

SURVEYOR RETRO-ROCKETS IN LROC IMAGES. P. J. Stooke¹, ¹Department of Geography, and Centre for Planetary Science and Exploration, University of Western Ontario, London, Ontario, Canada N6A5C2, <http://publish.uwo.ca/~pjstooke/>, pjstooke@uwo.ca.

Introduction: Five of NASA's seven Surveyor missions landed successfully between 1966 and 1968. Most were sent to regions where astronauts might land on the early Apollo missions: near the equator in the western, central, and eastern maria. As the Surveyors reached the Moon they were braked to near-zero velocity by a solid fuel retro-rocket mounted under the lander. The retro-rocket was ejected near the surface and three small Vernier thrusters ignited to bring the lander safely to the ground. None of the retro-rockets were imaged by the Surveyors, and Apollo 12 astronauts did not see the Surveyor 3 retro-rocket when they landed nearby. Can any be found in LROC images?

Surveyor 1: This landing site was not imaged at high resolution by Lunar Orbiter before the landing, so unlike Surveyors 3 and 6 there are no before-after comparison. High sun images show two possible candidates, and one, a dark halo crater on the bright ejecta of a fresh crater 300 m NW of the lander seems most likely to be the retro-rocket (Fig. 1).

Surveyor 3: The Surveyor 3 retro-rocket was observed previously and reported in 2010 [1]. It was noted as a dark spot visible in LROC-NAC images but not present in a pre-landing Lunar Orbiter image. More details are reported here. Other than the pre-landing image, the best evidence of the retro-rocket seems to be its appearance as a very dark spot in high sun images. Possible bounce marks were also suggested in an enlargement (Fig. 2). The highest resolution (25 km altitude) LROC-NAC image (M168353795R) reveals the dark spot as a crater. A small spot previously considered a bounce mark is now seen as a positive relief feature, possibly the engine nozzle, thrown clear of the rocket casing impact (Fig. 3a). The Apollo 12 astronauts could not see the impact site because it was in a local depression and not visible from the LM windows, but an analysis by Ian Regan has shown that the Apollo 12 descent video includes the impact crater (Fig. 3b). If this video had been compared with Lunar Orbiter images in late 1969 the retro-rocket would have been found at once.

Surveyor 5: This landing site was not imaged at high resolution by Lunar Orbiter or Apollo. LROC-NAC images were required to find the lander itself [2]. High sun images were examined for dark spots near the lander, and only one obvious candidate is apparent (Fig. 4). It also shows possible bounce marks nearby, again perhaps caused by the ejected nozzle or other

fragments. This is assumed to be the Surveyor 5 retro-rocket.

Surveyor 6: High sun images of this site were examined for dark spots near the lander, and two obvious candidates are apparent, but comparison with Lunar Orbiter 2 frame 121-H3 shows that one was present before the landing. The other is a new feature (Fig. 5). This dark spot, also a small crater, has several dark rays, as also seen at Surveyor 3. This must be the Surveyor 6 retro-rocket impact.

Surveyor 7: Here the search is complicated by the latitude, which precludes the possibility of high sun images. Despite this, three small dark spots can be found within a few hundred m of the lander (two to the ENE (Fig. 6) and one to the WSW (not shown), and one is located on the impact melt pond 1000 m NE of the lander which was the landing target. The distant spot is probably too far away to be correct, but any of the other three might be the retro-rocket impact. All three appear to be small craters in M175355093L, the best LRO image.

References: [1] Stooke, P. J. (2010) *41st LPS*, Abstract #1116. [2] Robinson, M, 2010. Blog post, <http://lroc.sese.asu.edu/posts/14>, March 21, 2010.

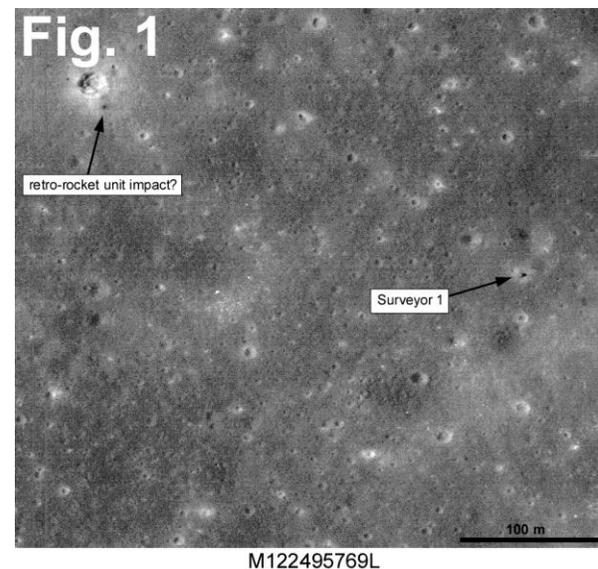


Figure 1. Surveyor 1 candidate retro-rocket impact.

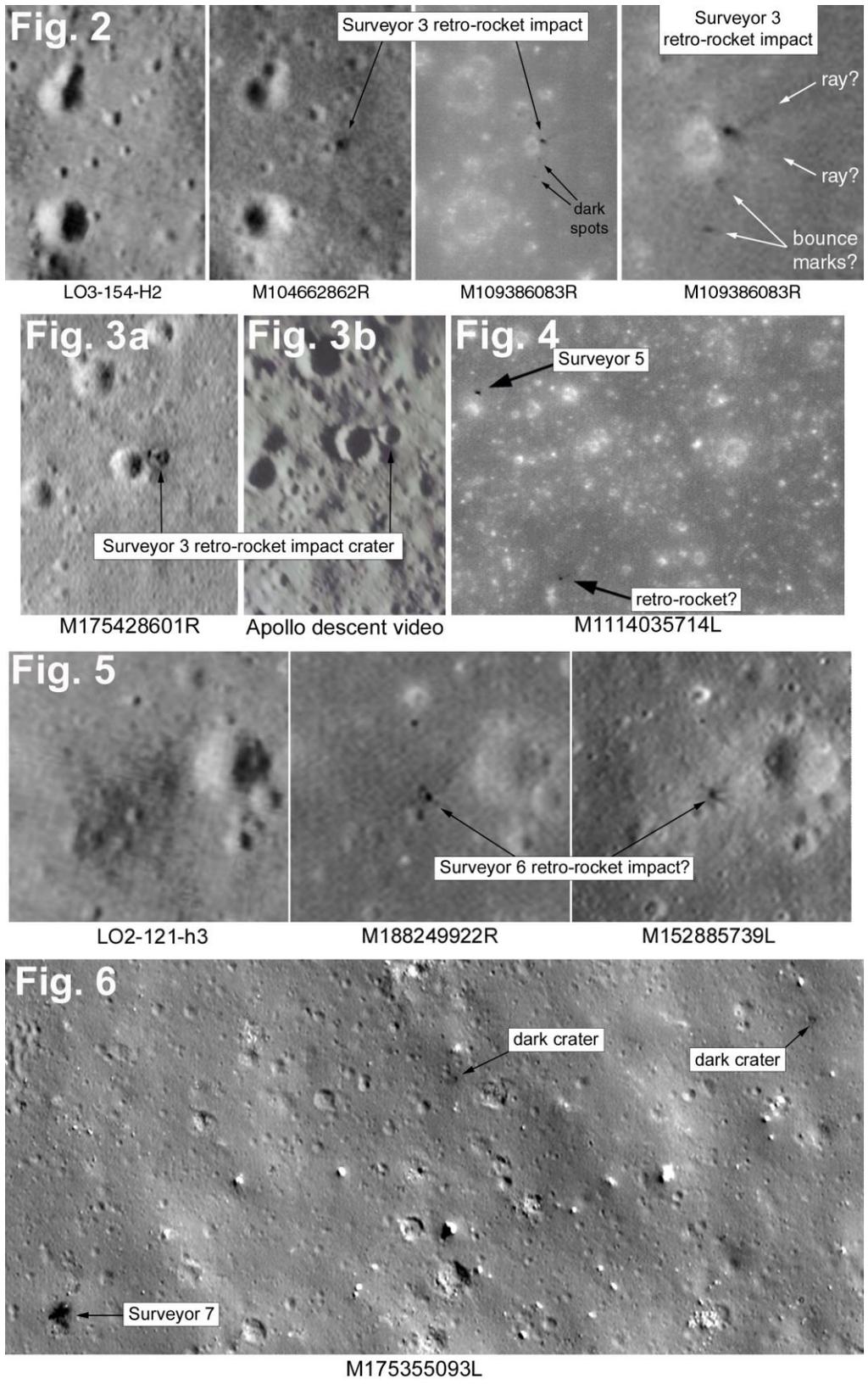


Figure 2. Surveyors 3-7 candidate retro-rocket impacts.