FAST EMERGENCY RESPONSE: AN OPPORTUNITY FOR NEW SAR AND OPTICAL EARTH OBSERVATION MISSIONS

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1. INTRODUCTION

Satellite imagery is growing in importance as a crucial means for disaster monitoring and emergency response applications. This is evident from the increased number of satellite missions targeting these areas and the ever more frequent activations of the Charter on Space and Major Disasters. The first Sentinel missions being developed within the GMES programme are mainly targeting the environmental aspects of the programme but now security related aspects – and among them emergency response – are gaining in priority.

Emergency response applications need a reliable and timely source of satellite imagery. Information requirements for emergency response applications vary depending on the nature of the crisis. Overview maps, detailed maps, damage assessment maps, and change detection over short and longer time intervals are all needed to provide the needed situational awareness. The major requirements that are not fulfilled by today's satellite missions are the need for providing high-resolution imagery (1m or less) with frequent revisit and fast system response.

Instead of designing an entirely new system trying to meet the demands of emergency response, and thereby overlapping the capabilities of existing and planned systems, synergy effects can be identified by designing, developing and implementing a complementary system to those already targeting these applications.

This approach has been followed for mission designs for a SAR and an optical constellation mission enabling high resolution imagery with unprecedented low system response times (<12 hours) considering the joint performance with existing and planned missions and state of the art performance as stand-alone missions. The SAR constellation consists of 3 satellites orbiting in a noon-midnight orbit and with a payload enabling both very high resolution imagery as well as overview images. The optical constellation of two satellites provides panchromatic and multispectral images and uses the spacecraft agility to enable mosaic images and low response time. Providing a cost-efficient solution has been a driving objective for the design at all levels of the systems. The systems are based on state-of-the art technologies and could be implemented within 4-5 years.

This paper will present the system and satellite design for both missions. The complementary approach to other missions will be demonstrated and the overall performance of the constellations, considered as complementary and stand-alone missions, will be presented.

2. SATELLITE SYSTEM REQUIREMENTS

Pure imagery as well as value-added products are needed both at the detailed level as well as for overview images. Spatial requirements for damage assessment maps can be seen in Table 1 providing requirements for both detailed maps and overview images. Generally one can see that there is a need for satellite image products with all spatial resolutions that are available.

Important for both types of products are:

- Adequate image quality.
- Reliable image and product provision.
- Timely delivery of images and products

The adequate image quality means that the images shall be good enough for feature recognition and rough land cover classification but not necessarily more. A system designed especially for emergency response could therefore have lower requirements for signal to noise ratio than systems targeting a wider range of applications where image quality is more important. Thereby a more cost-efficient solution can be provided.

Crisis Type	Detailed Level		Overview Level	
	Desired	Max	Desired	Max
Floods	1 m	5 m	3 m	20 m
Landslide	<1 m	5 m	1 m	2,5 m
Hurricanes and Storms	<1 m	5 m	3 m	20 m
Forest Fires	1 m	10 m	5 m	50 m
Earthquakes	<1 m	5 m	-	-
Volcanoes	<1 m	3 m	2 m	1000 m
Tsunamis	<1 m	5 m	3 m	20 m
Oil Spills	1 m	2,5 m	10 m	50 m
Refugee Camp Mapping	1 m	2,5 m	-	-
Population Gatherings	<1 m	1 m	-	-
Population Movements	<1 m	1 m	-	-
Asset damage	<1 m	2,5 m	-	-

Table 1 Spatial Resolution Requirements for Damage Assessment Maps [5]

Reliable and timely delivery of images and products are related in the sense that it is necessary to be able to rely on the timely delivery of information in order to benefit from it. Products that cannot be guaranteed delivered will remain as exotic add-ons and cannot be fully included in an operational scenario. GMES as well as the International Charter on Space and Major Disasters both utilise a number of different satellite missions to provide the required information. Satellite missions especially targeting these applications should therefore also consider this environment and identify how they optimally can provide added value to the existing and planned missions.

The following three high-level features should be considered:

Sensor Type: SAR + Optical. Both SAR and optical sensors are used at the moment and will continue to be used. SAR sensors provide all-weather day/night time imaging capability but have limited viewing geometry – especially in mountainous regions or in urban areas where high buildings cause shadowing effects. Optical imagery depends on sunlight conditions but have larger viewing geometry flexibility and can provide multispectral information.

Focus: Fast revisit / High resolution. Overview images can be provided in regular intervals by the medium resolution/large swath satellites. Fast and regular image updates however remains an unfulfilled requirement for emergency response as the high level of detail is related with a narrower swath width and usually a lower duty cycle limited by downlink opportunities for the large data volumes. Complementing the existing and planned space segment should therefore be targeting these applications.

Orbit: Sun synchronous noon/midnight orbits. Most other imaging satellite missions orbit in Sun Synchronous Orbits (SSO). New missions aiming to complement these missions should therefore also use SSO in order to provide regular intervals between the images from all missions.

Optical missions depend on the optimum sunlit conditions and therefore need to be orbiting with local times of node crossings close to noon.

SAR missions do not have this restriction and in fact most SAR missions orbit in dawn dusk orbits in order to benefit from the quasi-constant solar conditions facilitating the power generation for these power demanding missions. As most SAR missions orbit at dawn and dusk a coverage gap exist in the ~12 hours between these passes, which is irrespective of how many SAR satellites that are deployed into this orbit. A complementary SAR mission should therefore seek to close this gap by providing SAR imaging capability in between, i.e. in a noon-midnight orbit.

The following sections provide a description of the two proposed missions – one SAR and one optical - for emergency response and crisis management.

3. SAR CONSTELLATION

The SAR satellite mission consists of a constellation of three satellites orbiting in a sun synchronous orbit. The orbit has been optimised to complement the coverage performance of the Italian dual-use Cosmo-Skymed constellation so that high resolution SAR imagery can be provided with a maximum revisit time over 95% of the globe within 6 hours when both constellations utilise access modes with incidence angles of 20°-60° (Cosmo-Skymed) and 20°-55° (this constellation) on both sides (left and right-looking). The stand-alone revisit performance of the SAR constellation for the 95% global coverage is below 14 hours.

The SAR constellation has the following features.

- No of satellites: 3
- Orbit altitude: 659 km
- Inclination: 98°
- LTAN: 00:00 h

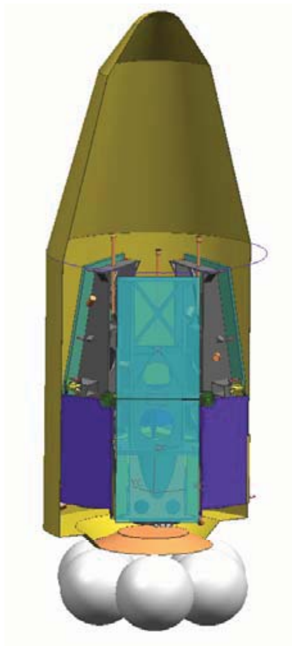

Figure 1 Accommodation of 3 SAR satellites in Soyuz

The three satellites could be together on a Soyuz launch vehicle or individually on a smaller launch vehicle like

Vega or Rockot.

To provide a fast system the satellites must be commandable in each orbit and be able to downlink the payload data in each orbit. A ground segment consisting of the ground stations Svalbard and Troll will provide a minimum contact duration per orbit of 10.5 min.

3.1. SAR Payload

The X-band SAR instrument is based on an active array concept, enabling electronic beam steering and the implementation of different modes with different resolutions and swath widths. This flexibility has been included in order to provide a flexible system to answer the variety of imaging needs required for emergency response applications. For the ScanSAR (Wideswath) mode the TOPS-SAR approach is implemented. This effectively removes the scalloping effect, and the NESZ and radiometric variation approaches that of a Stripmap image. Also, by adjusting the dwell time in concert with the azimuth scan rate, the azimuth resolution can be tuned to achieve the desired value.

Mode	Technique	Resolution	Swath width
VHR	Spotlight	1 m	10 km
HR	Stripmap	2.5 m	25 km
WS	TOPS	15 m	100 km

Table 2 SAR Payload Modes

3.2. SAR Satellite

The satellite design has been tailored to the mission and the payload. The principal design drivers have been:

- Accommodation of large and heavy antenna
- Enabling of multiple launch concept
- Noon/midnight SSO
- Left- and right looking payload

The flight configuration of the SAR satellite can be seen on Figure 2. A long stiff structure has been used to accommodate the long and heavy antenna without the use of deployment mechanisms. This saves mass and adds to the overall reliability of the satellite. The bus subsystems and the payload electronics are located in the bus compartment to maintain a low centre of mass of the satellite in the launch configuration. Two deployable and rotating solar panels are used for optimised solar incidence during the sunlit parts of the orbit.

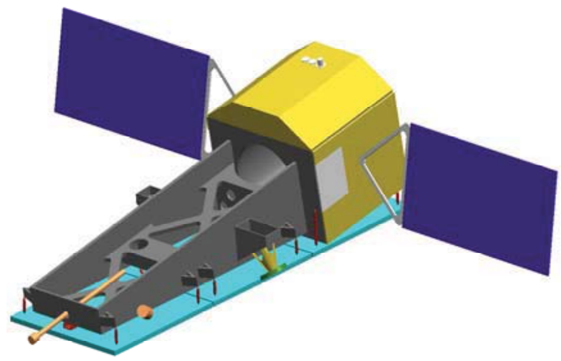

Figure 2 Flight Configuration of SAR Satellite

Satellite dry mass	955 kg
Propellant mass	55 kg
Average power consumption	400 W
Imaging duty cycle per orbit	2.2% - 5.3%
Lifetime	7 years

Table 3 SAR Spacecraft Characteristics

4. OPTICAL CONSTELLATION

The optical mission also seeks to provide its performance as a stand-alone system while complementing other existing and planned missions. The reference mission here is the dual-use two satellite constellation Pleiades. The mission shall combine the high resolution capability with fast response time meaning that a large accessible swath must be achievable. A large instrument swath is incompatible to a cost-efficient high resolution solution so instead the large accessible swath is achieved via spacecraft agility. The spacecraft agility enables the spacecraft to quickly change and stabilise its attitude for imaging of different scenes within the accessible swath. Furthermore the agility enables the spacecraft to make image mosaics of up to 4 image strips after another thus increasing the swath width by a factor of 4 compared to conventional nadir-looking satellites. Finally the spacecraft agility enables sun pointing of the solar panels and tracking of the ground station for high-gain payload data transmission.

Mission characteristics include:

- 2 satellite constellation, phasing 180°
- Altitude 614km, SSO
- LTDN 10:00
- Image mosaics: 4 x 12km swath
- Revisit time: <1 day at 95% of European latitudes in combination with Pleiades

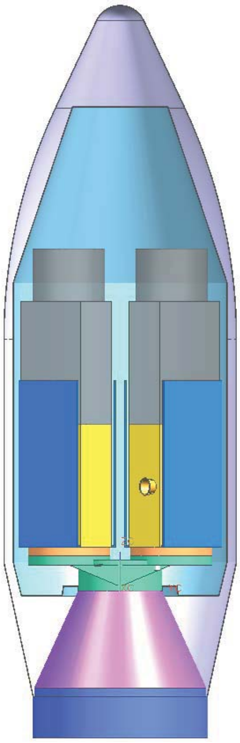

Figure 3 Dual Launch Configuration on Vega

The two satellites can be launched together for a cost-effective solution or individually.

4.1. Instrument

The instrument has been designed to provide the most cost-effective 1m resolution camera with adequate image quality as possible. This has resulted in a Korsch-TMA type telescope and a focal plane assembly with blue, green, red, near Infrared and PAN channels. TDI (Time Delay and Integration) is used for the PAN channel to increase the signal to noise ratio (SNR).

If necessary the SNR could be further increased by using the spacecraft agility to perform target pointing and thereby reduce the ground speed.

The optical instrument has the following features:

- 1m PAN
- 4m MS
- Five bands: Red, Green, Blue, PAN, NIR
- Swath width: 12 km

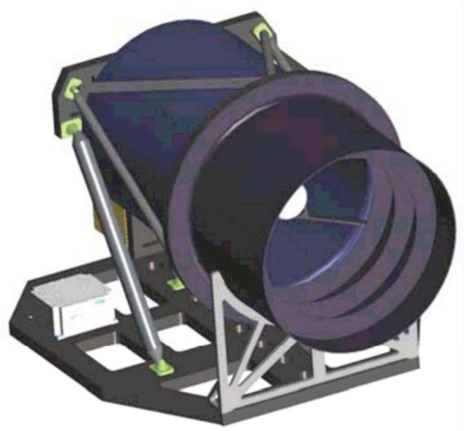

Figure 4 Korsch-TMA Telescope

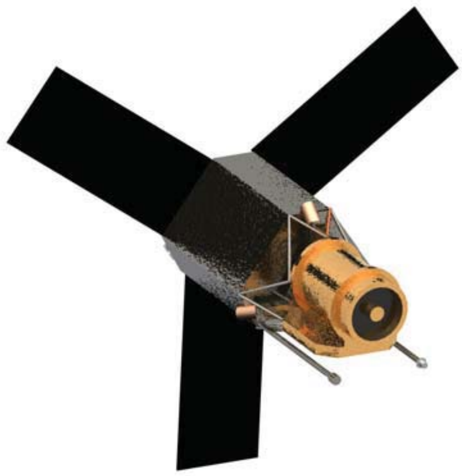

Figure 5 Optical Satellite in Flight Configuration

4.2. Satellite

The satellite has been designed for optimised payload accommodation, spacecraft agility and launcher accommodation. Three solar panels are mounted on the sides of the spacecraft and deployed after launch. The camera is mounted on top of the bus compartment which contains all bus subsystems and the payload electronics. A high gain fixed X-band antenna is used for payload data downlink. During data downlink the entire satellite performs a slew manoeuvre to direct the antenna towards the ground station.

Satellite features include:

- Satellite dry mass: 625 kg
- Propellant: 34 kg
- Average power consumption: 300 W
- Imaging duty cycle per orbit: 5%
- Lifetime: 7 years

5. SUMMARY

A SAR and an optical mission concept for emergency response and crisis management applications have been presented. The missions have been designed with the objective of providing complementary to existing and planned satellite missions to optimise their added value for the users. Both missions focus on providing very high resolution with fast turn-around times as this has been identified as a gap in the current data provision.

The SAR mission consists of a constellation of 3 satellites orbiting in a sun synchronous noon/midnight orbit to complement other SAR missions that mostly utilise a dawn-dusk orbit. Thereby a reduction of the maximum response time from ~13 hours to ~7 hours can be accomplished. The SAR sensor provides, in addition to its very high resolution mode, also the capability of high resolution and wide swath imaging to be able to offer the entire palette of detailed and overview images.

The optical mission consists of two satellites in sun synchronous orbit with a LTDN of 10:30. The satellites are designed around the instrument providing resolutions of 1m PAN and 4m MS with a swath width of 12 km. Satellite agility is utilised to increase the accessible swath width enabling mosaic'ing of 3 strips thereby enabling images of 36km x 36km. Satellite agility also enables a sun pointing configuration when not imaging and tracking of the ground station for data downlink with a fixed high gain antenna.

Both missions are designed to provide a cost-efficient solution for emergency response and crisis management applications. This have lead to e.g. joint launch concepts of multiple satellites, cost-efficient payload with adequate performance and a platform concept relying on state-of-the art components. The missions can be developed and launched within the next 4 years.

6. REFERENCES

[1] Website of the OHB-System AG Germany: www.ohb-system.de,
[2] International Charter "Space and Major Disasters". http://www.disasterscharter.org
[3] Respond. GMES Services Supporting Humanitarian Relief, Disaster Reduction & Reconstruction http://www.respond-int.org
[4] Unosat – Satellite Solutions for all. http://unosat.web.cern.ch
[5] GMES Fast Track – Emergency Response Core Service. Strategic Implementation Plan (With Annexes). ERCS Implementation Group. 24.04.2007
[6] De Zan, Francesco. Terrain Observations with Progressive Scan (TOPS) SAR. EUSAR 2006
[7] Italian Space Agency, Cosmo-Skymed System Description and User's Guide
[8] EOPortal. Pleiades-HR (High-Resolution Optical Imaging Constellation of CNES). http://directory.eoportal.org/get_announce.php?an_id=8932