Progress on Development of an Intelligent Landing System for Europa and Other Planetary Bodies[1]

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The Intelligent Landing System (ILS) was originally conceived to enable landing on the Jovian moon Europa [1]. The ILS combined lidar data with passive imaging to enable landing at very rough locations without high resolution orbital reconnaissance. The planetary decadal survey did not give Europa Lander a high priority, but it did promote other missions that could use ILS capabilities including Enceladus Orbilander, Ceres Lander and Centaur or Comet Sample Returns. Lunar and Mars robotic and crewed missions could also benefit. Given the broad applicability, ILS development has continued, but with a focus on lidar, so that ILS can enable landing under any lighting conditions and in extremely rough terrain. This presentation will cover a recent lidar field test and the ILS applicability to multiple NASA missions.

The Europa Lander technology program funded the development of two lidars. The first to be delivered to JPL, called ELSA, was built by Sigma Space Corporation based on requirements provided by the Europa Lander team [2]. The lidar utilizes a green laser and photo-multiplier tube for single photon counting in the extreme radiation environment of Europa. The lidar can be used in a staring ranging mode or a fast steering mirror can scan an arbitrary pattern across the surface. Altimetry is possible from 10km or higher to 10m range. A coarse scanning mode at 5km covers 1km x 1km with 5m pixels in 1 second to enable detection and avoidance of regional hazards like cliffs, craters and mountains. At 500m altitude, the lidar can cover a 100m x100m with 5cm pixels in 1 second to enable detection of small lander scale hazards like rocks, pits and small ripples. The complete lidar with electronics fits within 40x40x25cm and a mass of 9kg.

After delivery, the ELSA lidar was tested statically on the JPL Mesa and then dynamically over calibration targets and natural terrain during a helicopter field test. The top of Figure 1 shows a flat calibration board imaged from 360m range during static testing and the resulting 2.7cm estimate of range noise (1 sigma). The bottom of Figure 1 shows the compact ELSA lidar on a static gimbal attached to the helicopter and a raw point cloud from a dense scan of calibration target field. The data has very few outliers and the slopes of the target boards are clearly visible. Some gaps exist in the data due to helicopter motion during the scan but in the next version of ELSA, these will be removed through active motion compensation. The altimetry function was also demonstrated during the field test with flights around 3km AGL.

Figure 2 shows a generic ILS concept of operations built around the multi-functional ELSA capabilities and utilizing lidar based navigation and hazard detection algorithms developed in multiple programs [3]. First, while in orbit or during descent, the high altitude ranging mode is used to estimate altitude. This altitude measurement can be used to improve orbit determination and set up the later phases of landing. By combining multiple measurements over time an elevation contour can be constructed and then matched to a digital elevation map to generate a coarse position estimate for initial targeting. Once below 5km altitude, coarse scans can be taken and matched to a map to obtain a finer position estimate. If a map is not available, then the coarse scans can be used for regional hazard avoidance and multiple coarse scans can be matched to each other to refine the surface relative velocity. Once below 500m, the fine scanning mode can be enabled to detect lander scale hazards and refine the touchdown velocity by matching scan to scan. Finally, with the lidar, or possibly another active sensor like a remote sensing spectrometer, safe sites that are also scientifically interesting can be identified and selected for the final landing site.

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References

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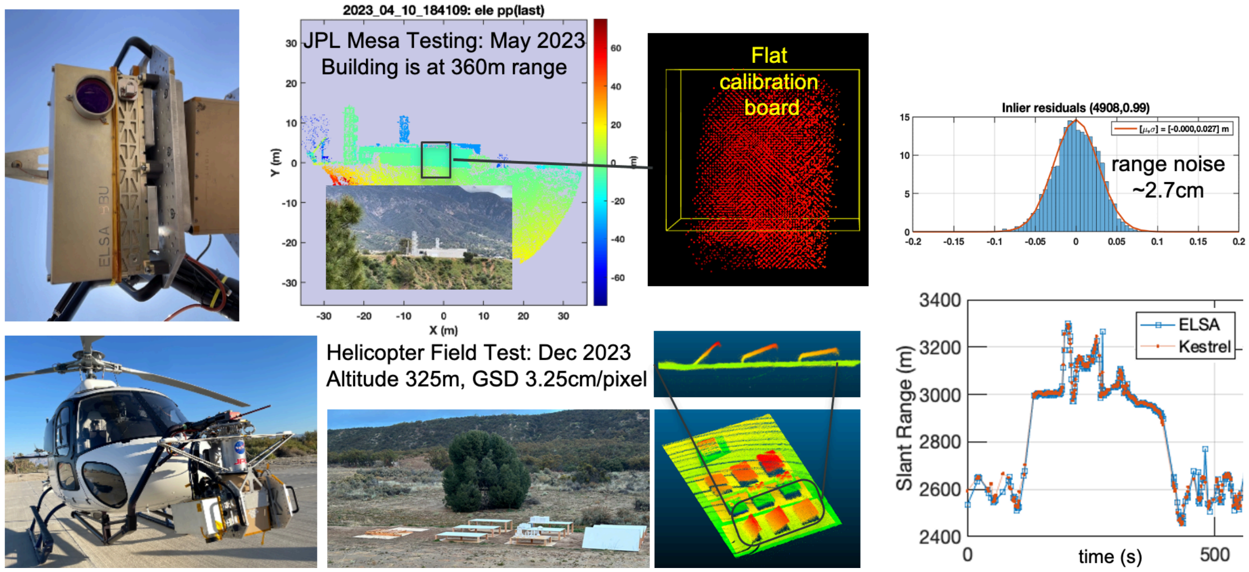

Figure 1: ELSA lidar field test results.

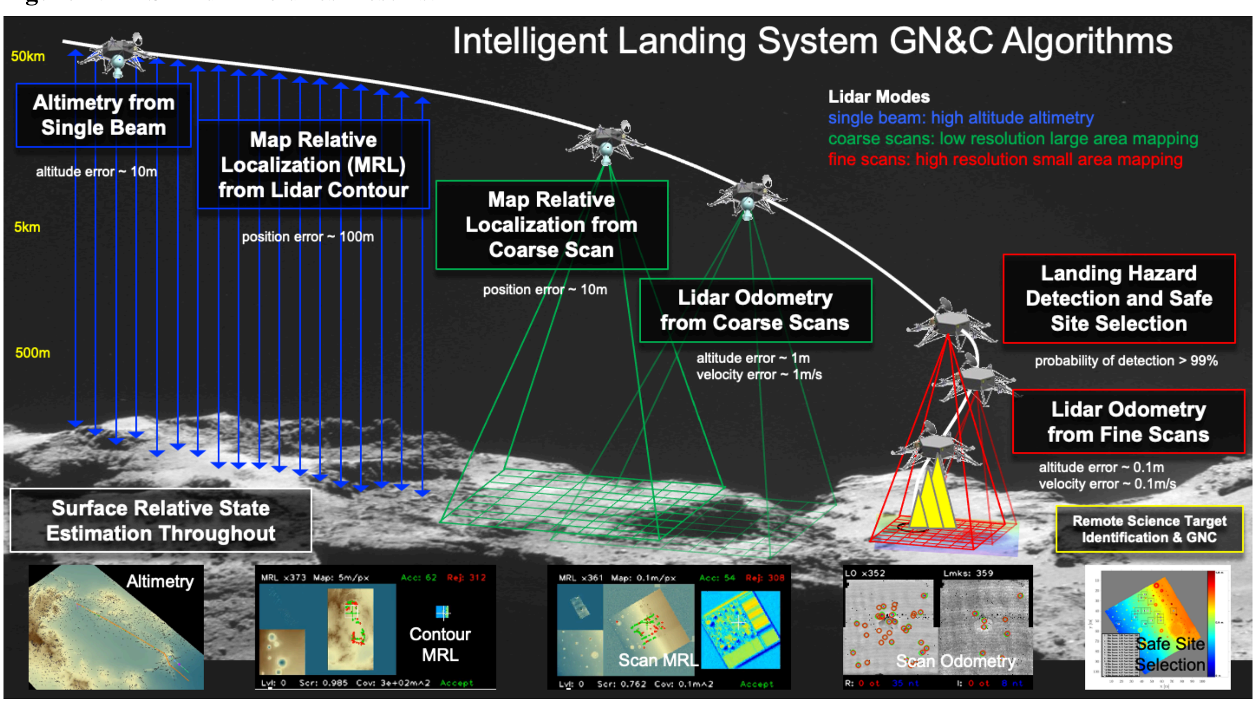

Figure 2: Intelligent Landing System navigation functions for anytime anywhere landing.