Acquisition and processing data in long-term aerospace missions

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Introduction

Aerospace mission: a mission performed by a flying vehicle which takes place in the atmosphere of Earth (aeronautics) or surrounding space (astronautics).

Great interest in **unmanned** aerospace missions due to:

- ***low risks***: no humans on the vehicle;
- ***low costs***: smaller and lighter structures, no human load;
- possibility of ***long-term missions.***

Typical aerospace missions can be:

- scientific missions: satellites, air balloons, drones with scientific instrumentation on board.
- rescue missions: drones in earthquake, avalanche, fire, flood scenarios to help human intervention.
- military missions: satellites, drones to spy or hit enemy territory.

Challenges

Monitor of the environment

Environmental sensors provide useful data to understand the operating conditions of the vehicle and of the instrumentation: redundancies, priorities, etc. must be managed.

Real-time control of vehicle

Flight and route stability imply a continuous processing of environmental and telemetric data to provide automatic or remote corrections.

Management of a remote system

The instrumentation, remote and/or in hostile environment, should autonomously manage its operation and errors but also should guarantee the human remote access.

Minimize power consumption

Unmanned vehicles don't have an unlimited source of energy; therefore it needs to optimize all the operations in order to minimize the consumption.

Communication with ground base

The vehicle must be in contact with the ground base and exchange telemetry and commands with it. Eventually it must be possible to communicate with multiple bases.

Data transmission

The bandwidth for data transmission is limited; this impose an intelligent filter on data to prioritize them and first select interesting events.

Solutions

Internet of Things (IoT) applied to the network: system of sensors communicating with a CPU and the ground base that in turn make appropriate operations according to the set of collected information.

Artificial Intelligence (AI) applied to the recognition of interesting data in such a way to keep only useful data and to assign them an appropriate level of priority.

Low level programming and optimization.

Client-server design pattern to send commands from the ground base and to receive either data or answers to commands.

Monitor of the environment

Real-time control of vehicle

Management of a remote system

Data transmission

Minimize power consumption

Communication with ground base

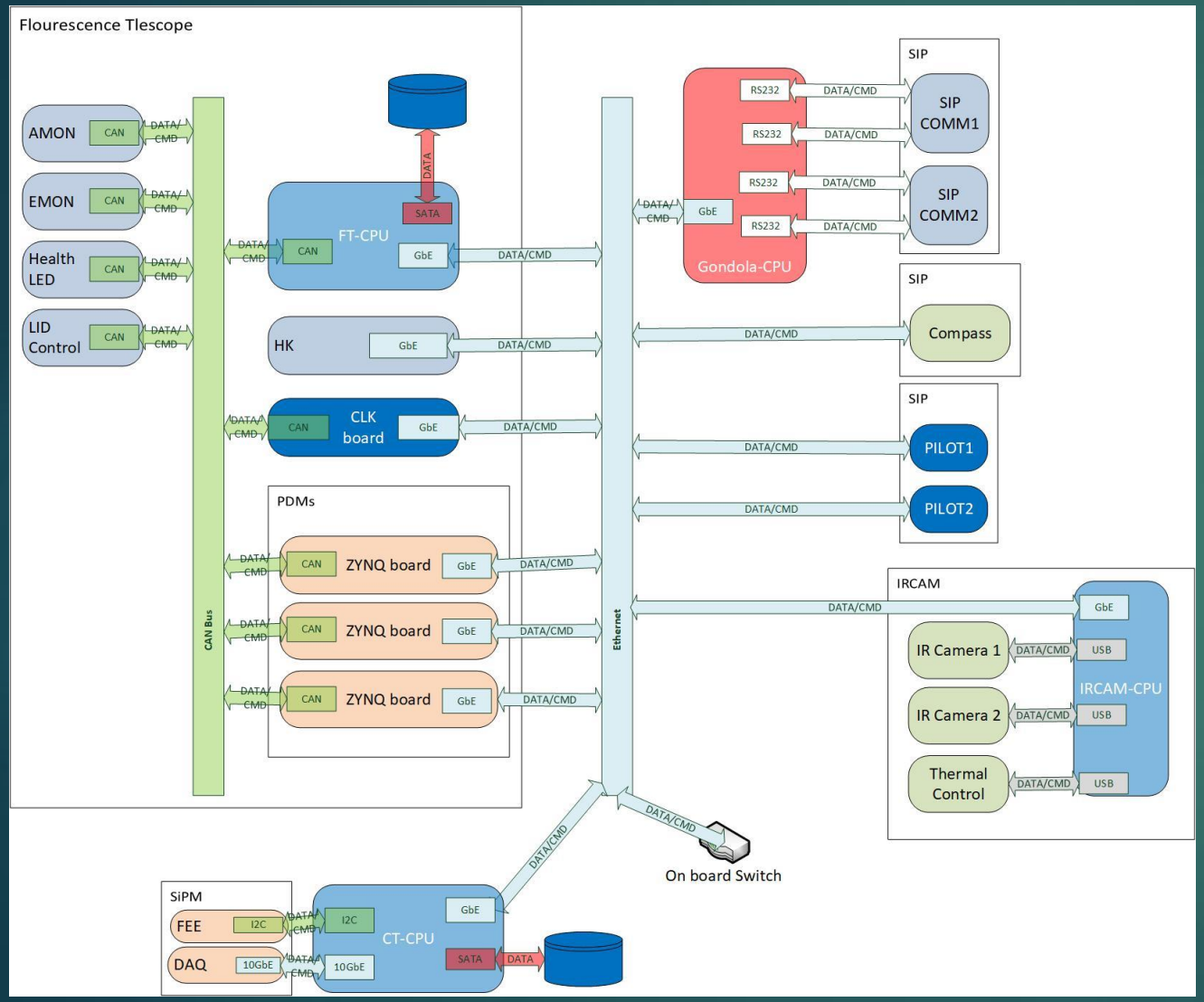
EUSO SPB2 MISSION

Extreme Universe Space Observatory on a Super Pressure Balloon 2

- Successor of SPB1 (2017), it is a scientific and technical sub-orbital precursor for the Probe of Extreme Energy Multi-Messenger Astrophysics (POEMMA), which main goal is to discover the nature and origin of the highest energy particles in the universe [1].
- Long-term unmanned mission: ~ 100 days in flight (expected) at about 33 km a.s.l. on an air balloon.
- Case study in which to test the solutions at the challenges.
- The Bari section of INFN is committed to design and develop the software of the CPUs.

[1] L. Wiencke and A. Olinto for the JEM-EUSO and POEMMA Collaboration, "The Extreme Universe Space Observatory on a Super-Pressure Balloon II Mission", *Proceeding of the 36th ICRC*, PoS (ICRC2019) 466.

Euso SPB2 mission



Data Processor (DP) of the Fluorescence Telescope (FT)

High level of complexity:
many sensors and subsystems to control, using different hardware and software technologies.

Heterogeneous networks:
CAN bus (green): typical of industrial application, used for data and command exchange among the FT-CPU and different types of sensors and systems;

Ethernet (light blue): typical of Internet application (therefore IoT oriented), it allows the communication among different modules like telemetry system (SIP), IRCAM system, etc.

Euso SPB2 mission

Example of possible application of AI techniques in SPB2:

a. **Pattern recognition.** Events are collected in form of telescope focal plane images shoot every few microsecond (2.5 or 1 μs). Patter recognition techniques can be applied to filter data and select best track candidates (second level trigger). This for best usage of the limited data transmission bandwidth and implement an early warning on possible shower candidates.

Data transmission

b. **Predictive analytics.** The complex sensor network is needed to monitor the environment and guarantee an efficient data acquisition on best effort basis. Moreover critical situation must be avoided for detector safety, i.e. auto or functional range temperatures or high light background level. For this AI can be used to predict critical situation and prevent possible sensor damages.

Monitor of the environment

The usage of the above-mentioned techniques will be investigated and tested in this project.

INDUSTRIAL PARTNERS

The Distretto Tecnologico Aerospaziale scarl based in Brindisi will make available its experience and knowledge in the aeronautic field in order to transfer the solutions found for the EUSO SPB2 to drones.

During the period at Enginsoft UK Ltd based in Coventry (UK), knowledge and industrial methodologies will be acquired in the field of numerical analysis to construct mathematical models which will allow to provide a support for new choices to follow.

Doctoral activity

1st year

- Literature review
- Collection of requirements and constraint of EUSO-SPB2 mission
- Data analysis of the previous flight SPB1 to construct an environmental model and/or to recognize schemes useful for pattern recognition

2nd year

- Design of the architecture of the sensors
- Design of the acquisition data infrastructure
- Collaboration with DTA and Enginsoft

3rd year

- Characterization and test of the apparatus
- Data analysis of the SPB2 mission

Thank you