

KINETX SPACE NAVIGATION, FLIGHT DYNAMICS, AND PLANETARY SCIENCE SERVICES

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KinetX Aerospace is a trusted and innovative engineering services and product company focused on leading, developing, and demonstrating solutions to global and space-based challenges. With world-class expertise in space navigation, flight dynamics, operations, and systems engineering, KinetX is the first private company qualified by NASA for deep space navigation. In the last 20 years, the KinetX Space Navigation and Flight Dynamics (SNAFD) team has navigated spacecraft on complex planetary exploration missions including MESSENGER, New Horizons, OSIRIS-REx, Lucy, LunaH-Map, and other international missions. Our proven track record is unmatched within private industry – with over 700 years of experience in flight dynamics for Earth-orbiting, sub-orbital, and deep space missions, including NEAR, Cassini, GRAIL, and Iridium. We deliver a full range of orbit dynamics and deep space navigation experience for every phase of a space mission. Our core service areas include Navigation and Mission Systems Development, Optical Navigation, Orbit Determination, Maneuver Design, Mission/Trajectory Design, and Constellation Design/Maintenance. The KinetX SNAFD team has also worked closely with mission scientists at the cutting edge of space exploration to rapidly develop tools and capabilities for scientific characterization. Additionally, KinetX has a 30 year history in communication systems, spacecraft constellation design and operational orbit maintenance which can be leveraged in unison with the SNAFD experience to deploy deep space constellations and communication networks.

On New Horizons, the team developed sophisticated image processing algorithms^{1,2} to perform attitude determination and planetary centerfinding in order to successfully navigate to the Pluto system in 2015³ and Kuiper Belt Object (KBO) Arrokoth in 2019.⁴ Limb-based centerfinding algorithms were developed to compute the relative position of New Horizons with respect to Pluto and its moons,⁵ and advanced astrometry techniques were developed specifically for detecting and centerfinding on the faint KBO Arrokoth,⁶ which was masked by a crowded background star field. These techniques were critical to mission success for both planetary flybys, and many of these techniques have been applied to current missions such as OSIRIS-REx and Lucy. This technology coupled with the KinetX team's operational experience can enable accurate navigation to many challenging small or faint targets.

On OSIRIS-REx, the KinetX team demonstrated unprecedented centimeter-level navigation performance in

proximity operations around asteroid Bennu.^{7,8} The KinetX flight dynamics team spent two years navigating the spacecraft in proximity of Bennu, setting spaceflight records for smallest body ever orbited, and lowest orbit achieved by a spacecraft, while building up an arsenal of Optical Navigation, Orbit Determination, Maneuver Design techniques for small body proximity operations.^{9–15} The tools, capabilities and operational experience gained by the unprecedented navigation performance at Bennu can directly enable success on future small body proximity operations and sample return missions. In addition to providing navigation technologies and services to OSIRIS-REx, KinetX employees also contributed directly to fundamental mission science.^{16,17} The team rapidly responded to the discovery of particle ejection phenomenon at Bennu with tools and capabilities for optically detecting, tracking, and reconstructing the orbits of these mm-to-cm size particles leaving the asteroid's surface,^{18–20} and in turn solving for an 8th degree and order gravity field of Bennu.^{21,22} KinetX engineers have been named as science co-Investigators for astrometry and geodesy on OSIRIS-APEX, the extended mission to rendezvous with asteroid Apophis in 2029. The technology and experience gained on OSIRIS-REx has direct application to missions to active small bodies, as well as those interested in carrying gravity probes for in-situ experiments to characterize internal structure.

On LunaH-Map, a NASA SMD lunar mission recently launched by SLS along with the Artemis-1 mission,²³ KinetX was required to develop several novel capabilities to address the fact that LunaH-Map is using a low-thrust propulsion system, required a demanding maneuver and operational schedule, and has been collecting navigation data from both Deep Space Network (DSN) and non-DSN ground station assets. The first critical enhancement has been to KinetX' low-thrust mission design capability, which has been modified to optimize maneuvers around operational schedules and consider loosely-defined boundary conditions. This and other major enhancements were required to allow the team to very quickly redesign mission trajectories when the launch dates and/or ground tracking schedules frequently changed. KinetX has also developed novel algorithms to optimize a low-thrust spiral down from high- to low-altitude orbit and station-keep a low-thrust low-altitude orbit, all while considering operational timeline constraints. In addition to these trajectory design improvements, several orbit determination and tracking data processing tools were developed to provide KinetX the ability to process ESA ESTRACK and

DSS-17 (Morehead State University) radio metric tracking data, as well as DSN differential one-way Doppler (INS) data. KinetX has recently verified these new capabilities by successfully fitting Doppler and ranging data from 4 different ESA stations, Doppler data from DSS-17, and INS data from each pair of DSN complexes within the LunaH-Map orbit determination filter. KinetX is also currently in the process of demonstrating an on-board image processing and optical navigation software suite that will autonomously process on-board stellar and planetary images to determine the spacecraft's attitude and target-relative state. This capability has expanded KinetX' experience with on-board navigation algorithms which will be critical to addressing the needs of future ambitious science missions.

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