Principali attività di ricerca in corso e possibili sviluppi

Guido Colasurdo, Nicola De Divitiis, Guido De Matteis
ING-IND/03

Incontro promozione attività di ricerca DIMA
Roma, 27 febbraio 2017

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Attività principale G. Colasurdo

Con A. Zavoli

Studio ed impiego di tecniche di ottimizzazione

- Metodi indiretti, basati sulla teoria del controllo ottimale e sulla soluzione numerica di un boundary value problem
- Algoritmi basati sulla genetica o sull'intelligenza degli sciami, adatti a problemi dove è estremamente ampio lo spazio delle soluzioni
- Metodi diretti per l'ottimizzazione di problemi molto complessi (in particolare modello complesso del veicolo o dell'ambiente di volo)

Temi di ricerca (1)

con A. Zavoli

Ottimizzazione di traiettorie di spacecraft

- Si usano tecniche indirette di ottimizzazione
- Recentemente l'attenzione è stata indirizzata al rendezvous cooperativo e al raggiungimento e alla modifica di configurazioni per il formation flying
- Attività avviata nell'ambito di un contratto con il CNES

Temi di ricerca (2)

con A. Zavoli

Ottimizzazione globale di traiettorie spaziali

- Si usano inizialmente algoritmi di tipo evoluzionistico e successivamente tecniche indirette di ottimizzazione
- Costituiscono un'attività hobbistica collegata alla partecipazione del Team Sapienza - Politecnico di Torino alla Global Trajectory Optimization Competition

GTOC5	2° classificato
GTOC6	1° classificato
GTOC8	3° classificato

Temi di ricerca (3) con A. Zavoli

Ottimizzazione di traiettorie di ascesa di un lanciatore

- Attività che dovrebbe essere oggetto di contratto con ESA-ESRIN
- Con tecniche indirette si può studiare l'ottimizzazione combinata della configurazione e della traiettoria di un lanciatore
- Definita la configurazione, per l'ottimizzazione finale della traiettoria del lanciatore, occorrerà realizzare un codice di ottimizzazione diretta

Flight dynamics of rigid aircraft in the presence of atmospheric turbulence

- DIMA personnel: De Divitiis
  - Estimation of the vehicle Kussner function by means of a proper unsteady version of Tait-Kirchhoff model incorporating free model parameters
  - Identification of the free parameters through the knowledge of the rotational force and moment aerodynamic derivatives
  - Determination of the turbulent velocity correlations using an original closure of the von Kàrmàn-Howarth equation and other models known from the literature
  - Calculation of the aircraft aerodynamic coefficients in the presence of turbulence as convolutions of Kussner function and pair velocity correlation functions.

Chaotic trajectories determination in atmospheric flight: the case of the booster stages

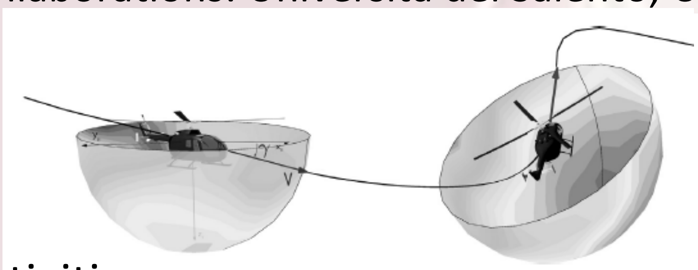
- DIMA personnel: De Divitiis
  - Aerodynamic Modelling of booster stages.
  - Analysis of chaotic motion through the Liouville theorem and the an Extented Lyapunov analysis of the motion equations.

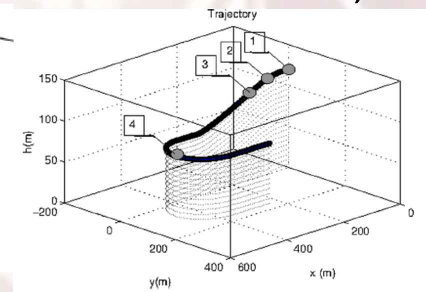
Main activities G. De Matteis

- Inverse simulation of rotary wing vehicles
  - Helicopter noise
  - Quadrotor control
  - Helicopter modelling
- Spacecraft attitude dynamics
  - Design of control laws
  - Design and validation of ADCS
- Flight dynamics of flexible aircraft
  - Modelling and stability analysis of flexible aircraft
  - Modelling and optimization for the design of HALE vehicles
- Flight dynamics of re-entry vehicles
- Design and flight dynamics & control of small RPV's

Inverse simulation

- DIMA personnel: De Matteis
- Background (since ~ 1999):
  - Multiple time-scale Integration methods for inverse problems
  - Trajectory generation and tracking for VTOL vehicles
- Collaborations: Università del Salento, Università RomaTre, Università di Bologna (Forlì)





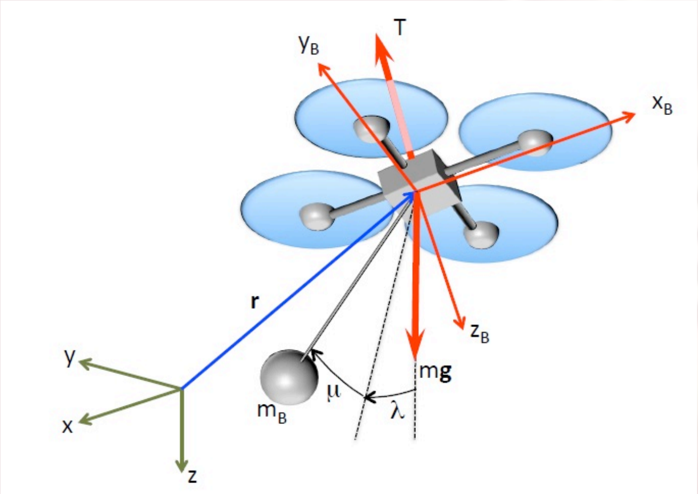
- Activities
  - Modellization of helicopter noise hemispheres in maneuvering flight conditions: for a specified trajectory control and state variables are determined as input for aeroelastic/aerodynamic/aeroacustic predictions; trajectory planning for the reduction of ground acustic impact
  - Assessment of helicopter model accuracy: models of different complexity are compared by computing inverse solutions obtained for the same maneuver

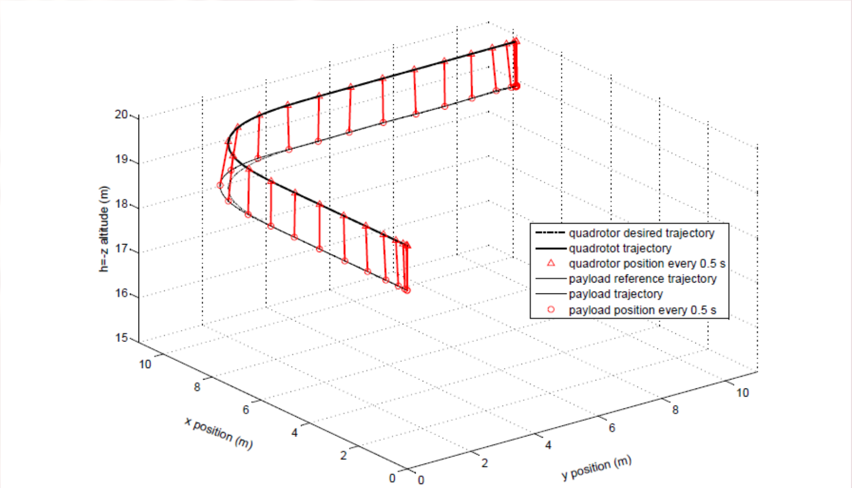
Table 1 Rotorcraft models test matrix (with line-style legend for the plots)

	Main rotor			Fuselage aerodynamics	
Model	*Rotor states*	*Inflow states*	n	A (*database*)	B (*parasite area*)
Individual blade models, $\ell = 1, ..., 4$	$\beta_\ell, \zeta_\ell, \vartheta_\ell, \dot\beta_\ell, \dot\zeta_\ell, \dot\vartheta_\ell$	$\nu_0, \nu_s, \nu_c, \nu_{0_{TR}}$	37	**A1**	
	$\beta_\ell, \zeta_\ell, \dot\beta_\ell, \dot\zeta_\ell$	$\nu_0, \nu_s, \nu_c, \nu_{0_{TR}}$	29	A2	
	$\beta_\ell, \dot\beta_\ell$	$\nu_0, \nu_s, \nu_c, \nu_{0_{TR}}$	21	A3	
2nd order TPP dynamics	$\beta_c, \beta_{1s}, \beta_{1c}, \dot\beta_c, \dot\beta_{1s}, \dot\beta_{1c}$	$\nu_0, \nu_s, \nu_c, \nu_{0_{TR}}$	19	**A4**	
	$\beta_c, \beta_{1s}, \beta_{1c}, \dot\beta_c, \dot\beta_{1s}, \dot\beta_{1c}$	$\nu_0, \nu_{0_{TR}}$	17	A5	
	$\beta_c, \beta_{1s}, \beta_{1c}, \dot\beta_c, \dot\beta_{1s}, \dot\beta_{1c}$	quasi-static $\nu_0, \nu_{0_{TR}}$	15	**A6**	**B6**
1st order TPP dynamics	$\beta_c, \beta_{1s}, \beta_{1c}$	$\nu_0, \nu_{0_{TR}}$	14		B7
	$\beta_c, \beta_{1s}, \beta_{1c}$	quasi-static $\nu_0, \nu_{0_{TR}}$	12		B8
	β_{1s}, β_{1c} (decoupled)	quasi-static $\nu_0, \nu_{0_{TR}}$	11		**B9**

Inverse simulation (2)

- Trajectory control methodology for quadrotor carrying suspended loads: design of feedforward control laws for control system design or assessment of performance limits

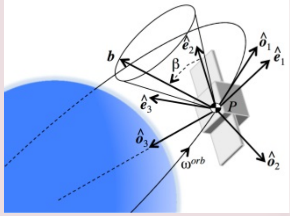


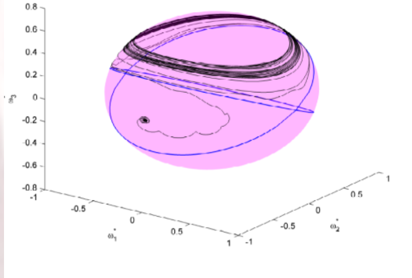


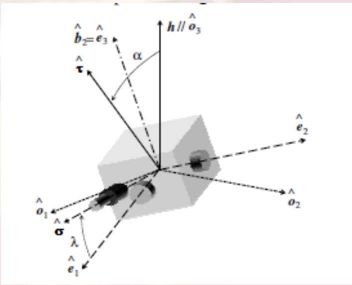
- Assessment of model fidelity for small scale rotorcraft and quadrotors: flight data are recorded for maneuvers tailored to excite specific modes; inverse simulation of the same maneuvers allows for the determination of the accuracy of specific models

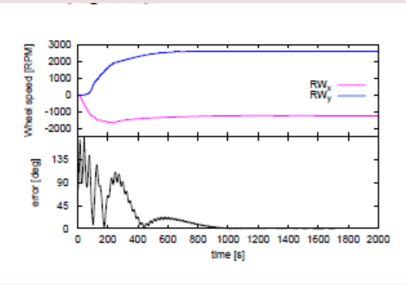
Attitude dynamics of small satellites

- DIMA personnel: De Matteis, Zavoli
- Background (since ~ 2001):
  - Command generation for spacecraft maneuvers using CGMs
  - Continuation of attitude motion of gyrostats
- Collaborations: Università del Salento, Università di Bologna (Forlì)





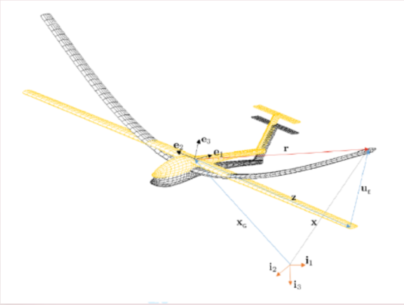


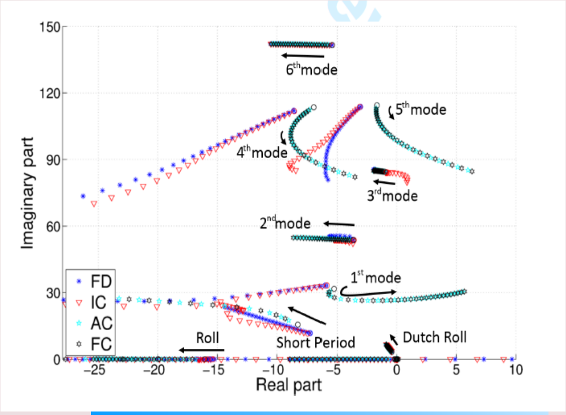


- Activities
  - Single magnetic torque-rod control for detumbling: convergence/stability analysis of the control law
  - Control of underactuated spacecraft: single axis pointing using two reaction wheels; design of control law and proof of stability

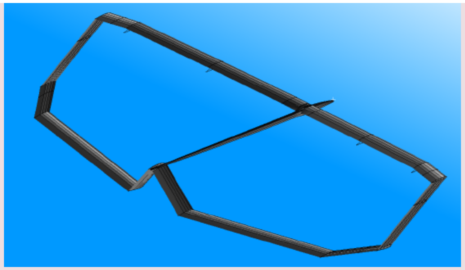
Flight Dynamics of Flexible Aircraft

- DIMA personnel: De Matteis; Mastroddi, Ph. Students Riso, Saltari



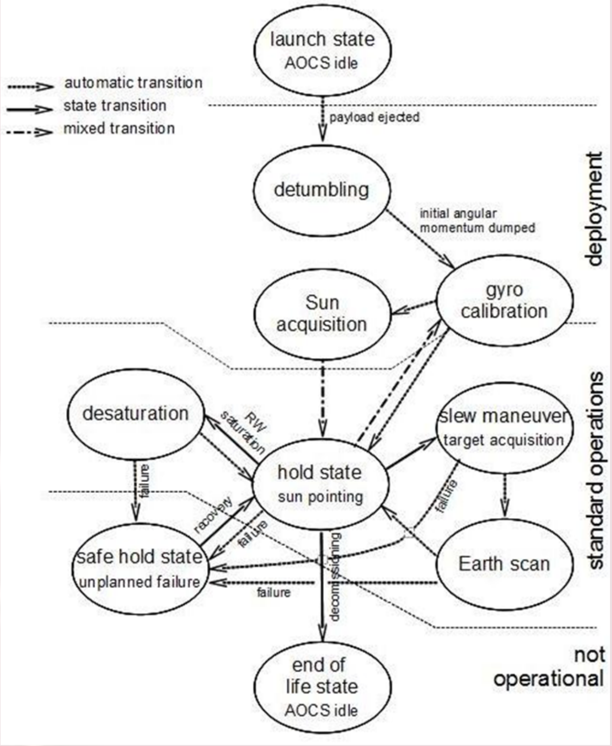


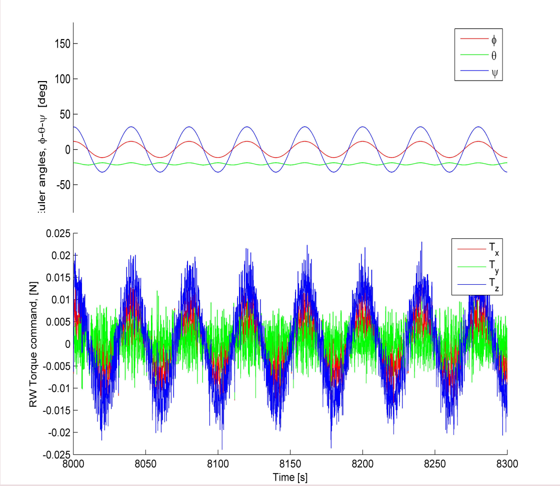
- Activities
  - Flight dynamics and aeroelasticity of flexible aircraft:
    - fully-coupled linear model linearized about aeroelastic trim conditions
    - State space formulation featuring rigid-body, elastic and aerodynamic state variables
    - Implementation using data from generic FEM solver
    - Unsteady aerodynamics modelled using a Double Lattice Method
  - Multi-disciplinary optimization fo the design of a sun-powered HALE UAV
    - requirement/constraint specification
    - Mission and performance analysis

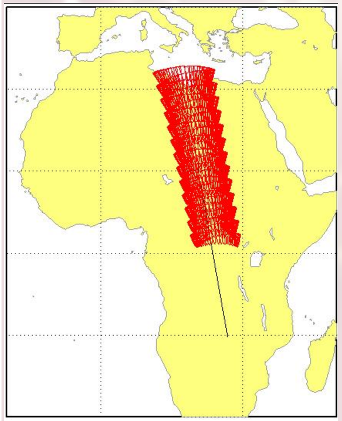


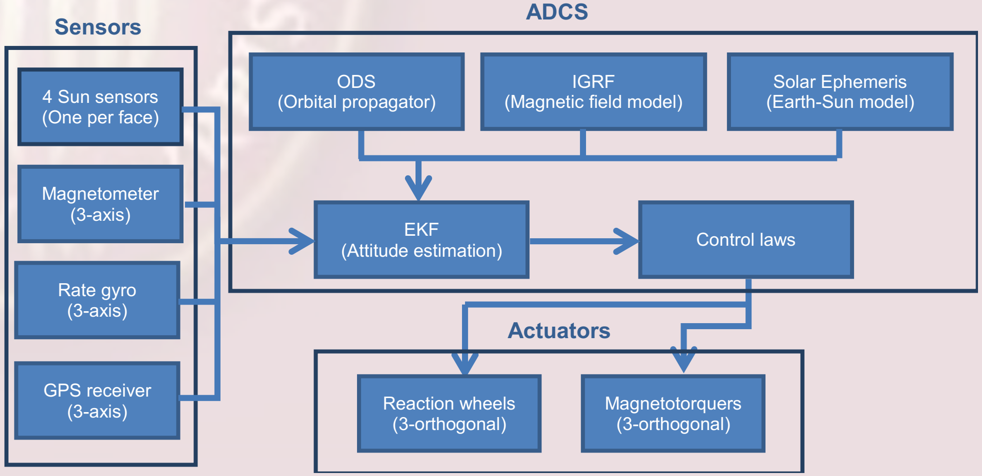
Attitude dynamics (2)

- ADCS design
  - The ACS stabilizes the spacecraft and orients it in desired directions during the mission
  - EKF for attitude determination
  - Automatic SW generation (C++)
  - Testing and validation using SITL, RT, HITL simulation (dSpace systems)



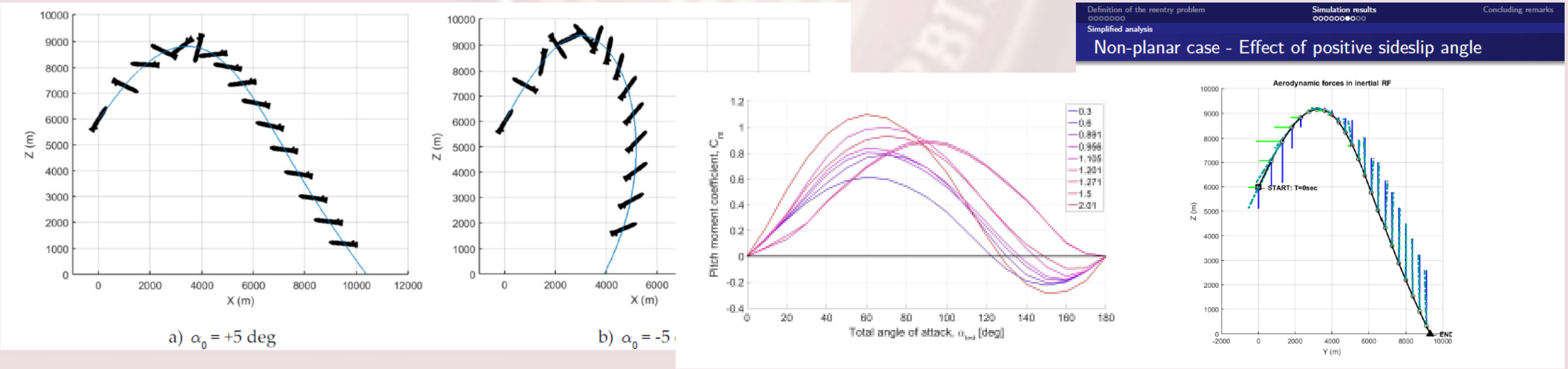






VEGA Launcher Fall Down Analysis

- DIMA personnel: Colasurdo, De Matteis, Zavoli
- Activities
  - analysis of the motion of a free-falling fragment of a launch vehicle from a given initial condition to its impact on the ground
  - interpret the simulation results and draw conclusions, based on the characteristics of the model, in order to support the activities carried out at ESA-ESRIN on the VEGA safety flight envelope analysis after P80 neutralization



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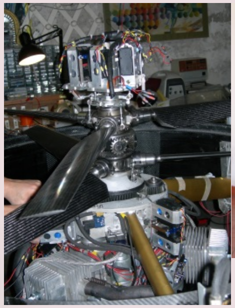
(Innovative) Small Vehicle Design and FCS Development

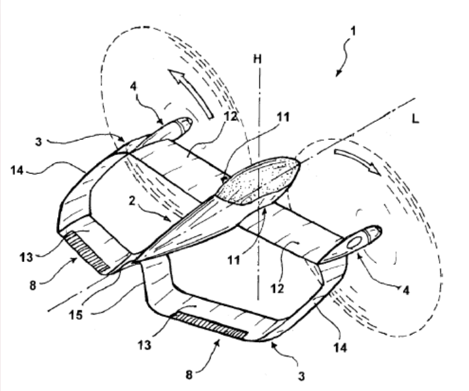
- DIMA personnel: De Matteis, a number of students
- Collaborations: Nardi, DIAG Robotics Lab
- Background (since ~ 2001):
  - Performance and stability of a ducted-fan UAV
  - Full envelope robust control of a shrouded fan UAV

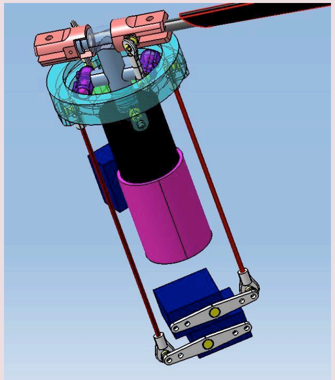


- Activities

✓ Design of a novel tail-sitter UAV configuration: the BoxRotor®, is a small electric VTOL UAS designed for close-range tactical operations

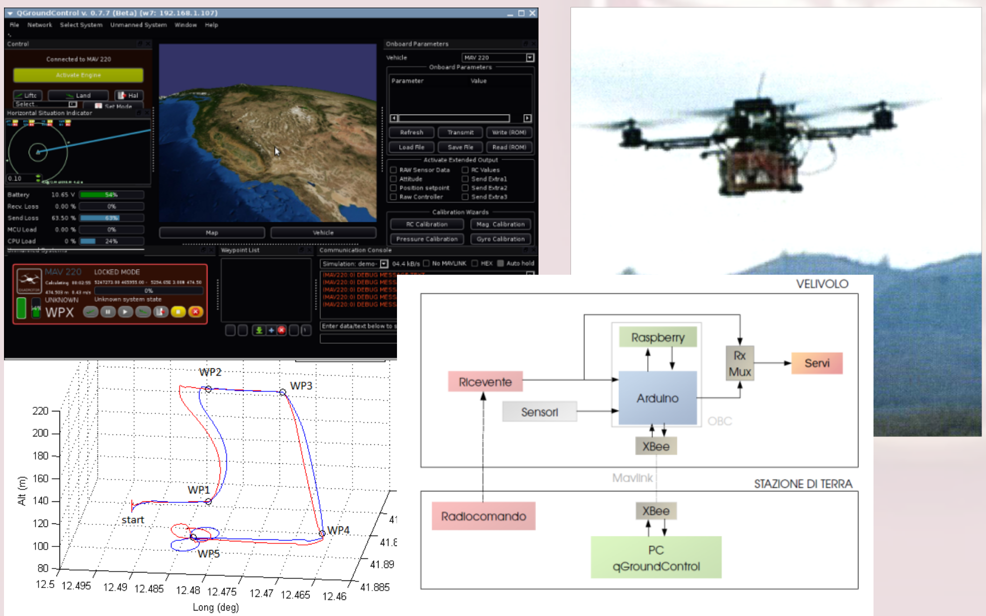
Main characteristics	
MTOM	5.1 Kg
Payload mass	0.5 Kg
Span	1.0 m
Length	0.8 m
Rotor diameter	0.7 m
Max. power	1.5 kW
Performance	
Endurance in hovering	30 min
Endurance in loiter	2 hr
Best range	55 Km
Max. speed	150 Km/h





Small Vehicle Development (2)

- Activities
  - Participation at the 2015 European Robotic Challenges (EUROC)
  - Design and validation of the FCS (mission manager) for small UAVs:
    - Algorithm design
    - HW and SW development
    - Testing by HITL simulation



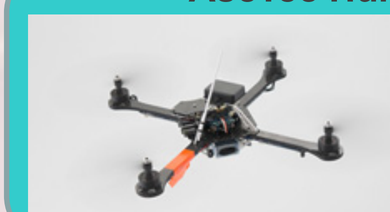
BERGEN INDUSTRIAL TWIN

Length: 1.5 m
h = 0.6 m
2 blades, b=0,81 m
MTOW = 200 N
Two-cylynder 52cc

YAK 112

b = 2.8 m
c = 0.4 m
S = 1.1 m^2
Length: 1.8 m
MTOW = 173 N
Single cylinder engine

AscTec Hummingbird



Size 54 x 54 x 8.6 cm
MTOW = 7 N
4 electric engines
HLP programmable using Simulink

Facility for Rapid Prototyping of (Flight) Control Systems (Flight Dynamics Lab via Tiburtina 205)

- DIMA personnel: De Matteis, Zavoli
- Activities
  - Real-time software implementation, Control system software testing, Control system functionality verification