Aalto–1 Remote Sensing Campaign

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Abstract

This paper describes the planned Aalto-1 remote sensing campaign. Additionally the satellite itself, its systems and payloads are briefly discussed as is the main payload, the AaSI (Aalto Spectral Imager). Current plans for the mission phases are discussed as well as technical demonstrations under consideration.

1 Introduction – Aalto–1 Nanosatellite Technical Details

Aalto-1 is a student nanosatellite with three novel payloads that aim for tests proving their capabilities in an actual space application. The three payloads are a spectral imager AaSI by VTT, a radiation monitor RADMON by Universities of Helsinki and Turku, and a plasma brake tether by the Finnish Meteorological Institute. This work will concentrate on the output of the AaSI spectral imager.

By design the satellite conforms to 3U CubeSat specifications [1], see Figure 1. The satellite has a mass of 4 kg, and external dimensions of 10 x 10 x 34 cm. The mechanical structure of the satellite consists of two subsystem PCB fastener stacks. The outer frame itself consists of several separate aluminium parts, both 1.5 mm thick, fastened together into one tubelike structure.

Fig.1: The satellite’s external dimensions are 10 x 10 x 34 cm (The position of a star tracker employed by the onboard ADCS is at the center of the – Y - side alongside the smaller GPS antenna, represented here by the bigger and smaller holes; the viewing holes for the AaSI spectral imager are on the right side of +X - side, while the electron guns are at the left side of the +X - side). The satellite’s velocity vector will be parallel to its –Y direction.

The satellite orbit is not yet finalized, as a contract with the launcher has not been signed. The ideal orbit is a sun-synchronous “midday-midnight” orbit, with an orbit altitude of 500 – 900 km, and is designed to have the possibility of a 10:30 - 13:30 o’clock variation.

The satellite will have three radio channels, of which UHF/UHF will be used for up/downlinking telemetry, tracking and commands, and S-band will be only a one-way link.
transmitter down to the ground segment. Depending on the orbit altitude, the S-band will be able to downlink 29 to 49 Mbytes per 24 hours, while UHF/UHF can up- and downlink 0.28 to 0.48 Mbytes per 24 hours (downlink 9600 bps), and can work as a limited backup for the S-band.

The satellite will have an attitude dynamics and control system (ADCS), designed and built by an external manufacturer Berlin Space Technologies. The iADCS-100 is a semi-autonomous ADCS, that will have attitude knowledge and pointing accuracy of less than a degree during AaSI imaging and less than 10 degrees during the operation of the plasma brake, with several operation modes for the entirety of the mission, and only rough positional information required. Target tracking, which is planned to be used in this mission, is also available. For gathering positional knowledge, an IT03 GPS receiver by Fastrax will be employed primarily, with a backup of radio positioning using ranging and Doppler distortion, as well as NORAD (North American Aerospace Defence Command) supplied TLEs (Two-Line Element). The GPS will be operated relatively rarely, and will be operational either just before the spectral imager takes an image, and later during the plasma brake experiment, once per orbit.

2 AaSI Payload Description

AaSI (Aalto Spectral Imager) is a Piezo-actuated, tunable Fabry-Perot interferometer (PFPI). It is able to record 2D spatial images at one to three wavelengths simultaneously. The interferometer consists of two highly reflecting surfaces separated by an air gap. Simultaneous multiple channel data collection is enabled by matching the multiple orders of the FPI transmission function with the sensitivities of a CMOS (Complementary metal-oxide-semiconductor) colour image sensor. Highly miniaturized, AaSI's mass is currently 682 g with a size of 97mm x 95 mm x 48.3 mm. The FOV (field of view) is 10 deg x 10 deg, instantaneous FOV being 0.02 deg (0.34 mrad). The sensor has a 2048x2048 pixel image size; however, only part of the sensor is used due to limitations in optics and the delivered spectral image size is 512x512. The wavelength range is 500-900 nm. Spectral resolution is 10-30 nm. In addition to the spectral imager, AaSI also houses a visual camera. Its design is based on the same image sensor, and it shares the mechanical housing and interface electronics with the AaSI [7].

3 Aalto-1 Technological Demonstration and Subsequent Science Phase

Once the satellite is deployed out of its CubeSat - deployer, it will remain in the same orbit throughout the first part of its science mission. During the latter part however, as the plasma brake experiment is active, its orbit altitude and other parameters as well will change thanks to the drag force caused by the tether.

Before starting the science phase in which the payloads will perform their targeted science observations, the satellite will go through the commissioning phase. During this phase, the satellite will be first booted up, contact made with the ground segment and pointed correctly towards nadir. After this has been achieved, the AaSI spectral image technology operation will be demonstrated by taking 6 minimum quality spectral images and one VIS-camera image, as well as operating the RADMON within the South Atlantic Anomaly (SAA) for altogether three days.

Once the technology demonstration goals have been met and in general the commissioning phase has gone according to plan, the science phase can begin, various selected and possible targets of which will be introduced in chapter 4. This phase is divided into two particular phases, the first of which will consist of science observations performed with the spectral image and the RADMON, and the latter for operating the plasma brake. This division of the science phase is due to the drastically different attitude, data rate and power requirements of the different payloads. The first phase, consisting science observations will last 6 – 12 months, depending on the satellite and payloads performance.
While performing the first part of the science phase, the satellite will assume either a nadir pointing or target tracking attitude, and operate both the spectral imager and the RADMON. The downlinking is the bottleneck for the science phase operations, as both the spectral imager as well as the RADMON during this time will rely exclusively on the S-band downlink for transferring their collected data to the ground segment, which in turn is limited by ground segment visibility time and power considerations. A preliminary estimate gives 29 - 49 Mbytes per 24 hours for the S-band for an orbit altitude of 500 – 900 km.

An average image size expected to be taken by the spectral imager is estimated to be around 8 Mbytes (512 x 512 pixels with 15 channels and 16 bits), which is for a minimum of 6 months science observations phase means being able to downlink around 623 – 1084 average images, depending again on the satellite orbit altitude. Thus the spectral imager will take images several times per 24 hours [2].

4 Various Science Phase Scenarios Using AaSI

Once the AaSI technology demonstration is complete the satellite can be used to perform different remote sensing studies which are yet to be determined. There are several possibilities to test the capabilities of the satellite and AaSI and it would be interesting to compare the results to those of existing remote sensing satellites and instruments. In this chapter we present four potential studies that have been discussed. Other possible deliverables include for example water quality and vegetation indices [3].

4.1 Forest biomass measurement in Finland

Remote sensing satellites are used to study amount of vegetation biomass. For example Muukkonen and Heiskanen have studied the remote sensing of forest biomass in Finland with data from instruments Advanced Spaceborne Thermal Emission and Reflection Radiometer (Aster) [5] and Moderate Resolution Imaging Spectroradiometer (MODIS) [6]. Aster has spatial resolution of 15 m and MODIS 250 m [6] and the latter is comparable to the expected resolution of AaSI [3].

A similar study could be conducted with AaSI by developing an empirical model to correlate measured reflectance spectra to forest biomass, but reference data is required. Finnish Forest Research Institute (Metla) has recently published wide forest inventory data which includes forest biomass [4]. This might serve as ground truth data, but further investigation is required.

4.2 Tree species recognition in Finland

Spectral information could theoretically be used to to determine the dominant tree species if the reflectance spectrum of each tree species differs sufficiently from the others. The purpose would be to create a map of dominant tree species from one spectral image using an empirical model. The Finnish Forest Research Institute forest inventory data could again serve as a reference. This data does not contain information of dominant tree species but it may be possible to derive it from other statistics [3]. However, more investigation is needed to determine if this study would be feasible.

4.3 Algae recognition

Satellite remote sensing of algae bloom in the Baltic Sea is an interesting topic and Aalto-1 might be able to attempt it using AaSI. Vahtmäe et. al. have studied the feasibility of hyperspectral remote sensing in algae detection, and AaSI specifications might be enough for a technical demonstration type of mission. Reference material for these measurements should be easily available. Current estimates of the Aalto-1 date launch also give the satellite a good timing for algae measurements [8].
4.4. Stereoscopic hyperspectral imaging

Another mission phase under consideration is stereoscopic imaging. This would allow AaSI to create DEM (Digital Elevation Model) of wanted targets. This would most likely target very large targets, such as the Himalayas, since accuracy will most likely not allow smaller targets. This would still serve as an interesting technical demonstration. Preliminary tests have shown that AaSI specifications will be sufficient to allow some kind of elevation measurements [3].

5 Conclusions

The most important objective of Aalto-1 remote sensing campaign is technology demonstration of RADMON and AaSI instruments and to verify their operation in space. When this primary goal is accomplished there is 6 - 12 month time period to conduct various remote sensing experiments with AaSI before the plasma brake mission begins. Remote sensing of forest biomass, tree species recognition, algae detection, stereoscopic hyperspectral imaging and spectral images for water and vegetation indices have been discussed. Further investigation is required to determine what studies would be feasible. It would be interesting to compare the remote sensing performance of a student - built nanosatellite to ongoing earth observation missions.

References