Sentinel-1A: Flight Dynamics Analysis of the August 2016 Collision Event

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Sentinel-1A and 1B form a 2-satellite, all-weather, day-and-night, radar monitoring system operated from the European Space Operations Centre (ESOC) in Darmstadt, Germany. Belonging to the Copernicus fleet of satellites, the European Commission's Earth Observation Programme, they provide land and ocean observations through a SAR radar instrument. The monitoring system replaces radar data provided by the now terminated ERS and Envisat Missions.

The satellites follow the same dawn-dusk sun-synchronous reference orbit at about 700 km altitude with a phase difference of 180 deg. The strict Mission orbit control requirements are achieved by the execution of weekly manoeuvres. The manoeuvre implementation process is highly automated. In the Flight Dynamics (FD) system, it involves a manual intervention the day of the command generation (Wednesday) and a manual performance check on the day following the manoeuvre execution (Thursday). During one of these routine checks, on the 25th of August 2016, the FD team noticed a degradation for Sentinel-1A in the quality of the GPS-based orbit determination. The cause was tracked down to an unexpected 'event' in GPS data occurring on the 23rd of August at 17:07 UTC and equivalent to a delta-v of 0.7 mm/s against the flight direction. Further investigation revealed a series of simultaneous features in the AOCS housekeeping telemetry: spikes in attitude rates, unexpected reaction wheels actuation, star tracker freezes, etc. In parallel, on the 25th of August, the Sentinel-1A Flight Control Team announced a drop in the output current of the +Y Solar Array Wing (SAW +Y). A few days later, a picture taken by the on-board camera revealed damage to the solar wing and confirmed the hypothesis of a collision with a space particle. The on-board camera picture is reproduced on Fig. 1a. The satellite attitude at the time of the impact with respect to the Orbital Reference Frame (ORF) is shown on Fig. 1b.

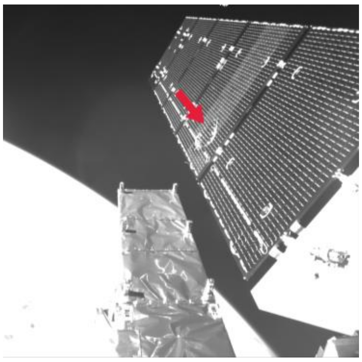

Fig. 1a. Picture of SAW +Y.

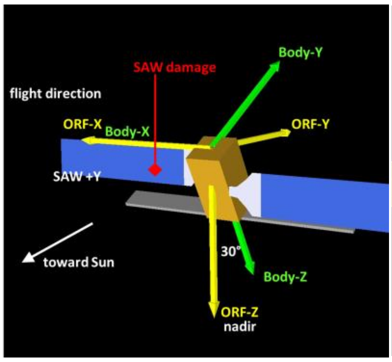

Fig. 1b. Sentinel-1A at the time of the impact.

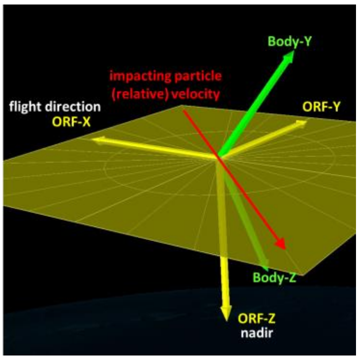

Fig. 2. Estimated impact direction.

This paper summarizes the analysis of the collision event carried out by the FD team. We describe the set of data and methodology used to estimate the linear momentum of the impacting particle and the corresponding uncertainty. We show that the solar wing was hit from its non-illuminated side with the impacting particle coming roughly from 1 to 2 o'clock as seen from the orbital frame (Fig. 2). A least-squares formalism is used to combine the data and uncertainties into an estimate of the momentum. We constrain the particle size from the momentum uncertainty distribution and simple considerations on the particle trajectory (e.g. minimum inertial velocity). Additionally, the paper presents a collection of lessons learned in terms of operational experience, in particular relating to the risk of running semi-automated operations. The operational setup lead to a detection of the collision event 2 days after it occurred. This provides an estimate of the time it might take to react to any minor damage, e.g. a leaky thruster branch, requiring a priori a quick ground response.