Title: **Nano SOS (Space Object Surveillance)**
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Need

Our live on earth depends more and more on the infrastructure in space. Many essential services, such as communication, navigation, earth observation or surveillance depend on a continuously working orbital infrastructure. Space related assets of our community are growing rapidly in both civilian and security related fields. Thus, any interruption or even total loss of such systems has the potential to heavily disturb our daily live on earth. It may come to us that there is no realistic reason to worry about the loss of our space based assets but if we think of the space debris due to large chunks of material from other satellites or pieces of burnt-out rocket stages, we would understand why we should worry because it is estimated that there are more than 19.000 Objects with a diameter larger than 10cm and millions of objects with a diameter less than 10 cm on near-Earth orbits.[1]

This problem has been recognized by the leading nations of the world and as an example; in Europe such concerns were raised regarding Europe's own capability to monitor the space assets appropriately. As a reaction to that, ESA has launched its Space Situational Awareness (SSA) program[2]. According to the user expert group of ESA; SSA can be preliminarily defined as a comprehensive knowledge of the population of space objects, of existing threats/risks and of the space environment. An operational SSA system would be a mega system composed of both terrestrial and space components. On the Earth, some radar and telescope sites could be used for that purpose while some dedicated space assets would compliment a true SSA system. Optical space sensors have been identified as one of the main components of such a system of systems for SSA capability. One of the clear advantages of a space based sensor is the weather independency. Such a sensor would contribute to the whole system by providing additional and unique capabilities regarding detection, orbit determination, correlation, and characterization of objects.

The aim of the proposed project is to develop a nano satellite based space sensor solution in the context of SSA. Taking the successful miniaturization of components for pico and nano satellites in recent years into account, a small and cost effective nano satellite solution seems to be promising. The major advantages of using a nano satellite is its significant low cost compared to larger micro satellites, weather independency and large field of view. All necessary key technologies will be involved in this nano satellite mission and demonstrate the feasibility of using nano satellites for the support of SSA. Once the necessary key technologies are

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[1] http://www.en.wikipedia.org/wiki/space_debris(Date of access: 15 December 2010)

[2] http://www.esa.int/SPECIALS/SSA/SEMFSG6EJLF_0_iv.html (Date of access: 17 December 2010)

developed and demonstrated in orbit, a larger constellation of nano satellites for SSA could then be deployed and be part of an operational SSA system at much lower cost than for micro satellites.

Mission Objectives

- The surveillance of objects (operational satellites, debris and space objects like asteroids, comets etc.) orbiting the Earth in various orbits by detecting, tracking and imaging them.
- Identifying the possible threat situations to the operational satellites due to space debris by processing the data coming from the on-board sensors and correlating them with the measurements of other terrestrial sensors.
- The observation of the Near-Earth space environment that includes identifying and assessing asteroids and comets, known as Near-Earth Objects (NEO), that pose a potential risk of collision with the Earth.
- Instrumenting the Near-Earth space weather by addressing primarily the effect of solar activity on satellites and ground infrastructure such as power grids and communication networks.

Concept of Operations

The proposed system architecture will be composed of the following systems;

- 3x3U CUBESATs dedicated for SSA mission primarily are required due to quick and full scan of whole sky with the EO sensor and to make use of Lambert's method for orbit determination of an object.[3]
- A dedicated ground control station for the CUBESATs.for the control, communication and data processing purposes,
- An existing communication (relay) satellite, if any, could be used to provide communication with the terrestrial SSA components and ground control station,
- Any existing terrestrial SSA systems like radars and telescopes,

The general operational concept of the Nano-SOS system is depicted in Figure-1. The dedicated 3x3U Nano satellites in conjunction with the terrestrial assets will observe the near-Earth space objects by using the on-board optical sensors, perform some portion of image and data processing on-board and generate an alarm condition as necessary. The conditions along with the collected data and images from all the subsystems will be processed and evaluated at the ground station with the human-in-the-loop cycle. The final precautions will be issued by the ground station personnel to the other parties so that the necessary measures could be taken.

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[3] Kayal, Hakan, "A Nano Satellite Constellation for Detection of Objects in Earth Orbit", 4th International Conference on Recent Advances in Space Technologies (RAST), June, 2009, Istanbul, Turkey.

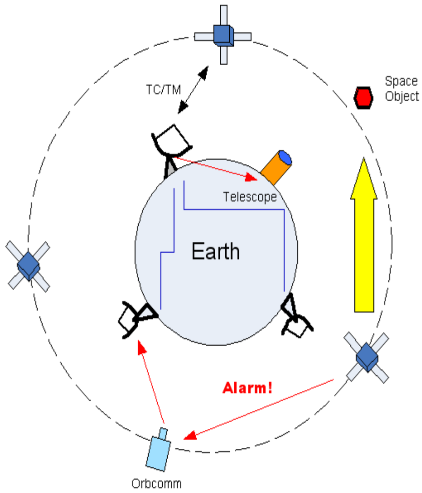

Figure-1: Nano SOS System Architecture

The data regarding the space weather collected by other on-board sensors like VLF receiver module and Langmuir probe will be processed by the ground station and could be made readily available to the other interested parties like the research institutions.

Key Performance Parameters

- Imaging system would be a small optical telescope with large FOV. Due to space limitation on the satellite, its aperture size is assumed to be 10mm maximum. A special EO sensor like the one in Figure-2 has already been developed and could be used in this project. It is required to detect objects larger than 10cm in diameter at a distance of 6000km and the orientation of which shall cover the whole sky.

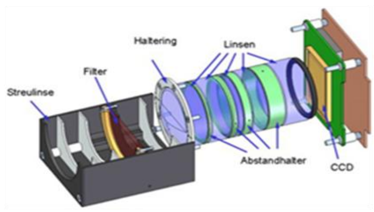

Figure-2: BRITE Telescope

- Image processing and orbit determination by a nano satellite is currently a very challenging task. Image processing could be done by an FPGA based on-board circuit card to implement various image processing algorithms. Regarding the orbit determination, the Lambert's method shall be implemented with a goal of 1 km accuracy.
- Transmission of selected events and data (images) shall be done via S-band communication link automatically or manually as desired by the operator.
- Generation of near real time alarm messages shall be done by the autonomous and co-operative operation of 3 nano satellites. So each will have an autonomous operation capability and a communication channel with each other and with the ground station.
- The final decision for acting against the alarm call will be made by the ground station

with an human-in-the loop cycle as the data from other sensors are collected and processed there.

Space Segment Description

Each of the proposed 3U Nano-satellites will have a structural look, functional composition and system architecture as depicted in Figures 3 and 4. They can be considered representative figures for a typical CUBESAT.[4]

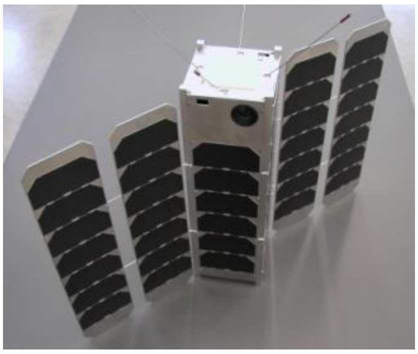

Figure-3: 3U CUBESAT with telescope

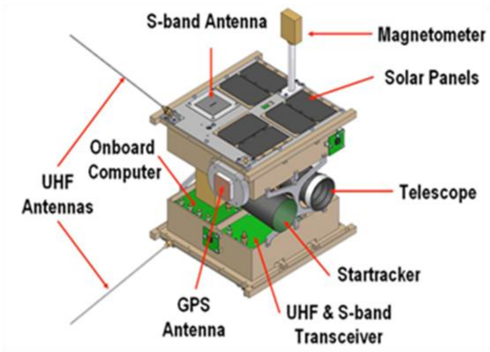

Figure-4: Internal Components of a CUBESAT

The main subsystems and components of the proposed 3U nano satellites together with their weight, power and link budget are given in the Table-1. The mass, power and link budget figures are very rough values based upon the given conceptual design and taken from similar CUBESAT projects. The continuing trend on the miniaturization of electronics will certainly make these figures better and hence allow the placement of more sensors and/ or extend the useful life of the satellite. The more realistic (and optimized) values will be presented within the final paper.

Table-1: Budget calculations

	BUDGET		
COMPONENTS	**Mass (kg)**	**Power(Watt)**	**Link (dBm)**
Structure	2.5	-	To be calculated in the final paper.
Solar Panels (GaAs)	1	+25	
Li-Ion Battery	2.5	-	
EPS	0.5	-0.8	
GPS	0.3	-0.9	
S-Band	0.2	-2.9	
UHF	0.3		
Magnetometer	0.2	-0.2	
Microwheels Sensor	0.4	-0.8	
Mission Computer	0.4	-0.5	
Memory	0.4		
Telescope & STELLA Startracker	0.4	-1.9	
Langmuir Probe	0.5	-1.5	
VLF Module	0.4	-0.5	
TOTAL	**10kg avg.**	**+15W avg.**	

4 Krishnamurty Narayanan, "Dynamic Modeling of Cubesat Project MOVE", MSc. Thesis, August 2008. Technical University of Munich.

Orbit/Constellation Description

A constellation of Nano satellites composed of 3x3U CUBESATs will be operating on a sun-synchronous LEO orbit. Their useful life time will be minimum 2 years and additional satellites could be launched piggy backed to ensure the continuation of the mission.

They will be placed apart to maximize the coverage of near-earth space and their orbit altitude would typically be 660km. Using 3 satellites leaves no dead zone in terms of coverage of the sky but a more detailed analysis and simulation study should be performed for the final version of this project proposal as to take into account the effect of direct look towards the Sun, search speed capacity of the optical sensor etc.

If it is required to change the mission to cover the surveillance requirements of a specific space asset like a large communication satellite, then the Nano-SOS constellation could be located on a suitable geo-synchronous orbit.

Implementation Plan

It is estimated that Nano-SOS Project could be realized within 24 months period under a 3-stage project management plan and with a budget of 5 million USD that includes all kind of life cycle costs but excludes the launch cost.

We are ready for any kind of collaboration with the foreign universities and academic institutions like the ones from Japan and Germany. Meanwhile we plan to implement the project in co-operation with the Istanbul Technical University that has extensive experience on the nano satellites. We shall get their support in terms of man-power, space laboratory and satellite test facilities usage. We also plan to get the support of Professor Hakan KAYAL of University of Wurzburg in Germany (MICROWHEEL, STELLA sensors and HISPICO communication suit), TUBITAK Space Institute (Laboratory and test facilities usage, Langmuir Probe, development of image & data processing hardware and software) and Professor Umran INAN of Koc University of Istanbul (VLF receiver).

It is also envisioned that some local defense and space related companies and institutions will provide their support to this project without any hesitation whenever needed.

As the useful life of nano satellites is about 2 years, subsequent launches for the new set of Nano-SOS satellites could be piggy backed for the continuation of the mission as required.

The top-level schedule for the project could be given as follows:

System/ Subsystem Spec. development	Preliminary Design	Critical Design	Development	Integration	Subsystem/ System Testing	Launch	Operation
SRR (t+3months)	PDR (t+6m)	CDR(t+10m)	TRR (t+20m)		FCA/PCA (t+22m)	LRR(t+ 24m)	PMR

SRR:Spec. Req. Review, PDR: Preliminary Design Review, CDR: Critical Design Review, TRR: Test Readiness Review, FCA/PCA: Functional/ Physical Config. Audit, LRR: Launch Readiness Review PMR: Program Management Review.

The major risks towards the Nano-SOS project are;

i. Obtaining the Electro-optical sensor (telescope) that is powerful enough for determining very small space debris from such distances and small enough to fit into a nano satellite,

ii. Detection of moving objects requires heavy image processing on board, which may be demanding from the performance and power point of view for the nano satellites.

iii. Autonomous detection of new objects is possible if orbit determination can be performed for detected objects. With the proposed system, this requires a robust inter-satellite link due to the triangulation method, which must be developed.

iv. Correlation of detected objects may also be demanding regarding the computation performance requirements, thus again increasing the power demand, which is limited because of the nano satellite constraint.

References

1. http://www.en.wikipedia.org/wiki/space_debris(Date of access: 15 December 2010)
2. http://www.esa.int/SPECIALS/SSA/SEMFSG6EJLF_0_iv.html (Date of access: 17 December 2010).
3. Kayal, Hakan, "A Nano Satellite Constellation for Detection of Objects in Earth Orbit", 4th International Conference on Recent Advances in Space Technologies (RAST), June, 2009, Istanbul, Turkey.
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