ESA STUDY CONTRACT REPORT

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ABSTRACT:

SMO FuegoTec Programme

FuegoTec is conceived as the technology and service demonstrator of an ambitious satellite based system called FUEGO. FUEGO is a constellation which intends to provide forest fire detection and monitoring services to fire fighting authorities and responsible.

ESA's SMO Initiative is the ideal vehicle to achieve the objectives of the FuegoTec mission: to validate the technologies to be used for the FUEGO system and to provide and validate the FUEGO preliminary services.

The study performed under the SMO Initiative covers three key points for the success of the project: the FuegoTec mission analysis, the establishment of the preliminary interface requirements to be required from the SMO service provider and a market analysis and business plan for the FUEGO system.

The user survey already done shows that a demonstration mission for the FUEGO system, as the proposed FuegoTec mission, is a mandatory requirement for the potential users.

The main conclusion of this study is that there is a good prospect for business on the basis of the customer value analysis, for the FUEGO system, that justifies a FUEGO technology and service demonstrator like FuegoTec. The demonstrator based on the SMO Initiative has the potential of a constellation and generates production leverage on the investment.

The work described in this report was done under ESA contract. Responsibility for the contents resides in the author or organisation that prepare it.

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1. Scope of the study

1.1 General aspects

Estimates of the economical losses induced by fire vary from one year to other but on the average, for the total surface affected by fires in the Mediterranean Europe, the estimate is between 400 and 900 MECU per year, during the last 5 years, depending on the inclusion and evaluation of the loss of commercial timber, commercial animals, wildlife habitat (including game and fish), non urban structures both government and private, tourism economy, urban and transport structures, ecological damage including hydrological changes due to loss of cover and non-forest area resource outputs (agricultural). Additionally, other losses should be considered both accountable, like reforestation costs, and non accountable, like loss of human life and non-fatal personnel accidents.

The accounted average burned surface per year in Europe, N. America, Russia and China is in the order of six million hectares of which southern Europe accounts for around half million. However, the origins and effects of European fires are peculiar:

- Mediterranean climate includes a dry and hot season often with strong winds, during which fuel flammability and combustibility are very high due to the extreme reduction in humidity and, therefore, ignition and rapid propagation have high probability.

- The prevailing topography varies but mountainous areas are common, leading to very high exposures to sunshine in some cases with corresponding humidity reductions. Orography also is a factor in local spread rates.

- Vegetation in the region produces lots of accumulated fine dead fuels in which fire can easily outbreak. Under the prevailing temperature and humidity conditions some of the typical vegetation formations in the Mediterranean biotype do produce essences with high flammability.

- Population in susceptible areas, which density increases significantly in the dry season, has today access to forests for recreation purposes incrementing risk factors. The traditional use of forest by-products is much lower due to the reduction of rural population but at the same time the traditional agricultural practices for use of fire for land and pasture have remained, creating non traditional risks.

- Generally, the population or human factors impact in fire risk will tend to be more critical in the Mediterranean region with time.

- Vegetation factors improvements result from a more careful management of species and stands with respect to fire, with increasingly better fire resistance. Climate is very cyclical showing extreme variations with strong droughts recurrence.

The statistics show that the number of fire outbreaks has a moderately increasing trend while the burned surface per fire has a moderately decreasing one. This is most probably the result of the considerable effort that has been devoted to pre-suppression in the recent years.

With regard to effects for the region the mean damage per ha will continue to be increasing, including the effects of one of the major damage drivers that is man made housing and structures destruction.

The public awareness for these losses and specially the ones associated with environmental values is today very high and is well taken into account by the administrations. For example, the Spanish Ministry of Agriculture Evaluation of losses in primary products and environmental benefits per ha shows a threefold increase in ten years to reach around 3000 ECU/ha.

The wildfire problem is, at least in the Southern European region, one of conservation of an environment of great value to human development and welfare, in contrast with the value of direct products like timber and others. The direct product value will continue to be shrinking in comparison with other potential benefits associated with alternate sources of value.

Therefore, a danger of non-conservation exists and can only be controlled by adequate information tools and by recognition of the appropriate externally by the authorities.

In recent years, increasing interest has been devoted to investigate the origin of forest fires, and some statistics are becoming available on the subject.

Knowledge of the origin of European fires allows, on one hand, the optimisation of the activities deployed to prevent them, particularly dissuasive surveillance, preventive forest management, and fire suppression command and control. On the other hand, it is a tool to forecast the future incidence of this phenomenon in view of understanding future needs.

The aforementioned aspects lead to the urgent establishment of a system dedicated to enhance and provide useful information to forest fire fighting authorities and responsible. It is however quite essential to focus on what kind of system is really needed. In this sense, our present understanding of the needs can be summarised as follows:

- There is a strong correlation between the time to reach the location of the fire by the first attack aircraft or crew, and the surface burned that suggests that overall times to reach the fire from outbreak should not average in excess of ½ hour. The impact of this parameter is, however, very dependent on the type of vegetation and the wind present.
- Day and night operation is a very desirable feature in view of the impact of both lightning and intentional fires.
- Direct communication to the suppression crews, ground or airborne, of the information about the detected fires is essential to maintain the total intervention time low.

- Location and intensity of the fire have to be reported with fairly good accuracy, say 100-200 meters.
- False alarm rates should be very small considering that the system should take into account controlled and known agricultural or forestry fires.
- The scanned areas should be limited to risk areas as determined by the methods discussed previously; typically 3-5 Million ha in Spain and equivalent size countries should be sufficient.
- Cost should be a fraction of the equivalent coverage IR tower system.

A group of companies and institutions, led by INSA, is studying to establish in the near future a satellite based system capable of satisfying most of the information needs identified so far, in particular, early detection of fire outbreaks and fire monitoring. This system is called FUEGO and will be briefly presented later in this document.

As an innovative mission, FUEGO presents a set of advanced elements based on state-of-the-art IR sensor technologies. However, these elements can be obtained from current high technology providers. One of the FUEGO Programme priorities is to define, design and manufacture a first prototype. This prototype has been named FuegoTec or, as a first step of the FUEGO Programme, FUEGO 1st satellite.

1.2 Study aspects

FuegoTec is, therefore, a technology demonstration mission and, as such, it is a candidate for ESA Small Mission Opportunity (SMO) Initiative. Within this approach, ESA has placed a contract to some four European companies to produce a mission proposal sufficiently detailed to allow for its consideration for a potential implementation phase within the SMO Initiative context, establishing whether a real interest exists for such a demonstration mission on the part of the potential users of the global system. In the case of the FUEGO 1st satellite mission, these users are forest fire fighting responsible, mainly at national and regional level.

The following statement is used to briefly describe the SMO Initiative concept: to provide a cost competitive, technological up-to-date, European Small Missions service, which is made up of separated but interrelated satellite bus services, launch services and payload services on a baseline contract-to-launch schedule of about 2 years.

To perform this study for the FUEGO 1st satellite mission, a team has been formed by INSA (Spain) and Officine Galileo (Italy). INSA was the responsible and manager of the study and in charge of the mission definition, SMO interface requirements study and market analysis and business plan. Officine Galileo was responsible for the detector definition. The structure of the study is explained in the paragraph Study logic.

2. Objectives of the study

The main objectives of the study are stated in consonance to fulfil the purposes established by ESA by placing this contract:

- to provide ESA with an assessment of the FUEGO 1st satellite characteristics
- to provide ESA with the interface requirements of FUEGO 1st satellite for a SMO service
- to study the financial feasibility of the FUEGO 1st satellite

3. Study logic

In order to achieve the mentioned objectives, the study has been divided in three different parts:

- Mission definition
- SMO interfaces requirements establishment
- Market analysis and Business plan

3.1 Mission definition

The mission definition study identifies, first of all, the technical objectives of the mission by mean of establishing the technology requirements needed and providing a first mission profile, first payload description and first global system definition for the FUEGO 1st satellite mission.

Secondly, and starting from the provided first payload description, it performs a basic payload definition, giving emphasis in the IR detector focal plane array, payload optics and payload refrigeration system.

Finally, a complete mission definition is produced at level of a pre-phase A, including mission profile, platform, ground segment, launcher, operations and user segment.

3.2 SMO interface requirements

Once the FUEGO 1st satellite mission has been pre-defined, the next step is to translate the complete set of characteristics and requirements established in task 1 into SMO specifications, mainly in bus or platform requirements and operation procedures. These requirements should ensure the correct interfaces between the payload and the SMO bus, and between the spacecraft and the SMO ground segment.

3.3 Market analysis and Business plan

A market analysis was performed to provide the business rationale of FuegoTec and describing the potential for the FUEGO system itself. The FUEGO system costs throughout the operational period were estimated and, after analysing the market, a business profile for FUEGO was derived.

The market analysis was done by gathering the potential user requirements by means of personal or telephonic interviews with main fire fighting responsible and Civil Protection authorities in Spain, Italy, Greece, Portugal and France. A specific questionnaire was done to get these requirements.

Due to the size of their requirements, special emphasis was put in Spain and Italy. Contacts have also been made with the fire fighting responsible representative in other world-wide risk areas as California (US), Chile and Australia.

4. Documents

4.1 Reference documents

- A feasibility study: California Department of Forestry and Fire Protection Utilisation of IR Technologies for Wildland Fire Suppression and Management. JPL. 1990.

- Satellite Technology and GIS for Mediterranean Forest Mapping and Fire Management. 1993.

- The Infrared Handbook. W. Zissis. 1993.

- Optics. E. Hecht. 1987.

- Course on Decision Making applied to Forest Fire Detection. 1996.

- Small Mission Analysis and Design. Wertz and Larson. 1992.

4.2 Documents generated

The generated documents are:

TN 01.- Mission definition and SMO basic requirements

TN 02.- Preliminary mission analysis and schedule

TN 03.- Payload preliminary description

TN 04.- Detector and optic definition

TN 05.- SMO interface requirements

TN 06.- Business analysis and planning

SMO FuegoTec Final report

SMO FuegoTec Executive Summary

4.3 List of abbreviations

AOCS: Attitude and Control Subsystem

EU: European Union

FF: Firefighting

FOV: Field of View

FPA: Focal Plane Array

GIS: Geographical Information System

INIA: Instituto Nacional de Investigaciones Agrarias

INTA: Instituto Nacional de Técnica Aeroespacial

Mbps: Megabytes per second

MIR: Medium Infrared

MLI: Multilayer Insulation

NEDT: Noise Equivalent Delta Temperature

PLM: Payload Module

ROI: Return of Investment

SMO: Small Mission Opportunities

SVM: Service Module

TBC: To Be Confirmed

TBD: To Be Defined

TDM: Terrain Digital Model

TIR: Thermal Infrared

TN: Technical Note

TT&C: Telemetry Tracking and Command

UAV: Unmanned Air Vehicle

UTM: Universal Transverse Mercator

VIS: Visible

5. The FUEGO Programme

As the prototype of FUEGO system, FuegoTec payload and mission have to be as much as possible similar to the FUEGO system payload and mission. Therefore, it is worth to give a brief description of the proposed FUEGO system and FUEGO Programme.

The FUEGO system is intended to be a constellation of new generation small low cost satellites which integrate an IR two band instrument with a powerful processor. The final objective is to obtain on board the detection of fires with high resolution and the identification of fireline position and intensity in the monitoring mode. The full constellation is aimed to be operative by the year 2001.

Presently, the FUEGO Programme is starting a feasibility and definition phase, supported by the European Community through its DG-XII, under the Environment and Climate Programme. INSA is the co-ordinator of the programme and the contractors are the already mentioned Officine Galileo, the Spanish National Institute for Aerospace Technologies (INTA) and SEMA Group (France). The Spanish research institutes INIA and CIF act as associated contractors.

The FUEGO Programme is highly user-oriented. Some of the preliminary requirements coming from the potential users of the systems are already included in the mission concept. For example, the synoptic fireline data are being required to be directly downlinked to the field, where it can be received by a handheld terminal on ground or on board an aircraft. Wherever is feasible, new features are explored, like the possibility of generating an estimate of wind velocity and direction in the nearby of outbreaks. Following this user-oriented approach, both a User Committee and a User Group are being formed to enhance user fluid contact. A first user conference will be held in May 97 and a second in March 98.

The payload instruments of these satellites are intelligent IR sensors in a mission optimised to solve:

- Saturation problems
- Spatial resolution limitations
- Occultation and uncertainty problems
- Revisit time limitations as a LEO constellation

These issues and the consideration of the user requirements generate the inputs to perform the FUEGO mission analysis, which will be mentioned later in this document.

The system intends to provide autonomously three modes of operation:

- detection of fires within the designated risk areas
- monitoring of designated fires and hot spot detection within the fire perimeter
- risk management functions

6. Major results of the study

FuegoTec mission is a prototype of FUEGO and has, obviously, not all the same capabilities of FUEGO.

The FUEGO 1st satellite main objectives are the following:

- to provide preliminary practical data and information that can be used and validated by users
- to demonstrate the performance of some of FUEGO high technology elements and their interfaces

6.1 FuegoTec mission analysis

The orbit characteristics of the FUEGO 1st satellite will be always subordinated to the ones of the FUEGO, because of the need of demonstrating the performance of the subsystems under those conditions.

The requirement for the FUEGO 1st satellite project is to monitor fires in the same way as in the FUEGO constellation and to provide fire inventory (as a first approximation to the detection mode of the FUEGO Programme[1]). The fire inventory produces synoptic information about number, position and characteristics of present fires. These should not be considered as images but as information relative to the fire (intensity, temperature, fire perimeter, size, ...).

The key requirement for FUEGO is the time between consecutive windows of observation. Hot spot detection will be performed by sub-pixel techniques. The central area of the total swath can be used to acquire better quality images to monitor fires.

After the considerations made before, the FUEGO constellation has been placed in an altitude of 599 km (7 day cycle). So, for the FuegoTec, the selected altitude is 599 km. The needed field of view of the sensor to achieve the image size is around 4.7°.

Since the FUEGO Programme has to optimise the coverage in the South European region, the inclination of the orbits of the constellation is set around 47.5°, and this figure is also taken for FUEGO 1st satellite. One of the main constraints of the FUEGO and FUEGO 1st satellite missions is the fact of not being sun-synchronous orbit; in this case, the decrement of the ascending node longitude is 4.9° (~20 min) per day.

Under these conditions, the required swath width for the FUEGO sensor is 2500 km, that is to say, a capability of across pointing of ±59°. The monitoring function is carried out in a central band of 1250 km width (±44°), in which the pixel distortion makes it possible to generate scenes. As can be seen in the following plots, the

[1] *Inventory and detection mode are used indistinctly for the case of the FuegoTec mission.*

monitoring mode ensures 3 or 4 scenes per day and per satellite, whereas the inventory one provides at least 5 of them.

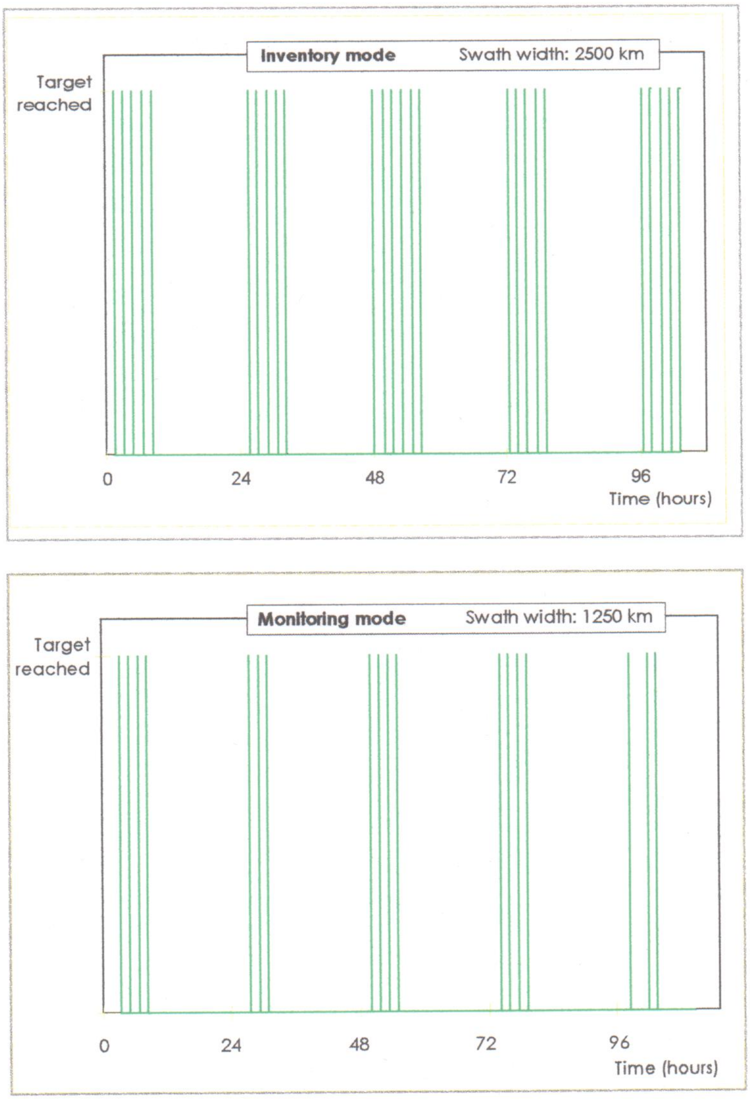

Figure 1.- Scenes per day

Because of the movement of the ascending node, this cycle is not fixed in the time of the day. Each 73 days the cycle is completed (relative to earth). If it is considered that the risk interval is the daylight period, it will be very well covered (3 or 4 passes separated 97 min) during around 36 days, which has to coincide with the high risk European summer season.

As the complete year includes exactly 5 cycles of 73 days, every year the cycle is the same and the situation repeats.

The summary of the configuration is:

Satellite ID	Altitude (km)	Inclination (deg)	Period (min)	Ascending node change (deg/day)
FUEGO 1st sat.	599	47.5	96.7	4.9

The coverage characteristics are (European risk area):

Inventory mode			Monitoring mode		
Swath (km)	Max. across pointing (deg)	Consecutive passes (min)	Swath (km)	Max. across pointing (deg)	Consecutive passes (min)
2500	±59	5 - 6	1250	±44	3 - 4

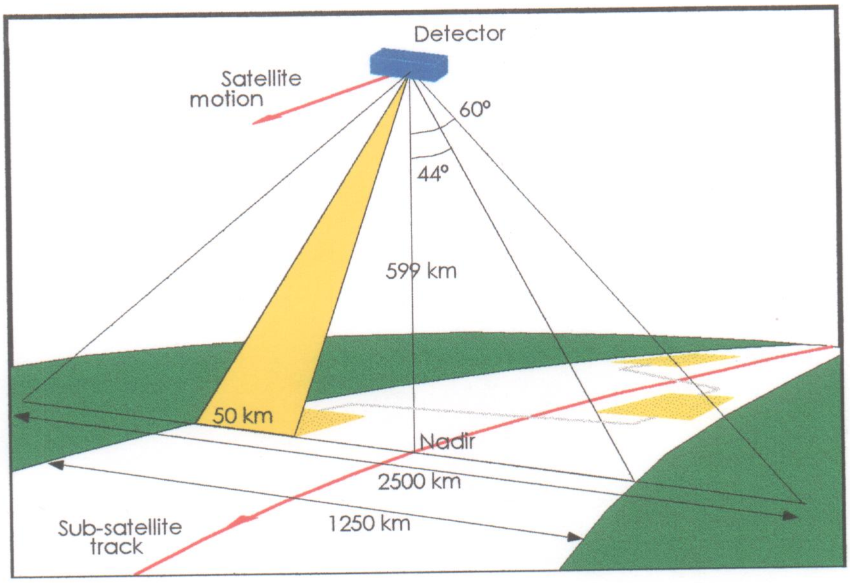

Figure 2.- Summary of FuegoTec parameters

6.2 FuegoTec payload description

The FuegoTec payload is composed by the following units:

- The sensor assembly
- The payload processor
- DC/DC converter and power distribution
- A cryo-cooler for each Focal Plane with its driving electronics
- Ancillary elements

The sensor assembly includes:

- A telescope common to all channels
- A beam splitter to separate visible from IR bands
- A beam splitter to separate MIR and TIR channels
- One focusing objective for each channel
- One detector enclosed on a dewar for IR each channel
- The visible panchromatic camera
- Front end electronics for each detector providing clock signals, readout circuitry, multiplexing and Analog to Digital Conversion
- Interface electronics with the Processor

The ancillary elements include:

- A mechanical structure to support the Units
- Thermal hardware (MLI, survival heaters, thermistors etc.)

A block diagram of the sensor assembly is shown in figure 3.

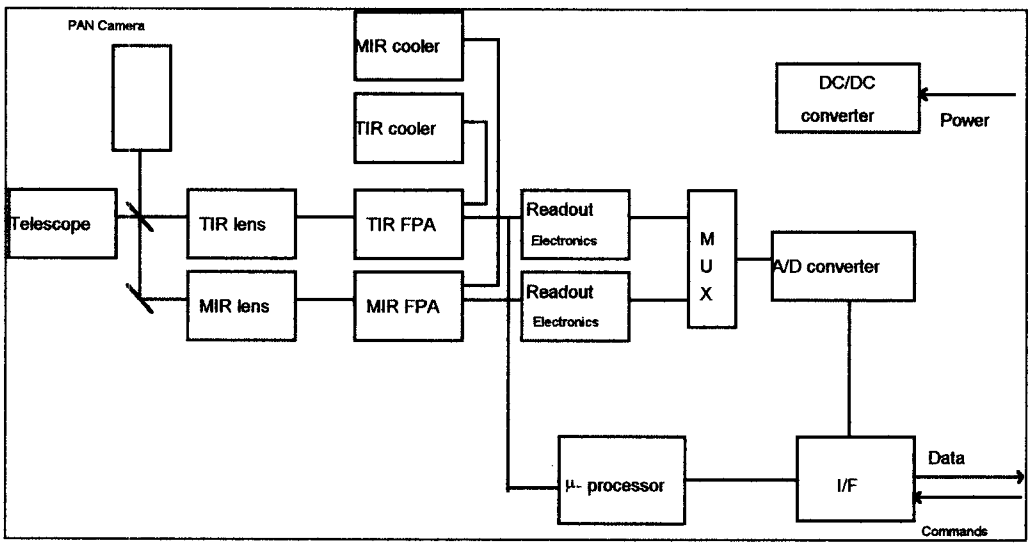

Figure 3.- Block diagram of the IR sensor

6.2.1 Optics description

The optical system of FuegoTec has been designed taking into account the following requirements:

6.2.1.1 Aperture

60 mm for TIR channel, with possibility to increase up to 100 mm

100 mm MIR channel

6.2.1.2 Field of view (FOV)

4.8 deg corresponding to 50 km swath at nadir

6.2.1.3 Focal length

MIR: 560 mm (pixel size 25 μm)

TIR: 140 mm (pixel size 28 μm)

6.2.1.4 Reflective telescope

The reflective telescope is common to IR channels and panchromatic visible channel. It consists of the following units:

- Common reflective telescope
- Beam splitter to separate visible channel from IR channels
- Beam splitter to separate MIR channel from TIR channel
- Relay lens for TIR
- Relay lens for MIR

The need of relay lenses is due to the need to locate the exit pupil on the cold window of the dewar, in order to avoid background thermal input to the detectors. Due to the different focal lengths of the two IR channels, there is one lens for each channel.

The baseline design is based on a focal telescope made of two confocal off-axis parabolas, with a demagnification factor of 3, followed by the relay lenses of:

- magnification 0.427 for TIR
- magnification 1.7 for MIR

The overall layout is shown in figure 4.

A second possibility for the telescope has been preliminarily investigated, based on a three mirrors anastigmatic configuration. This solution results feasible, presents an excellent image quality and could allow to reduce the number of optical elements. On the other hand, it is more difficult to build and more expensive, due to the degree of asphericity of the mirrors and to the difficulty to align them.

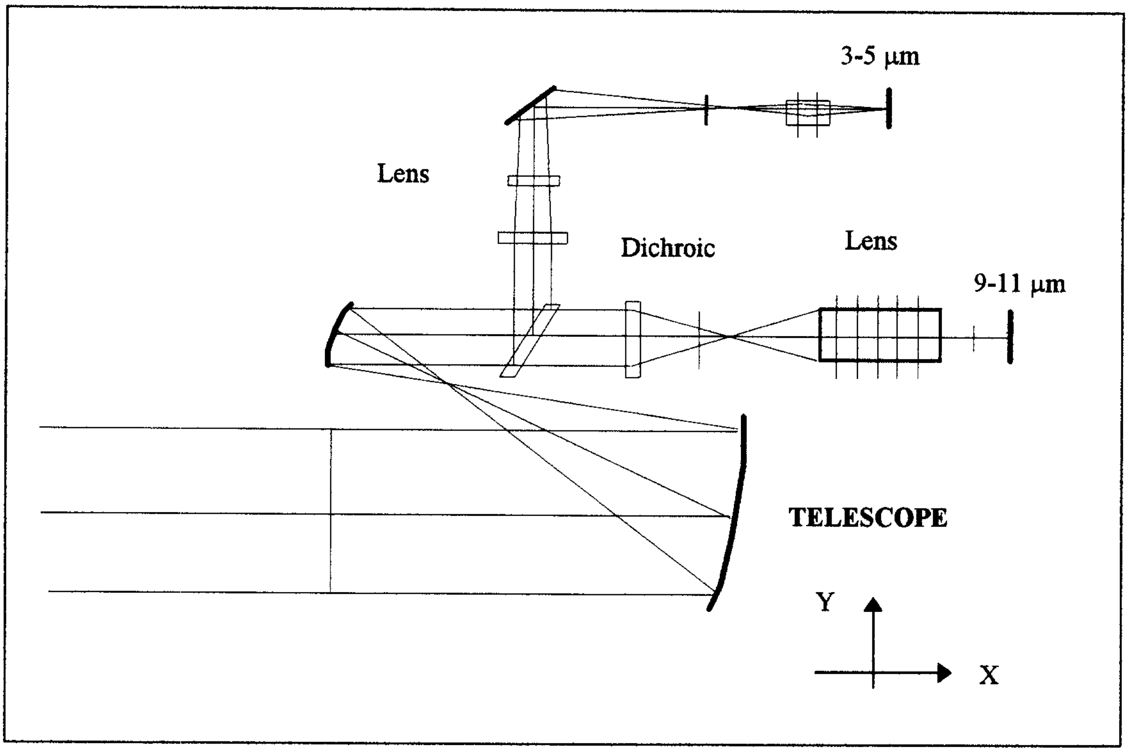

Figure 4.- Overall layout of the optical system based on off-axis parabolas telescope

6.2.2 Performance Budgets

The obtained performance budgets are the following.

6.2.2.1 Channels

VIS: panchromatic between 0.6-0.9 µm

MIR: centred at 3.7 µm with 1 µm bandwidth

TIR: centred at 9 µm with 1.4 µm bandwidth

6.2.2.2 Spatial resolution

VIS: 20 m

MIR: 30 m

TIR: 90-120 m

6.2.2.3 Swath

50 km

6.2.2.4 Steering capability

Provided by scan mirror: ± 57 deg

6.2.2.5 Number of pixels

VIS: 2500

MIR: 1660

TIR: 555-420

6.2.2.6 Estimated performances

- Monitoring

NEDT < 1 K in TIR channel

NEDT < 5 K in MIR for T> 400 K

NEDT < 1 K in MIR for T> 500 K

- Detection

Hot spots (800 K) smaller than 3x3 m^2 in MIR

6.2.3 Payload Interfaces

Assuming an orthogonal co-ordinate system where:

Z is the nadir direction

Y is the S/C velocity direction

the instrument shall be mounted in the nadir facing side or in the anti-velocity side of the satellite with clear view at nadir of:

5 deg along track

60 deg across track

Access to deep space of TBD steradians shall be provided to accommodate a passive radiator to dissipate at ambient temperature the heat dissipated by the cryo-coolers.

6.2.4 Engineering budgets

6.2.4.1 Payload typical dimensions

Payload typical dimensions are (according to the above mentioned reference system):

800 mm	X direction
500 mm	Y direction
500 mm	Z direction

6.2.4.2 Mass

The FuegoTec mission payload mass breakdown is the following:

Scan mirror	8 kg
Telescope	6 kg
Lenses	4 kg
IR focal planes with dewars	3 kg
VIS camera	2 kg
Cryo-coolers	12 kg
Processor	10 kg
Electronics	8 kg
Structure	10 kg
Thermal hardware	2 kg
Others and margin	10 kg
Total	75 kg

6.2.4.3 Power consumption

FuegoTec mission payload power requirement during operation is 100 W, including two cryo-coolers. Payload power requirement during non-operation periods is less than 30 W.

6.2.4.4 Data rate

The required data rates for the FUEGO 1st satellite payload are:

VIS camera:	9 Mbps
MIR channel:	4 Mbps
TIR channel:	0.25 Mbps

6.2.5 Overall instrument configuration

As an output of the results obtained in this technical note, it is possible to establish the overall arrangement of the instrument elements, which is shown in figure 5.

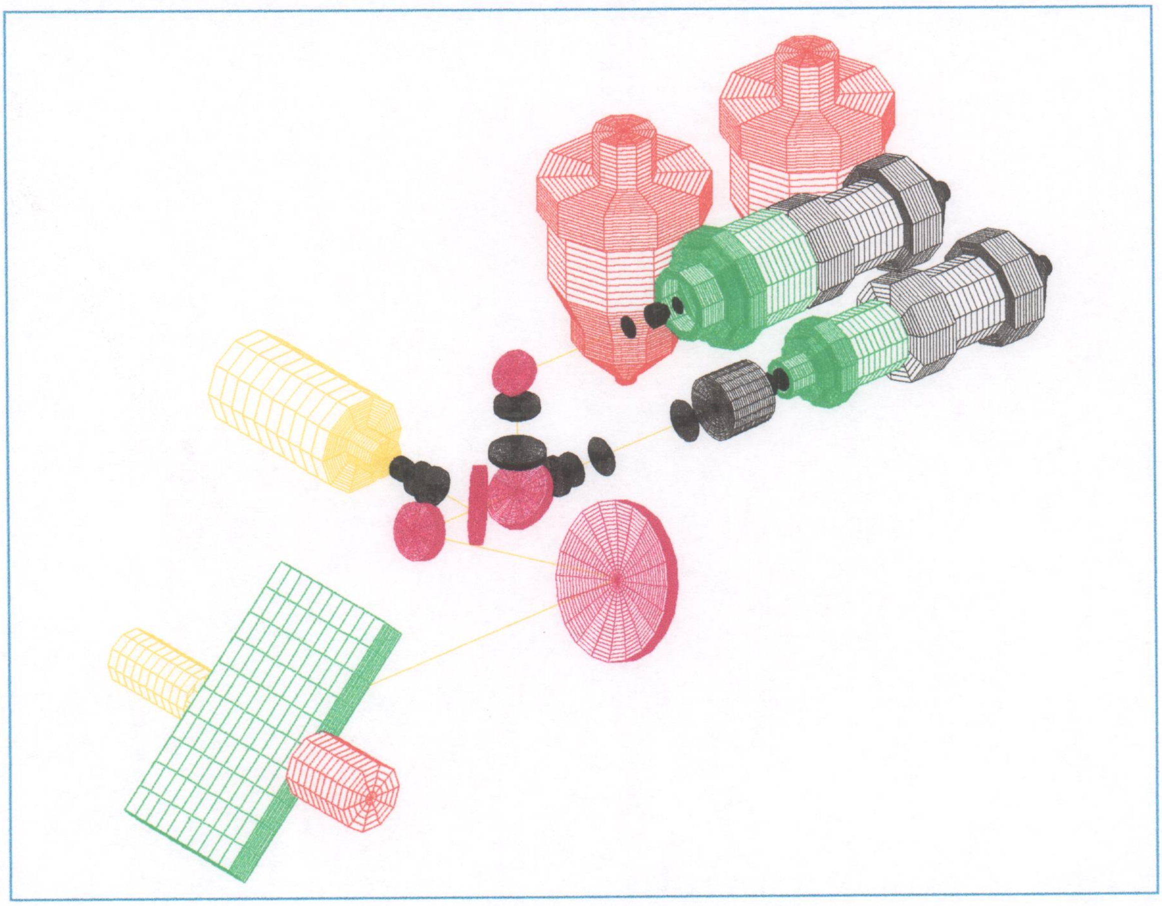

Figure 5.- Overall instrument configuration

6.3 FuegoTec user products

Even though the operational capabilities of the FUEGO 1st satellite mission are in the monitoring mode, users could be also provided with detection capability so that the system is validated in terms of the offered product but, obviously, not in terms of the required detection time.

Consequently, two type of products will be produced: detection and monitoring.

6.3.1 Detection products

The detection or inventory products for FuegoTec mission are very much similar as the expected for the complete FUEGO system except for the timeliness and delivery forms. For FUEGO, the space segment will forward directly to the user the detection products with a detection time average of about 20 minutes. For FuegoTec, the inventory products are delivered to the user upon his request with a delay of several hours.

The FUEGO 1st satellite detects the potential fires every pass, establishing their position, size and intensity. It stores the information received after it is seen by the ground reception station. Then, it downlinks the information to the reception station, where this information is checked and distributed. A fire inventory will be produced and distributed together with a message showing the detection hour.

The location of the fire will be made through a reference system for the satellite and will be translated into a reference system familiar to the user, in this case a layout of columns and lines but can also be latitude and longitude, UTM, toponimic or other co-ordinate systems.

Additionally, the system will provide the user with a second message. Once the first message has been received in the user terminal, the user, typically the fire fighting chief of a brigade, will be able to obtain simultaneous information on the fire intensity and dimensions, and location and characteristics of the terrain, as the slope, the uses and values of the field, fuel characteristics, co-ordination priorities, etc.

This second message is shown in the following sketch in where are also represented two GIS layers with the level curves and the road layout of a certain area.

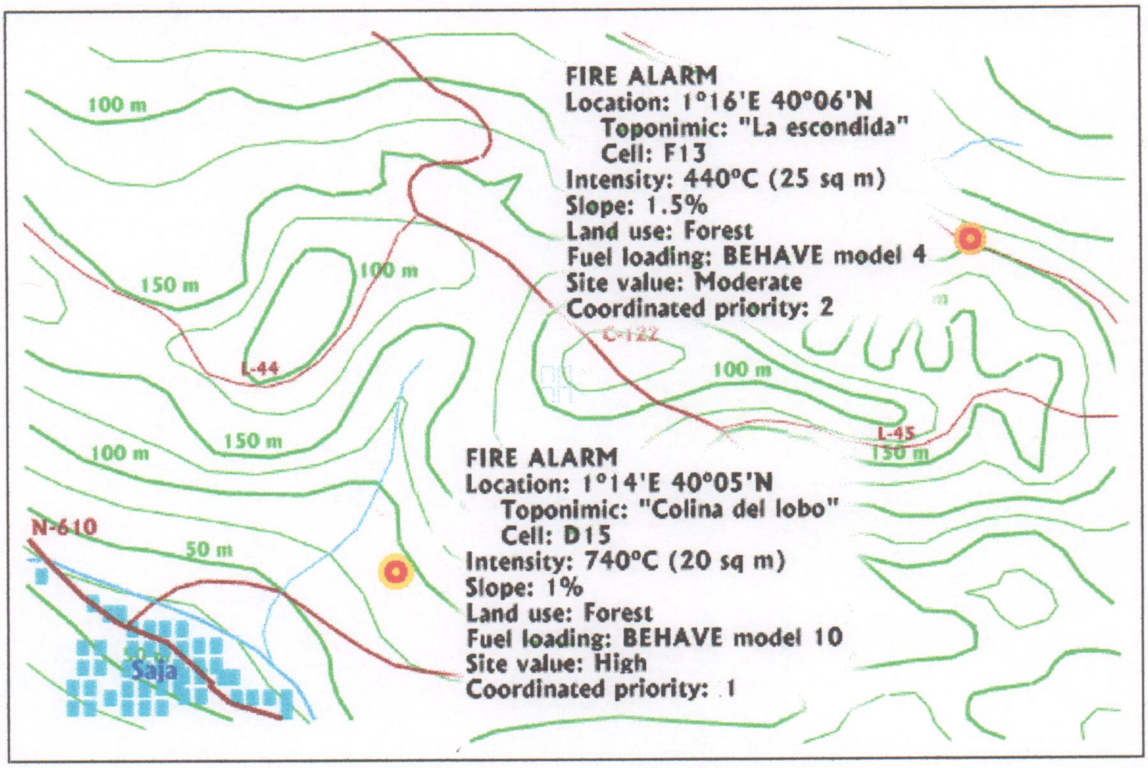

Figure 6.- Detection products

The GIS will be operative in the user terminal. It is to be underlined again that the FuegoTec mission detection products are not operational tools for the potential users and this capacity is contemplated only for detection product testing and inventory purposes.

6.3.2 Monitoring products

After fire detection, it might be convenient for the fire fighting responsible to have more information on relevant aspects of the on-going fire or fires.

FUEGO 1st satellite monitoring products will provide the user with synoptic calibrated images of 35 m ground resolution, showing the fire line position and colour coded intensity. Again, this information is sent to the user under request. On-ground processing could be necessary as a difference with the FUEGO system concept, in which the information will be sent directly to the user after his request. This information is complemented by means of a GIS residing in the user specific terminal, which will show the layers with fuel maps, terrain digital model (TDM), roads, orography, resources pre-positioning, vegetation maps, water location and so on. The proposed monitoring product is shown hereunder.

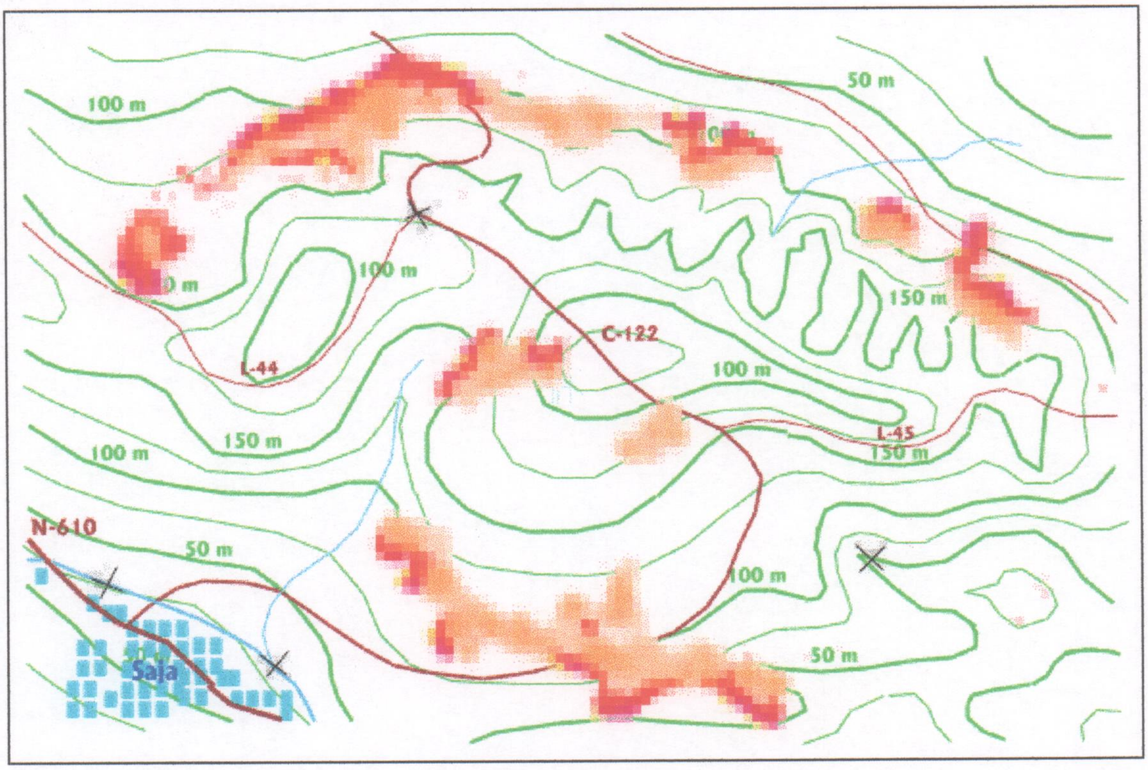

Figure 7.- Monitoring products

In this particular case, it is shown the fire intensity, the site orography and roads. There are also depicted the populated areas in the zone. An expert system can use these inputs to proposed the most effective ways of fire extinction.

6.4 FuegoTec operational concept

The data provided by the FUEGO 1st satellite mission will be forwarded to users at three different level: national, regional and local.

The responsibility of forest fire fighting is normally delegated in Europe to the regions. Furthermore, the final extinction action resides in the local centres which are most of the time in charge of doing the first attack while other resources arrive to the site.

Due to the characteristics of the limited detection mode, this capability will be aimed mainly at national and regional level to check its performances. It is planned to agree some field controlled burning in certain areas when the satellite passes over, so that the detection performances of the system can be checked out.

On the contrary, FuegoTec monitoring mode and products will be useful for the users in a quasi-operational manner. Therefore, the service should be focused at regional and local level in where the information should be able to reach the different functional areas (prevention and extinction) and operative segments (fire fighting brigades, on-ground and aerial extinction resources and other operative supply units).

To ensure the effectiveness of the proposed products, two points should be highlighted specially: to provide the adequate interface with the Geographical Information Systems (GIS) and the handheld terminal and to provide the proper operational interface with high resolution simulators.

Once the information has arrived to the user terminal, an expert system such as the mentioned before will manage the satellite data, together with the ground information, to provide the user with:

- fire extension maps
- arrival time for the available extinction resources maps
- optimised trajectories for the extinction resources
- foreseen actions for fire extinction
- optimum fire attack
- consequences of the defined attack actions
- radio-electric coverage map

These capabilities are to be implemented within the framework of the FUEGO Programme.

6.5 SMO requirements

Although some issues are obviously yet to be defined, the global requirements to be asked for to the SMO Service Provider are herewith compiled.

- Payload operative life: the FUEGO 1st satellite mission is designed for a nominal operative lifetime of two years.

- Orbit capabilities: the requested orbit parameters of the FUEGO 1st satellite mission are 599 km height and 47.5 ° inclination.

- Payload mass: the FUEGO 1st satellite estimated payload mass is 75 kg.

- Payload dimensions: the payload main dimensions are shown in figure 4. The instrument has to be mounted with clear view at nadir of 5 ° in the along track and 60° in the across track (see figure 8 for the reference system).

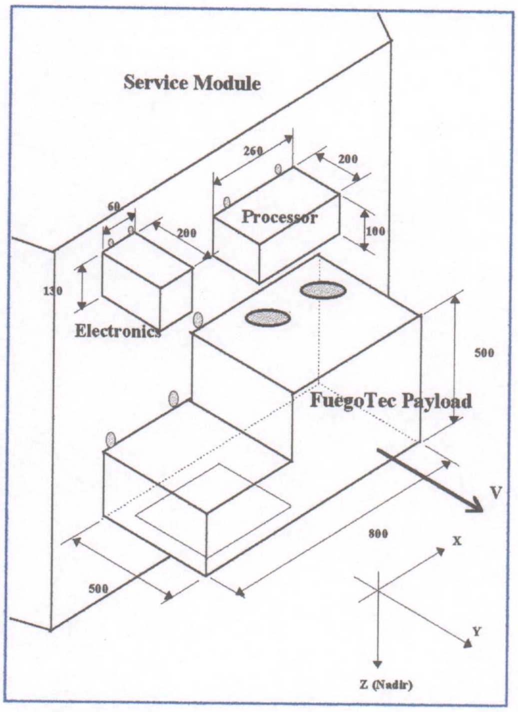

Figure 8.- Payload general dimensions and SVM interfaces

- Payload power requirements: the FUEGO 1st satellite payload estimated required power is in the range of 100 W. That leads to a total spacecraft required power of 250 W during acquisition periods and 75 W during non-acquisition. The eclipse time for the selected orbit is shown in figure 9.

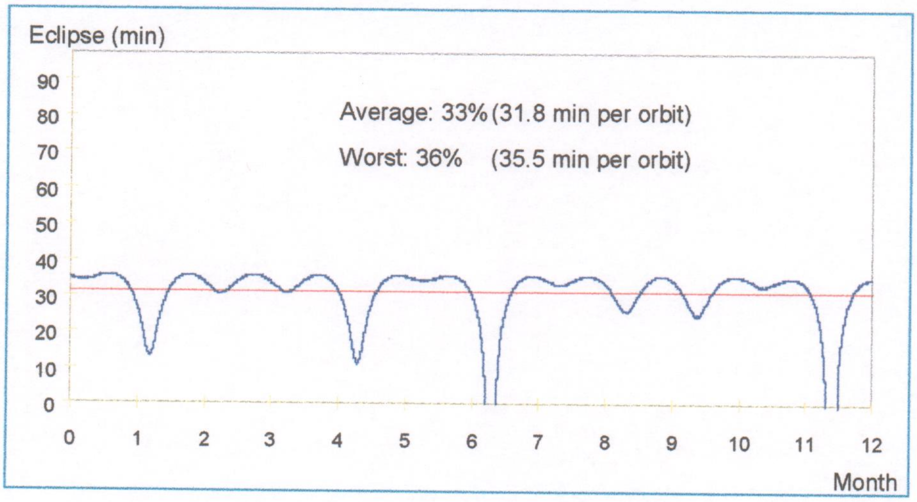

Figure 9.- Mean time eclipse

During operation, 250 W are requested for 10 minutes sun-illuminated and 5 minutes eclipse.

- Spacecraft mass: the estimated mass required for the FuegoTec bus (SVM) is in the range of 175 kg, yielding a total spacecraft mass of 250 kg.

- Spacecraft power requirements: the total maximum power consumption during FuegoTec mission operation is about 250 W (peak power). A total battery capacity of 8 Ah is required.

- Pointing requirements: FuegoTec mission requested control accuracy is 0.1 deg. Attitude knowledge requirement is estimated at 10 arcsec. These requirement lead to a 3-axis stabilisation AOCS, with star sensors for attitude knowledge at least.

- Propulsion requirements: as a baseline, no RCS will be needed for the FuegoTec mission.

- Ground segment and link capabilities: payload data acquisition will be done in X-band to allocate the large bandwidth necessary for dumping the bit-stream generated by the payload. TT&C links will be through S-band. FUEGO 1st satellite required data rate are 15 Mbps for the downlink, 2 kbps (TBC) for uplink and 64/32 kbps (TBC) for housekeeping purposes. A 10 Gb on-board solid state memory will ensure downlink capability of data up to ground reception visibility.

- Launcher baseline: the launcher required for the FUEGO 1st satellite injection into the requested orbit is any with sufficient performance and reliability to provide this injection in an effective way. As a baseline, the Pegasus XL was selected to carry out the present study.

- Payload data delivery strategy: FUEGO 1st satellite mission payload data are on-board processed and stored at the ground segment. Data will be compatible with commercial network for distribution to end users.

- Mission reliability: no formal study has been performed to work out the FUEGO 1st satellite mission reliability but it will be designed in order to ensure 0.7 reliability for the nominal lifetime of the mission.

- Mission cost: an estimate of payload foreseen cost was provided in TN 06, Business analysis and planning. The mission is considered to be in the intermediate complexity missions.

- Contract duration: the preliminary duration of the SMO activities from Kick-off meeting to Launch is 18 months, although the development plan for FuegoTec considers a 3-year period up to launch. This discrepancy might be solved during further contacts with ESA.

A 3-D view of the complete FuegoTec satellite, including payload and platform, is shown in figure 10.

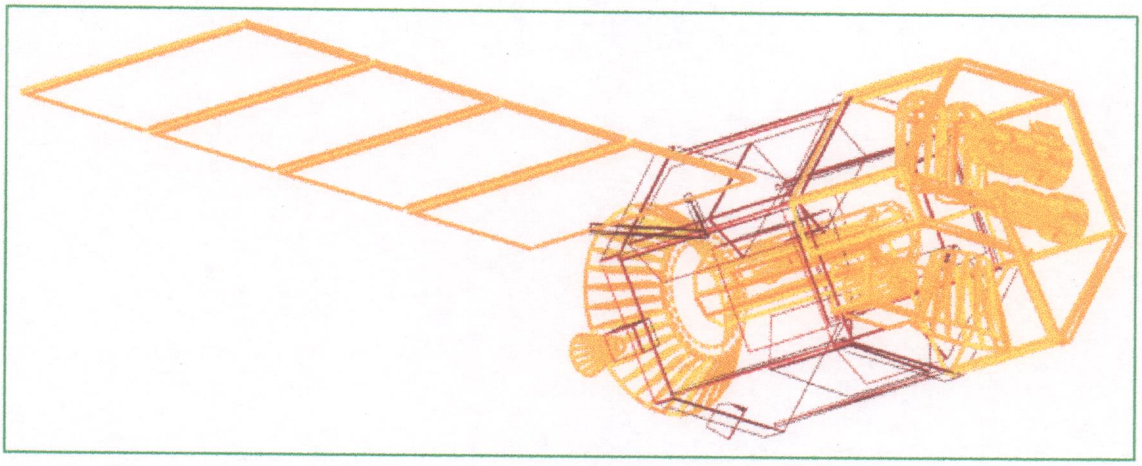

Figure 10.- FuegoTec satellite

6.6 Business analysis and planning

The business value of the FUEGO system in the light of ESA's SMO Initiative was identified by studying the present situation of the detection and monitoring services. Ratings that define the profile of value for the service in detection and monitoring and ratings of present systems were identified. Besides, basic areas of improvement as felt by the potential users, and volume and accessibility of the market were studied.

6.6.1 Present situation of forest fire detection and monitoring services

European fire fighting support is structured in two categories:

- Pre-suppression: including prevention, detection, fire attack forces, fire aviation operations, fuel management and new technologies insertion.

- Suppression: including fire attack forces operation, fire aviation on contract, fire aviation supplies, emergency medical support and planning and management of operations.

During the high risk season, the typical operations are based on the deployment of fixed and mobile observers, aerial surveillance, first attack or rapid mobile units, firefighting units, fire fighting aircrafts and co-ordination centres.

The paramount criterion to reduce fire effects is to reach the fire early enough to allow its control. Rapid reaction or first attack is very critical. In this sense, it is considered that a reaction time to achieve the fire from the time of its identification of 15 minutes is good for most conditions. Rapid reaction relies on early and reliable detection, pre-positioning of units and availability of access routes or aircrafts and helicopters. The second strategic line deals with escaped fires; the knowledge of fire evolution by knowing the present status of the fire line, atmospheric conditions in the fire area and fuel and fuel conditions in this area.

6.6.2 Present status of fire detection means

Presently, look out towers are the dominating technique to spot fires. The response time of the observer is not instantaneous but has the advantage of recognising smokes, if the person is well trained.

The big disadvantage is that the observer job is a seasonal one, discontinuous and coincident with most other agricultural and services seasonal jobs of people in the country side.

The detection systems based in infrared towers are expensive and, according to the users interviewed, not very efficient.

Although aircraft based sensors are seeing increased popularity, they are extremely expensive comparatively. It is true that the assets are used only during the high season but, on the other hand, those assets do not find complementary uses for most of the rest of the year. Additionally, the use of light aircraft under bad weather conditions is quite limited. Satellite sensors have not been affordable so far.

The interest and the willingness to pay for services is structurally growing in the prevention and detection areas. However, there are no comprehensive statistics on the cost dedicated to forest fire fighting in the Mediterranean countries. An estimate of the total cost incurred in these countries can be done based on:

- the number of persons engaged in observation tasks per region and per country
- the total number of persons dedicated to forest firefighting per region and per country
- the total budget allocated per region and per country
- the total number of aircraft used for firefighting and information purposes as discussed in the various interviews.

Typical values of the period 93-95 have been reported. They vary because the impact of more or less severe conditions imply more or less cost incurred.

Some structural change factors can be identified both on the demand and the supply side in the economic sector of firefighting (FF):

On the demand side, the most outstanding changes are the following:

1. Personnel availability for the observing task is becoming a problem.
2. The FF on ground operations are tending to be more dynamic with eventually less amount of personnel, better mobility, much better communications, and much better information.
3. The administration criteria are moving toward "pay per value" rather than "pay per cost".

4. The administrations are considering increasingly the use of contract services based on the performance of a complete service by companies, either with the necessary assets provided by the administration in part or in full, or with a complete package contracted.

5. As Europe goes through a period of improved economics at the beginning of the 2000's, the special request of urban population to access forest areas on weekends and holidays will continue to grow. The risk generated by visitors will increase and, at the same time, pressure for stable landscapes and fire avoidance will grow.

6. The pressure will increase to avoid large fires.

7. A cycle of expenditure will finish by the end of the century, when most of the payments in the EU nations regarding large amphibious aircraft acquisitions will end. Spain has finished its purchase of CL215T aircraft, France and Italy CL415 with possible ongoing purchases for Italy. Greece may have to retrofit or upgrade its fleet of CL215, or possibly gradually change it. It is assumed that the fleet of smaller aircraft will grow, but finance availability should be released from those line items.

8. Severe criticism of new technology products and services is being made by the administration users because promises of the past did not get really fulfilled.

9. The US position with respect to forest fires may change very rapidly. So far, Congress has accepted the steady increase in expenditure but this situation may change and a much larger emphasis on fire prevention and early detection may evolve.

10. Regionalisation and Europeanisation of the FF responsibility.

11. The representative figure of merit will be, more and more, the average surface burned per outbreak.

On the side of the supply the situation is the following:

1. As a result of the reduction of overall military aircraft production volume, aircraft and helicopter costs are set to go up in the coming future, except for light aircraft, where the market will benefit from new US legislation regarding liabilities passed in 1995.

2. Communication equipment will set a breakthrough for firefighting. Large scale constellations and GSM full coverage should make much easier to maintain continuous contract for command and information exchange between the various operational levels and units.

3. Satellite costs are being reduced considerably as a result of the same rapid growth in the communication satellites market and through the reductions in components costs. Also, the continued reduction in processing costs and in general of microelectronics pieces, translates into better cost effectiveness. The availability of computing power makes it possible for new satellites to process on board most of the information they collect routinely.

4. A considerable reduction of launch cost has to occur in the 2000's. Some signs of this trend can be seen today. A more steady process should occur as Russia stabilises and assumes a more normal production capability. Additionally, several initiatives in the US and Europe should materialise.

5. The ground equipment such as IR towers are too expensive for the value they provide, are difficult to maintain and install and, moreover, are intrusive in the forests and landscape. The users are not satisfied with the type of devices existing so far and their lack of mobility and adaptability to risk is against the way things move.

6. Watch aircraft are just expensive to run and, unfortunately, they have accidents from time to time, which means a serious the risk of producing potentially dangerous fires. They are, however, not seen as a thoroughly mean for fire detection, but could be used as a supplement.

The result of this situation is that the users are expecting something else from technology: reliable and thorough information. The technology is available to build affordable satellites that provide a substantial part, not all may be, of this information. Theses devices shall be essentially autonomous, that is, without intervention other than user and housekeeping.

The user will require a certain time to believe and more time to adapt its structures sufficiently. The most critical step is to trust a non traditional source of information without having the raw data on its hand (images, etc). However, the user is permeable to technology that proves to be useful.

The moment to have this new solution has to be the end of the century, when a further push of the economics of the EU will make it necessary to maintain or improve the efficiency of firefighting and much more difficult to find people to stay in observer towers.

6.6.3 The ideal profile of a new service offer

On the basis of the performed interviews and user discussions, it can be described what the ideal information system to support forest firefighting could be:

- Prior to a fire outbreak: providing location of risk areas with their risk index, in a way that allows to preposition first attack assets and providing location of agricultural burning to allow enforcement of limitation.

- At outbreak: providing fire location and intensity and wind local status at the district centre level, within minutes of outbreak. The maximum average delay is not easy to determine but is in the order of 10 minutes. The service required is independent of cloud coverage or condition as a system, and is day and night.

- After the outbreak, on demand: where is the fireline, what structure it has and when the fire is escaped or advancing. An almost continuous monitoring is desirable, providing a good resolution (30 m or less, with excellent accuracy 100-200 m) every, say 30 minutes or, in some cases with heavy winds, even less. Hot spot location when the fire is controlled is also highly desirable.

- After the fire is controlled or suppressed: perimeter of burned land and surface.

The cost is to be commensurate with the service provided and, in any case, lower than the present cost with the present organisation.

6.6.4 The market

The functional services that are identified are as follows:

1. Provision of high frequency Canopy Surface Temperature and derived Risk Maps. This product can be provided separately but should be an option on the Basic Service.

2. Provision of Early Fire Detection over Risk Areas with results directly broadcasted to the Regional contact point.

3. Provision of Fireline Synoptic and Area Schematics.

4. Provision of Hot Spot Screening.

5. Burned Surface Perimeter and total area and Fire Outbreak Statistics.

The highest value item is type 2, but in some cases it may be that some regions may require only type 3, 4 or even 5.

The EU is the primary market and was evaluated in TN06, Business analysis and planning.

The other identified markets are as follows:

- US/Mexico: because of the size and budget it has to be taken into account.

- Australia

- South America: including Chile, Argentina, and to some extent Brazil, Ecuador.

- OTHERS: Other Mediterranean countries, China and the Pacific countries are possible targets, size TBD.

6.6.5 Estimated system cost

The simplified FUEGO system cost breakdown is as follows:

- Satellites	90 MECU
- Launch	30 MECU
- Ground Segment	3 MECU
- User Segment	2 MECU
- Operational Reserve	15 MECU
Total System Cost:	140 MECU

The system is meant to be operational for a period of 7 years at least, so its estimated a cost of operation composed of:

- Operation of System Ground Segment
- Distribution and Billing
- Help desk and user support
- Management of the Business

for a total of 1,5 MECU per year. Users and customers in the regions were considered here and, therefore, an effort to distribute that would be reduced if the service was purchased at national level. For a 7 year lifetime this represents 10,5 MECU.

6.6.6 Business profile

The FUEGO System represents a viable option to provide a system with good user acceptance and for which there is willingness to pay. However and in order to make it a reality, the following aspects have to be taken into account.

1. The usage of the system in EU should be quite high since the 1st year of operations.
2. The usage in Non-EU countries has to be stimulated very strongly to achieve an adequate income.
3. As a corollary of 1 and 2, a precursor program has to be generated to cover the development costs of the system, not included in the cost calculated here, and the demonstration system as a pre-operational.
4. The business is still risky for purely capital market fund raising and some risk sharing with the administration will be necessary in order to make the operation more attractive.

A relatively large production batch would be produced and, consequently, a substantial industrial capability would be used.

The business analysis and plan that has been made shows that the system is a good investment with an acceptable ROI.

7. Conclusions and recommendations

The FUEGO 1st satellite mission, also called FuegoTec, has been defined in order to achieve the established objectives of the FUEGO system: to validate the technologies to be used and to provide potential FUEGO users with information on forest fires detection and monitoring to be validated and used by them.

The proposed mission fulfils all the preliminary requirements established by the SMO service. As a result of the performed studies, the basic requirements for the proposed FuegoTec mission have been identified.

It would not be possible to launch an application program like FUEGO without a precursor mission. Such mission FuegoTec completely develops the payload module and the integration with the service module. It allows to demonstrate to the users the type of service they will get and to create sufficient credibility to obtain long term contracts for the constellation service or public participation in the funding.

Timing for FUEGO is of the essence. FuegoTec should create a strong awareness of the possibilities of the European technology to fulfil the requirements of users. After the market first pull has arisen, the supply should follow immediately.

The Non-EU market is extremely important for FUEGO. The potential for EU funding to support FUEGO usage in developing countries is also to be considered. It should not be forgotten that wildfires are a problem that grows with economic development and urbanisation.

A clear effort has to be made to extend the FUEGO and FuegoTec awareness to temperate forest countries beyond the EU. In this sense, Australia and South America are areas of high priority.

FuegoTec has to come at the right time, which is understood to be 1999 because of:

- the potential US competition based on available technology sourced by the military
- the generation gap created by obsolescence of old systems and the new economic cycle in Europe.

SMO is the ideal vehicle to do it. FuegoTec is an ideal mission for SMOI. It has the potential of a constellation and generates production leverage on the investment.

FuegoTec could be conceived within SMO with various degrees of integration. The most critical and essential one is the launch capability. This working team believes that having this affordable launch capability confirmed is paramount for the feasibility of the concept.

The platform for the FUEGO system could be a generic one (SMOI) or a specific one adapted to the mission and optimised for production.

The FuegoTec payload should be ready by 1999. In this sense, steps are being taken with the EU to request funding for this payload, and the commitment of the companies and institutions backing FUEGO to promote the system does exist.