FIRE-RS Project

A Nanosatellite & UAVs hybrid system for wildfire characterization.

Fernando Aguado, Franco Pérez, Diego Nodar López, Alberto González, Miguel Castro

Rome 04/12/2017 – II Congreso de Ingnenierían Espacial

faguado@tsc.uvigo.es

Universidade Vigo

Introduction

Wildfires are natural processes which allow the regeneration of our forest and are an essential part of ecosystems. Currently, a forest fire is directly associated with a catastrophic phenomenon that devastates the nature and often causes human victims [1].

- one of the greatest threats and environmental disasters that occur annually in the European territory
- the most effective way to combat this disaster is through prevention
- once it occurs, it is necessary to act quickly and effectively to minimize damage to the environment
- the area burned Europe during 2015 was around 1 million hectares; Spain, one of the most affected countries, with a total of 103200 hectares [2].

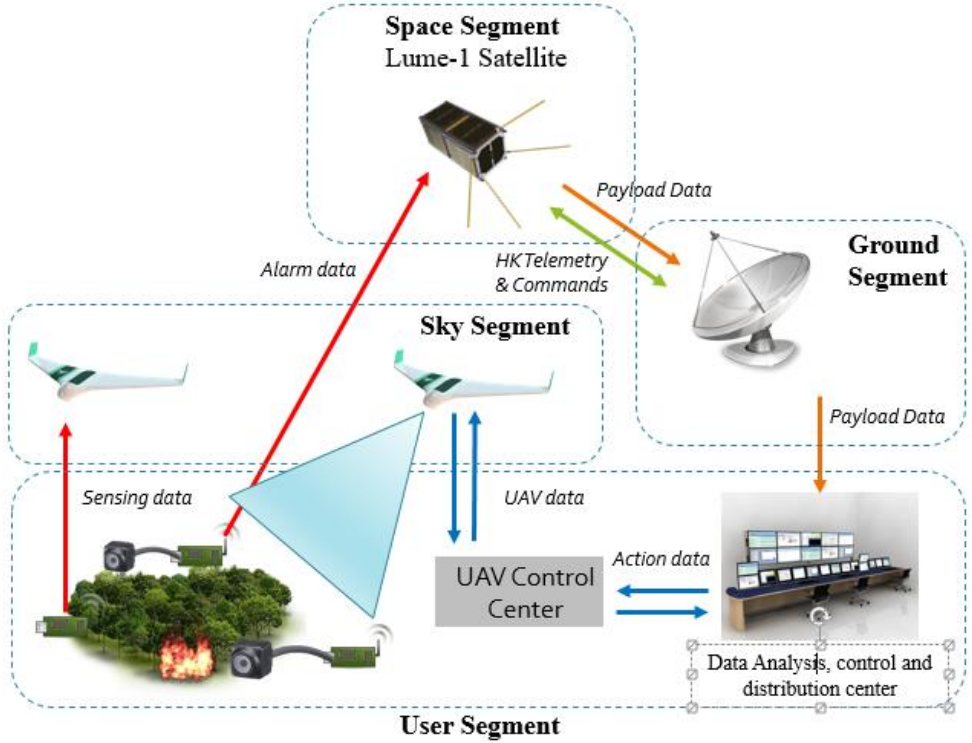
FireRs Concept

FireRS (acronym of wildFIRE Remote Sensing), is an innovative tool for prevention, detection and mapping of wild-land fires. This tool is obtained through the synergy of four technologies:

- **Infrared sensors** for fire in-situ detection
- **CubeSat satellite** for early warnings and communications coverage
- **UAV**s for high-accuracy fire mapping
- Situation **assessment** and **observation planning software**

Keywords: Wild land fire, CubeSat, UAVs, IR Sensors

FIRE-RS Project



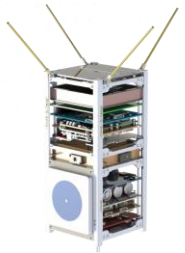
International project:
- Universidade de Vigo (prime contractor)
- Centre National de la Recherche Scientifique
- Universidade de Porto

Universidade de Vigo

U.PORTO FEUP FACULDADE DE ENGENHARIA UNIVERSIDADE DO PORTO

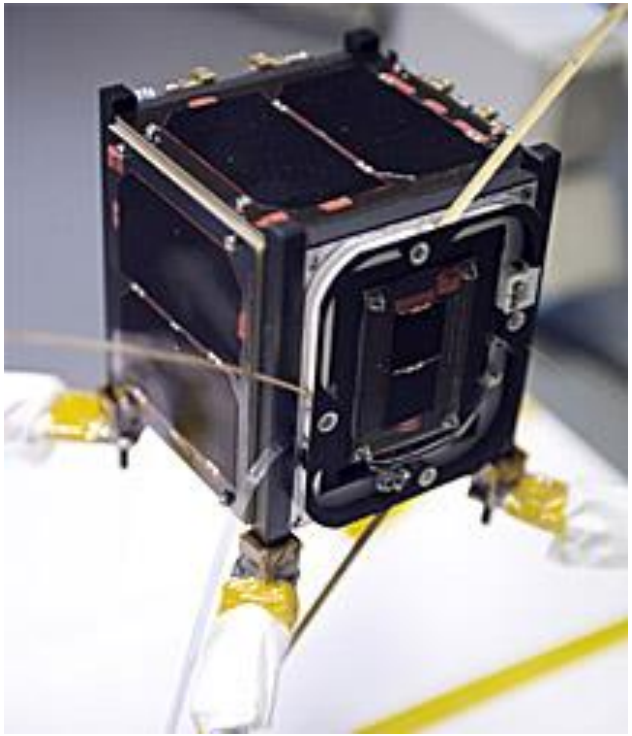
LAAS CNRS

UVIGO is developing:
- LUME-1 Spacecraft
- The Ground Segment
- Terrestrial sensors



UVIGO Background

UVIGO Background: Xatcobeo



- **First spanish cubesat (1U)**
- **Three Payloads**:
  - Software defined Radio (UVIGO).
  - Radiation Sensor (INTA)
  - Panel deployer mechanism (INTA).
- **Satellite developed tailoring the professional standards of the ESA (ECSS) with the support of INTA.**
- **Launch in inaugural Vega flight (13/02/2012)**
- **2.5 Years until re-entry**

UVIGO Background: Humsat-D

- **Second spanish cubesat (1U)**
- **Two Payloads**:
  - HUMPL (Messages communications system)
  - Radiation Sensor
- **Humsat Constellation demonstrator**
- **Launch in Dnepr (November 2013)**
- **1 Year of operation**

UVIGO Background: Serpens

Sector B

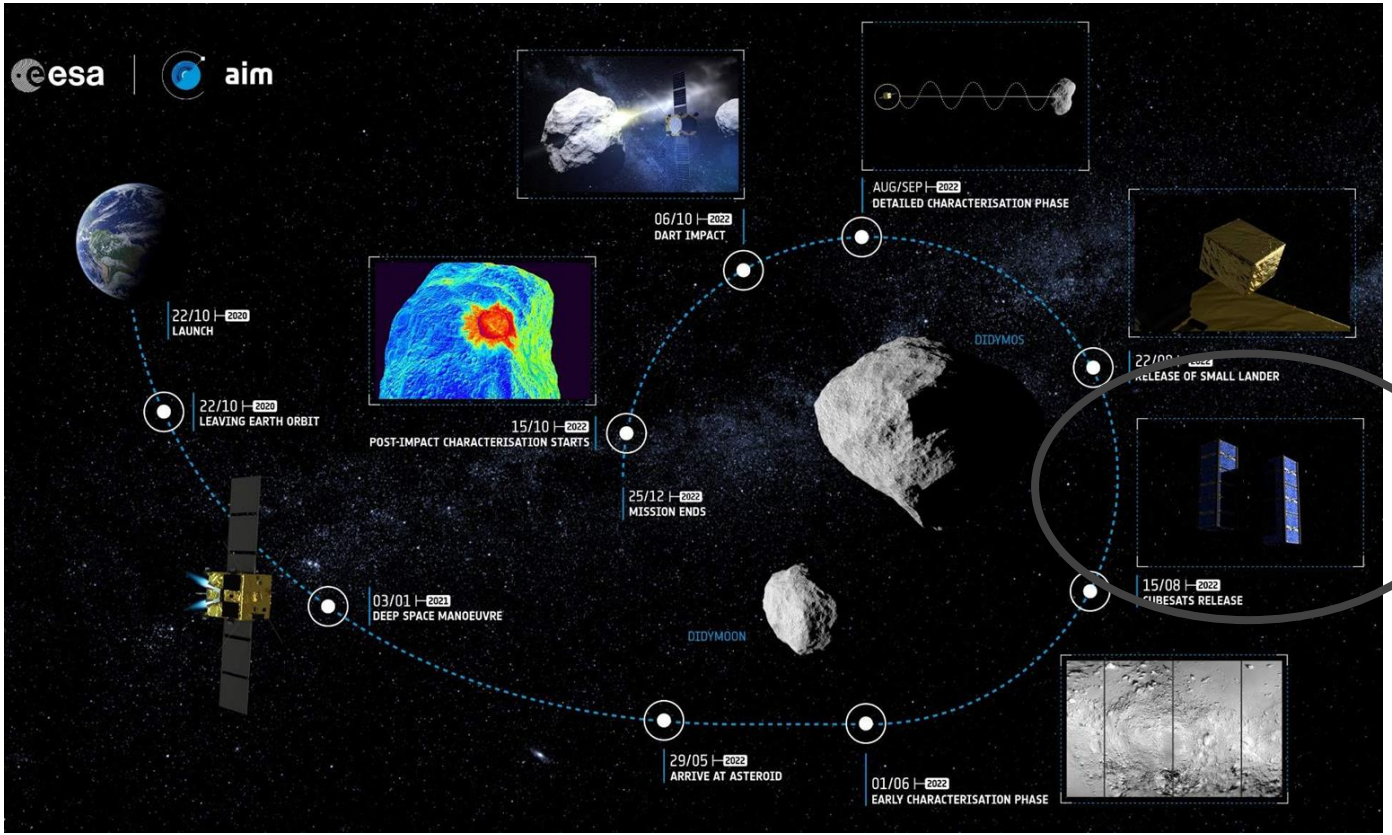
Humsat Satellite

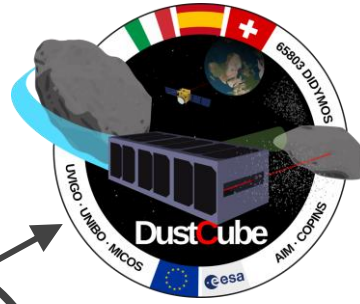
Sector A

Brazilian University Consortium

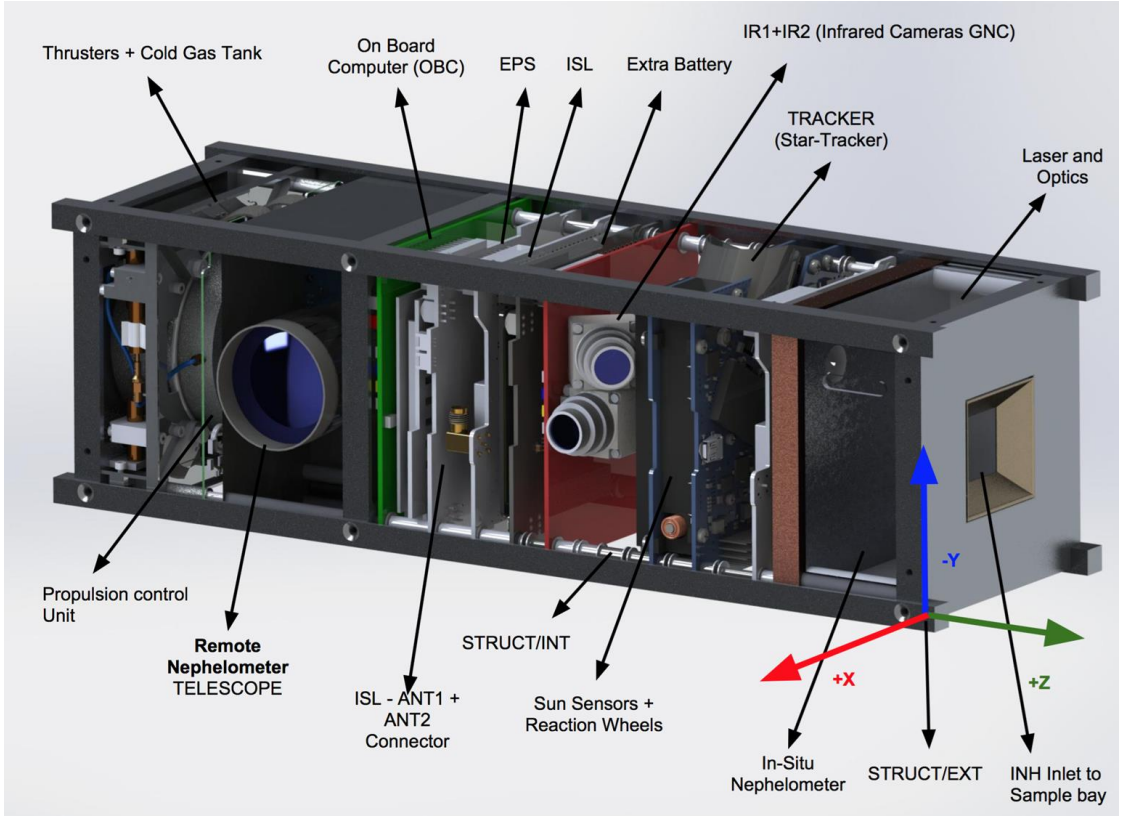
- **Third Cubesat of the Team (3U)**
- **Funded by Agência Espacial Brasileira (AEB)**
- **Two different sectors. Sector-B fully developed by UVIGO**
- **2º Humsat Constellation service tested over:**
  - Europe, South-America, EEUU, Antarctica
- **Launch from the ISS (19/08/2015)**
- **Re-entry at April 2016**
- **Automatic Operations, more than 50000 Telecommands executed by Serpens (Sector-B) until re-entry**

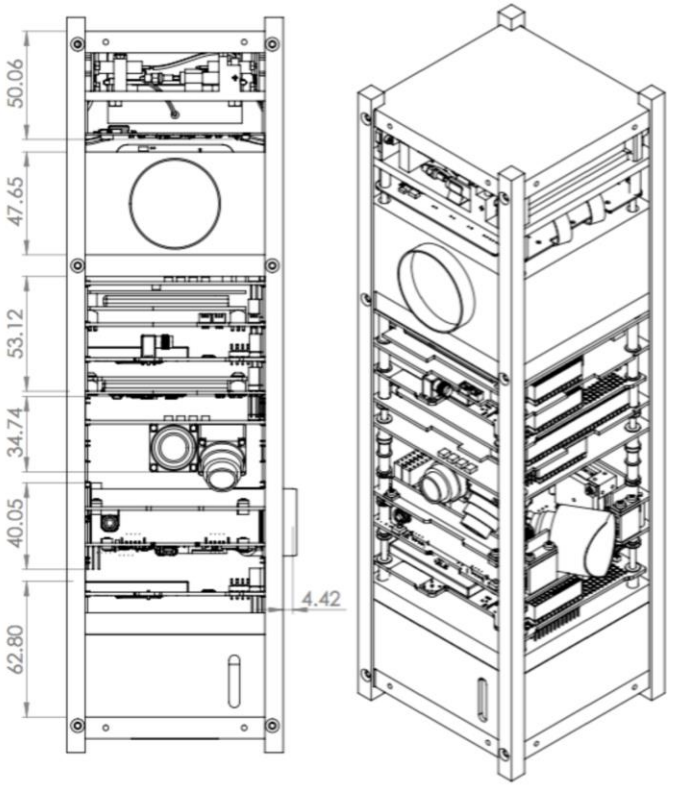
UVIGO Background: DustCube





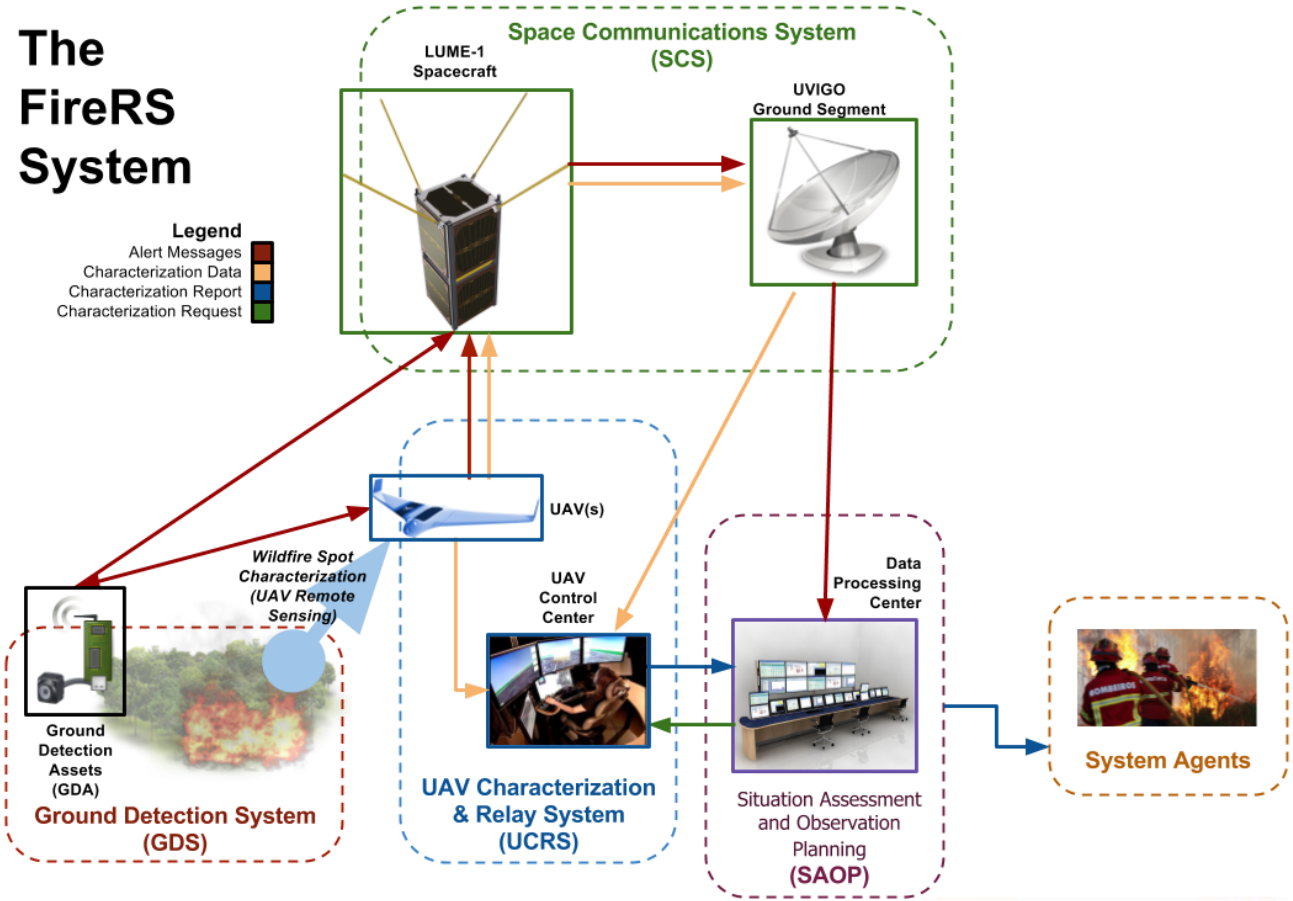
UVIGO Background: DustCube



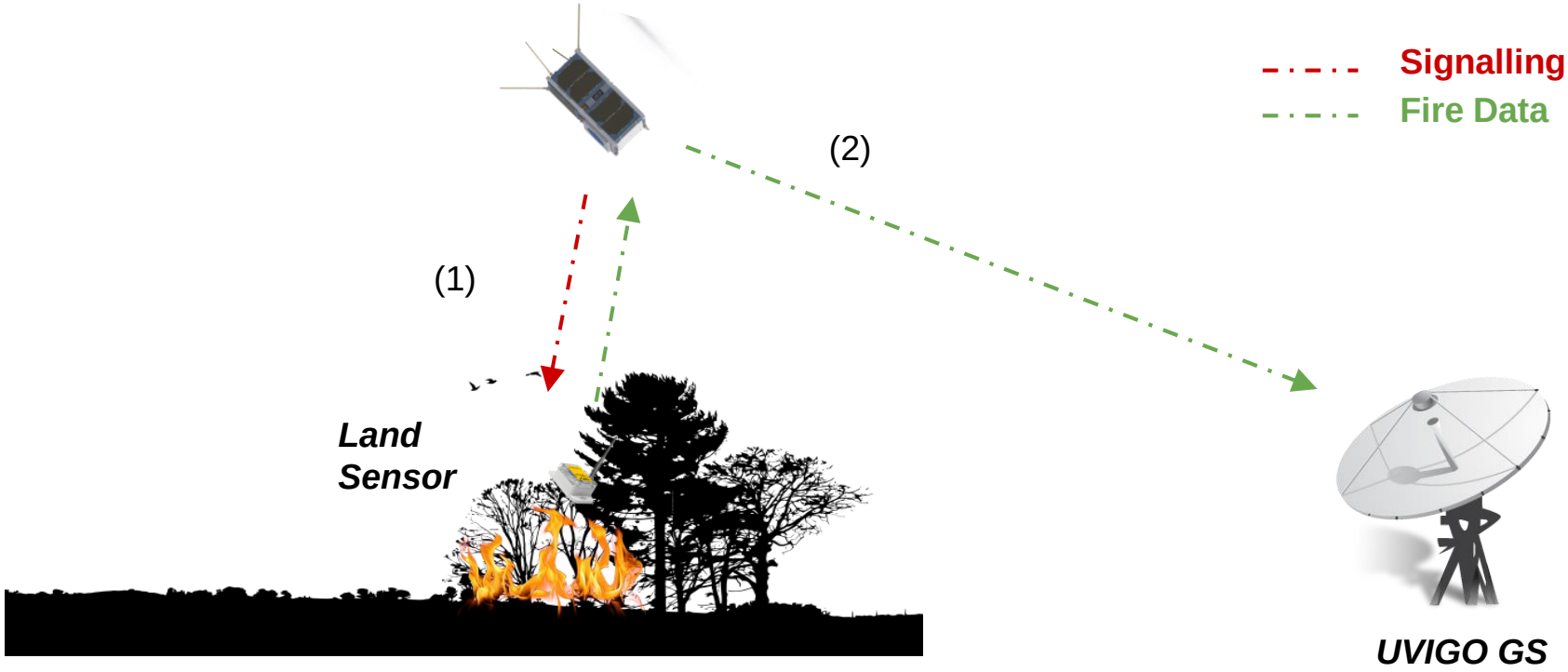


FIRE-RS System

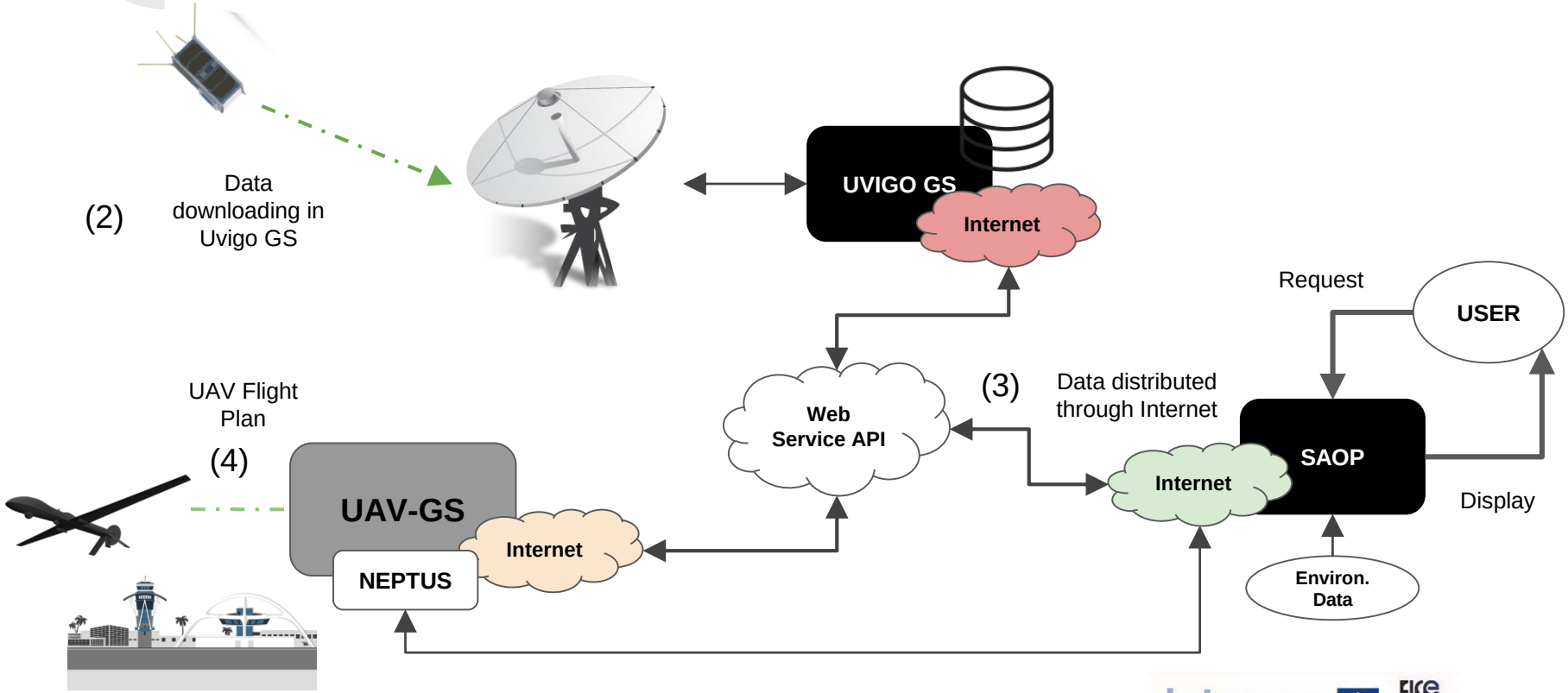
System Architecture



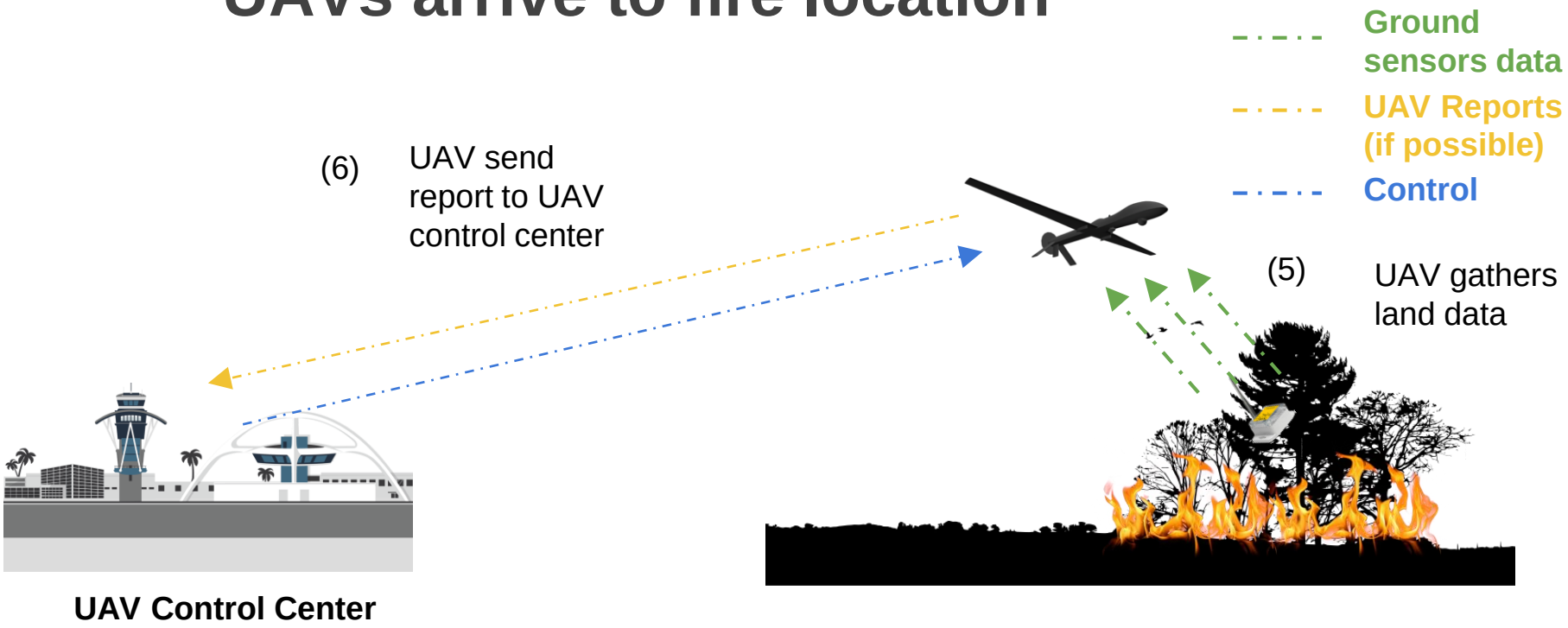
Concept or Operation: Fire detection



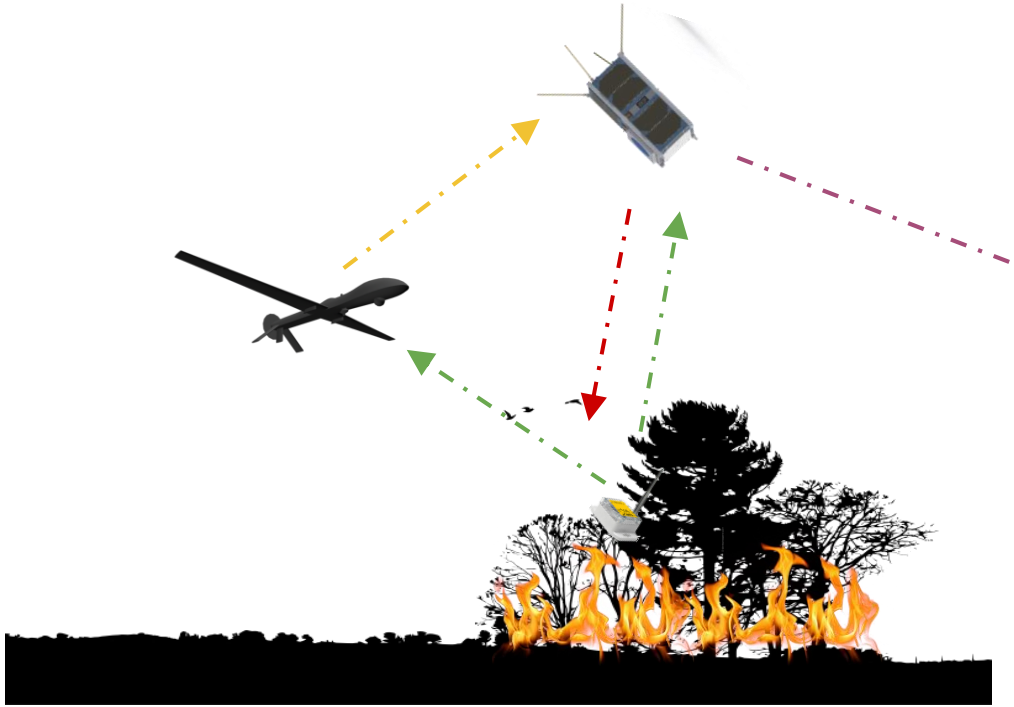
Concept of Operation: Data distribution



Concept of operation: UAVs arrive to fire location



Concept of operation: Final scenario



Signalling

Land sensor Data

UAV Data

UAV + land data

UVIGO GS

Ground Detection System

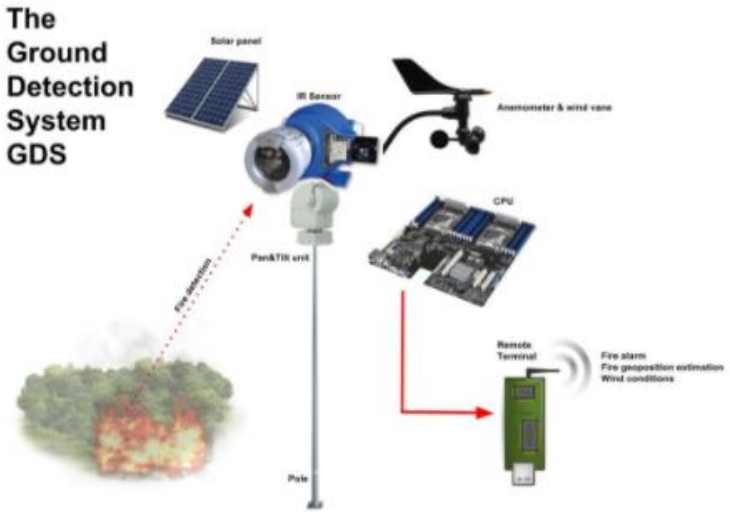
Ground **D**etection **S**ystem, **GDS**: formed by the set of systems in charge of the fire initial detection. The main components which form the GDS are:

-Pan&Tilt camera with a fire detection algorithm for forest monitoring

-CPU for the data processing and GDS control

-Communication interface

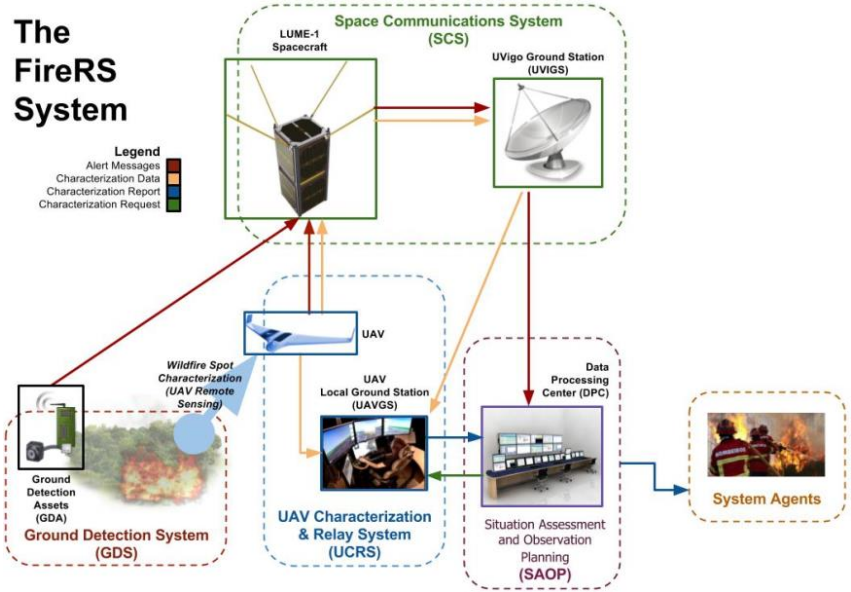
-Energy supply and structural support



The FireRS project. Functionalities

Four main functionalities will be available inside FireRS system:

- Fire detection
- Alarm confirmation & exact geolocalization
- Fire monitoring
- Burned area monitoring

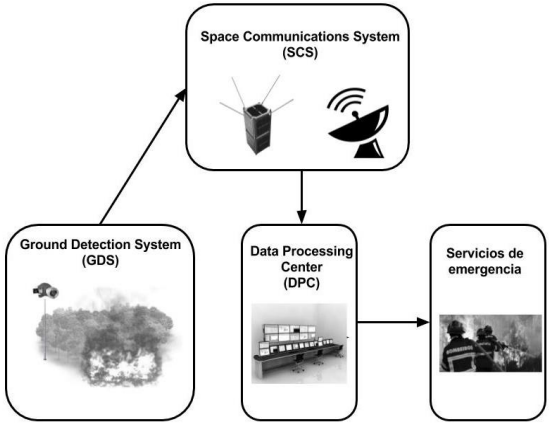


The FireRS project. Functionalities

Fire detection: this phase corresponds to the emission of an alarm by the GDS associated with the presence of a fire within the control field of the infrared terrestrial sensors. The GDS system also makes an estimation of the position of the fire, which allows the UCRS to create a flight plan adapted to the position of the focus.

The different subsystems that come into play in this part are:

- the **GDS** that detects, locates and sends the alarm signal to the **SCS**
- the **SCS** transmits the alarm to the **DPC**
- the **DPC** is responsible for sending the alarm to forest agents and authorities

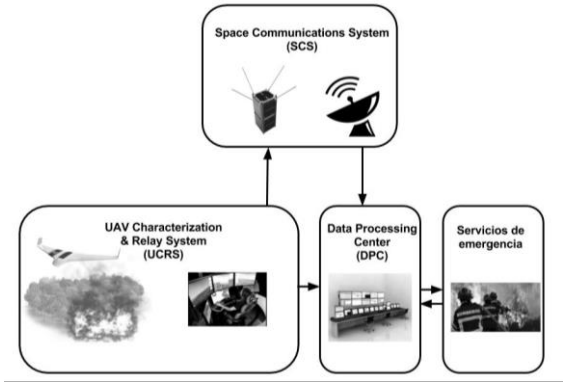


The FireRS project. Functionalities

Alarm confirmation & exact geolocalization: once the alarm is received, the emergency services evaluate if it is a false alarm or if, on the contrary, it is really a forest fire. This phase involves the takeoff of at least one UAV unit that has the task of flying over the supposed area where the alarm has been detected in order to accurately map the fire.

The systems involved are:

- the different emergency services and authorities
- the **DPC** in charge of programming a mission for the flight of the UAV
- the **UCRS** in charge of launching the UAV and ordering the mission

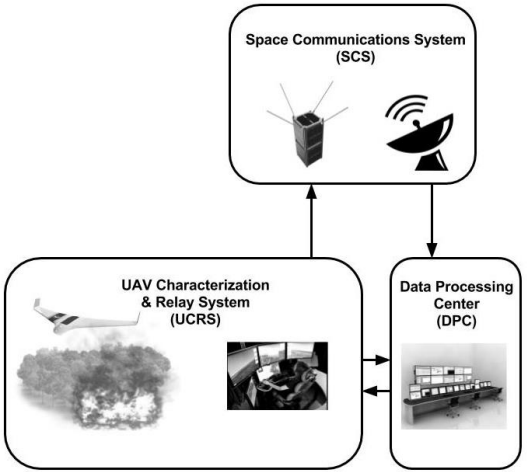


The FireRS project. Functionalities

Fire monitoring: a continuous control of the evolution of the fire through the UAVs is carried out. This information is sent to the DPC that is responsible for processing it and predicting the behavior of the fire in the short term; then, a flight plan is created for the UAVs so that the monitoring of the same is as efficient as possible.

In this phase, the following systems come into play:

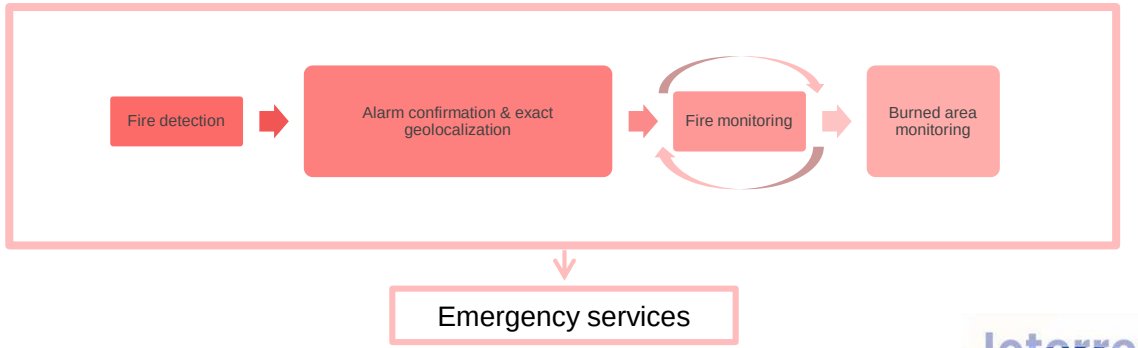
- The **UCRS** in charge of coordinating the UAVs and ordering the flight plan
- The **DPC** predicts the short-term behavior of the fire and generates the flight plans
- The **SCS** as a communication link between the different subsystems



The FireRS project. Functionalities

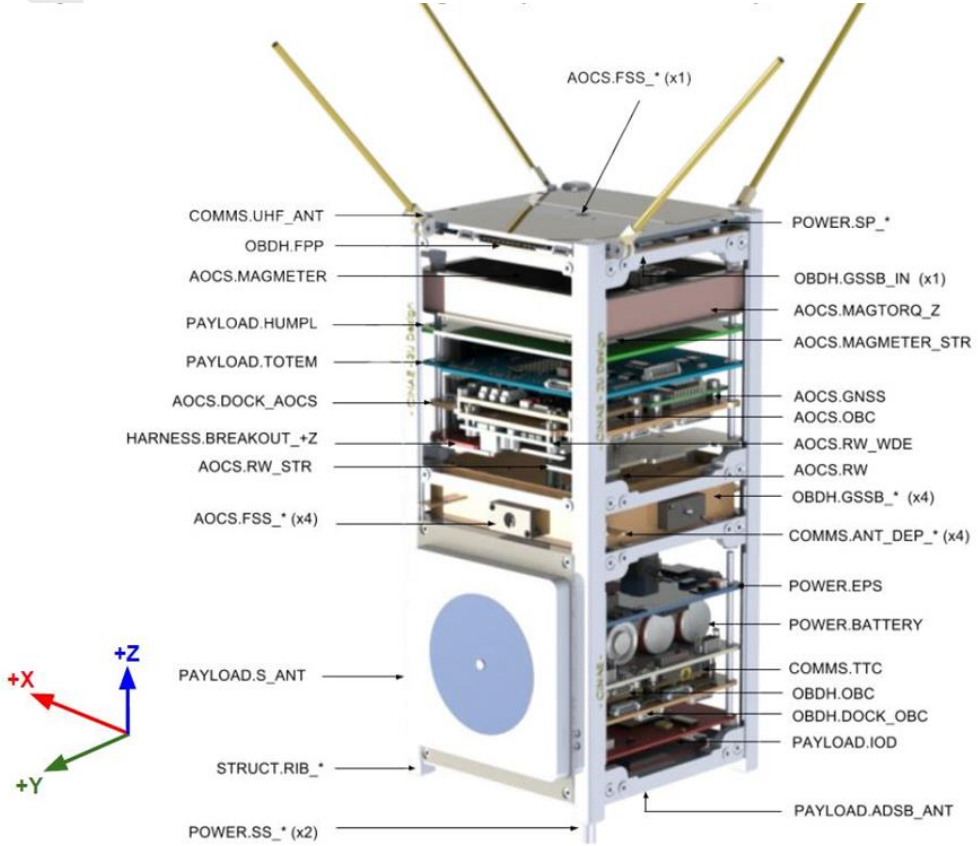
Burned area monitoring: important phase for the control of possible reactivations of already extinct fires. All systems intervene in this phase.

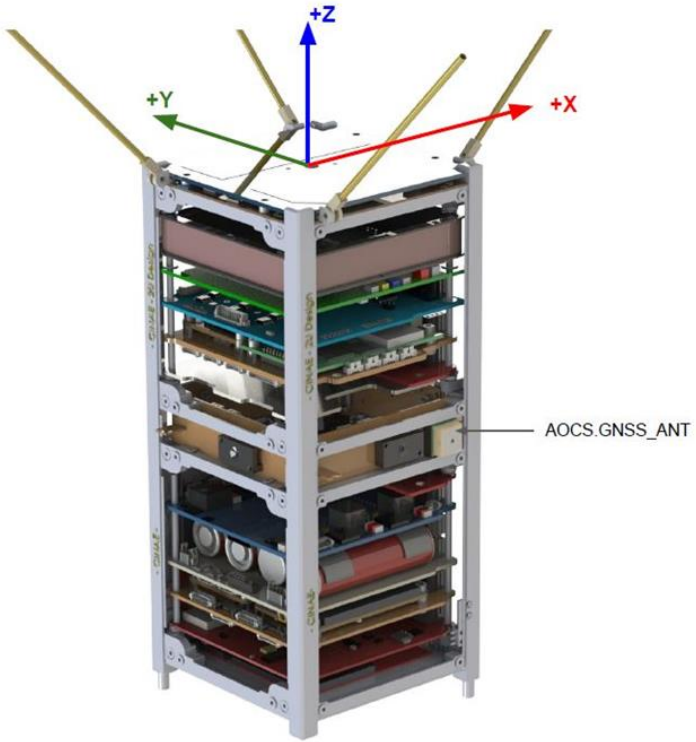
- the infrared sensors perform a continuous scan of the burned area
- the UAVs are responsible for sweeping the entire burned surface, providing real-time images to the DPC and emergency services
- the SCS works as a link between the systems to speed up communications.



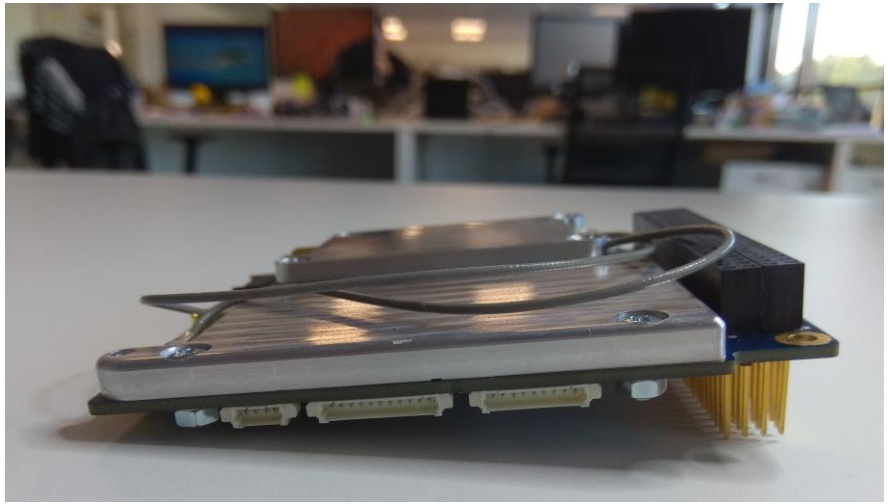
LUME Satellite

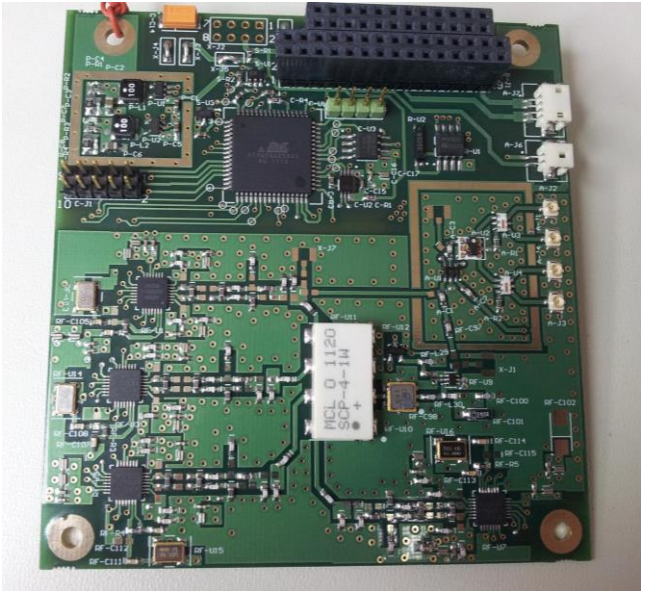
LUME-I: Spacecraft design





LUME-I: Payloads





TOTEM

Software Define Radio

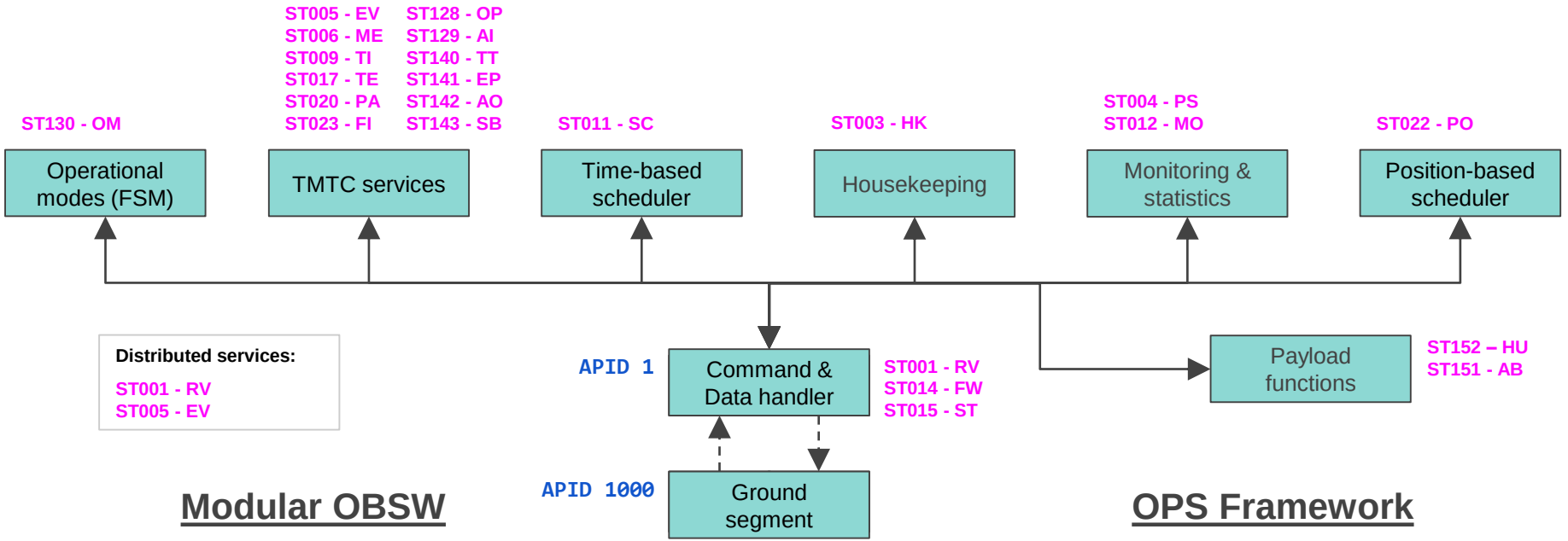
UHF M2M Payload + S-Band transmitter

HUMPL

Humsat System Payload

UHF M2M Receiver

LUME-I: Software and operations



Modular OBSW

Integration on multiple providers

FreeRTOS

Easy Payload Integration

Optimized FDIR

OPS Framework

TMTC Library (Full PUS adaptation)

Constellations Scalability

Automatized operations on GSSW

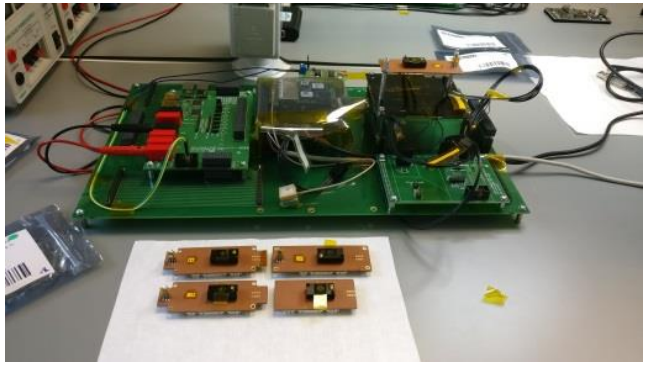
Easy scheduler programming

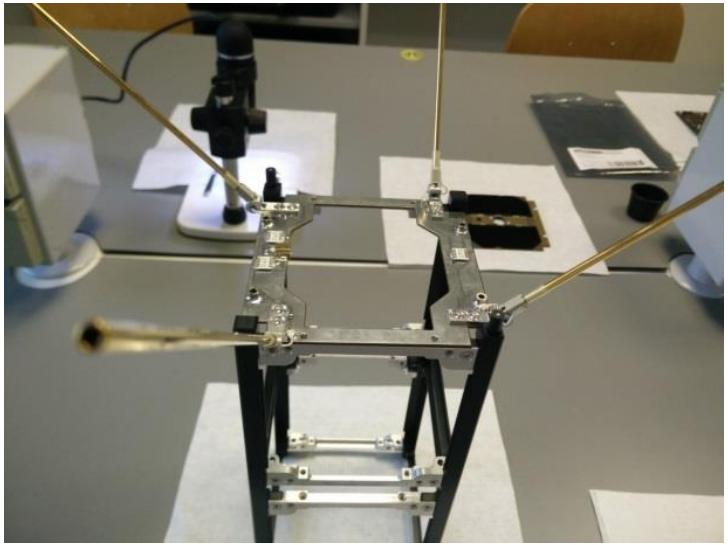
LUME-I: Current state

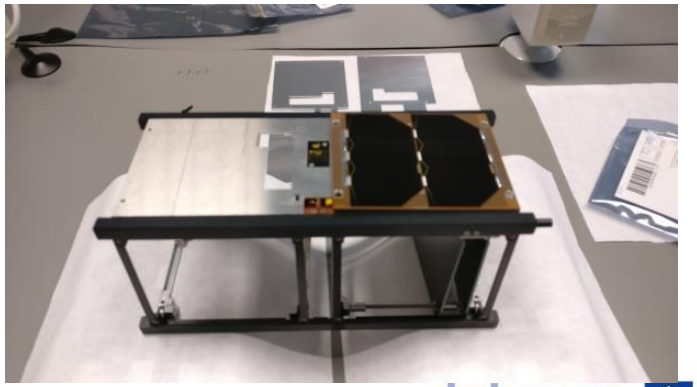
Activity	2017				2018				2019	
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2
Design										
Procurement										
AIV										
Launch										
Test scenarios										

The FireRS project. Current status

Satellite LUME-1



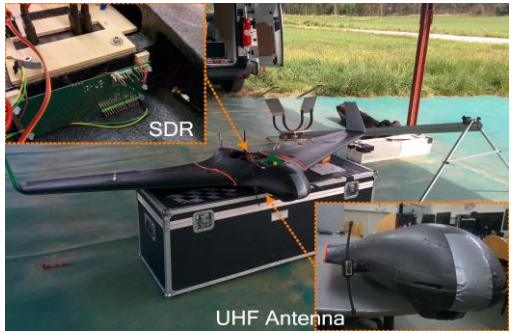




The FireRS project. Current status

UAVs developments

The Laboratório de Sistemas e Tecnollogía Subaquática (LSTS) in conjunction with the UVigo team, was able to successfully integrate the SDR with its X8 UAV. This integration was not only tested within the lab, through bench testing, but also in real test flights. Preliminary tests to the communication link were done during these flights having a ground station simulator at the UVigo receiving station.



The FireRS project. Current status

Developments on SAOP software

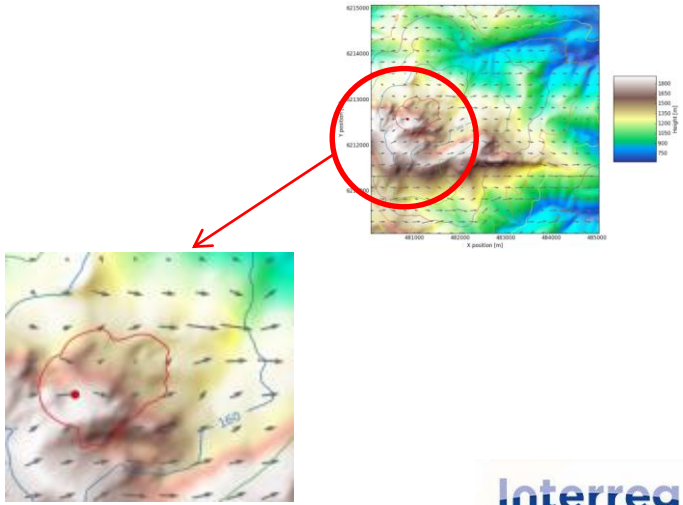
First developments on the SAOP sub-system have consisted in defining a nearly real-time fire propagation model that integrates:

-fire observations

-wind forecasts

-terrain topography

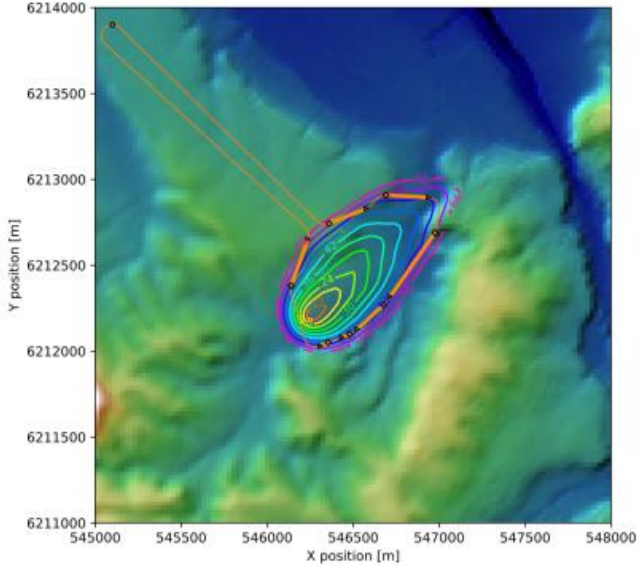
-properties of the vegetation



The FireRS project. Current status

Developments on SAOP software

On the basis of this propagation model, a system that plans the fire observation trajectories for the UAVs has been developed: it specifies the trajectory to execute within the flyable time range.



Here a fire is simulated on a digital elevation map

- x/y represent the East/North axes, ruled in meters
- the position of the fire front is represented by curves, with the time denoted in minutes from the ignition
- The UAV takes off from a position located on the top-left (north west) corner of the terrain
- thick orange straight segments correspond to the parts of the trajectory where the UAV is actively taking footage
- thin orange curves describe the trajectory that relies two observation segments

Thank you very much !