OPTICAL NAVIGATION PREPARATIONS FOR NEW HORIZONS PLUTO FLYBY

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ABSTRACT

The New Horizons spacecraft will encounter Pluto and its satellites in July 2015. As was the case for the Voyager encounters with Jupiter, Saturn, Uranus and Neptune, mission success will depend heavily on accurate spacecraft navigation, and accurate navigation will be impossible without the use of pictures of the Pluto system taken by the onboard cameras.

Traditional optical navigation, taking exposures of foreground target objects against a background of catalogued reference stars, does an excellent job of determining the inertial direction to those targets. It does not do at all well at determining the distance to the targets, especially if their size and surface features are not well known. For a flyby encounter such as New Horizons at Pluto, approach imaging therefore determines the location of the incoming asymptote of the spacecraft's hyperbolic trajectory well, but it does little to improve the knowledge of the time of closest approach. Timing information becomes available only when the geometry has changed enough so that the spacecraft's incoming velocity vector makes a significant angle with the line of sight to the target. The last pictures are the most critical of all.

Because optical navigation uses spacecraft resources, cooperation between the navigation team and the rest of the project (both engineers and scientists) is an essential aspect of the planning process. This is true for all projects, and it is particularly true for New Horizons owing to the spacecraft's limited downlink capability. The number of navigation pictures has a firm upper limit if all the pictures are to be received in a timely fashion, but navigation performance will suffer if there are not enough pictures. To produce the final picture schedule therefore requires negotiations and compromises, and the expected navigation performance in turn informs the design of the science plans.

The picture schedule was first developed in 2004, well before launch. It relied only on pictures taken by the Long-Range Reconnaissance Imager (LORRI; 1024×1024 5-μrad pixels) of Pluto and its largest satellite Charon. Unlike the four gas giants explored by Voyager, the barycenter of the Pluto system lies outside Pluto itself. Imaging Pluto as well as Charon is important in order to locate the barycenter and thus determine the mass ratio, a task which to date has proven difficult to perform accurately even with Hubble imaging.

The picture schedule was changed significantly after the 2005 discovery of Nix and Hydra. Hydra, the outermost, provides better information about the arrival time than Pluto and Charon alone, for its larger orbit will provide the necessary parallax sooner. Pictures were added throughout approach in order to detect Nix and Hydra early and update their orbits in time to support near-encounter imaging.

Further revisions to the schedule have added pictures taken by the lower-resolution Multispectral Visible Imaging Camera (MVIC; 5028×128 20-μrad pixels) imager in order to mitigate the risk that LORRI might fail.

The current schedule contains 787 pictures beginning one year before encounter, including 330 LORRI exposures in its 4×4 binned mode and 32 MVIC exposures. Plans are in place to downlink the most critical pictures, those taken in the last week, quickly. Furthermore, the navigation team has identified some science pictures as dual use and will incorporate that imaging into the navigation data set.

Picture planning is the largest component of preparation but by no means the only one. The most difficult task faced by the optical navigators is that of extracting the (x, y) coordinates of images within the pictures. The brightness profile of the targets depends not only on the viewing geometry but also on the reflectance characteristics of the surface. Rigorous testing is required for any mission, but especially so when a priori knowledge is lacking. Pluto's radius remains uncertain to 10 km; the sizes of Nix and Hydra have not been measured directly but are only inferred from their brightness. Pluto is known to have significant albedo variations, and because it is in synchronous rotation with Charon's orbit, errors in Pluto's albedo map will translate directly into errors in its Charon-relative position and therefore into errors in Charon's eccentricity, in the mass ratio and in the location of the barycenter. This situation will improve as Pluto's apparent diameter grows during approach. The effects of Pluto's tenuous atmosphere on imaging are expected to be small. Likewise, errors in the size and assumed spherical shape of Nix and Hydra can be no larger than some fraction of their own radii.

The above image processing risks are being mitigated by using two optical navigation teams, one at JPL and one at KinetX, using different software and different centerfinding techniques. The two teams expect to compare results regularly and investigate any systematic differences.