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# Operational Concept of a Picosatellite Release from a LEO Satellite

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This paper addresses the design of an operational Flight Dynamics concept to inject the picosatellite BEESAT4 in low Earth orbit after separation from the small satellite carrier BIROS (Berlin Infrared Optical System). Scheduled for launch in spring 2016 the BIROS satellite (60x80x80 cm) will be operated by the German Aerospace Center (DLR). Its primary task will be the observation of wildfires in the frame of the FireBird mission [1]. In addition, it will host several technology demonstration experiments among which the AVANTI (Autonomous Vision Approach Navigation and Target Identification) experiment. The main goal of the separation strategy is to establish a passively safe formation as initial condition for the formation flying AVANTI experiment.

The AVANTI experiment is intended to demonstrate vision-based noncooperative autonomous rendezvous operations of an active small satellite (BIROS) within separations between 10 km and few hundreds of meters from a picosatellite (10x10x10 cm) making use of angles-only measurements only [2]. The picosatellite is originally carried by BIROS and later on ejected through a Picosatellite Orbit Deployer (POD) after the successful check-out and commissioning of all relevant BIROS subsystems. The AVANTI experiment is intended to start after the BIROS /Picosatellite formation has been brought to an initial safe configuration at about 5 km separation with minimal residual drift in along-track direction. This delicate operational task is solely ground-based and performed by the Flight Dynamics Services (FDS) division of the German Space Operations Center (GSOC), which is in charge of the orbit determination and control of the FireBird mission.

The separation scenario was previously designed and published in [3]. This work formalized the separation requirements and safety constraints in the Relative Orbital Elements [4] framework, with the goal to establish a safe and stable relative orbit based on relative eccentricity/inclination vector separation. As a result, a two maneuver strategy was proposed: the first maneuver was the ejection of the Picosatellite and the second one an orbit correction maneuver performed by the BIROS satellite to stop the drift and establish the relative eccentricity/inclination vector separation. The practicability to accomplish only two maneuvers came at the cost of a delta-v expensive correction of the BIROS orbit.

This scenario is no longer feasible as the satellite integration progressed making re-evaluation necessary for several reasons. First of all, the design of the release mechanism has been set to a delta-v of ~1.5

m/s, while the maximum delta-v of a single orbital maneuver with BIROS propulsion system is fixed to ~0.3 m/s. Hence, it is not possible to compensate the initial relative drift with a single BIROS maneuver and a multi-maneuver strategy has to be planned. As a benefit, this strategy can be optimized to reduce the total delta-v consumption. Furthermore the new operational scenario has to incorporate several external constraints, such as the need to perform the separation during a ground station contact (preferably a polar one). The separation shall as well be filmed by an onboard RGB camera, which requires that the release takes place in an illuminated part of the orbit, but the camera must not be blinded by the sun. Another important constraint is that the camera-based relative orbit determination can only be activated after the start of the AVANTI experiment. Hence an initial orbit determination has to rely on ground based radar tracking. As this is very crucial for the safety and the success of the experiment, the sequence of events has to be planned thoroughly with backup plans in place for a possible missed contact or tracking pass.

This paper presents the development of a realistic operational concept with baseline and backup plans for the ejection of the BEESAT4. It includes an assessment of the accuracy performance of the establishment of the AVANTI initial conditions and leads to the draft of an operational schedule containing all relevant events and actions.

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[2] Gaias G., Ardaens, J.-S., and D'Amico, S. (2014): "The Autonomous Vision Approach Navigation and Target Identification (AVANTI) Experiment: Objectives and Design." 9th International ESA Conference on Guidance, Navigation & Control Systems, Porto, Portugal.

[3] Wermuth, M., Gaias, G., and D'Amico, S. (2014): " Safe Release of a Picosatellite from a Small Satellite Carrier in Low Earth Orbit", Journal of Spacecraft and Rockets, accepted for publication, also 24th AAS/AIAA Space Flight Mechanics Meeting, Santa Fe, USA, AAS14_414.

[4] Gaias, G. and D'Amico, S. (2014): "Impulsive Maneuvers for Formation Reconfiguration using Relative Orbital Elements." Journal of Guidance, Control, and Dynamics, accessed April 22 2014, doi: 10.2514/1.G000189.