

From the Earth to the Moon: LUNEX – Lunar Unified Navigation EXchange Format

Cislunar PNT Workshop, 10-13.02.2026

On behalf of the **IGS RINEX Committee**

Chair: **Francesco Gini**, Navigation Support Office, ESA/ESOC

Vice-Chair: **André Hauschild**, DLR



Outline

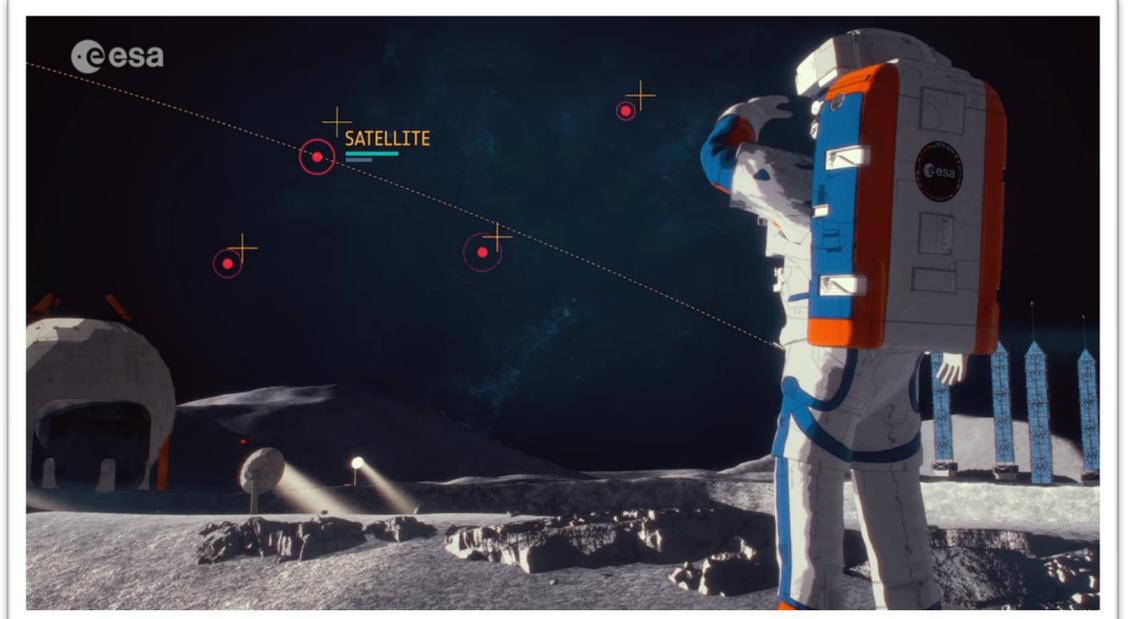


From the Earth ...

- Overview of RINEX Committee's functions
- RINEX: purpose and historic overview
- Lessons learned from the RINEX experience

... to the Moon:

- LUNEX: the lunar RINEX
- Recommendations and open questions



The RINEX committee in the IGS structure

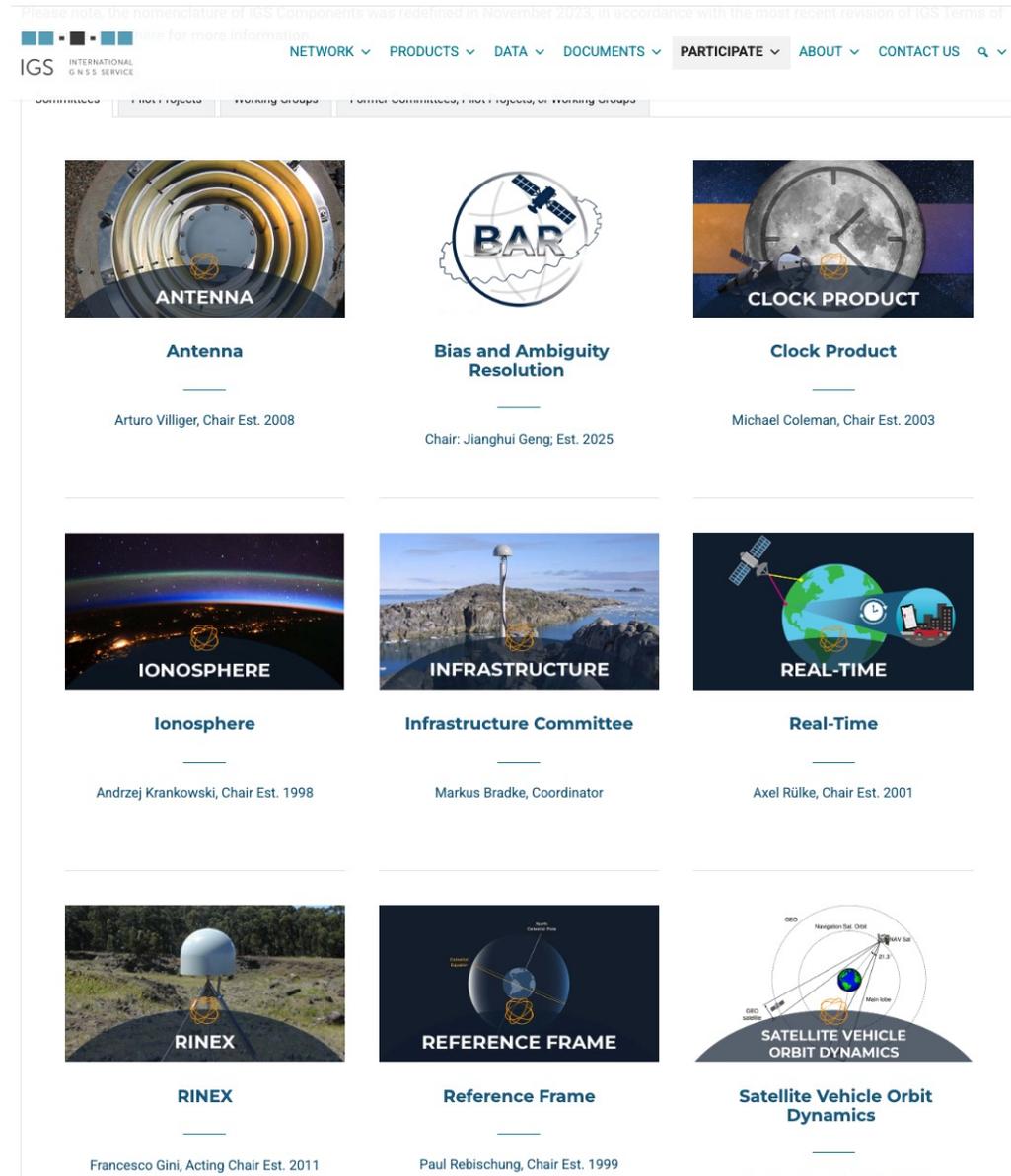
The IGS accomplishes its mission through many of its components such as **Committees, Pilot Projects, and Working Groups.**

Committees are established to oversee and continuously develop operational IGS products or core components and provide governance and support to IGS Data, Products and Services.

Pilot Projects are established to investigate or develop a new IGS product or core component.

Working Groups are established to address a specific scientific or technical issue or work on a particular topic related to the IGS mission.

Please note, the nomenclature of IGS Components was redefined in November 2023, in accordance with the most recent revision of IGS Terms of Reference for more information.



The screenshot shows the IGS website with a navigation menu and a grid of nine committee and working group cards. Each card features a representative image, a title, and the name of the chair and establishment year.

Committee/Working Group	Chair	Established
Antenna	Arturo Villiger	Est. 2008
Bias and Ambiguity Resolution (BAR)	Jianghui Geng	Est. 2025
Clock Product	Michael Coleman	Est. 2003
Ionosphere	Andrzej Krankowski	Est. 1998
Infrastructure Committee	Markus Bradke	Coordinator
Real-Time	Axel Rülke	Est. 2001
RINEX	Francesco Gini	Acting Chair Est. 2011
Reference Frame	Paul Rebischung	Chair Est. 1999
Satellite Vehicle Orbit Dynamics		

The IGS RINEX Committee

IGS RINEX Committee Goals and Responsibilities:

- **Maintain the GNSS Format Standard *RINEX*** to support operational and new navigation satellite systems based on Signal-In-Space ICDs
- **Coordinate** with other IGS components (real-time, Infrastructure, ...), and industry (RTCM, manufacturers, ...)

Standardization process of RINEX format:

1. Release of **new GNSS system ICD update** and new signal/data transmitted in space
2. **Request from GNSS community** to have this new data recorded
3. **Review of request** by RINEX committee
4. **Proposed implementation** in new RINEX version
5. Formal **approval** of 1) *IGS RINEX Committee* and 2) *IGS Governing Board*
6. **Publication of new RINEX** format release, particularly to the GNSS receiver manufacturers
7. IGS's role is to **promote the early adoption** of new RINEX format

--> GNSS data conversion to RINEX is a task of the station operators

The GNSS format Standard

RINEX: definition and purpose

- **RINEX** stands for **Receiver INdependent EXchange** format
- It is **the geodetic data interchange format** for raw satellite navigation system data - GNSS
- Its application is (mostly) for post-processing purposes:
 - **Validation and refinement** of receiver's navigation solution
 - **Scientific applications** (e.g., geodetic, Earth observations)
- It is used to store:
 - **Observations data records:**
 - Pseudoranges
 - Carrier-phase
 - Doppler
 - Signal-to-noise ratio
 - **Navigation Messages:**
 - Ephemerides of GNSS satellites
 - System Time Offsets
 - Earth Orientation Parameters
 - Ionospheric Model parameters



GNSS Providers



BDS
China



Galileo
European Union



NAVIC
India



QZSS
Japan



GLONASS
Russia



GPS
USA

Courtesy: NASA, Introduction to the "Interoperable GNSS Space Service Volume" (2021)

→ RINEX ensures consistency of the data for all GNSS constellations and all GNSS receivers

Brief History of RINEX:

1. **The first RINEX** was developed in 1989 by the Astronomical Institute of the University of Bern [Gurtner et al., 1989], [Evans, 1989] to ease the exchange of GPS data, from 60 GPS receivers of **4 different manufacturers**.

Extract of the first version of RINEX

The ideal case would be if the receiver manufacturers themselves developed the necessary software to translate the raw data of their receivers into RINEX because probably nobody else knows their receiver better.

2. **RINEX 2** came in 1990 to include tracking from **different satellite systems**, such as GLONASS and SBAS
3. **RINEX 3** was introduced in 2007 to support **multi-GNSS observation** data storage, adding BeiDou, Galileo and QZSS, and tracking data from **space-born receivers**
4. **RINEX 4** was introduced in 2021 to **modernize of the GNSS Navigation message** format and add necessary clarifications and **new observations codes**.

This is the current format and is normally updated on a yearly basis.

The RINEX Committee meets at least once a year to discuss extensions to the format to accommodate the changing needs of the GNSS community.

Lessons learned from the RINEX experience:

- **Definition and maintenance** of the format is non-trivial, and **requires a continuous** effort to keep up with the GNSS Providers ICDs and to agree on a common, easy-to-read, easy-to-exchange standard
- **Heterogeneity and neutrality** of the group responsible for the maintenance of the format is key: it is based on 1) the needs and 2) the expertise of the geodetic community (scientists, academia, agencies, professionals), industry, and the receivers' manufacturers and software developers.
- It requires the **collaboration of the receivers' manufacturers** to output the receivers' data in the agreed common format and to develop translators when necessary.
- It requires the **receivers' operators to output the data in the agreed format**, being them stations or space-borne receivers' operators, or at least provide all the necessary information to do it

The RINEX Experience 2/2

Lessons learned from the RINEX experience:

- It requires **agreement in the naming of RINEX files** to avoid confusion, duplication and to help in identification, now and in the long term. This can be either following the RINEX format standard recommendations or some other project naming agreement.
- It requires **agreement in the storage of RINEX files** in a reliable Data Center that properly caters for all intended users so that data is not lost. Data Center have the responsibility to maintain the data accessible for state-of-the-art in GNSS data processing and historic data re-processing.
- In IGS, **RINEX follows the open data policy**, as well as any other data or product

Parallelism between Earth and Moon “RINEX”

RINEX: definition and purpose

- RINEX stands for **Receiver INdependent EXchange format**
- It is the geodetic data interchange format for raw satellite navigation system data – GNSS + Augmentation
- Its application is (mostly) for post-processing purposes:
 - Validation and refinement of receiver’s navigation solution
 - Scientific applications (e.g., geodetic, Earth observations)
- It is used to store:
 - Observations data records:
 - Pseudoranges
 - Carrier-phase
 - Doppler
 - Signal-to-noise ratio
 - Navigation Messages:
 - Ephemerides of GNSS satellites
 - System Time Offsets
 - Earth Orientation Parameters
 - Ionospheric Model parameters
- It ensures consistency of the data for all GNSS constellations and all GNSS receivers

LUNEX: preliminary definition and purpose

- LUNEX stands for **Lunar Unified Navigation EXchange format**
- It shall be the selenodetic data interchange format for raw satellite navigation system data – Lunar Navigation System + Augmentation (+ GNSS ?)
- Its purpose will (mostly) be for post-processing purposes:
 - Validation and refinement of receiver’s navigation solution
 - Scientific applications (e.g., selenodetic, Moon observations)
- It shall store:
 - Observations data records:
 - Pseudoranges
 - Carrier-phase
 - Doppler
 - Signal-to-noise ratio
 - Navigation Messages:
 - Ephemerides of Lunar Navigation satellites
 - System Time Offsets (e.g., to UTC, to LCNS, to GNSS)
 - Moon & Earth Orientation Parameters
 - ...
- It shall ensure consistency of the data for all Lunar Navigation constellations and all Lunar Navigation receivers – and GNSS ???

The GNSS format Standard

Open Questions:

- *Technical aspects*
 - **How will the new Lunar Unified Navigation EXchange format look like?**
 - many similarities and duplication of RINEX could be expected
 - **Will Moon receivers track both Lunar Navigation Systems and GNSS?**
 - shall a common format be defined, or RINEX evolved?
- *Programmatic aspects*
 - **Who will define, maintain and coordinate the new standard?**
 - **Who will ensure consistency and coordination of its exploitation?**
 - **Will the data be open to the scientific community?**
 - this is the only efficient way to ensure collaborations and interdisciplinary contribution to Science, industry, and system providers

The Lunar Navigation format Standard

Recommendations:

- **Creation of a neutral entity responsible for the definition and maintenance the ONE standard**, from the very beginning (now!)
→ the entity could (should) coordinate much more, such as precise products, satellite/stations metadata, feedback from & to scientific community etc.
- **Early publication of Lunar Navigation System ICDs** to allow a timely format definition
- Aim at a possible shift of paradigm with respect to RINEX: **Aim to define the standard before the signals are available**
- Encourage the **Lunar Receivers manufacturer to adopt ONE common standard format** and **provide the tools** to generate it
- **Explore applicability of other formats** (e.g., CCSDS Tracking Data Message)

IGS goes to the Moon?

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IGS

Previous IGS Presentation
at Cislunar Workshop 2025

[IGS goes to the Moon?](#)



<https://igs.org/wg/rinex/>



NASA

LunaNet Interoperability Specification (LNIS)
[LunaNet Interoperability Specification – Version 5](#)

Thank you!