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FROM GRACE TO AVANTI: 15 YEARS OF FORMATION-FLYING EXPERIENCE AT DLR

Abstract

In the last decade, the German Space Operations Center (DLR/GSOC) has been building up a unique expertise in the field of spacecraft formation flying. This adventure started with GRACE, a loose formation of spacecraft flying on the same orbit but separated by hundreds of kilometers. This first experience in operating a multi-satellite mission was crowned with a challenging swap episode, during which the order of the spacecraft had to be inverted. During this sequence, the separation between the satellites dropped to a few hundred meters and provided a unique opportunity to develop tools and methods for mitigating the risk of collision (based on the separation of the relative E/I vectors) as well as new software capability for very precise relative navigation using differential GPS. The resulting know-how served as starting point for the design of the TanDEM-X formation flying mission, which required a nominal inter-satellite distance of a few hundred meters and the ability to provide precise GPS-based relative positioning products accurate at the mm level. This formation was much more difficult to operate, since frequent formation control maneuvers were necessary to fulfill the formation control requirements. At the same time, it became obvious that future formation-flying missions would benefit from a larger autonomy to satisfy the increasing control requirements. This triggered the design of the experimental TanDEM-X Autonomous Formation Flying (TAFF) system, which could demonstrate in orbit that such a formation could be more precisely autonomously controlled using GPS, and thus enabling very demanding campaigns such as along-track interferometry for ocean current measurements. At the same epoch, a flight opportunity was given to DLR to contribute to the PRISMA formation. Based on a novel GPS-based navigation system, several experiments from different space agencies demonstrated ultimate relative navigation and control performance in low-Earth orbit up to the centimeter level, closing momentarily the chapter of cooperative formation-flying. In fact, it appeared afterwards also interesting to tackle the problem of rendezvous with non-cooperative targets, in view of future on-orbit servicing or debris removal missions. The latest DLR's formation-flying experiment, called Autonomous Vision Approach Navigation and Target Identification (AVANTI), was designed for this purpose and successfully conducted in autumn 2016. Overall it could demonstrate autonomous orbital rendezvous from 50km to 50m with a non-cooperative target using a single camera. The paper summarizes the key achievements of this formation-flying story, focusing especially on the newest AVANTI results and outlining the possible future research topics.