PRISMA – FORMATION FLYING PROJECT CLOSE TO LAUNCH

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ABSTRACT

The PRISMA project is a technical demonstration mission for formation flying and rendezvous in space. The mission can be considered as an in-obit test-bed where different experiments involving Guidance, Navigation and Control (GNC) algorithms, sensors and actuators can be tested. The project is also a demonstration mission for two novel propulsion technologies. The project consists of two satellites, of which one is manoeuvring relative to the other, using different sensors and algorithms.

The project is run by Swedish Space Corporation (SSC) with important contributions from the German Aerospace Center (DLR), the French Space Agency (CNES) and the Technical University of Denmark (DTU). The project started in beginning of 2005. The satellites are now basically on the launch pad, scheduled for launch on June 15, 2010 from the Russian site Yasny.

The ground segment, consisting of a Mission and Operations Control Centre in Solna, Sweden, has been established and is ready for launch.

1. BACKGROUND

Formation flying, i.e. two or several satellites in a closed loop position/velocity control solving one common task and operated as one entity, is a hot candidate for solving future mission tasks such as building large antennas or telescopes of for coordinate measurements of other kinds. However, very few projects have passed the study phase.

Another area involving several satellites is Rendezvous. Typical applications may be in orbit servicing, inspection and assembly, where autonomous vehicles must be able to operate in close vicinity of another spacecraft.

In early 2005, SSC formulated a mission concept, consisting of two satellites and a series of experiments in order to demonstrate formation flying and rendezvous technology in a real space mission. The mission concept attracted DLR to contribute with GPS sensors and a navigation system, Alcatel (later replaced by CNES) to join with the Formation Flying RF sensor (FFRF) under development, and DTU to contribute with a development of the DTU star camera technology into a Vision Based Sensor (VBS).

Together with the SSC and Swedish National Space Board's (SNSB) ambition to test in flight two new motor technologies developed in Sweden, PRISMA was established as a test bed with two satellites, demonstrating GNC technology and sensor/motor technology, but also to gain experience in operating multi-satellite systems under real conditions.

2. OBJECTIVES

2.1 Primary objectives

The primary objective of PRISMA is to develop and demonstrate in space GNC algorithms and sensor technology in the field of Formation Flying and Rendezvous technique. This shall be done by a series of experiments divided in GNC experiments and sensor/actuator experiments.

An important focus is to demonstrate onboard autonomy.

The GNC experiment sets consist of open loop and closed loop orbit control experiments conducted by SSC, DLR and CNES as in the following table:

Table 1

GNC Experiment Sets	
Passive formation flying	
Autonomous formation flying (AFF)	SSC
Autonomous formation control (AFC)	DLR
RF-based formation flying	CNES
Forced motion	
Proximity Operations (PROX) Final Approach and Recede (FARM)	SSC
Forced RF-based Motion Collision Avoidance	CNES
Autonomous Rendezvous (ARV)	SSC

The different GNC experiment sets are divided into two classes: Passive Formation Flying and Forced Motion. Passive Formation Flying makes use of the orbit period to obtain a relative motion that only needs a maintaining orbit control. Forced Motion concerns formation flying in a more arbitrary relative trajectory.

The GNC experiments are further described in [4], [5], [6] and [10]

Related to these GNC tests, hardware related tests will be conducted according to the following:

Table 2

Hardware Related Tests	
HPGP Motor Tests	SSC/ECAPS
Microthruster Motor Tests	SSC/Nanospace
Vision Based Sensor (VBS)	DTU
RF Sensor Test	CNES

The HPGP motor is a development by the Swedish company ECAPS, who has developed a motor with similar or better performance than hydrazine, but with a non-toxic, environmentally friendly fuel based on ADN. (See further [2]).
The Microthruster system [3] is a development by Swedish company Nanospace. It is heated cold-gas system partly in MEMS technology, capable of producing variable low-noise thrust from 0 to 2 mN.
The VBS sensor [9] is developed by DTU. The purpose is to create a rendezvous sensor based on star camera technique only, capable of e.g deliver pose and range information (within 80 m) both to a cooperative and non-cooperative target. The sensor will be utilized in the SSC experiments described in [6, 10].
The FFRF instrument [5] is a RF-based navigation instrument development by Thales Alenia Space and CNES, aiming to be a cornerstone instrument on several future CNES and ESA formation flying missions. PRISMA will be their first flight for the new instrument.

2.2 Secondary Objectives

In addition to the primary objectives, the mission has the following secondary objectives:

- Provide test flight for newly developed system unit and power control unit with battery management electronics (SSC).
- Act as model project for new model based development of on-board software (SSC).
- Demonstrate Autonomous Orbit Keeping of a single spacecraft (DLR).
- Demonstrate a newly developed Ground Support and Operational Support Equipment for multi-vehicle missions, the RAMSES system [7] (SSC).
- Provide a test flight for a Digital Video System developed by Techno System in Italy.

- Provide a test flight for a MEMS-based particle sensor from the Institute of Space Physics in Kiruna, Sweden.

3. MISSION OVERVIEW

3.1 The satellites

The PRISMA mission consists of two satellites: MAIN and TARGET. The MAIN satellite is 3-axis stabilized and has full 3D delta-V manoeuvrability independent of the spacecraft's attitude. A hydrazine propulsion system with 6 thrusters is implemented on MAIN and has approximately 120 m/s delta-V capability. The central body of MAIN has exterior dimensions 750×750×820 mm. When deployed, the distance between the tips of the solar panels is 2600 mm.
The TARGET satellite has a simplified, yet 3-axis stabilizing, magnetic attitude control system and no orbit manoeuvre capability. The TARGET body is 570×740×295 mm.
The wet mass of the two spacecraft is 195 kg. MAIN is 145 kg and TARGET is 40 kg.
Figure 1 shows an impression of the two PRISMA spacecraft close to each other in orbit.

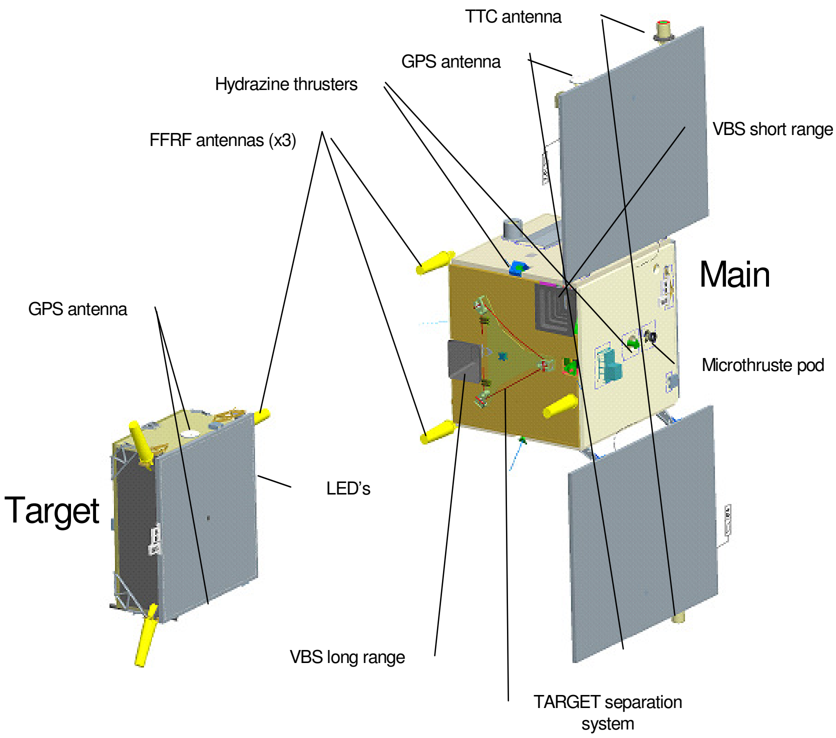

Fig 1: Main and Target layout in flight configuration

PRISMA will be launched into a sun synchronous orbit with 725 km altitude and 0600h ascending node, i.e. in a dawn-dusk orbit. The MAIN and TARGET spacecraft are launched clamped together as depicted in Figure 2. TARGET is separated from MAIN, after an initial commissioning campaign during which all on-board equipment is checked out. The separation of TARGET is observed with MAIN's on-board Digital Video System (DVS).

During the whole mission, ground only communicates with MAIN. The TM rate is approximately 1 Mbps. Main in turn communicates with TARGET via an intersatellite link (ISL) on 400 MHz. The data rate is 19.2 kbps and range at least 10 km.
The mission is planned to last for approximately 320 days, divided into Commissioning, Basic mission, and Extended mission, where the Extended mission contains the least prioritized tasks which are the least painful if they were would not be fulfilled. Figure 3 illustrates the content of the mission parts.

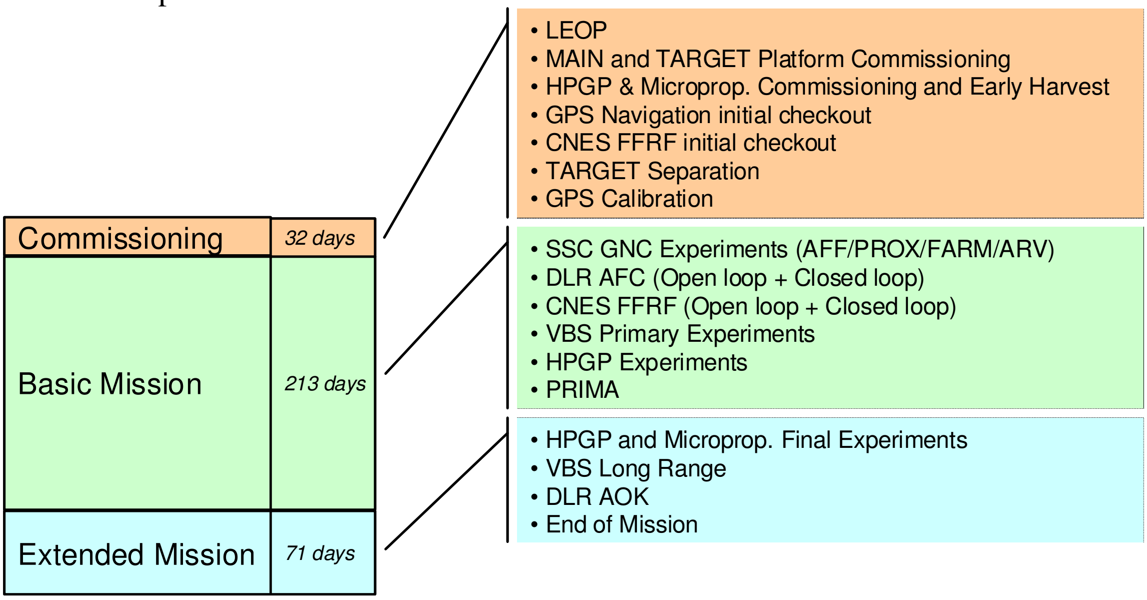

Fig 3: Mission content

The sequence of experiments is planned in increasing order of difficulty, and according to a certain dependency, see figure 4. Each experiment group is divided into an early harvest part and a part that completes the experiment. The different experiment sets will also be ordered in a way that is considered increasing in difficulty or complexity.
The initial experiments consist of passive formation flying checking out the GPS navigation functionality, mainly provided by DLR [4]. These functionalities will be fundamental to the continuation of the mission and to the correct functionality of Safe Orbit Control.
These experiments are followed by DLR's passive formation flying, and a checkout of the VBS, and RF instruments during a campaign of GPS based forced motion.
The most complex functionality is considered to be the VBS autonomous rendezvous [10] during which the far range detection capabilities of the VBS is examined and during which a fully autonomous rendezvous with TARGET is performed down to sub-meter distance.

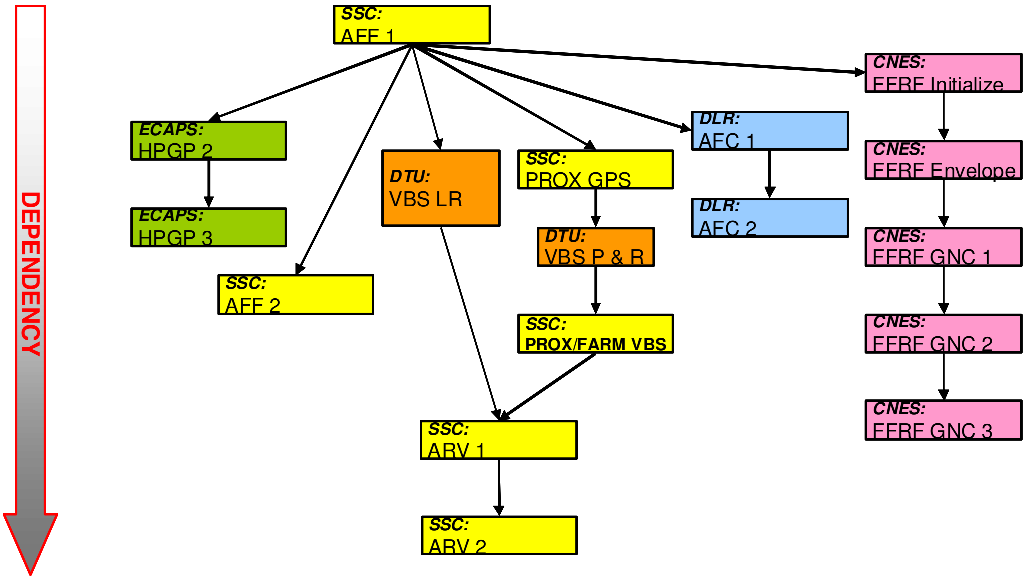

Fig 4: Mission Timeline dependency – Basic Mission

4. LAUNCHER

A cluster launch on a DNEPR launch vehicle was selected at an early stage. This was very much due to the fact that the CNES satellite PICARD (a myriade class scientific mission) requested a similar orbit as PRISMA. In fact the PICARD request on a sun synchronous orbit with Local Time of Ascending Node (LTAN) on 06.00 was ideal since this minimizes the eclipse time and makes S/C design issues simpler.
The DNEPR capacity is >400 kg to SSO 700 km, and is ideal for the PRISMA/PICARD combination of approximately 360 kg.
The launch site will be Yasny, located in the Orenburg region near the Kazakhstan border. The launch company Kosmotras has established a very modern integration facility in Yasny, and utilized military installations and silos for the launch activities. Yasny is chosen to be a more flexible alternative than the heavily exploited base Baikonur in Kazakhstan.

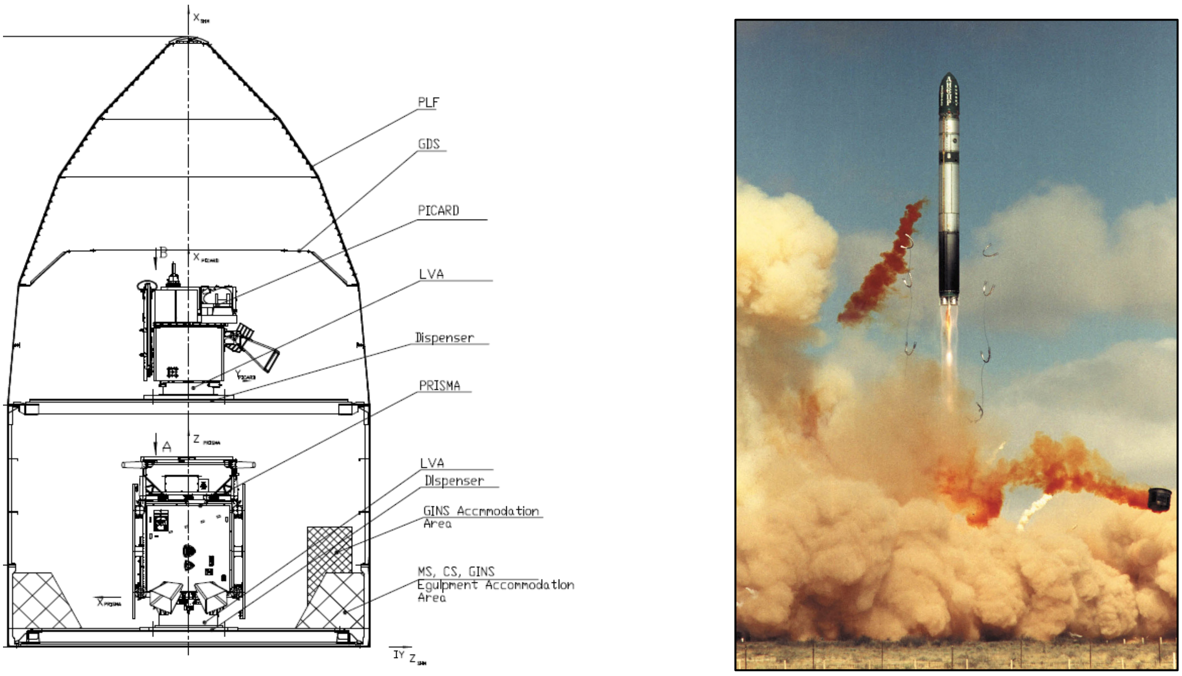

Fig 2: PRISMA and PICARD accommodation in the Dnepr fairing and Dnepr launch (courtecy ISCK Kosmotras)

5. GROUND SEGMENT

The ground segment is implemented by SSC and utilizes both existing parts of the SSC Satellite Operations facilities in Kiruna, as well as introduces the newly developed Check-out and control ground support equipment RAMSES [7]. The elements are the following (see figure 3.)

- Operations Control Centre (OCC) located at SSC Solna or at the SSC Esrange satellite control centre in Kiruna. The OCC provides the routine operations and surveillance and executes the TM/TC up/downloads according to MCC instructions. OCC utilises existing antennas and infrastructure, but has been completed with a RAMSES installation
- Mission Control Centre (MCC) located in Solna, Stockholm. The MCC contains the Mission manager and the engineering and analysis power. MCC prepares the operations, generates and validates (via a simulator environment) the flight procedures and analyses generic platform performance flight data.
- Experiment Control Centres (ECC), one for each experimenter group. These can be located at SSC, but may also work remotely via internet. The ECCs prepare experiment scenario procedures (for MCC to validate) and analyses experiment data.
- A data archive (not depicted on the figure). All flight data (raw as well as processed data) will be located on the internet accessible for all experimenters.

A more thorough walkthrough of most of the SSC mission control concept can be found in [12].

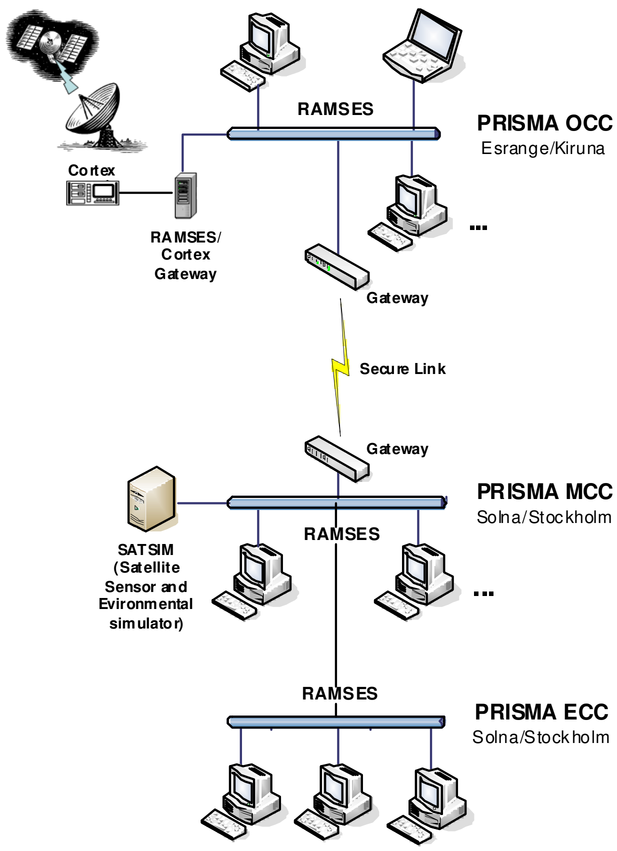

Fig 5: The ground segment components

6. CURRENT STATUS

A Flight Acceptance Review (FAR) was conducted in June 2009. A final closeout of the review could however not be held until November 2009 due to a very late delivery of the flight FFRF instrument. The review concluded the sufficient verification of the satellites and the ground segment. (A deeper insight in the PRISMA verification activities are found in [13].
A series of tests (fit check, separation shock test, vibration test) was performed in December-January in Ukraine at the rocket manufacturer, using the STM model of PRISMA (and PICARD) together with the space Head Module (the upper stage payload compartment of Dnepr). The test demonstrated basic compatibility and integrity to shock and loads.
Since November 2009, the project has been basically ready for launch, only waiting for the final authorizations from Russian and Kazakhstan. Due to the fact that Dnepr launcher drops the 1:st stage on Kazahstan territory, this signature process has taken longer time than expected. However, this problem currently is solved.
The operations personnel has been preparing and improving operational procedures together with experiment groups, and several rehearsals on critical operations have been performed in the Satsim simulator. The rehearsals shall be intensified during the last month before launch.

7. LAUNCH CAMPAIGN

The PRISMA launch starts on May 17, 2010. The campaign is optimized in time and resources in order to have as short campaign as possible. The activities cover 18 days of activities from arrival at the base to the moment when the satellite is mounted on the Dnepr Space head Module (i.e. the nosecone part which subsequently will be mounted on the rocket in the silo). These activities include filling operations of three propulsion systems: pressurization of the cold gas system, and filling of the HPGP and the Hydrazine thruster systems.

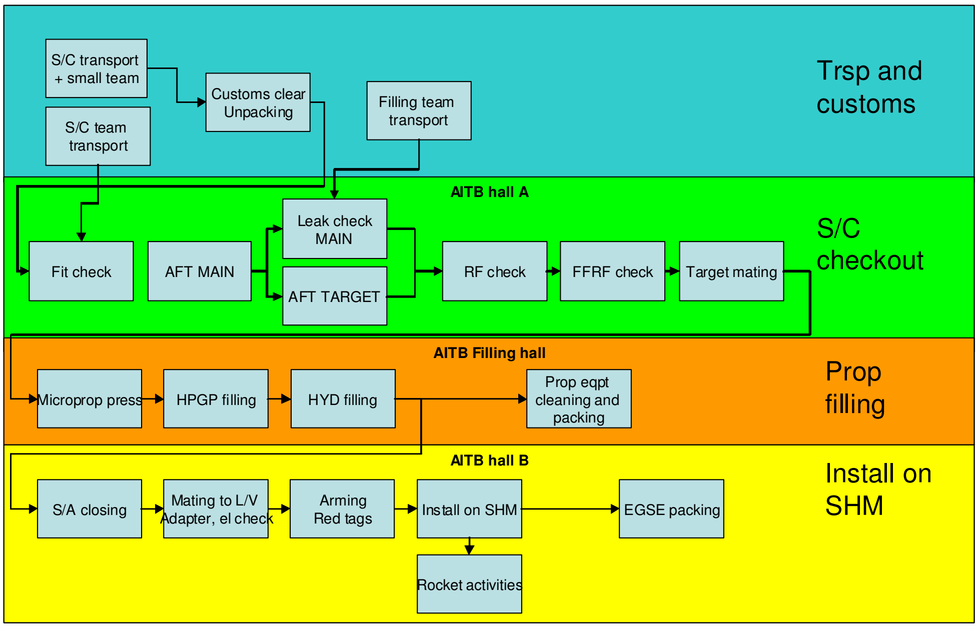

Fig 6: Launch campaign activities

After the attachment of PRISMA on the Space Head Module, PRISMA is completely OFF until separation with no monitoring possibilities except for temperature control.

<u>The nominal launch time is set to: JUNE 15, 14:42:16 UTC</u>

8. CONCLUSION

The PRISMA formation flying and autonomous rendezvous demonstration project is now ready for launch campaign, launch and operations. Both space and ground segment has been validated and and an overwhelming part of the extremely ambitious goals set forth in the project beginning has been validated and has a very good chance of being successfully demonstrated in space.

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