Title: Fire Alert Constellation (FALCON)
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Need

One of the main disadvantages in the fight against wild fires is the impossibility to face them from the moment they start. Since the start until they are detected, crucial minutes pass during which fires expand without control, making their extinction more difficult and representing a bigger risk to emergency services (e.g. In 2008, uncontrolled fires in Paraná River delta, in Buenos Aires, was not detected on time and over 70,000 hectares burnt while the capital was covered by a dense carbon monoxide curtain).

Nowadays, Earth monitoring systems based on satellites can't provide a response quick enough to fight against wild fires. Some of them (BIRD, NIRST) consists of one satellite, whereas others can monitor fires on demand (e.g. Deimos-1 systems can take photos on demand). In this context, a constellation of small satellites can be used as a good complement to more complex satellites or systems like GMES (Global Monitoring for Environment and Security) in order to reduce the time it takes to detect a fire. This system can also help forest guards or emergency services to monitor zones with difficult access or visibility.

Mission Objectives

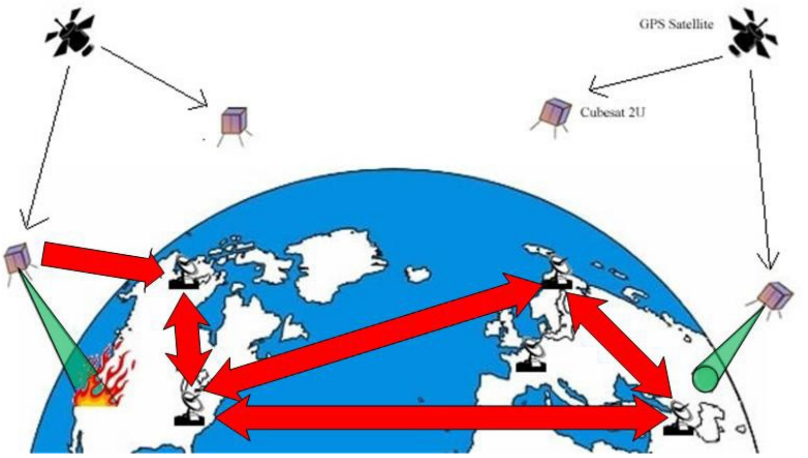
- Technology demonstrator system: Feasibility of a system capable of detecting wild fires [1] by using a constellation of low cost small platforms (~ 2kg) like Cubesats. If the selected elements had not been proved in space, the system will test their feasibility to perform the operations needed.

- Detecting fires with an IR sensor [2] and a visible camera. In this point, it is necessary to evaluate if COTS components can be used. Otherwise, the correct performance of each component must be guaranteed.

- Early warning: quick response to prevent uncontrolled expansions of fires.

Concept of Operations

For the correct operation of this mission, we propose a ground segment with a coverage so that one satellite can communicate with at least a ground station in any moment of its orbit. In this context, the increasing coverage of GENSO (Global Educational Network for Satellite Operations would make this concept feasible in a close future. GENSO ground stations communicate with satellites using a UHF down-link and VHF up-link. Received data can be shared with other nodes in the network via Internet.



The main payload of the space segment will consist of two cameras. One of them will be a QWIP (Quantum Well Infrared Photo-detector) sensor able to detect simultaneously a range of MWIR and LWIR wavelengths [3] [4]. In addition, a standard camera will be used to take pictures in the visible spectrum.

Different operation modes are defined to perform all the mission requirements:

- Mode 1 (Standard mode): The QWIP will capture images that will be analyzed by an on-board signal processor system. If no active IR pixels are present, the image is discarded and the visible camera is not active.

- Mode 2 (Detecting fires): If active IR pixels are present, the visible camera turns on and takes a picture. This picture is sent to Earth immediately together with the coordinates and the IR capture.

- Mode 3 (Capturing images on demand): The satellite may be asked to take images on IR and visible spectrum in a specific range of coordinates. These images will be stored (a high storage memory chip will be needed, e.g. a SD-card) and sent to Earth when possible.

- Mode 4 (Stand-by mode): Using a GPS receiver, a range of coordinates over which it is unnecessary to monitor wild fires can be defined (e.g. over the poles or oceans). Communications system will stay active anytime.

- Mode 5 (Emergency mode): If the QWIP sensor cannot take any image, the system will turn off the IR camera and images will be only captured on demand in the visible spectrum. This point can be also reached in case of failure of the signal processor (or after checking that the detection of active IR pixels is not correct anytime). If the visible camera fails before the IR camera, it will be turned off and all the defined operation modes will continue without taking or sending images in the visible spectrum.

Key Performance Parameters

-Camera and sensor resolution: Resolution of the two cameras is the main key performance parameter of this mission. In altitudes between 500 and 700 km, the ground sampling distance that actual sensors can offer is 100 m and the ground sample distance (with a field of view of 15.6º, like NIRST) is 185 km. Since July 2010 [5], it has been proven that this configuration can detect wild fires spanning 200 m^2 by using QWIP with resolutions lower than the proposed. The visible camera will use similar resolutions than the QWIP, using fields of view about 49º diagonal.

-Response time: To offer a quick response near to real time to prevent uncontrolled expansions of fires, existing GENSO ground stations can be used. These stations can be communicated at any moment via Internet.

-Lifetime: The lifetime of this mission depends on the altitude of the chosen orbits. Each satellite can be substituted with a new one at a low cost in cases of failures or in case one of them reaches the end of operations (empty batteries). The mission would not be compromised and could be continued as long as needed.

Space Segment Description

In order to present reasonable and feasible parameters according to the current state of technology, the development of the mission is based on existing components, many of which have already been proved in space conditions.

The constellation to develop this mission will be composed by identical satellites using a two unit cubesat standard structure and the primary payload will be composed of two cameras. The main performance will be made by the IR camera. It will consist of a QWIP (Quantum Well Infrared Photodetector) capable of detecting MWIR and LWIR both at the same time. This kind of FPA (Focal Plane Array) is based on materials that form quantum wells sensitive to MWIR and LWIR wavelengths [6], creating energy bands where quantum effects respond to the IR incident radiation. The process to produce them is not expensive, and they are preferred to CMOS or CCD sensors because of the higher detector uniformity, the lower power consumption and the lower noise introduced in the system. Although resolutions of 4096x4096 pixels are being manufactured, sensors with resolutions of 2048x2048 pixels can perform the operations properly.

The visible camera system allows to use resolutions up to 5 Mega-pixels (existing models like Bitec Santa Cruz Camera, which uses the OV5620 sensor by Omnivision), with a typical sensitivity about 1.2 V/Lux/sec with a S/N ratio of 42 dB and a dynamic range of 60 dB.

The on-board signal processor system [7] is designed to analyze the images captured by the QWIP in order to check if any IR focus has been detected. This component is quite important because it will determine if a focus has been detected without sending the images to Earth, making the process quicker and reducing the time response. For this reason, another signal processor can be included to prevent false alarms in case of failure of the component when detecting an IR focus. Since 2006, different models like Xilinxs Virtex-II have been tested processing 2048x2048 pixels per frame with a data rate of 80 Megapixels per second.

GPS receivers as SGR-05U are already used in cubesat systems to establish with precision the position of the satellite (position accuracy of 17 m and ranging accuracy of 0.9 m in developed systems). The synchronization can be made with data rates up to 4800 bps and the receiver sensitivity normally is -132 dBm.

The mission also requires an on-board computer (like models developed by GomSpace) to coordinate the different actions to be performed. Some memory systems (like Flash Memory or SD card support) are needed to perform the defined operations (i.e. to store the images captured before being sent to Earth) and the implementation of software will be very important, especially when the on-board signal processor analyzes any possible IR focus. The system will use the standard bus PC104 or I2C.

Regarding to the communication and telemetry system, a full duplex transceiver (UHF 435 MHz down-link, VHF 140 MHz up-link) is recommended. These systems have a sensitivity of -100 dBm to get a BER of 10^{-5}, down to -120 dBm at 1200 bps (although GENSO also admits bit data rates of 9600bps).

The proposed configuration for the antenna system will consist on four monopoles no longer than 17 cm as other similar systems actually use (e.g. OPTOS). It is recommended to use circular polarization in Z-axis and lineal polarization in X,Y-axis to offer an omnidirectional pattern. With four monopoles, different configurations can be implemented (one turnstile, two dipoles, one dipole and one monopole, one or two monopoles).

Considering the capture of images as the critical point of the mission, a reaction wheel is recommended to assure that both cameras are oriented to the Earth surface (stabilization in the z-axis, perpendicular to the ecliptic) [8]. In addition, three magneto-torques embedded in the solar panels in order to stabilize the satellite in the three axis should be included. A sun sensor will be used to give an inclination of 45º relative to the sun in X,Y-axis to make the solar panels receive as much luminous energy as possible (e.g. OPTOS satellite).

Next table summarizes the main parameters, mass and power budgets needed to implement the whole system:

	Size (L x w x h cm)	**Weight (grams)**	**Power Consumption**
QWIP IR sensor	4 x 4 (without lens)	60 - 70	10 mW
Visible camera	0.57x0.43 (sensor only)	40	0.4 W
Signal Processor	4 x 10 x 1.5	22 - 25	0.3 - 0.5 W
OBC	10 x 10 x 1.5	38 - 45	0.5 W
GPS receiver	7 x 4.5 x 1.5	40	0.5 - 0.8 W
Comm. System	9.6 x 9 x 2.5	85	< 2.1 W
ACS	Distributed in the unit	< 700	< 1.5 W
Total (Max. possible)	**10 x 10 x 12**	**1350**	**5.3 W**
~10 % Margin	2 cm high	135	530 mW
Total estimated	**10 x 10 x 14**	**1485**	**5.83 W**

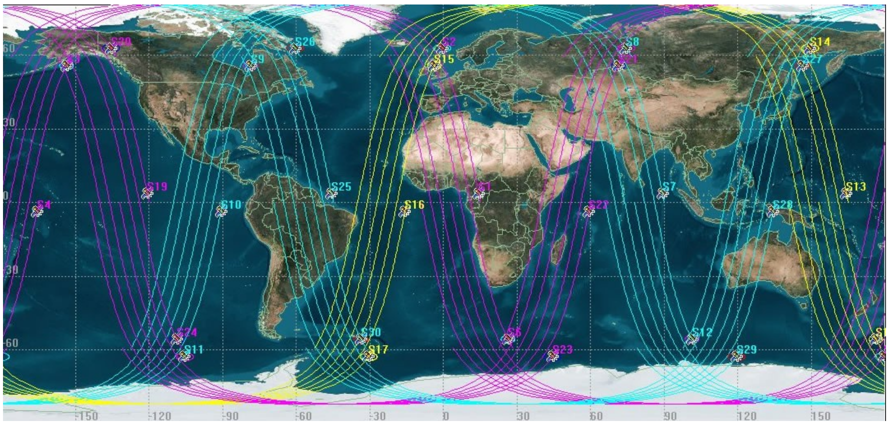
It is important to notice that this maximum estimated power is the peak value that the system could reach in case that all the components worked at the same time. With the defined operation modes, this situation will never happen and the power consumption will be lower.

The best distribution for the solar panels consists of four lateral panels and another one on the top side of the satellite, all of them based on triple junction GaAs cells. With this configuration and numerical data from Clyde Space (efficiency of 35% and fill factor of 85%), expected average power produced is about 1.82-2.59 W, depending on the temperature of the solar cells.

The mass introduced by the solar panels is about 75 grams (~ 84 mg/cm^2) so, as long as the space available inside the satellite and the mass limitations of the structure allow it, Lithium-ion batteries will be included. The capacity of each of these batteries is estimated in 1800 mAh.

Orbit/Constellation Description

Using a sun-synchronous orbit is the best way to have images of places with similar conditions each day. With the needed altitude of 600 km (97 deg.), a 30/5/1 Walker constellation has been simulated on STK. As result, one single point is evaluated by the constellation at least 11 times in a day, which means that each 130 minutes on average we can identify possible fires in a location. The same simulation has computed that the coverage would be global (~93%) by using the whole constellation represented in the image.



Implementation Plan

One of the main advantages of using a standardized 2U cubesats to perform this mission is the possibility of launching a variable number of units in the same launcher (preferably by using PSLV as best option to launch the satellites into sun-synchronous orbits) and that launch costs are lower than a standard satellite mission (cubesats can be launched as secondary loads).

The best implementation plan for this mission consists of developing a single satellite in the first stages (as a Technology demonstrator system). The design phase (subsystem specification and design, COTS selection) is estimated in 4 months and the Engineering Model can be completed in 6 months. The Flight Model can be developed in 4 months. In parallel, needed ground stations have to be designed and adapted for the mission (data processing center needed for mission analysis and housekeeping available in UPM).

Estimated costs for the single unit excluding launch (and knowing that highest cost corresponds to the IR camera as the primary payload) will be:

Project Component	Costs (€)
Prototype	290 000[1]
Personnel (15 persons)	450 000
Travels (Two missions of 3 days for two persons)	3 000
Total	743 000

After making the first unit, the next step must be to operate in space to test that wild fires can be detected with this system. This would reduce a lot of costs in case that the system doesn't work properly because different components could be replaced to improve the performed operations in order to develop a more sustainable system. With the tests already made and the first unit operating properly, the whole constellation can be progressively launched. New satellites can include new upgrades but their development time is reduced compared to the first one.

[1] The QWIP sensor is a prototype (HAWAII-2RG 2048x2048 hybrid FPA) valued in 250 000€ as of 2009, it is foreseen that prices will be lower in the future

Participants in this mission would be Bachelor, MsC and PhD students (UPM has degrees in all Engineering areas, laboratories and facilities) supervised by University Professors (with strong experience in ESA and EC Projects and contracts with space industry). Moreover, this mission would also have support from local space industry (consulting, technical, laboratories, tests, hosting of students) and the project will be implemented following the ECSS Standards.

Risks:

1. COTS failure: Although the vast majority of the systems studied to be part of the satellite have already flown in missions in space, most of the QWIP sensors have not been tested yet. As the first unit will be a technology demonstrator system, improvements to prepare the sensor or any other component for the correct performance of the mission can be studied and developed in the following units.

2. Failure during the first stages: Operations of attitude control system will be critical in the first stages after the lunch, because a wrong aiming of the satellite will alter all the measures and the images taken. The emergency mode implemented can be used to manage some failures and the chosen orbits guarantee that no space debris will remain after a year.

3. Inadequate sensitivity of IR sensor: Another main risk is not to reach the necessary sensitivity to detect wild fires with the QWIP sensor. If needed, similar alternatives with higher sensitivity can be considered.

4. Wrong detection of IR pixels: A malfunction in the on-board signal system processor could generate false alarms or be unable to confirm detected wild fires. In this case, commands can be sent to deactivate the signal processor and the satellite could be used only on demand.

5. Insufficient GENSO coverage would compromise response time.

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