e-Truck System Integration – Pure Electric & Fuel Cell

Professional Certification Program

Demo Session

Organized by:

PEVAcademy
pManifold Group

Enabling Smart & Clean Tech Markets

Research | Consulting | Program | Data

Energy E-Mobility LVDC Enviro Urban

P' in our name stands for triple bottom line sustainability of people, profit and planet that we want to bring in all our internal functioning, projects we do, and industries we support. It also keeps us prompt, progressive and partnership valuing. **Manifold** represent abstraction of complex problem to smaller dimension, still preserving elements which matters and are available to influence/control and also measure the system dynamics. We are **'small data'** company and take pride in collecting and analysing most relevant data to help our clients with decisions and actions.

Certification Partner:

ASDC
AUTOMOTIVE SKILLS DEVELOPMENT COUNCIL

Course Motivation & Objective

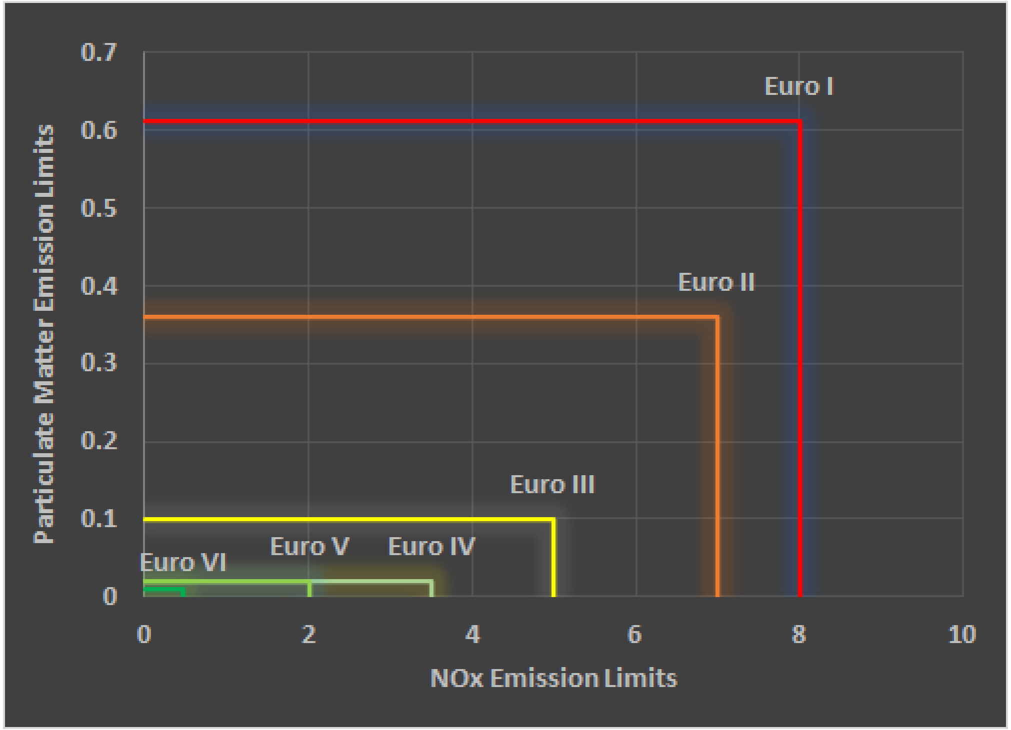
- ✓ **Most Truck EV systems are decades old technology having multiple non-automotive applications as well (E.g. electric motors, power electronics, batteries, etc.).**
- ✓ **Most of the courses offered currently are focused towards Automotive applications.**
- ✓ **But as an employee of Truck industry, the systems engineering of EV's is also of great importance.**
- ✓ **With virtual model-based systems engineering, a lot of development & integration activities can be front loaded. This provides ample course correction opportunities during development without having to build costly.**

Course Objective

To provide an overview of Electric Truck Integration. We will introduce the concepts and terminology, the global best practices in virtual model-based development, EV sub-system working principles, systems engineering and basics of control systems.

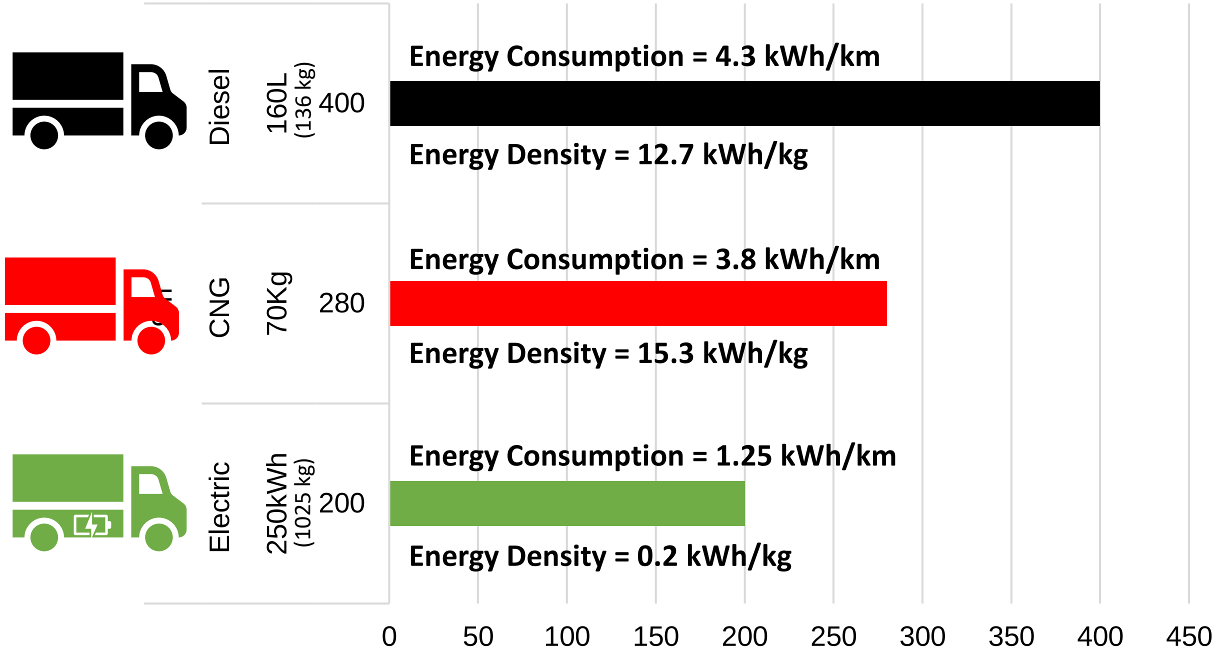
Upon completion of this course, trainees should be able to follow the literature on these subjects and perform independent design, research and development work in this field applying systems engineering approach using virtual models.

Trucks: Emissions and Range



Source: Euro Norms

Range (km): Range of typical 9m Non-AC bus – Diesel, CNG, Electric



Source: pManifold

Emission norms are successively getting so stringent norms ICE vehicles will soon become impractical

e-Truck range is lower than equivalent ICE truck

However, the energy efficiency is significantly higher

Trucks: All set to have CAFE soon!

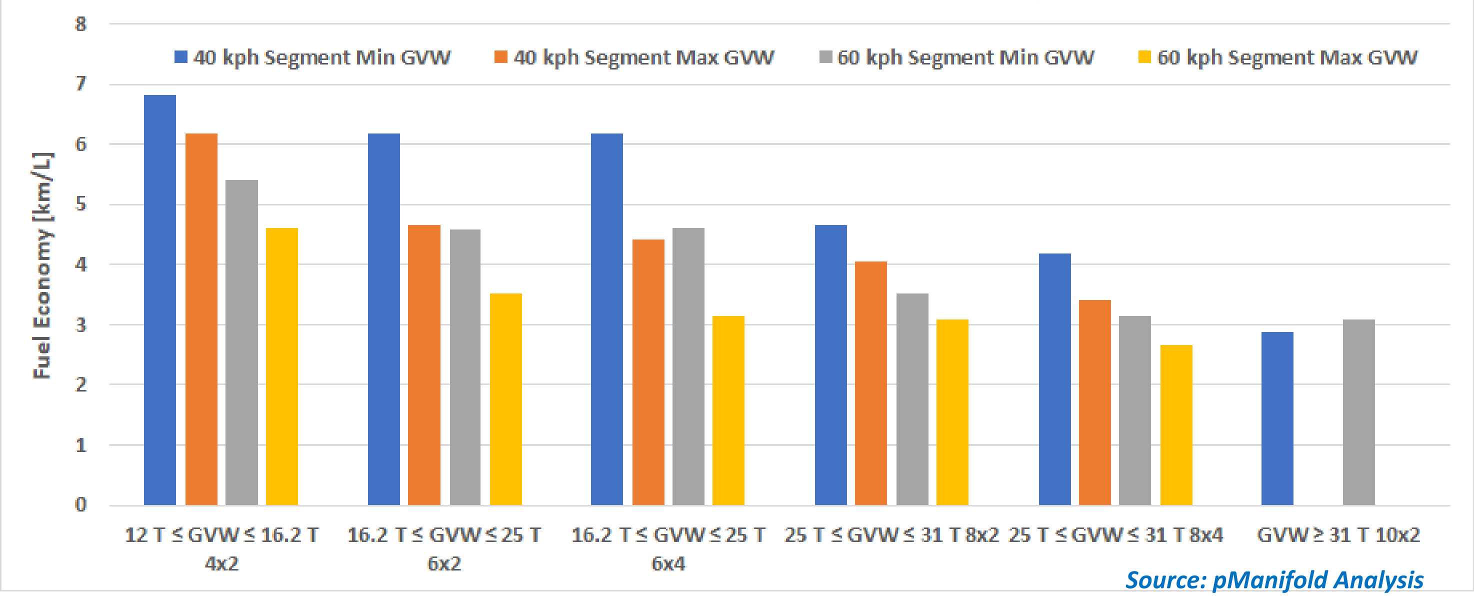
Indian Fuel Consumption Regulations for Trucks

Truck Segment	40 kph constant speed		60 kph constant speed	
	A	B	A	B
12 T ≤ GVW ≤ 16.2 T 4x2	0.362	10.327	0.788	9.003
16.2 T ≤ GVW ≤ 25 T 6x2	0.603	6.415	0.755	9.546
16.2 T ≤ GVW ≤ 25 T 6x4	0.723	4.482	1.151	3.122
25 T ≤ GVW ≤ 31 T 8x2	0.527	8.333	0.65	12.16
25 T ≤ GVW ≤ 31 T 8x4	0.928	0.658	0.968	7.692
GVW ≥ 31 T 10x2	0.96	5.1	0.65	12.16

Source: Ministry of Road Transport and Highways

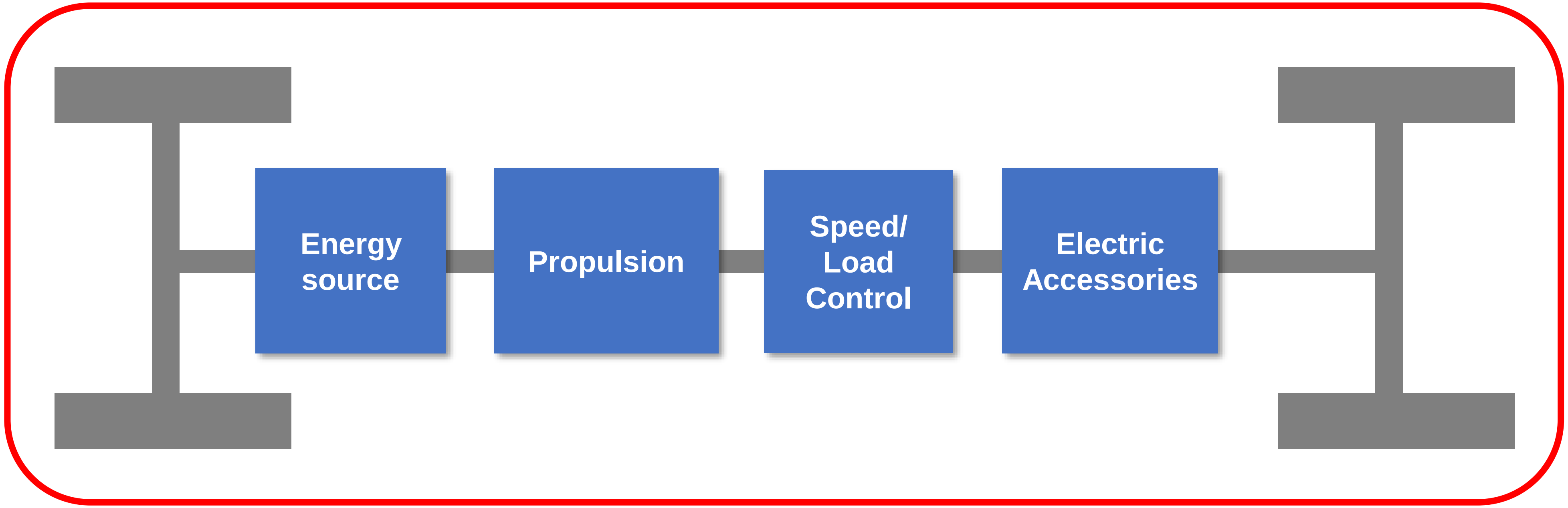
- Currently, it is estimated that most trucks are over these limits
- The cost of technology to make ICEs efficient will decrease disparity between ICE & e-Trucks

Fuel Consumption = (A x GVW) + B
Fuel Economy = 100 / Fuel Consumption



Source: pManifold Analysis

Trucks: Propulsion System Layout Comparison



Energy source

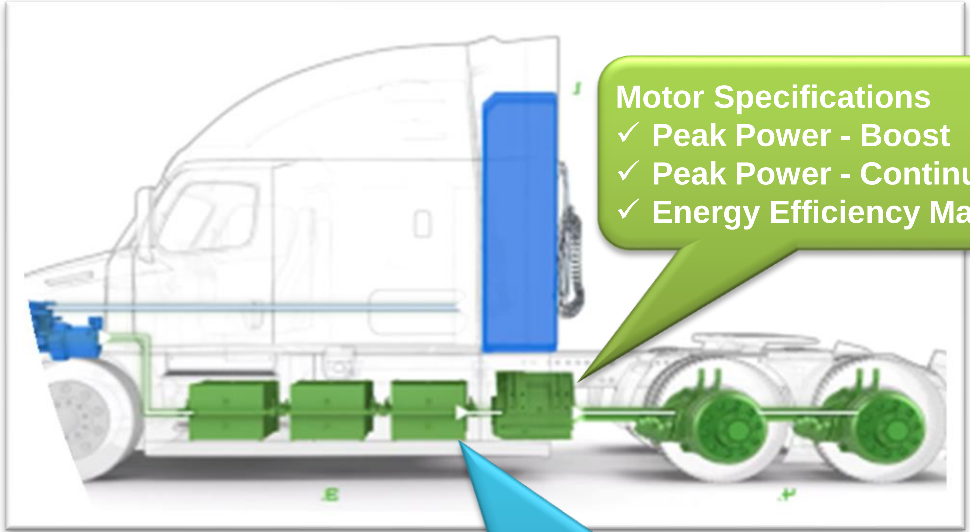
Propulsion

Speed/ Load Control

Electric Accessories

IC Engine	Diesel/CNG tank	ICE	Engine Management system	Alternator	No energy regeneration
Pure Electric	Battery	Traction motor	Electronic controller	LV DC-DC converters	Regen braking
Fuel-Cell Electric	H2 Tank + FC + Small Battery	Traction motor	Electronic controller	LV DC-DC converters	Regen braking

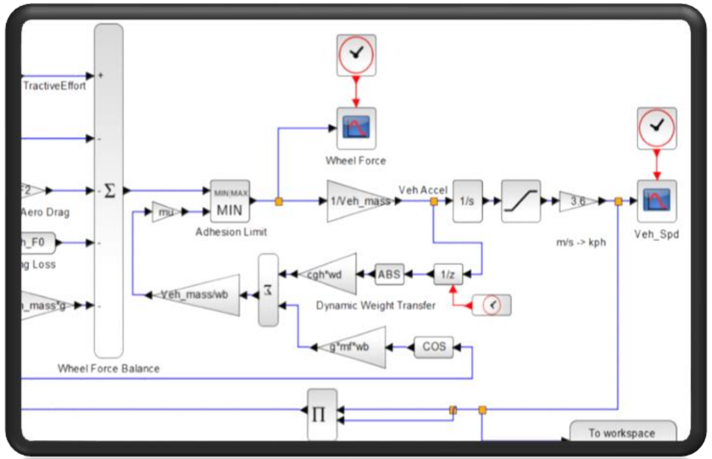
Sub-System Sizing Using Modeling



Motor Specifications
- ✓ Peak Power - Boost
- ✓ Peak Power - Continuous
- ✓ Energy Efficiency Maps

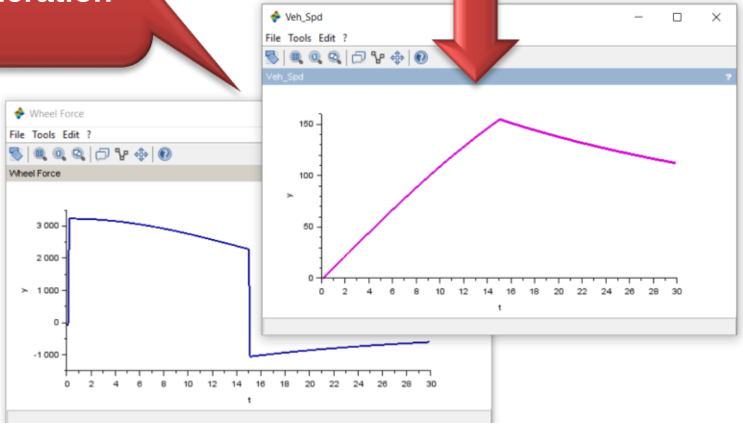
Battery Pack Specifications
- ✓ Power Capacity
- ✓ Energy Capacity
- ✓ Pack Voltage

Vehicle Requirements…
- ✓ Peak Power
- ✓ Charging & Regeneration
- ✓ Range



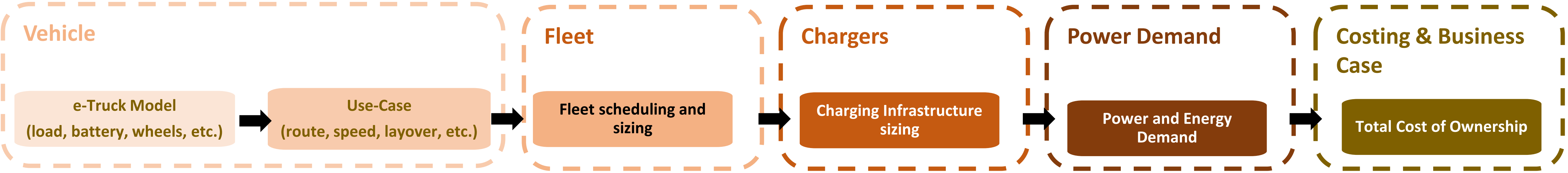
Virtual Vehicle Model

Source: pManifold's EVSysSim©



Virtual models enable capturing of requirements much early in the development

E-Truck Use-case and Feasibility Case Study – Approach



Vehicle

e-Truck Model
(load, battery, wheels, etc.)

Use-Case
(route, speed, layover, etc.)

Fleet

Fleet scheduling and sizing

Chargers

Charging Infrastructure sizing

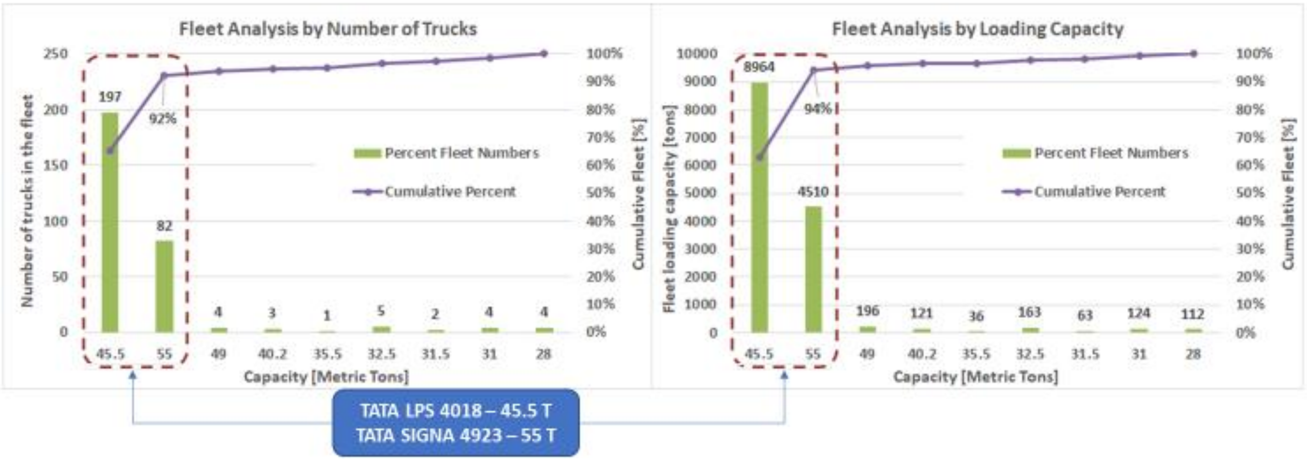
Power Demand

Power and Energy Demand

Costing & Business Case

Total Cost of Ownership

Current Fleet Composition and Vehicle Technical Specifications



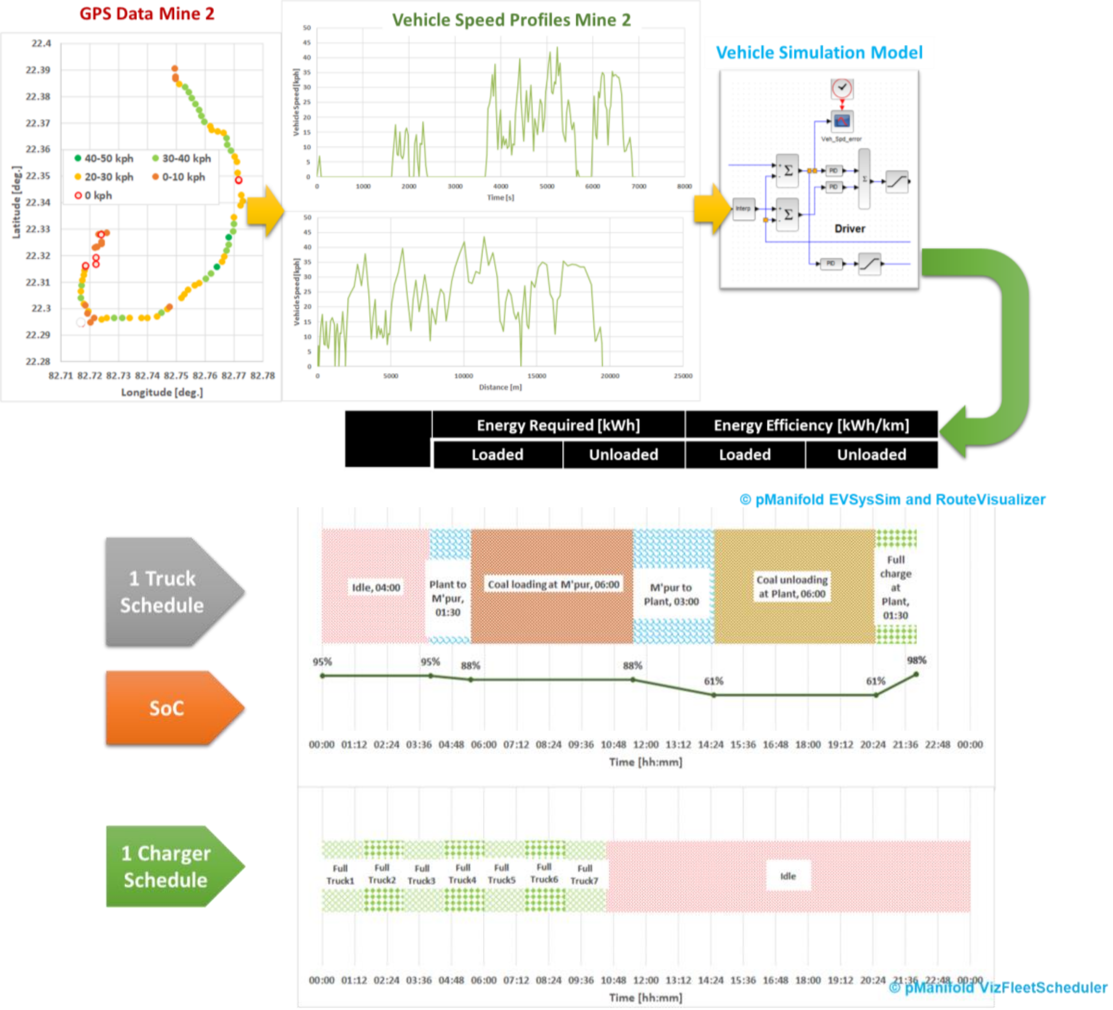
	Existing ICE Fleet Model	Proposed e-Truck Model
Parameters	**Tata 4923s BS-IV**	**e-Truck[1]**
Gross Vehicle Weight [kg]	49000	51900
Kerb Weight [kg]	8280	11180
Load Capacity [kg]	40720	40720
Maximum Power [kW]	170 kW @ 2500 rpm	255 kW @ 2500 rpm
Max Torque [Nm]	850 Nm @ 1300-1800 rpm	1000 Nm @ 1250-2000 rpm
Gearbox	Manual 9 Forward / 1 Reverse	Manual 2 Forward
Tyre	10R20 16 PR	10R20 16 PR
Energy Capacity	400 L Diesel Tank	256 kWh Li-Phosphate Battery
Cost [lakh INR]	~ 40	~ 90

[1] Assumptions based on information available for an actual e-Truck model

Source: pManifold

E-Truck Use-case and Feasibility Case Study for Coal Handling

Use Case Generation & Fleet Optimization



Captive Fleet:
Total cost of ownership & comparison with ICE fleet

Fleet	Number of trucks	Truck Purchase Cost[6] [Crore INR]	Number of Chargers	Charger Purchase Cost [Crore INR][6]	Total CapEx [Crore INR]	e-Truck Cost Extra [Crore INR]
ICE	364	145.6	NA	NA	145.6	
e-Truck	342	307.8	43	5.59	313.39	167.79

Fleet	Fuel Cost / year[2] [Crore INR]	Maintenance Cost / year[3] [Crore INR]	Insurance Cost[4] [Crore INR]	Driver Cost[5] [Crore INR]	OpEx/year [Crore INR]	e-Truck OpEx Savings/year [Crore INR]
ICE	20.16	4.37	2.18	8.736	35.45	
e-Truck	2.45	2.05	4.62	8.21	17.33	18.12

Source: pManifold

Financial Performance

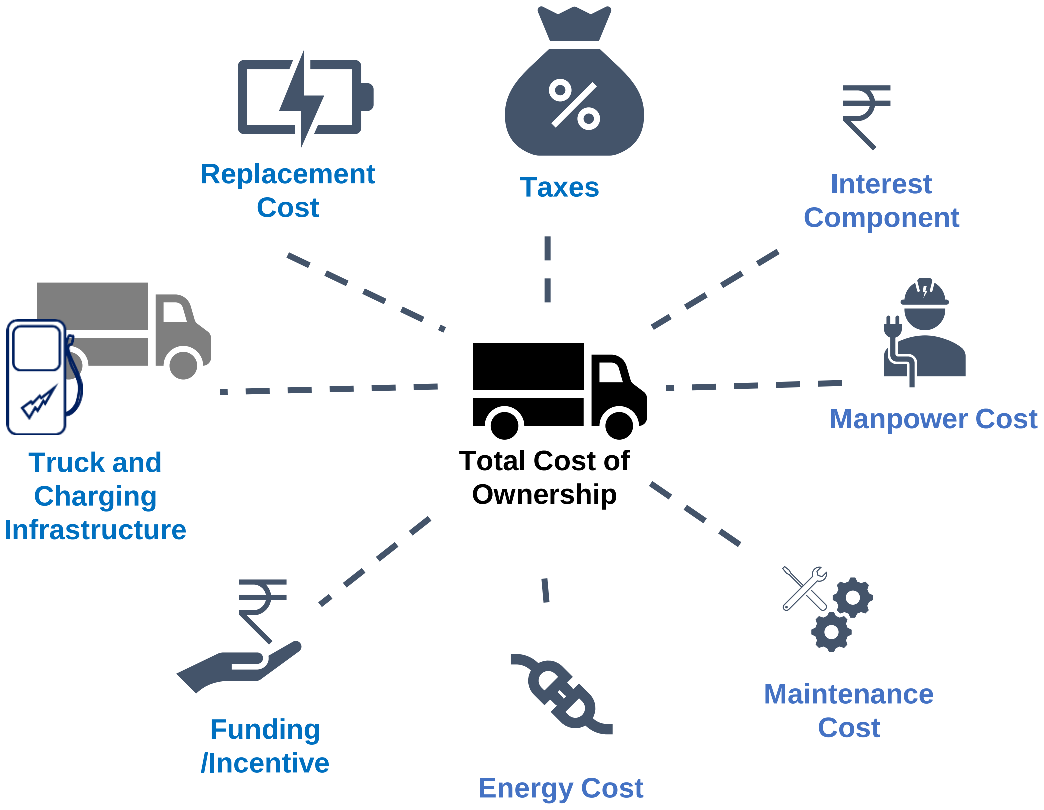
Financial performance constitutes

- ✓ Capital Costs

Additional Investment

- ✓ Operational Costs

Savings



Total Cost of Ownership

Replacement Cost

Taxes

Interest Component

Manpower Cost

Maintenance Cost

Energy Cost

Funding /Incentive

Truck and Charging Infrastructure

Benefits of Systems Engineering Using Virtual System Models

Systems Engineering

- ✓ Focused on the usage of product by the end user
- ✓ Prioritizes optimized system over great individual sub-system
- ✓ Trade-offs are more robust as well as all inclusive
- ✓ Traceability, failure mode effect, and root cause analysis are much easier
- ✓ Helps drive standardization by enabling precise sub-system requirements

Virtual System Model

- ➢ Provides end user perspective very early in product development
- ➢ Enables sub-system selection as well as system optimization studies
- ➢ Helps generate all scenarios for well informed trade-offs
- ➢ Helps catch failures much early in the program
- ➢ Helps explore the performance bandwidth of standard systems using control’s tuning

Who will Benefit?

- **Public Transport Authorities, Private Operators**
- **Government personnel / Policy makers**
- **Professionals, Consultants**
- **Students, Academicians**

- **e-Bus Manufacturers, Infrastructure & Services Providers**
- **Researchers, Think tanks**
- **Multilaterals, Funding Agencies**

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Program Schedule & Structure

Module	Module Title	Week	Day	Session No.	Session Title	Topics coverd	Duration [hr]
Module 1	Electric Truck Basics	Week 1	Tuesday	Session 1	Course Introduction & Truck Classifications	Course structure, Tools used, Truck classifications based on GVW across US, Europe and India Markets, Fuels used, Axles used	1
			Thursday	Session 2	Basics of e-Truck M & HD Applications	Turck Applications and Use-cases, Regulatory Requirements on Truck Axles and Dimensions, Axle & Tyre Selection	1
Module 2	Electric Truck Modelling		Saturday	Practical 1	Introduction to Modeling Tools	Truck Axle & Tyre load related calculations	2
		Week 2	Tuesday	Session 3	Batteries for e-trucks	Battery working principle, Battery sub chemsitries, Battery types, Battery series and Parallel combinations, Battery Sizing, Battery specifications	1
			Thursday	Session 4	Motors	Motor woking principle, Motor specification review, Motor selection for PTOs	1
			Saturday	Practical 2	Battery Pack Sizing & Modelling	Scilab exercise (Battery functional model), Battery sizing for desired Range (excel)	2
		Week 3	Tuesday	Session 5	Truck Power Requirements	Propulsion energy, PTOs, Steering power, Auxiliary powers	1
			Thursday	Session 6	Truck Power Train Integration	Product Development process, Evolving design criteria, Gradeability effect, Range effect, battery & Motor sizing	1
			Saturday	Practical 3	Motor & Vehicle Modelling	Excel Modelling for Vehicle Level calculations including PTOs for a duty cycle	2
		Week 4	Tuesday	Session 7	Battery Management System	SoC & SoH estimation, Corrections & Compensations, Regeneration Controller, etc.	1
			Thursday	Session 8	Charger Selection & Sizing	Charging Strategy, Opportunity Charging, Charger Sizing, Charging Duration, etc.	1
			Saturday	Practical 4	BMS and Charging Modeling	Modeling Regen & Current Control, CCCV Charge Control and charging duration	2
Module 3	Cost Modeling	Week 5	Tuesday	Session 7	Charging Infrastructure	Charging systems- classifications, Charging modes, Charging standards, Highway Public charging Infrastructure	1
			Thursday	Session 8	Capital & Operational Expenditures, TCO	Purchase cost comparison, Drive Train cost comparison, Fuel Cost ocmparison, Maintenance cost comparison	1
			Saturday	Practical 4	TCO Modeling	Capital expenses, Operating expenses, sensitivity to subsidies, cost assumptions and trends, etc.	2
Module 4	Hydrogen Technology	Week 6	Tuesday	Session 9	Fuel Cells for e-trucks	Fuel Cell working Principal, Fuel Cell Types, BOP components overview,Polarization curve,	1
			Thursday	Session 10	Hydrogen Infrastructure	H2 ICE working principles, Stoichiometric ratio, Challenges, using H2 Technology as Range extender, H2 estimation	1
			Saturday	Practical 5	Internal Project Reviews		2
Evaluations		Week 7	Thursday	Session 14	Online Exam		1
			Saturday	Practical 7	Project Evaluations		3

Primary Trainers

Mr. Rahul Bagdia

Managing Director and Partner, pManifold

20+ years global experience and leading e-Mobility and Utilities Practice at pManifold. Have worked with National and City Governments in India and other developing countries supporting e-Mobility strategic road maps, regulations, policies, standards, charging infrastructure development, new business models, and pilots, including EV fleet assessment with multiple operators.

Mr. Vikrant Vaidya

Partner and VP – EV Systems Engineering, pManifold

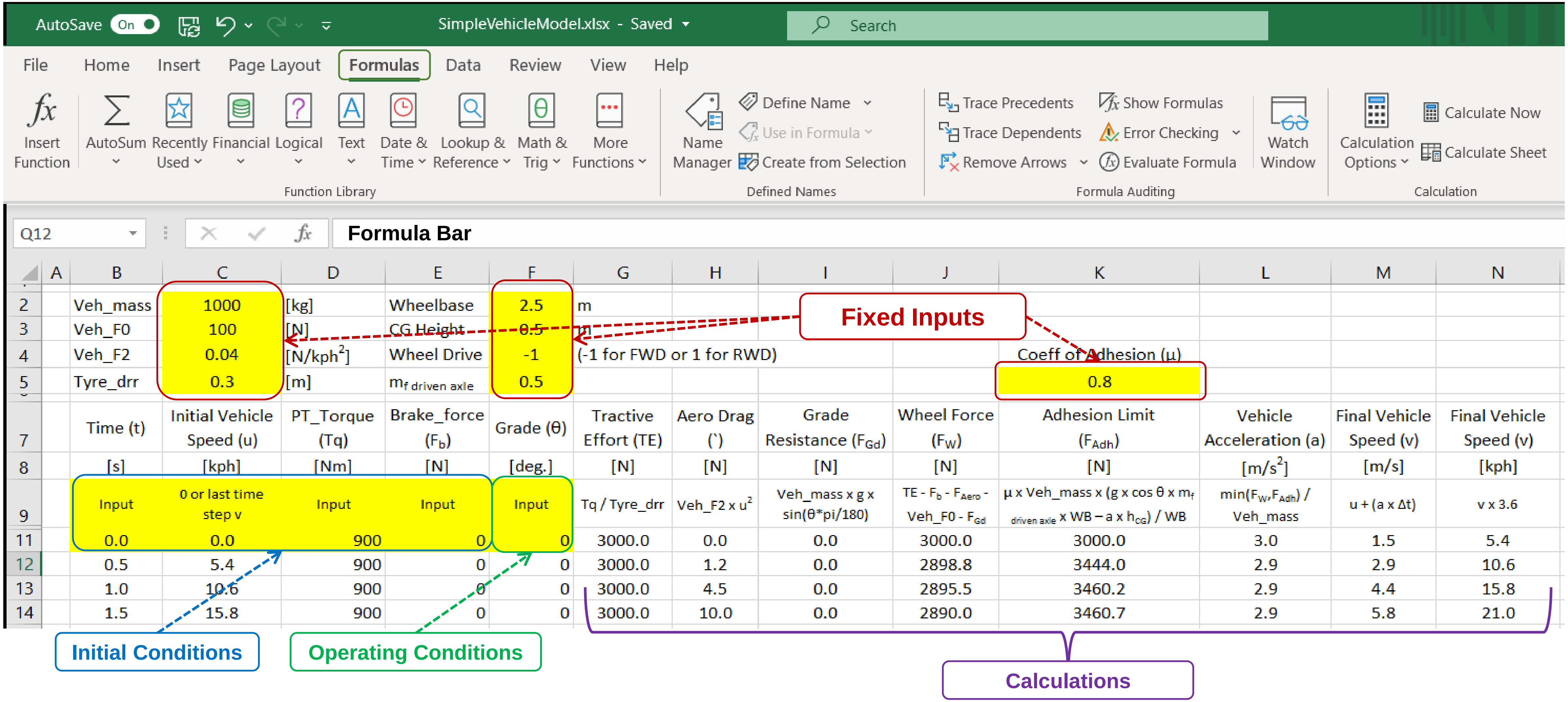
20+ years experience in global automotive design and product development on multiple EVs and Hybrid vehicle platforms, specialising in model-based design, calibration, testing and system integration; a Six-Sigma Green Belt and a Master Trainer for EVs model-based development and systems engineering.

Mr. Soma Sekhar P

Senior Consultant – EV Systems Engineering, pManifold

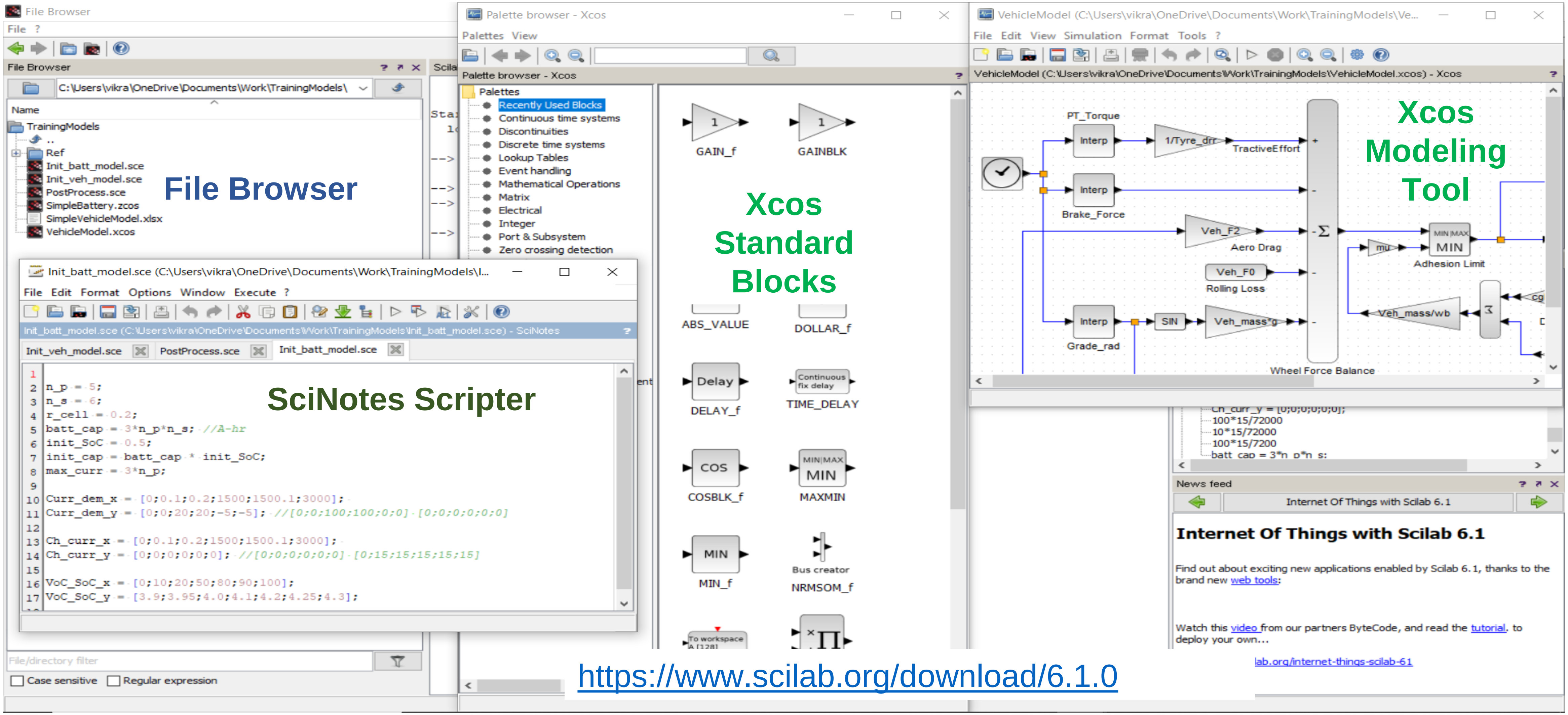
15+ years experience in global automotive design and product development on multiple commercial and special purpose vehicles specializing in powertrain design and integration; a Six-Sigma Green Belt and a Master Trainer for EVs model-based development and systems engineering.

Calculation Tool – MS Excel (pManifold *EVFleetPlanner©* is based on Excel)



	A	B	C	D	E	F	G	H	I	J	K	L	M	N
2		Veh_mass	1000	[kg]	Wheelbase	2.5	m							
3		Veh_F0	100	[N]	CG Height	0.5	m							
4		Veh_F2	0.04	[N/kph^2]	Wheel Drive	-1	(-1 for FWD or 1 for RWD)				Coeff of Adhesion (µ)			
5		Tyre_drr	0.3	[m]	$m_{f\ \text{driven axle}}$	0.5					0.8			
7		Time (t)	Initial Vehicle Speed (u)	PT_Torque (Tq)	Brake_force (F_b)	Grade (θ)	Tractive Effort (TE)	Aero Drag (`)	Grade Resistance (F_{Gd})	Wheel Force (F_W)	Adhesion Limit (F_{Adh})	Vehicle Acceleration (a)	Final Vehicle Speed (v)	Final Vehicle Speed (v)
8		[s]	[kph]	[Nm]	[N]	[deg.]	[N]	[N]	[N]	[N]	[N]	[m/s^2]	[m/s]	[kph]
9		Input	0 or last time step v	Input	Input	Input	Tq / Tyre_drr	Veh_F2 x u^2	Veh_mass x g x sin(θ*pi/180)	TE - F_b - F_{Aero} - Veh_F0 - F_{Gd}	µ x Veh_mass x (g x cos θ x $m_{f\ \text{driven axle}}$ x WB – a x h_{CG}) / WB	min(F_W,F_{Adh}) / Veh_mass	u + (a x Δt)	v x 3.6
11		0.0	0.0	900	0	0	3000.0	0.0	0.0	3000.0	3000.0	3.0	1.5	5.4
12		0.5	5.4	900	0	0	3000.0	1.2	0.0	2898.8	3444.0	2.9	2.9	10.6
13		1.0	10.6	900	0	0	3000.0	4.5	0.0	2895.5	3460.2	2.9	4.4	15.8
14		1.5	15.8	900	0	0	3000.0	10.0	0.0	2890.0	3460.7	2.9	5.8	21.0

Simulation Tool – Scilab + Xcos (pManifold *EVSysSim©* is developed in Xcos)



File Browser

Xcos Standard Blocks

Xcos Modeling Tool

SciNotes Scripter

Init_batt_model.sce (C:\Users\vikra\OneDrive\Documents\Work\TrainingModels\Init_batt_model.sce) - SciNotes

```

n_p = 5;
n_s = 6;
r_cell = 0.2;
batt_cap = 3*n_p*n_s; //A-hr
init_SoC = 0.5;
init_cap = batt_cap * init_SoC;
max_curr = 3*n_p;

Curr_dem_x = [0;0.1;0.2;1500;1500.1;3000];
Curr_dem_y = [0;0;20;20;-5;-5]; //[0;0;100;100;0;0] [0;0;0;0;0;0]

Ch_curr_x = [0;0.1;0.2;1500;1500.1;3000];
Ch_curr_y = [0;0;0;0;0;0]; //[0;0;0;0;0;0] [0;15;15;15;15;15]

VoC_SoC_x = [0;10;20;50;80;90;100];
VoC_SoC_y = [3.9;3.95;4.0;4.1;4.2;4.25;4.3];
```

```
Ch_curr_y = [0;0;0;0;0;0];
100*15/72000
10*15/72000
100*15/7200
batt_cap = 3*n_p*n_s;
```

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Internet Of Things with Scilab 6.1

Internet Of Things with Scilab 6.1

Find out about exciting new applications enabled by Scilab 6.1, thanks to the brand new web tools:

Watch this video from our partners ByteCode, and read the tutorial, to deploy your own...

lab.org/internet-things-scilab-61

https://www.scilab.org/download/6.1.0

Charging Your EV Journeys

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Business Plans
Feasibility
City EV Charging Infra
Workshops
Industry Outlook
Pilots Management
Policy

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Greenhouse Gas pollution challenges