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1 INTRODUCTION

1.1 SCOPE OF DOCUMENT

This is the Executive Study for ESA Contract No. 21488/08/NL/HE Concepts for the Demonstration of Enhanced EO Technologies. This study was executed by Systems Engineering and Assessment ltd (SEA) ,and a consortium of the following contractors :SSTL, SULA, Qinetiq, FFI, and Academic consultants, between May '08 and April '09.

1.2 APPLICABLE AND REFERENCE DOCUMENTS

The following documents contain the high level requirements applicable to this study ([AD1]) and the various output documents produced and which form the basis for this study abstract document.

AD1 Statement of Work Concepts for Demonstration of Enhanced EO Technologies Definition Study (TEC/SY/1/2007/SOW)

RD1 SEA/08/TN/6757, TN1: Review of EO technology demonstration payloads and compatibility with small satellite demonstration
RD2 SEA/08/TN/6805, TN2: Payload requirements analysis
RD3 QINETIQ/S&DU/SPACE/CR0601136 Frequency Monitoring Package (FMP) Final Report: Summary
RD4 SEA/08/TN/6902, TN3: Preliminary Payload definition and subsystem concept
RD5 SEA/08/TN/6809, TN4: Report on S/C platform derived requirements
RD6 SmarTeam #0122691, TN5: Mission Concept Definition
RD7 SEA/08/TN/6963, TN6: Accommodation Analysis of payloads for enhanced EO technology demonstration
RD8 SEA/09/TN/6964, TN7: Preliminary Interface Requirements Document
RD9 SEA/09/TN/6956, TN8: Reference Small EO technology demonstration mission
RD10 SEA/09/TN/6966; TN 9 : EO Technology Demonstrator Final Report

2 OVERVIEW

As ESA's missions become more complex and challenging, technology qualification through simulation and ground testing is not always sufficiently representative. Mainstream missions tend to require low-risk and therefore evolutionary technology development.

For revolutionary techniques and technologies, demonstration in the space environment is essential prior to adoption for major missions and this is one of the most important roles of small satellites.

While there are relatively frequent opportunities for secondary passengers to Geosynchronous Transfer Orbit (GTO), such opportunities to Low Earth Orbit (LEO) are rarer. Such an opportunity to demonstrate novel Earth Observation (EO) technologies in LEO is offered by the Vega Research and Technology Accompaniment (Verta) Programme

The objective of this EO Technology Demonstrator Study was therefore to investigate in-orbit demonstrations of spacecraft and EO technologies on a small mission within the 150 kg range exploiting the lessons learned with PROBA-1 and GIOVE-A and taking into account the near term flight opportunities

The study included a range of European companies which have expertise in the various payload and technology demonstration issues which were identified as being of interest to ESA at the start of the study.

One of the clear results was to show that the payload concepts which offer the most in-roads into new technology development and capabilities within Europe are also the most challenging to do in this way and are likely to be the most expensive. However this fact does not detract from the aims of the In Orbit Demonstrator (IOD) venture. In fact it further substantiates the need for such a programme since conventional routes are even more expensive and challenging in absolute cost and schedule terms.

The use of a near "off-the-shelf" platform has been shown in this study to be worthwhile and there are two very viable platforms identified which will provide an IOD workhorse to demonstrate many types of technology for Earth Observation needs. The issue of mass capability is one which needs to be further refined in order to show that there is sufficient margin to provide flexibility during the development programme in case new technology opportunities are identified or existing technology opportunities are stopped for some reason. By providing this flexibility there will be scope for keeping a fixed target launch date which is one of the most important programme management tasks. Schedule management will be a key to keeping overall costs down.

Six different mission scenarios have been shown to be viable within a timeframe of a launch before end 2013 within a modest estimated price boundary. However these estimates include a number of assumptions and contingencies which need to be investigated through a better understanding of the status of some of the ongoing technology items. This will involve discussion with other ESA TRP and study programmes.

A number of technology risks have also been identified together with a set of mitigation actions which need to be performed.

It is recommended that a pre-phase A study is initiated at the earliest opportunity in order to closeout out these remaining open points and to address some of the design issues. This study would be of the order of six to nine months long and would lead to specific design and development plans and design concepts being defined, amongst other key elements.

The study team believes that due to the lessons learned from previous missions of this class, a low cost In Orbit Demonstration programme can be achieved through a number of points, for example, managing a tight schedule by providing continuity and experienced systems engineering at all stages and at all decision points; use of COTS type parts where needed and feasible; and by the use of pragmatic approaches to model philosophy and documentation requirements.

3 PAYLOAD CONCEPTS AND DEMONSTRATION OBJECTIVES

The following table summarises the main EO Payload Technologies to be demonstrated and which were evaluated in the course of this study.

Payload	EO Objectives/Domain	New Technology Demonstration
Beaconsat	Laser Occultation to derive atmospheric constituents of set of greenhouse gas species – Differential absorption principle. Vertical resolution 1-2km Concentration of specific gases measured < 1-5% Wind profiles through doppler	Active Laser terminal at 2.1µm (IR), High stability laser with stable output power. Wavelength controller accuracy to $1x10^{-8}$ Wavelength tuning of DFB laser for gas species Demonstrator for Accurate Mission
CIWSIR	Global measurements of cloud ice water path (IWP), which are urgently needed for climate model validation Ice Particle Size resolution 10-50µm Millimetre and Sub-millimetre observations to fill the gap between optical/IR and microwave observations of ice cloud types/habits.	Validation of the retrieval algorithms which will provide unique measurements of ice cloud properties : Qualification of ambient sub millimetre-wave receivers (eg mixer diodes and multipliers up to 664GHz, calibration sources (up to 664GHz), local oscillators Prototyping of elements for ESA's first scanning millimetre-wave radiometer:
MIBS	Earth Radiation budget and Thermal Imaging of Sea Surface temperatures; To determine the spectral response of the CO2 absorption and ozone levels in the upper atmosphere;	To validate the use of a prism based spectrometer in conjunction with microbolometer; To further establish the detector capability within Europe for this type of payload (i.e. ambient temperature radiometer).
FMP	Improve data quality from existing EO sensors, Support regulatory protection through International Telecommunications Union (ITU). Characterise EO environment for RF levels and interferences.	Development of high dynamic range signal detectors and receiver electronics Frequency range: 9.2-13.75GHz and 23.6-24 GHz Development of synthesiser and digital analyser, wide and narrow band receive selection. Sinuous Antenna design for multi band receivers
AIS	Collection of VHF AIS signals and messages from Shipping traffic. Large area coverage of shipping traffic from space	High dynamic range VHF detection and signal processing Handling of multi sector messages and message collision processing Demonstration of post-processing software for

Payload	EO Objectives/Domain	New Technology Demonstration
		message content forwarding
VHRS	Fluxes of mass and chemical constituents between the troposphere and stratosphere. Chemical processes, transport, and mixing by day and night (particularly in the lower stratosphere). Tropospheric temperature and water vapour retrievals.	Spatially Modulated Interferometer (SMI), Fourier Transform Spectrometer beam splitting prisms rather than moving mirror design to generate an interferogram on a linear detector array. Lightweight and compact design (<3kg). Development of retrieval algorithms
ComPAQS	Monitoring of atmosphere pollutant species using spectroscopy in UV and visible spectral bands, from satellites in either geostationary or low Earth orbit (GEO or LEO). Precursor to Sentinel 4/5	Very compact (concentric) spectrometer design offering low mass and volume (<10kg), Wide spectral range instrument using single-channel spectrometer to replace 2 channels High spatial resolution ~1km and development of retrieval algorithms.
GNSS Reflectometry	Ocean Roughness measurement in support of SMOS Soil Moisture Ice Extent Mapping Potentially - Tsunami warning, Storm Warning	Bistatic Radar techniques for reflective GNSS signals (GPS,Galileo). Collection of sampled IF data and development of data processing algorithms

Table 3-1 : Key EO Demonstrator Objectives

Each of the above payloads was analysed in terms of development status, value to EO community in terms of relevance of product and impact on system resources in the context of a small satellite demonstration mission. Those which were deemed to be outside of the scope of this study were not considered further while the remainder were evaluated in terms of incorporating within a small sat demonstration mission.

This was done in consultation with ESA, and the various Payload experts from industry and the scientific community.

The result of the down-selection and investigation of the resource demands for a small satellite the study focussed on main missions using either and SSTL 100 platform or an SSTL 150 platform. These platforms have a heritage for small EO missions (eg UK-DMC, Topsat, RapidEye) and were considered to be suitable for this demonstration mission as a low-cost option.

The down-selected missions were based around three main payloads : Beaconsat, CIWSIR and MIBS, while the following remaining payloads ; AIS, GNSS Reflectometry, FMP where considered as potential opportunity (piggyback) payloads which would not drive the mission requirements.

4 MISSION REQUIREMENTS SUMMARY

The SSTL-100 satellite configurations are compatible for installation within the proposed VESPA launch adaptor for launch on Vega. The SSTL-150 configurations match the VESPA dimensional requirements but in a different orientation and their mass is slightly in excess of the assumed limit. Once more detailed launcher accommodation information becomes available the suitability of the SSTL-150 platform or the changes needed to accommodate the SSTL-150 on the VESPA launch adapter can be re-assessed.

By comparison of the Vega launch loads with those of the DNEPR launcher, on which several SSTL-100 and SSTL-150 platforms have been launched, it can be concluded that the SSTL platforms are compatible with launch on Vega pending on more details of the Vega dynamic loads for which there are currently no values in the 100 to 150kg range.

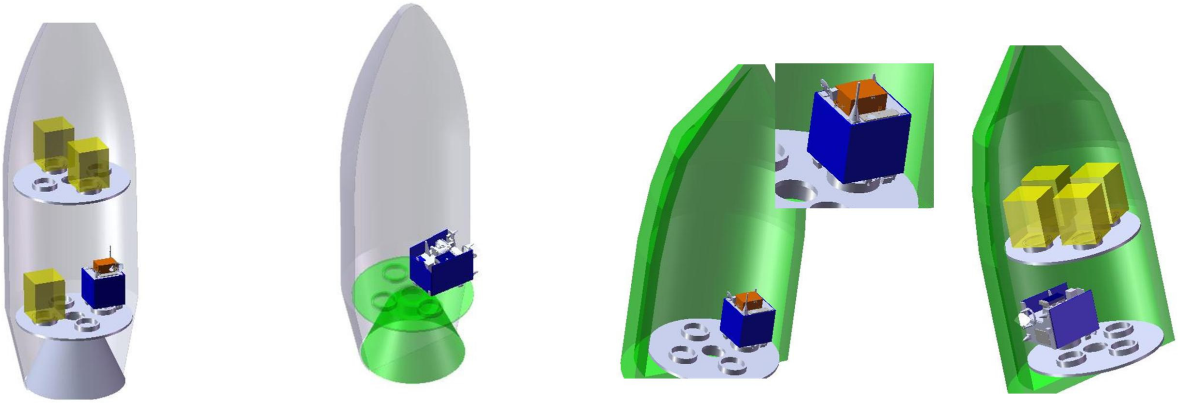


Figure 4-1 : Launcher Accommodation (Left : VEGA – showing potential conflict with fairing to be resolved, Right : DNEPR also showing potential fairing conflict to be resolved)

None of the payloads under consideration have stringent orbit requirements. All are compatible with near circular sun synchronous orbits for a range of altitudes and node times making them compatible with a shared or free launch for demonstration purposes.

In addition, none of the payloads have any stringent orbit maintenance requirements therefore; there is no need to install a propulsion system for orbit establishment or maintenance. However, if no propulsion system is installed, the operational orbit should be greater than 500km to prevent premature orbit decay.

If the current requirement to dispose of LEO satellites within 25 years of the end of their operational lifetime applies to the demonstrator then the maximum altitude will have to be restricted. For altitudes below 600 km the natural decay will generally be such that satellites will re-enter the Earth's atmosphere within 25 years. For altitudes above this a propulsion system could be used to accelerate the natural decay but even if a propulsion system was installed only for use for disposal, the altitude of the SSTL platforms would have to restricted to 700 km to achieve re-entry within 25 years of end of operational life. A target altitude of 600km was considered to be optimum for the demonstrator.

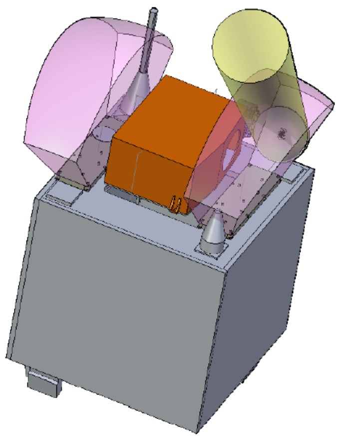
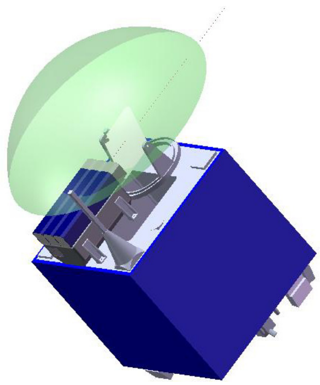
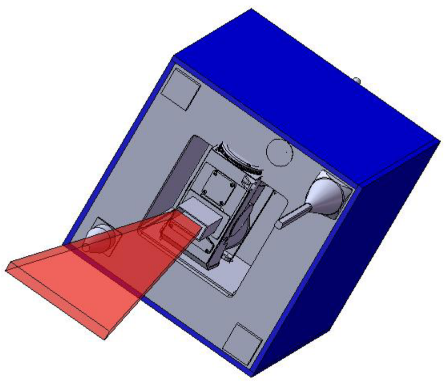
It is proposed that the demonstrator satellites can either be operated :

- via Redu (using interfaces to the SSTL TM/TC protocols via racks provided and commissioned) or
- from the ground station and Satellite Control Centre (SCC) in Guildford using its standard TC/TM commanding and scheduling procedure and interface with ESA.
- Or by a combination of the above methods

Additional ground stations need to be selected for downloading payload data during the operational phase and increasing the satellite access time during the commissioning phase, particularly for the LEOP.

5 MISSION CONCEPTS

The following mission concepts (6) were presented, as being feasible, and providing a low cost route to flying and qualifying European technologies whilst also proving a set of scientific measurements which could offer a good return on investment.

Mission 1 • SSTL100 platform • CIWSIR payload • GNSS Reflectometry • AIS payload Mass : 113 kg	
Mission 2 • SSTL100 platform • Beaconsat payload • GNSS Reflectometry • AIS payload Mass : 107 kg	
Mission 3 • SSTL100 platform • MIBS payload • GNSS Reflectometry • AIS Payload Mass : 101 kg	

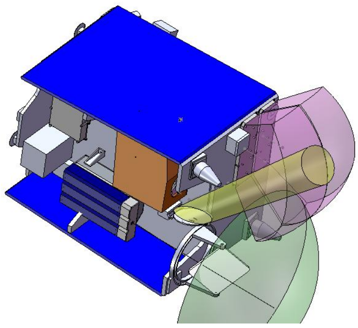
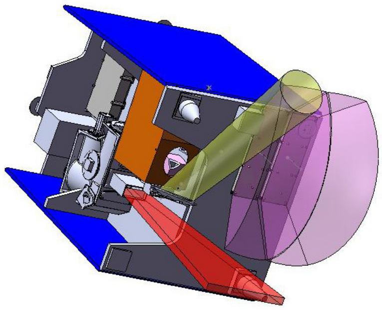
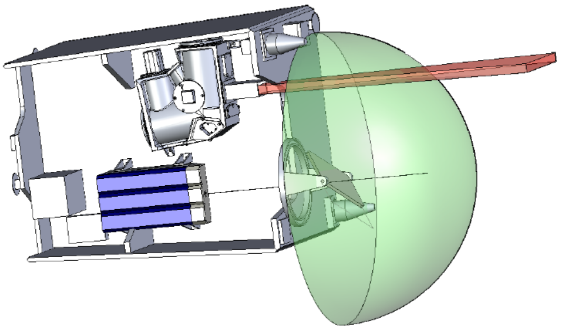
Mission 4 • SSTL150 platform • CIWSIR payload • Beaconsat payload • GNSS Reflectometry Mass : 177.9 kg	
Mission 5 • SSTL150 platform • CIWSIR payload • MIBS payload • GNSS Reflectometry Mass : 172 kg	
Mission 6 • SSTL150 platform • CIWSIR payload • GNSS Reflectometry Mass : 166.4 kg	

Table 4-1 : Mission Concepts Overview