A Satellite Cluster for Comprehensive Monitoring of High Temperature Events and Related Combustion Products for Application and Scientific Use

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Abstract

The objective of the project is to design, to produce and to operate a cluster of largely identical satellites for the detection, the monitoring and the interdisciplinary evaluation of high temperature events (HTE) on Earth. The named category comprises wild fires (e. g. forest and steppe), fire events in urban and industrial areas (oil well fires), coal seam fires, peat bog fires and volcanoes. Simultaneously monitored are the aerosols and trace gases generated and emitted by the respective HTEs, their spreading and their time depending physical and chemical alterations.

By use of this dedicated satellite constellation will a systematic collection of the relevant parameters of high temperature events be performed in order to establish a decision base for early warning, fire prevention and fire management. In addition will comprehensive information on the type, the amount and the origin of particular aerosol compounds and trace gases originating from different fire types be collected. These effects are monitored together with the subsequent physico-chemical alterations of aerosols and their interaction with atmospheric components and atmospheric conditions. In this way will the effects on health and the influence to weather conditions and eventually the change of the climate be unveiled.

1. Introduction

Despite the progress in space borne monitoring of naturally and anthropologically generated fire events are the processes of fire initiation, fire behaviour, fire spreading, fire extinction and the impact of wildfire emissions on human health, the environment and climate change on a global scale not yet very well understood.

The principle objective of the suggested Wild Fire Satellite (WFS) project is to provide a data base in order to overcome this lack of knowledge in fire incidents, or more generally, HTEs in their products and their time depending alterations and impacts, and also to find means and methods to increase the capabilities for fire / HTE prevention and disaster management.

The named category of HTE comprises wild fires (e. g. forest and steppe), fire events in urban and industrial areas (oil well fires), coal seam fires, peat bog fires and volcanoes.

[1] Author footnote style (use different footnote numbers for authors at different locations). Include address and e-mail.

2. Scientific and Application Oriented Requirements

The UN convention at Sidney 2003 declared the monitoring and treatment of fire events as a principle and urgent problem worldwide. Monitoring and treatment refers here to application and science oriented aspects.

The suggested WFS is designed in such a way as to satisfy comprehensively and complementary the demands of both domains.

2.1. Application Aspects:

The current satellite systems provide image and non-image data with insufficient spectral and insufficient geometrical resolution and inadequate time-periodicity in monitoring the same area within short-term periods.

For this reason is up to the present a systematic evaluation of different fire types and their time-depending behaviour due to different local, regional and global interactions not possible.

It is for this reason why a systematic investigation of a variety of relevant parameters is mandatory in order to obtain knowledge and to found a decision base for early warning, fire prevention and fire management. Such an application oriented treatment of HTE of different types and expressions requires information not only on the fire itself but also on the objects and circumstances adjacent to the HTE location. These additional information allow a prediction of the damages and losses to be caused by HTE a priori and a posteriori and thus give the prerequisite for optimum methods and measures for short-term occurring fire fighting missions.

The suggested satellite system provides the relevant data and information to obtain the envisaged goal, which are besides others:

- Identification of the type of fire recognisable by its pattern, its temperature and the generated emission products;
- Recognition of the fire line and the time-dependent course of the fire line;
- Recognition of the vegetation cover at or near the fire location for the prediction of the fire forward movement and the expected fire intensity;
- Recognition of the actual status of a region´s infrastructure in order to prepare and perform measures for fire management and rescue missions;
- Determination of the structuring of the adjacent and the distant environment in order to determine material value losses;
- Determination of the structuring of fire relevant regions in order to take measures (also for the future) concerning the prevention or mitigation of damages.

2.2 Scientific Aspects:

Besides the direct damages and losses of material values at the location of the HTE are the secondary effects caused by the event products of equal importance.

There are no comprehensive information available on the type, the amount and the origin of particular aerosol compounds and trace gases originating from different fire types. Additionally are the subsequent physico-chemical alterations of aerosols and their interaction with atmospheric compounds at particular atmospheric conditions not conclusively known.

The properties of the aerosols have characteristic effects and consequences on the health and they also influence the weather conditions and eventually the change of the climate.

An evaluation of these effects and interactions was until now not possible due to the lack of systematically and in short term periodically collected data on the aerosol compounds, the particle size, the concentration in different layers of the atmosphere and their courses and physico-chemical changes.

The suggested satellite system provides the relevant data and information to obtain the envisaged goals, which are besides others:

- Identification of the type of fire, recognisable by its pattern, its temperature and the generated emission products;
- Detection of the spectral signatures of fire generated products, such as of aerosol and trace gases;
- Recognition of the type of vegetation near the fire location for the prediction of the fire type and the associated fire products;
- Determination of atmospheric conditions near the fire location to identify type and extent of products and subsequent atmospheric interactions;
- Observation of the life cycle of fire products in the atmosphere as function of altitude and location.
- Observation of the impact on atmospheric features (in particular clouds) and of the impacts on terrestrial and marine environment.

2.3 For **Application and the Scientific Aspects**

will the following capabilities and information be provided by the suggested satellite concept:

- Coverage of large parts of both hemispheres, if possible global coverage;
- Multiple detection of HTE relevant sites per day;
- Observation of fire relevant parameters at a coarse and a magnified geometrical resolution;
- Short time interactions to determine the data acquisition mode for the next satellite overpass, e. g. preference of a particular area, mode of resolution;.

2.4 In order to satisfy the **Users` Demands** the following technical capabilities and means for the provision of terrestrial data storage and evaluation have to be provided:

- Quick access to the data in pre-processed form, including relevant additional information for the evaluation and interpretation of the data;
- Provision of a search-and-find option in order to assure the detection of fire events for the purpose of a detailed monitoring;
- Transmission of the detected data in real time to the operation centre, where data are pre-processed immediately so that a distribution to the user can be achieved within one hour at the maximum;
- Pre-processing, storage and quick look display of the actually acquired data to support the selection of feasible data by the user;
- Provision of a down-load possibility of relevant data by authorised users.
- Provisions of data storage for subsequent studies.

3. Mission Performance Requirements

Based on the application and science oriented requirements were the following constraints to the WFS performances considered of being essential and accomplishable:

Subject Characteristics:
Identification, location and tracking the development and spreading of HTEs, determination of thermal conditions within HTEs, determination of fuel for and products of combustion;
Quantity:
At least 20 HTE are to be identified, located and tracked simultaneously;
Timeliness:
Multiple detection of HTEs per day, report on detected HTEs and transmission of HTE parameters to the relevant user communities within 30 minutes after discovery;
Revisit Intervals:
Multiple update of HTEs per day and atmospheric status as a result of fire impact, the propagation of fire products and their atmospheric interference and physico-chemical properties and changes every 90 minutes;
Geolocation accuracy:
Determination of location and extent of fire within 1 km; determination of interaction of atmospheric fire product in clouds within 100 m at a geometrical resolution of 50 m^2;
Completeness:
Global mapping of HTEs, their location and the amount and properties of combustible materials;

In order to satisfy the imaging and non-imaging requirements are at least three sensor types necessary:

Electro-optical in the Visible and Near Infrared domain for monitoring fire light, smoke clouds, vegetation and non-vegetation cover;
Spectrometer from the Ultraviolet to the Thermal Infrared domain for monitoring spectral signatures of combustion product / aerosol chemistry and size, and of combustion gases;
Radiometer in the Thermal Infrared domain for monitoring the fire temperature and spatial intensity distribution.

The physical phenomena are obtained by the detection of multispectral signatures of the particular processes.

Particular care for the sensor selection and combination has to be taken in order to prevent false alarm situations that could arise by confusing hot spots caused by reflected sun radiation with hot spots generated by HTE.

4. Description of the instruments

The properties of the instruments and their design represent the principal basic status as a result of a feasibility investigation. For the realization will these items be up-dated and modernized.

a) Visible V1, V2, V3, V4
The existing design bases on photodiode arrays with 4096 pixel elements. The modification to the actual design consists in using four linear arrays instead of three and in a change of the telescope.

This design is derived from a space based (military) camera with three spectral channels and a geometrical resolution of $(80\ m)^2$.

b) NIR ATOF Spectrometer
A large aperture AOTF is being used with a spectral resolution of ~ 50 cm^{-1}. The detectors are two staggered InGaAs 512- element arrays of 25 µm * 250 µm pixel elements. The square field of view is formed by a diaphragm.

The AOTF is tuneable for any wavelength within the spectral range. Monochromatic images and/or multi-spectral images can be obtained. The time for the AOTF to change frequency is 1 ms. The spectral "depth" of the multi-spectral images is limited by the information flow.

c) MIR
The MIR two-band camera shares one telescope and two detectors in normal and magnifier mode. The detectors are arrays with 640 * 512 pixels, 20 µm * 20 µm each. The detectors are optionally stacked. On the matrices are four linear arrays of 1280 * 1 pixels formed, two spectral channels and two for magnification. The position of the linear arrays can be chosen (also during the mission) among adjacent pixel rows, if one or more pixels in the array become defect.

Detectors are cooled with Stirling coolers. The baseline of the design is to use an on-shelf package, consisting of the detector + the cryostat + the cooler. An optimised cooling scheme together with TIR is subject of adaptation.

d) TIR

The TIR three-band camera shares one telescope and four detectors in normal and magnifier modes. The detectors consists of four arrays of 320 * 256 pixels, 20 µm * 30 µm each. The availability of an advanced 640 * 512 pixel thermal IR array similar to those used for the MIR camera is subject of advanced considerations. The detectors will be optically stacked. On the matrices are six linear arrays of 1280 * 1 pixel formed, three for spectral channels and two for magnification. The position of the linear array can be chosen (also during the mission) among adjacent pixel rows if one or more pixels in the array become defect.

Detectors are cooled with Stirling coolers. The baseline is to use an on-shelf package, consisting of detectors + cryostat + cooler. An optimised cooling scheme together with MIR channels is subject of adaptation.

e) UV-NIR Grating Spectrometer

The detector is a 512 * 512 front-illuminated UV-coated CCD.

f) Fourier Spectrometer

The Fourier spectrometer uses a 9-pixel detector, covering a swath of 150 km. The footprint of each pixel will be 10 km * 10 km, the detection time for one spectrum is 0.5 s, resulting in a smear of 3.5 km. There are gaps between the pixels. The detectors are photo-conductive MCT. The cooling system is shared with the MIR and TIR instrument.

No Fourier transform is foreseen onboard; the interferograms are compressed and transmitted to Earth.

The parameters of the instrument sensitivity are shown in Table 1.

Table 1. Properties of the Fourier Spectrometer and noise parameter

Spectral interval	µm	2…22
Spectral resolution	cm^{-1}	0.5…5
Noise level (NESR)	$W\ cm^{-2}\ sr^{-1}/cm^{-1}$	10^{-8}
Angular FOV	deg	1×1
Time to measure 1 spectrum	s	0.5
Interval between measurements	s	0.1
Optical path difference	mm	17
Telescope diameter	mm	50
D*	$W^{-1} cm\ Hz^{½}$	2×10^{10}
Pixel dimensions	mm	0.8×0.8

5. Orbit Parameters and Swath Width

The designed swath width is 200 km. By implementation of certain design conditions can a swath width of 300 km also be obtained instead of the basic 200 km swath width.

In the basic static configuration, the swath maintained symmetrically to the orbit Nadir line, that is 100 km to its right and 100 km to its left.

In order to obtain a reasonable geometrical resolution is a circular orbit of about 570 km altitude with a repetition time of about 90 minutes assumed, equivalent of 15 revolutions per day.

In order to cover the entire equator belt region for a sun-synchronous polar orbit with the assumed 200 km swath width are about 12 satellites necessary. For a swath width of 300 km the number could be decreased to about 9 units.

The number of satellites is further reduced for non-polar orbits. With a 72 degree inclination are all principal forest areas of the Earth covered and in addition is an overlapping of the ground coverage at the equator region also obtained.

For this configuration is the direct monitoring of aerosols and combustion gases in the region north and south of 72 degree latitude not possible.

By additional use of a co-called scanning mirror within the optical system of the satellite(s) can with the same sensor equipment the overlapping rate of the monitored areas be increased. The associated mirror operates in a dynamic (scan) mode and a static mode.

In the dynamic mode is the mirror swinging or rotating to image the region outside the 200 km static swath width. In this way can the swath width be increased by the factor 2.5 to 3 with resulting swath width of 500 to 600 km compared to 200 km of the basic design.

By combination with a larger basic swath width > 200 km can the overlapping range be increased up to about 800 to 900 km. This leads also to a nearly complete coverage in equatorial regions with less satellites than indicated above. It should, however, be taken into consideration that the geometrical resolution in the region at distances larger than about 250 km (for a basic 200 km swath width) is decreasing significantly with increasing aspect angle to the relevant locations away from the Nadir.

The increase of the observed area using the scanning mirror provides also the possibility to monitor HTEs of the previous and the succeeding overpass strip while monitoring the strip of the actual overpass.

For the increased swath width of more than 600 km can the integration time be reduced if the geometrical resolution is kept to the value of the normal operation mode. Thus are spots of high temperature events still recognizable at the most distant locations.

For the static application is the scan mirror tilted to a position at which the 200 km swath is projected to either one side of the orbit projection line on the ground. By remaining statically in this position a strip slightly larger than 200 km (because of the larger aspect angle) is sensed parallel to the basic swath region, but again with decreased geometrical resolution.

So taking into consideration different design features can with 7 to 9 satellites the complete equatorial region be monitored for HTE during daytime at the geometrical resolutions necessary for fire and combustion product monitoring as well as identification of fire type, fuel materials and the combustion relevant properties.

In this way is a monitoring repetition rate of about 90 minutes for all locations guaranteed.

Of importance is the fact that all sensors units of the sensing equipment can make use of this scanning mirror mechanism.

6. Spectral Bands and Sensor Unit Properties

The spectral bands provided are given in Table 2a and Table 2b. The properties of the geometrical resolution are representative for the 200 km swath configuration.

There are two observation modes possible:
* the normal mode, applicable simultaneously by all sensor units,
  or
* the magnifier mode, applicable simultaneously for the MIR and TIR channels.

The magnifier effect for the MIR and TIR sensor is obtained by use of an additional optical device.

The magnifier mode is used for detail investigation of a segment within the swath area for the normal mode. This mode is applied only for TIR and MIR. These channels provide crucial insight into features that are mandatory for aerosol / trace gas investigations and to a certain exent also for fire management.

6.1 Detection of HTEs and burned areas:

Fire detection will be performed by application of the MIR band sensors.

The fire detection in two separate bands near 3.8 µm provide a high sensitivity to the temperatures of fires. The use of these bands is important for the identification of fire intensity and the type of combustion (e. g. flaming vs. smouldering).

The combination of the high intensity signals from the MIR and TIR channels allows observation of high temperature events without sensor saturation also within the sub-pixel region. Because of the high spatial resolution can much smaller fires, such as camp fires, also be detected and identified as such. This property decreases in addition the false alarm rate caused by reflection of solar radiation on terrestrial objects.

Table 2: Spectral Bands

Normal Mode

Table 2a

Channel	Spectral Range µm	Spectral Resolution	Number Pixels	Swath Km	Geometric Resolution m	Product
VIS1	0.42 - 0.50	NA	4096	200	49	Image
VIS2	0.52 - 0.60	NA	4096	200	49	Image
VIS3	0.61 - 0.69	NA	4096	200	49	Image
VIS4	0.76 - 0.89	NA	4096	200	49	Image
NIR - ATOF	0.9 -1.65	20 nm	1024	200	195	Spectro-Image
MIR	3.4 - 3.8	NA	1280	200	160	Image
MIR	4.5 - 5	NA	1280	200	160	Image
TIR1	8.4 - 9	NA	1280	200	160	Image
TIR2	10.7 – 11.3	NA	1280	200	160	Image
TIR3	11.7 – 12.3	NA	1280	200	160	Image
Grating spectrometer	0.3 - 0.9	5 nm	512	200	800	Spectro-Image
Fourier spectrometer	2.0 - 22.0	1 cm^{-1}	9	150	10 km	9 Spectra with resolution of 10 km distributed over 150 km

Magnifier Mode

Table 2b

MIR	3.4 - 3.8	NA	1280	64	50	Image
MIR	4.5 - 5	NA	1280	64	50	Image
TIR1	8.4 - 9	NA	1280	64	50	Image
TIR2	10.7 – 11.3	NA	1280	64	50	Image
TIR3	11.7 – 12.3	NA	1280	64	50	Image

In addition can fire emissions be detected. The evolution of the smoke plumes at high temporal resolution allows insight into the dynamics of smoke emission and smoke dispersion and also into chemical processes, and potential interactions between fire aerosols and clouds.

The combination of VIS1, VIS2, VIS3, VIS4 and NIR AOTF bands provide information on land surface properties, in particular on vegetation type and a variety of other combustible and non-combustible materials. These information are essential for establishing emission inventories.

6.2 Geometrical Resolution Properties

Horizontal Resolution

A good cloud detection in the MIR and TIR channels is essential for accurate aerosol retrieval. Small pixel sizes will promote the spatial association between aerosols and clouds.

The following parameters will be achieved for horizontal resolution:
* normal mode: 160 m * 160 m;
* magnifier mode: 50 m * 50 m at a limited region of 64 km * 64 km.

Vertical resolution

Height information is essential for chemical processes (trace gases), atmospheric transport (aerosol and trace gases), and the occurrence of potential cloud interactions with combustion products.

(Biomass) aerosol require UV sensor data and for clouds TIR sensor data. In addition, altitude information will be provided at coarser resolution for cloud-fields based on data of the near-IR oxygen bent and by the CO_2-slicing method in the far infrared.

The following performances will be achieved:
* Tropospheric resolution: at least for four altitude levels;
* Cloud top height: better than 1 km for optically thick clouds.

Temporal resolution

The obtainable overpass times satisfy also the requirements for HTE monitoring for the purpose of fire management and aerosol / trace gas monitoring.

An overpass over the same location will be about every 90 minutes.

The orbit parameters for each satellite can be slightly modified by use of a cold gas system. This permits the optimisation of temporal overlapping with measurements of current and historical sensor platforms for cross-calibration, for provision of supplementary data to sensor data of other platforms and a linking to historical long-term data sets.

These measures ensure quality and consistency among sensors on the basis of identical targets and to simultaneously detecting sensors on other platforms.

Spatial coverage

See chapter 4. Orbit Parameters and Swath Width

6.3 Atmospheric Interactions

Clouds

The altitude retrievals in the NIR and in TIR complement each other.

The following spectral bands are used for the determination of
* optical thickness and partical size: 660, 860 and 2200 nm;
* altitude: 10 µm;
* CO_2 slicing near 15 µm;
* optical depth: 550 nm;
* cover: variability of VIS multi pixel detection;
* phase (ice/water):1600 nm and 1650 nm;
* droplet size: 550 nm and 2200 nm.

Smoke aerosols

In particular are these bands of interest for the detection of aerosol properties.
*Optical thickness and altitude: globally for the biomass aerosol type (absorption and size) at 340 nm, 380 nm;
* Optical thickness and size: over ocean: 440 nm, 550 nm, 670 nm (and 1600 nm, 2200 nm for coarser aerosol sizes);
* Biomass optical thickness: over land: 550 nm, 2200 nm (use the “constant” albedo ratio between 5500 nm and 2200 nm) to filter unknown surface contributions at 550 nm;

Trace gases

In particular these bands are of interest for the detection of aerosol properties:
* to monitor ozone: 940 nm;
* to monitor total ozone: 300-340 nm;
* to monitor nitrate oxides (e.g. NO_2): near 450 nm.

CO_2 is a trace gas abundantly emitted during vegetation fires. CO-monitoring can provide information on the amount of emission produced by the fires, but also on the combustion stage (flaring vs. smouldering). NO_2 and O_3 provide important information on photochemical reactions.

Formaldehyde, a potentially carcinogenic compound, is abundantly produced by vegetation fires and is released proportional to many of the other compounds of incomplete combustion. Knowing its atmospheric fate would improve health exposure assessment.

It is also desirable to monitor S-containing species. Observed increases of S in fire aerosols during the 1997 / 1998 Indonesian and 2002 Moscow smoke haze to enhanced S-emissions by peat fires with corresponding negative impact on human health and acid rain. For comprehensive assessment of health impacts, a detailed monitoring of a wider spectrum of toxic compounds (e. g. PAH) would be advantageous.

Table 3a: UV spectral range (Reference: Wagner, IUP Heidelberg)

Species	Wavelength range [nm]	Spectral resolution [nm]	Main sources
O3 profiles	240-300	~1.0	
O3	320-340	0.4 - 0.7	
NO2	350-390	0.4 - 0.7	-fossil fuel burning -lightning -biomass burning -soil emission
SO2	310-330	0.4-0.7	-volcanoes -fossil fuel burning -biomass burning
HCHO	330-365	0.4-0.7	-biogenic emissions -biomass burning -photochemical smog
BrO	340-365	0.4-0.7	-autocatalytic release
OClO	360-390	0.4-0.7	-stratospheric chlorine activation
O4	350-390	0.4-0.7	

Table 3b : Visible spectral range (Reference: Wagner, IUP Heidelberg)

Species	Wavelength range [nm]	Spectral resolution [nm]	Main sources
NO2 total column	410-450	0.7-1.2	-fossil fuel burning -lightning -biomass burning -soil emission
O3	440-640	1-1.5	
IO	420-470	0.7-1.2	-algae
Glyoxal	420-460	0.7-1.2	-biogenic emissions -biomass burning -photochemical smog
NO3	620-680	0.7-1.2	-NO2 + O3
H2O a	480-520	0.7-1.2	
H2O b	610-680	0.7-1.2	
O2 a	610-680	0.7-1.2	
O2 b	760-780	~0.05	
O4 a	450-500	1-1.5	
O4 b	550-600	1-1.5	
O4 c	610-680	1-1.5	

Table 3c: Near IR spectral range (Reference: Wagner, IUP Heidelberg)

Species	Wavelength range [nm]	Spectral resolution [nm]	Main sources
CH4 a	1940-2040	~1nm	-wetlands -ruminants -rice
CH4 b	2265-2380	0.2-0.6nm	
CO2	1940-2040	~1nm	
CO	2265-2380	0.2-0.6nm	-biomass burning -fossil fuel burning
Ice/water	1000-1750[5]	1-3nm	

Table 3a, 3b, and 3c refers the spectral ranges and instrumental requirements for trace gas retrievals in the atmosphere from satellites in the UV/VIS/NIR spectral range

It has to be taken into consideration, that
* spectral sampling should be ≥4 detector pixels per full width at half maximum;
* typically is the total atmospheric column of a trace gas is determined; for most trace gases (except for OClO). Also the tropospheric partial column can be determined;
*the atmospheric mixing ratios of the oxygen molecule (O_2) and dimer (O_4) are constant and can thus be used as indicators for variations of the atmospheric light path, especially caused by clouds.

Vertical aerosol information

Aerosol altitude detection and aerosol detection over land are desirable. Scattering phenomena (non-spheres have a larger side-scattering than similar sized spheres) also allow information on aerosol morphology.

The following bands are of particular interest:
* with fixed angle (a forward look and a backward look): 550 nm of VIS2;
* range monitoring: 440 nm of VIS1;

6.4 Proposal for Calibration / Validation Concept

The following calibration procedures have to be taken into consideration.

a) Pre-flight calibration in the laboratory

The calibration is performed by use of e.g. black body devices of different temperature, filament band lamps and lambertian screens.

Absolute calibration of the equipment is made periodically by institutes for optical standards.

b) Post-flight calibration on board
The post-flight calibration can be obtained in two ways,

either b.1 by activating a calibration system installed on-board the satellite
On board calibration is performed for MIR, TIR and the Fourier spectrometer by use of a small source of radiance (specific for each instrument) which is activated once per revolution or on special command.

and/or b.2 by use of sample areas on the ground
Areas with specific radiation properties are selected. The accuracy of in this way performed calibration is estimated to be 10 to 15 percent.

c) Validation
Two principal alternatives will be applied,

either c1. Comparison of the sensor-measured value with the value generated and in situ verified at the reference target on the ground.
The reference values on ground will be determined by a variety and a combination of different instruments depending on the parameters to be validated, e.g. Lidars, ground Fourier stations and ozone networks.

and/or c2. Cross validation by comparing the value detected by the satellite sensors to the value of the same or a similar feature detected by reference satellites of other projects.
For cross validation will data from satellites be used that are in operation at that time.

The VIS channels will remain stable in their performance over the assumed life time of five years.

MIR and TIR channels will have some degradation, but still be usable.
For this occurrence will calibration procedures more extensively be applied.

Degradation effects may occur for the Stirling cooler used for the TIR sensing unit..

7. The Satellite Design Parameters

Total mass

of the satellite will be not higher than 120 kg.

Energy requirement

is 90 W per orbit , including 40 W for platform bus.

Chemical batteries with a capacity of 10Ah are used.

Attitude Control

The three axis attitude control is performed with the following sensors:
* the star sensor (star tracker) (two units) is the main sensing device for attitude determination;
* the sun sensor (three units),
* the three-axis magnetometer (two axis) is used for initial attitude control and as a back-up device;
* the spin rate measuring laser gyroscope.

Actuators for attitude control

The following actuators are used for attitude control:
* reaction wheels (4 units) with cold reservation of electronic part of each unit. The capacity of each wheel is 0.12 Nm;
* Magnetotorquers (3 units) plus 3 in cold reservation for external momentum dumping.

The attitude control system will allow to deviate the sensing instrument axis off 35 degrees from Nadir in orbit plane and out of orbit plane.

Assuming standard intercalibration of the optical instruments mounted onboard the satellite and use of star sensors error of less than one angular minute be expected.

Under these conditions can a printing error (targeting error) of less than 6 angular minutes be obtained.

For a tilting manoeuvre with the purpose to point continuously to a target location or area on the ground will the error be about 1 angular minute, for complicated manoeuvres (multi axis tilting) it can reach the value of 6 to 10 minutes at the maximum.

Orbit Navigation

The GPS or in the future the Galileo or any other system is used for orbit navigation. The maximum error in each of the three coordinates is expected to be less than 20 m.

Orbit Changes / Corrections

Corrections and changes of the orbit are performed by a cold gas reaction unit.

Communication

A telemetry bit rate of 1 Mbit/s and a command bit rate of 5 kbits/s is assumed. The data rate is estimated to range up to 5000 Mbit per day.

8. Typical Mission Profile

The search-and-find mode *:*

For a pre-selected swath range are those locations determined at which the temperature of an events exceed a certain threshold value. This evaluation of the MIR and TIR signal is performed onboard. In addition are the temperature and the area of the event evaluated and as a result of the search-and-find mode transmitted to the next available receiving station.

*** Special event treatment:**
For the case that the event seems to be remarkable and assuming the event is situated at a reasonable distance to the satellite are the characteristic signatures of the event, its surrounding and the emission products monitored either in normal or in high resolution mode. The result of this process is transmitted to the next available receiving station.

*** Current treatment:**
Upon these findings will the events come on the list of the current tasks for monitoring or it will be treated as an outstanding case.

*** Special treatment request:**
The request for special treatment can be issued from an application or scientific user. In order to prevent confusion, a priority and request scheme has to be elaborated.

*** Collection treatment:**
For the case that no particular request is to be treated, will the satellite be operating in a collection mode at which the complete or a selected set of the sensors are used at normal or magnifier mode to collect the status of the terrain and the atmosphere without any particular preference. So will e. g. the thermal signature of land and water bodies continuously be registered if the relevant sensors are not occupied by other tasks.

Operations requirements:
In order to be of value for the user community it is necessary to adapt and concentrate the satellite performance in short term to a particular task. Therefore are the communication links, the attitude control and the orbit navigation a crucial part for the success and the benefit of the mission and the project.

9. Statement concerning Complexity of Mission and Maturity of Design

The satellite and the sensor design consists of proved technologies. Therefore is a high degree of safety and reliability ensured.

The short term task alterations require a reliable communication and control network. Therefore have the receiving stations and the control centre to be updated with actual equipment and software. This, however, does not increase the complexity of the mission.

The high degree of redundancy in the sensor package (four VIS-sensors, three spectrometers with overlapping spectral bands) decrease the risk of a complete loss of data and a loss of the mission. This risk will be further reduced by the fact that a reasonable number of satellites are in orbit (almost) simultaneously. (See: Chapter 4. Description of the instruments).

The risk is highest for the MIR and the TIR sensor segment because only they provide the temperature signatures and there is no redundancy involved in the spectral bands of the MIR and TIR sensors. The risk in this case is not so much a possible degradation of the sensor sensitivity but more in the failure of the cryogenic section of the cooling system. The extreme contrast of high temperature events to the background area will in spite of such a loss of functionality still allow to perceive the location of high temperature events. The contrast of the scene signature and the accuracy of the temperature determination will, however, be reduced.

10. Realization Time Schedule and Milestones

The entire process from the design start to the ready-for-launch status of one satellite is performed in three stages:

a) Manufacturing or purchasing components, particularly for the payload segment;
b) Platform design and construction, there included the complete bus system;
c) Assembly, integration and testing.

Investigations showed that the time critical path is determined by the purchase activities. All the other actions base on experience in past similar projects and can be started without delay.

Even under consideration of the indicated impediment can one satellite be made available for launch in more than 24 months, but in less than or equal to 30 months. As all satellites are similar in design, can the whole constellation be treated in parallel activities so that the other satellites of the cluster can also be made available in a short term period.

References

This document bases on an investigation, titled “A Cluster Satellite Concept for Discovery, Observation and Monitoring of High Temperature Events (HTEs), their Product (Aerosols / Gases) Emissions and Spreading …”, compiled by Dr. Rudolf H. Dittel, Mundi Reales Consult.