Distress Monitoring and Tracking for The Next Generation of Lunar Exploration

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Bottom Line / Objective(s)

Bottom Line Up Front

GSFC Lunar Search and Rescue (LunaSAR) team is developing an international, community-wide distress notification and tracking beacon system architecture for use with lunar surface user engaged in exploration in the Lunar South Pole and other areas

Current breadboard work has focused on development of appropriate distress tracking waveforms and frequency allocations for lunar and future Martian SAR services

LunaSAR concept goal is to provide **persistent**, **reliable**, and **accurate** distress location and notification services to lunar surface users and human-tended surface mobility elements.

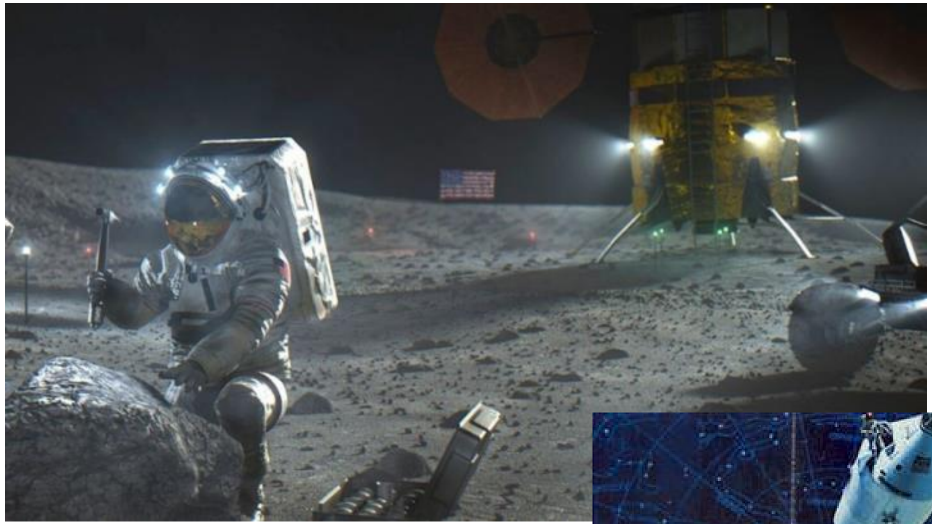
Key element of beacon architecture is use of surface and orbital PNT solutions to allow for determination of location and rebroadcasting of distress data (plus location information) on dedicated distress notification frequencies

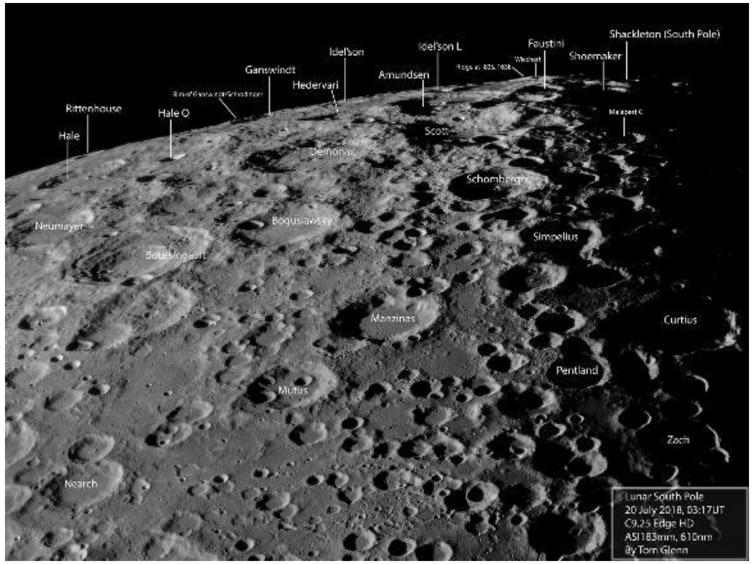
Key areas under investigation and integration are space element (LunaNet) and overall surface conops in order to define dedicated distress frequencies / waveforms for lunar surface operations. Primary gating function/path is performance of analysis on waveform, bandwidth and frequency allocation definition with NASA Lunar Spectrum Management Team.

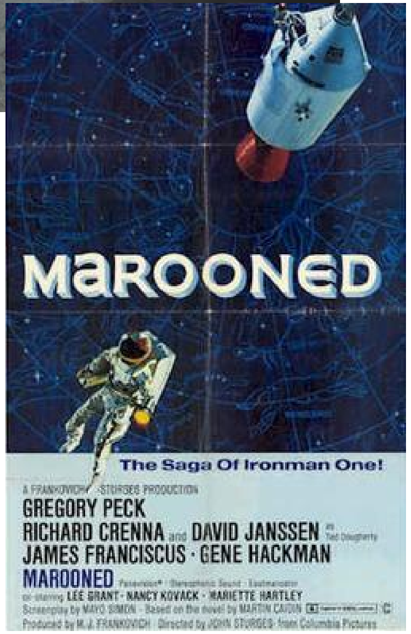
SAR

Lunar Surface Rescue – Why?

- Artemis (and commercial, civilian, and other government) exploration at the Lunar South Pole presents unique terrain and lighting challenges driving an increased risk posture
- Much like the maritime industry, provision of a cislunar and lunar surface distress tracking/notification system a key element of <u>safe</u> exploration and development of space-faring nations' <u>appropriate</u> rules of behavior
- NASA Agency-Level requirement to give **capability to safely abort lunar surface operations, including EVA, and execute all operations required for a safe return to Earth**.
  - Use cases include **incapacitated crew rescue** (ICR), necessitating **accurate** and **timely notification of a distress event** prior to crew member expenditure of life support consumables (within 1 hour).
- Rescue requirements include the initial location determination of injured crew members, same as international Personnel Recovery (PR) policy
- Other US Government agencies have national level policy/draft requirements for future personnel recovery in the lunar domain…a "whole-of-government" desire for enabling capabilities
- GSFC-funded Aerospace / HEOMD trade study in work to determine the current and near-term operational requirements







Relevant, and timely capability development enabling automated distress tracking and notification for a growing ecosystem of lunar surface users

LunaSAR Operational Objectives

- LunaSAR architecture looks to leverage 40+ years of global SAR operations to provide:
  - Capability for automated distress tracking of surface explorers
  - International cooperation on lunar distress messaging standards
  - Close integration of a standardized distress message into current surface “mesh”/relay concept, and NASA Lunar Comm and Nav Relay Service (LCRNS) development with commercial industry
  - Surface geolocation and rebroadcast for a wide range of landing sites / areas, specifically the Lunar South Pole during distress events
  - Near-term development of a developmental test objectives for use in a 2027-timeframe potential test on the lunar surface
  - Integration into Lunar Base Camp planning, using Lunar Base Camp as a rescue coordination hub for 2+ crew EVAs

LunaSAR Concept Overview

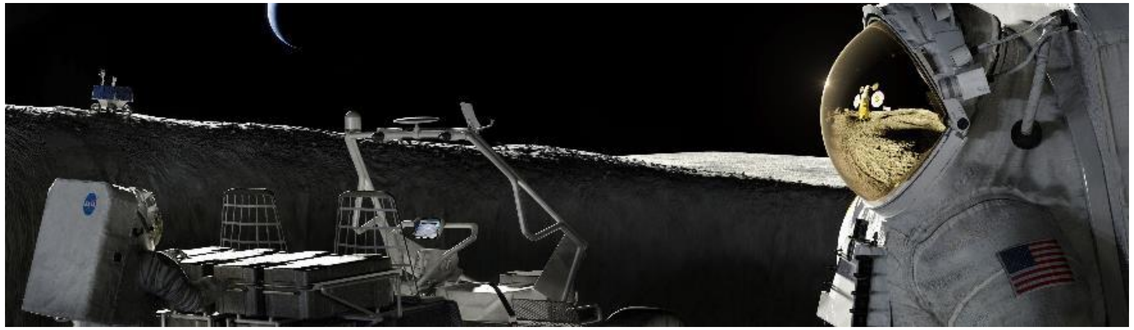
- Lunar Search & Rescue (LunaSAR) architecture modelled after current Cospas-Sarsat system, and maritime industry's Global Maritime Distress Safety System (GMDSS)

- Users in distress can indicate distress status, with health and telemetry data sent via dedicated UHF and S-Band distress frequencies defined by NASA and International Telecommunication Union (ITU)

- LunaSAR will enable secure bi-directional lunar messaging capability (think of a SPOT beacon on the moon)

- LunaSAR encompasses the following segments:
  - User Segment - surface beacons / emitters
  - Cislunar Space Segment - cislunar PNT/comm segment, the intermeshed cislunar network (LunaNet) and Direct-to-Earth (DTE) capabilities
  - Notification Segment – rescue coordination / information dissemination, either earth, lunar or lunar-orbiting

- Initial Operating Capability (IOC) may look different than a Final Operating Capability (FOC)
  - IOC may rely on existing frequency allocations and software prioritization of distress messages versus dedicated frequency allocations
  - FOC ideally will tie into dedicated lunar spectrum allocations
  - IOC to FOC transition mirrors same processes seen in historical use of Cospas-Sarsat beacons from 1982 to today



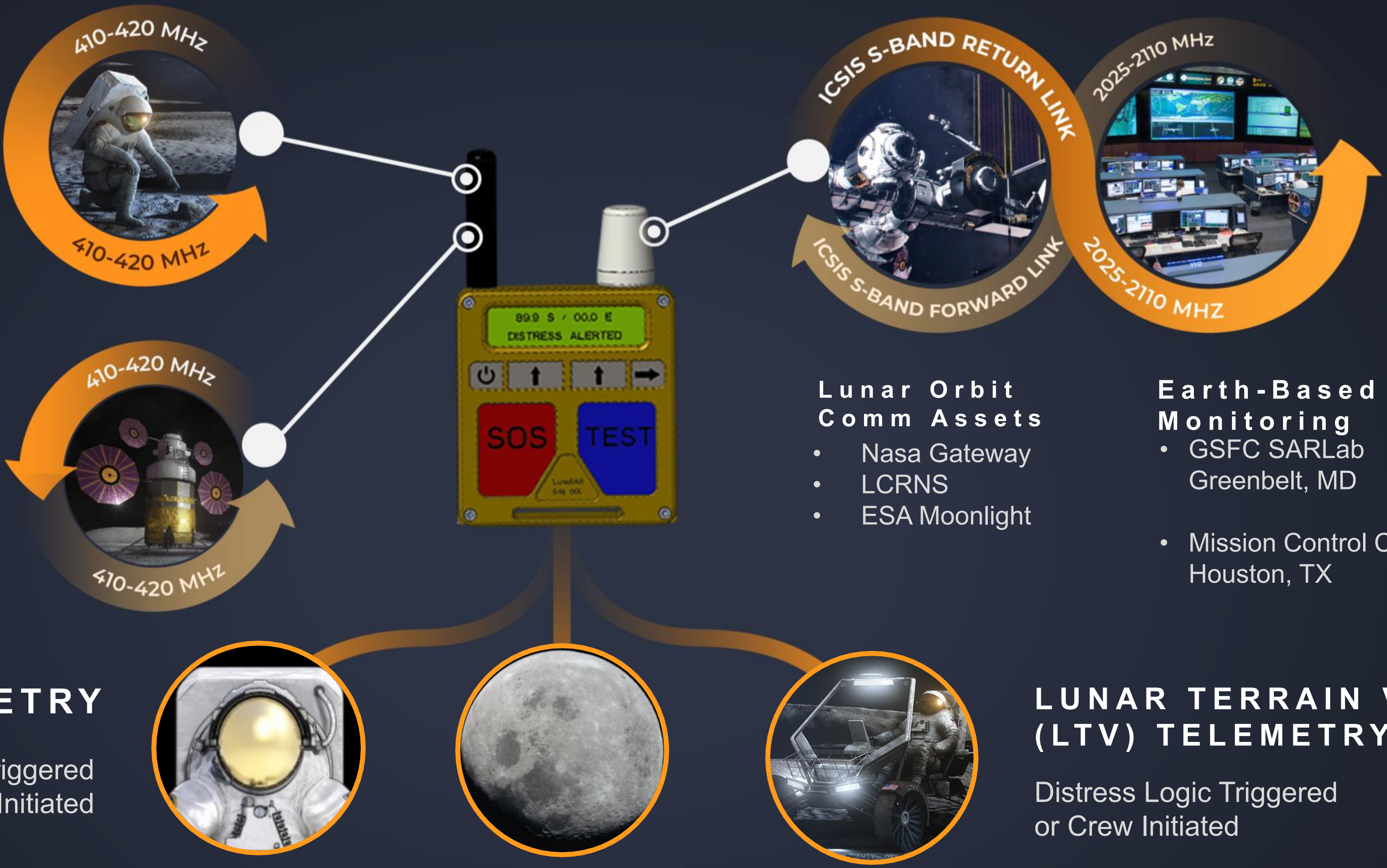
On-Ramping Pathway / Considerations

- SAR Coverage will exist, leveraging varied Lunar PNT types
  - SAR architecture open to surface based triangulation and S-Band “signals-in-space” GPS-like navigation
- LunaSAR message formats as proposed provide low data-rate backup to suit and/or vehicle communication systems, including encryption for biometric data
- LunaSAR as an element of LunaNet broadcast services provides safety tracking of assets/crew beyond the horizon, enabling safer science exploration
- LunaSAR team currently looking at examples of user-initiated distress messaging, providing a safety net for crew who may become incapacitated or unable to move

LunaSAR Comm Paths

PARTNER ASTRONAUT(S)

SURFACE ELEMENTS



Lunar Orbit Comm Assets

- Nasa Gateway
- LCRNS
- ESA Moonlight

Earth-Based Monitoring

- GSFC SARLab Greenbelt, MD
- Mission Control Center Houston, TX

SUIT TELEMETRY

Distress Logic Triggered or Crew Initiated

LUNAR PNT

LUNAR TERRAIN VEHICLE (LTV) TELEMETRY

Distress Logic Triggered or Crew Initiated

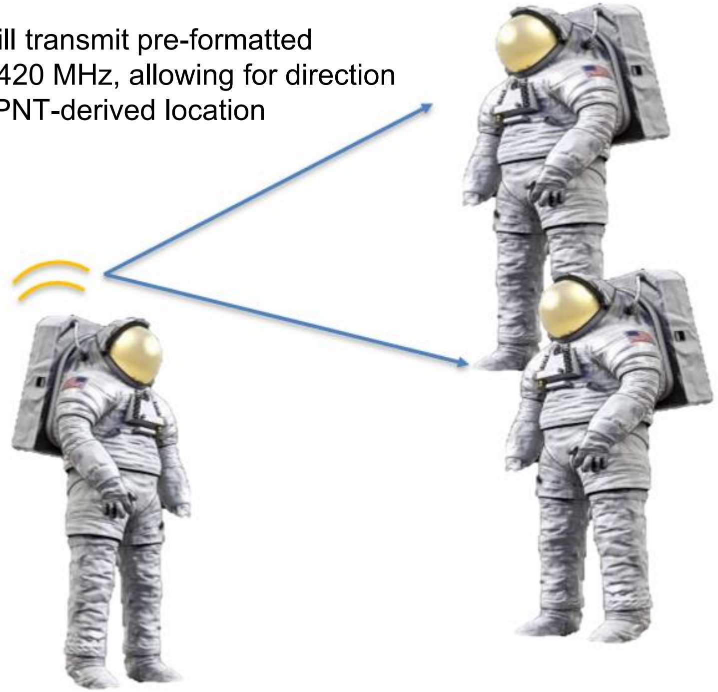
Note - Beacon Handset Notional Concept

Dual-Mode Conops (UHF & S-Band)

UHF-Surface Transmissions
(Local Data Transmission & Homing)

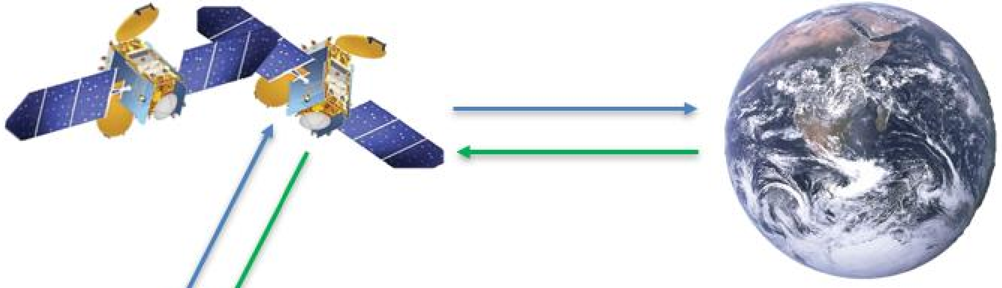
Current **Initial Goal** is to enable UHF point-to-point surface transferal of information as well as potential swept-tone transmission for localized direction finding

LunaSAR beacon will transmit pre-formatted messages on ~410-420 MHz, allowing for direction finding & display of PNT-derived location



Localized direction finding – key to the "last 100 yards" of a SAR operation, especially in a Position, Navigation, and Timing (PNT)-degraded environment

S-Band Transmissions
(Bi-Directional Messaging Capability)



Current **Target Goal** is to enable Return Message Service (RMS) bi-directional distress messaging using "Rotating Field" element of message transmissions and encoded PNT data

Lunar surface user could send pre-formulated "canned" messages via handset, and receive responses from Lunar or Earth-based SAR coordinators/responders

System modelled after Cospas-Sarsat Return Link Service (RLS) on European Galileo satellite SAR payloads

Assured survivor communications – key to bringing the right survival/medical/technical supplies in a timely manner

SAR

Notional Message Formatting

Field	CBOR Byte	Value	Description	Comment
CBOR Item Header	0	0x8F	Intentionally left blank	CBOR: list of 15 elements follows
Message Version Major	1		Allows room for future development and legacy version compatibility	Message Version Type major revision, allowable values 0-23 (CBOR short)
Message Version Minor	2			Message Version Type minor revision, allowable values 0-23 (CBOR short)
CBOR Item Header	3	0x1a	Intentionally left blank	CBOR: uint32_t follows
Time	4..7		GNSS Epoch time rounded to nearest second (or fraction of second)	Intentionally left blank
Priority Tag	8		Single bit denoting high-priority message	Priority Tag encoded as CBOR True/False type
CBOR Item Header	9	0x46	Intentionally left blank	CBOR: 6 byte binary string follows
Encoded Location	10..15		Identical to terrestrial Cospas-Sarsat message configuration, lat/lon converted to binary	47 bit C/S T.018 location encoding stored in least significant bits (LSB) of 6 byte field, big-endian
PNT/Location Source	16		Detailing source of encoded location - the LunaNet constellation, or surface-derived via surface beacons, etc	PNT/Location Source and PNT Receiver Status bitpacked into LSB of one byte CBOR unsigned integer type short count
Triggering Event	17		Manual, telemetry actuated, fall detection, etc.	Triggering Event enumerated with one byte CBOR unsigned integer type short count
Condition Stage/ Rotating Field Identifier	18		4-bit designator for variety of distress messages pre-allocated per TBD international spec	Condition Stage/ Rotating Field Identifier bitpacked into LSB of one byte CBOR unsigned integer type short count
CBOR Item Header	19	0x19	Intentionally left blank	CBOR: uint16_t follows
Country Code	20..21		Country Code stored in uint16_t	Intentionally left blank
Homing Device Feature	22		Denotes homing feature active/included, Return Link Service, and Test Protocol Active	Bitpacked into LSB of one byte CBOR unsigned integer type short count
CBOR Item Header	23	0x19	Intentionally left blank	CBOR: uint16_t follows
Beacon ID	24..25		Denotes assigned user of radio, i.e. a specific rover, EVA participant	Intentionally left blank
Beacon Type	26		Denotes category of beacon (EVA, rover, etc)	Beacon Type bitpacked into LSB of one byte CBOR unsigned integer type short count
CBOR Item Header	27	0x18	Intentionally left blank	CBOR: uint8_t follows
TX Message Sequence	28		Incremental Message Counter for Message for the Transmitter	Intentionally left blank
CBOR Item Header	29	0x18	Intentionally left blank	CBOR: uint8_t follows
RX Message Sequence	30		Incremental Message Counter for Message for the Receiver	Intentionally left blank

Preamble
(50 Bits)

Fixed Header
w/ Location, Time, PNT
Source, etc

Rotating Field(s)

Text Messaging Slot

Heart Rate Trigger

Suit Pressure Trigger

Surface Radiation Trigger

Etc.…

LunaSAR Message Format modelled after terrestrial Cospas-Sarsat beacon message structures coupled with Concise Binary Object Representation (CBOR) to allow for relatively small message size and ease of implementation across varied service providers

Currently assuming PNT services formatted in NMEA format like current terrestrial GNSS receivers

FY21 into FY22 Thrust Efforts

- FY21
  - Successful NASA Internal R&D Effort to develop prototype LunaSAR beacon using Space-Rated target hardware
  - Development of community-wide standards for message format and beacon performance
  - Release of Interoperability Standards at part of LunaNet US Govt / Commercial Industry engagement
- FY22
  - System level emulation and analysis of LunaSAR beacon/transceivers for use on lunar surface
  - Benchtop testing of distress message transmission and formatting
  - Field testing of prototype hardware devices with NASA UHF-band ground station

Questions & Comments

Please Reach Out With Questions & Comments

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