Università degli Studi
di Napoli Federico II

I sistemi integrati di navigazione e gestione del volo

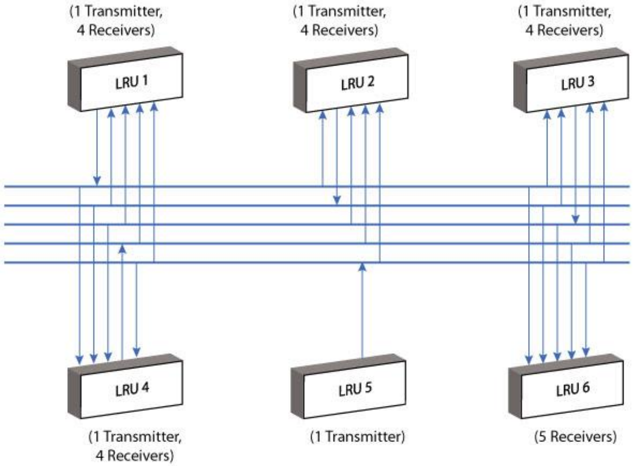
Seminari interdisciplinari di cultura aeronautica
Nuovi Impianti e sistemi di bordo, meccatronica e sistemi di missione e controllo
Aula “S. Bobbio”, Scuola Politecnica e delle Scienze di Base – 22 ottobre 2016

Outline

- Architecture;
- Applications
  - Navigation;
  - Situational awareness;
  - Flight Management;
- Historical remarks about onboard integrated systems;
- Integration
  - Integrated Systems;
  - Data Fusion;
- Integrated systems worldwide;
- Integrated systems experiences at UNINA;
- Conclusion;
- Spunti di riflessione (in Italian).

ARCHITECTURE

- Most onboard systems are located in the “Avioncs Bay”, i.e. a rack with several avionics units;
- The systems installed in the rack are called Logic Replacable Units LRU;
- Each unit can perform onboard data exchange by means of a deterministic data bus, i.e. a data network, such as ARINC 429, ARINC 629, and MIL 1553.

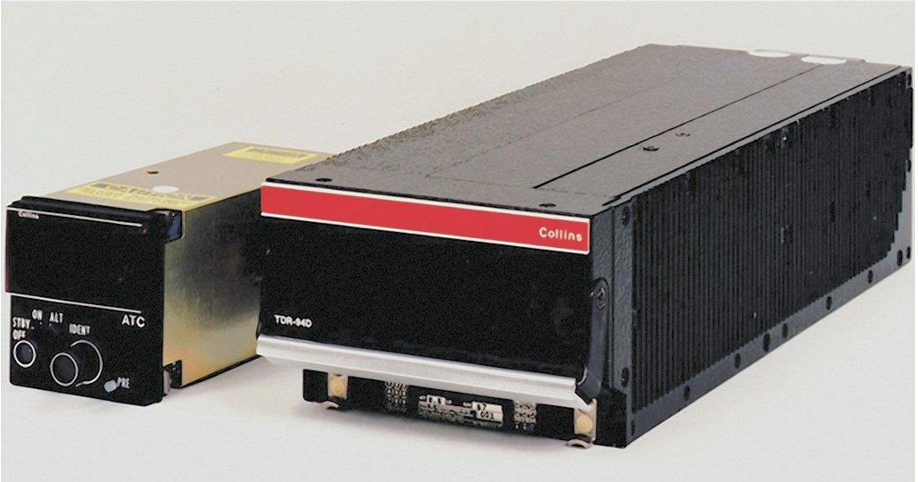


APPLICATIONS

Navigation

- Radio Navigation Services
  - Terrestrial
    - VOR;
    - DME;
    - NDB/ADF;
    - ILS;
    - TACAN;
  - Satellite/Augmented
    - GNSS (GPS, GALILEO, GLONASS);
- Inertial
  - AHRS;
  - INS;
- Autonomous Systems
  - Radar Doppler Altimeter;
  - Magnetometer;
  - Air Data System;
- Navigation Indicators and Displays
  - Basic T;
  - EFIS (PFD, NFD).

- Surveillance (separation and collision avoidance)
  - 1090 MHz Transponder
  - ADS-B
  - TCAS
  - TAWS
  - GPWS
- Communications
  - Voice
    - VHF Radio
    - HF Radio
  - Digital
    - VDL
    - ACARS
- Emergency
  - ELT



Flight Management

- Data bus (ARINC 429, ARINC 629, MIL 1553);
- Flight Management System;
  - End effectors;
  - Autopilot;
  - Control of actuators (flight control surfaces, landing gear, etc.);
- Fuel System;
- Engine Monitoring System;
- Electric Power System.

HISTORICAL REMARKS

EARLY YEARS

- Available stuff: barometer, anemometer, angle of attack vanes, magnetometer, fuel-quantity gauges;
- 1920 Voice Radio;
- 1929 Dolittle Radio Assisted “Blind Flight”;
- 1930 Introduction of NDB
- World War II:
  - IFF transponders;
  - VOR;
  - ILS;
  - LORAN.
- In the year 1947, ICAO was formed and introduced international regulations.
- 1950: Development of DME

Aircraft Equipped with 1st generation avionics

- 1947 MD DC-6
- 1953 MD DC-7
- 1954 Boeing 707
- 1955 MD DC-8
- 1963 Boeing 727
- 1965 MD DC-9
- 1967 Boeing 737
- 1969 Boeing 747
- 1970 MD DC-10
- 1983 MD 80

2.1.1 Cockpit Regulations

Regulations and standards influence not only what appears in the cockpit, but also its arrangement. Requirements for the certification of aircraft are contained in the Federal Aviation Regulations (FARs). Many sections of FAR Part 25 specify what equipment is required on transport category aircraft and where the equipment is to be placed.

FAR Part 25, section 1303 gives the layout requirements of basic flight instruments. The arrangement of flight displays describes a "T" configuration which is found in the older analog cockpits such as the Boeing 727 or McDonnell-Douglas DC-9. In the modern glass cockpits, such as the McDonnell-Douglas MD-11, these functions have been integrated into one display called the Primary Flight Display (PFD). Figure 2.1-1 shows the basic layout of information for the PFD.

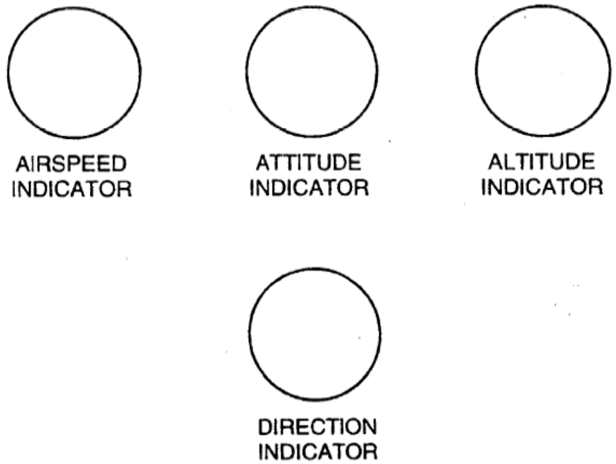
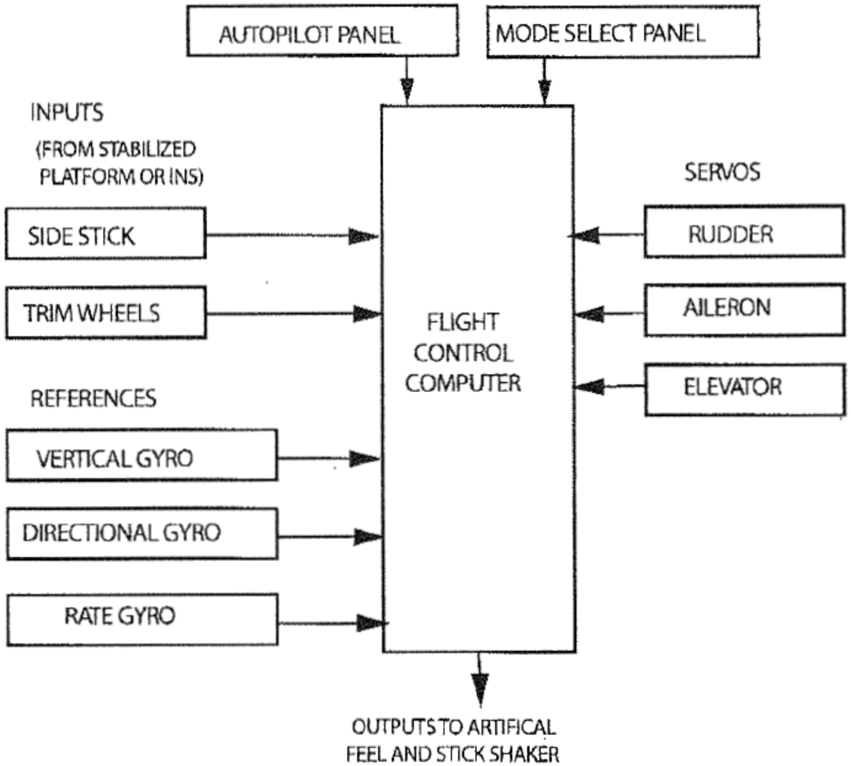


FIGURE 2.1-1. PRIMARY FLIGHT DISPLAY LAYOUT

1970 - DC-10 Traditional cockpit

- High-performance microprocessors and microcontrollers;
- High-performance electric motors;
- Deterministic data buses (ARINC 429 – ARINC 629 – ARINC 829 – MIL 1553);
- Fly-by-wire architecture;
- Availability of novel display technologies: CRT, LCD, LED + Touch.

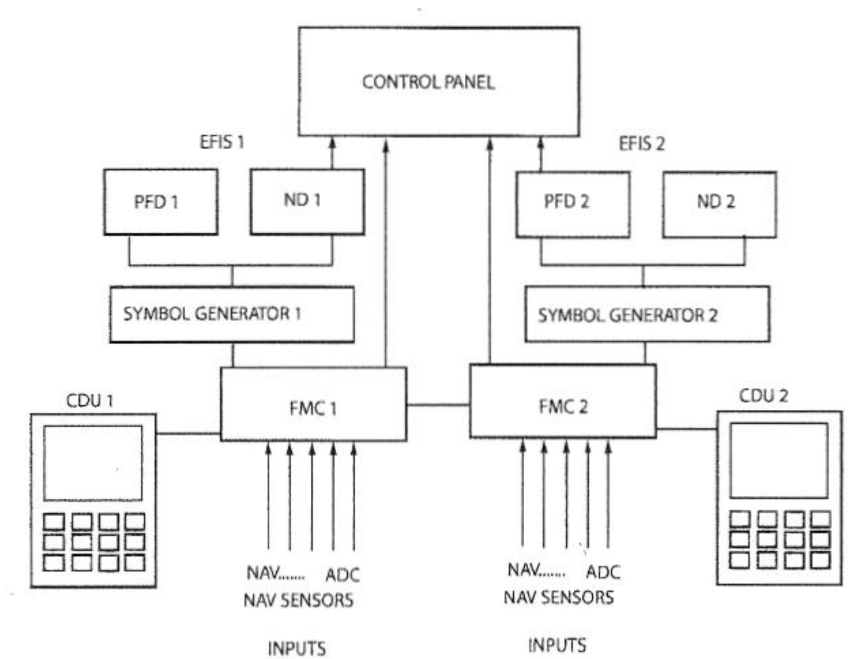


EFIS - Glass Cockpit

Electronic Flight Instrument System

- Primary Flight Display;
- Multi-Function Display/Navigation Display;
- Engine Indications and Crew Alerting System (EICAS)/Electronic Centralized Aircraft Monitoring (ECAM);
- Input System (Keyboard, Trackball, Touch Screen).

Fly-by-wire technology.



PFD = Primary Flight Display
FMC = Flight Management Computer
ND = Navigation Display
CDU = Control/Display Unit

1983 - B757 1st generation glass cockpit

1988 - A320 2nd generation glass cockpit

First large scale example of “Fly-by-wire”

Joystick replaces Control Stick

1998 - Gulfstream GV glass cockpit on GA aircrafts

2005 – Airbus A380

2009 – 787 glass cockpit

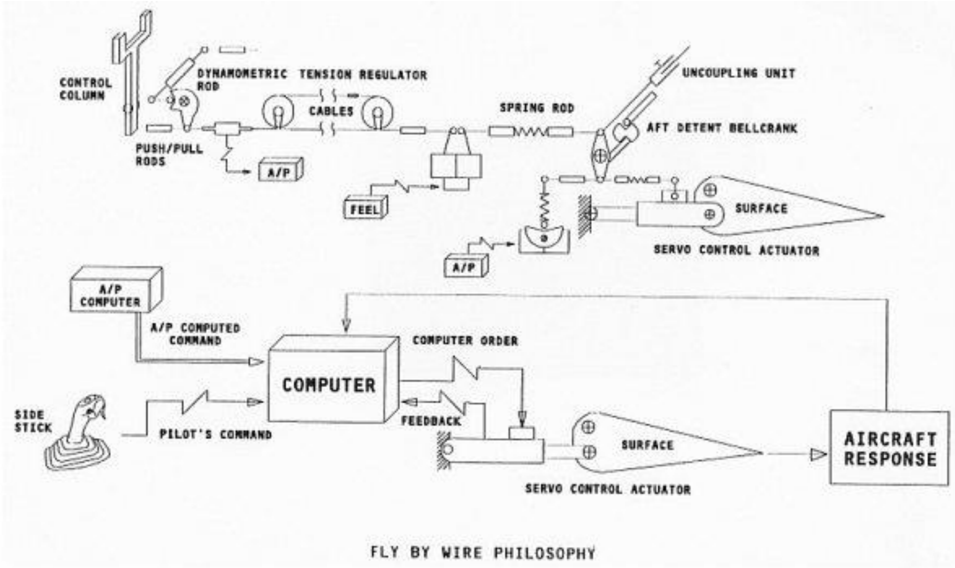
INTEGRATION

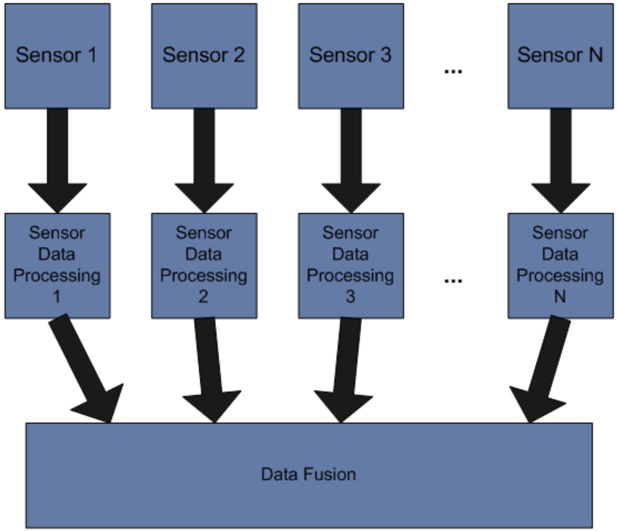
Dual layer approach

- Hardware – Integrated Systems;
- Software – Data Fusion.

Advantages

- Reduced pilot workload;
- Reduced nuisance;
- Increased awareness;
- Increased reliability.





Enabling technologies

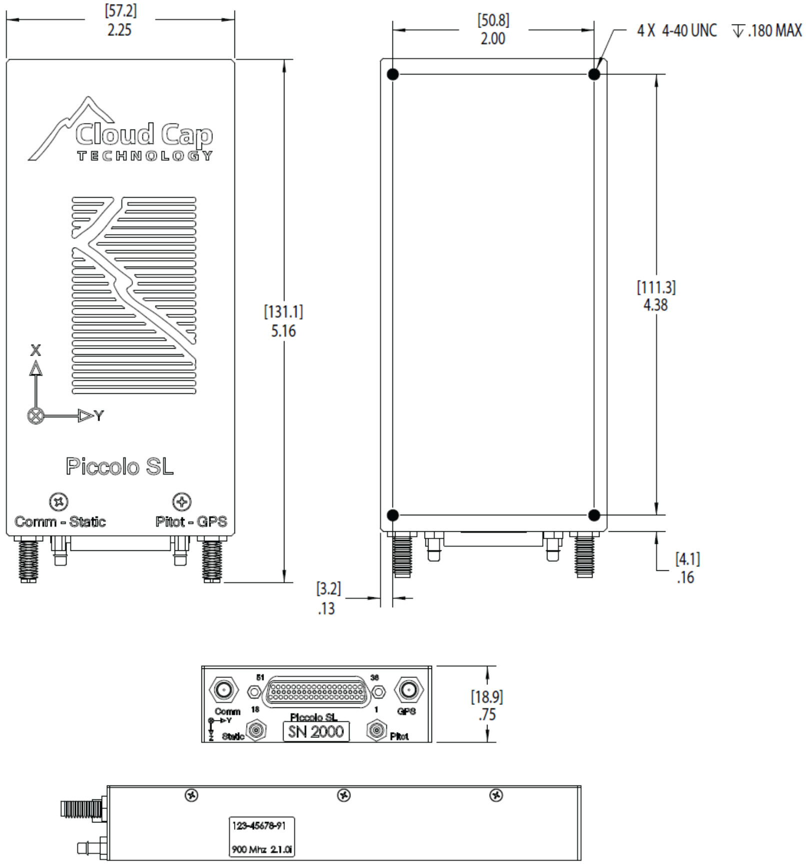
- Fly-by-wire;
- Deterministic Data Buses (ARINC 429 – ARINC 629 – ARINC 829 – MIL 1553);
- LCD displays with touch;
- Digital communications;
- GNSS;
- ADS-B;
- Digital communications;
- TCAS;
- GPWS.

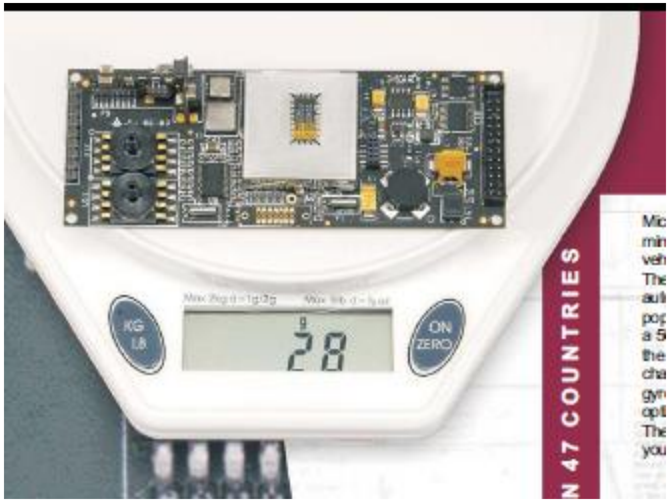
- Data fusion is used to produce synthetic information from multiple sources;
- Data fusion algorithms help to reduce pilot and crew workload and risk of misunderstandings;
- The goal is to display the no more than information needed for taking decisions.

- Information that can exploit data fusion:
  - Navigation (inertial, GNSS, terrestrial radio aids, Doppler radar)
  - Surveillance (TCAS, ADS-B)
  - On-board diagnostics.
- Methods for sensor data fusion
  - Kalman Filter;
  - Advanced Filters;
  - Voting.

Beyond Civil Aviation - UAS Avionics

Dimensions in [mm] inches





Eurofighter Typhoon

F35

- Performance based navigation:
  - Large use of GNSS;
  - Curved approach;
  - Bypass of DME capacity limitations;
- Self separation:
  - ADS-B;
- Integration of Unmanned Aircraft into Traffic:
  - Sense and Avoid;
  - Safe Flight Termination;
- Integrated Modular Avionics (LRU can share functions to increase reliability).

- Rockwell-Collins Pro Line Fusion

- Honeywell Primus

- Thales ODICIS

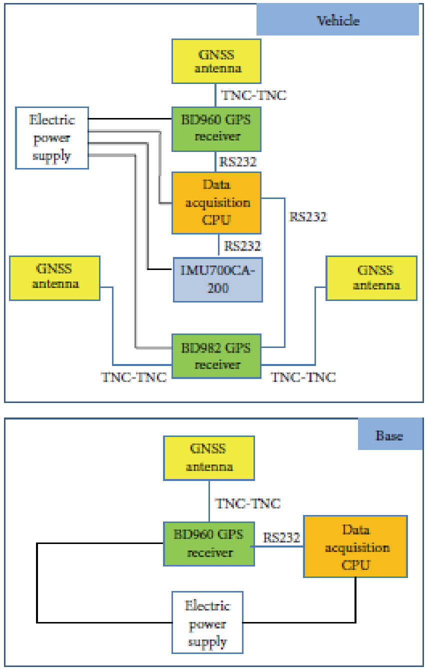
- GARMIN G1000

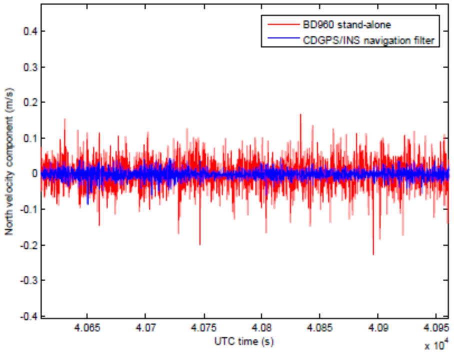
- Avidyne Entegra

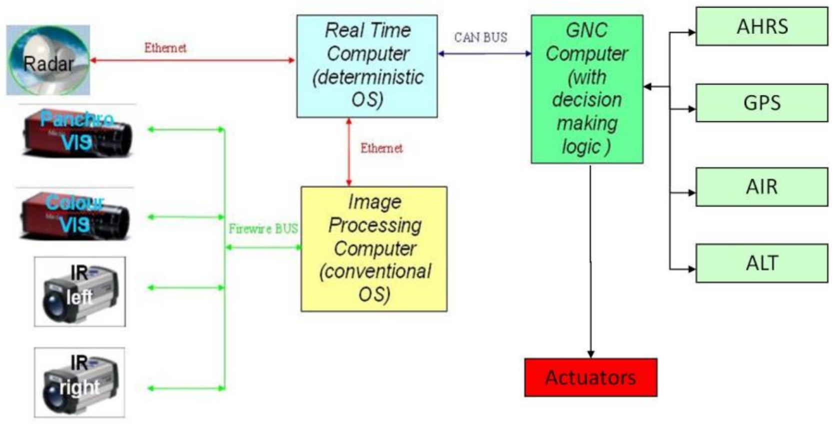
- Aspen Avionics Evolution 2500

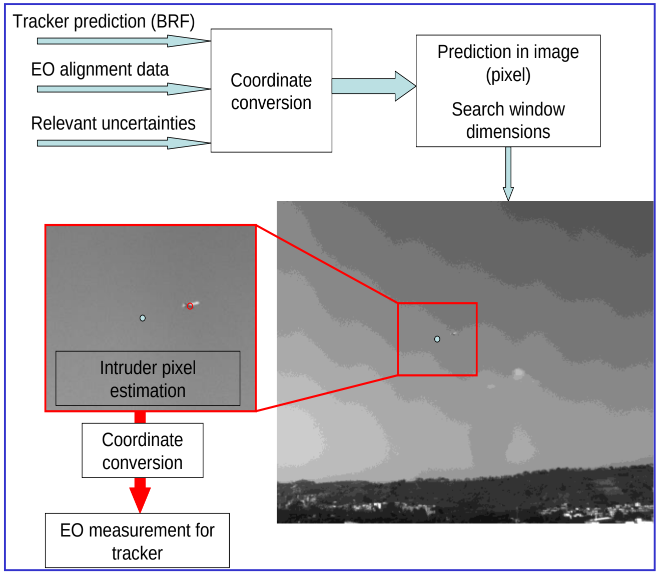
INTEGRATED SYSTEMS EXPERIENCES AT UNINA

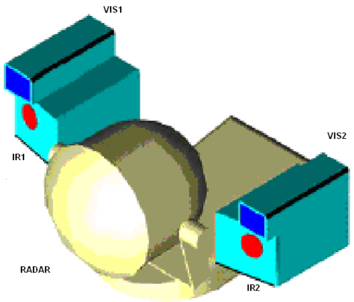
- AHRS performance evaluation integrating multi-antenna carrier phase differential GPS and inertial systems – In cooperation with GMA



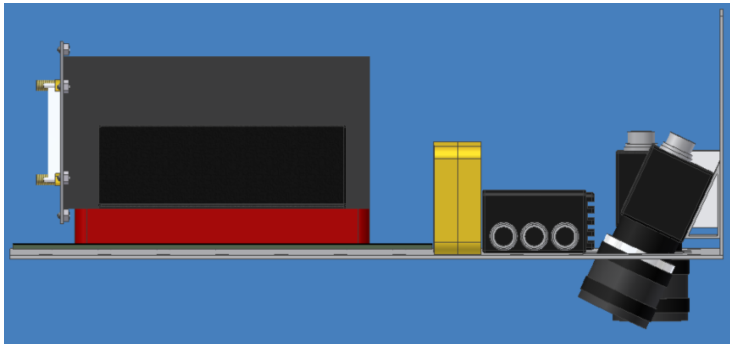



Radar
Ethernet
Real Time Computer (deterministic OS)
CAN BUS
GNC Computer (with decision making logic)
AHRS
GPS
AIR
ALT
Panchro VIS
Colour VIS
IR left
IR right
Ethernet
Firewire BUS
Image Processing Computer (conventional OS)
Actuators


Tracker prediction (BRF)
EO alignment data
Relevant uncertainties
Coordinate conversion
Prediction in image (pixel)
Search window dimensions
Intruder pixel estimation
Coordinate conversion
EO measurement for tracker

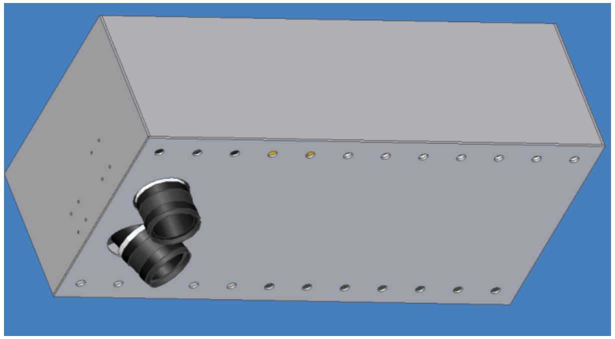

VIS1
VIS2
IR1
RADAR
IR2

SISTS Onboard Unit

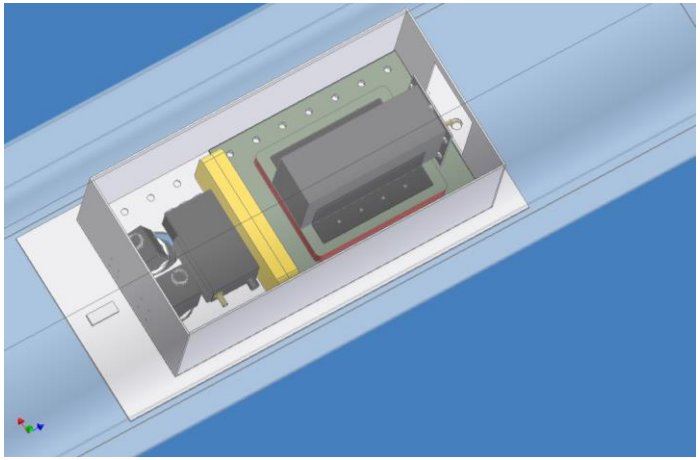


Lateral view of GN&C system and payload

Lateral view of UAV fuselage with GN&C system and payload installed



Payload enclosure



GN&C system and payload enclosure installed into UAV fuselage

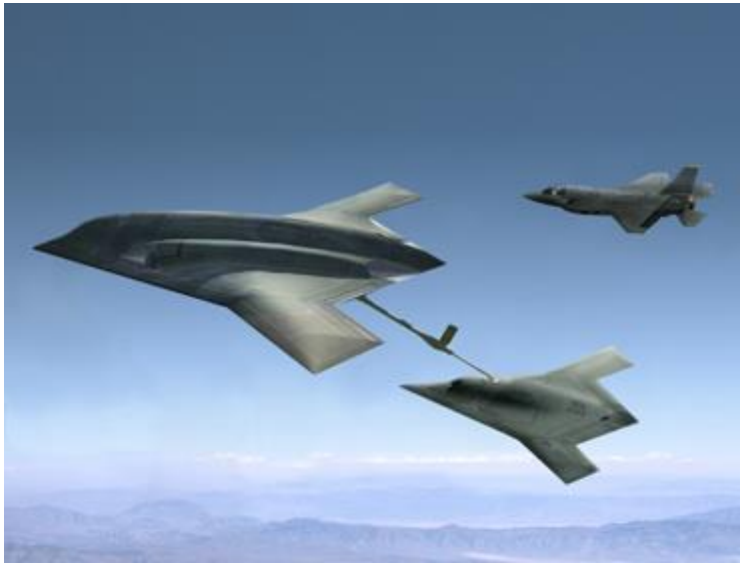
SISTS UV100

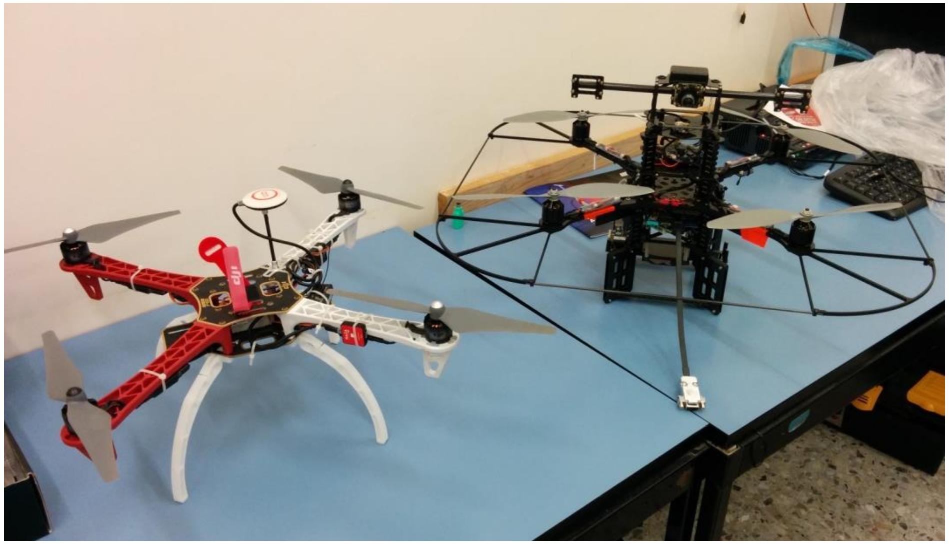
AIRCRAFT SPECIFICATIONS

Parameter	Value
Wing span	3 m
Fuselage length	3 m
MTOW	300 N
Payload Weight	60 N
Maximum fuel capacity	5 kg
Propeller power	10 Hp
Maximum ground speed at sea level	200 km/h
Takeoff distance	50 m
Autonomy	1 h

- Original algorithms are being tested for cooperative navigation based on distributed GNSS, vision, and inertial sensors

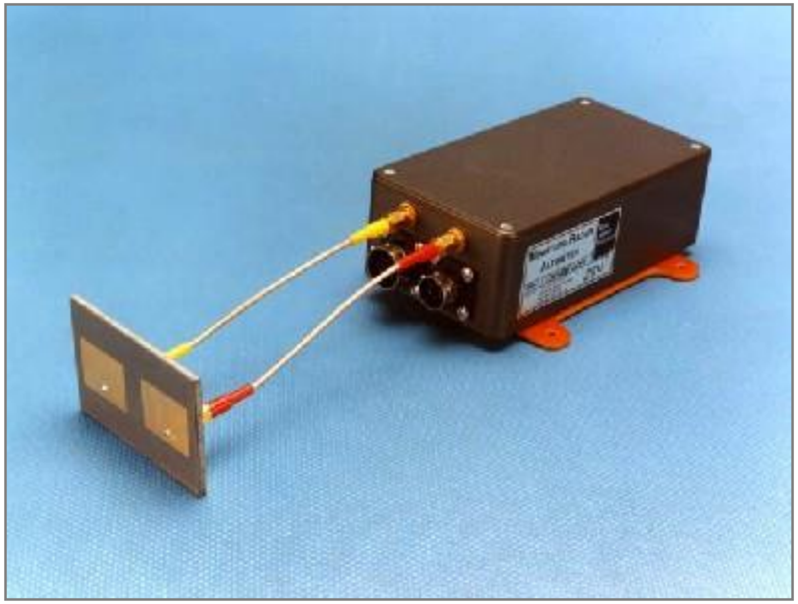
- Rotary wing and fixed wing micro UAVs are used as test platforms





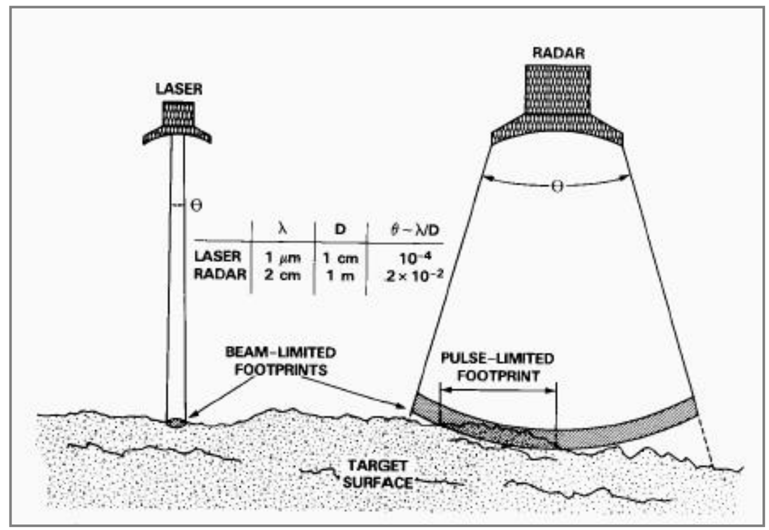
- The UNINA- DII (former DIAS) Aerospace Group supported CIRA for its Autonomous Take Off and Landing (ATOL) project;
- The project involved flight testing an Autonomous Flight Control System for UAVs onboard a small platform;
- UNINA supported CIRA in the following activities:
  - Selection of altimetric sensors (in cooperation with CoRiSTA);
  - Developement of a real time Integrated Navigation System based on sensor data fusion by Kalman Filtering;
  - A study on GPS accuracy applied to UAV landing requirements.

ATOL altimetric hardware



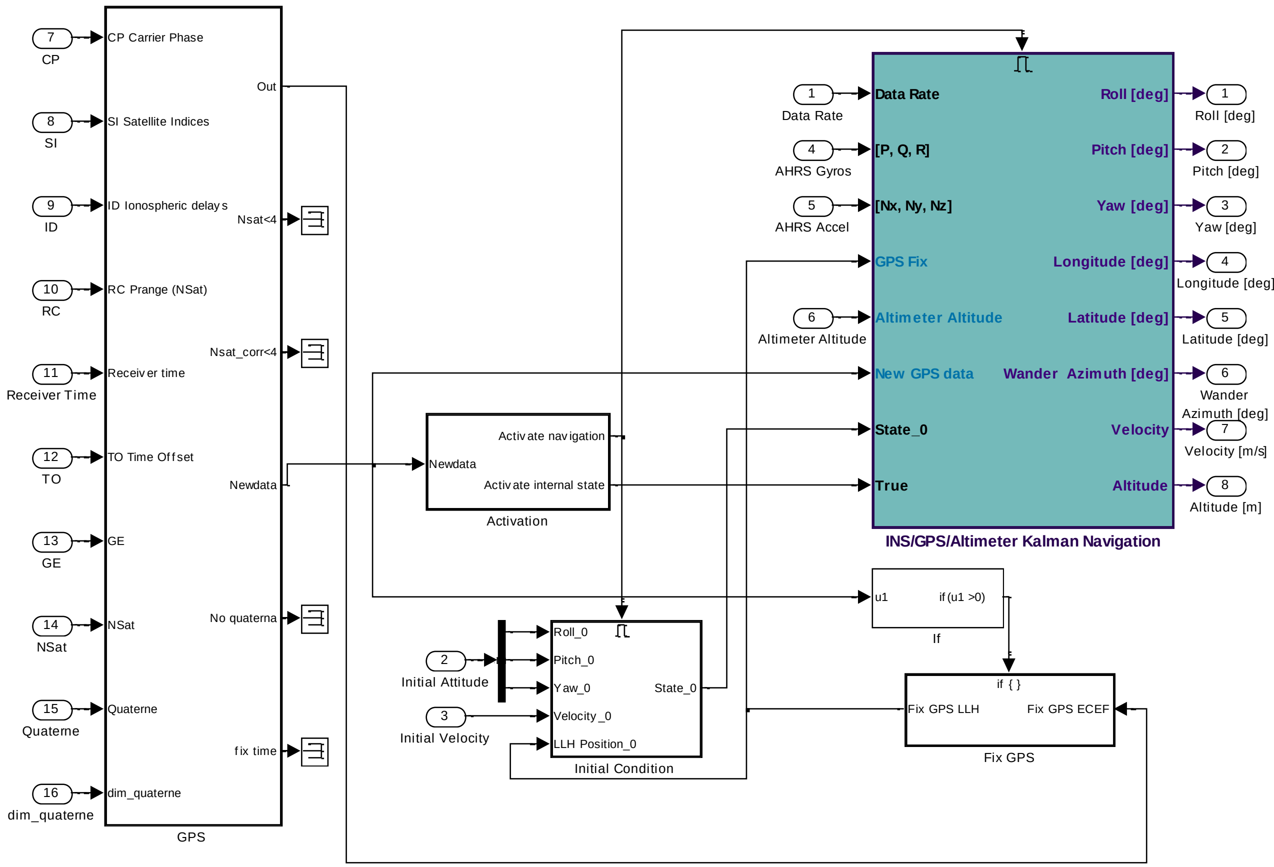
The Aerospace System Group at UNINA and CoRiSTA supported CIRA in the following activities:

- Selecting a radar altimeter and a laser altimeter adequate to be installed onboard a small UAV;
- Developing real time software to extract ground altitude from raw sensor data;
- Performing an error budget analysis of sensor output.



Data Fusion GPS/INS & Altimeter

- Data fusion algorithm based on 9-dimensional Extended Kalman Filter integrating inertial unit,GPS, magnetometer, and altimeter;
- Algorithms coded for Mathworks™ Simulink™ and integrated in a real time CPU
- The algorithm was tested in flight



- A drone testing facility, i.e. a netted area, is under construction at UNINA San Giovanni a Teduccio facility;
- It will be a part of Centro Studi Metrologici Avanzati (CeSMA).

- Development of Aircraft Flight Trajectory Prediction tool for an enhanced Flight Data Processing (eFDP) system;
- The above described activity software has been registered with an International Patent by Selex SI S.p.A. (patent no. US20120158220A1)
- http://www.google.com/patents/US20120158220

- Project HALA! (www.hala-sesar.net)
- The group is a member of the Internetional Research network named HALA! (Higher Automation Levels in Aerospace) funded by EUROCONTROL in the framework of the European Joint Undertaking SESAR;
- A PhD grant has been funded by HALA! to investigate the application of advanced filtering techniques, i.e. Particle Filters and Unscented Kalman Filters, to increase the performance in estimating the collision status by exploiting autonomous sensor measurements.

- Development of aircraft integrated systems has been presented;
- The availability of enabling technology determined the innovations in terms of cockpit;
- Current cockpit exploit data fusion in order to maximize performance;
- Future systems will increase the level of autonomy.

- Le tecnologie dei sistemi sono tecnologie aerospaziali a contenuti avanzati, ma sono light dal punto di vista dei costi industriali (trasporti, consumi di energia, logistica);
- In altri paesi (USA, Australia, Giappone) lo sviluppo di tecnologie di sistemi di bordo ha fornito nuova linfa a regioni che vivevano con più difficoltà la crisi aerospaziale;
- Grazie allo sviluppo di nuove forme di trasporto aerospaziale (droni, personal aircraft, ecc…) è possibile pensare di profittare di un "salto generazionale" di tecnologia, così come è capitato alla telefonia mobile in Cina;
- In Campania, sono presenti diverse realtà impegnate nei sistemi di bordo: imprese piccole, medie e grandi, centri di ricerca, università;
- Domanda: è pensabile "Produrre i sistemi facendo sistema"?