Pointing control challenges of the ST3 formation flying stellar interferometer

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Abstract - The Space Technology 3 (ST3) mission is intended to demonstrate the technologies of precision formation flying and long-baseline stellar interferometry necessary for future astrophysics missions such as the Terrestrial Planet Finder. Scheduled for launch in 2005, ST3 will consist of an optical interferometer operated in distributed fashion on two spacecraft with separations ranging from 40 to 600 meters (corresponding to baselines of 30 - 125 m). ST3 represents the first use of a novel Parabolic Geometry Interferometer (PGI) in which the collector spacecraft is maneuvered along a parabolic curve while the combiner spacecraft remains at the focus of the parabola, thus achieving the desired range of baselines. The right arm of the PGI is formed by a siderostat and fixed delay line on the combiner spacecraft. The left arm of the PGI is formed by a variable delay line and second siderostat on the combiner spacecraft which point at another siderostat on the collector spacecraft. The siderostats must accommodate a large range of bearing angles (12- 46 deg) to support the various baselines. This paper describes the pointing control challenges involved in acquiring and maintaining interspacecraft metrology and starlight at the levels required for stellar interferometry. The basic process is as follows: (1) The formation geometry is adjusted to generate the desired baseline using spacecraft thrusters and a Ka-band 4π steradian Autonomous Formation Flying (AFF) sensor which provides 2 cm range knowledge and 1 arcminute bearing angle knowledge (1 sigma, best performance over a 2 deg cone). (2) Acquisition of the right starlight beam is performed on the combiner spacecraft using spacecraft attitude control and siderostat pointing control. The relatively narrow field of view of the interferometer requires few-arcsecond pointing knowledge for each of the associated components during acquisition. (3) Acquisition of interspacecraft metrology involves capturing a 20 arcsecond wide laser beam from the combiner spacecraft with an intensity gradient detector on the collector spacecraft based on initial arcminute pointing provided by the AFF sensor. Once the metrology beam is acquired, the angular metrology pointing control loop is closed with the left combiner siderostat which allows acquisition of linear metrology by retro-reflecting the beam back to the combiner spacecraft. Once active, metrology provides 25 um/s interspacecraft range rate knowledge and 10 arcsecond (1 sigma) bearing angle knowledge. (4) Acquisition of the left starlight beam is then accomplished. With both starlight control loops closed, overlap between the two beams within the beam combiner is held at the sub-arcsecond level (differential). (5) Interferometric delay and delay rate are estimated using data from all of the sensors described above. (6) The formation is then trimmed to reduce the delay rate to a level acceptable for fringe acquisition, 100 μm/s.(7) The fringe is acquired by servoing the combiner delay line in a search algorithm based on the delay estimate. (8)

With all loops closed, the ST3 formation-flying interferometer will achieve fringe tracking control at the 35 nm level during observations.