SAOCOM-CS: Flight Dynamics operational approach to a highly demanding formation

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The concept of a passive receiving small satellite flying in formation with an active satellite for bistatic Synthetic Aperture Radar (SAR) imaging has been the subject of numerous international studies. In 2013, ESA received an offer from the National Commission for Space Activities of Argentina (CONAE) to collaborate with SAOCOM mission (L-band SAR). Following this offer, ESA defined SAOCOM-CS as a passive-receive-only satellite flying in formation with the SAOCOM–1a/-1b satellite and capturing SAOCOM radar echoes reflected from Earth's surface. The combined mission supports multiple science objectives by varying the relative in-orbit positions of SAOCOM-CS satellite with respect to SAOCOM-1a/-1b. These include four specific geometries:

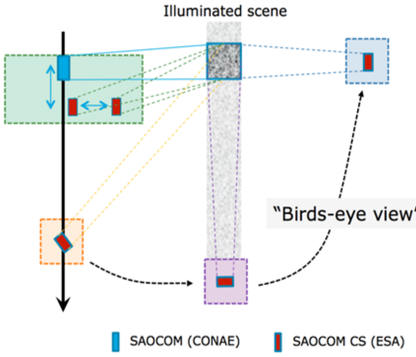

Fig. 1. SAOCOM_CS geometry

1. Tomographic Geometry which is defined by short along-track baselines and variable across-track baselines (Fig. 1 green box).
2. Along-Track Bistatic geometry which is defined by large along-track displacements and small across-track baselines (Fig. 1 orange box).
3. Perpendicular Bistatic geometry with is defined by both large along-track and across-track baselines (Fig.1 purple box).
4. Specular geometry in which the companion satellite views the illuminated scene from the specular direction (Fig. 1blue box). Each of the four geometries results in unique imaging and information extraction capabilities, which relate to different application fields.

The current paper gives an overview of the formation flying design and safety concept of SAOCOM-CS mission. Having two spacecraft in close formation, the key principle of the mission shall be safety. Other important drivers for the mission design are to keep a simple operational concept and to optimize the delta-v while enhancing the scientific return.
The most challenging part of the mission is the tomographic phase. During this phase SAOCOM-CS will fly ahead SAOCOM with an along-track distance between 5km to 7 km. On top of that a changing across-track drift is imposed by the science requirements. The formation needs to be inherently safe, such that if the orbit control of either spacecraft is lost, the uncontrolled evolution of the relative along-track distance should not lead to a major collision risk. Moreover none of the orbit control maintenance manoeuvres during this phase shall pose a major risk. The orbit control strategy of SAOCOM-CS consists not only of small in-plane manoeuvres to maintain the along-track distance, but also of larger semi-major axis corrections to replicate the SAOCOM drag compensation manoeuvres, coordinated collision avoidance manoeuvres and, in order to achieve the across-track drift, out-of-plane manoeuvres that are typically two orders of magnitude larger than the maintenance in-plane manoeuvres. All this minimising the formation break-up duration. Taking into consideration that the two satellites are controlled from two different Mission Control Centres, each located on a different continent, it becomes clear that coordination of operations will play an essential role for the success of the SAOCOM-CS Mission .
The other phases of the Mission are not exempt from challenges, the transition between the different geometries of the mission, including the initial orbit acquisition, shall optimize the delta-v consumption and comply with the timeline and the stringent geometry requirements to fulfil the scientific objectives.
The paper describes the current FD operational approach in response to all these challenges, proving the SAOCOM-CS formation flying concept and control to be safe and robust while optimizing the scientific requirements.