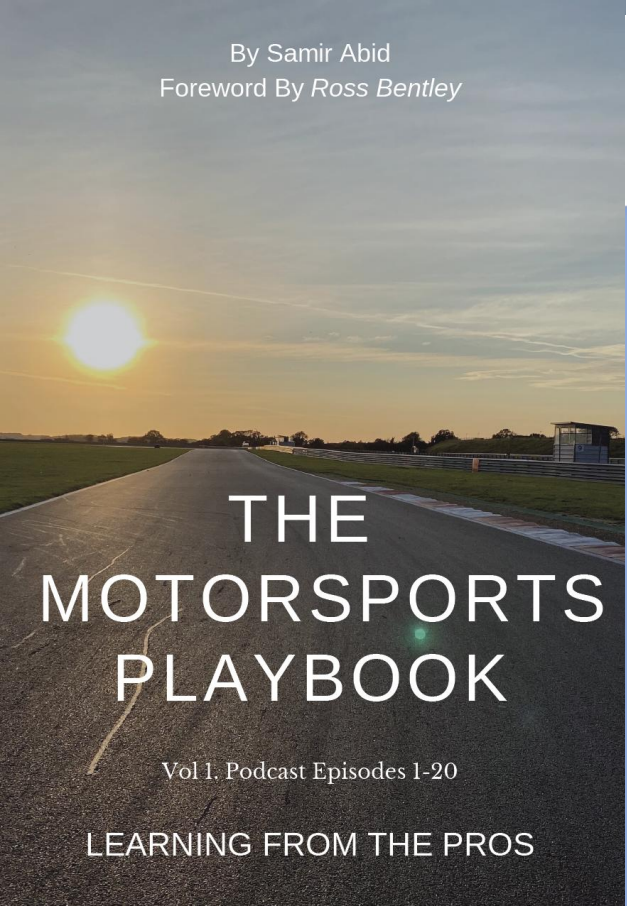
Level ①

Telemetry: How to create relevant Race Data on Track?



Shell Eco-marathon Data & Telemetry Community

Check out this guys Ressources



ARTICLES SIGN IN

Let's Make Driving Faster Easier for You

Not more Complex.

[Explore the Resource Library ->](#)



academy.yourdatadriven.com



PY

New Python content every day. Follow to join our 3.5M+ monthly readers.

Following



Chapter 5: F1 Telemetry — 10 Chapter Python course using F1 data with the FastF1

Learn Python with F1 Data



Raul Garcia

Following

16 min read · Oct 22, 2025



84





Thank You
and Good Luck
On the Track

Business

- CEO
- Head of R&D
- Owner



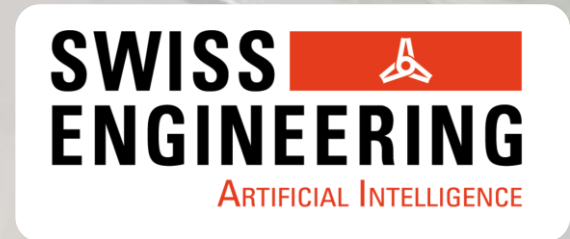
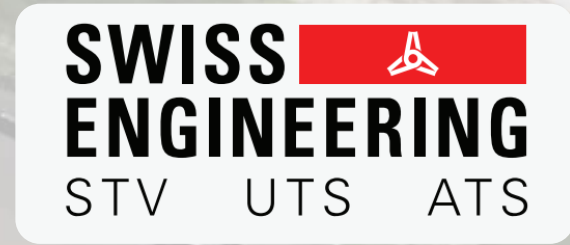
Private

- Married, two kids
- Year of construction: 1969
- Cooking, Wines
- Travelling, Nature, Camping
- Skiing
- Rollerblades

Technical Interests

- Embedded-Systems
- IoT-Systemes, Telemetry
- Knowledge Graphs / AI
- LabVIEW
- Minimum Viable Products
- Complexity
- Networks
- Shell Eco-marathon Trainer

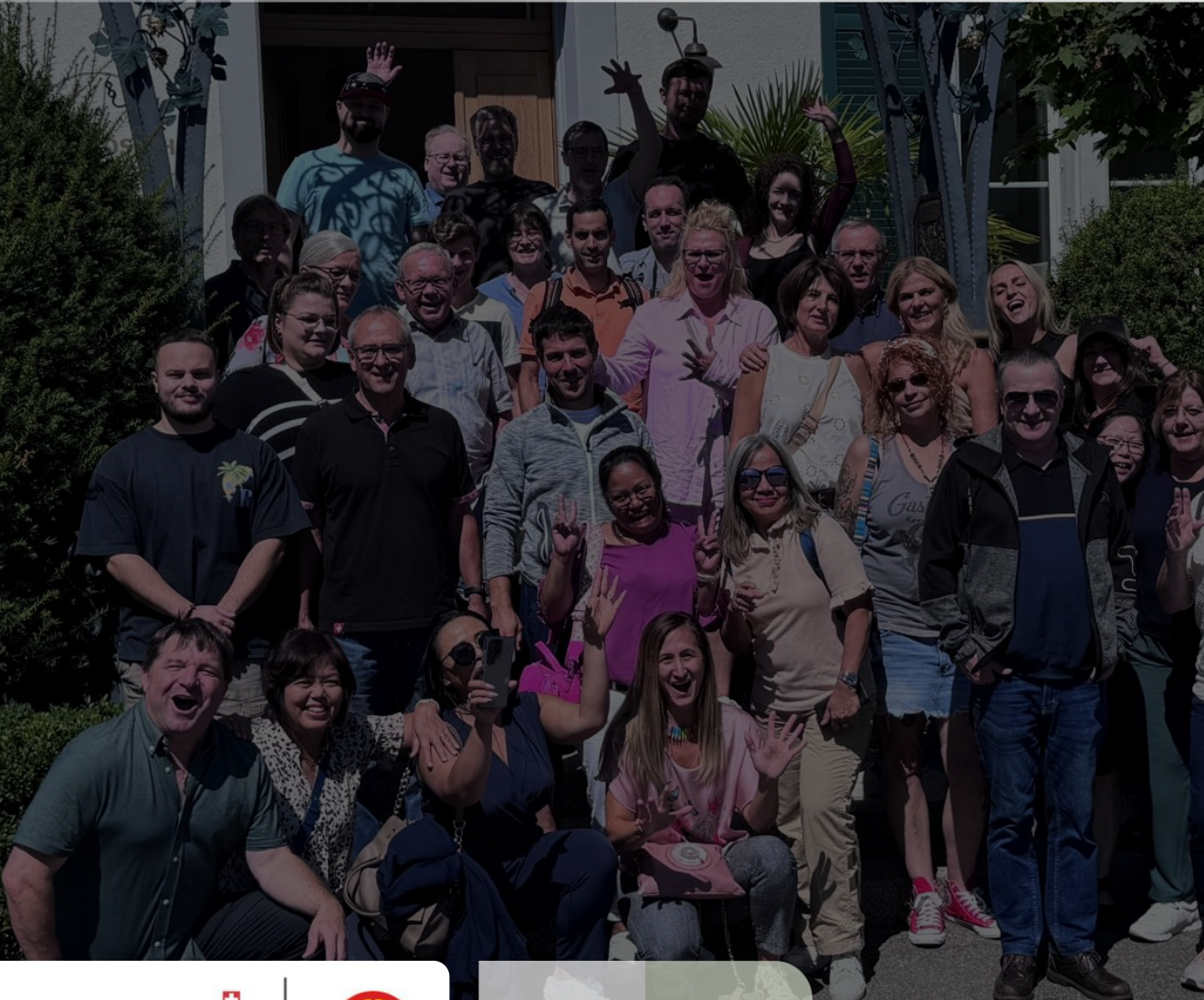
Communities



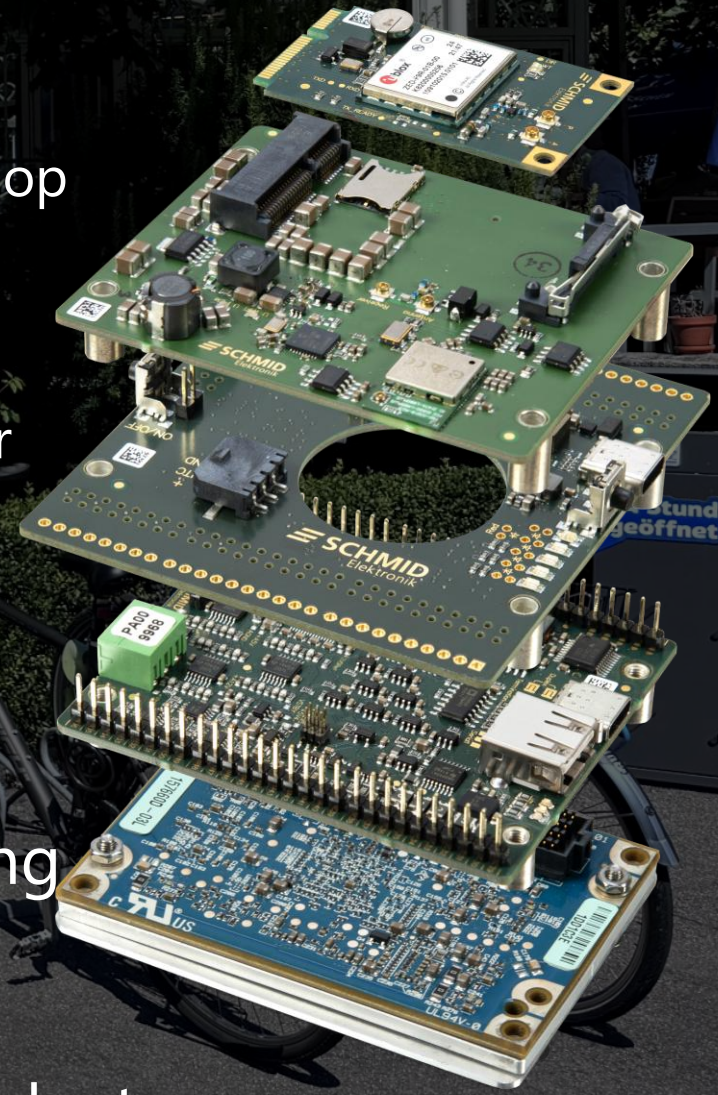
Contact

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- ▶ Family SME
- ▶ Elektronik one-stop-shop
- ▶ 38 People
- ▶ 50+ Years
- ▶ Shell Partner
- ▶ NI Partner



- ▶ Design
- ▶ Prototyping
- ▶ MVPs
- ▶ Series Products



Shell Eco-marathon Partner



Partner

SYSTEM INTEGRATION