Aeromovel™:

A Pneumatically Propelled Automated People Mover

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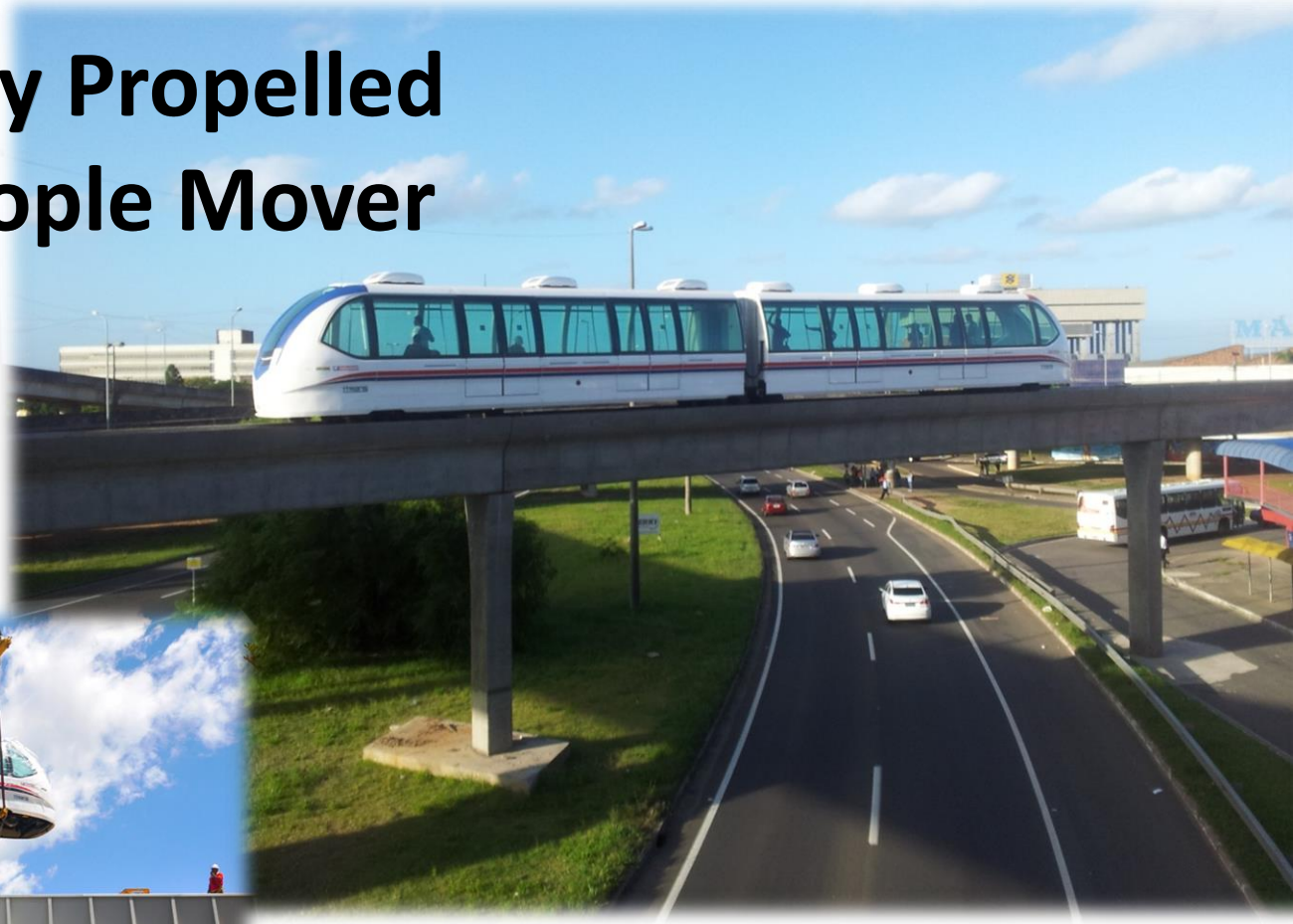

Propulsion concept

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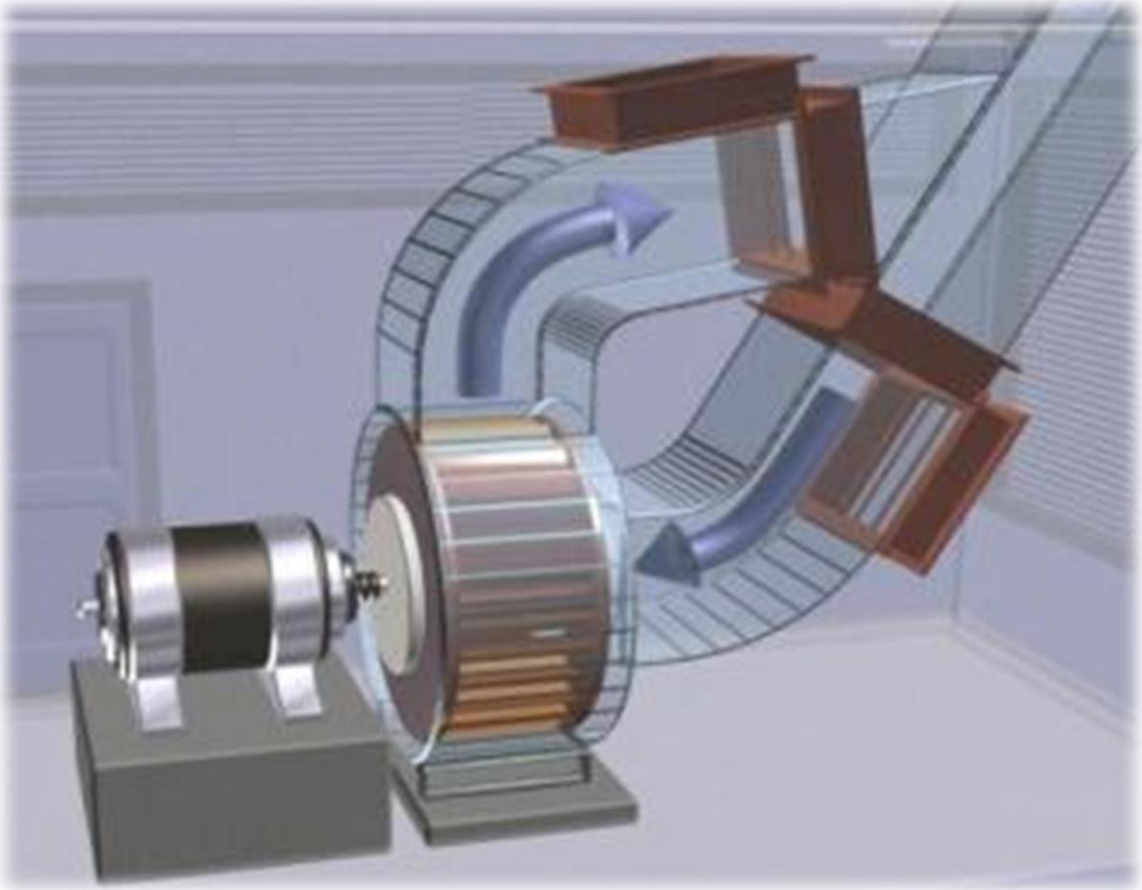
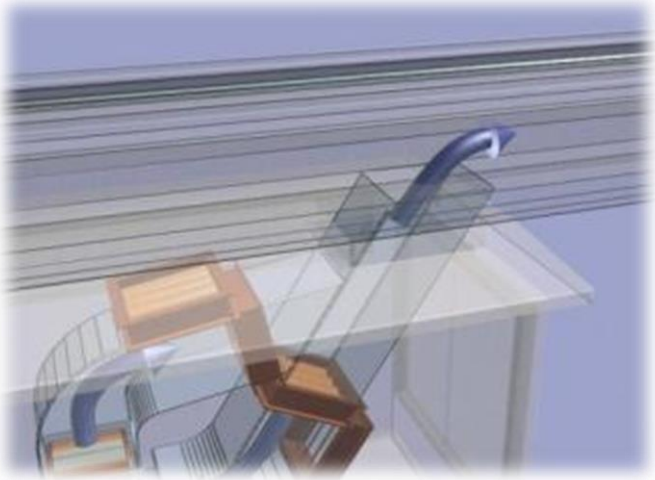
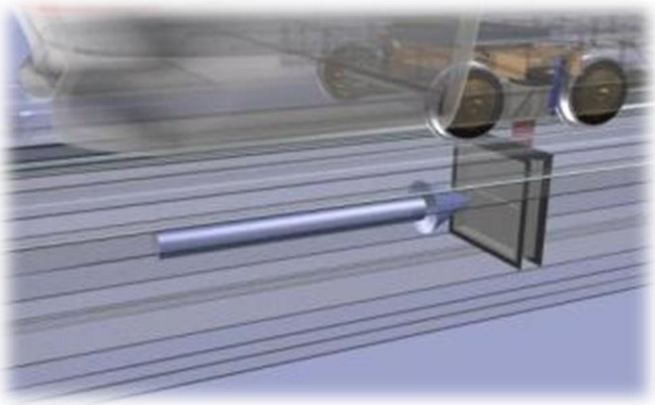
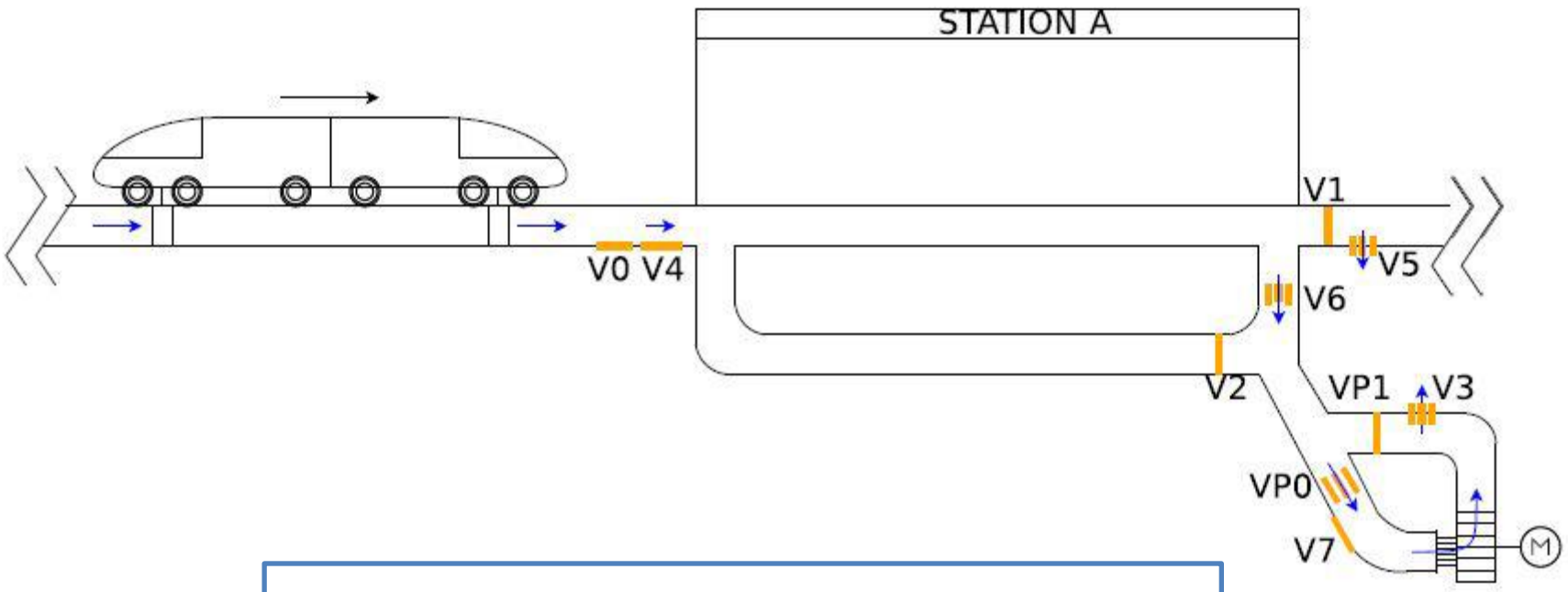




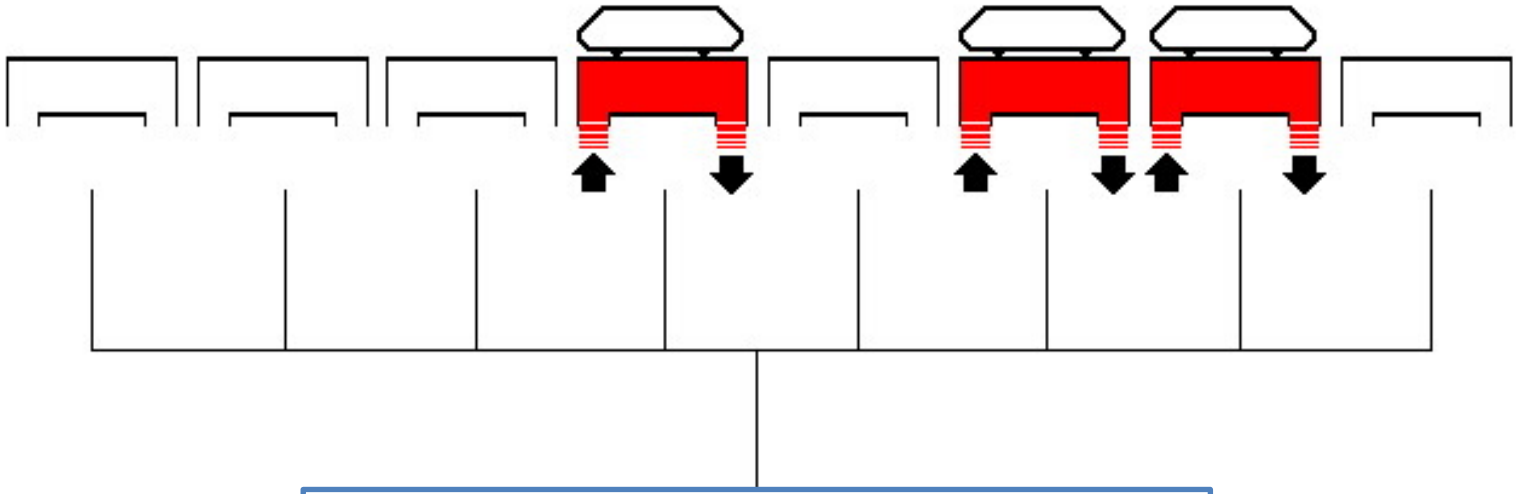


Propulsion blocks



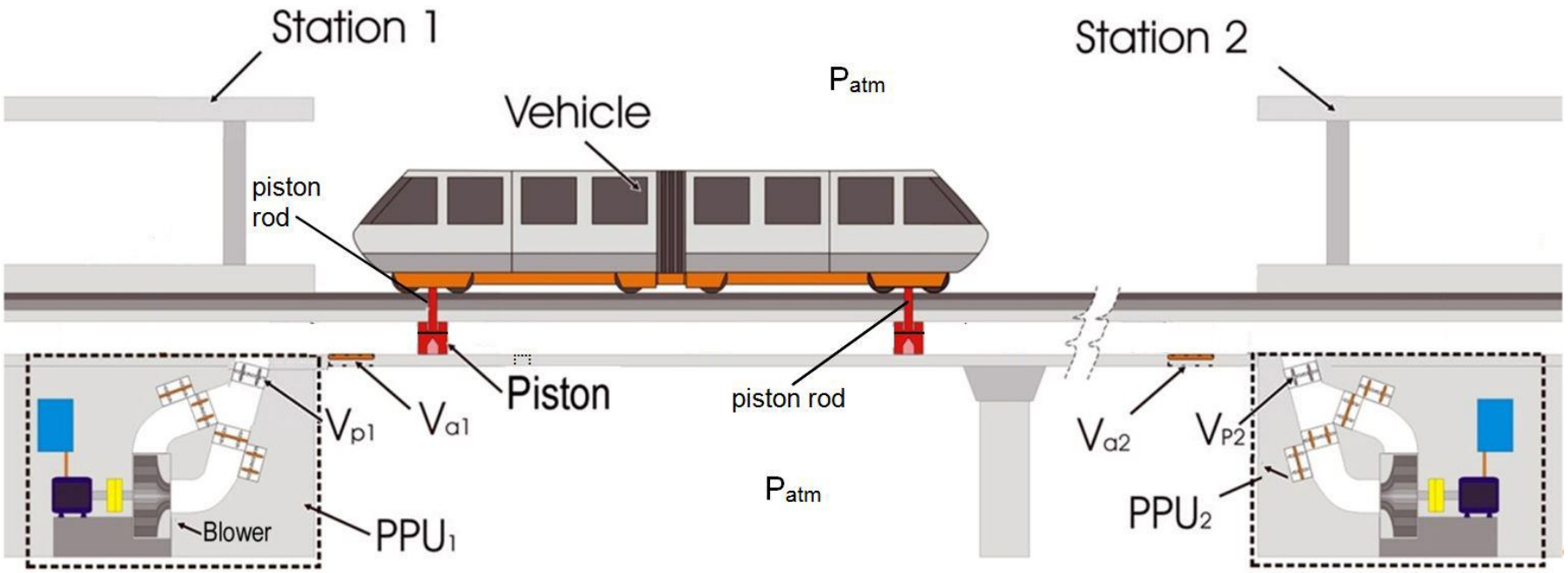
Power train group: pull from left

Propulsion blocks



Vehicle control based on independent propulsion blocks

Propulsion concept



Main charecteristics

a) Innovative technology invented and developed in Brazil

b) Local supply chain

c) *commercial off-the-shelf* industrial equipments

d) Simplicity

e) Substantially low capital costs

f) Easy and fast construction based on prefabricated concrete modules

g) Elevated guideway with very light weight and low visual impact

h) Emergency exit using the guideway itself, without need for extra structures

i) Low energy consumption due to its light weight vehicles

j) Ecofriendly

k) No need for costly third rails to power up the vehicles

l) Short headways, compact stations

m) Operantion on sharp curves (25m) and steep grades (up to 12%).

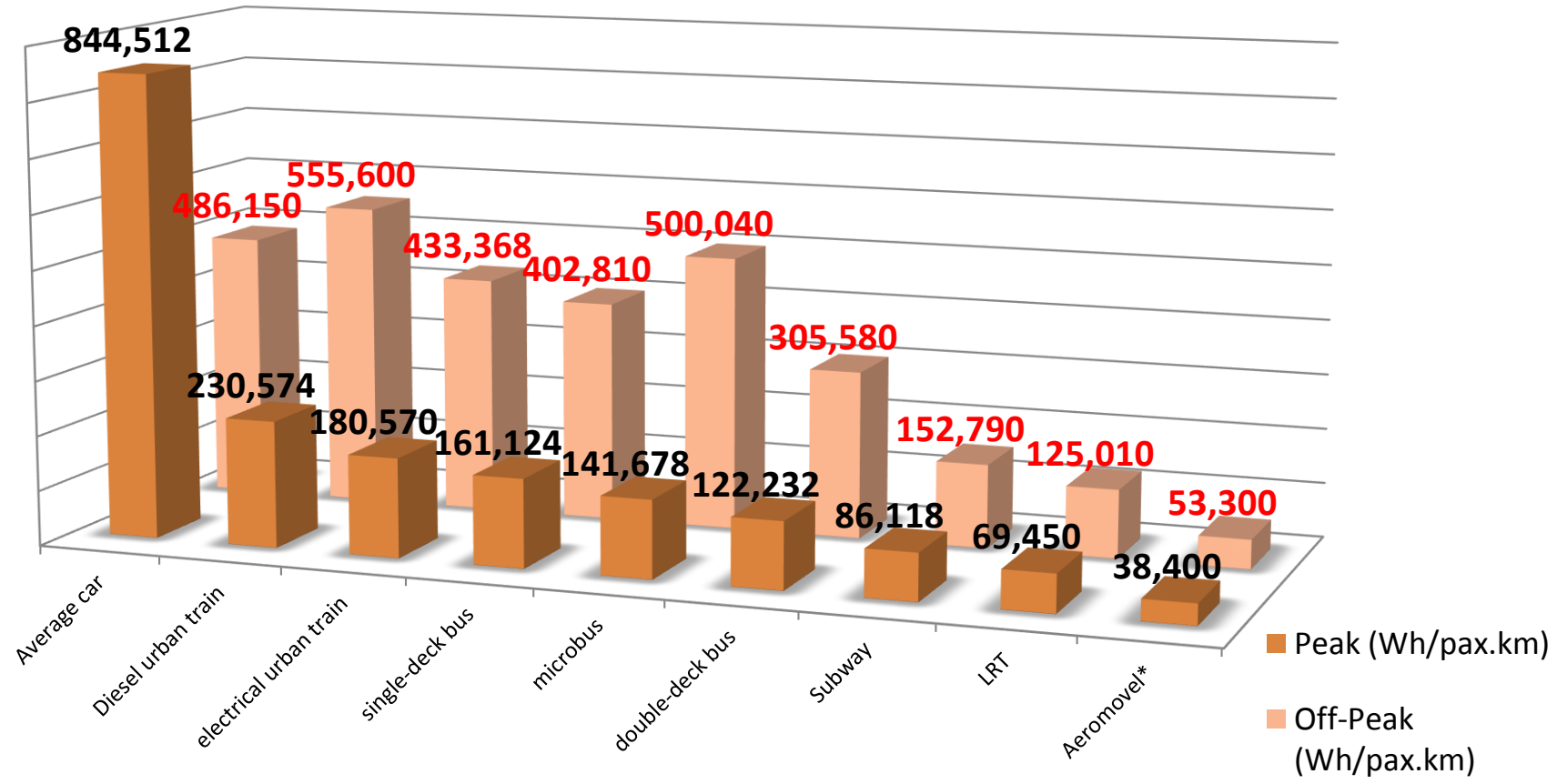
n) High redundant propulsion system that makes it very dependable

o) Derailment is prevented by the propulsion plate that locks the vehicle onto the guideway

p) Intrinsecally safe against collisions due to the air buffer compressed between two vehicles

q) Double braking system (pneumatic and onboard friction brakes)

Energy consumption



Fonte: *VUCHIC*, 2007 - Urban Transit Systems and Technology
***** *FUNDATEC-UFRGS*, 1984 - Projeto Aeromovel - Análise do Sistema de Propulsão (Contrato EBTU/COESTER/FUNDATEC/IPT)

Technical data:

Line range	1.600 mm
Maximum speed	•80 km/h (urban applications)
Control system	ATO/ATP/ATS (fully automated)
Signaling	CBTC - Communications-based train control
Transportation capacity	25.000 passengers per hour per direction

Applications

Porto Alegre Pilot Line

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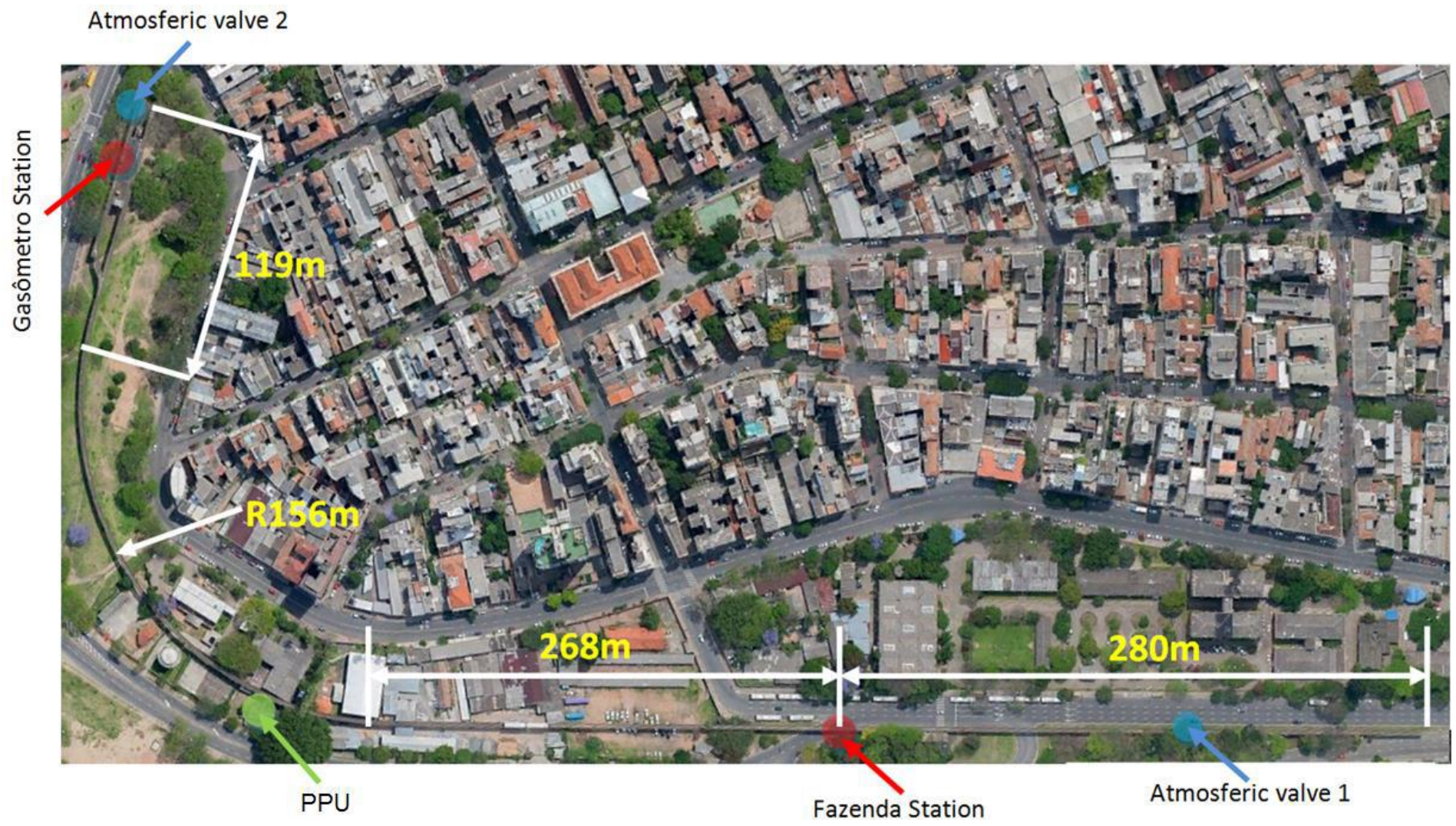
Porto Alegre Pilot Line



Technical data

Openning	04/10/1983
Location	Porto Alegre downtown (public area)
Status	Private line for test and demonstration
Extension	1.067,1m (single and dual track)
Maximum grade	5%
Number of stations	02
Vehicle	One vehicle for 288 pass
Maximum speed	65 km/h
Line capacity	12.986 pphpd
Propulsion	01 Power Propulsion Unit of 260kW

Jakarta, Indonesia

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Jakarta, Indonesia

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Technical data

Openning	04/20/1989
Location	*Taman Mini Indonesia Indah*, Jakarta, Indonesia
Status	Private line in revenue operation
Extension	3.135 m (single track loop)
Beams	142
Minimum radius	25,2m
Maximum grade	9,63%
Number of stations	06
Vehicle	three vehicles for 288 passangers each
Propulsion	05 Power Propulsion Units of 110kW
Maximum designed speed	70 km/h
Number of employees (2009)	34
Energy consumption (1994)	2,93 kWh/vehicle-km
Operational cost (2009)	US$ 107.000,00 (year)

Porto Alegre Airport Line

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Techincal data

Openning	08/10/2013
Location	Salgado Filho International Airport
Status	Public line in revenue operation
Extension	1.011m
Minimum radius	35m
Maximum grade	3,0%
Guideway Switch Device	Radius 30m
Vehicle	One 150-pass vehicle and one 300-pass vehicle
Maximum designed speed	65 km/h
Transportation capacity	4.857 pphpd (shuttle service)
Propulsion	02 redundant Power Propulsion Units of 300kW

Airport Line - Construction

Airport Line - Construction

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Airport Line - Vehicle

Airport Line – Dual track

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Airport Line - Guideway

Airport Line - Station

Airport Line - Vehicle

Airport Line - Vehicle

Airport Line - Vehicle

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Airport Line - Vehicle

Airport Line - Vehicle

LAMECC – UFRGS – DEMEC- PROMEC

Laboratório de Mecatrônica e Controle

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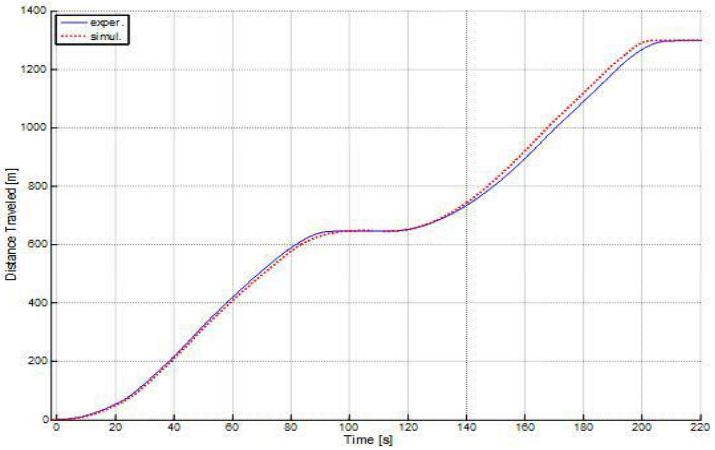
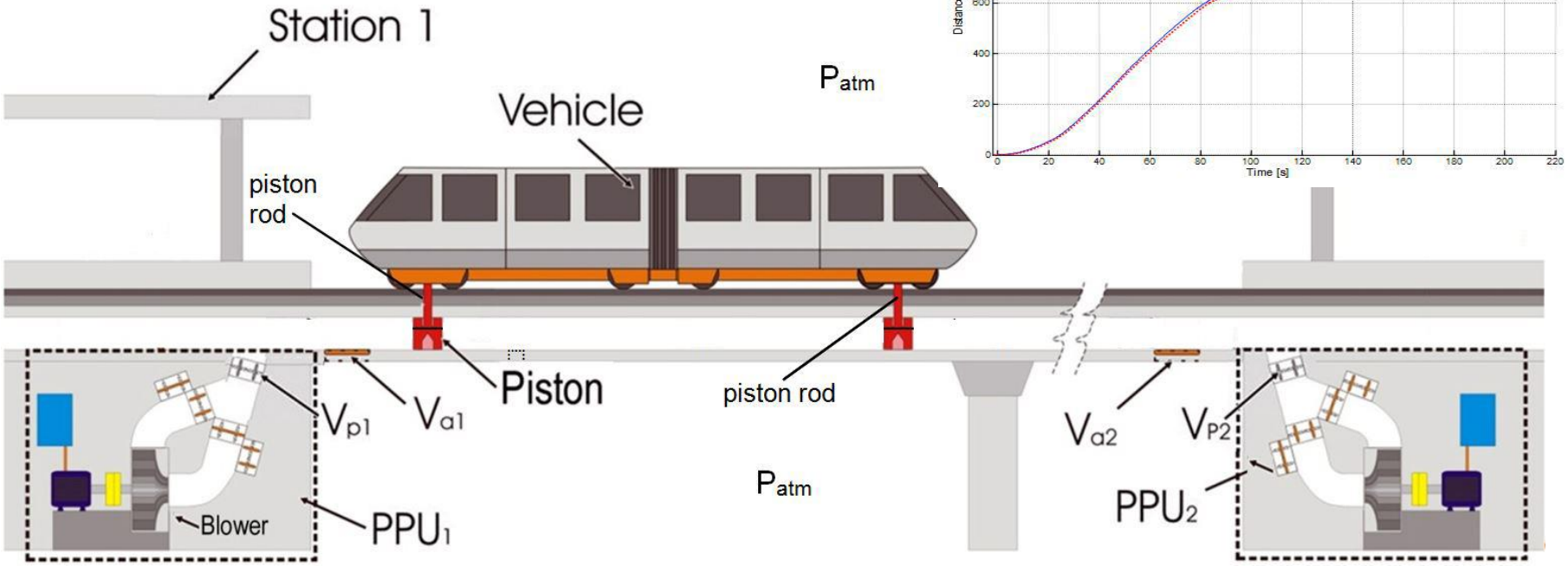
LAMECC – Campus Central da UFGRS – Porto Alegre – RS – Av. Sarmento Leite, 425 sala 204

Laboratório de Mecatrônica e Controle

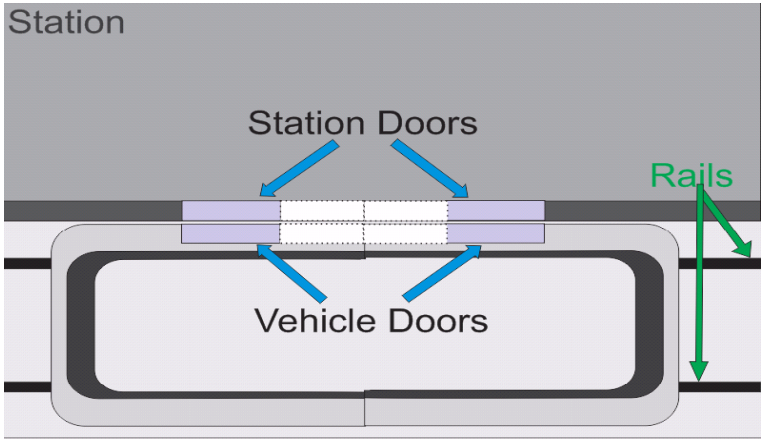
Research: Physical System Modelling

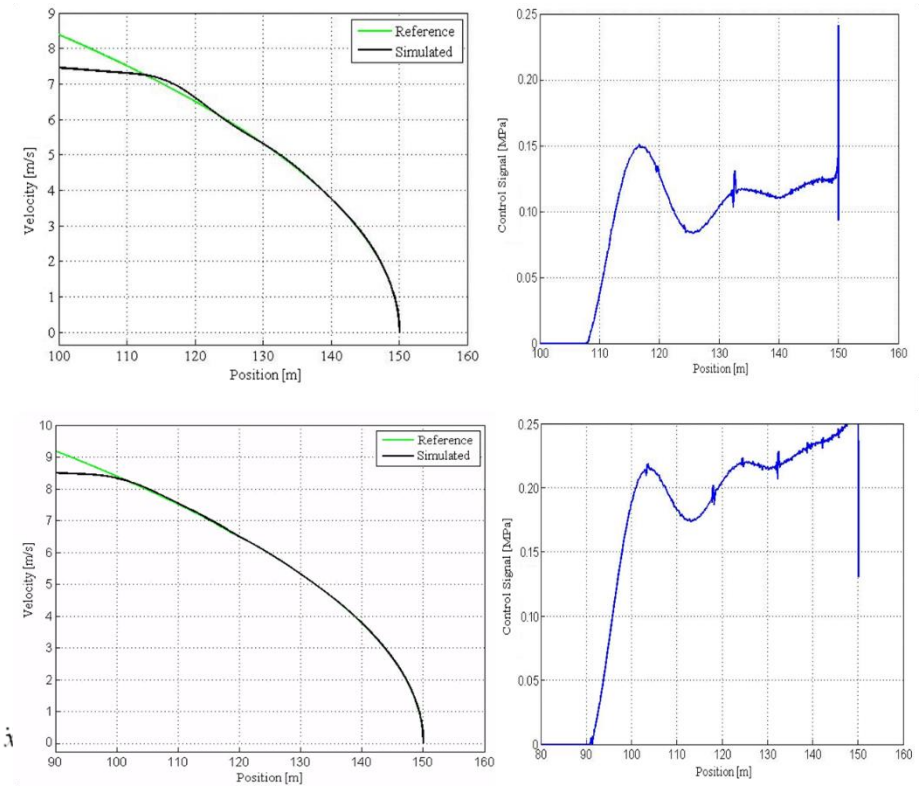
- Dynamics modelling and computational simulation

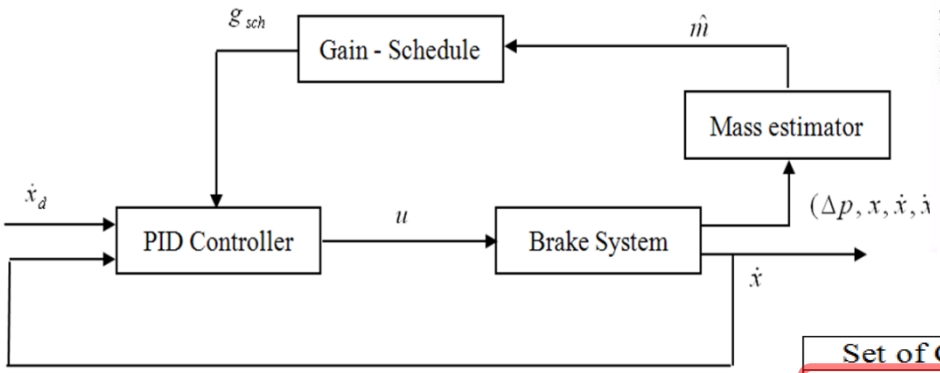




Research: Precise Braking Control





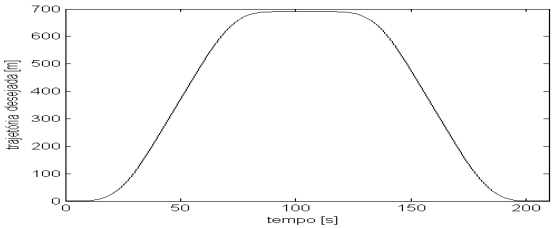


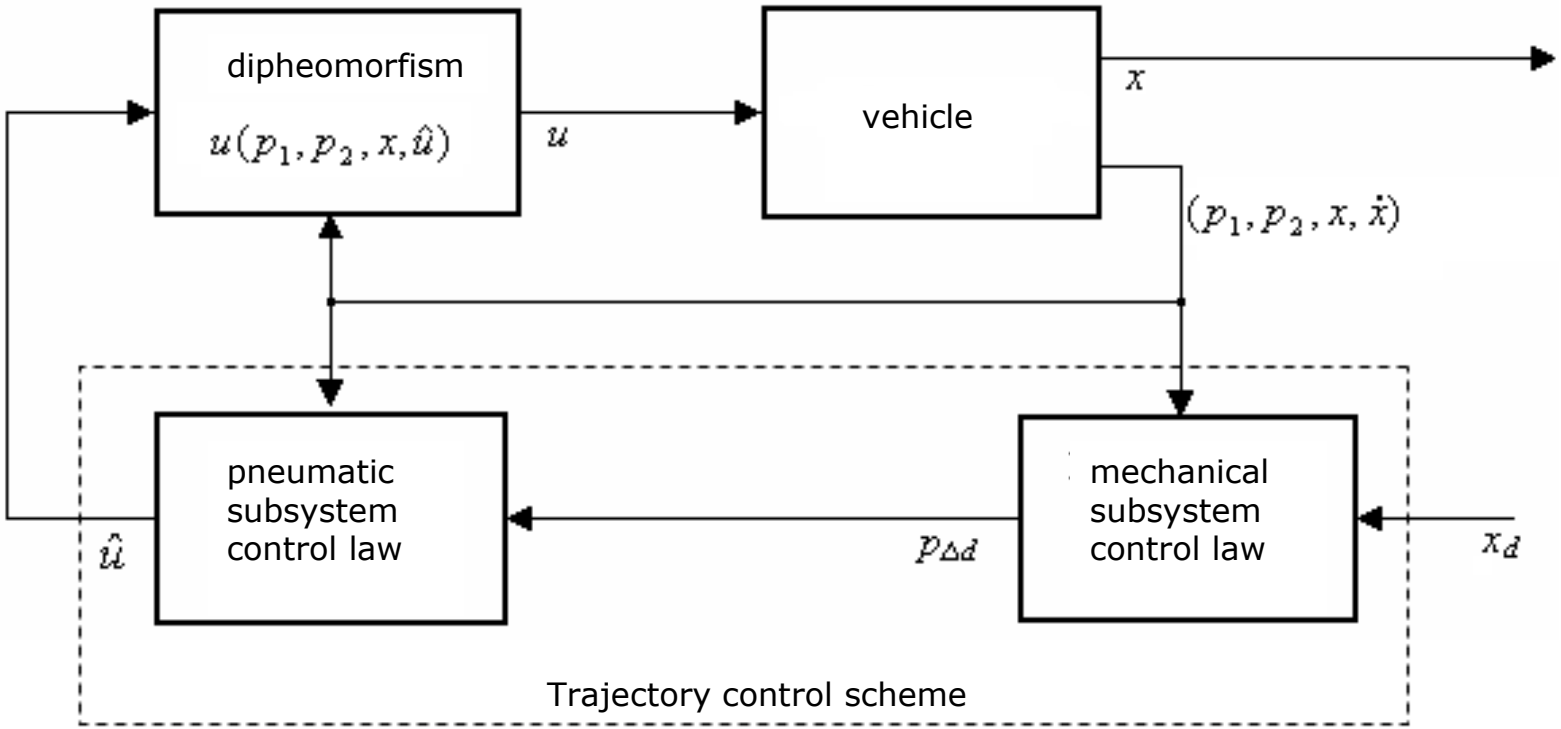
Complete control system

Set of Gain	Nominal Mass (kg)	K_p	T_i	T_d	T_{tc}
1st	7735	3,8169	3,4509	0,8627	1,7254
2nd	9610	4,8433	3,4274	0,8569	1,7137
3th	11485	5,6357	3,4985	0,8746	1,7492
4th	13360	6,7315	3,6271	0,9068	1,8136

Research: Vehicle control

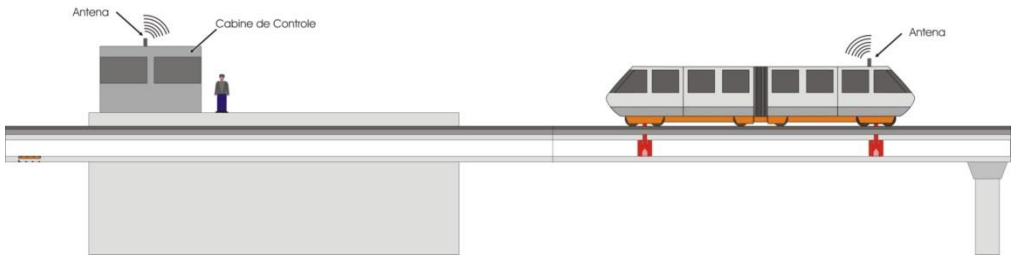
- Control strategy

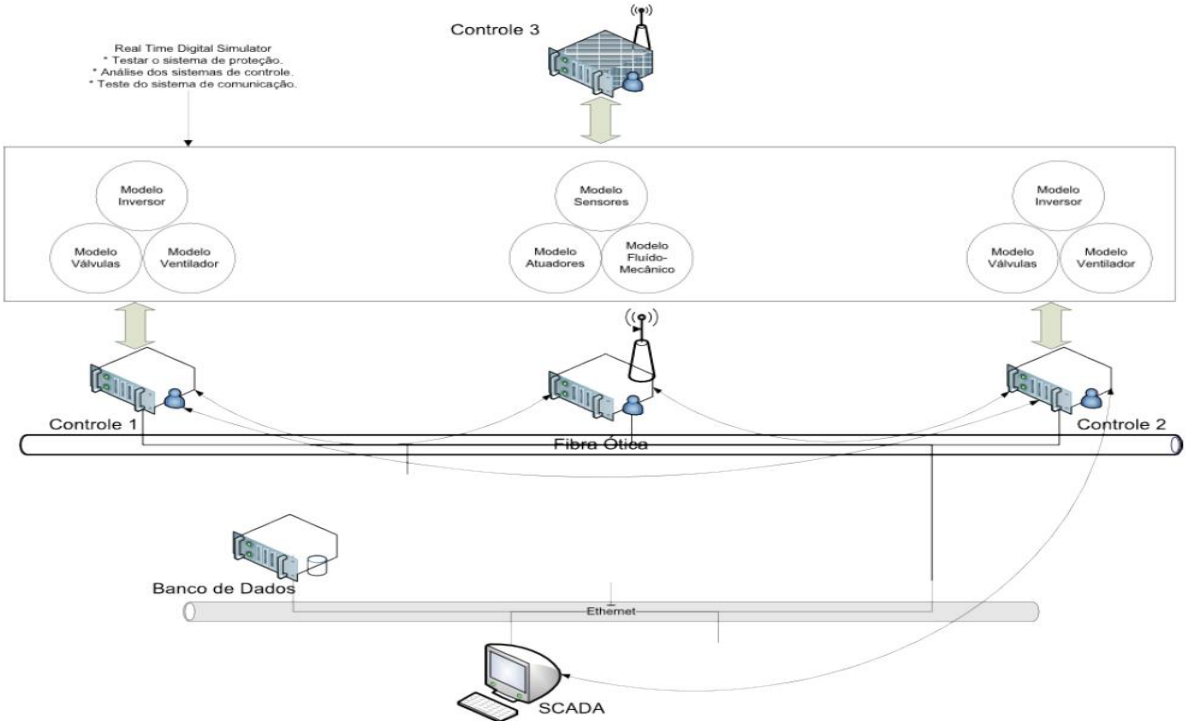




Research - Comunication

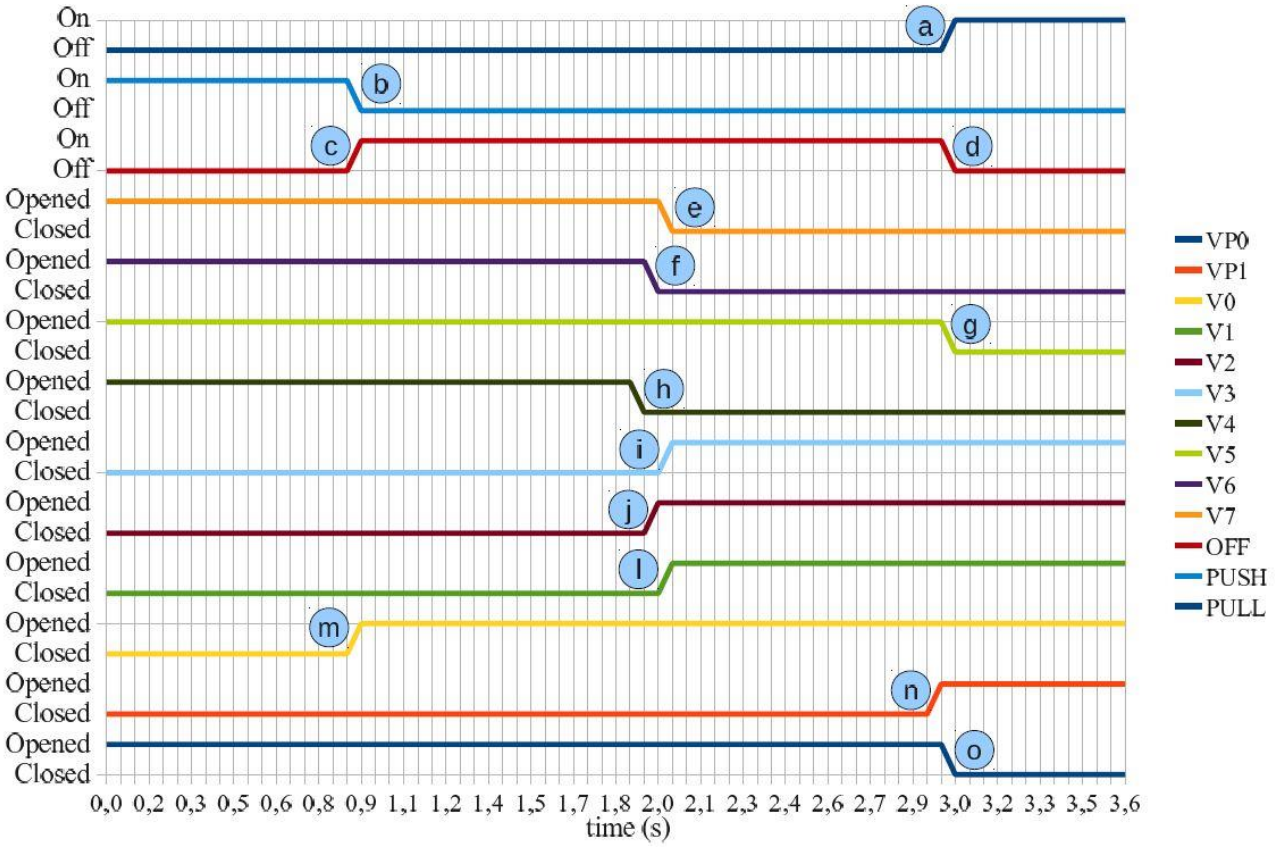
- Data interchanging among station, power unit and vehicle.





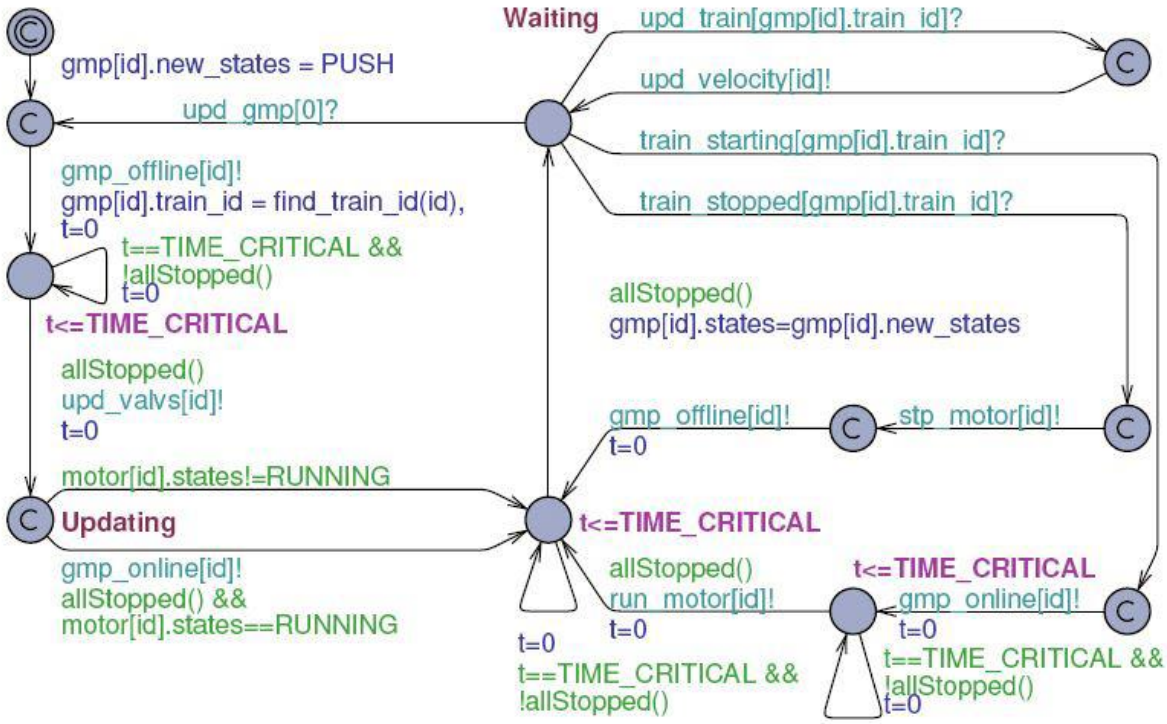
Research – Automatic Train Control

- Power system discrete control



Research – Command System discrete modelling and analysis

- Simulation, formal verification and conformance testing.



Propulsion System Controller Model

Research – technical and academic publications

- BRITTO, João Francisco Fleck Heck, PERONDI, E. A., SOBCZYK S., Mário Roland ***Dynamic Model of a Pneumatic Automatic People Mover (Aeromovel System)***. International Journal of Fluid Power. , v.15
- KUNZ, Guilherme, PERONDI, E. A., MACHADO, J. ***A Dependable Automated People Mover System Modeled and Verified using Timed Automata: A Case Study*** In: 21st International Congress of Mechanical Engineering, 2011, NATAL-RN-BRAZIL.
- CARVALHO, C. A., PERONDI, E. A., SOBCZYK S., Mário Roland ***Gain-Schedule Control Based on Mass Estimation Applied to the Braking System of an Urban Automated People Mover*** In: 21st Brazilian Congress of Mechanical Engineering, 2011, NATAL-RN.
- KUNZ, Guilherme de Oliveira, PERONDI, E. A., MACHADO, J. M. ***Modeling and Simulating the controller behavior of an Automated People Mover using IEC 61850 Communication Requirements*** In: 9th International Conference on Industrial Informatics (INDIN), 2011, Lisboa - Portugal.- 2011 IEEE 9th International Conference on Industrial Informatics. Lisboa - Pt: IEEE, 2011. v.1.
- KUNZ, Guilherme de Oliveira, MACHADO, J. M., PERONDI, E. A. ***Modeling And Simulation of IEC 61850 Requirements Applied to an Automated People Movers Controller*** In: International Conference on Informatics in Control, Automation and Robotics (ICINCO), 2011, Noordwijkerhout - Netherland. 8th International Conference on Informatics in Control, Automation and Robotics. Noordwijkerhout: ICINCO, 2011. v.1.
- CARVALHO, C. A., PERONDI, E. A., SOBCZYK S., Mário Roland, ***Aplicação de um Algoritmo Recursivo de Estimativa de Massa a um Sistema Automático de Transporte Urbano*** In: CONEM 2010, 2010, Campina Grande - PB.
- SOBCZYK S., Mário Roland, BRITTO, João Francisco Fleck Heck, PERONDI, E. A. ***Cascade Nonlinear Control of Pneumatic Actuators Applied to the Aeromovel Transport System*** In: 5th PhD Symposium of the Fluid Power Net International, 2008, 2008, Cracóvia. Proceedings of the 5th PhD Symposium of the Fluid Power Net International, 2008. Cracow University of Technolog: Fluid Power Net International, 2008. v.1.
- PERONDI, E. A., SOBCZYK S., Mário Roland, BRITTO, João Francisco Fleck Heck, ***Controle em Cascata e a Estrutura Variável Aplicado ao Seguimento de Trajetória de Um Trem Urbano Movido a Ar (Sistema Aeromovel)*** In: Congresso Brasileiro de Automatica, 2008, Juiz de Fora. Anais do XVII Congresso Brasileiro de Automatica. Porto Alegre: SBA, 2008. v.1.
- SOBCZYK S., Mário Roland, PERONDI, E. A., BRITTO, João Francisco Fleck Heck, ***Nonlinear Cascade Control Applied to a Pneumatic Urban Transport System*** In: In: 8th Portuguese Conference on Automatic Control CONTROLO 2008, 2008, Vila Real - Portugal. Proceedings fo the 8th Portuguese Conference on Automatic Control CONTROLO 2008. Vila Real - Portugal: University of Trás-os-Montes and Alto Douro, 2008. v.1. p.155 - 160
- **TESE DE DOUTORADO** - Guilherme de Oliveira Kunz. **Metodologia para desenvolvimento de sistemas de controle de APM (Automated People Movers) com aplicação ao sistema Aeromovel de transporte de passageiros.** 2012. Tese (Programa de Pós Graduação em Engenharia Mecânica) - Universidade Federal do Rio Grande do Sul
- **DISSERTAÇÃO DE MESTRADO** - Carlos Arthur Carvalho Sarmanho Junior. ***Aplicação do Algoritmo de Gain Schedule Baseado na Estimativa de Massa no Controle do Sistema de Freios do Sistema AEROMÓVEL***. 2009. Dissertação (Engenharia Mecânica) - Universidade Federal do Rio Grande do Sul
- **DISSERTAÇÃO DE MESTRADO** - João Francisco Fleck Heck Britto. ***Modelagem dinâmica do sistema Aeromóvel de transportes***. 2008. Dissertação (Engenharia Mecânica) - Universidade Federal do Rio Grande do Sul
- **TESE DE DOUTORADO** – Serguei Nogueira da Silva. **Análise da Sustentabilidade e Eficiência de Sistemas de Transporte Urbano por Meio de Ferramentas Termodinâmicas.** 2013. Tese (Programa de Pós Graduação em Engenharia Mecânica) - Universidade Federal do Rio Grande do Sul