UVSat and other Polish satellite missions

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We briefly present the concepts of the several space missions in which Polish teams participate, with special attention devoted to UVSat – a new space telescope that will be fully designed and manufactured in Poland.

1 Introduction

In this preliminary overview, we selected the basic satellite missions in which Polish teams participate. The idea of the selection is to show the natural continuation from the the most current projects (already signed and covered by contracts) to the proposal of the Polish National Science Satellite – UVSat. So, the selection starts from the CaSSIS, ASIM, MERTIS and STIX, international missions for which power, optoelectronics and processing units are already delivered, goes through AIS-Sat and HyperSat, the examples of on-going contracts for Polish small satellite platforms, and ends on the discussion on the UVSat, based on the Feasibility Study already finished for this mission.

2 ExoMars

The 2016 ExoMars Trace Gas Orbiter (TGO) is the first in a series of Mars missions to be undertaken jointly by the two space agencies, European Space Agency (ESA) and Roscosmos. A key goal of this mission is to gain a better understanding of methane and other atmospheric gases that are present in small concentrations (less than 1% of the atmosphere) but nevertheless could be evidence for possible biological or geological activities. One of the instruments of TGO is Colour and Stereo Surface Imaging System (CaSSIS), which is a high resolution camera (5 metres per pixel) capable of obtaining colour and stereo images over a wide swath. CaSSIS will provide the geological and dynamical context for sources or sinks of trace gases detected by two other instruments: NOMAD and ACS. Space Research Center Polish Academy of Sciences (SRC PAS) is responsible for delivery of CaSSIS Power Supply Unit.

3 BepiColombo

BepiColombo is ESA's mission to Mercury. Among the terrestrial planets, Mercury plays a special role. It is the smallest planet, the densest, the one with the probably oldest surface heavily gardened by space weathering, and shows large daily surface temperature variations. Knowing Mercury is crucial to develop better understanding of the early processes in the inner solar system, how our Earth formed, how it evolved, and how it interacts with the Sun. SRC PAS is involved in development of the Mercury Radiometer and Thermal Infrared Spectrometer (MPO-MERTIS).

The scientific goal of MERTIS is to provide detailed information about the mineralogical composition of Mercury's surface layer by measuring the spectral emission in the range of $7 - 14\,\mu$m with a high spatial and spectral resolution. The general instrument architecture comprises two separate parts – the Sensor Head including optics, detector and proximity electronics and the Electronics Unit containing sensor control and driving electronics as well as power supply. This highly integrated measurement system is completed by a pointing device which orients the optical path to the planet and the calibration targets. The SRC PAS is responsible for designing and manufacturing of the electro-optical subsystem called: MPO-Pointing Unit, which is a part of the spectrometer.

4 Mission for the International Space Station – ISS

The Atmosphere-Space Interactions Monitor (ASIM) aboard ISS is proposed for studying the high-altitude, thunderstorm-related optical emission from the stratosphere and mesosphere (Crosby et al., 2009). One of the two main instruments of ASIM is the Miniature-X and Gamma-ray Sensor (MXGS) designed by the University of Bergen and University of Valencia in cooperation with SRC PAS in Warsaw. The SRC PAS is responsible for designing and manufacturing the Power Supply Unit and its autonomous Housekeeping System.

5 Solar Orbiter – SOLO

The Solar Orbiter (SOLO) will be launched by ESA in 2018 to perform observations of the Sun, the inner heliosphere and the solar wind (Skup et al., 2012; Meuris et al., 2012; Krucker et al., 2016). SOLO will fly towards the Sun and will approach the star closer than any other previously launched spacecraft. One of the SOLO instruments is an X-ray spectrometer which is going to provide imaging spectroscopy of solar X-ray emission in a wide energy range. The Spectrometer Telescope for Imaging X rays (STIX) provides imaging spectroscopy of solar thermal and non-thermal X-ray emissions from 4 to 150 keV, with unprecedented sensitivity and spatial and spectral resolution. STIX plays an important role in enabling Solar Orbiter to achieve two of its major science goals: 1) determining the magnetic connection of Solar Orbiter back to the Sun and 2) understanding the acceleration of electrons at the Sun and their transport into interplanetary space. The remote-sensing X-ray measurements made with STIX will determine the intensity, spectrum, timing, and location of accelerated electrons near the Sun. Flare-accelerated electrons escaping the Sun can then be tracked into the inner heliosphere through their type-III radio emission, observed and detected to provide direct tracing of the magnetic structure, field line length, and connectivity. The Polish team from the SRC PAS is involved in the development of STIX electronics: IDPU (Instrument Data Processing Unit) and Aspect System, thermal modeling and EGSE (Electronic Ground Support Equipment).

6 The Automatic Identification System – SAT-AIS-PL

The main objective of the SAT-AIS-PL Polish mission is the detection of Automatic Identification System (AIS) messages generated by vessels and providing this data to a data centre localized in Poland (Walczak et al., 2015). Having its origins in late

90's, AIS system has been designed de facto as a navigation aid. Nowadays, it is becoming one of the basic tools for ship traffic monitoring and e-navigation, while still providing the navigational information to the ship Master. Continuous evolution of the AIS widely described in available scientific materials and ITU's (International Telecommunication Union) documents led to increase situational awareness on open waters. AIS provides a continuous, automatic and autonomous information exchange in both relations: ship-to-ship as well as ship-to-shore. It is expected that SAT-AIS-PL satellite will be equipped with a new standard VDES (VHF Data Exchange System) which is currently under the standard preparation process coordinated by ITU. VDES is a future version of AIS which does not suffer from messages' collisions. Moreover, VDES actively includes space component in its frame, considering satellites ready for VDES as an important part of the standard. In a frame of SAT-AIS-PL Pre-Feasibility Study, it has been identified that Polish governmental authorities are interested in obtaining, archiving and using of data related to vessels traffic and routes. According to that, AIS data as also other data related to detection, positioning and identification of maritime traffic members is in a scope of interested of proposed satellite payload.

7 HyperSat – new open source microsatellite platform

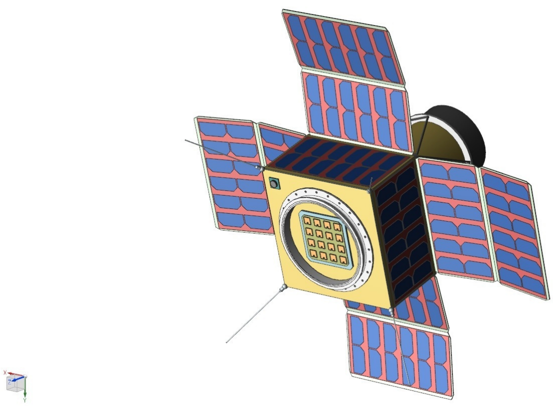

Fig. 1: Illustration of the HyperSat – new open source microsatellite platform.

HyperSat is a universal satellite bus designed for space missions realized in short time and at a low cost. It can support missions of a single satellite or constellations of spacecraft. The bus comprises exchangeable modules which offer different functionalities. The smallest bus configuration measures $30 \times 30 \times 10$ cm^3 and has the mass of 10 kg. It can be extended to reach $30 \times 30 \times 60$ cm^3 and the mass of 60 kg by adding additional modules or instruments. Currently, the HyperSat bus prototype is being developed as illustrated in Fig. 1. Electronics design will cover all subsystems, among them power, on-board computer and communications. Major advantages of a new bus will be provided by its modularity and repeatability. Customers will be able to configure the satellite using readily available modules. HyperSat is defined similarly as a smaller CubeSat ($10 \times 10 \times 10$ cm^3, 1 kg), but will be able to carry bigger instruments, so its usefulness will be obvious. The bus will be compatible with majority of devices designed for CubeSats. That will make a significant number of components available to potential customers. A standard separation system and known bus dimensions will ease launch logistics and help in securing faster delivery times to orbit. The HyperSat bus is being developed as an open system: a description of its structure and drawings, as well as electronics schematics like HyperSat Data Bus will be available under open license. The Hyper Bus Development project will be carried out by Creotech Instruments S.A. together with partners like SRC PAS and Warsaw University of Technology.

8 Polish Ultraviolet Satellite - UVSat

Ultraviolet (UV) is the spectral range in which hot objects emit most of their energy. This spectral region is therefore crucial for understanding young and massive objects like OB stars, Wolf-Rayet stars or Luminous Blue Variables, but also for objects at the final stages of their stellar evolution (white dwarfs, hot subdwarfs). Many non-stellar objects, like active galactic nuclei (AGN), including quasars and blazars, also emit a significant fraction of their energy in UV. The present-day possibilities of carrying out UV observations are confined to several UV space missions or dedicated experiments onboard X-ray satellites. These are: Swift with its 30 cm UVOT telescope, Optical Monitor aboard XMM- Newton, GALEX with 50 cm Ritchey-Chretien telescope (Siegmund et al., 2004; Morrissey et al., 2007) and ASTROSAT mission carrying twin 37.5 cm UVIT telescopes (Kumar et al., 2012). Several instruments onboard HST (System Desing Report, 1976) have also the capability of doing UV spectroscopy and photometry. The proposed UVSat mission will have the added advantage of being able to do simultaneous spectroscopy and photometric imaging with high time resolution, a capability which hitherto has not been exploited very much (Studium wykonalności, 2016; Pigulski et al., 2017). It is this potential which makes UVSat particularly interesting, as well as exploiting new technologies which will make such a mission more effective and put on a more compact platform than previous UV space observatories. In all cases, UV spectroscopy simultaneous with photometry greatly increases the scientific yield. None of the working or planned for the next decade UV missions has a similar ability. With the UVSat, we will therefore fill an important observational niche in the study of the variability of hot objects. It can be also complementary to the other large planned UV mission like UVMag/Arago (Neiner, 2015) or WSO-UV (Boyarchuk et al., 2016).

However, existing UV spectroscopic instruments in space (e.g. HST, ASTROSAT) have a limited amount of life left, at most a few years, and ARAGO will not fly before 2030 at the earliest. Therefore, there is a great need for some UV spectroscopic capability in the 2020's, at the time when vast numbers of objects needing UV spectroscopy will be discovered by new ground-based systems such as well as space-based wide-field systems. The basic technical concept of the wide-field long-term high-cadence UV photometry was discussed and presented by (Pigulski et al., 2017). We would like to present the concept of simultaneous photometry and spectroscopy mission from space namely UVSat. UVSat offers the possibility of a unique capability: being able to simultaneously perform UV photometry over the wide field $10 \times 10\,\mathrm{deg}^2$, visible light photometry over a smaller field, $0.5 \times 0.5\,\mathrm{deg}^2$, and FUV or NUV, high resolution or low resolution spectroscopy of the star in the centre of

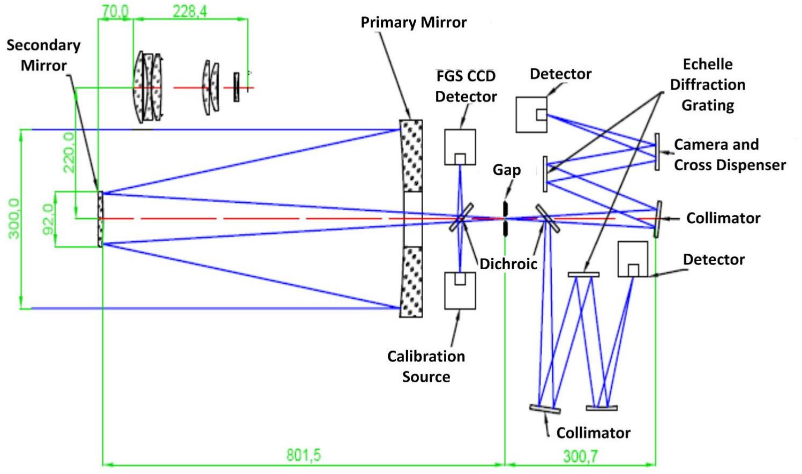

Fig. 2: Generic simultaneous spectroscopic and photometric scheme of UVSat optics.

the field.

8.1 Telescope Aperture and Optics

While the size of UV-Sat will not be great, experience has shown that space-based instruments of even modest size can contribute vital science. The example of IUE for spectroscopy (aperture 45 cm) and for photometry CoRoT (27 cm), GALEX (50 cm) and MOST (15 cm) are most applicable. For the baseline UVSat concept, we chose an aperture of 30 cm for the spectroscopic telescope and an appropriate aperture of $3-10$ cm for the photometric telescope.

A standard two-mirror reflector providing a 0.5 deg field of view (or larger if possible) would be best (e.g. Ritchey-Chretien, but this will be studied further). Fig. 2 shows the baseline design scheme for simultaneously photometry and spectroscopy optics.

8.2 Technical details

The basic concept of the UVSat photometric mode can be defined as follows:

- The satellite will host two refracting telescopes, one with optics designed to wide-band UV observations ($200-300$ nm), the other, for observations in the visual band ($500-600$ nm).
- The field of view of both telescopes will be the same and of the order of $10\times 10\,\mathrm{deg}^2$.
- The observations will be carried out in selected fields and will last one to six months. In each field, a sample of a few hundred objects will be monitored with a cadence of the order of a few seconds or longer.

The basic concept of the UVSat spectroscopic mode can be defined as follows:

- We assume a slit width corresponding to $1.0''$ on the sky, therefore, the spacecraft will need to guide within $1''$ or better to keep the star image on the slit.
- The choice of wavelength regions to study: FUV: 115 – 160 or 200 nm , and NUV: 160 or 200 – 320 nm.
- The high resolution side would be satisfied at resolution $R \sim 30,000$, corresponding to a velocity width of 10 $\mathrm{km\,s^{-1}}$, although some interest has been expressed in going as high as $R \sim 60,000$ (5 $\mathrm{km\,s^{-1}}$) for cometary studies. This means that an Echelle configuration is needed.

The UVSat project will be carried out by NCAC PAS (Nicolaus Copernicu Astronomical Centreof the Polish Academy of Science) together with partners like SRC PAS, Creotech Instruments S.A., University of Toronto and Astronomical Institute of the Wrocław University.

Acknowledgements. The scientific and technical rationale for HyperSat and UVSat was prepared as a part of feasibility study funded by the Polish Space Agency (POLSA) and The National Center for Research and Development (NCBiR)

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