POLITECNICO DI MILANO

DIPARTIMENTO DI ELETTRONICA, INFORMAZIONE E BIOINGEGNERIA

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e-Bikes: present and future of high-tech solutions

INTERNATIONAL LI-ION E-BIKE INDUSTRY SUMMIT

Shanghai, China, April 13th, 2014

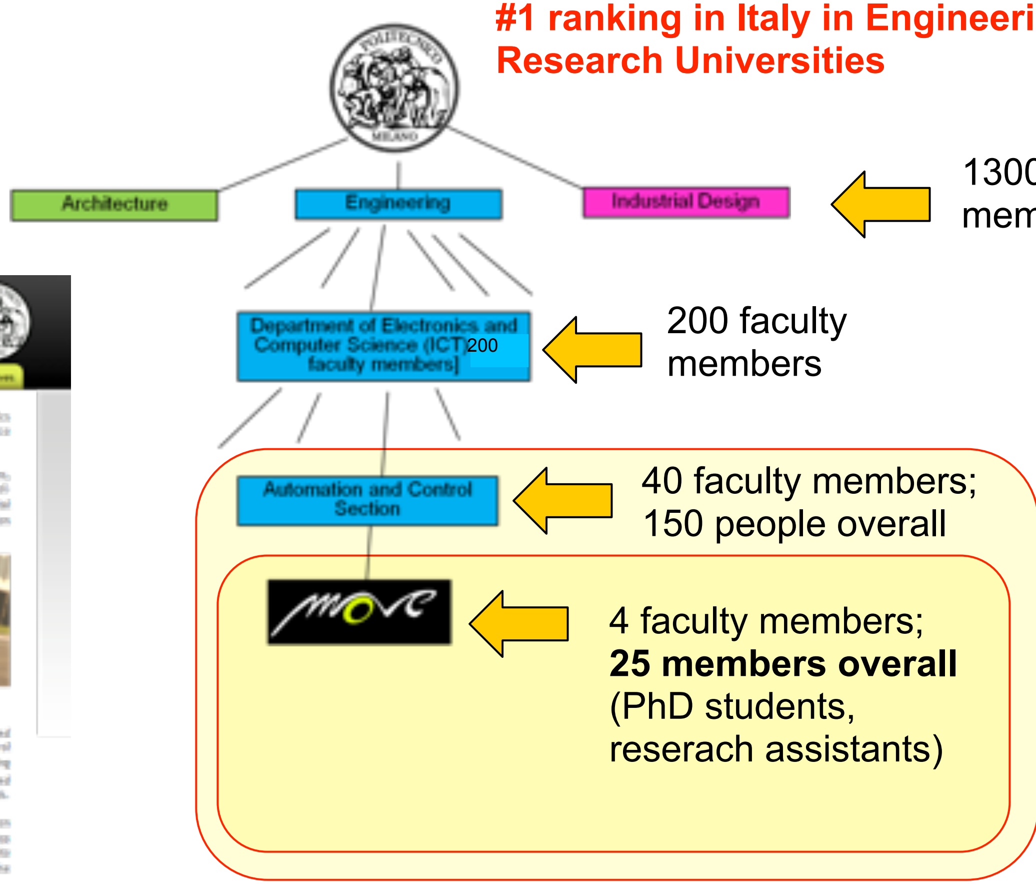
Prof. Sergio M. Savaresi
sergio.savaresi@polimi.it
http://move.dei.polimi.it/

Time-slot: 20 minutes

Introduction: speaker presentation

The “mOve” research group

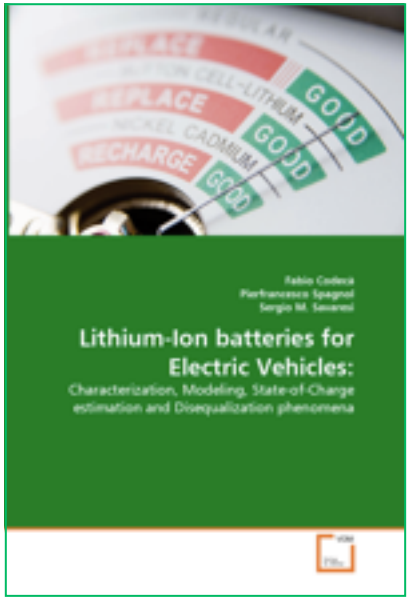
#1 ranking in Italy in Engineering Research Universities



One of the biggest EU acedemic research group focused on vehicle control

http://move.dei.polimi.it

Technology-Transfer examples: small electric vehicles



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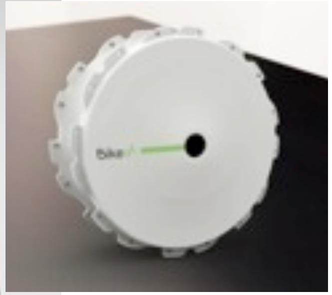


spin off®
POLITECNICO DI MILANO

ZEHUS
Zero Emission Human Synergy

Basic research (book, papers) → **R&D Industrial cooperations** → **Spin-off company**

E-Bikes: classification, with a glance on the future

Lesson learnt from cars…

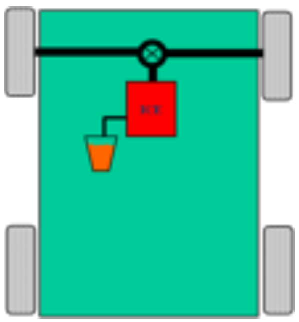
ICE (classic)

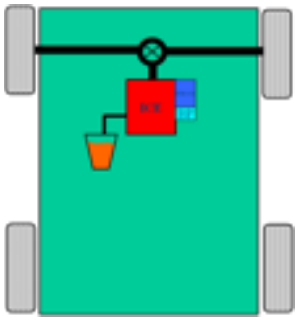
Parallel Hybrid

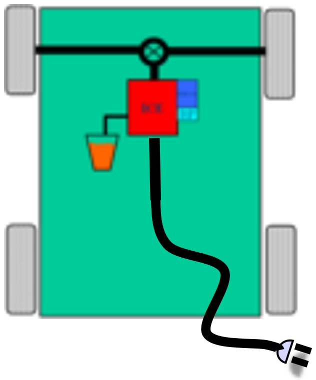
Parallel Hybrid
Plug-IN

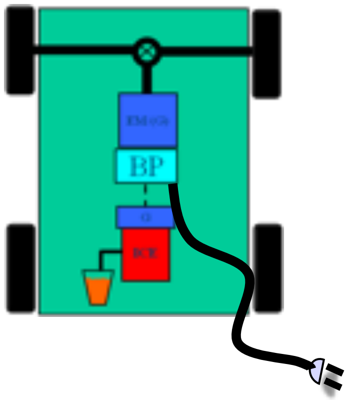
Serial Hybrid
Plug-IN

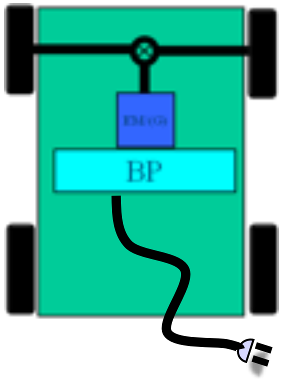
Electric
Plug-IN











Internal Combustion Engine (ICE)

Carbon-based-(fossil) fuel

Electric machine (motor/generator)

Battery-pack

Internal Combustion Engines (ICE)…

Carbon-based (fossil) fuel

Food

Oxygen

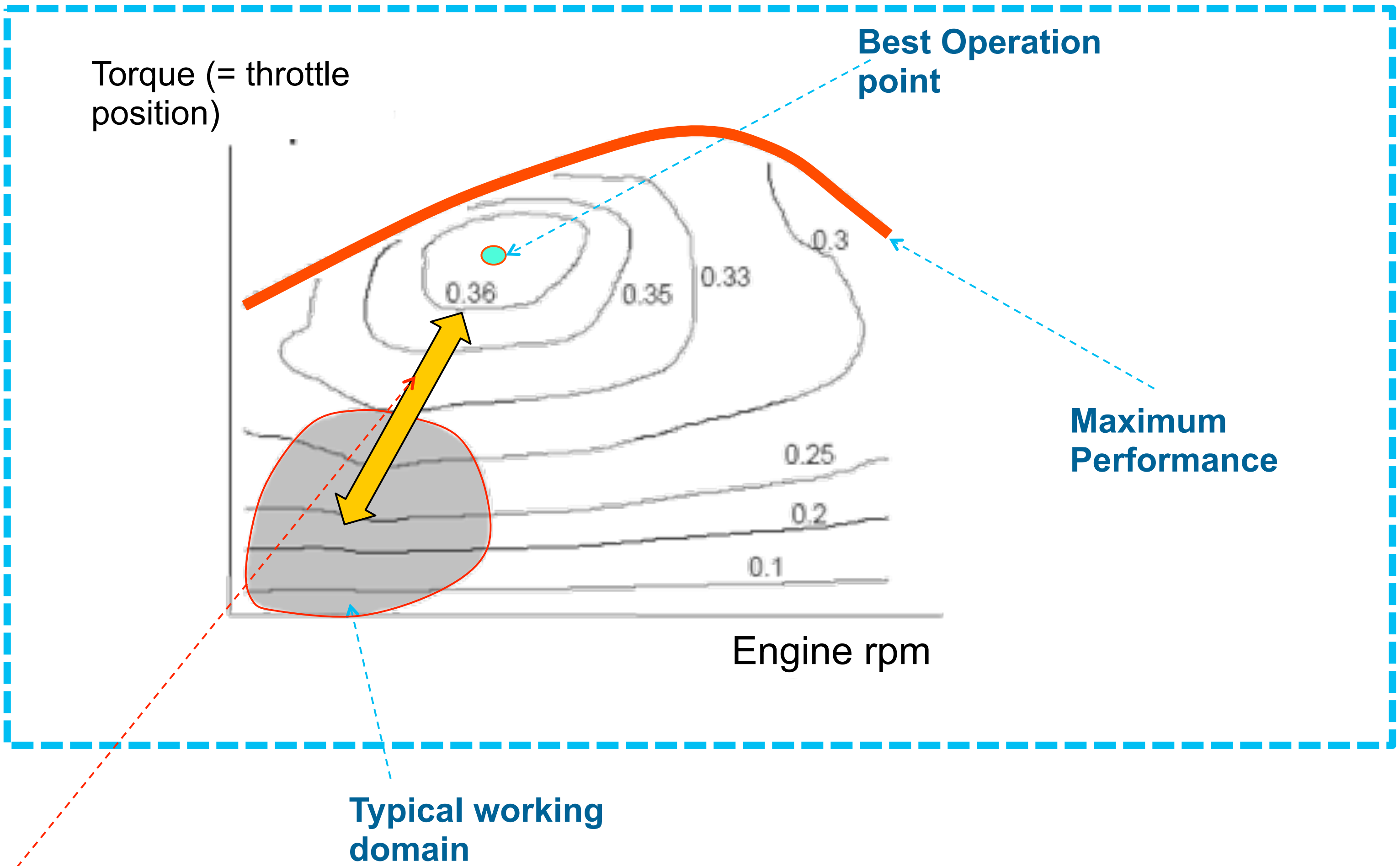
«Hot» combustion

«Cold» combustion

Mechanical power

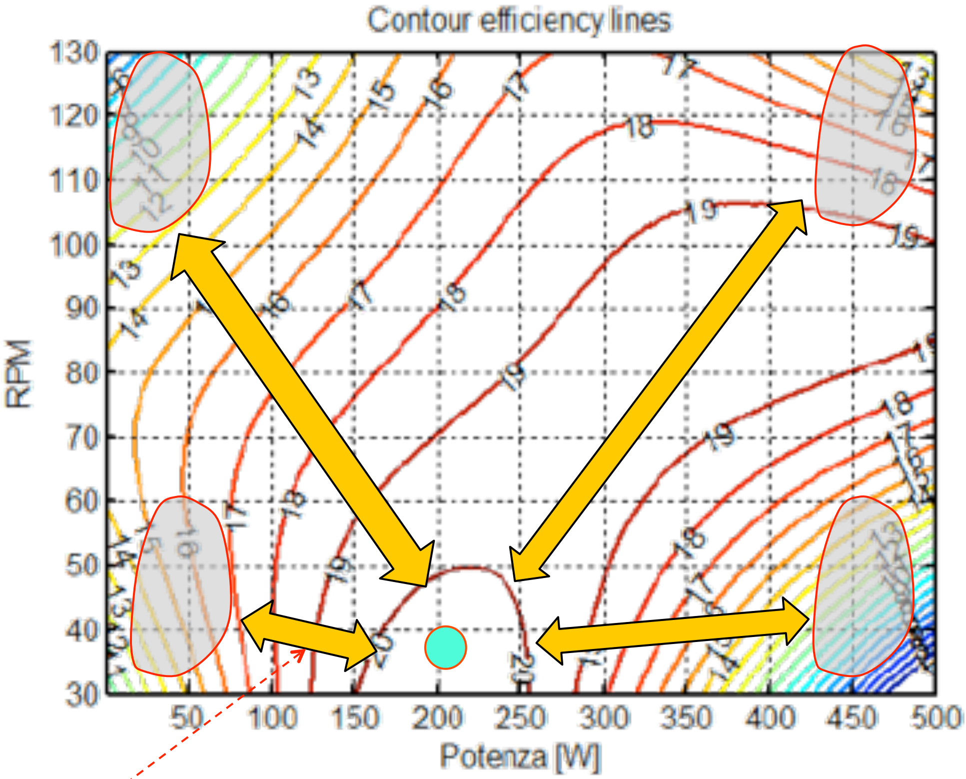
Mechanical power

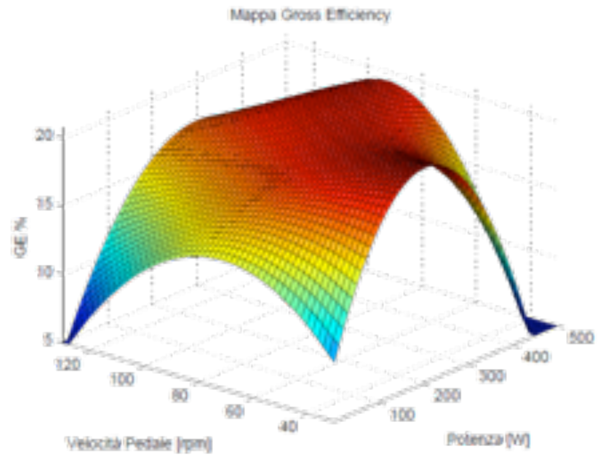
Internal Combustion Engine



Large efficiency GAP

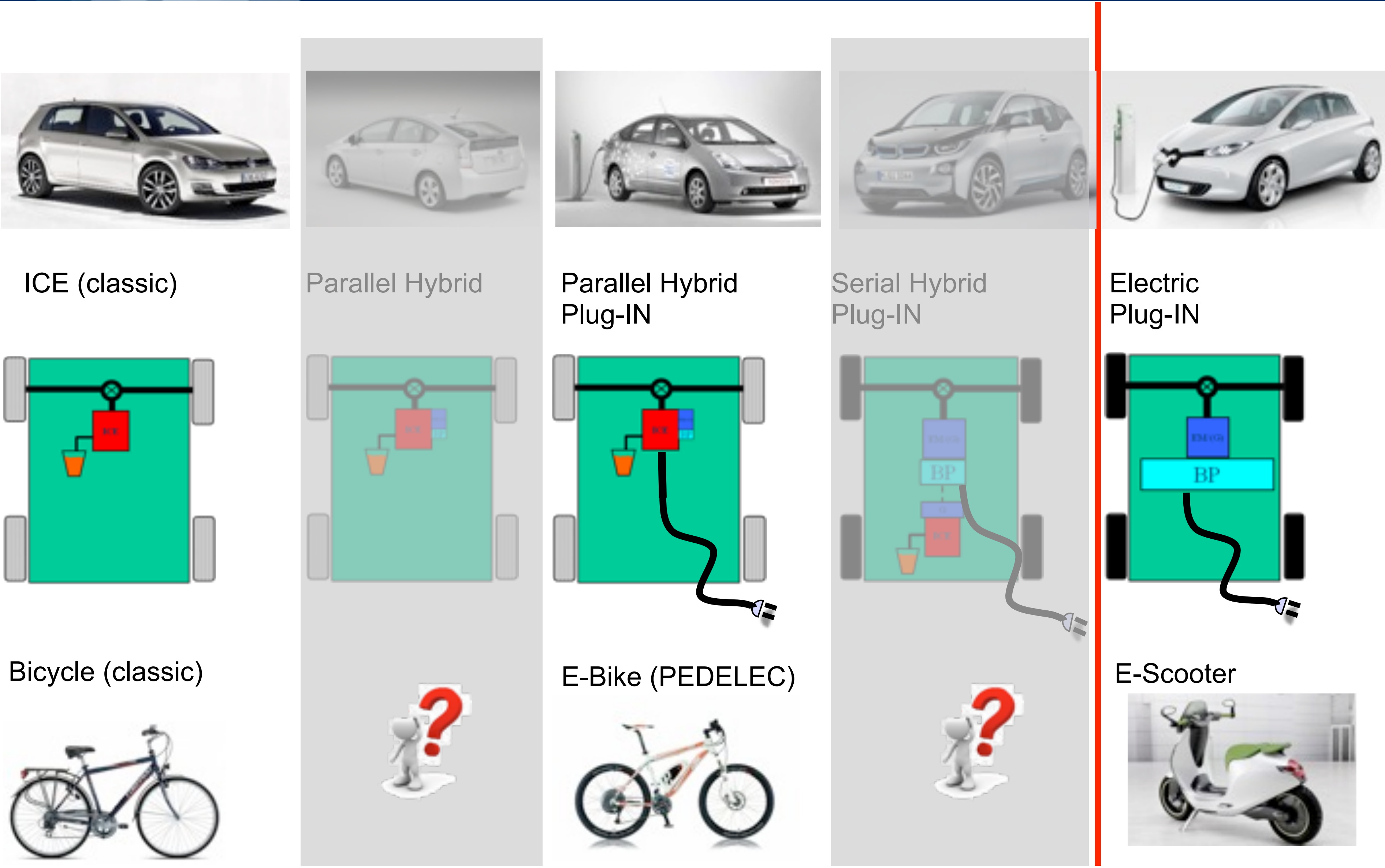
«HUMAN» Internal Combustion Engine





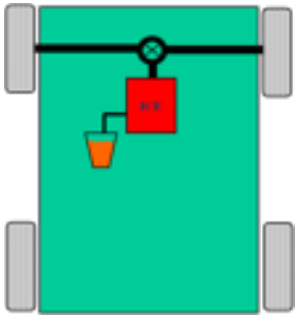
Very similar: large efficiency GAPs

New «pedal-assisted» segmentation: learn form cars…



ONLY Internal Combustion Engine (ICE) vehicle

ICE (classic)



Bicycle (classic)

Simple and classical architecture

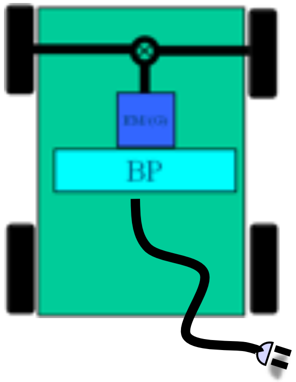
Light/cheap

Easy to use

Low-efficiency (fatigue and anaerobic power-peaks for the bike,…)

All-electric vehicle

Electric
Plug-IN



E-Scooter

Simple and classical architecture

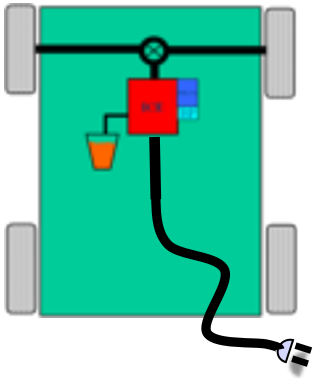
High-efficiency

Limited-range (range anxiety)

Slow-refueling

Weight/Cost of battery-pack

Parallel-hybrid PLUG-IN vehicle



Parallel Hybrid
Plug-IN

E-Bike (PEDELEC)

Higher efficiency (than ICE-only)

Possibility to use electric-energy from the grid

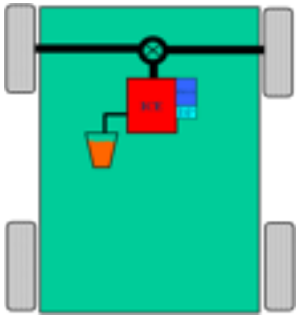
Weight/Cost of battery-pack

Limited-range with electric assistance (eBike)

Remark: slightly different architectures: PEDELEC, when battery empty, becomes a classical bike (no efficiency improvement)

Parallel-hybrid vehicle (NOT plug-in)

Parallel Hybrid

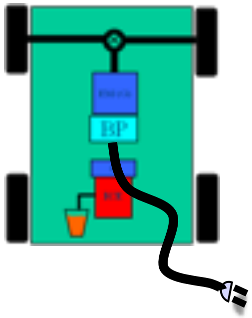


- Higher efficiency (than ICE)
- Completely grid-independent
- Light-cheap (small battery)
- Easy (no recharge from grid)

Cannot use electric energy from the grid

Lower help/assistance than a classical parallel-plug-in eBike

Serial-hybrid vehicle (EV with Range extender)



Serial Hybrid
Plug-IN

All the benefits of an electric vehicle

Maximum flexibility of ICE/human-power management

Battery-pack can be lighter and cheaper than an EV

No range-anxiety

Space-requirements (2 electric machines on board)

The «missing products» - examples

Example (first, only) of Parallel Hybrid (not-plug-in): ZEHUS «Bike+»

What is «Bike+»?

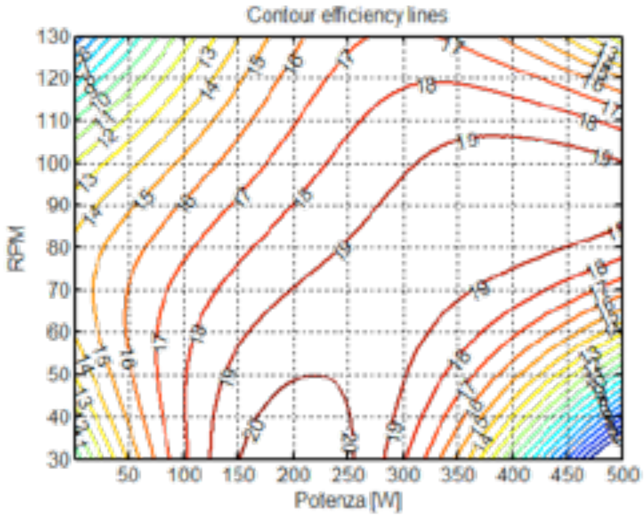
A NEW type of vehicle that:

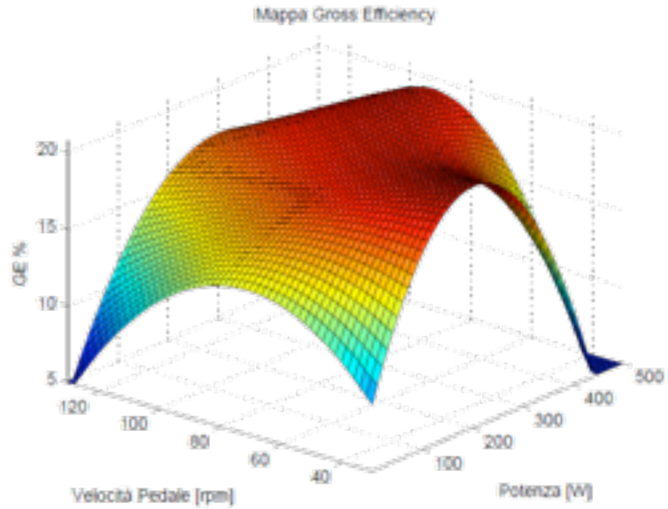
- Is USED exactly like a bicycle
  - Never needs recharging
  - Very light
  - Switches on automatically
  - Switches off automatically
  - No user interface

- Reduces the cyclist fatigue
  - by better managing his/her energy
  - Using a sophisticated and «smart» power-pack (electric motor, sensors, batteries, electronics, SW,…)

How does (can) it work?

- **Human body has large efficiency gaps, similarly to an Internal Combustion Engine**





- **Using these efficiency gaps, energy can be optimizied using an electric energy buffer and sophisticated control algorithms**

- **Bike+ is the first example of optimized electric-human synergy**

The benefit has been scientifically PROVEN

- Testing protocol (on a flat cycling track)

Normal bicycle

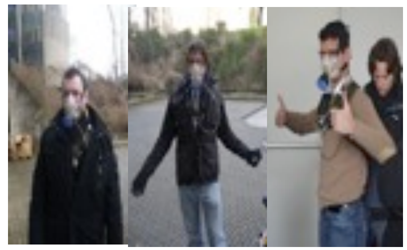
Accumulated fatigue

Intial SOC: 70% → **Final SOC: 70.5%**

Bike+

Constant fatigue

Time [s]



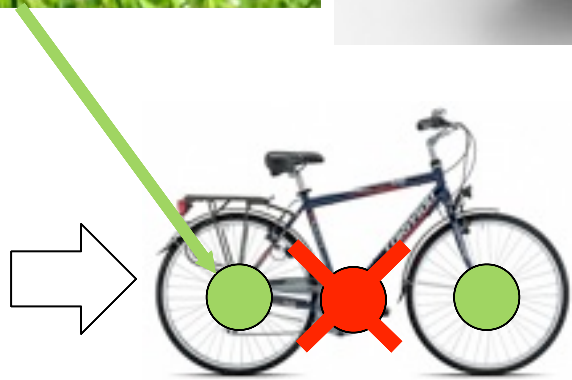
Fatigue reduction: up to <u>+30-40%</u>

Bike+ in a PRODUCT

An **all-in-wheel rear-hub** solution that integrates Bike+ technology

Technical remark: Bike+ concept requires:

- Energy recuperation from **braking**
- Energy recuperation in **downhill slope**
- Energy generation from **pedaling**



Not (easily) feasible with central-motor layout

Who can be interested?

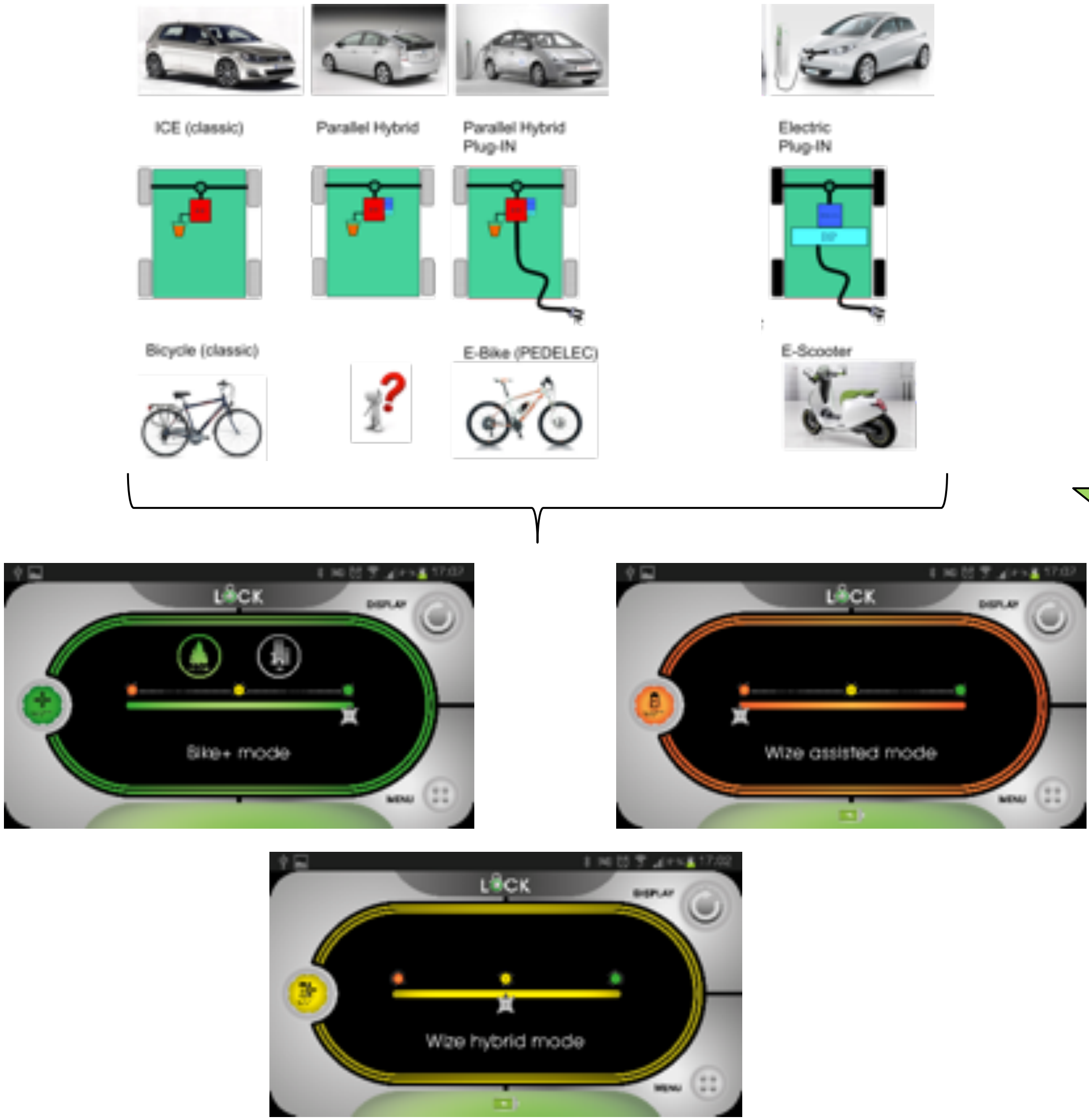
Private users who:

- like the lightness and simplicity of a bycycle
- like having assistance in hard situations

Bike-sharing initiatives that:

- have already an infrastructure for bike-sharing
- would like to upgrade to pedal-assisted vehicles WITHOUT changing the infrastructure

Remark on ZEHUS Bike+: «4-in-1»



ZEHUS «Bike+» covers a wider spectrum of modes and architectures:

- Classic bike (when off, with a negligible weigth increment and aesthetic modification)
- Parallel-hybrid not-plugin (in «Bike+mode»
- Parallel hybrid Plug-in (with human-synergy optimization and different levels of assistance and range)
- Full-assistance (almost electric)

Example of Serial Hybrid, plug-in:

«SENZA»

Serial-hybrid: two products

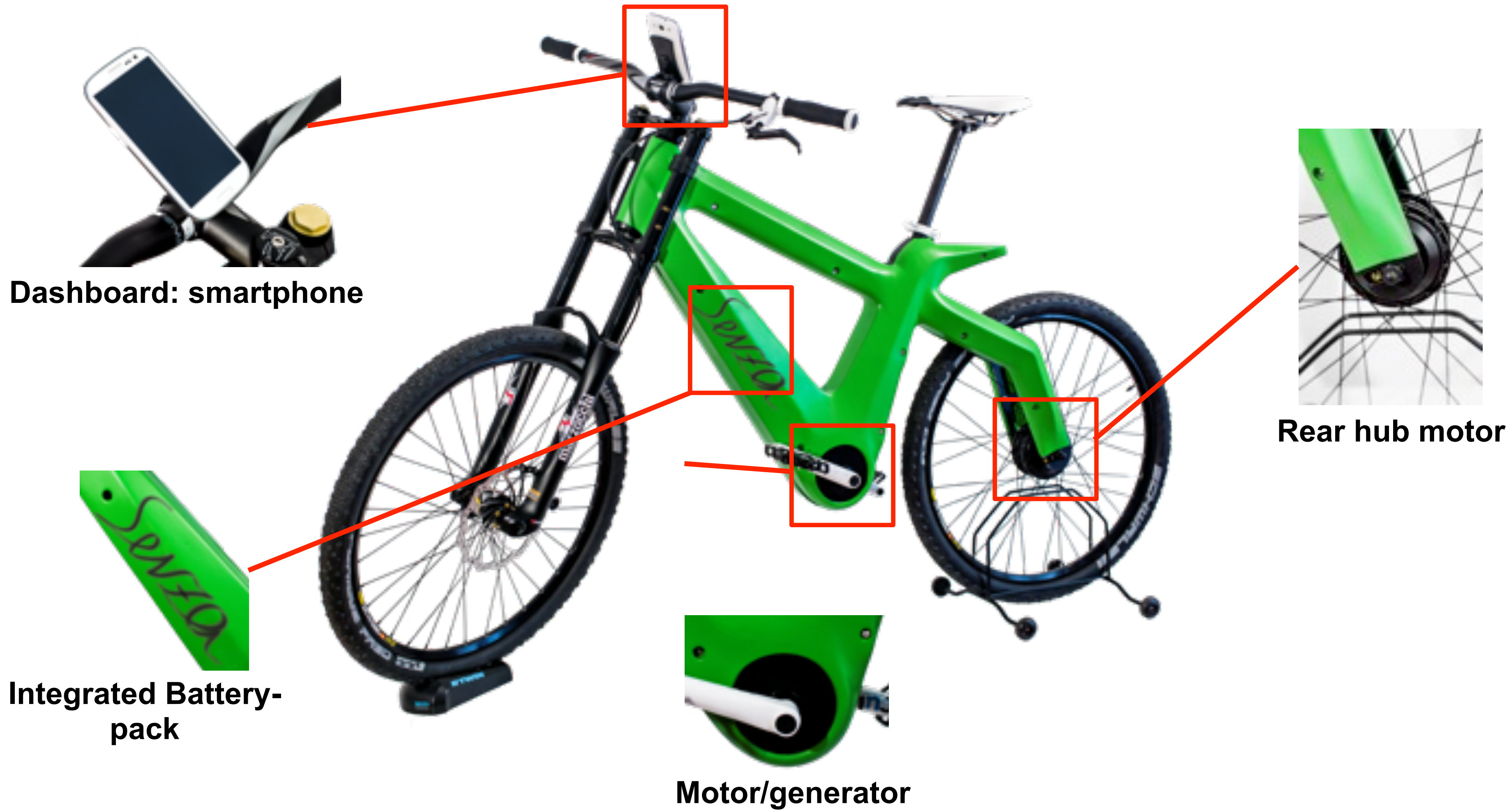
MANDO «footloose»
In production

Emphasis on: folding features

ZEHUS «senza»
Start Of Production : 2015

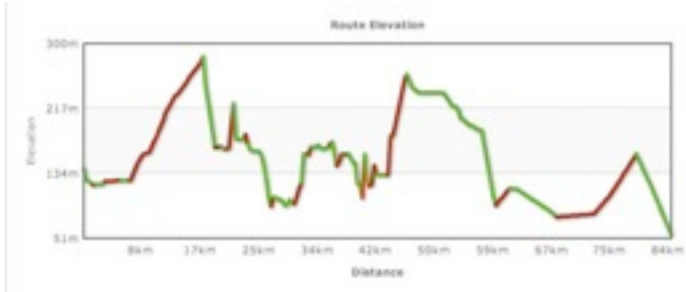
Emphasis on: human-synergy

SENZA: main elements



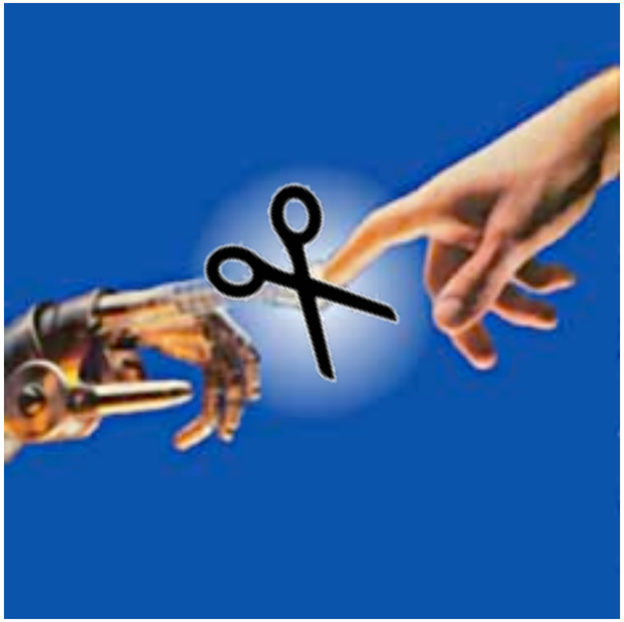
Plug-in serial Hybrid - Opportunity: effort and vehicle-dynamics decoupling

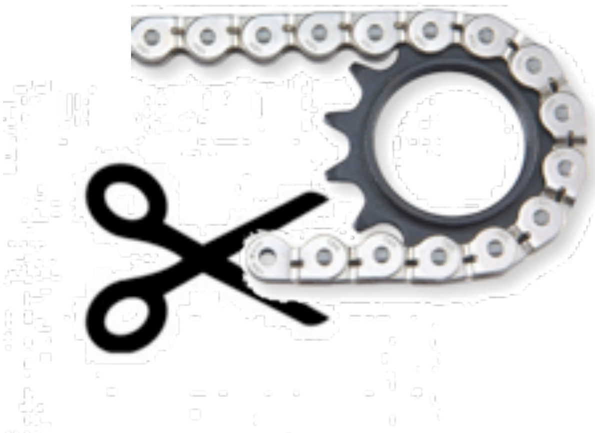
Human effort – Fatigue – Heart-beat profile



Road profile and vehicle dynamics (slopes, speed, accelerations, etc.)

Plug-in serial Hybrid - Challenge (threat): Human-Machine-Interface





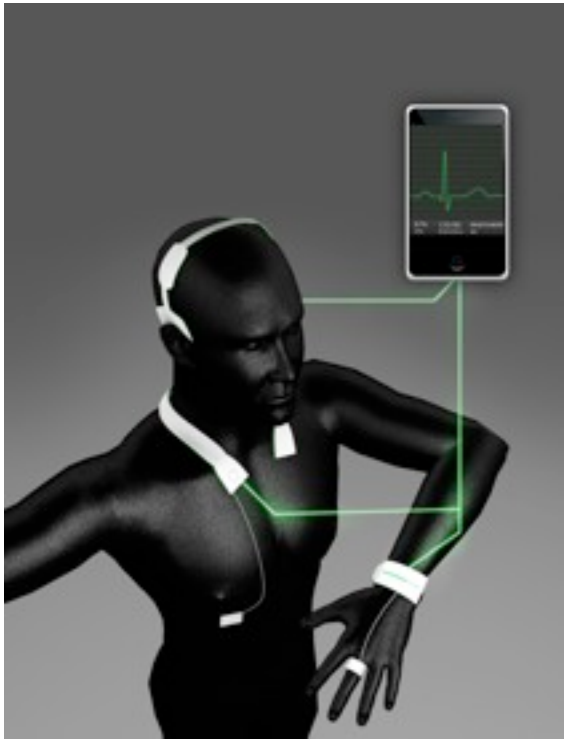
Conection is LOST!

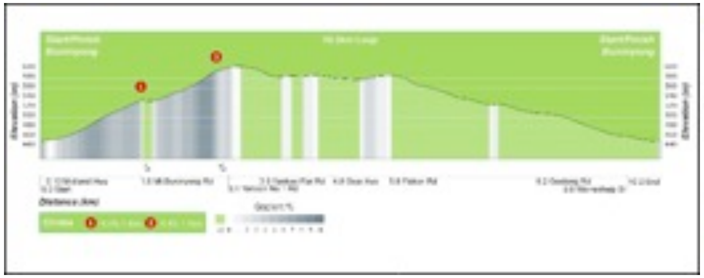
The HMI on the pedals must be rebuilt «electronically»

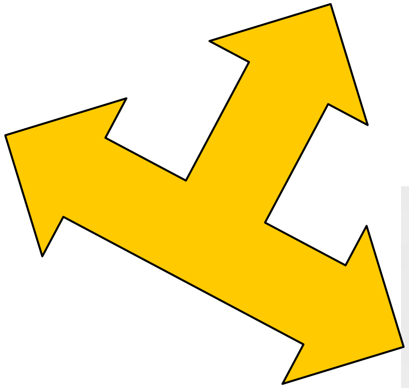
Conclusions

E-Bikes technologies: future (3) main technology challenges

Challenge #1: human synergy







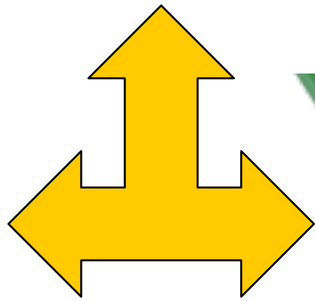
Direct and **controlled** interaction of:

- Ambient conditions
- Human body
- Electric motor/generator

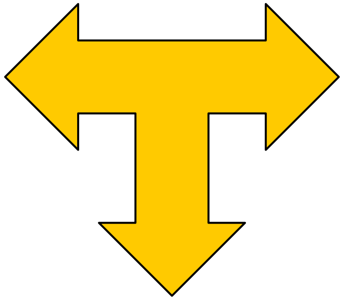
Challenge #2: Human Machine Interface

Develop and personalize:

- Pedal-Force-feedback Interface
- Personal mobile device interface



Challenge #3: Internet of Things (IoT)

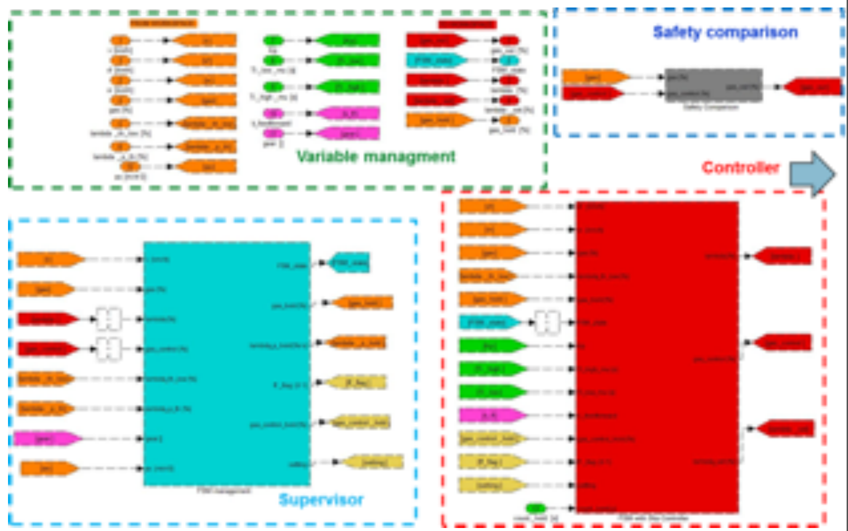


Intergrate the e-Bike in the networked social life of the user:
- Directly
- Via mobile device

Final remark: hidden (key) tecnologies

Sensing (slope, torque, road, etc.) or SW-sensing

Control algorithms (energy, force feedback, body parameters, vehicle dynamics)



Conclusions

1)The technology-portfolio of pedal-assisted vehicles still has some gaps

2) Main technologies to be developed:
Human-synergy
HMI (mostly on pedals)
Networking

3) Hidden key technologies:
- Sensing
- Control

Thanks for your attention