Let's Find Eagle: Cislunar Space Domain Awareness Meets Archeoastronomy

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ABSTRACT

Most of the Apollo-era spacecraft sent to the Moon either remain on the surface, returned to Earth with their crew, or were intentionally crashed into the lunar surface. There are two notable exceptions: the ascent and decent modules from Apollo 10, "Snoopy;" and Apollo 11 ascent module, "Eagle." The latter two were only "assumed" to have crashed. Recent reconstructions of the orbits based on the Apollo missions' final reports of these two objects by Meador (2021) show there is a good chance they are still in lunar orbit. Moreover, these reconstructions show that Eagle may well be constrained to a relatively small, square cross-section toroidal volume close to the lunar equator, approximately 1 x 1 arcminute in size.

Can Eagle be found? Bistatic radar could potentially detect Eagle, assuming it is still intact. However, that is no simple endeavor as it involves facilities that are in great demand. Optically, Eagle should appear 18th magnitude or brighter in g-band when fully illuminated – which is faint, but not challenging for a meter-class or larger telescope, except that its expected position is roughly 50 arcseconds from the limb of the fully illuminated Moon. That close to the Moon, light scattered by the molecules and aerosols in Earth's atmosphere create a background surface brightness far in excess of the range where most telescopes normally operate. Internal scattering of light in the telescope, from both the mechanical structures of the optical system as well as imperfection in the primary optical surface only makes this worse and is in most cases, this internal scatter completely dominates the background. The "cone of shame" comes primarily from the telescope!

Solar astronomers understand this well and terrestrial coronagraphs can measure faint emission and scatter from the Sun's corona down to 1.05 solar radii: 45 arcseconds from the solar limb. These coronal measurement systems have scattered light performance several orders of magnitude lower than normal telescopes, often 10-5 - 10-6 lower than the solar surface brightness. All of the same scattering effects apply to observations near the lunar limb, so the same optical system design techniques can be applied to cislunar SDA optical systems, making a target like Eagle detectable with a 1–2 m telescope.

At its apparent apex elongation from the Moon, Eagle's transverse apparent angular velocity with respect to the Moon is very small, so integration times greater than 30 – 60 seconds are possible. If Eagle is still there, it will be in a retrograde equatorial orbit with a period of roughly two hours. A well-designed instrument could observe near the lunar limb in the expected area watching for a periodic faint detection moving at approximately the same rate as the Moon itself.

To date, we have found no existing instrumentation that can make these measurements: existing astronomical telescopes are not designed to work so close to the lunar limb and existing solar telescopes are designed for very narrow band imagery. We discuss several the design issues and consider some candidate instrumentation. Along the way, we hope to drum up some excitement.

So, let's find Eagle! Aside from its use as a cislunar SDA test object, it is an artifact of immeasurable value: a literal "Lost Ark."