The Role of a Reference System in Lunar Safety of Navigation

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NGA Missions (Title 10 of US Code)

§442. Missions

(a) National Security Missions.—(1) The National Geospatial-Intelligence Agency shall, in support of the national security objectives of the United States, provide geospatial intelligence consisting of the following:

(A) Imagery.

(B) Imagery intelligence.

(C) Geospatial information.

(3) Geospatial intelligence provided in carrying out paragraphs (1) and (2) shall be timely, relevant, and accurate.

(b) Navigation Information.—The National Geospatial-Intelligence Agency shall improve the means for safe navigation by providing, under the authority of the Secretary of Defense, accurate geospatial information for use by the departments and agencies of the United States, the merchant marine, and navigators generally.

(c) Maps, Charts, Etc.—The National Geospatial-Intelligence Agency shall acquire, prepare, and distribute maps, safe-for-navigation charts and datasets, books, and geomatics products as authorized under subchapter II of this chapter.

(d) National Missions.—The National Geospatial-Intelligence Agency also has national missions as specified in section 110(a) of the National Security Act of 1947 (50 U.S.C. 3045(a)).

(e) Systems.—The National Geospatial-Intelligence Agency may, in furtherance of a mission of the Agency, design, develop, deploy, operate, and maintain systems related to the processing and dissemination of imagery intelligence and geospatial information that may be transferred to, accepted or used by, or used on behalf of—

(1) the armed forces, including any combatant command, component of a combatant command, joint task force, or tactical unit; or

(2) any other department or agency of the United States.

(f) Validation.—The National Geospatial-Intelligence Agency shall assist the Joint Chiefs of Staff, combatant commands, and the military departments in establishing, coordinating, consolidating, and validating mapping, charting, geomatics data, and safety of navigation capability requirements through a formal process governed by the Joint Staff. Consistent with validated requirements, the National Geospatial-Intelligence Agency shall provide aeronautical and nautical charts that are safe for navigation, maps, books, datasets, models, and geomatics products.

Reference System and it Relationship to Navigation Safely

Reference System Purpose - Ensure that positioning and navigation solutions reach the same point regardless of the technology used

Components –

1. Reference Frame Definition and Realization
2. Ellipsoid and Geoid Definitions
3. Necessary Environmental Models – (Gravity, Magnetic, etc.)

Published standard –

1. Enables vendors to build different technologies to the same positioning standard
2. Assists in the interoperability of different technologies

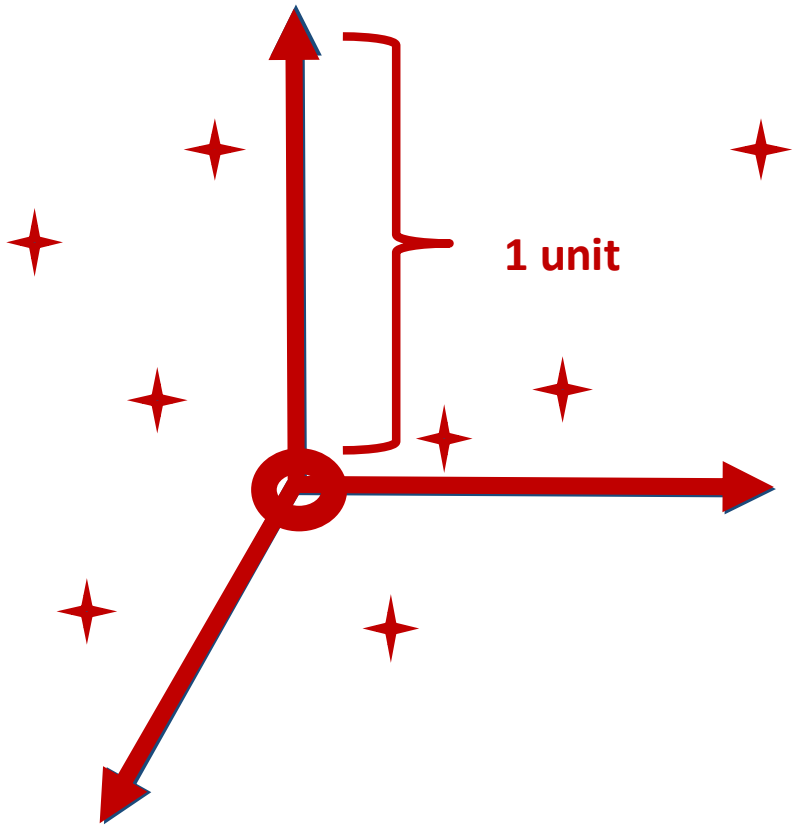
What makes up a reference frame?

1. An origin – simply the point in space from which everything is measured ZERO

2. An axis for each spatial dimension – a line for each direction, usually 3 lines

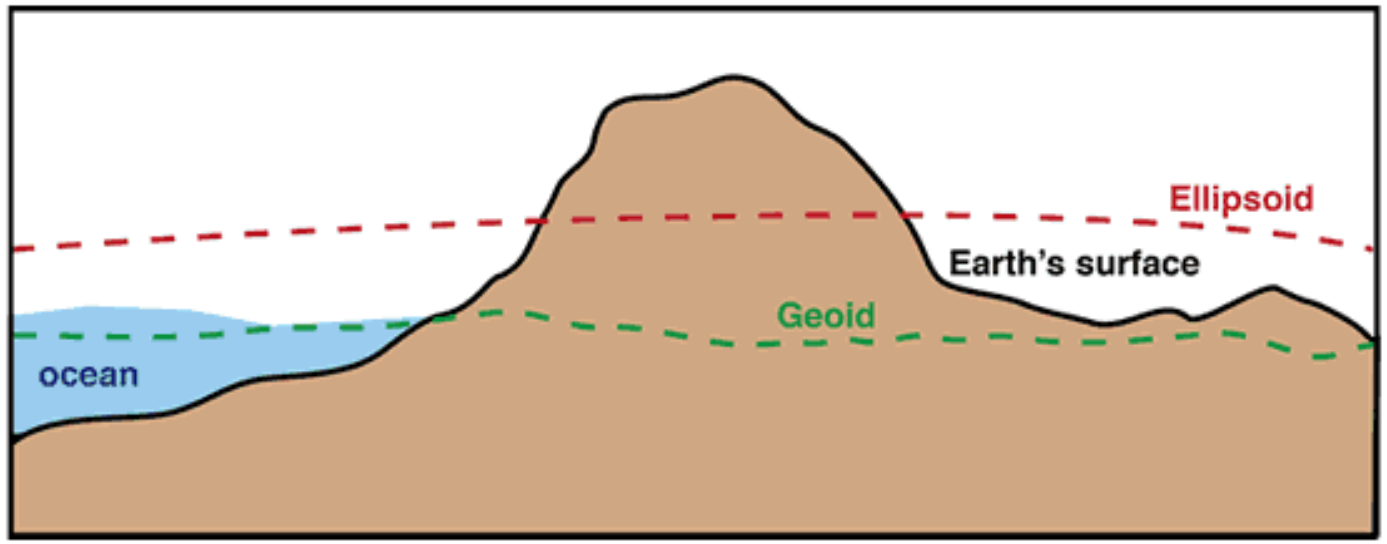
3. A scale – units of length or distances within the reference frame

4. Reference Points – real world points that uniquely fix the coordinate system



Reference Frame realization – the process of calculating the reference frame from the reference points

Reference Frame Surfaces



Ellipsoid – a mathematically smooth reference surface that describes the basic shape of the solid body

Geoid - the surface of constant gravity potential

Topographic surface – the physical surface encompassing every feature of the landscape

Environmental Models

Gravity Model – Describes the basic variations in the local gravitation field

- Used by Inertial Navigation Systems
- Typically described by a high-order spherical harmonic model

Magnetic Field Model – Describes the core magnetic field

- Used by compasses and other magnetic guidance systems
- Impacted by space weather which limits its usefulness

Topographic Model – Describes topographic features

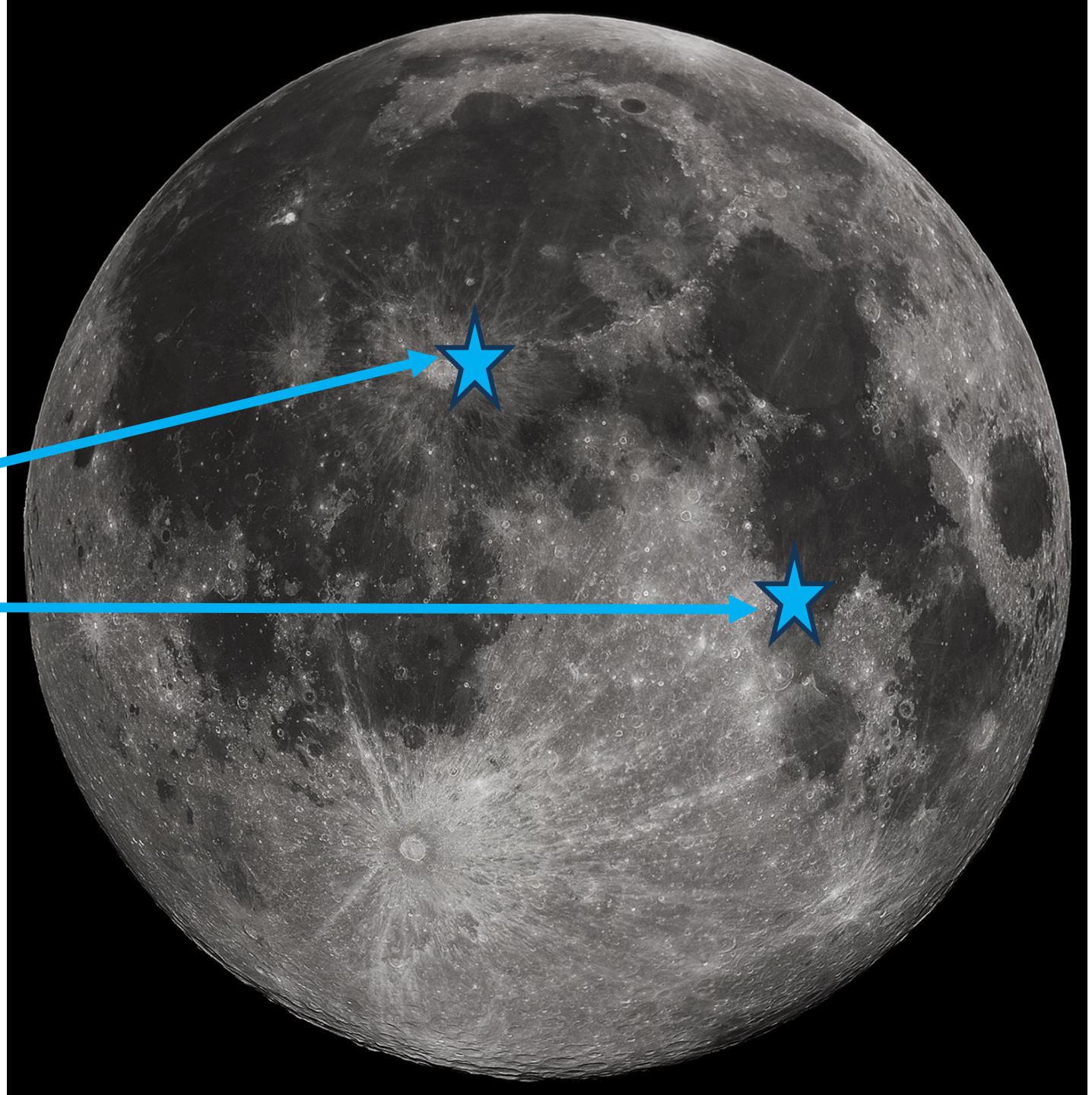
- Not usually included in reference system
- Digital Elevation Models (DEM) – provide topographic features by different post spacing (pixel sizes)
- Used by visual navigation systems

World Geodetic System 1984

- NGA's most used product
  - Estimated 4 to 5 billion users daily
- Official DoD Terrestrial Reference System
- Described in NGA Standard 36
  (https://gwg.nga.mil/ntb/baseline/docs/HSI/NGA.IP.0006_1.0.pdf)
- Updated on a regular schedule
  - Next update to be released in 2022
- Includes:
  - WGS 84 Reference Frame (G1762) realization
  - Earth Gravity Model 2008
  - World Magnetic Model 2010

WGS 84 gets us from here to there.

So how do we get from here to there?



Lunar Reference System (LRS)

- Starting from NASA's current reference system
- Moon-centered, moon-fixed reference system
- Requires high precision gravity model
- Requires multiple realization points
    - Fixed points for the reference frame
    - Waypoints for lunar surface navigation

Lunar Reference System (LRS) Working Group

- Interagency working group planning a lunar reference system
  - NGA
  - NASA
  - USN/USNO and NRL
  - Interior/USGS
  - USSF/AFRL
  - NOAA/NGS
- Developing a white paper on the gaps between the current scientific baseline and a reference system needed for surface navigation
  - Improving the current accuracy and resolution
  - Enable as many different navigation technologies as possible

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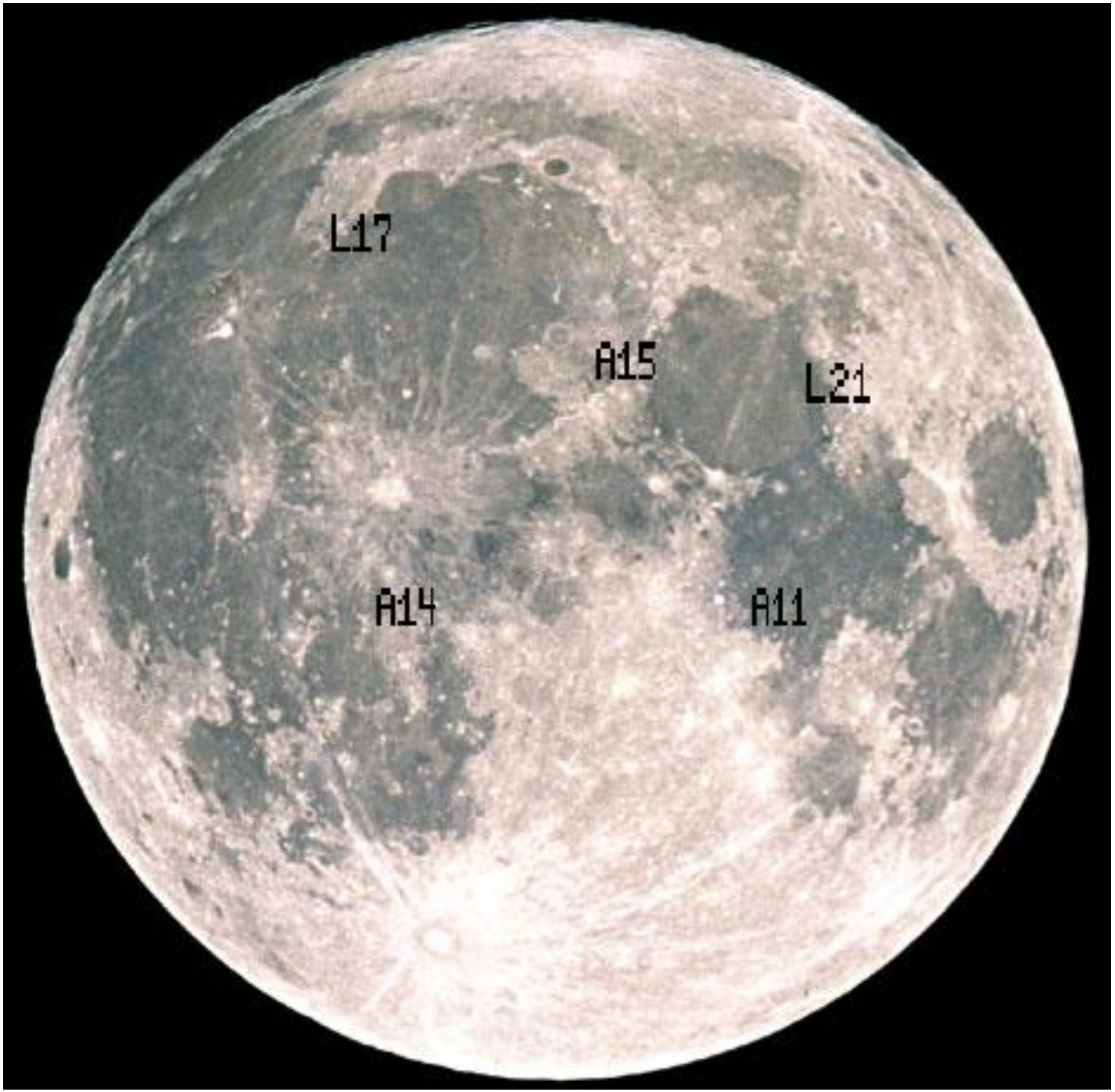
BACKUP MATERIAL



Current Lunar Reference Points

Lunar Laser Ranging Retroreflectors placed in placed during Apollo (USA) and Luna (USSR) missions

No reference points on the far side of the Moon.

NGA