

**University of Rome "La Sapienza"**  
Mechanical and Aerospace Engineering Department

# **Introduction to the course of Vehicle System Dynamics**

Gianluca Pepe  
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**9 marzo 2023**



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# JOIN TO: Vehicle System Dynamics 2023

The screenshot shows a course management interface for 'Vehicle System Dynamics 2023'. At the top, there's a blue header with the course title and a 'Personalizza' button. Below the header, there are several cards:

- Meet**: A card with a 'Partecipa' button (blue with white text) and a note that it's visible to students.
- Codice del corso**: Shows the code **6ex5gb4** with a copy icon.
- In consegna**: Shows no assignments due soon and a 'Visualizza tutto' button.
- Stream**: A larger card titled 'Qui inserirai le comunicazioni per il tuo corso' (Where you will insert the communications for your course). It includes a 'Pubblica un annuncio per il tuo corso' button, a double arrow icon for sharing, and an 'Impostazioni dello stream' button. There's also a small icon of a person at a desk with a computer and a clock.
- Personalizza**: A small button in the top right corner of the main header area.

Prof. Antonio Carcaterra 3 CFU  
Prof. Gianluca Pepe 3 CFU



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# JOIN TO: Vehicle System Dynamics 2023

The screenshot shows a course management interface for 'Vehicle System Dynamics 2023'. At the top, there's a decorative banner with school supplies like pens and books, and a 'Personalizza' button. To the right, a yellow box highlights the 'ClassRoom Course code' as '6ex5gb4'. Below the banner, the course title is displayed. On the left, there are several cards: one for 'Meet' (with a 'Partecipa' button), one for the 'Codice del corso' (showing '6ex5gb4'), and one for 'In consegna' (showing 'Nessun lavoro in consegna a breve'). A blue arrow points from the 'ClassRoom Course code' text to the course code '6ex5gb4' in the 'Codice del corso' card.

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Prof. Gianluca Pepe 3 CFU



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# MEETINGS FOR REVISION: Vehicle System Dynamics 2023

Vehicle System Dynamics 2023

Meet

Partecipa

Visibile agli studenti

Codice del corso

6ex5gb4

In consegna

Nessun lavoro in consegna a breve

Visualizza tutto

Pubblica un annuncio per il tuo corso

Personalizza

Qui inserirai le comunicazioni per il tuo corso

Usa lo stream per condividere annunci, pubblicare compiti e rispondere alle domande degli studenti

Impostazioni dello stream

Conference meeting  
Meet code

<https://meet.google.com/puo-ojkv-cdx>

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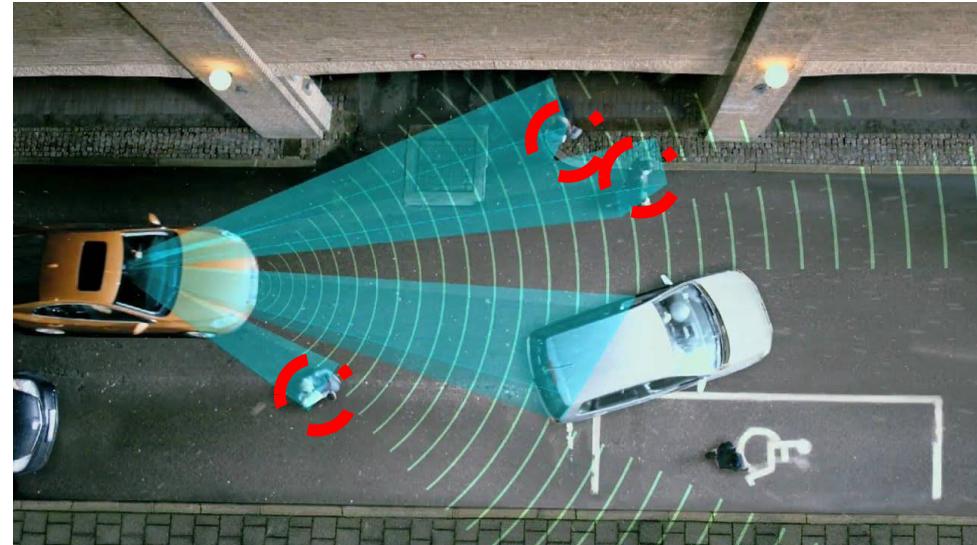
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# LAB OF AUTONOMOUS DRIVING: CARS AND SWARMS

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9 marzo 2023



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# LAB OF AUTONOMOUS DRIVING: CARS AND SWARMS

The screenshot shows a digital course interface. At the top, there's a banner with three devices (laptop, tablet, smartphone) and a 'Personalizza' button. Below the banner, the course title 'Lab of Autonomous Driving Cars and Swarms 2023' is displayed. On the left, there are several cards: one for 'Meet' with a 'Partecipa' button, one for 'Codice del corso' showing '7j7pz56', and one for 'In consegna' stating 'Nessun lavoro in consegna a breve'. In the center, there's a large box for 'stream' communications with icons for scissors, a gear, and a magnifying glass, along with a 'Pubblica un annuncio per il tuo corso' button and an 'Impostazioni dello stream' button.



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# LAB OF AUTONOMOUS DRIVING: CARS AND SWARMS

The screenshot shows a digital course interface. At the top right, a yellow box contains the text "ClassRoom Course code". Below it is a large blue box with the course code "7j7pz56". To the left of the code is a section titled "Lab of Autonomous Driving Cars and S" (partially cut off). On the far left, there's a "Meet" button with a "Partecipa" button and a "Visible agli studenti" link. Below that is a "Codice del corso" section showing "7j7pz56" with a copy icon. At the bottom left is an "In consegna" section stating "Nessun lavoro in consegna a breve" with a "Visualizza tutto" link. In the center, there's a "Stream" area with a "Qui inserirai le comunicazioni per il tuo corso" heading, a "Pubblica un annuncio per il tuo corso" button, and a "Impostazioni dello stream" button. The background features a dark blue header with a smartphone and laptop icon, and a decorative red floral graphic on the right.

Personalizza

ClassRoom  
Course code

Lab of Autonomous Driving Cars and S

Meet

Partecipa

Visible agli studenti

Codice del corso

7j7pz56

In consegna

Nessun lavoro in consegna a breve

Visualizza tutto

Pubblica un annuncio per il tuo corso

Qui inserirai le comunicazioni per il tuo corso

Usa lo stream per condividere annunci, pubblicare compiti e rispondere alle domande degli studenti

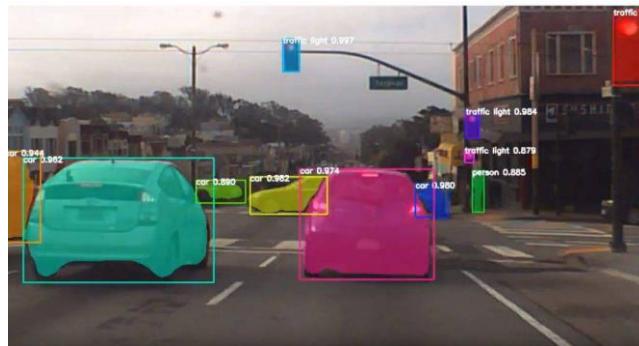
Impostazioni dello stream



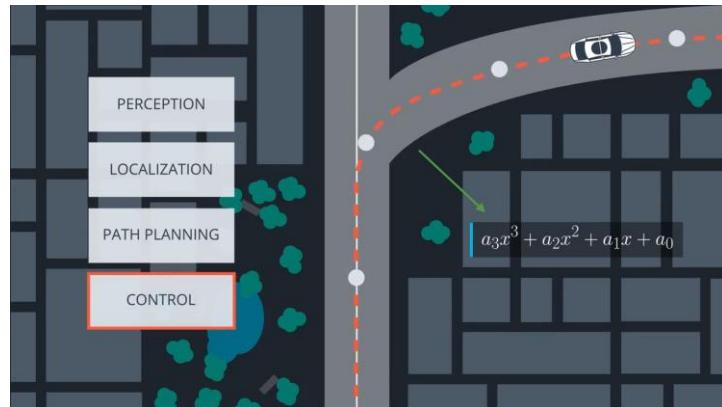
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# Why sign-up LAB of autonomous driving: cars and swarms

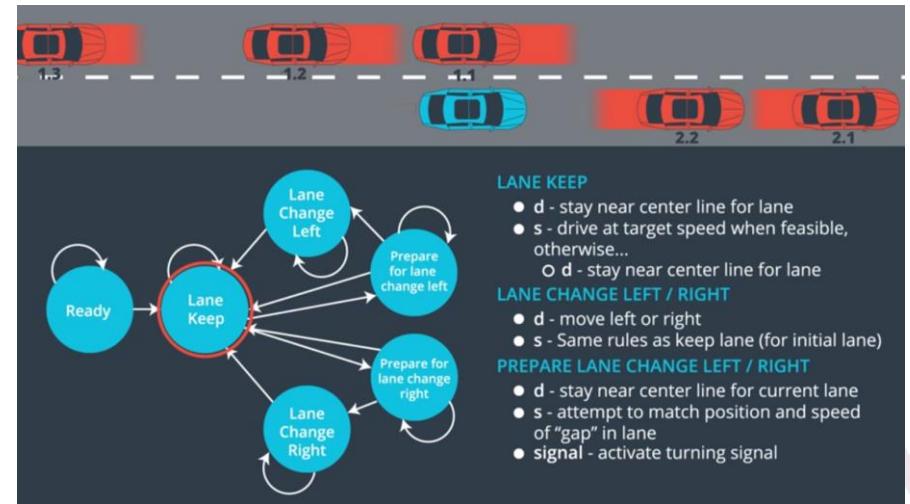
## Perception



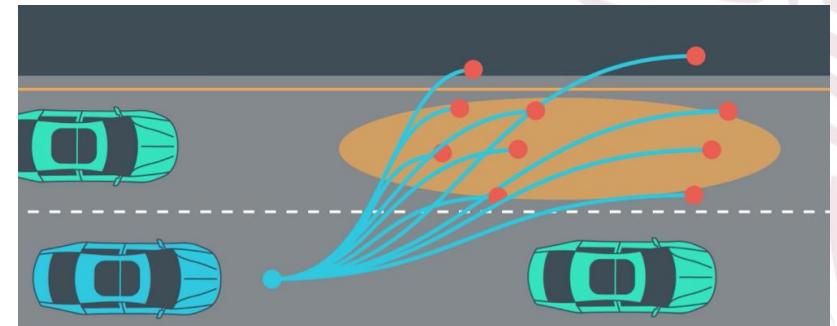
## Feedback control



## Behavioral Layer



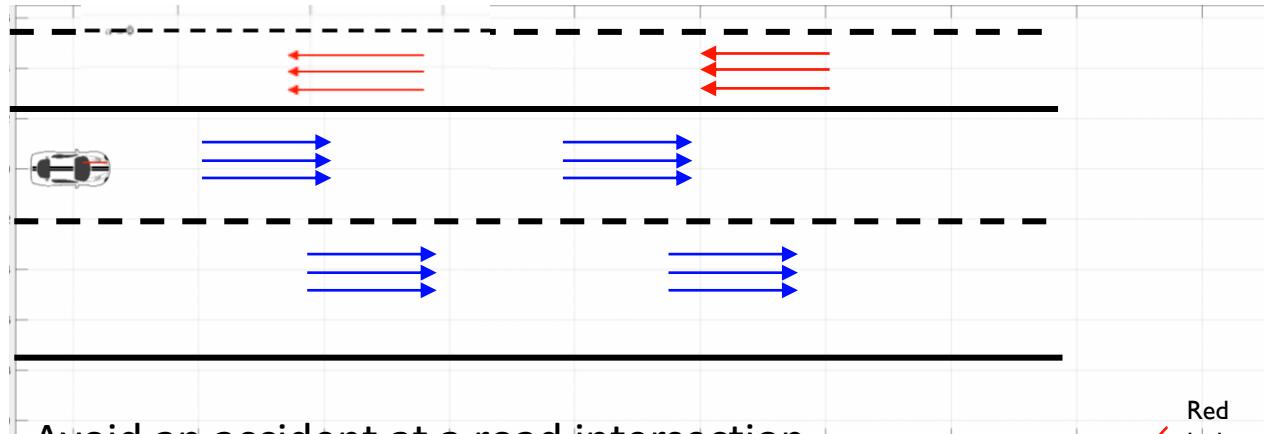
## Trajectory planning



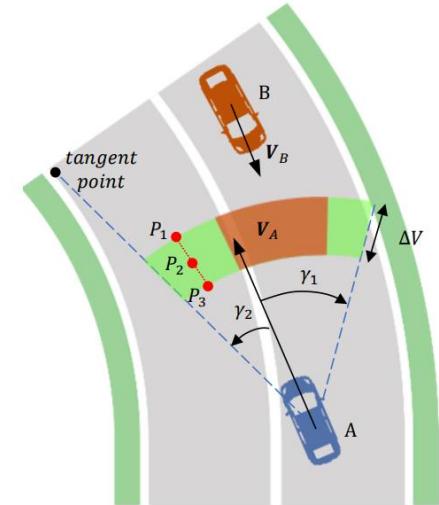
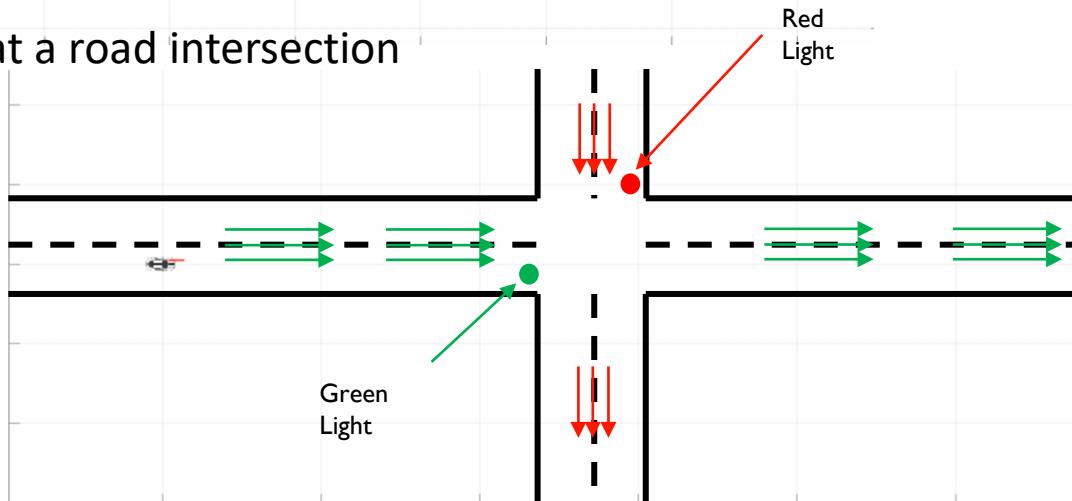
# Lab: crash avoidance

## Identify control strategies for automated driving

Avoidance of a frontal accident or a rear-end collision



Avoid an accident at a road intersection



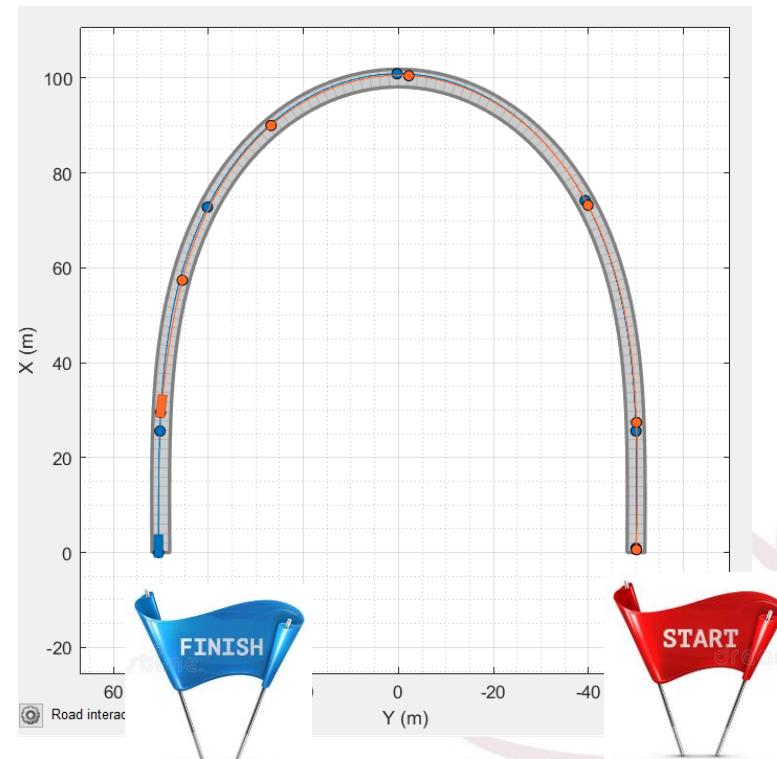
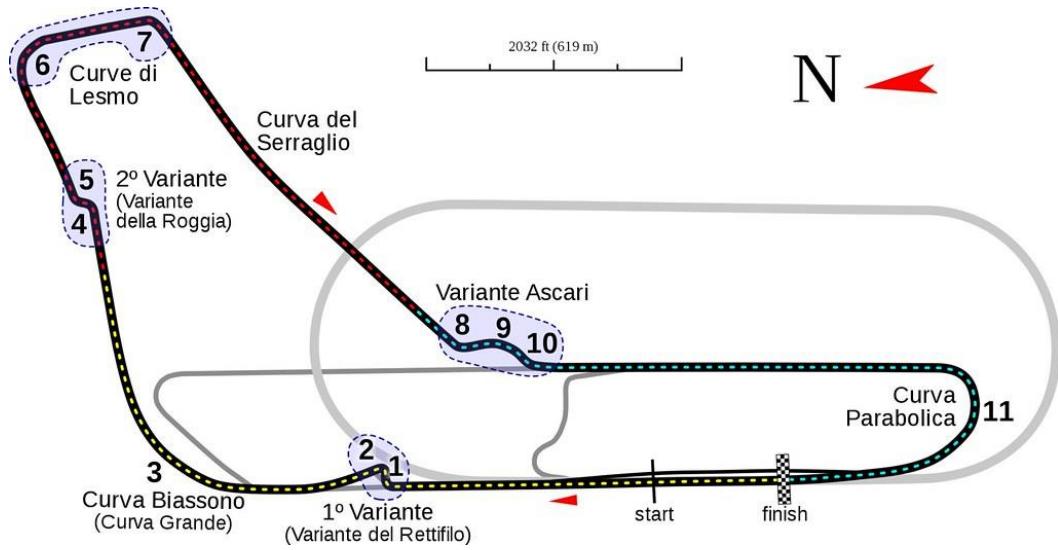
# Lab: optimal trajectories

## Optimal trajectory identification for a race circuit

Trajectory generation techniques

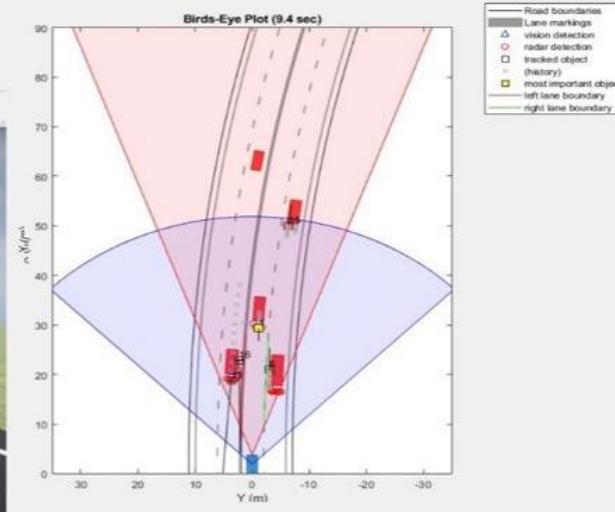
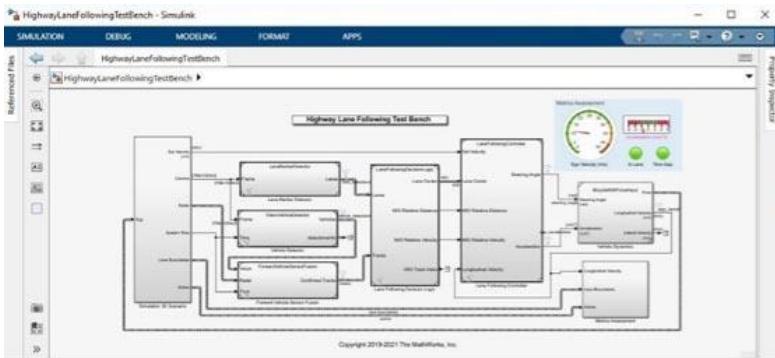
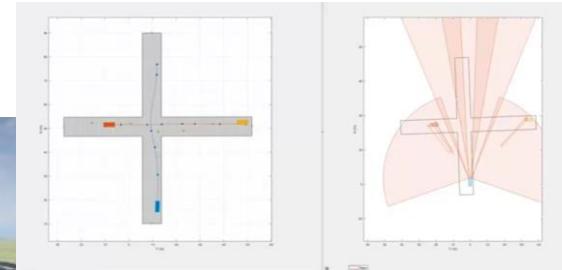
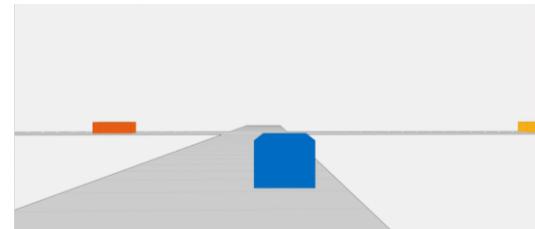
through the use of **optimal control**

**theory and nonlinear algorithms**



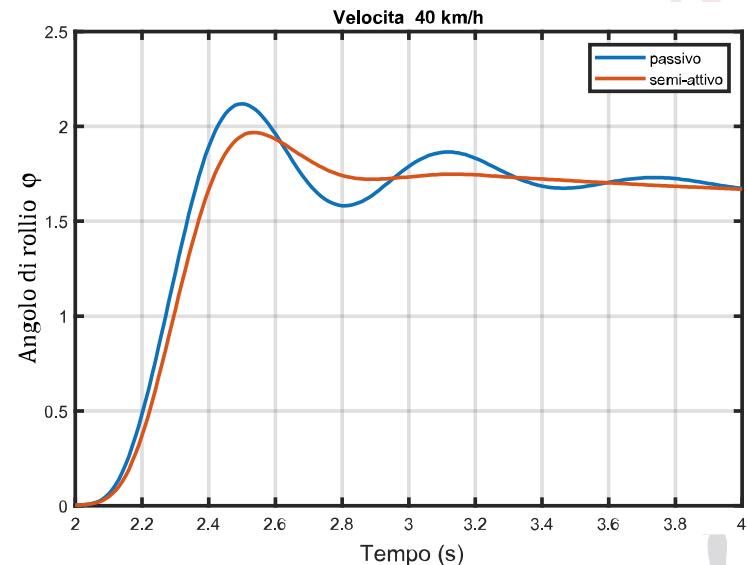
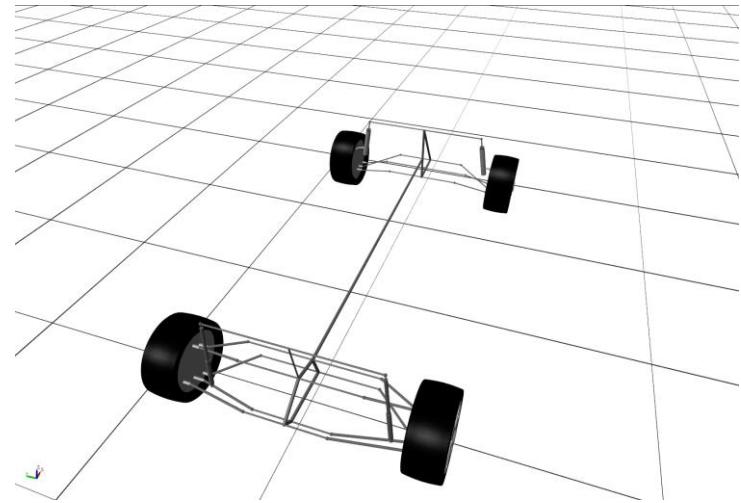
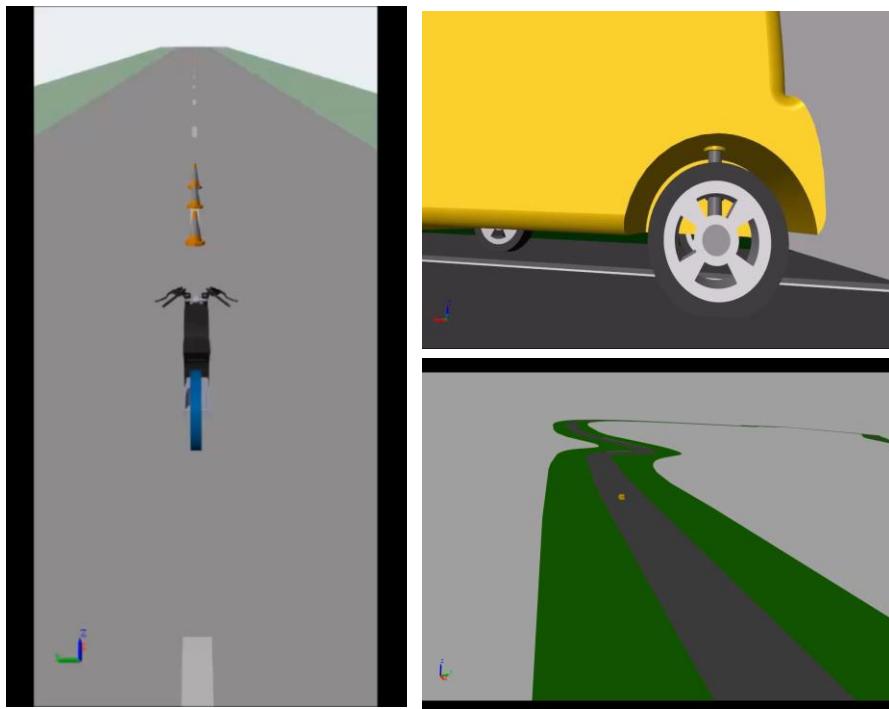
# Lab: Vehicle Matlab Toolbox

You will learn how to use the Matlab and Simulink toolbox



# Lab: Simscape Toolbox

You will learn how to use a Multibody software



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# Why studying Vehicle System Dynamics

**Like the steam engine or electricity, vehicles are transforming our world, our society and our industry. Vehicles are increasingly changing the life of humanity.**

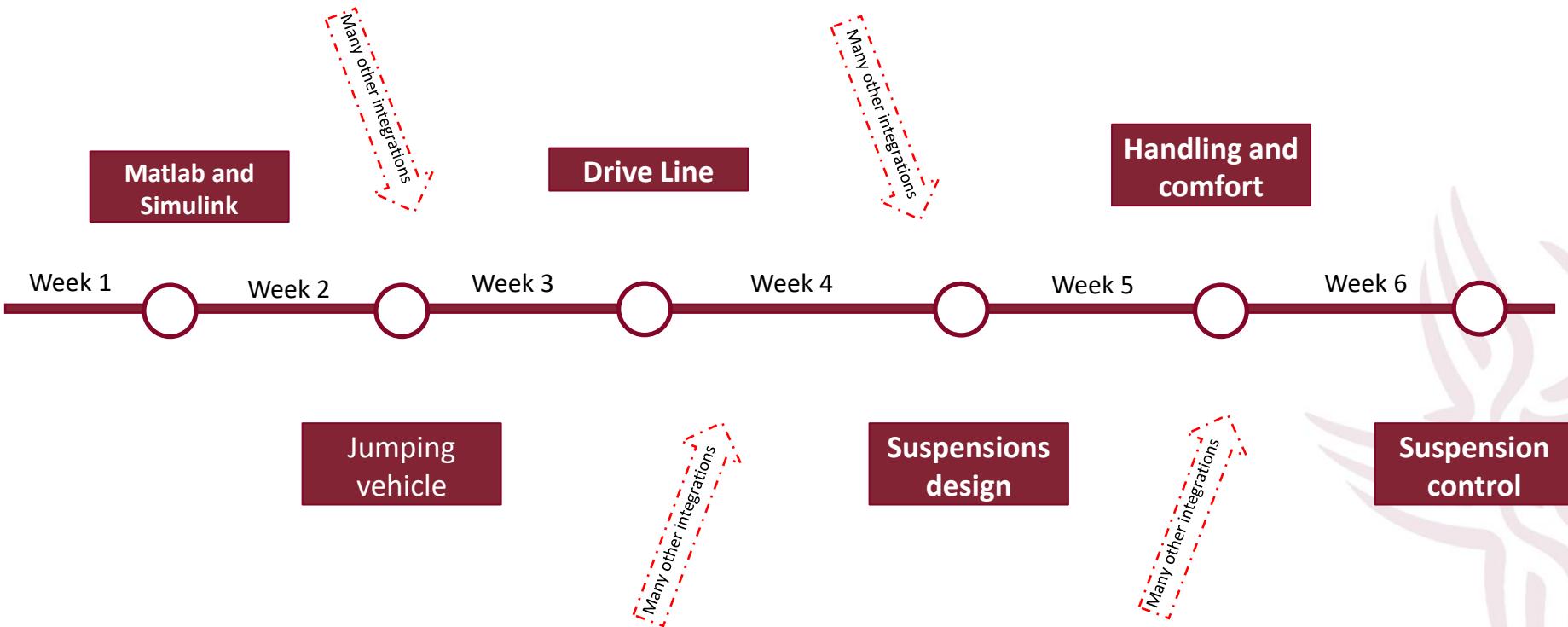
The main goal of the course is:

- to provide a knowledge basis to understand the new challenges of Vehicle System Dynamics,
- to support the student, in the assessment on how to model and understand complex dynamic models such as drones, autonomous cars, underwater vehicles, and legged robots.



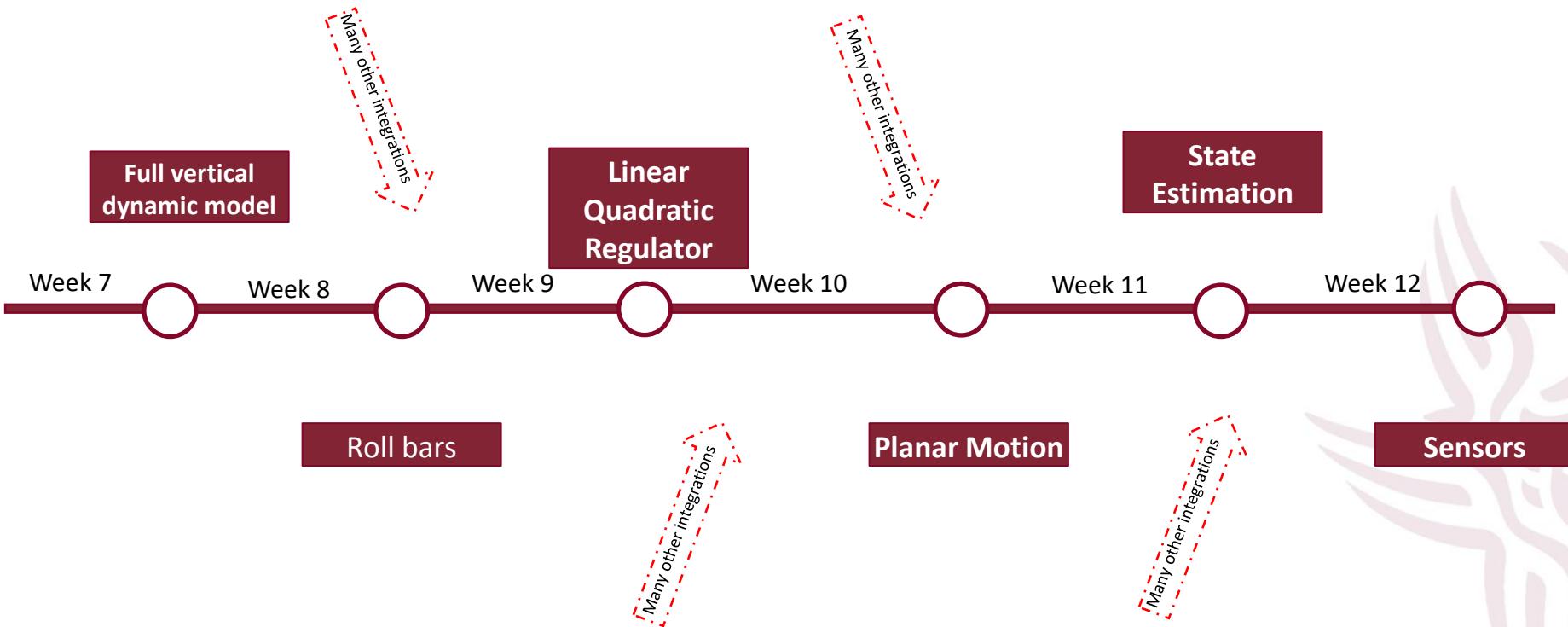
# The structure - Roadmap

The student learns the new technologies, applications, and methods through both theoretical and a hands-on approach



# The structure - Roadmap

The student learns the new technologies, applications, and methods through both theoretical and a hands-on approach



# Evaluation criteria and mode

The students have the opportunity to put into practice some of the knowledge acquired during the course with practical cases.

## Final exam

# 100%

Oral presentation of a  
case study

The project can be group or individual, through:

- PowerPoint presentation
- Matlab and Simulink project



# Project specifications

It is widely suggested to compose mixed groups between mechanical and automatic engineers.

## Content of the project:

- The principle idea can be inspired by a patent or a journal paper or your personal idea.
- The analysis of the real model must be done to propose mathematical models that can best describe it.
- Different typologies of dynamic models should be analyzed and compared
- Different typologies of control algorithms should be analyzed and compared.
- Actuators should be modelled by imposing limits on power, speed, and strength.
- Virtual sensors and state estimation models should be implemented.
- Finally is needed a discussion of the results.



# An example of a start

(19) United States

**(12) Patent Application Publication**

(12) *Patent Applications*

US 20020040821A1

(19) **United States**

(12) Patent Application Publication (10) Pub. No.: US 2002/0040821 A1

(42) Patent Application Publication (43) Pub. Date: Apr. 11, 2002  
Domenicali et al.

(54) MOTORCYCLE WITH ACTIVE REAR SUSPENSION UNIT PROVIDING IMPROVED BRAKING

### **Publication Classification**

(51) Int. Cl.<sup>7</sup> ..... B62M 7/00

(52) U.S. Cl. .... 180/227; 180/219

(75) Inventors: **Claudio Domenicali**, Bologna (IT);  
**Filippo Preziosi**, Calderara Di Reno  
(Bologna) (IT)

(57)

## ABSTRACT

**Correspondence Address:**  
**STEINBERG & RASKIN, P.C.**  
**1140 AVENUE OF THE AMERICAS, 15th**  
**FLOOR**  
**NEW YORK, NY 10036-5803 (US)**

(73) Assignee: DUCATI MOTOR HOLDING S.p.A.

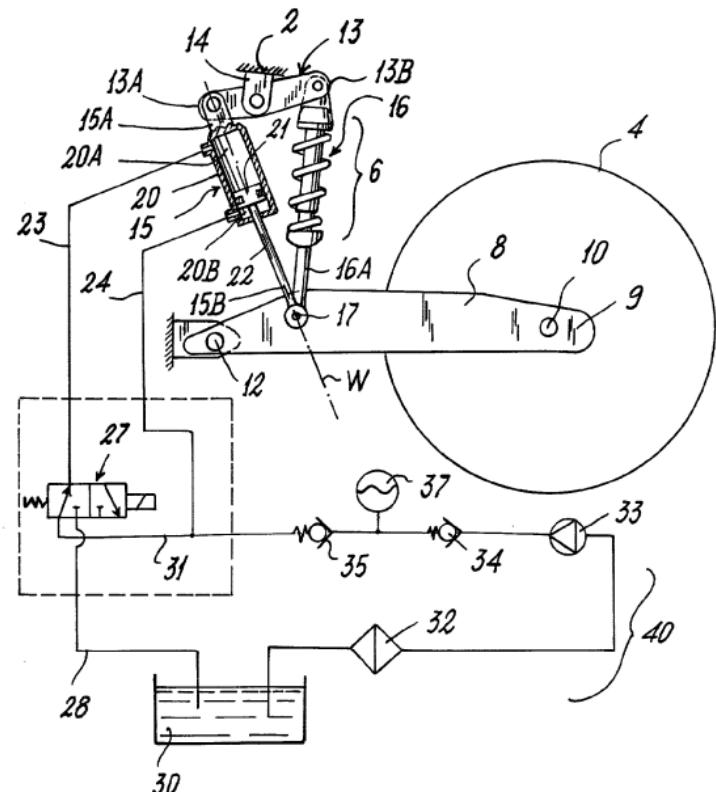
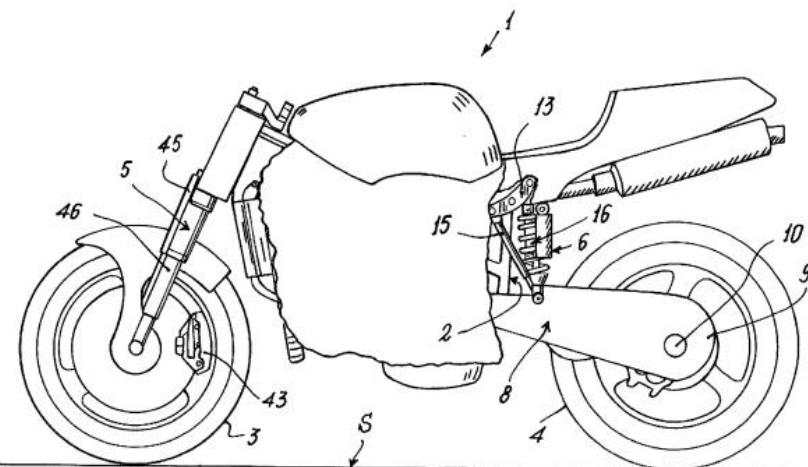
(21) Appl. No.: 09/974,603

(22) Filed: Oct. 10, 2001

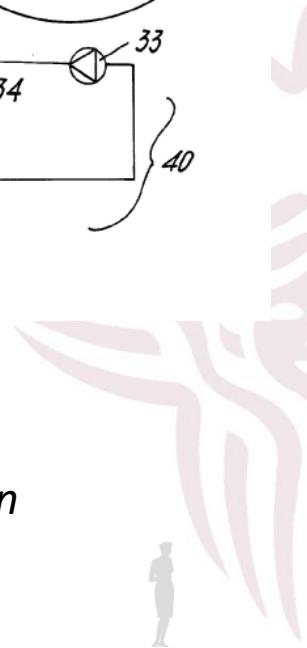
(30) Foreign Application Priority Data

Oct. 10, 2000 (IT) ..... MI2000A 002184

A motorcycle (1) having a frame (2) mounted on a front wheel (3) and on a rear wheel (4), each wheel (3, 4) operatively cooperating with a corresponding suspension unit (5, 6) connected to the frame (2), the wheels (3, 4) resting on a support surface (S); the rear suspension unit (6) including a reaction rod (15) selectively yieldable along a longitudinal axis (W) and having two opposing ends (15A, 15B), the ends (15A, 15B) being selectively approachable to each other when the vehicle (1) is braked in order to obtain lowering of the barycenter of the motorcycle (1) towards the support surface (S) to enable greater braking of the vehicle (1) and greater vehicle stability during this braking.



*“reading the claims and understanding the secrets on how it works”*



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# Introduction to VSD

## Gianluca Pepe

Mechanical and Aerospace Engineering Department  
Sapienza University of Rome

# Exam instruction

To discuss the project the student must book on Infostud and send us an email, before the examination date, with the following instructions:

**Object email:** VSD exam (Group Name)

**Text email:**

Name1 Surname1 Matricola (Mechanical or Control) Engineer

Name2 Surname2 Matricola (Mechanical or Control) Engineer

....

**Attached file:**

Matlab and simulink code

PowerPoint

Report (optional)



# How many people should a group consist of?

The best composition is:

- 2 Mechanical Engineers
- 2 Control Engineers

But you are free to prepare an individual work or up to 6 people.

The more you are and more should be accurate the case study.



# Project assessment

The evaluation of the project depends on the composition of the group along with the topics developed.

If the group consists only of mechanical engineers, we appreciate the modeling of the control system by comparing different techniques.

If the group consists only of control engineers, we appreciate the modeling of original or well-detailed dynamic systems.

Existing projects on the web, tutorials or Matlab/Simulink help documents **are not accepted**.



# I don't want to do a project, how can I do it?

Alternatively, you can also decide to take the oral exam on the entire program of the course.

The reference handouts are the book of Prof. Carcaterra together with the presentations of the course of Prof. Pepe

A.Carcaterra, VEHICLE SYSTEMS DYNAMICS, Edition 2018



**VEHICLE SYSTEMS DYNAMICS**

**AND MECHATRONICS**

A. Carcaterra

Sapienza University of Rome



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Introduction to VSD  
Gianluca Pepe

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Sapienza University of Rome

# Presentation of the Vehicle Dynamics and Mechatronics Lab

Gianluca Pepe

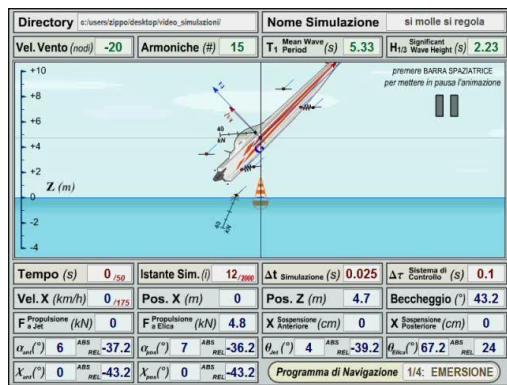
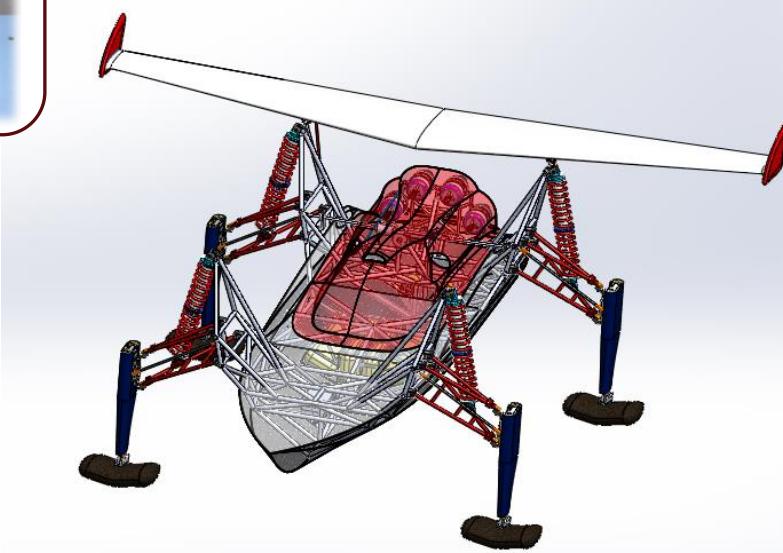


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# Scientific research: SEALAB

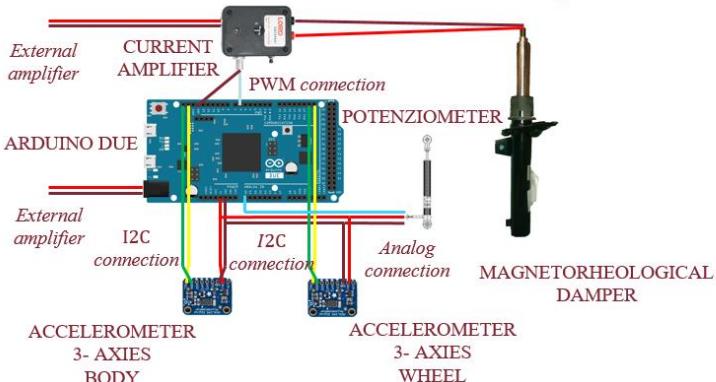
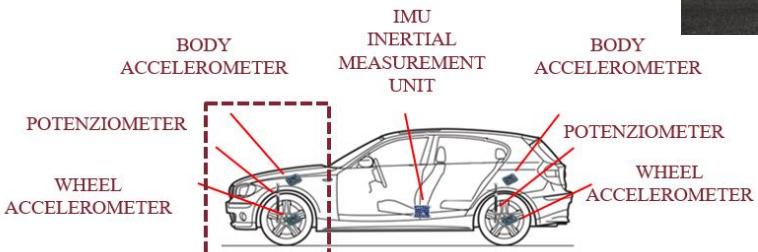
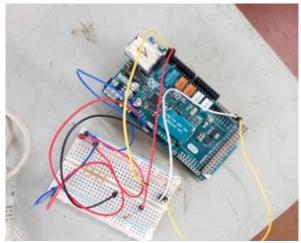
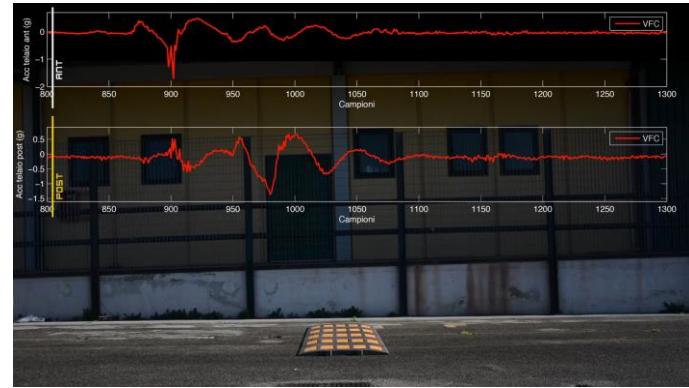


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# Scientific research: Smart suspension

Semiactive control system with magneto rheological device



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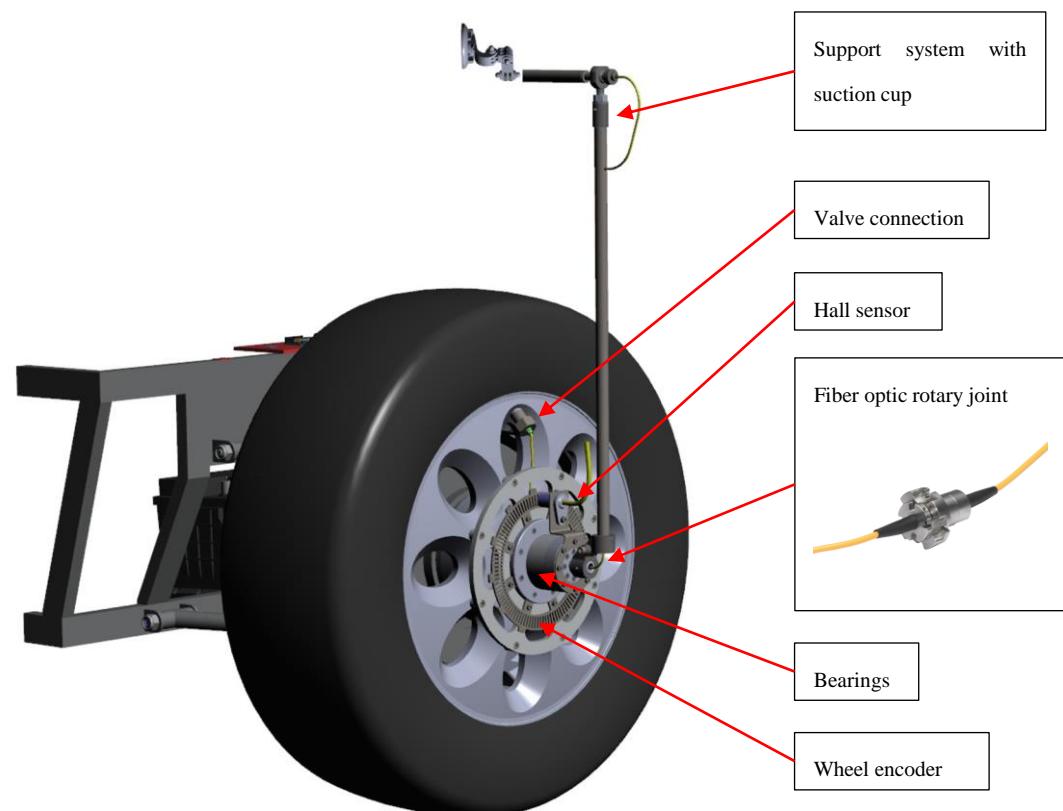
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# Scientific research: Smart tire

Optical fiber sensor FBG for real-time grip monitoring

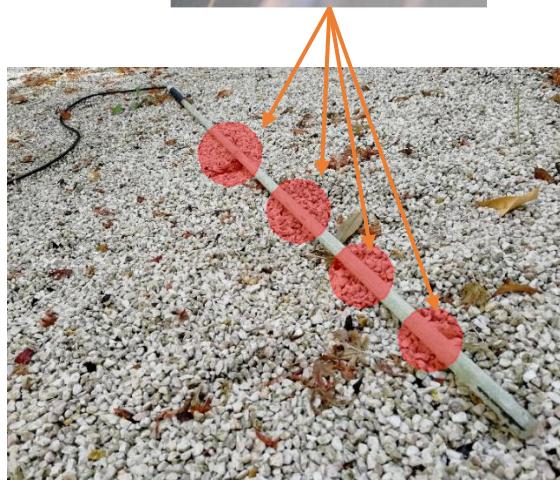


# Smart GFRP bars

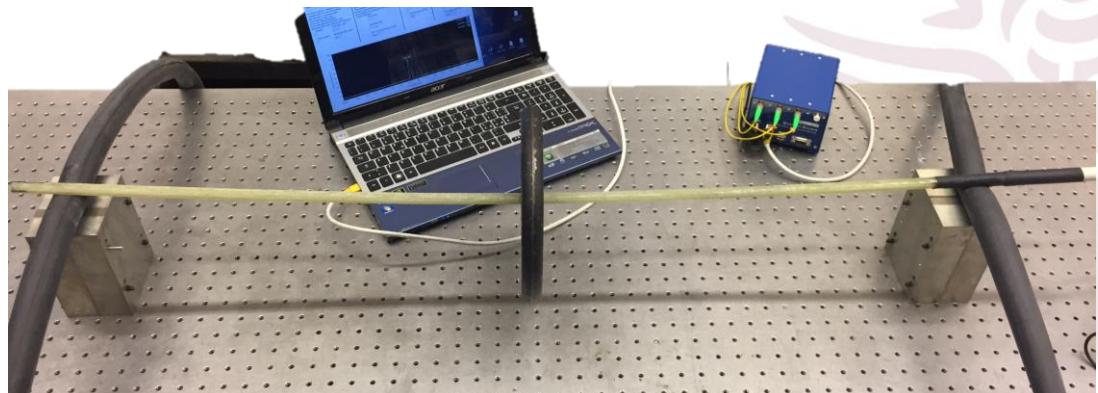
Optical  
fiber  
FBG



Stress test of Glass Fiber Reinforced Polymers



Smart bar with embedded sensors



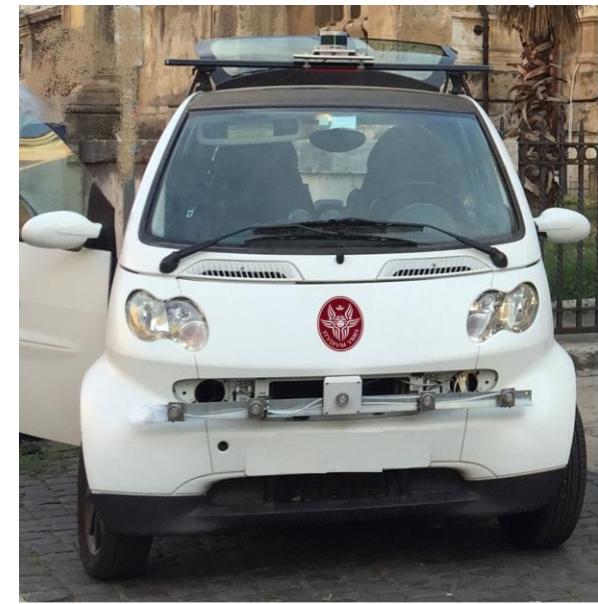
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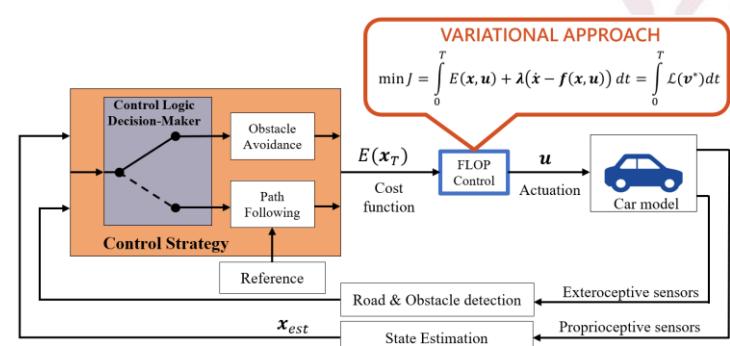
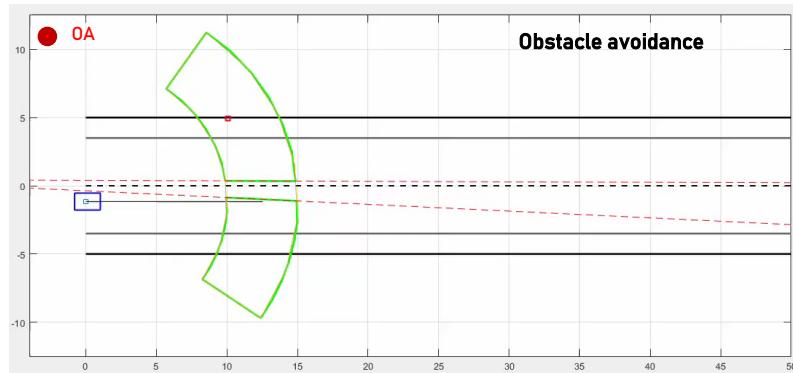
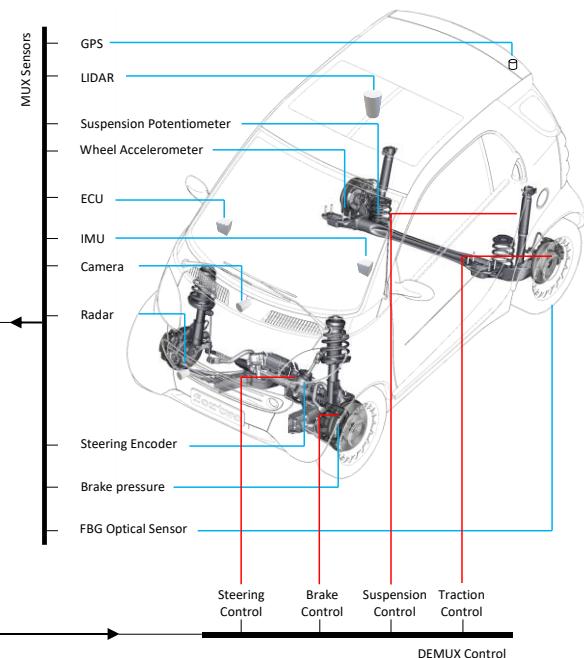
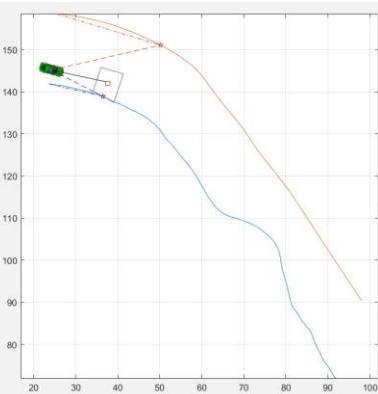
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# Scientific research: Auto-Sapiens

- Obstacle avoidance
- Decision algorithms
- Trajectory planning
- Predictive control
- Steering Control
- Torque vectoring
- Thrust control

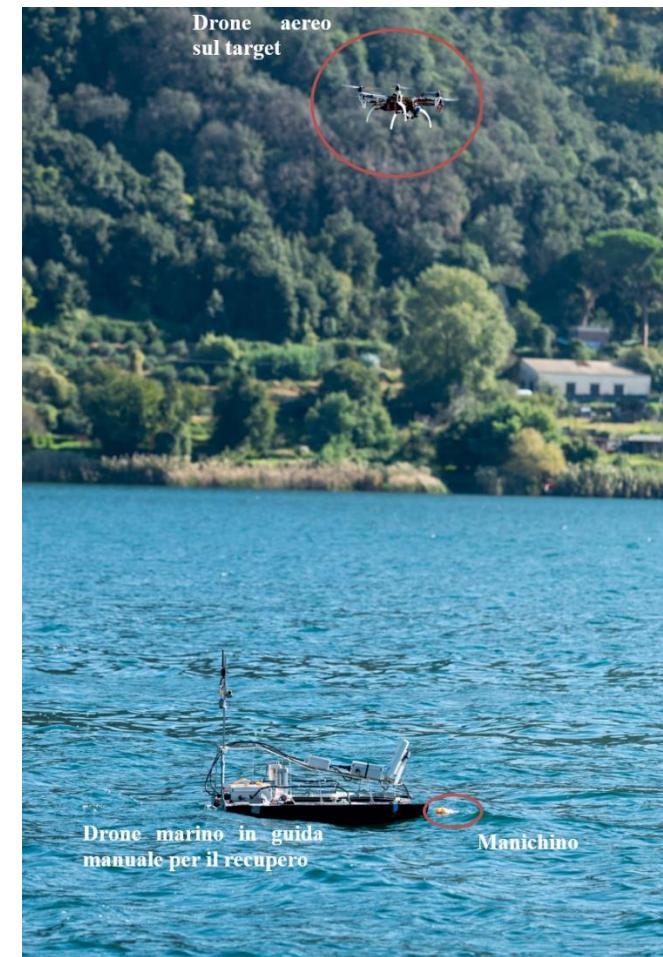
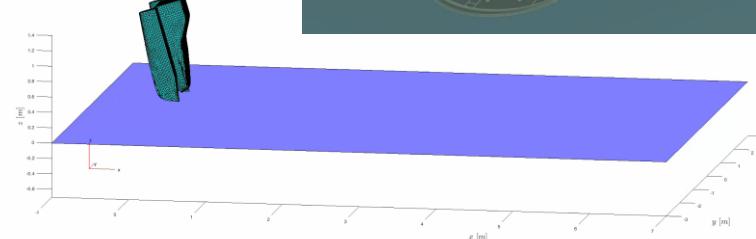
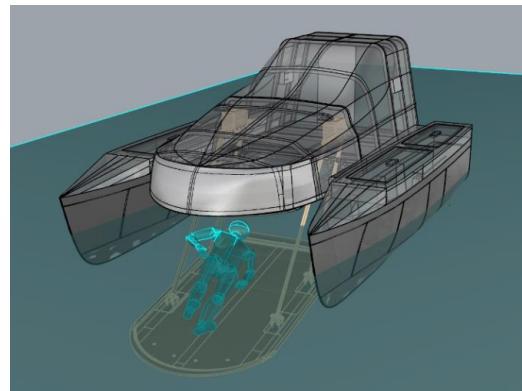


# Auto-Sapiens: Main characteristics



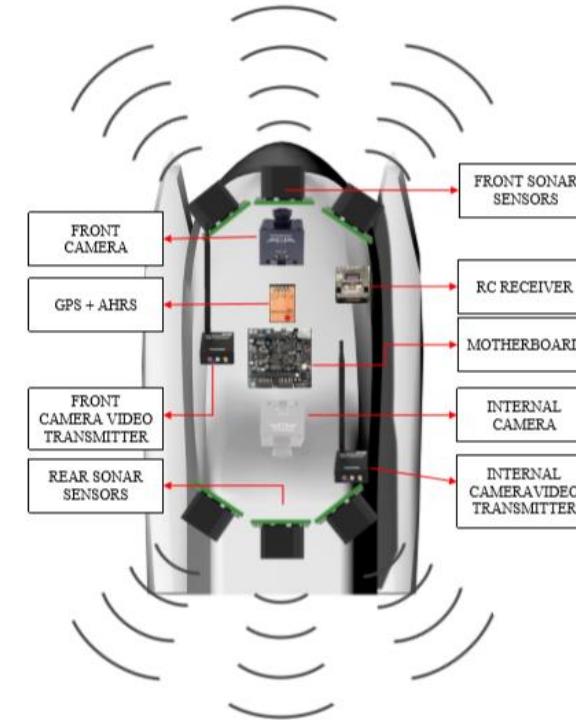
# Scientific research: Secure Platform

Rescue robot for castaway



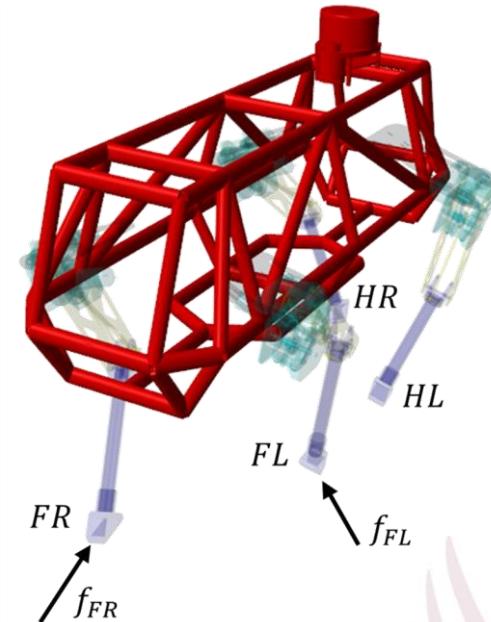
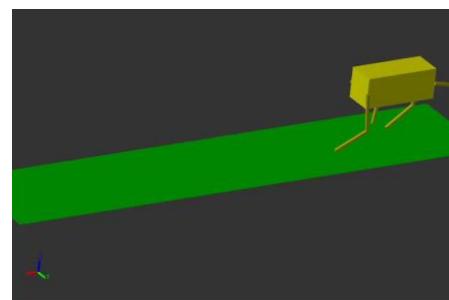
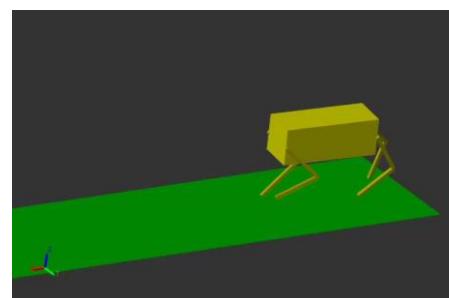
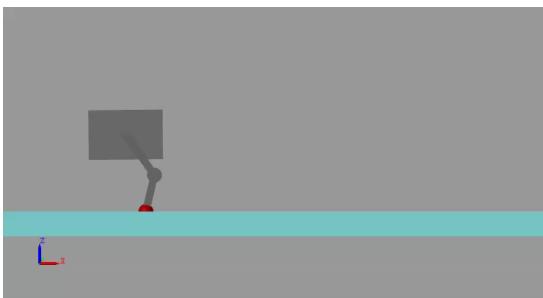
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Rescue robot for castaway

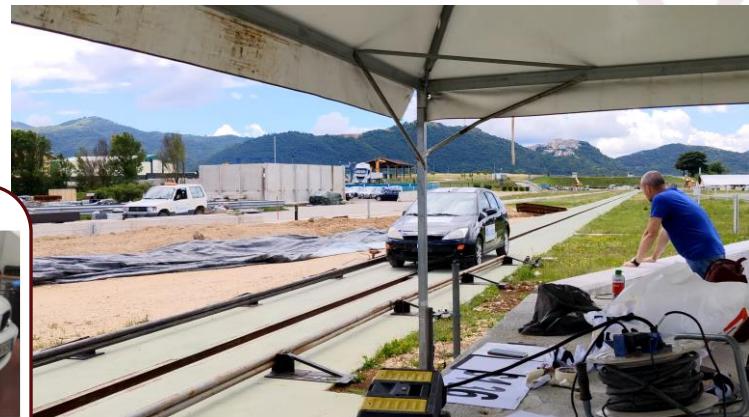
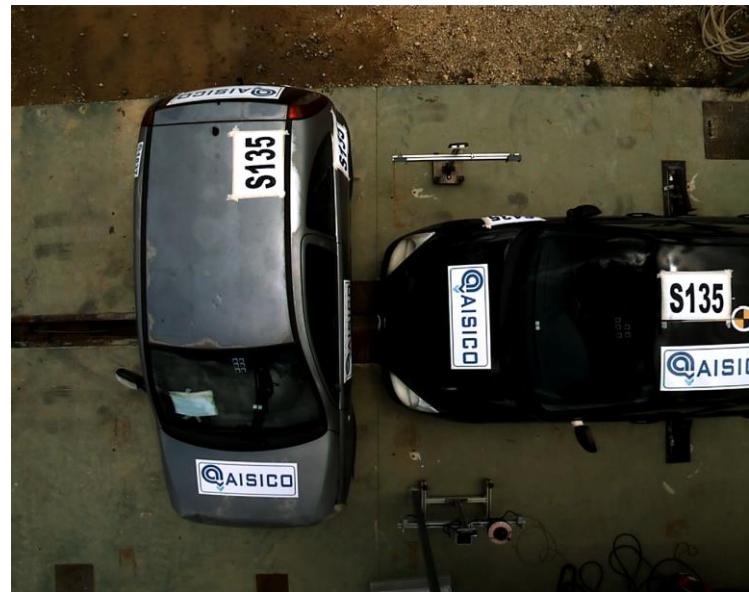
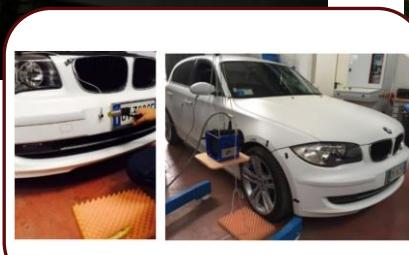


# Scientific research: Legged locomotion

## Gait optimization



# Scientific research: Mini crash detection

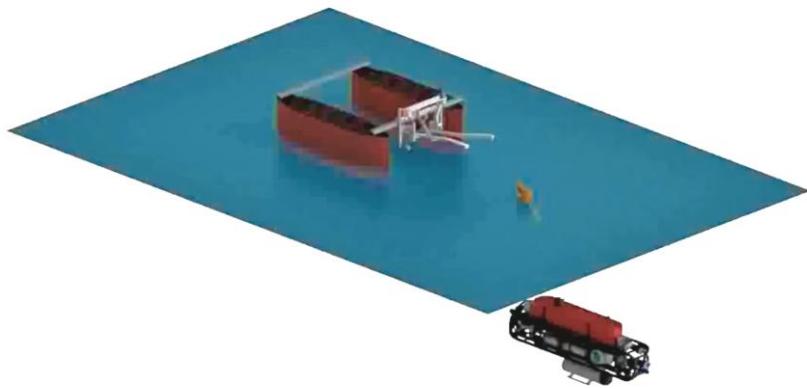
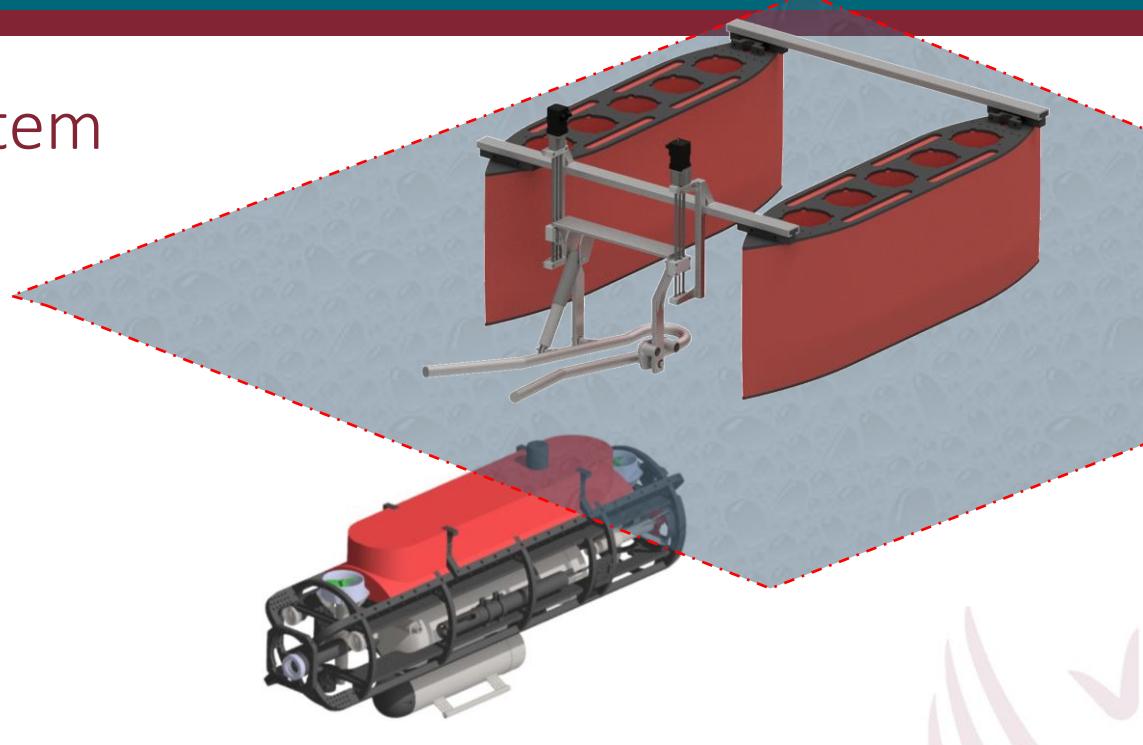
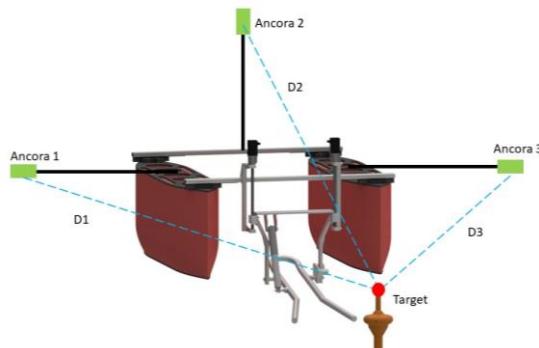
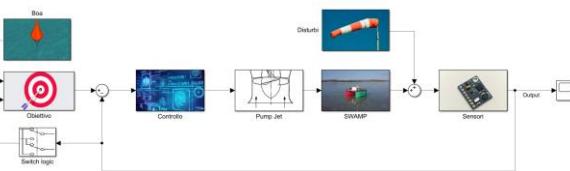


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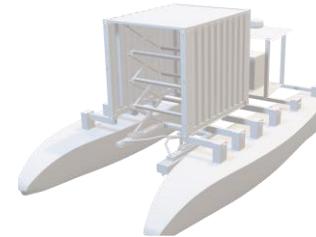
Introduction to VSD  
Gianluca Pepe

Mechanical and Aerospace Engineering Department  
Sapienza University of Rome

# Lunch and recovery system

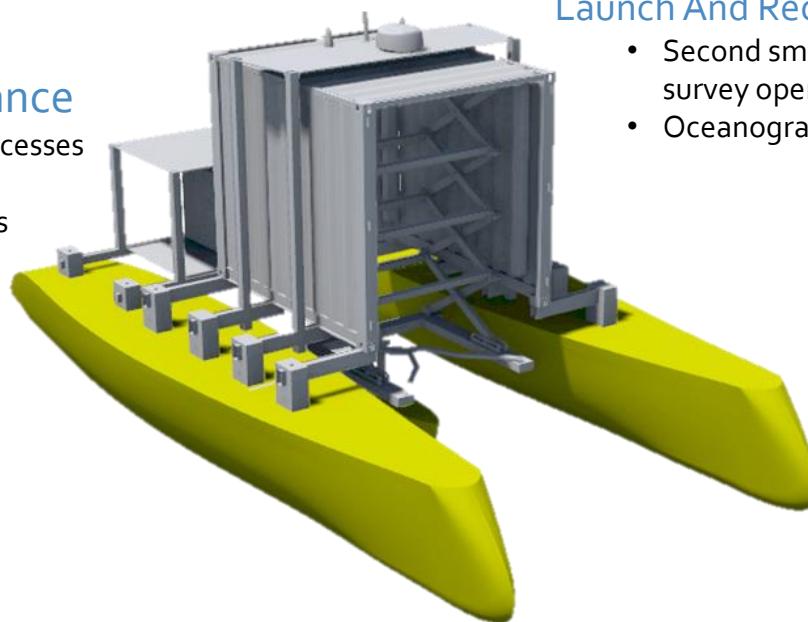


# SanMare research project



## Autonomous guidance

- decision making processes
- obstacle avoidance
- harbour manoeuvres



## Launch And Recovery System (LARS)

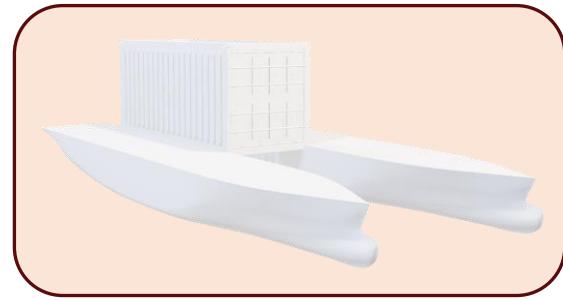
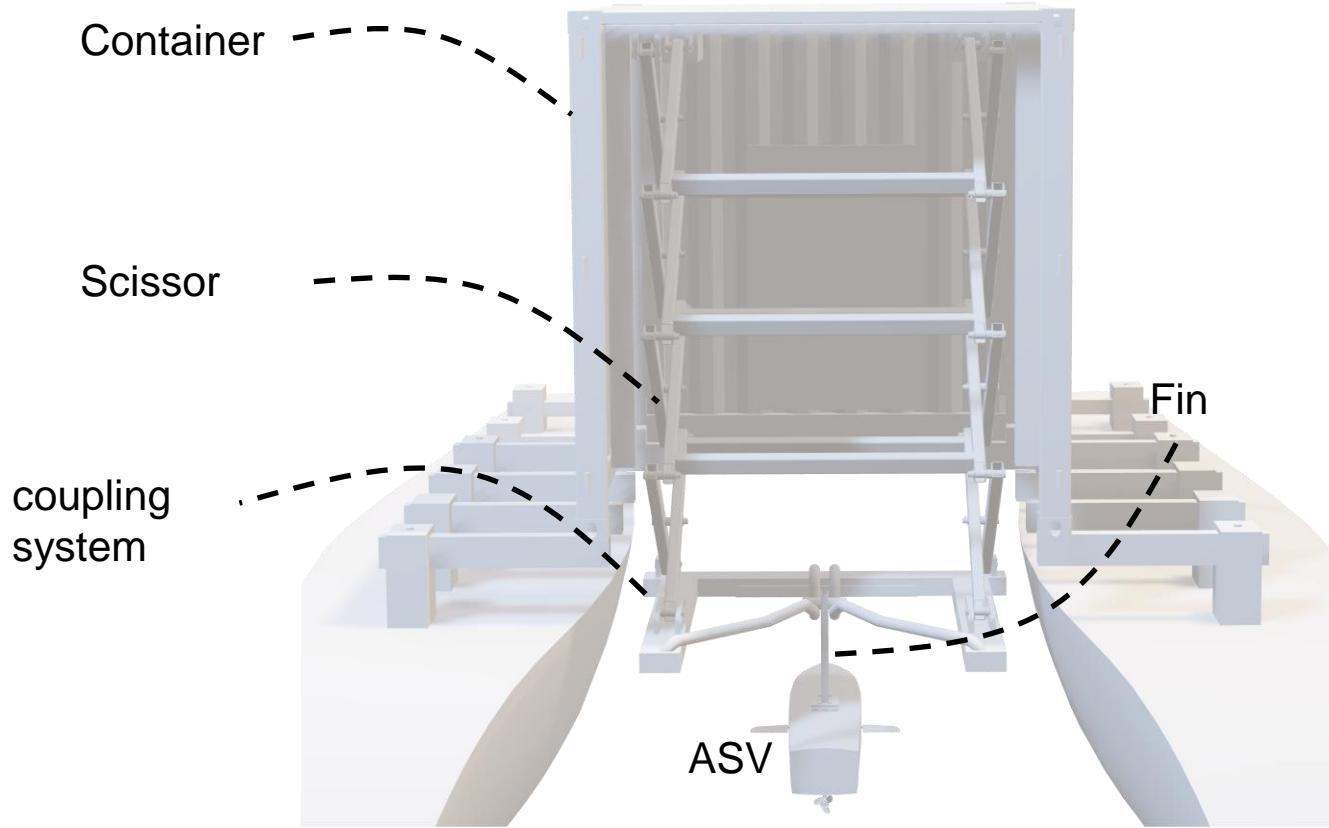
- Second smaller autonomous vehicle for survey operations
- Oceanographic measurements

## Structure

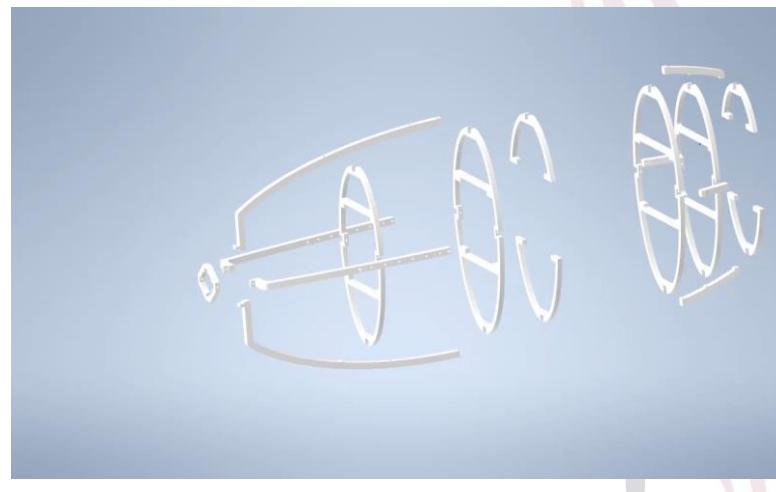
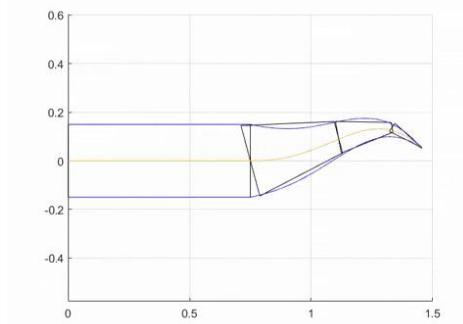
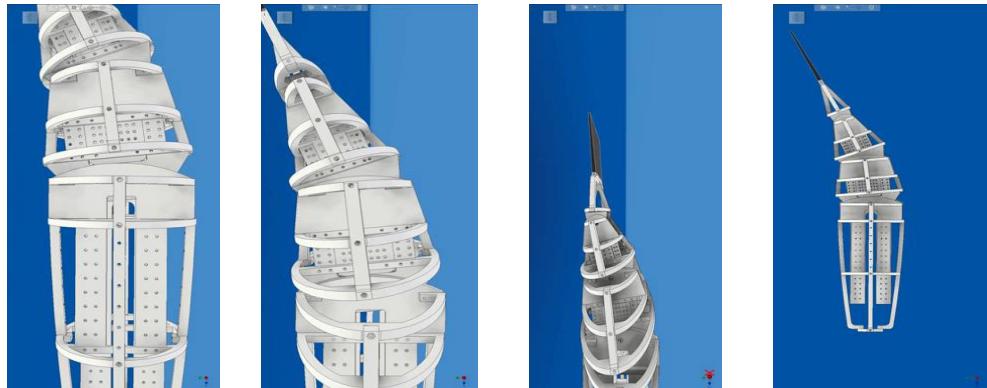
- transportable, modular, and customizable
- adapts to different missions
- resilient to different and adverse sea conditions
- eco-sustainable
- recyclable materials
- green propulsion system



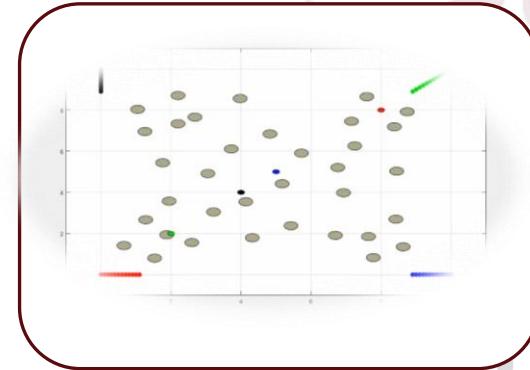
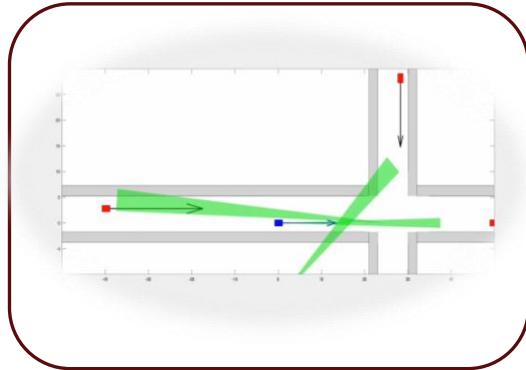
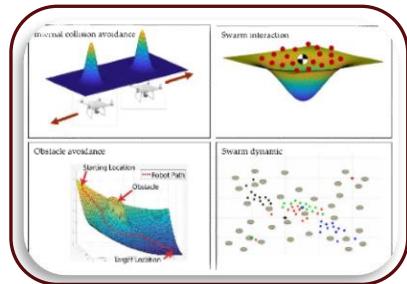
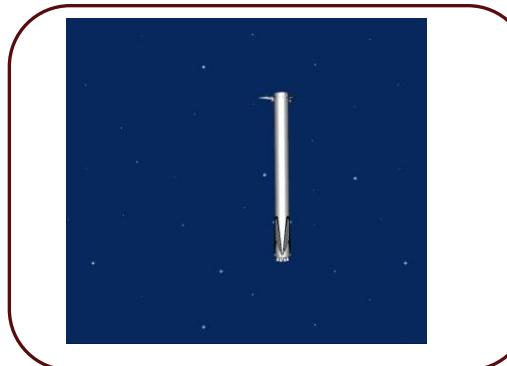
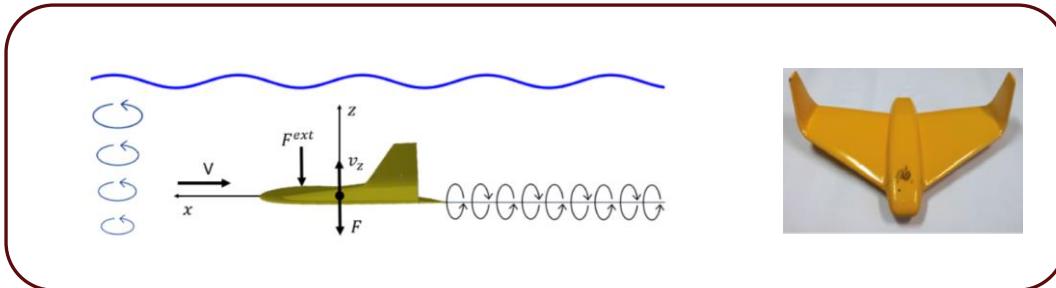
# SanMare research project



# Robotic fish



# Many others



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# Accedi a MATLAB - MATLAB & Simulink (mathworks.com)

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Sia che tu debba analizzare dati, sviluppare algoritmi o creare modelli, MATLAB è stato progettato per adattarsi al tuo modo di pensare e lavorare.



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Invia



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# Matlab Installation

>> ver

MATLAB Version: 9.11.0.1769968 (R2021b)

MATLAB License Number: 40576534

Operating System: Microsoft Windows 10 Home Version 10.0 (Build 19042)

Java Version: Java 1.8.0\_202-b08 with Oracle Corporation Java HotSpot(TM) 64

Server VM mixed mode

MATLAB	Version 9.11	(R2021b)
Simulink	Version 10.4	(R2021b)
5G Toolbox	Version 2.3	(R2021b)
AUTOSAR Blockset	Version 2.5	(R2021b)
Aerospace Blockset	Version 5.1	(R2021b)
Aerospace Toolbox	Version 4.1	(R2021b)
Antenna Toolbox	Version 5.1	(R2021b)
Audio Toolbox	Version 3.1	(R2021b)
Automated Driving Toolbox	Version 3.4	(R2021b)
Bioinformatics Toolbox	Version 4.15.2	(R2021b)
Communications Toolbox	Version 7.6	(R2021b)
Computer Vision Toolbox	Version 10.1	(R2021b)
Control System Toolbox	Version 10.11	(R2021b)
Curve Fitting Toolbox	Version 3.6	(R2021b)
DDS Blockset	Version 1.1	(R2021b)
DSP System Toolbox	Version 9.13	(R2021b)
Data Acquisition Toolbox	Version 4.4	(R2021b)
Database Toolbox	Version 10.2	(R2021b)
Datafeed Toolbox	Version 6.1	(R2021b)
Deep Learning HDL Toolbox	Version 1.2	(R2021b)
Deep Learning Toolbox	Version 14.3	(R2021b)
Econometrics Toolbox	Version 5.7	(R2021b)
Embedded Coder	Version 7.7	(R2021b)
Filter Design HDL Coder	Version 3.1.10	(R2021b)
Financial Instruments Toolbox	Version 3.3	(R2021b)
Financial Toolbox	Version 6.2	(R2021b)
Fixed-Point Designer	Version 7.3	(R2021b)
Fuzzy Logic Toolbox	Version 2.8.2	(R2021b)
GPU Coder	Version 2.2	(R2021b)
Global Optimization Toolbox	Version 4.6	(R2021b)
HDL Coder	Version 3.19	(R2021b)

HDL Verifier	Version 6.4	(R2021b)	
Image Acquisition Toolbox	Version 6.5	(R2021b)	
Image Processing Toolbox	Version 11.4	(R2021b)	
Instrument Control Toolbox	Version 4.5	(R2021b)	
LTE Toolbox	Version 3.6	(R2021b)	
Bit	Lidar Toolbox	Version 2.0	(R2021b)
MATLAB Coder	Version 5.3	(R2021b)	
MATLAB Compiler	Version 8.3	(R2021b)	
MATLAB Compiler SDK	Version 6.11	(R2021b)	
MATLAB Report Generator	Version 5.11	(R2021b)	
Mapping Toolbox	Version 5.2	(R2021b)	
Mixed-Signal Blockset	Version 2.1	(R2021b)	
Model Predictive Control Toolbox	Version 7.2	(R2021b)	
Model-Based Calibration Toolbox	Version 5.11	(R2021b)	
Motor Control Blockset	Version 1.3	(R2021b)	
Navigation Toolbox	Version 2.1	(R2021b)	
OPC Toolbox	Version 5.0.3	(R2021b)	
Optimization Toolbox	Version 9.2	(R2021b)	
Parallel Computing Toolbox	Version 7.5	(R2021b)	
Partial Differential Equation Toolbox	Version 3.7	(R2021b)	
Phased Array System Toolbox	Version 4.6	(R2021b)	
Powertrain Blockset	Version 1.10	(R2021b)	
Predictive Maintenance Toolbox	Version 2.4	(R2021b)	
RF Blockset	Version 8.2	(R2021b)	
RF PCB Toolbox	Version 1.0	(R2021b)	
RF Toolbox	Version 4.2	(R2021b)	
ROS Toolbox	Version 1.4	(R2021b)	
Radar Toolbox	Version 1.1	(R2021b)	
Reinforcement Learning Toolbox	Version 2.1	(R2021b)	
Risk Management Toolbox	Version 1.10	(R2021b)	
Robotics System Toolbox	Version 3.4	(R2021b)	
Robust Control Toolbox	Version 6.11	(R2021b)	
Satellite Communications Toolbox	Version 1.1	(R2021b)	
Sensor Fusion and Tracking Toolbox	Version 2.2	(R2021b)	
SerDes Toolbox	Version 2.2	(R2021b)	
Signal Integrity Toolbox	Version 1.0	(R2021b)	
Signal Processing Toolbox	Version 8.7	(R2021b)	
SimBiology	Version 6.2	(R2021b)	
SimEvents	Version 5.11	(R2021b)	
Simscape	Version 5.2	(R2021b)	
Simscape Driveline	Version 3.4	(R2021b)	
Simscape Electrical	Version 7.6	(R2021b)	
Simscape Fluids	Version 3.3	(R2021b)	
Simscape Multibody	Version 7.4	(R2021b)	
Simulink 3D Animation	Version 9.3	(R2021b)	
Simulink Check	Version 5.2	(R2021b)	
Simulink Code Inspector	Version 4.0	(R2021b)	
Simulink Coder	Version 9.6	(R2021b)	
Simulink Compiler	Version 1.3	(R2021b)	
Simulink Control Design	Version 6.0	(R2021b)	
Simulink Coverage	Version 5.5	(R2021b)	
Simulink Design Optimization	Version 3.10	(R2021b)	
Simulink Design Verifier	Version 4.6	(R2021b)	
Simulink Desktop Real-Time	Version 5.13	(R2021b)	
Simulink PLC Coder	Version 3.5	(R2021b)	
Simulink Real-Time	Version 7.2	(R2021b)	
Simulink Report Generator	Version 5.11	(R2021b)	
Simulink Requirements	Version 1.8	(R2021b)	
Simulink Test	Version 3.5	(R2021b)	
SoC Blockset	Version 1.5	(R2021b)	
Spreadsheet Link	Version 3.4.6	(R2021b)	
Stateflow	Version 10.5	(R2021b)	
Statistics and Machine Learning Toolbox	Version 12.2	(R2021b)	
Symbolic Math Toolbox	Version 9.0	(R2021b)	
System Composer	Version 2.1	(R2021b)	
System Identification Toolbox	Version 9.15	(R2021b)	
Text Analytics Toolbox	Version 1.8	(R2021b)	
UAV Toolbox	Version 1.2	(R2021b)	
Vehicle Dynamics Blockset	Version 1.7	(R2021b)	
Vehicle Network Toolbox	Version 5.1	(R2021b)	
Vision HDL Toolbox	Version 2.4	(R2021b)	
WLAN Toolbox	Version 3.3	(R2021b)	
Wavelet Toolbox	Version 6.0	(R2021b)	
Wireless HDL Toolbox	Version 2.3	(R2021b)	

