MONTE for Orbit Determination

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The Mission Analysis, Operations, and Navigation Toolkit Environment (MONTE) is the Jet Propulsion Laboratory's (JPL) signature astrodynamic computing platform. It was built to support JPL's deep space exploration program, and has been used to fly robotic spacecraft to the Moon, Mars, Jupiter, Saturn, Ceres, and Solar System small bodies. At its core, MONTE consists of low-level astrodynamic libraries that are written in C++ and presented to the end user as an importable Python language module. These libraries form the basis on which Python-language applications are built for specific astrodynamic applications, such as trajectory design and optimization, orbit determination, flight path control, and more.

Perhaps nowhere is MONTE's versatility and excellence better demonstrated than in its application to orbit determination. Over the period of 2007 – 2016, MONTE was the prime software used to construct orbit determination solutions for fourteen JPL flight missions. It was also used to generate independent, shadow orbit determination solutions for seven non-JPL missions (Table 1). These missions span the range of Solar System destinations and operational protocols, yet each were able to be serviced by MONTE's flexible orbit determination library. MONTE provides a navigation operations interface, called simply the "UI System", that implements JPL's classic "lock-update-run" workflow. This system allows an analyst to drive the main elements of an orbit determination solution – trajectory modelling, measurement processing, filter estimation, and solution analysis – using intuitive data constructors and command line executables. This system is lightweight enough to be quickly deployed for small, simple missions, but allows the customization necessary for challenging, new applications.

Table 1. Flight missions using MONTE for orbit determination, 2007 - 2016

Prime OD		**Shadow OD**
Phoenix	Chandra	Rosetta
Juno	Spitzer	Hayabusa
Cassini	Kepler	Hayabusa 2
GRAIL	MAVEN	Chandrayaan
EPOXI	MRO	Planet-C
MSL	SMAP	MOM
Dawn	Odyssey	New Horizons Pluto

This paper reviews the missions on which MONTE has been used for orbit determination, with an eye toward pointing out the different ways it has been deployed to solve unique problems. It also gives an outline of the main elements of the orbit determination library and how they work together to navigate flight missions.