An Exploration of the Lunar Reference Frame

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SUMMARY

As humanity once again returns to the Moon, this time to stay, there are calls for the delivery of accurate autonomous navigation service infrastructure like those on Earth. Lunar navigation services, in the form of orbiting satellite delivering a GNSS-like ranging signal, have been proposed by numerous space agencies, including NASA with LunarNet, ESA with Moonlight, and Japan with the Lunar Navigation Satellite System. Central to any such navigation infrastructure is the definition and realisation of a unified, stable reference frame.

Lunar reference frame definitions were first proposed in the Apollo-era , adopting what was known as the Basic Reference Coordinate System centred at the Moon centre of mass. Its inertial orientation was defined by the line of interest between mean Earth equatorial plane and the mean ecliptic, with an epoch established on Besselian year, 1st January 1971.

Definitions have evolved to the context of recently launched lunar missions. The Lunar Reconnaissance Orbiter, launched in 2009 on a mission to map the surface and measure the gravitational and magnetic field, as well as other primary instruments, required a new definition that adopted a body-fixed frame. The first definition was established at the mean Earth sub-point, which was established by taking an average of the lunar surface position that is closest to the Earth centre of mass. The second definition adopts the Moon principal axis as an approximate ellipsoidal body.

In the context of these new efforts to establish a lunar navigation infrastructure, and a significant increase in surface activities, a renewed effort to realise a harmonised and centralised frame is called for. The Moon's geophysics is not as dynamic as the Earth's. There is no plate motion, moonquakes only reach to magnitude 5, there is a near non-existent magnetic field and there is no atmosphere or ocean. Having said this, Earth tidal forces are strong and the gravitational field is

unstable. The interior structure of the Moon is much less known compared to the Earth.

The proposed presentation, in the context of the Reference Frames in Practice (RFIP) workshop, will explore old and new definitions of the lunar reference frame to promote discussion and conversation in this evolving topic within the FIG community. Definitions will be explored from the Apollo era to the context of NASA and ESA navigation infrastructure endeavours, as well as geophysical descriptions of the lunar planetary system.