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LunaSAR Basics

Bottom Line Up Front
GSFC developing Lunar Search and Rescue (LunaSAR) as an internationally-compatible distress notification and tracking system architecture for use with lunar users exploring the Lunar South Pole and cislunar space

LunaSAR goal is to provide **persistent**, **reliable**, and **accurate** distress notification with both Independent Location (non-PNT) and Encoded Location (PNT-enabled) capabilities

Key element of architecture is use of varied navigation solutions to allow for rebroadcasting of location-tagged distress data and use of nav-service-enabled forward link messaging services (akin to terrestrial return link services) – **maximum reuse of terrestrial PNT/SAR methodologies**

**Key areas for partnering and integration include:**
- Distress message contents and standardized preambles
- Nav service forward-link message structures & decoding
- Radiofrequency direction-finding / geolocation of LunaSAR RF signals

Current and future planned Lunar PNT Services are a key element of cost-effective Search and Rescue communications
Lunar PNT Forward Links across varied space segments (LCRNS/NASA, LNSS/JAXA, Moonlight/ESA) provides critical acknowledgment and forward link communications during LunaSAR use.
LunaSAR Recent Accomplishments / Updates

• **Space Frequency Coordination Group Agreements**
  – Attained agreement with SFCG to use 2299 MHz for Lunar Search and Rescue distress transmissions moon-wide for operations within and outside the SZM
  – Attained agreement within the SFCG held July 2022 to use the 406-406.1 MHz frequency band for LunaSAR services outside of the Shielded Zone of the Moon (SZM)
  – Key steps in regulatory framework for non-terrestrial search and rescue services, opening doors for governmental and commercial engagement for service provisioning

• **Hardware-in-The-Loop Capabilities Under Evaluation**
  – Benchtop & board-level work underway for LunaSAR message formulation and S-Band transmittal using lunar-rated hardware components based on biomedical and lunar rover rollover-triggered events
  – End-to-end distress alerting and responses to be evaluated in Lunar Orbiting Signal Testbed (LOST) development environment at the Goddard Spaceflight Center
  – Underscores a phased approach to distress notification services aligned with government and commercial lunar exploration plans
GNSS-Enabled SAR Today – C/S Two-Way Comms

- **GNSS Enabled SAR – SAR/Galileo**
  - SAR/Galileo currently implementing “Return Link Messaging / RLM” enabling two-way communications with Cospas-Sarsat beacons
  - Users indicate distress / message their status via Cospas-Sarsat uplink (406 Mhz) and receive acknowledgement via PNT signal downlink
  - Specific RLM bits allocated in Galileo PNT Signal-In-Space specifications

- **Parallels to Lunar Search and Rescue**
  - Lunar PNT systems developed in compliance with LunaNet Interoperability Specification (LNIS) offer ability to on-ramp PNT signal-in-space enabled forward link messaging for LunaSAR purposes
  - Lunar beacons will uplink to PNT satellites at 2299 MHz and receive downlinks on assigned PNT forward signal frequencies
  - SAR message acknowledgment and SAR coordination response messages under development within Appendix Document 7 (AD7) under LNIS effort

Note: Images from SAR/Galileo Service Definition Document
LunaSAR Distress Message Format

LunaSAR message format totals approximately ~350 bits including provision for encoding PNT-provided time and location data as well as Rotating Fields.

Common Distress Message format allows for international interoperability and partnering.

LunaSAR Message Format modelled after terrestrial Cospas-Sarsat beacon message structures and industry best practices to allow for small message size and ease of implementation across varied service providers.

LunaSAR Message Format
Preamble
Fixed Header w/ Location, Time, PNT Source, etc
Rotating Field(s)

Text Messaging
Telemetry Triggered Msg
Biomedical Triggered Msg
Etc....

Currently assuming PNT services formatted in NMEA format like current terrestrial GNSS receivers.
Key Interface Areas w/ Lunar PNT Providers

- **Uniform Allocation of Distress Forward Link Bits Among Interoperable PNT Providers**
  - For cross-provider interoperability, standardization of Forward Link Message Content for LunaSAR needs baselining and agreement
  - Current benchtop evaluations assume a NMEA-0183-like message from a Lunar PNT receiver for simplicity
  - LNIS AD7 document details distress message, but Acknowledgement and Forward Link responses currently not-yet defined
  - Key element for cross-provider services specifically for search and rescue comms

- **Standardized Distress Message Alert / Response Message Set**
  - Based on Cospas-Sarsat Two Way Communications (TWC) formulation, standardized alert message and response catalog needed for effective distress communications
  - Standardized messages allow for cross-provider integration in a sparse satellite environment and fielding of user terminals compliant across varied PNT space segments akin to current Cospas-Sarsat TWC plans
  - Message content / mapping is a first step for operationally-relevant LunaSAR capabilities enabled with lunar PNT services