EUFIRELAB

EVR1-CT-2002-40028

D-07-07

http://eufirelab.org

EUFIRELAB:

Euro-Mediterranean Wildland Fire Laboratory, a "wall-less" Laboratory for Wildland Fire Sciences and Technologies in the Euro-Mediterranean Region

Deliverable D-07-07

Infrared imager

its interest for wildland fire monitoring

Collective work moderated by Francisco RODRIGUEZ Y SILVA

June 2004

CONTENT LIST

Summary ... 1

1 Infrared energy: introduction ... 2
- 1.1 Infrared energy ... 2
- 1.2 The electromagnetic spectrum ... 2
- 1.3 Concepts of radiometry ... 3
  - 1.3.1 Radiometry magnitudes ... 3
  - 1.3.2 Emittance, reflectance, absorptance and trasmittance ... 3
  - 1.3.3 Principles and laws of the electromagnetic radiation ... 3
- 1.4 Infrared instruments ... 4

2 Space platforms ... 5
- 2.1 Resolution of a sensor system ... 5
  - 2.1.1 Spatial resolution ... 5
  - 2.1.2 Spectral resolution ... 5
  - 2.1.3 Radiometric resolution ... 5
  - 2.1.4 Temporal resolution ... 5
  - 2.1.5 Angular resolution ... 5
- 2.2 Types of sensors ... 5
  - 2.2.1 Passive sensors ... 5
  - 2.2.2 Active sensors ... 6
- 2.3 Space platforms ... 6
  - 2.3.1 NOAA ... 6
  - 2.3.2 Landsat ... 7
  - 2.3.3 SPOT ... 8
  - 2.3.4 ERS ... 8
  - 2.3.5 RADARSAT ... 9
  - 2.3.6 JERS ... 9
  - 2.3.7 EOS ... 10
  - 2.3.8 DMSP ... 11
  - 2.3.9 GOES ... 11
  - 2.3.10 TRMM ... 12
  - 2.3.11 IRS ... 12
- 2.4 Satellital applications in forest fires ... 12
  - 2.4.1 Fire potential ... 12
  - 2.4.2 Fire detection ... 13
  - 2.4.3 Fire monitoring ... 13
  - 2.4.4 Fire assessment ... 13
- 2.5 Specific satellite platforms ... 14
  - 2.5.1 FUEGO Programme ... 14
  - 2.5.2 BIRD Mission ... 15
  - 2.5.3 Others ... 15

3 Fixed platforms ... 16
- 3.1 Bosque system ... 16
  - 3.1.1 Introduction ... 16
  - 3.1.2 Bosque System applications ... 16
  - 3.1.3 General description ... 16
  - 3.1.4 System elements ... 16
  - 3.1.5 Bosque System improvements ... 18
- 3.2 Bright Spot Detection System (B.S.D.S.) ... 18

4 Airborne platforms 19
4.1 Introduction 19
4.2 Airborne platform equipment 19
4.2.1 Aircraft 19
4.2.2 Infrared imager 19
4.2.3 Complementary equipment 20
4.2.4 Crew 20
4.2.5 Ground services 20
4.3 Airborne applications 20
4.3.1 Fire detection 20
4.3.2 Fire monitoring 21
4.3.3 Fire mapping 21
4.3.4 Fire assessment 21
4.4 Examples of existing airborne infrared applications. 21
4.4.1 Surveillance and co-ordination airplane ACO, Spain 21
4.4.2 Phoenix system (U.S.A) 21
4.4.3 Airborne Infrared Disaster Assessment system (AIRDAS) (U.S.A) 22
4.4.4 Daedalus System 22
4.4.5 Wildfire Airborne Sensor Programme WASP 23
4.4.6 Airborne Wildfire Intelligence System AWIS 23

5 Handheld Ground Mobile Platforms 24
5.1 Handheld instrumentation 24
5.2 Handheld instrumentation applications 24

6 Bibliography 25
6.1 References 25
6.2 Internet links 25

SUMMARY

This document reminds basic characteristics concerning infrared energy: electromagnetic spectrum, radiometry concepts and infrared instruments (chapter 1).

It describes in the four following chapters:

- the space platforms: it indicates their spatial, spectral, radiometric, temporal and angular resolutions, and defines the active and passive sensors; it describes 11 space platforms detailing their characteristics and instrumentation; it presents the satellital applications to wildland fires and some specific platforms dedicated for that purpose,
- the fixed platforms: it describes to of them the Spanish Bosque system and the American BSDS
- the airborne platforms: it details their characteristics and specificity for wildland fire detection, monitoring, mapping and assessment, and presents six examples of them
- the handheld ground mobile platforms: some information upon this type of platform and its instrumentation is given.

In a brief bibliography chapter, the document gives a long list of links to Internet sites dedicated to these devices.

GLOSSARY

None

ASSOCIATED FILES

None

1 INFRARED ENERGY: INTRODUCTION

1.1 INFRARED ENERGY

Infrared energy is part of the electromagnetic spectrum.

The electromagnetic energy travels according to the ondulatory theory through space at the speed of light with a sinusoidal way:

$$C = \nu\lambda$$

where

- C is a constant which value is $3*10^8$ m/s
- ν is the frequency, its unit is the Herz (Hz)
- λ is wavelength, unit the micrometer.

The wavelength of IR energy is about an order of magnitude longer than visible light, between 0.75 and 1000 µm. IR radiation is similar to visible radiation in its physical properties although is invisible to the eye.

The infrared radiation is a electromagnetic radiation that is emitted by all objets as a function of their temperature. Infrared energy is generated by the rotation and vibration of atoms and molecules.

The higher the temperate of an object, the more the motion and hence the more infrared energy is emitted.

1.2 THE ELECTROMAGNETIC SPECTRUM

Electromagnetic radiation is categorised by wavelength or frequency.

The value series of wavelength are continuous but we can discriminate a series of bands where the electromagnetic radiation have a similar behaviour.

The organisation of this bands of wavelength or frequency composes the electromagnetic spectrum.

The unit of measurement is the micrometer (µm).

The width of the bands changes according to different authors but the more usual classification for the infrared radiation is between 0.75 to 1000 µm.

Besides the IR region is divided in:

- Near IR: 0.75 to 3µm. NIR
- Medium IR: 3 to 6 µm. MIR
- Far or Thermal IR: 6 to 15 µm. TIR

:

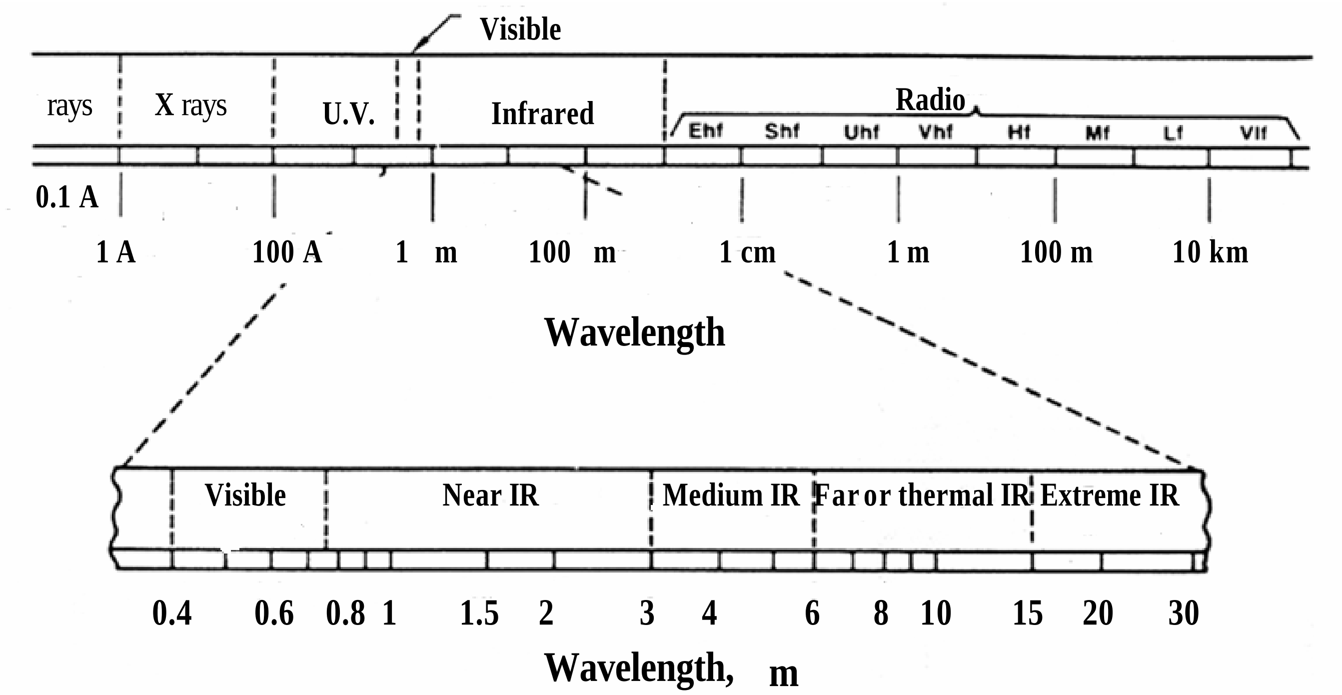


Figure 1-1: The electromagnetic spectrum

1.3 CONCEPTS OF RADIOMETRY

1.3.1 Radiometry magnitudes

The radiometric magnitudes more common and used in the IR field are the following.

1.3.1.1 Radiant energy (Q)

The total radiated energy in all direction.
The unit of measurement is Joule (J).

1.3.1.2 Radiant flux (Φ)

It measures the power transported by the radiation.
It is the total radiated energy in all direction per time unit. Unit: Watts (W).

1.3.1.3 Exitance (M)

When radiation emitted, rather than incident, is considered, the magnitude is called exitance.
It is the total energy radiated in all direction from an area unit in a time unit.
The measurement unit is Watts per square meter.

1.3.1.4 Irradiance (E)

Total energy radiated on an area unit per time unit.
It is referred to the incident energy.
It is measured by Watts per square meter (Wm^{-2}).

1.3.1.5 Radiant intensity (I)

The total energy that is radiated per time unit and per solid angle.
The measurement energy is Watt per stereo-radian.

1.3.1.6 Radiance (L)

The most basic task when performing IR measurements is to estimate the exitance of a given source, knowing the irradiance it creates on a detector.
In order to solve this problem, it is convenient to use another magnitude called radiance.
It is the total radiated energy in a determined direction per area unit and per solid angle.
Units of radiance are Watts per square meter per stereo radian. ($W/m^{-2}sr^{-1}$).
A simple and important case is that of a Lambertian source, for which emission is isotropic (L does not depend on the direction).
The importance of radiance stems mainly from the invariance theorem (NICODEMUS, 1963) that states that, in any optical system, the radiance along the path of a ray is invariant (if the refractive index changes, L must be divided by it).
This theorem greatly simplifies radiometric calculations.

1.3.1.7 Spectral radiance (L_λ)

It is the total radiated energy in a determined wavelength per area unit and per solid angle.
All the other radiometric magnitudes introduced above may be defined as spectral, that is to say, per unit wavelength (or, equivalently, per unit wave number).

1.3.2 Emittance, reflectance, absorptance and trasmittance

The emittance (ε) is the relation between the emittance of a surface (M) and the emittance of a perfect emitter (black body) at the same temperature (Mn).

When light strikes a body, a part of it is reflected, a part is absorbed and a part is transmitted. So we can define:

- Reflectance (ρ): fraction of power reflected, it is the relation between incident flux and the reflected flux.
- Absorptance (α): fraction of power absorbed, it is the relation between incident flux and the absorbed flux.
- Transmittance (τ): fraction of power transmitted

Obviously, $\rho + \alpha + \tau = 1$

Most solids can be regarded as opaque (τ = 0) and then $\alpha = 1 - \rho$ (solid).
On the other hand, gases have zero reflectance and $\alpha = 1 - \tau$ (gas)

These parameters depend on the material, on the wavelength and, to a certain degree, on temperature.

A body for which $\alpha = 1$ for all wavelengths (i.e., a body that absorbs all the radiation that strikes upon it) is called a blackbody.
A body for which α is constant (<1) for all the wavelengths it is called a grey-body.
Usually, solids can be treated as grey-bodies, whereas gases have a strong spectral structure.

1.3.3 Principles and laws of the electromagnetic radiation

The main and more general law that describes the behaviour of the electromagnetic energy is the Plank law.
The Plank law connects the energy flux with the wavelength:

$$M_{n,l} = \frac{2phc^2}{l^5\left\{\exp\frac{hc}{lkT} - 1\right\}}$$

where:

- M is the spectral radioactive emittance of a blackbody at a determined wavelength.
- H is Plank Constant ($6.626*10^{-34}$ Ws^2)
- K is Boltzmann constant ($1.38*10^{-23}$ Ws^2K^{-1})
- C is the speed of the light
- λ is the wavelength
- T absolute temperature of a blackbody.

The Plank law indicates that an object under absolute zero (-273ºC) emits energy, and this energy increases with the temperature.
Besides is the temperature is greater, the wavelength is shorter.

Derived from the Plank law we can define two important laws:
- Stefan-Bolztman law
- Wien law.

The Wien law allows calculate the wavelength where a blackbody mitts the maximum emittance, knowing the temperature:

$$l_{max} = \frac{2898}{T} mmk$$

where:
- T is the temperature (in Kelvin).

Thanks to this law it can be selected the spectral band more adequate to detect an object in a determined temperature.

The Stefan-Bolztman law integrates the spectral emittance of a blackbody for every wavelength.
We can calculate the total energy that it emits per area unit:

$$M_n = sT^4$$

where:
- σ Stefan-Bolztman constant (5.67*10^{-8} W$m^{-2}K^{-4}$)
- T is the temperature (in Kelvin)

1.4 INFRARED INSTRUMENTS

From the EUFIRELAB Deliverable D-07-04 we can presents below the IR instrumentation used to measure the infrared energy.
For further information see this Deliverable D-07-04.

An IR detector is a device that provides a signal proportional to the IR radiation that falls unto it.
We will assume the usual case in which the signal is a voltage and the radiation is defined as irradiance (power per area).
There is a large variety of IR detectors (VINCENT, 1990), that can be divided broadly into two families:
- Thermal detectors (bolometers, thermopiles, pyro-electric detectors) are sensitive to the entire IR spectrum and may operate at room temperature.
- Quantum detectors (usually, photodiodes or photo-conductors made of semiconductors) are much faster than thermal detectors, but they operate only in a specific spectral range, and usually require cooling at cryogenic temperatures.

Both kinds of detectors are used in IR instrumentation.

From the point of view of the user, however, the main distinction does not arise from the detector type but from the operating mode.
The two relevant variables here are spectral resolution and spatial resolution. According to this, four types of IR instrumentation can be distinguished:

The output of a simple IR detector without any accessories (except for the read-out and, eventually, the bias circuits) will be a voltage proportional to the irradiance that falls on the detector in the spectral band in which the detector is sensitive.

For all the applications, some kind of optics is adapted to the sensor.

	Resolution	
Instrument	Spatial	Spectral
Radiation thermometers	No	No
IR cameras	Yes	No
IR spectrometers	No	Yes
Imaging spectrometers	Yes	Yes

The output of a simple IR detector without any accessories (except for the read-out and, eventually, the bias circuits) will be a voltage proportional to the irradiance that falls on the detector in the spectral band in which the detector is sensitive.

For all the applications, some kind of optics is adapted to the sensor.
In the simplest case, the optics serves only to restrict the field of view to a certain solid angle.

This simple configuration forms the basis of a radiation thermometer (the irradiance is related, through Planck's law, to the temperature of the object in the field of view).
Related instruments are the heat flux transducers.

Both kinds of devices have neither spatial nor spectral resolution, and their output is a number.

If a wavelength selecting device (for instance, a prism or a diffractive grating) is coupled to the optics, an instrument with spectral resolution can be made-up.

This is the case of IR spectrometers, whose output is a spectrum.
IR spectrometers integrate the incoming radiation over the whole field of view of the instrument.

An instrument can be conceived that discriminates between different points within the field of view, i.e., that has spatial resolution.

Most of these instruments do not have spectral resolution, and are called IR cameras. Their output is an image.

Finally, the instruments that combine spectral and spatial resolution are called imaging spectrometers.
Their output, sometimes called a spectral cube, can be viewed as an image for each wavelength of the spectral range or, equivalently, as a spectrum for each point of the field of view.

The term infrared imager includes the Infrared devices that obtains images from the electromagnetic band of the infrared.
Depending on the different authors and the specific characteristics of the instrument the used nomenclature can change but all names can be included in the term infrared imager.

2 SPACE PLATFORMS

2.1 RESOLUTION OF A SENSOR SYSTEM

We can define resolution of a sensor system as the capability to discriminate detail information (ESTES y SIMONETT, 1975).

2.1.1 Spatial resolution

The spatial resolution determinate the smallest object that can be discriminate on a image. In a photographic system is the minimal distance where two objects appears different and separated.

The units of measurement are the millimetre (mm) for the photograph and the meter (m) for the land.

It depends on the focal length of the camera and the height from the surface.

The spatial resolution of the earth observation sensors currently contain a wide range.

The satellites with a mayor spatial resolution have a resolution next to 1x1 meter.

The satellites destined to natural resources shows spatial resolution from 6x6 meter for panchromatic sensor IRS-IC to 120x120 meter for Landsat-TM.

Sensors destined to global uses like Modis, SPOT-Vegetation or NOAA-AVHRR gives spatial resolution between 200 and 1100meters.

And on the other hand meteorological geostationary satellite, Meteosat or GOES have a resolution of 5 km.

2.1.2 Spectral resolution

The spectral resolution indicates the number and width of spectral bands than the sensor can discriminate.

The photographic sensors usually offers 1 band with panchromatic film or natural colour or infrared colour films (4 bands).

The optics-electronic sensors offers a wide range from the SPOT-HRV with 4 bands to 36 channels of Modis.

2.1.3 Radiometric resolution

The radiometric resolution is the sensibility of the sensor. It is the capability to detect the changes of spectral radiance that the sensor receives.

For photographic sensors the radiometric resolution is measured by the number of greys.

In the case of optics-electronic sensors is used a digital codification that express the number of bits that requires each element of the image to be stored.

For example Landsat-MSS 128 levels of codification, others usually 256, although NOAA-AVHRR works with 1024, and Modis, ERS or Radarsat with 65536.

2.1.4 Temporal resolution

The temporal resolution is the coverage frequency that the sensor provides.

It is the periodicity with the sensor acquires images from the same portion of the earth surface.

It depends on the orbital characteristics of the platform (high, velocity, inclination) and the sensor (opening total angle).

It also depends on atmospherics conditions.

The geostationary satellites (Meteosat, GOES) gives a temporal resolution of 30 minutes, NOAA each 12 hours, Landsat 16 days or ERS 31 days.

2.1.5 Angular resolution

The angular resolution is the capability of a sensor to watch the same zone from different angles.

The sensors that can watch simultaneously from several angles received the name of multi-angular sensor.

2.2 TYPES OF SENSORS

Depend on the procedure of receiving the energy of the surface the sensors can be classified in two categories: Passive Sensors and Active Sensors.

- Passive sensors: the energy is from an exterior focus.
- Active sensors: the sensor can emit its own energy beam

2.2.1 Passive sensors

The passive sensor receive the energy beam from an exterior focus.

They can be classified in three types in function of the recording way the received energy:

- Photographic sensors.
- Optic electronic sensors: scanners, pushbroom imager, video cameras.
- Antenna: Microwave radiometer.

A photographic camera records the reflected energy on photosensitive emulsions thanks to an optic system.

Four elements allows different possibilities: type of film, number of lens, observation angle, and platform high.

The type of film can be: panchromatic (black and white), colour visible, and colour or black and white infrared.

Depending on the number of lens the cameras are mono or multi-band covering one or more regions of the electromagnetic spectrum.

The observation angle is perpendicular or oblique.

The platform high allows to discriminate between airborne or satellite photograph, in the first case the spatial resolution and the sharpness is better and in satellite photograph is the surface coverage and the geometric precision.

We can classified the optic electronic sensors in three types: Scanners, Pushroom imagers, Video cameras

The scanners are a type of sensors combines an optic similar to photograph with electronic sensor.
It has a mobile mirror that osciles perpendicular to the direction of the trajectory.
In the Pushroom the mobile mirror is eliminated.

The video camera is the other optic electronic sensors that can work in a panchromatic or multi-band way.

Finally the microwave radiometer is the last passive sensor. It operates in the spectral range respective to millimetric waves, normally between 6,8 and 90 GHz.

2.2.2 Active sensors

The active sensors are the sensors that can emit its own energy beam.
It can be classified in two types: Radar and Lidar

2.3 SPACE PLATFORMS

In this chapter we carry out a revision of the main and most interested space platform destined to obtain images of natural resources in order to be used in forest fires applications.
From space platforms and its sensors destined to global studies (including forest fires applications) to specific platforms specifically developed for wildland fires applications.

Before this review we show a first classification of the satellites depending on its orbit. We distinguish two kinds of satellites:
- Geo-synchronous satellite
- Sun-synchronous satellite

The geo-synchronous satellites are located in very high orbits that allow that the satellite is synchronised with the rotation movement of the earth, observing always the same zone of the earth.
They observe the whole image of the earth from the longitude that they were located.
For example Meteosat satellite is placed on longitude 0º acquiring always images from Europe while the GOES for example are on longitude 70º and 140º observing the EE.UU: east and west coast respectively.
This type of satellites have and high temporal resolution but its spatial resolution is lower.

The sun-synchronous satellites have a lower orbit that usually is circular and polar (perpendicular to equatorial plane).
It observe different zones of the earth and it use the rotation movement of the earth to placed in the same point at the same time.
Because of the Earth rotes from West to East and the platform orbits from North to South in a constant way, the satellite will be able to observe the same point of the earth after a concrete time that it depend on the velocity and height of the orbit.
In general terms in these satellites the temporal resolution is lower while the spatial resolution is higher.

2.3.1 NOAA

The National Oceanic and Atmospheric Administration (NOAA) of the USA is in charge of the series of NOAA satellites which each has the Advanced Very High Resolution Radiometer (AVHRR) sensor.
This sensor collect global data on a daily basis for a variety of land, ocean, and atmospheric applications.
This sensor can be used to multiple applications included:
- Forest fire detection
- Vegetation analysis
- Weather analysis and forecasting
- Climate research and prediction
- Global sea surface temperature measurements
- Ocean dynamics research and search and rescue.

The AVHRR sensor is a five or six channel, depending on the model, scanner, sensing the visible, near-infrared, and thermal infrared regions of the electromagnetic spectrum.

NOAA Instrumentation: AVHRR Sensor

The main characteristics of the AVHRR sensor located in NOAA satellites are the following:
- Swath width: 2399km
- Resolution at nadir: 1.1km approx.
- Altitude: 833km
- Quantisation: 10 bit
- Orbit type: Sun synchronous
- Nº. of orbits per day: 14.1 (approx.)

The spectral characteristics of AVHRR sensor can be summarised in the next table:

	Wavelength		
No	NOAA-12	NOAA-15, 16, 17	Typical use
1	0.58 - 0.68	0.58 - 0.68	Daytime cloud and surface mapping
2	0.725 - 1.00	0.725 - 1.00	Land-water boundaries
3	3.55 - 3.93	N/A	Night cloud mapping, sea surface temperature
3A	N/A	1.58 - 1.64	Snow and ice detection
3B	N/A	3.55 - 3.93	Night cloud mapping, sea surface temperature
4	10.30 - 11.30	10.30 - 11.30	Night cloud mapping, sea surface temperature
5	11.50 - 12.50	11.50 - 12.50	Sea surface temperature

2.3.2 Landsat

The ERTS (Earth Resource Technology Satellite) was launched the 23rd of July of 1972.

It was the first satellite of Landsat series.

Since this first launch it has been carried out others than can be seen in the next table:

Satellite	Launch Date	Notes
Landsat 1	23/01/1972	Decommis. 06/01/1978
Landsat 2	22/01/1975	Decommis. 25/02/1982
Landsat 3	05/03/1978	Decommis. 31/03/1983
Landsat 4	16/07/1982	Decommis. DD/062001
Landsat 5	01/03/1984	Operational
Landsat 6	DD/10/1993	Failed on launch
Landsat 7	15/04/1999	Operational

The Landsat series has carried several sensors on board:

- Multispectral Scanner (MSS) with 80 metre pixels and four spectral bands
- Thematic Mapper (TM) sensor with a 30 metre resolution and 7 spectral bands.
- Enhanced Thematic Mapper Plus (ETM+) sensor. This sensor has the same 7 spectral bands as its predecessor, TM, but has an added panchromatic band with 15 metre resolution and a higher resolution thermal band of 60 metres. The ETM+ sensor also has a five percent absolute radiometric calibration.

The Landsat 1,2 and 3 satellites carried the Multispectral Scanner (MSS) and a set of three video cameras.

The following ones, Landsat 4 and 5 eliminated the video camera in order to be replaced by a new scanner the Thematic Mapper (directly designed for thematic mapping).

In the last Landsat satellite launched (Landsat 7) it has been incorporated a new sensor, the Enhanced Thematic Mapper Plus (ETM+) sensor.

Landsat Instrumentation

The Landsat instrumentation is composed by:

- Multispectral Scanner (MSS)
- Thematic Mapper (TM)
- Enhanced Thematic Mapper Plus (ETM+)

The sensors Enhanced Thematic Mapper Plus (ETM+) and Thematic Mapper (TM) have the following radiometric characteristics of the ETM+ and TM Sensors.

Band Nr	Spectral Range (µ)	EM Region	Generalised Application Details
1	0.45 - 0.52	Visible Blue	Coastal water mapping, differentiation of vegetation from soils
2	0.52 - 0.60	Visible Green	Assessment of vegetation vigour
3	0.63 - 0.69	Visible Red	Chlorophyll absorption for vegetation differentiation
4	0.76 - 0.90	Near Infrared	Biomass surveys and delineation of water bodies
5	1.55 - 1.75	Middle Infrared	Vegetation and soil moisture measurements; differentiation between snow and cloud
6	10.40- 12.50	Thermal Infrared	Thermal mapping, soil moisture studies and plant heat stress measurement
7	2.08 - 2.35	Middle Infrared	Hydrothermal mapping
8	0.52 - 0.90 (panchromatic)	Green, Visible Red, Near Infrared	Large area mapping, urban change studies

Other Satellite and Image Characteristics

Property		Landsat 7 ETM+	Landsat 5 TM
Ground Sampling Interval (GSI) (pixel size)	Bands 1-5 & 7 Band 6 Band 8	30 x 30 m 60 x 60 m 15 x 15 m pixel size (18 x 18m GSI)*	30 x 30 m 120 X 120 m N/A
Swath width		185 km	185 km
Repeat coverage interval		16 days (233 orbits)	16 days (233 orbits)
Altitude		705 km	705 km
Digitalisation		Best 8 of 9 bits	8 bits (256 levels)
On-board data storage		375 Gb (solid state)	Magnetic tape failed
Orbit type		Sun-synchronous	Sun-synchronous
Inclination		98.2°	98.2°
Equatorial Crossing		Descending node: 10:00am	Descending node: 10:00am

On the other hand the radiometric characteristics of the Multispectral Scanner (MSS) can be summarised in the next table:

Band Number Landsat 1-3	Spectral Range (µ)	EM Region
4	0.5 - 0.6	Visible Green
5	0.6 - 0.7	Visible Red
6	0.7 - 0.8	Near Infrared
7	0.8 - 1.1	Near Infrared

Band Number Landsat 4 & 5	Generalised Application Details
1	Assessment of vegetation vigour, coastal water mapping
2	Chlorophyll absorption for vegetation differentiation
3	Delineation of water bodies, biomass surveys
4	Delineation of water bodies, biomass surveys

Other Characteristics of MSS are:

- Ground Sampling Interval (pixel size) Landsat 1-3 57 x 79 m
- Quantisation6 bit (64 levels)
- Ground Sampling Interval (pixel size) Landsat 4,5 57 x 82 m
- Scene Size 184 x 185.2 km
- Quantisation8 bit (256 levels)

2.3.3 SPOT

The series of satellites SPOT (Systeme Pour l'Observation de la Terre) started in 1986 with the launch of the SPOT-1.

The SPOT satellites has been developed in France in collaboration with Belgium and Sweden.

The main satellite characteristics are:

- Altitude: 822 km.
- Inclination: 98º
- Orbital Period: 110 min.
- Cycle: 26 days
- Orbit type: Sun synchronous

<u>SPOT Instrumentation</u>

The more interest instrument on board SPOT is a pushrooom imaging sensor denominated HRV (Haute Resolution Visible).

Each SPOT satellite contains two units of HRV.

This sensor is able to obtain images in two modalities: panchromatic and multiband (Green, Red and Infrared) with a spatial resolution of 10 and 20 m respectively and a covered area is 60 km.

This sensor is also capable to change the vision field, allowing 27º at both sides of nadir.

With the launch of SPOT-4 the HRV was replaced by a new sensor denominated HRVIR that increases the first version of HRV.

It incorporates a new band in the short wave infrared band.

Besides the orientation of the cameras is independent allowing get vertical and oblique images.

The other important sensor on board SPOT satellite is the “Vegetation”.

It is used in global studies of the earth.

It is equipped with four spectral bands: blue, red, near infrared and short wave infrared, providing a spatial resolution of 1 km.

The SPOT satellites are also equipped with two instruments more:

- DORIS that provides and accurate satellite position
- POAM (Polar Ozone and Aerosol Measurement) that measures the content of ozone, aerosols, nitrogen, oxygen and water vapour

2.3.4 ERS

The European Remote Sensing Satellite (ERS) was the first satellite that was developed by the European Space Agency's (ESA).

The first satellite called, ERS-1 was launched on 17 July 1991, then it was launched the ERS-2 on 20 April 1995.

They were designed to complement the satellites Landsat and SPOT and their main objective was the study of the ocean and the cryo-sphere although it can also use in land resources.

The ERS satellite orbits at 780 km. Of height.

<u>ERS Instrumentation</u>

The instruments on board of ERS satellites are:

- AMI Active Microwave Instrument, a microwave instrument that works in C band.
- The Radar Altimeter that operates in K band.
- The Along-Track Scanning Radiometer (ATSR)

The ATRS counts with four bands in the infrared region and its spatial resolution is 1 km.

The ERS-2 incorporates a new ATRS called ATRS-2 that incorporates three new bands in visible and near infrared band and with the possibility of two angles of vision.

The ERS-2 is also equipped with GOME, Global Ozone Monitoring Experiment, an instrument destined to measure the ozone content of the atmosphere.

The ESA has launched a new project denominated Envisat in order to observe the earth and complement the ERS series.

Envisat is a sun synchronous satellite with an altitude of 800 km and 35 days of cycle.

The main instruments on board of Envisat are:

- SAR Synthetic Aperture Radar
- MERIS Hyperspectral sensor
- AATSR Advanced thermal radiometer

The SAR is an active microwave sensor capable of imaging earth resource targets regardless of time of day, cloud, haze or smoke cover of an area.

The ERS SAR characteristics are:
- Frequency 5.3 GHz
- Bandwidth 15.55 MHz
- Band Name C Band
- Wavelength 56mm
- Incidence Angle 23 deg (mid swath)
- Polarisation Vertical

The applications of this satellite are the following:
- Meteorology: Interrelationship between oceanographic and climatic phenomena and their influence on global climatic change
- Geology: Structural mapping, volcanism studies, coastal erosion studies.
- Vegetation Monitoring: Vegetation change, crop monitoring.
- Hydrology: Soil moisture studies, surface water body morphology, snow extent and condition.
- Land Use: Mapping, change assessment.
- Oceanography and Glaciology: Monitoring of polar ice sheets and sea ice; monitoring ocean circulation, currents and tides.

2.3.5 RADARSAT

RADARSAT satellite is the first platform developed by the Canadian Space Agency (CSA). The RADARSAT satellite was launched on 4 November 1995. Its main objective is complement and improve the radar data form land resources so its main applications are:
- Agriculture: Crop monitoring.
- Forest and vegetation monitoring.
- Hydrology
- Oceanography.

The RADARSAT orbits with an altitude of 798 km and with an inclination of 98,6º.

<u>RADARSAT Instrumentation</u>

RADARSAT satellites are equipped with a Synthetic Aperture Radar (SAR) sensor on board.

This sensor can operate in a variety of imaging modes to suit a range of applications.

The SAR sensor on RADARSAT has the unique capability to acquire data in any one of a possible 25 imaging modes.

Each mode varies with respect to swath width, resolution, incidence angle and number of looks.

Because different applications require different imaging modes, RADARSAT gives users tremendous flexibility in choosing the type of SAR data most suitable for their application.

The main characteristics are:
- Frequency: 5.3 GHz
- Band name: C Band
- Incidence Angle: Operative mode 20-50, Experimental mode 10-60º
- Polarisation: Horizontal
- Spatial Resolution: 11-100 m
- Temporal Frequency: 24 days

In the new RADARSAT-2 an advanced SAR is incorporated that improve the characteristics of RADARSAT-1.

2.3.6 JERS

The Japanese Earth Resources Satellite-1 (JERS-1) is a joint project between the National Space Development Agency of Japan (NASDA) and the Ministry of International Trade and Industry (MITI).

NASDA is in charge of the satellite while MITI is responsible for the observation equipment.

JERS-1 was launched in February 1992.

It was designed to observe the earth's surface.

<u>JERS Instrumentation</u>

The equipment on board JERS-1 combines passive and active instruments.

The passive or optical instruments operates in eight bands of the visible and infrared region while the active ones, specifically, SAR sensor, that operates in the L-band of the microwave wavelengths.

Visible and Near Infrared (VNIR)

Band Nº	Spectral Range (µ)	EM Region	Generalised Application Details
1	0.52 - 0.60	visible green	Vegetation surveys; land use; water monitoring
2	0.63 - 0.69	visible red	Chlorophyll absorption for vegetation differentiation
3	0.76 - 0.86	near infrared	Biomass surveys (nadir viewing)
4	0.76 - 0.86	near infrared	Biomass surveys (forward looking, at 15.3 degrees, to give stereo coverage with band 3)

Short Wave Infrared (SWIR)

Band Nº	Spectral Range (µ)	EM Region	Generalised Application Details
5	1.60 - 1.71	middle infrared	Vegetation moisture
6	2.01 - 2.12	middle infrared	Hydrothermal mapping (eg. soils; geology)
7	2.13 - 2.25	middle infrared	Hydrothermal mapping (eg. soils; geology)
8	2.27 - 2.40	middle infrared	Hydrothermal mapping (eg. soils; geology)

Optical Data Characteristics (VNIR and SWIR)
- Product Pixel Size: 18 meters
- Scene Size: 75 km x 75 km
- Data quantisation: 6 bits

Synthetic Aperture Radar data (SAR) characteristics
- Frequency 1.3 GHz
- Band Width 15 MHz
- Band Name L-Band
- Wavelength 235 mm
- Off Nadir Angle 35 degrees
- Ground Resolution 18 meters
- Swath Width 75 km
- Polarisation Horizontal

The general applications are:

- Geology — Geological structural mapping
- Forestry — Tree density; Forest-type mapping
- Soils — Soil moisture studies
- Agriculture — Crop type discrimination
- Land Use — Surface feature discrimination

2.3.7 EOS

The Earth Observing System (EOS) is the main part of NASA's Earth Science Enterprise (ESE).

It is composed of a series of satellites, a science component, and a data system supporting a co-ordinated series of polar-orbiting and low inclination satellites for long-term global observations of the land surface, biosphere, solid Earth, atmosphere, and oceans.

The main EOS satellites are the Terra satellite formerly called EOS AM, signifying its morning equatorial crossing time and Aqua satellite formerly denominated EOS PM because of its afternoon equatorial crossing.

Terra (EOS AM-1) satellite was launched on 18 December 1999 and Aqua (EOS PM-1) on 4 May 2002.

Terra, Latin for land, its more important tasks are the mapping Earth's surface and measuring light, heat, atmosphere, lands, oceans, life.

Terra is a multi-national, multi-disciplinary satellite carrying a payload of five sensors that measures the state of Earth’s environment and ongoing changes in its climate system.

Terra is complemented by its twin sister Aqua satellite in order to obtain a whole view of the Earth.

Aqua Latin for water, is the other satellite of EOS that is devoted to study the Earth's water cycle, including evaporation from the oceans, water vapour in the atmosphere, clouds, precipitation, soil moisture, sea ice, land ice, and snow cover on the land and ice.

Aqua satellite has a payload of six sensor that

Aqua and Terra are designed to fly in low polar sun synchronous orbits 705 km above Earth.

The two satellites circle Earth 14 times a day.

Aqua crosses the equator at approximately 1:30 AM and 1:30 PM, local time, about 3 hours behind Terra (10:30).

2.3.7.1 Terra instrumentation

The instruments onboard Terra satellite (polar sun-synchronous orbit, 10:30 a.m. descending node) are the following:

- Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER)
- Clouds and the Earth's Radiant Energy System (CERES) (two identical scanners)
- Multi-angle Imaging Spectroradiometer (MISR)
- Moderate Resolution Spectroradiometer (MODIS)
- Measurements of Pollution in the Troposphere (MOPITT).

ASTER is developed by the Japanese Ministry of International Trade and Industry (MITI). ASTER is formed by three separate sensor subsystems covering 14 multi-spectral bands from visible to thermal infrared.

The spatial resolution scales are 15m, 30m, and 90m in the visible, short-wave IR, and thermal IR, respectively.

Its objective its to obtain the images of the land surface, water, ice, and clouds.

The first CERES was used on the TRMM mission.

On board of Terra flies two units of CERES. CERES uses a broadband scanning radiometer with bolometers detectors.

These units has three telescopes short wave, long wave, and total and can operate in either a cross-track scanning mode, or a bi-axial scanning mode to obtain angular information.

It is used to measure Earth's radiation budget and atmospheric radiation from the top of the atmosphere.

MISR measures top-of-atmosphere, cloud and surface angular reflectance functions, and measures aerosol, and vegetation properties using four spectral bands in each of nine pushbroom imaging cameras oriented at different angles along-track.

The detectors are CCDS.

MOPITT is developed by the Canadian Space Agency (CSA).

MOPITT is in charge of measuring carbon monoxide and methane in the troposphere using correlation spectroscopy with pressure modulated and length modulated gas cells with three spectral band in IRM.

Detectors are cooled using a Stirling Cycle mechanical cooler.

MODIS measures biological and physical processes on land and the ocean using a cross-track scanning multi-spectral radiometer with 36 spectral bands from visible to thermal infrared.

MODIS data will improve the understanding of global dynamics and processes occurring on the land, in the oceans, and in the lower atmosphere.

MODIS Characteristics:

- Swath Dimensions: 2330 km (cross track) by 10 degrees of latitude (along track at nadir)
- Telescope: 17.78 cm diam. off-axis, a-focal (collimated), with intermediate field stop
- Size: 1.0 x 1.6 x 1.0 m
- Weight: 228.7 kg
- Power: 162.5 W (single orbit average)
- Data Rate: 10.6 Mbps (peak daytime); 6.1 Mbps (orbital average)
- Quantization: 12 bits
- Spatial Resolution: 250 m (bands 1-2), 500 m (bands 3-7)
- 1000 m (bands 8-36)
- Design Life: 6 years

Aqua instrumentation

The six instruments onboard of Aqua satellite are the next:
- Atmospheric Infrared Sounder (AIRS)
- Advanced Microwave Sounding Unit (AMSU-A)
- Humidity Sounder for Brazil (HSB)
- Advanced Microwave Scanning Radiometer for EOS (AMSR-E)
- Moderate-Resolution Imaging Spectroradiometer (MODIS)
- Clouds and the Earth's Radiant Energy System (CERES).(two units)

AIRS is an High Resolution Infrared Radiation Sounder that contains 2378 infrared channels and four visible/near-infrared channels.

AIRS has a swath of 1650 km and spatial resolution of 13.5 km at horizontal at nadir and 1 km vertical.

The main objective is to obtain highly accurate temperature profiles within the atmosphere plus a variety of additional Earth/atmosphere products.

AMSU-A Advanced Microwave Sounding Unit, is a microwave sounder with the aim of obtaining temperature profiles in the upper atmosphere, specially the stratosphere, and providing a cloud-filtering capability for tropospheric temperature observations.

The AMSU is also on board of the National Oceanic and Atmospheric Administration's (NOAA's) NOAA 15 satellite.

AMSU-A has 15 microwave channel with a frequency range of 15-90 GHz and a spatial resolution of 40 km.

AMSU-A is part of a set of instruments that includes the AIRS and HSB.

HSB Humidity Sounder for Brazil is a multi-channel passive radiometer that contains four channels:
- 1 at 150 GHz,
- 3 at 183 GHz.

It is designed to obtaining humidity profiles throughout the atmosphere. Its spatial resolution is 13.5 km horizontal at nadir.

The Advanced Microwave Scanning Radiometer for EOS (AMSR-E) is a passive-microwave radiometer system with twelve-channel, six-frequency and total power.

It measures brightness temperatures at 6.925, 10.65, 18.7, 23.8, 36.5, and 89.0 GHz.

The measurements can be vertically and horizontally polarised at all channels.

The spatial resolution of the individual measurements varies from 5.4 km at 89.0 GHz to 56 km at 6.9 GHz.

The Moderate-Resolution Imaging Spectroradiometer (MODIS) and the two unit of the Clouds and the Earth's Radiant Energy System (CERES) have been revised in the above section, Terra instrumentation.

2.3.8 DMSP

DMSP Defence Meteorological Satellite Program (DMSP) was designed originally to provide information related to cloud coverage for the US Department of Defence.

The DMSP satellites operate in a sun-synchronous orbit, normally with two satellites in operation at any one time, one in a morning and one in an afternoon equatorial crossing time.

DMSP Instrumentation

The DMSP instrumentation includes the following sensors:
- Nimbus
- Microwave radiometer, SSM/I (Special Sensor Microwave Imager) that complements the old sensor Nimbus
- Operational Linescan System OLS

The Operational Linescan System (OLS) instrument, operates in two bands, one in the visible/near-infrared and one in the thermal infrared.

The OLS provides a spatial resolution of about 0.56 km, although it usually works with 2,7 km.

The OLS spectral and sampling characteristics were earlier proposed as a tool for fire detection and recent research has employed the OLS for night-time global city light and fire detection.

Because of this instrument's sensitivity in identifying and separating anthropogenic night-time light sources from fires, this sensor will be of particular importance in mapping night-time fires.

2.3.9 GOES

The fist geostationary satellite was launched in 1966 by the NASA and was denominated ATS Applications Technology Satellite. Since 1975 this satellite series was renamed with the name of GOES Geostationary Operational Environmental Satellite.

GOES Instrumentation

The main sensor that are installed on GOES satellites are:
- Scanner denominated Imager.
- Microwave Sounder

Imager is a scanner with five channels: one on visible band, two on medium infrared and other two on thermal infrared. Its spatial resolution is 1 km.

For visible band and 3 km for three of the four infrared bands.

Its main objective is obtain meteorological data, although it can be used to monitor fires using the GOES-8 Automated Biomass Burning Algorithm (ABBA).

The geostationary perspective offers the opportunity to capture fires as they occur with the capability for early detection of rapidly growing fires and diurnal high-temporal monitoring of subpixel fire characteristics.

A new experimental version of the GOES ABBA is the Wildfire ABBA that has been implemented for real-time wildfire monitoring throughout the Western Hemisphere.

The Wildfire ABBA has been redesigned to enable fire monitoring in most ecosystems and has been streamlined to allow for rapid processing of diurnal multispectral GOES-8 and GOES-10 data.

The other important sensor is a microwave sounder that provides a temperature and atmospheric moisture profile and a ozone distribution.

2.3.10 TRMM

TRMM Tropical Rainfall Measuring Mission is a joint mission of NASA and NASDA

The first application of TRMM is the study of the atmospheric circulation, ocean-atmospheric coupling, and tropical biology.

The TRMM satellite has a low-inclination (equatorial) orbit, with an inclination of 35 degrees.

TRMM instrumentation

The instruments on board of TRMM satellite are:
- Precipitation Radar
- TRMM Microwave Imager
- Visible Infrared Radiometer VIR
- Cloud and Earth Radiant Energy Sensor CERES
- Lightning Imaging Sensor

The Visible Infrared Scanner (VIRS) measures scene radiance in five spectral bands in the visible, near infra-red and thermal infrared with an horizontal resolution of 2 km at nadir.

VIRS provides imagery in the tropical and sub-tropical zones up about +/- 40 degrees north and south latitude.

VIRS is used also to obtain fire map.

2.3.11 IRS

IRS Indian Remote Sensing Satellite has been developed by the Indian spatial agency (NRSA).

Since 1988 four launchings have been carried out with the goal of obtaining information related to environmental resources.

IRS instrumentation

The IRS instrumentation is composed by:
- Two LISS linear Imaging Self Scanning
- High Resolution panchromatic camera
- WIFS

The IRS are equipped with two LISS linear Imaging Self Scanning, a high resolution scanner.

Its spatial resolution is 72,5m (LISS-I) if one camera operates and 36,25 (LISS-II) with two cameras operating.

The covered surface is 148 km for LISS-I and 74 km for LISS-II.

It has four spectral bands from blue to near infrared for the two first and between red and short wave infrared for the other two.

The panchromatic camera has a high resolution of 5,8 m and a coverage of 70 km while the WIFS, a regional observing sensor, has 188 m of resolution and 810 km of covered area.

2.4 SATELLITAL APPLICATIONS IN FOREST FIRES

2.4.1 Fire potential

Fire potential depends on several aspects:
- Amount of dead and live vegetation
- Moisture in the live vegetation
- Moisture in the dead vegetation.

The use of a high resolution sensor such as Thematic Mapper from Landsat satellite or SPOT multi-spectral scanner; or a lower resolution sensor, such as Advanced Very High Resolution Radiometer (AVHRR) aboard of National Oceanic and Atmospheric Administration's (NOAA satellite) or Moderate Resolution Imaging Spectrometer (MODIS) from Terra or Aqua satellites allows the acquisition of a land cover map that thanks to it is possible estimated the amount of dead and live vegetation.

On the other hand the moisture of the live vegetation can be estimated with sensors with a low spatial and high-temporal resolution such as AVHRR that monitors near real-time changes in the vegetation vigour, that is related with the moisture in the live vegetation.

The moisture in the dead vegetation is estimated from knowledge of local weather conditions.

Several countries have developed method to assess and map areas to estimate the potential for fires.

There are zones where the fire risk is different from another.

This circumstance must be studied to identify the critical zones.

Fire managers must developed protection strategies for these areas.

The main planning task is to assess and map, for areas, the local potential for a major fire to occur.

Using such geospatial information, managers can establish priorities for prevention activities to reduce the risk of wildfire spread and for allocating suppression forces to improve the probability of quickly controlling fires in areas of high concern.

BURGAN et al. and KLAVER et al. (1997) developed a Fire Potential Index

This index is based on the moisture of the live vegetation, the moisture of the dead vegetation, and the amount of the live and dead vegetation.

The first requirement is derived from the relative greenness of the Normalised Difference Vegetation Index (NDVI) from the AVHRR sensor (BURGAN and HARTFORD 1993).

The moisture of the dead vegetation is calculated from temperature, relative humidity, and the state of the weather (FOSBERG and DEEMING 1971).

The amounts of live and dead fuels are derived by reclassifying existing baseline land cover maps to the National Fire Danger Rating System's (NFDRS) fuel models (DEEMING and others 1978), which provide information on the loading of live and dead fuels (BRADSHAW et al. 1984).

The fire potential and actual fires need to be modelled in concert with socio-economic information (KLAVER R.W. et al 1998), such as population and land use, to determine costs to the human population in the actual burned areas and in neighbouring areas affected directly by the smoke and haze and indirectly by economic losses, such as drops in forest or range productivity and tourism.

2.4.2 Fire detection

The sensors aboard of satellites can detect fires in the visible, thermal, and mid-infrared bands.

Active fires during the day can be detected by sensor that works in thermal or mid-infrared band or night or by the light from the fires at night. It is needed two characteristics:

- High frequency of over-flights
- Near real-time data.

For example the NOAA-AVHRR sensor, which has a thermal sensor and daily over-flights, and the Defence Meteorological Satellite Program's Optical Linescan System (OLS) sensor have these characteristics.

Band 3 of AVHRR, in combination with bands 4 and 5, has been shown to be effective for detecting wildfires (ROBINSON 1991; LANGAAS 1992; CHUVIECO AND MARTIN 1994; KENNEDY, BELWARD, AND GRÉGOIRE 1994; MALINGREAU and JUSTICE 1997; POZO, OLMO, AND ALADOS-ARBOLEDAS 1997).

As with OLS images, significant agricultural fires were detected.

2.4.3 Fire monitoring

Fire monitoring is useful to measure and determinate the growth of fires that help the fire managers to know the behaviour of the active fires.

The growth of the fire, extent of the smoke plume, and mapping of the fire scar are very important in fire monitoring.

For fire monitoring, thermal and night-time visible images are useful and effective for mapping changing fire patterns.

Monitoring the extent of the smoke plume requires analysis of visible and near-infrared wavelengths.

Tracking the smoke plume allows the impact of fires on neighbouring human populations to be estimated.

2.4.4 Fire assessment

If forest fires occur, damage assessment is needed to determine the economical, ecological and social impact and to improve the fire risk assessment.

When dealing with the fire damage the following information is needed.

Firstly, some estimate of the total burned surface should be made.

Secondly, related to this first requirement, is some preliminary assessment of the cost of the damage.

Thirdly, the information on the starting point of the fire would help to investigate the original cause of the fire.

For fire assessment a combination of low resolution images such as AVHRR and higher resolution images such as SPOT or Landsat can be used to assess the extent and impact of the fire.

Information related to new fire scars and vegetation succession within the scars can be used to update the baseline vegetation map used for fire prediction.

Continued monitoring of the fire scars provides extensive information on land cover transitions involving changes in productivity and bio-diversity, which, in turn, influence fire potential.

Knowledge of the extent and intensity of the fire scars provides important information for the rehabilitation of the burn areas.

So other important use of infrared radiation is the forest fire damage assessment not only to quantify the amount of timber burnt also to estimate the environmental impact of forest fires on landscapes which leads to land degradation and often prevents vegetation recovery.

There are several studies devoted to the damage assessment with infrared techniques or another techniques that use infrared radiation.

2.5 SPECIFIC SATELLITE PLATFORMS

2.5.1 FUEGO Programme

FUEGO Programme is a system dedicated to early fire outbreak detection and monitoring by means of a dedicated constellation of small satellites.

FUEGO Programme is funded by the European Commission R & D Framework Programme IV, the European Space Agency and the industrial team lead by INSA (Ingeniería y Servicios Aeroespaciales).

Information acquired on the INSA website.

2.5.1.1 Architecture of the system

FUEGO system is composed basically by the following segments:

- Space segment: It is formed by the constellation of small satellites. Each satellite is equipped by different devices including infrared sensors.
- Ground segment: The FUEGO Ground Segment consists of the following elements
  - Primary Ground Station. This facility comprises the Primary Tracking Station and the Mission Control Centre.
  - Secondary Ground Station. This will be located at USA to increase contacts of the system with the satellites

The FUEGO User Ground Segment will be made up of a network of local receiving stations, called Primary User Stations.

User Stations are connected through public network to the Mission Control Centre.

They receive the FUEGO data in real time and the processing of this data is performed on line at these stations

Optimised payload communications coverage concentrate satellite transmitter power on the ground areas accessible by the payload observation beam

2.5.1.2 Applications and Services of FUEGO System

The FUEGO Services will be able to provide a valuable contribution in improving the necessary data information detecting fires, forecasting or supporting the management activities and damage assessment.

These services are as follows:

1. Areas of Surveillance

FUEGO Graphic User Interface at the user station will provide with a tool to design the local areas of surveillance, information that will be stored in vector formats.

Surveillance of forested areas with a high revisit time is important for planning and management of operations and fire occurrence.

2. Monitoring of Risk

It will consist of the provision of dynamic risk maps based on Normalised Difference Vegetation Indices.

This maps will be in digital formats connected to a relational database, where updated data are stored.

Risk monitoring is an important identified need to prevent the fire occurrence and the harmful effects of fire events; it is useful for prevention and planning.

3. Fire Detection Alarm:

The fire detection consists of the position of the fire, size and intensity, place name, access, fuel presence and conditions, slope and initial fire trend, map of the area and other related information.

This information is the combination of the one offered by the satellite (fire alarm, location, size and intensity of the fire) with the one resident in the user terminal database (historical data and GIS data).

4. Monitoring of Fires:

The monitoring of fires consists of a geo-referenced image of the fire front of already developed fires together with information on the surroundings of fires.

The image size must be able to enclose the typical large fires in the temperate forests.

For large forest fires, where large fronts are present, it is useful to have a large view of the fire to identify hot spots in it and then to select the best strategy to put the fire out.

5. Fire Evolution Analysis:

The system will give the fire evolution using multi-temporal analysis of the fire monitoring products.

Near real time monitoring of the evolution of the crisis situation is important, because of its capability to evaluate the effectiveness of the operations and to highlight areas where forest fire could potentially restart.

It is important the association of this product to key meteorological parameters such as wind, temperature and relative humidity.

6. Fire Evolution Prediction:

The Fire evolution prediction will be based on the FUEGO detection and the monitoring products.

This tool will also be fed with other information stored in the user database (fuel, maps, topography...) and external sources with meteorological data.

The fire propagation product will be very useful to prevent the fire evolution consequences and to re-assess the fire-attack strategy.

7. Cloud Coverage:

Cloud coverage maps will be provided as a complement of the FUEGO products.

They will consist of a geo-referenced raster map expressing the degree of opacity produced by clouds.

This masking highlights areas hidden by clouds where FUEGO service is unavailable or degraded.

This information will help users for planning and management of forces and activities.

8. Damage Assessment:

FUEGO monitoring data will give a first analysis of the immediate damage, which consists of area and perimeter of the burnt area.

It will also generate fine resolution damage assessment for several purposes as: deforestation assessment, insurance activities, etc.

FUEGO system provides other secondary services:
- Volcano Monitoring.
- Large Area Fire Incident Inventory: for the purpose of aiding in Global Change Dynamics.
- Frost Detection: The frosts appear in the first hours of the days during winter and spring, that is, when the fire risk is low, so the system could survey the areas searching for frosts

2.5.2 BIRD Mission

2.5.2.1 Introduction

The main objective of BIRD Mission is a new approach in the design of a small satellite mission dedicated to hot spot detection and evaluation.

The mission has been carried out by the DLR (Deutsche Forschungsanstalt für Luft- und Raumfahrt).

The whole mission is characterised by a strict design to cost philosophy.

2.5.2.2 Architecture of the system

The mission is characterised mainly by two segments: Space segment. and Ground segment

In the space segment are included the satellites which contains the following scientist payload:
- Wide-angle Opto-electronic Stereo Scanner WAOSS.
- Two- channel infrared sensor system for hot spot recognition. MWIR - Medium Wave Infrared and LWIR - Long Wave Infrared.
- Payload data handling with a mass memory.
- Neural network classificator.

The infrared sensor has the next characteristics:

	MWIR	LWIR
Wavelength	3.4-4.2µm	8.5-9.3µm
Focal length	46.6mm	46.6mm
Field of view	19°	19°
Pixel size	30µmx30µm	30µmx30µm
Pixel number	2x512 staggered	2x512 staggered
Quantization	16bit	16bit
Ground pixel size	290m	290m
F# number	2.0	2.0
Swath width	148km	148km
Net data rate	420kbps	420kbps

The ground segment has the main ground stations in WEILHEIM and NEUSTRELITZ (Germany) and a mini ground station in Berlin-Adlershof for experimental purposes.

This ground station should be an example of a low-cost ground station with the possibility of scientific data reception and housekeeping and up-link of commands (in experimental mode).

The architecture of the mission can be seen in the following Graph.

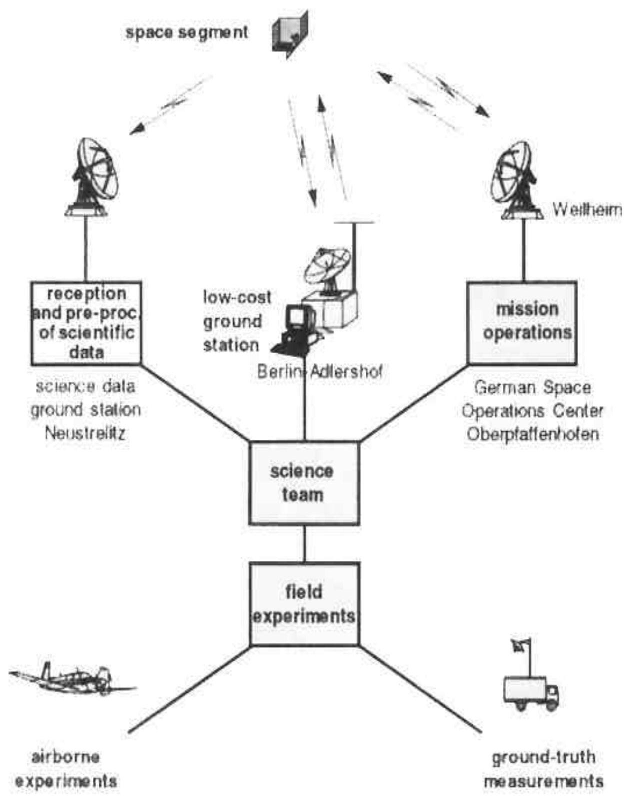


Figure 2-1: Graph: From BIRD Project

2.5.2.3 Objectives and application of BIRD Mission

The main objective of the BIRD system are the following:
- Test of a new generation of infrared array sensors adapted to earth remote sensing objectives by means of small satellites
- Detection and scientific investigation of hot spots (forest fires, volcanic activities, burning oil wells or coal seams)
- Thematic on-board data processing, test of a neuronal network classificator in orbit

Due to its scientist payload it is possible the combination of a stereo camera and two infrared cameras gives the opportunity to acquire:
- More precise information about leaf mass and photosynthesis for the early diagnosis of vegetation condition and changes.
- Real time discrimination between smoke and water clouds

2.5.3 Others

Other specific satellites used for wildland fires applications are:
- the American FIRES programme,
- the Russian NOMOS programme,
- the German EKOSAT IR programme.

3 FIXED PLATFORMS

3.1 BOSQUE SYSTEM

3.1.1 Introduction

Bosque system is a surveillance and automatic forest fire detection system.

By means of the combined utilisation of TV and infrared cameras located in fixed point or observation stations distributed in the survey area, images are captured and via radio send to a operation central.

Beside the system allows the interfaces in order to ingrate the management of resources against forest fires.

The main characteristics of the system are:

- Fire detection in a initial phase, detecting 1 m^2 fire, at 10 km.
- Wide area coverage: 30.000 Ha. Per Observation Station.
- Minimal Surveillance personnel: only one person in Control Console up to 8 Observation Stations.
- Stand alone Observation system.
- Video recording. Deterrent against arson.
- Easy operation mode.
- Easy installation on existing watcher towers.
- Observation Station with independent solar power supply.
- Flexibility of configuration to adapt particular zones.
- Central Command post to supervise fire-fighting activities.
- Automatic fire location by line of sight or by triangulation (UTM or grid).
- Capability to install meteorological stations using system software and communications.

The Bosque system has been designed and built by the Spanish company IZAR-FABA. (The currently information are from this company).

3.1.2 Bosque System applications

The applications of Bosque System are:

- Automatic surveillance thanks to repetitive sweeps.
- Forest fire automatic detection.
- Automatic fire location and map presentation.
- Monitoring of forest fire and fighting works.
- Fire suppression confirmation.
- Fire fighting training
- Review and report by fire monitoring

3.1.3 General description

The Bosque System is composed by a group of Observation Stations which survey a designated area by means of infrared cameras, the automatic detection is carried out by a Central Control Unit, linked via radio with each Observation Station which is manned by one operator.

The infrared camera on each Observation Station is complemented with a colour vision camera.

The whole unit is mounted on a positionator that permits rotation (pan) and vertical movement (tilt), supporting a global coverage of the area under surveillance by means of sequentially sweeps.

The infrared image and status details are sent to the Central Control Unit via communications network.

When the signal is received, the image is digitally processed, triggers an alarm in the case of fire and simultaneously appears on the TV monitors on the main Control Console.

Operational instructions for each Observation Station are controlled from the Control Console via radio.

The whole process takes place in less than one minute.

This characteristic allows fire fighting to begin when the blaze is still in its first stages.

3.1.4 System elements

The bosque system is composed by the following elements:

- Observation Stations: a variable number depending the characteristics of the zone to survey.
- Central Control.
- Radiocomunication system

The system can be complemented by communication repeaters to connect each Observation Station with the Central Control.

3.1.4.1 Observation Stations

Each Observation Station is composed by:

A) Positionator and Infrared and TV cameras set.: the positionator permits rotation (pan) and vertical movement (tilt).

The cameras are installed on the positionator.

The infrared camera gives a video contrast image that is proportional to the temperature difference between the different objects that conform the scene.

The colour vision camera complements and helps to identify and locate the fire.

The whole set is protected against the elements.

B) Communications Unit: it contains the communications equipment between the Observation Stations and Central Control.

And in any cases it also can contains a repeater.

The video transmission is carried out by unidirectional mode and the data transmissions in order to control the Observations Stations is made by bi-directional mode.

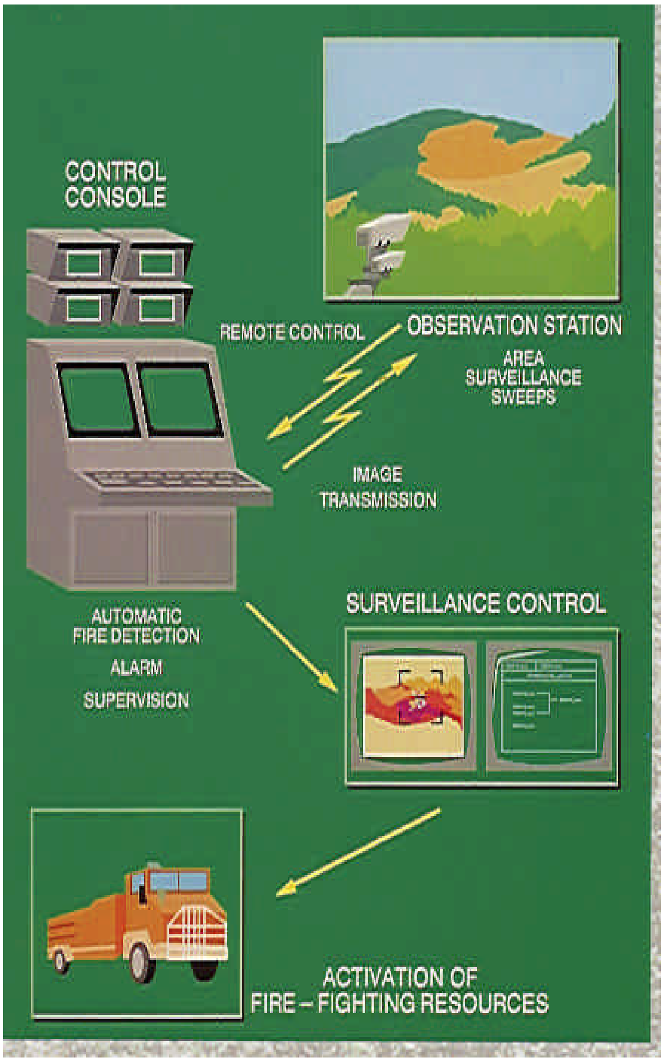
VHF/UHF equipments. This unit also contains the adequate antennas.

C) Control Unit: The necessary equipments to control the Observation equipments in function of the via radio received orders from the Central Control and to decodify and send via radio the data from the Observation Station.

This units contains a microcomputer and interphases with the communications unit and the positionator and cameras set.

It can receive meteorological data if meteorological sensors have been installed. (Optional).

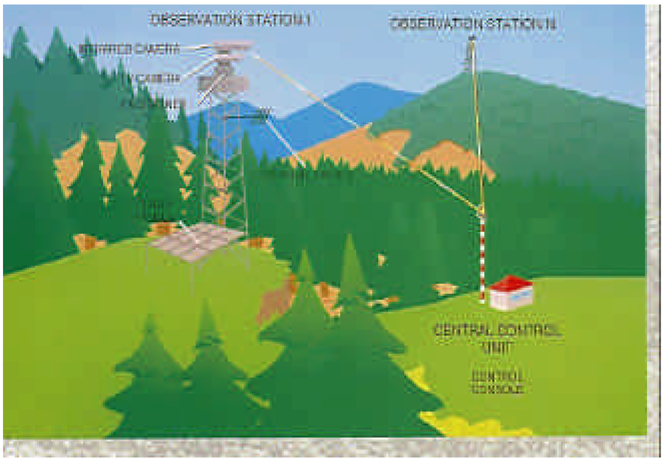
- Power system: In general terms it is made by solar panels, batteries and a regulator. It can be used eolic generators, eolic-solar generators or also if it were possible the general electric net.
- Autoprotection system: Physical protectors against access and sabotage. Sensors to detect intruders. The alarms are detected by each Observation Stations and are sent via radio to the Central Control.
- Each Observation Station have born and alarm lights.

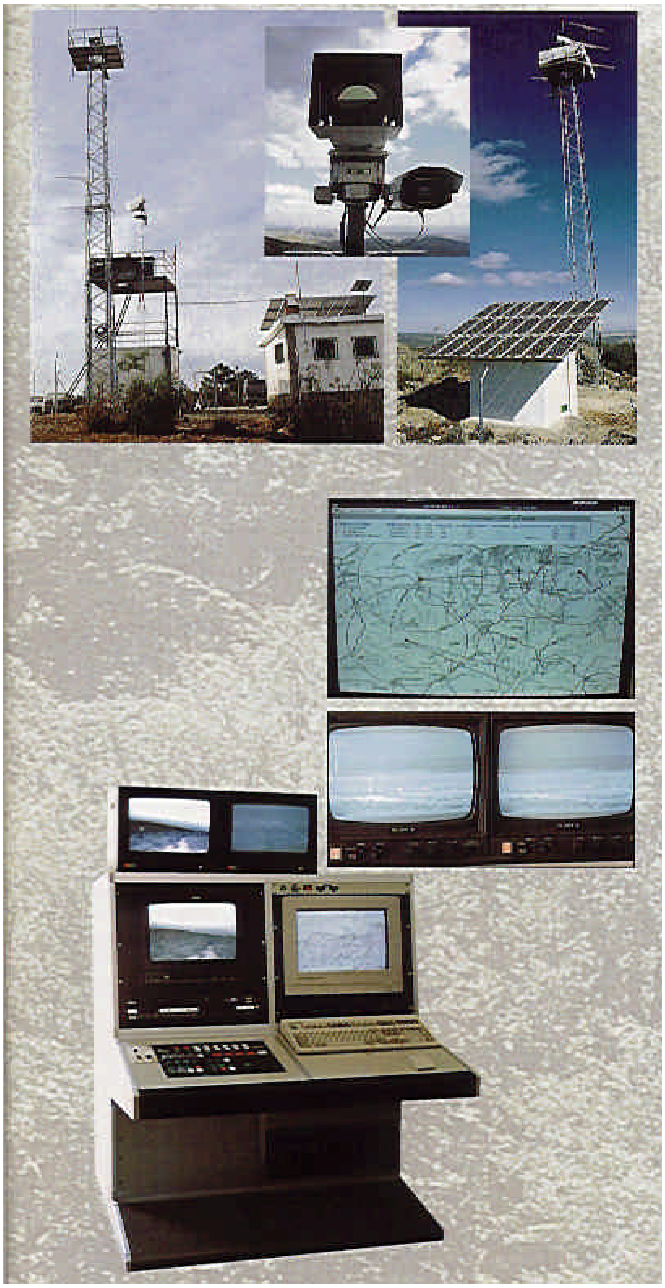


3.1.4.2 Central control

The Central Control is composed by:

- Control Console: From the console the operator controls the whole system. It contains:
  - Data monitor to show the operation data.
  - Main monitor to show the infrared or TV image from the selected Observation Station.
  - Video process computer that are communicated with each Observation System to carried out the automatic detection.
  - Control computer in order to manage the system.
  - Alarm and control panel.
  - VHS video recorder.
- The console also contains optional interphases to integrate the system with automatic resources management system.
- Auxiliary monitors: Each monitor contains the image from one Observation Station.
- Communications Unit: it contains the communications equipments between the Observation Stations and Central Control. Symmetric equipments to the equipments from the Observation Stations.





3.1.5 Bosque System improvements

Several studies have been carried out in order to improve the BOSQUE system and solve the problems o deficiencies that the system could present like the case of false alarms.

One of these studies was developed by the team of the Seville University partner P007 that was funded by the company than carried out the BOSQUE system, FABA BAZAN.

They used techniques of visual and infrared images processing, terrain information and heuristic knowledge.

3.2 BRIGHT SPOT DETECTION SYSTEM (B.S.D.S.)

The Bright Spot Detection System is a system developed by an Italian company called TELETRON Electronics.

It is a telematic and information system for the detection of the first stages of forest fires in a determined area.

It automatically informs fire-fighting units of the co-ordinates of the fire and supplies information on: weather conditions, the possible evolution of the fire, location of any sources of water present, practicable roads, type of vegetation and so on.

At present is the only system of its kind installed in Italy and abroad that is based on automatic infrared remote sensing.

The characteristics of B.S.D:S. also allow its use in the creation of monitoring and warning centres on the regional or national scale.

4 AIRBORNE PLATFORMS

4.1 INTRODUCTION

The satellite platforms and their respective sensors for wildland applications have been used for many years providing a great important information to the personnel in charge of the fight against the forest fires but there are certain fields where the satellite platforms do not reach.

This void is occupied by the aerial platforms that complement the satellite information.

In fire mapping applications aerial platforms are very important because of their characteristics.

They fit perfectly in this field.

The different satellite platforms have a spatial resolution too high and/or temporal resolution too low for this wildland fire objective.

The use of aerial platforms is also profitable because of the advances in uncooled Forward Looking Infrared (FLIR) units, hand-held units and digital cameras with infrared filters used in different aerial platforms.

The airborne platforms used can be classified in two types:

- Fix wing (Airplanes)
- Rotor wing (Helicopters)

4.2 AIRBORNE PLATFORM EQUIPMENT

The necessary equipment in order to develop wildland fire applications with aerial platforms is composed as indicated here below.

4.2.1 Aircraft

As we have seen above, in aerial infrared imaging operations two types of aircraft can be used: fix wing ones (aeroplanes) and rotor wing ones (helicopters).

Each one of these two types have their advantages and their disadvantages.

The rotor wing units have more facilities to carry out determines movements so thy are more manoeuvrable than fix wing ones.

Other advantage of rotor wing units is the capability of being able to fly closer to the ground.

However fix wing aircrafts, aeroplanes fly higher, although they have less vibration problems and have faster ferry speeds.

Because of this characteristics, in general terms, the aeroplanes need sensors with a higher spatial resolution although the more important thing is determinate the needs of each application in order to choose the aerial platform that fits better with this task.

4.2.2 Infrared imager

The infrared instruments used in aerial applications are the same in relation to other applications, the same type of instruments that we saw in chapter 1.4.

In airborne platforms we can make a first division, classifying the infrared instruments in two types:

- Hand-held infrared unit.
- Fixed mount infrared unit.

The hand held unit are the advantage of supposing a low cost but the obtained results are worse or less accurate than the fixed mount instrument.

In turn the fixed mount equipment can be divided in three types:

- Solid mounted unit.
- Turret mounted unit.
- Manually articulated unit

The advantages of solid mount units are their easiness and the low cost of their installation.

Their problem is their operation mode, they need an accurate aircraft with a trained crew to locate the Infrared sensor in the adequate position in order to obtain a right imagery of the objective.

The turret mounted units have the possibility of allowing a payload of several instruments or sensors and having automatic tracking capabilities.

The turret may be an axis gyro-stabilised gimbals system that allows the movement in the different axes (pan, tilt, horizon roll).

This type of fixed type are the more accurate and flexible for the different tasks.

The obtained results are more professional and effective.

The main disadvantage is its expensive cost.

Another aspect to take in account with turret mounted units is the aircraft where the unit is going to be placed.

The use of these types of system are only certified for specific models of aircrafts.

Any modification must be approved by aviation authorities.

Finally manually articulated instruments are mounted in a conventional aeroplane camera hole and as its name indicated are articulated manually.

4.2.3 Complementary equipment

Besides the infrared imager or the set of infrared instruments used to obtain the necessary images, there are several equipments that complements the work of the sensors a board of the aircrafts.

This instruments may be the following:

- computer and monitor,
- recording equipment,
- navigation system,
- communication system,
- safety equipment.

Aboard of the different types or aircrafts may be placed a personal computer that provides help to manage the received information of the infrared sensor.

Together with the computer must have a monitor.

It is preferable having a good monitor with a screen large enough to see the infrared details in order to facilitate the work to the personnel who operates the equipment.

Other complementary equipment is the recording unit where the different obtained images will be recorded and stored.

There are different types of storage medium as they are: tapes, digital tapes, flashcards,...

An important element not only for its application to aerial infrared imaging tasks but for the precise function of any aircraft is the navigation system.

Among the different navigation system it can be outline the Global Positioning System GPS and the Inertial Navigation System INS.

The navigation system help the pilot facilitating his position, direction,...specially when the pilot may be unfamiliar with the area and it is dark outside (this situation is characteristic in aerial infrared applications).

Also locations of fires can be geo-referenced with the Global Positioning System (GPS).

The communication system is in charge of sending the obtained infrared information to the different ground bases.

There are several modes to send this information, currently it is being used satellite communication in a great number of applications.

Finally and more important is the safety.

All instrument used in the aircraft must be secure.

The different equipment can not obstruct the view of the instruments or interfere with the controls of the aircraft.

4.2.4 Crew

The crew of an aircraft with infrared instruments destined to wildland applications may be composed by one or more people depending on the requirements of the target or the normative of the different organism.

With the pilot may be a trained infrared thermographer, forest engineer, navigator and/or helper.

Among the requirements we can outline the following: flight duration, seating and weight limitations.

4.2.5 Ground services

The main objective of the ground services is the analyse of the images from the aircrafts and produce reports that help the ground personnel to manage the different resources to fight against the forest fires.

This service is composed by the specific personnel, thermographers and the technical instrumentation.

This technical instrumentation includes a computer workstation complete with digital photographic and thermographic imaging peripherals for handling infrared images.

With the computer is needed specialised software of video capture, image processing, CAD, mapping or GIS geographic information system.

A trained and specific personnel is very important to obtain good and useful results.

This personnel composed by termographers or infrared interpreters can locate in infrared images hot spots, hand lines, doze lines, roads, streams,... making accurate maps that can help to manage the tasks of the different resources.

4.3 AIRBORNE APPLICATIONS

Among the airborne application of infrared thermography for wildland it can be outlined the following:

4.3.1 Fire detection

Firstly, before the occurrence of a wildfire, the airborne platforms are very useful in tasks of surveillance.

Both types of aerial platforms can be used to survey the zones that have an high Fire Potential Index.

Its main function is to discover or perceive the existence or presence of hot spots.

It is very important knowing the co-ordinates where the hot spots are, how hot they are, how large and if they are located in critical areas.

It is also important in the field of the detection the location of burned areas, water and saturated conditions, vegetative surface changes, fire suppression features or interface structures.

During the wildland fire infrared technology is useful to detect new hot spots that can produce new fires.

Besides it can be used to help the fire-fighters in safety tasks, detecting escape routes or security zones, in areas where the human visibility is null because of the smoke.

Mop up is a critical period after the fire.

The airborne platforms develops an important work, helping ground resources to discover hot spots, sparks and smouldering fires than can grow into new fires.

Specially in crevices and roots several meters underground that can ignite and produce a new fire.

4.3.2 Fire monitoring

This application is developed when a known fire is growing. Fire monitoring is capable of measuring and describing the growth oh the fire.

It can be studied and predicted the behaviour of the fire. It is useful at night to follow the behaviour of the fire, obtaining vital information about the fire that can help the fire managers to carry out the attack plan and organise the ground resources.

4.3.3 Fire mapping

The fire mapping application can be developed during and after a forest fire,

In this case the objective is the realisation of maps that can help the fire manger in the organisation of resources involved in the suppression tasks.

Because of these map it is possible know the location of:

- Hot-spots
- Fire perimeter
- Burned and unburned areas
- Interface zones
- Points of water
- Hand, dozer lines
- Road, paths,..

4.3.4 Fire assessment

The second utility of fire mapping is the fire assessment after the fire has been extinguished.

Fire assessment is needed to know the economical, ecological and social impact of the fires.

4.4 EXAMPLES OF EXISTING AIRBORNE INFRARED APPLICATIONS.

In this chapter we can revise several existing system used for different countries to incorporate an infrared equipment in order to help in the forest fires fight.

4.4.1 Surveillance and co-ordination airplane ACO, Spain

The DGCN Dirección General de Conservación de la Naturaleza belonging to the Ministry of Environment of Spain has used since 1992 aeroplanes of surveillance and co-ordination.

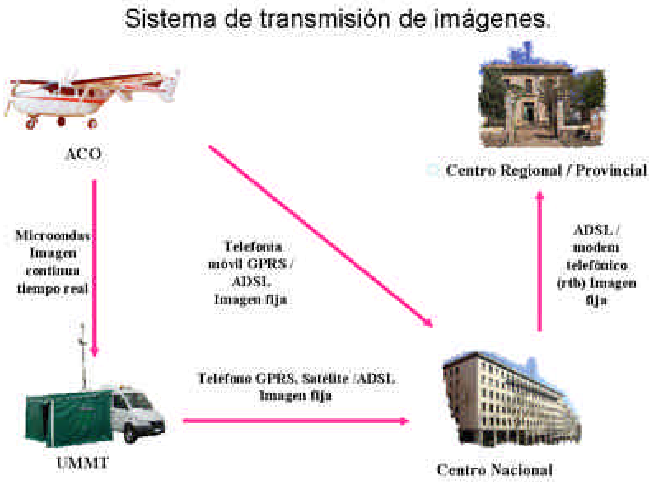
Their main function are:

- Co-ordination of the aircrafts involved in the fire.
- Surveillance the burned areas
- Monitoring the forest fires
- Mop up tasks

Initially mono-engine OPTICAL OA7 were used and then they were replaced by twin-engine aeroplanes model Cessna 337 Skymaster Push Pull.

The system is mainly composed:

- Infrared and visible cameras installed on gimbals.
- Communication system that transmits via GPRS photographs and via microwaves continuos video to ground resources.



In this case the infrared instrumentation is managed by a forestry technician that choose the images more appropriate.

4.4.2 Phoenix system (U.S.A)

The Phoenix system is the new forest service airborne infrared fire detection and mapping system.

The government with private companies has developed a specific system for the USDA Forest Service that can be used for tactical fire intelligence and mapping.

The Phoenix is aboard of two types of aeroplane the Cessna Citation Bravo jet and the King Air 200 turboprop aircraft.

Its cruise speed is 200 knots and fly with an height of 3000 m covering an area of 6,515 hectares in one minute with a resolution 0f 6.3 m/pixel.

With this characteristics the Phoenix system can detect fire spots of 15-20 cm in size.

The Phoenix system is mainly composed by two thermal infrared detectors.

One detector in the 3-5 µm band and another in the 8-14 µm band.

According to the Plank law the second band is used to generate the background imagery and the another sensor is in charge of detecting wildland fire.

The Phoenix system uses a Kennedy Optics style RS 25 line scanner that spins at 4000 rpm, produces 200 scan lines per second with 120 degree field of view.

It is also equipped with an advanced GPS inertial measurement unit in order to generate geo-corrected results and operational orientation.

The airborne signal of the Phoenix system is performed on a Digital Signal Processor (DSP) with a PC aboard of the aircraft.

The output of the system is a continuos strip image and a geo-referenced ".tiff" file CD-ROM.

4.4.3 Airborne Infrared Disaster Assessment system (AIRDAS) (U.S.A)

NASA-Ames Research Centre with the US Department of Agriculture Forest Service has developed a fire surveillance technology that increase the efficiency of monitoring wildland fires.

One of the main aims of the project is providing accurate wildfire data in a shorter time thanks to the combined use of Unmanned Aerial Vehicles (UAVs) and thermal infrared imaging technology and data telemetry.

The whole project entitled, "NASA Wildfire Response Research and Development, Applications and Technology Implementation is divided into three fundamental elements.

The first element includes sensor development technology using NASA's Airborne Infrared Disaster Assessment System (AIRDAS) that can be carried aboard both piloted or UAV aircraft.

AIRDAS sensor is a multispectral scanner that was built primarily for understanding and measuring the impacts of fire on ecosystem and atmospheric processes; however, it also has application in disaster monitoring and assessment.

Among the advantages of the AIRDAS system it can be outlined the following;

- Ability to fly on multiple aircraft
- Quantifiable, unsaturated data from active fires
- High temperature calibration to accurately measure flame temperature
- Telemetry compatible for real time analysis.

AIRDAS is a four-channel line-scan instrument that has been laboratory-calibrated over a temperature range from 300K to 900K.

It has four spectral regions:

- Band 1, 0.61 - 0.68 micron
- Band 2, 1.57 - 1.70 micron
- Band 3, 3.60 - 5.50 micron
- Band 4, 5.50 - 13.0 micron.

Band 1 is suitable for monitoring smoke plumes and distinguishing un-obscured surface features.

Band 2 is useful for analysis of vegetative condition, as well as very hot fire fronts (above 300°K), and is effective at penetrating smoke plumes.

Band 3 is used for sensing high temperature conditions.

Band 4 collects thermal data on earth ambient temperatures and on the lower temperature soil heating conditions behind fire fronts.

Its total field of view is 108° cross-track, with instantaneous field of view of 2.62 milliradians and its spatial resolution is approximately 2,6 meters per 1000 meters of altitude.

The second element is a data telemetry.

Data transmission options, such as satellite up-links or wireless LAN technology, to send in the fastest way the AIRDAS infrared imaging data to the fire manager on the ground.

The last element is data integration, changing the data into an easily understood information format similar to that of a map that help the fire manager.

In general terms the system stand out because of the capability of discriminating flaming from superheated soils and quantifying fire intensity or amount of energy being produced by the fire.

Besides it can be used to support disaster management and assessment.

Thanks to payload of instruments is useful for fire detection, landslide assessment, earthquake damage and pollution monitoring.

4.4.4 Daedalus System

The company Daedalus Enterprises built multispectral scanners that can be used for wildland application, such as surveillance, detection, monitoring and mapping.

Among these scanners we can stand out the Daedalus 1268 (TMS: Themathic Mapper Simulator) and the Daedalus ABS 3500.

- it is a widely used digital multispectral that simulates the performance of the Thematic Mappers (TM) aboard of Landsat 4 and 5 satellites,
- its sensor collects data in 12 channels, including Landsat TM bands 1-7 (band 6 is collected in both low-gain and high-gain modes) and four additional bands between the Landsat TM bands.
- it provides data for land use and land cover analysis, forestry applications, geologic studies and disaster assessments that can be transmitted in real time.
- its sensor is being used in a variety of airborne platforms such as the ER-2, Cessna 402/4004 or LearJet.

The Daedalus ABS3500 System (Aerial BiSpectral System) uses a 2-color/band system in the 3-5 µM and the 8-14 µM range.

4.4.5 Wildfire Airborne Sensor Programme WASP

The Rochester Technology Institute has developed a system entitled WASP Wildfire Airborne Sensor Program.

The system is composed by four cameras that work in the visible, short wavelength IR, medium wavelength IR and large wavelength IR bands respectively.

It is also equipped with a precision inertial measurement unit and GPS antenna that allow the production of images geo-referenced.

Its main application are the fire detection ad the fire mapping.

4.4.6 Airborne Wildfire Intelligence System AWIS

Finally we outline the AWIS Airborne Wildfire Intelligence developed by Range and Bearing Environmental Resource Mapping Corporation.

AWIS acquires digital thermal infrared images and records of inertia using a twin engine aircraft that is IFR (Instrument Flight Rules) capable, although most scanning is conducted under VFR (Visual Flight Rules) conditions.

Proprietary processing software is applied to perform geometric corrections and produce geo-referenced thermal image mosaics, which are then distributed.

5 HANDHELD GROUND MOBILE PLATFORMS

5.1 HANDHELD INSTRUMENTATION

The handheld instrumentation used in wildland fire applications are the same that the others use in other type of platforms.

We can distinguish the next instruments:

- Infrared viewers or Infrared cameras.
- Infrared temperature scanner.
- Thermometer.

Because of his handheld characteristic one of the more important consideration for these instruments is the ergonomic.

The complexity and danger of the different works that the fire-fighters must do in order to fight against forest fires, the environment in where they develop their job and the special characteristics of fire behaviour take us to considerate the ergonomic and easy operation as the more important things in order to use handheld devices in forest fires applications.

Others characteristics that we must take in account are the following:

- For infrared viewers or infrared cameras:
  - Wavelength of infrared energy that the sensor is sensitive to. In forest fires are adequate two types: Middle infrared and Far infrared. The far infrared sensors are less probably to see hot gases and solar reflections.
  - Detector technology: Cooled and un-cooled.
  - Resolution (pixels): It is preferable great resolutions..
  - Battery life, power consumption, size and weight.
  - Lens length: For forest fires applications like others the most suitable lens length is 50 mm to 75 mm.
- Infrared temperature scanner and thermometer:
  - Auto-zero ambient reference range.
  - Temperature range
  - Accuracy
  - Resolution
  - Spectral range
  - Battery life, power consumption, size and weight.

Besides the appropriate characteristics of the instruments one the most important thing that allows successful works with infrared instrumentation is the use of experienced operators that can take advantage all the opportunities that infrared technology gives us.

5.2 HANDHELD INSTRUMENTATION APPLICATIONS

The infrared cameras can be used in the following cases in order to prevent and fight against wildland fires:

- In mop up task the handheld infrared viewers play an important role. Thanks to their use the fire-fighter that collaborate in mop up works can locate hotspots. They can locate smouldering fires and determinate that the fires were completely out before moving on to other areas.
- They also can detect fire in crevices and roots underground. This is an important application because smouldering zones can igniting to flame and produce great fires.
- They can see through smoke to detect and locate the borders of a fire.
- The ground handheld infrared cameras are an important help to aerial ones. Both of them can work in a combined way to facilitate the fire-fighters works.

The handheld infrared temperature scanner and thermometer are not very appropriate in wildland fires tasks (GASVODA, D. 2000).

They are more suitable in industrial uses or in laboratory test.

These types of instruments can be used like an support to the forest fires fight by means of different searching lines that increases the knowledge of the fire behaviour.

The main problem to use them in forest fires activities is that their detection range is short and the field of view is narrow.

6 BIBLIOGRAPHY

6.1 REFERENCES

BECK, J. "Capabilities of airborne infrared remote sensing system to detect hotspots". *Advantage.* FERIC, Vol. 5, No.11, 2004.

BRASS, J.A., AMBROSIA, V.G., RIEKER, J.D., ROBERTS, A.C. 2001. *Forest firefighting from real-time airborne infrared remote sensing*

BRIEß, K., JAHN, H., RÖSER, H.P. 1997. *BIRD A DLR Small Satellite Mission for the Investigation of Vegetation Fires and Vegetation Condition* (IFFN No. 16 - January 1997)

CHUVIECO, E. 2000. *Fundamentos de Teledetección Espacial.* Rialp. Madrid.

CHUVIECO, E. 2002 *Teledetección Ambiental: la observación de la Tierra desde el espacio.* Ariel. Barcelona

GASVODA, D. USDA Forest Service Paper. *Handheld infrared viewers for wildland fire applications.* 2000.

GREENFIELD, P.H., SMITH, W., CHAMBERLAIN, D.C. Paper. *Phoenix-The new forest service airborne infrared fire detection and mapping system.*

KLAVER, R.W. et al. 1998. *Spatially Explicit Fire Management System.* First International Conference on Geospatial Information in Agriculture and Forestry. Paper.

MELÉNDEZ J; DE CASTRO AJ; ARANDA JM; LERMA AM; LÓPEZ F. 2004.- *Infra-red measurement devices principles and basic results*. Eufirelab Deliverable, D-07-04

MELÉNDEZ J; DE CASTRO AJ; ARANDA JM; LERMA AM; LÓPEZ F. 2004.- *Infrared Cameras: Principles and General Presentation*. Eufirelab Deliverable, D-07-05

MELÉNDEZ J; DE CASTRO AJ; ARANDA JM; LERMA AM; LÓPEZ F; DUPUY JL; VACHET P; MARECHAL J; PORTIER D. 2003.- *Infrared measurements methods adapted to laboratory fires of wildland fuel.* Contrat n° EVG1-CT-2001-00041. Fire Star Deliverable D5-02

ORLOVE, G. 2000. "The top ten questions people ask about infrared termography" . *Inframation*. Vol 1.

VELEZ, R. 2000. *La defensa contra incendios forestales: Fundamentos y Experiencias.* McGraw-Hill. Madrid.

6.2 INTERNET LINKS

http://aqua.nasa.gov/

http://dmsp.ngdc.noaa.gov

http://geo.arc.nasa.gov/sge/airdas/maryflood.html

http://grid2.cr.usgs.gov/globalfire/indofire/firepaper.html

http://landsat.gsfc.nasa.gov/

http://plata.uda.cl/minas/apuntes/Geologia/EXPLORAC/TEXT/02024concept.html

http://sauron.geocortex.net/awisweb/info.htm

http://stocktoninfrared.com

http://terra.nasa.gov/

http://trmm.gsfc.nasa.gov/

http://waste.ideal.es/sistemabosque.htm

http://www.airtargets.com.au/aaaars3.html

http://www.asprs.org/asprs/publications/pe&rs/2001journal/january/highlight.html

http://www.cis.rit.edu/research/dirs/research/fires.html

http://cwfis.cfs.nrcan.gc.ca/en/background/bi_FM3_faq_e.php

http://www.eorc.nasda.go.jp/JERS-1/

http://www.fas.org/spp/guide/india/earth/irs.htm

http://www.flirthermography.com

http://www.fs.fed.us/fire/niicd/Infrared/Infrared.html

http://www.ga.gov.au/acres/prod_ser/noaadata.htm

http://www.geoinsight.com/Knowledgebase/RemoteSensing/Daedalus.cfm

http://www.geomatics.ucalgary.ca/~nel-shei/forest.htm

http://www.goes.noaa.gov/

http://www.gsfc.nasa.gov/topstory/2003/firesames.html

http://www.iffm.org/NOAA.html

http://www.incendiosforestales.org

http://www.infocarto.es/servicios/case/607438.htm

http://www.insa.es/fuego/

http://www.ktca.org/newtons/11/infrared.html

http://www.mantenimiento-predictivo.com/fundamentos_termografia.htm

http://www.raytheoninfrared.com

http://www.spotimage.fr

http://www.teletron.it/bsdseng.htm

http://www.uav-applications.org/services/payload_platform.html