National Aeronautics and Space Administration

FY24 R&TD Innovative Spontaneous Concepts (ISC)

Global Localization for a Lunar Rover utilizing Celestial Navigation

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Strategic Focus Area: Innovative Spontaneous Concepts

Objectives: The prime objective is to show how Celestial Navigation can determine Lunar rover location to **10 meters** without reliance on GPS-like information, allowing a Lunar Rover to autonomously drive long distances

Background: On Earth, latitude and longitude is conveniently provided by the Global Positioning System (GPS). Unfortunately, GPS does not extend well to the Moon. The 2023 Planetary Sciences Decadal Survey advocated for alternative global localization methods for lunar missions. Its critical importance is recognized first hand as part of the JPL's on-going Endurance A pre-project studies.

Our approach was inspired by the celestial methods used by sailing ships which measured star positions, and the direction of gravity to determine latitude and longitude. The angle between star and the local gravity vector at an accurately known time provides the needed information. Our approach derives an analogous approach using star trackers, inclinometers, and moon gravity maps. This potentially will eliminate the reliance on external resources and enable autonomous driving over long distances.

Approach and Results: Our global localization instrument design contains an inclinometer, star trackers, a rotating platform, and a tip-tilt mechanism for alignment, as illustrated in Fig 1. On the moon, as on earth, the star measurements are used to map the inclinometer measurements into a moon inertial frame, giving the direction to gravity to high precision. A Grail gravity direction model (Fig 2) corrects gravity direction to allowing surface latitude and longitude to be calculated. **Ignoring the gravity direction offset can lead to 5000 meter errors in position estimate.** The rotating platform allows biases and misalignments to be calibrated and removed by observing from different rotational orientations. Our instrument design contributes about 1 to 1.2 arcseconds error in gravity direction (8 to 10 meters). The gravity map (Fig 2) is used to compute position from gravity direction. For the moon, the position estimate accuracy is likely limited by the accuracy of the gravity map. Experimentally we constructed a breadboard (Fig 3) with functional equivalents of the design components. A JPL parking lot test was conducted to demonstrate basic functionality with about 0.15 degree accuracy, under non-ideal conditions due leveling issues and mechanical setup.

Fig 1

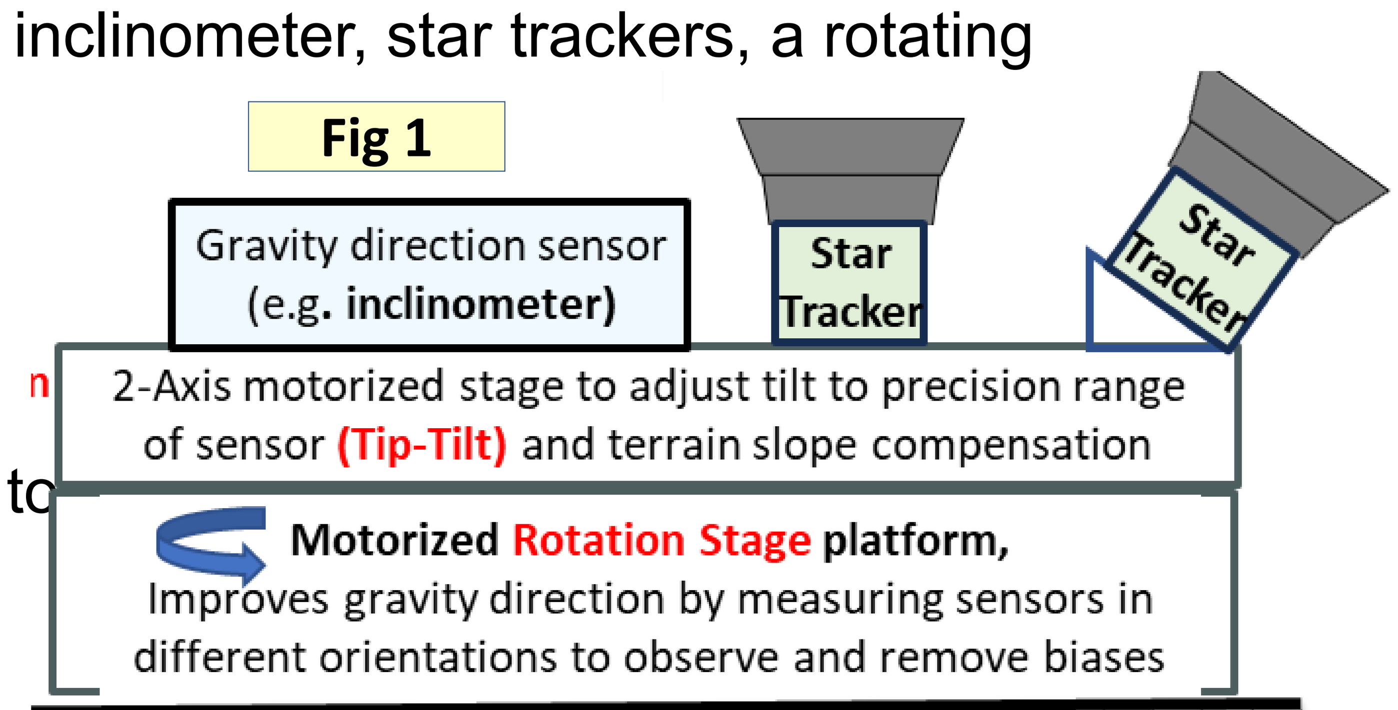
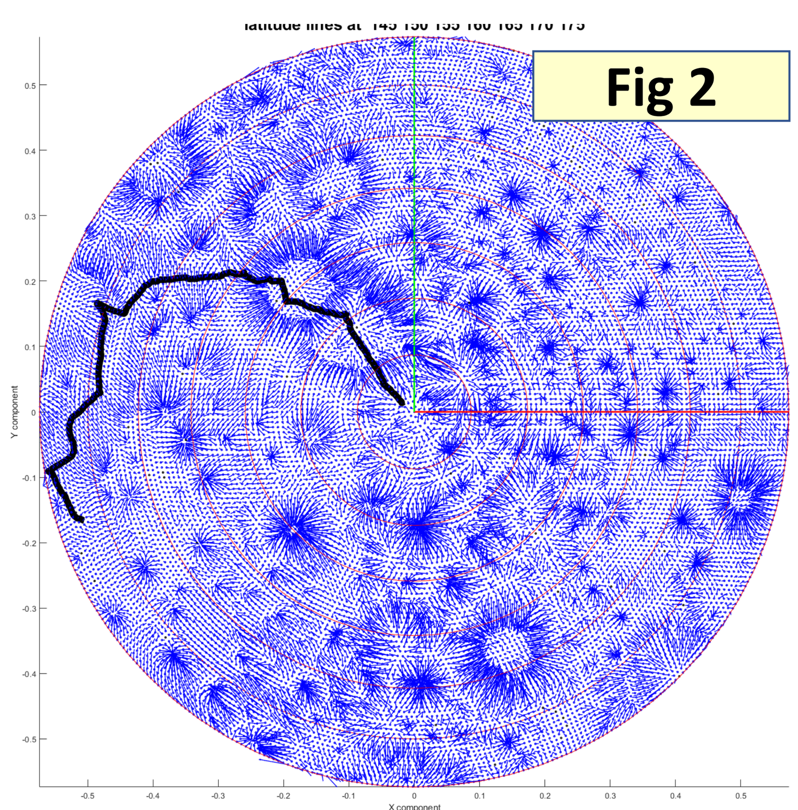


Fig 1. Design of Global Localization Hardware, with star tracker, inclinometer, rotational stage, and tip –tilt mechanism to align the inclinometer

Fig 2.Grail based model gravity direction offset from geometric center (latitudes 40 deg from south pole). The black line is the 1800km lunar rover path.



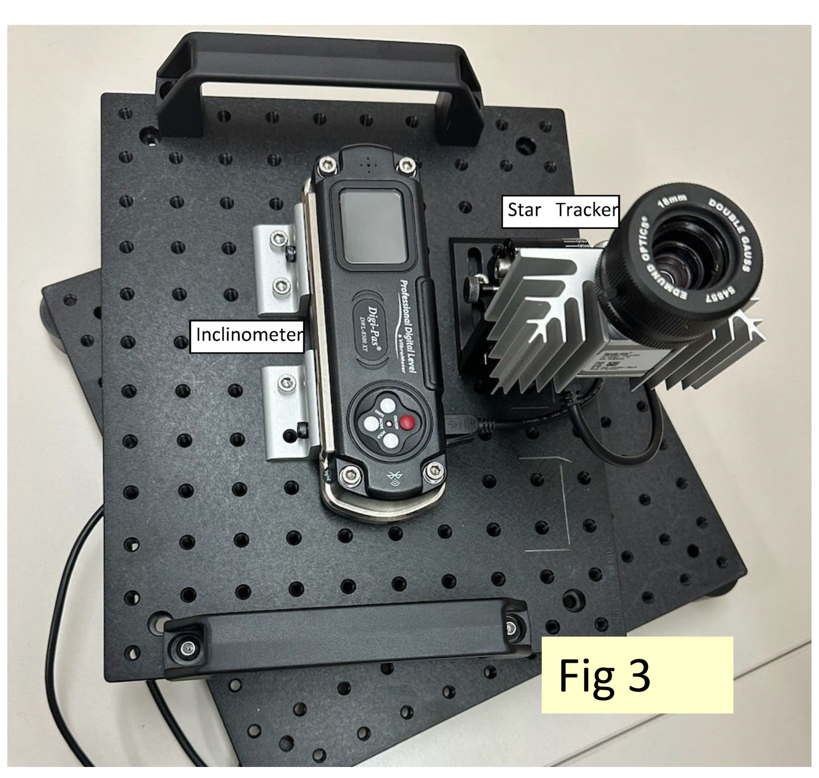


Fig 3. Breadboard hardware with inclinometer, star camera, and manual rotation stage. Tip-Tilt controlled by shimming lower platform feet.

Significance/Benefits to JPL and NASA: This technology promises to enable autonomous lunar rover missions where GPS or satellite communications are not available. The gravity direction map appears as the limiting error source. Where a good map exists or can be constructed, we can expect close to 10 to 20 meter accuracy.

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