Need for international cooperation and collaboration for safe and sustainable Moon operations

by

Tommaso Sgobba
IAASS Executive Director

60th STSC COPUOS

Wednesday 8 February 2023

International Association for the Advancement of Space Safety

Scope

This presentation will concentrate on the need of international cooperation and collaboration in the field of Lunar Search and Rescue as "common denominator'' of any Moon mission safety program.

"Cooperation" would serve the interest of each country by ensuring the availability of extra resources to help their astronauts in distress, while "collaboration" refers to the organized team efforts in case of emergency.

While international cooperation and collaboration for emergencies on Earth is widely available with no restrictions (Cospas-Sarsat, ISMERLO, Arctic and Antarctic), Lunar Search and Rescue is affirmed in principle (OST, Artemis Accords) but not (yet) pursued in practice because of some national legal barriers. **This is a matter of great urgency** because the development of lunar systems has started, and SAR capabilities need to be part of the design and development activities since the beginning, otherwise it will be almost impossible to introduce them retroactively.

International Lunar SAR & Space Governance

However, Lunar SAR is only one of the many space safety and sustainability issues that require international cooperation to be adequately controlled (e.g., risks related to launch and re-entry operations, as well as Earth and Moon space debris proliferation control and space traffic management).

Space is in dire need of good governance. To produce good governance, wide consultation and agreement between all space faring countries is needed. If space governance can neither be agreed upon nor enforced, then space exploration could significantly further increase competition and geopolitical tensions between countries, instead of contributing to lower the tensions.

Introduction: the need for Lunar SAR

Year 1969

On July 20, 1969, the NASA Apollo 11 astronauts Neil Armstrong and Edwin "Buzz" Aldrin became the first to walk on the Moon. But landing was only half of the mission. There was a 10 % chance of failure of the single engine of the ascent vehicle. President Nixon had a contingency plan ready that did not involve rescue. If the ascent engine failed, the Apollo Command Module with Collins on board was to return to Earth leaving Aldrin and Armstrong marooned on the Moon. President Nixon, had a speech ready in advance:

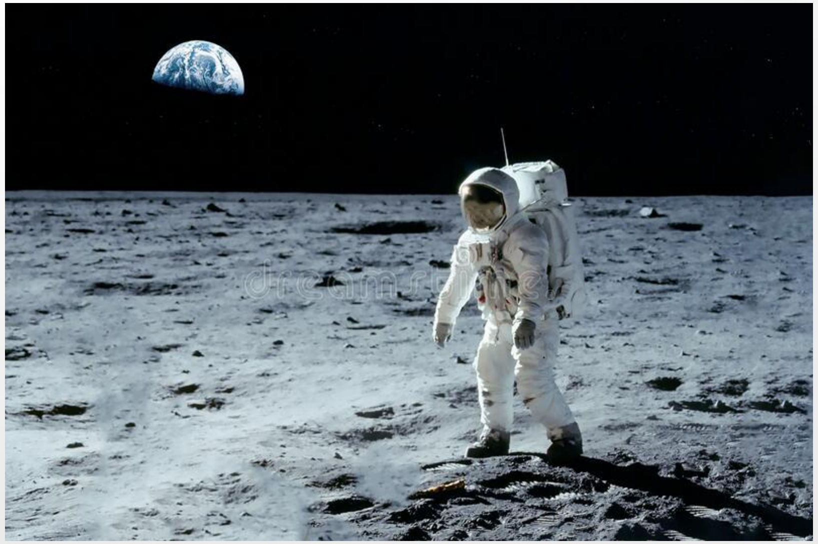
"Fate has ordained that the men who went to the Moon to explore in peace will stay on the Moon to rest in peace. These brave men, Neil Armstrong and Edwin Aldrin, know that there is no hope for their recovery…"

Introduction: The need for Lunar SAR (cont'd)

Fast forward to year 2035

Thankfully, the Nixon's speech was never required, and the Apollo 11 crew returned home safely. Now imagine a different outcome few years from now. Hypothetically in the year 2035.

Imagine that a European crew is stranded on the Moon because their ascent vehicle failed. They cannot be helped from their orbiting module or get rescued from Earth before their supplies are finished. However, there is a Chinese mining colony on the Moon at 50 km distance, well beyond the half kilometer that a fully suited astronaut can cover by walking before becoming exhausted by fatigue…



Introduction: the need for Lunar SAR (cont'd)

…Year 2035

…Assume that there is no shared satellite-based or radio communication system on the Moon to call for help. Or even if the request for help reaches the colony via Earth, they have no rover (or other mobility system) for covering a rescue round trip at that distance, or they have the vehicle with the range, but it can carry only one astronaut at a time as passenger. Or the rover has an old-fashion navigation system based on inertial platforms which is fine at short distances for the miners to reach the colony nuclear reactor at 2-3 km from the habitat, but it could accumulate error on longer distances with the risk that the rescue team itself could become lost. Also consider that the maximum speed of a Moon rover is about 11 km/h when following a known safe path. Finally, even if the stranded European astronauts can be brought safely to the Chinese colony, their space suits would not be compatible with the airlock interfaces to access the habitat. In one way or the other, the story would end up in a disaster because of lack of a search and rescue capabilities.

LUNAR POTENTIAL ACCIDENTS

Lunar hazards

On the Moon surface there are many hazards:

Functional

Operational

Environmental

that could lead to emergency and SAR scenarios.

Functional hazards

There are all kind of systems failures possibly leading to an emergency, including mobility systems failures, failures of EVA suits, failure of descent/ascent vehicles, depressurization/fire/toxicity of habitats. Not to mention that there will be radioisotope power systems (RPS) and fission reactors for electric power generation and heating on the Moon bringing their own unique hazards of exposure to ionizing radiation.

Operational hazards

Disorientation and misjudging distances and sizes can easily happen on the Moon, increasing the risk of following unsafe paths.

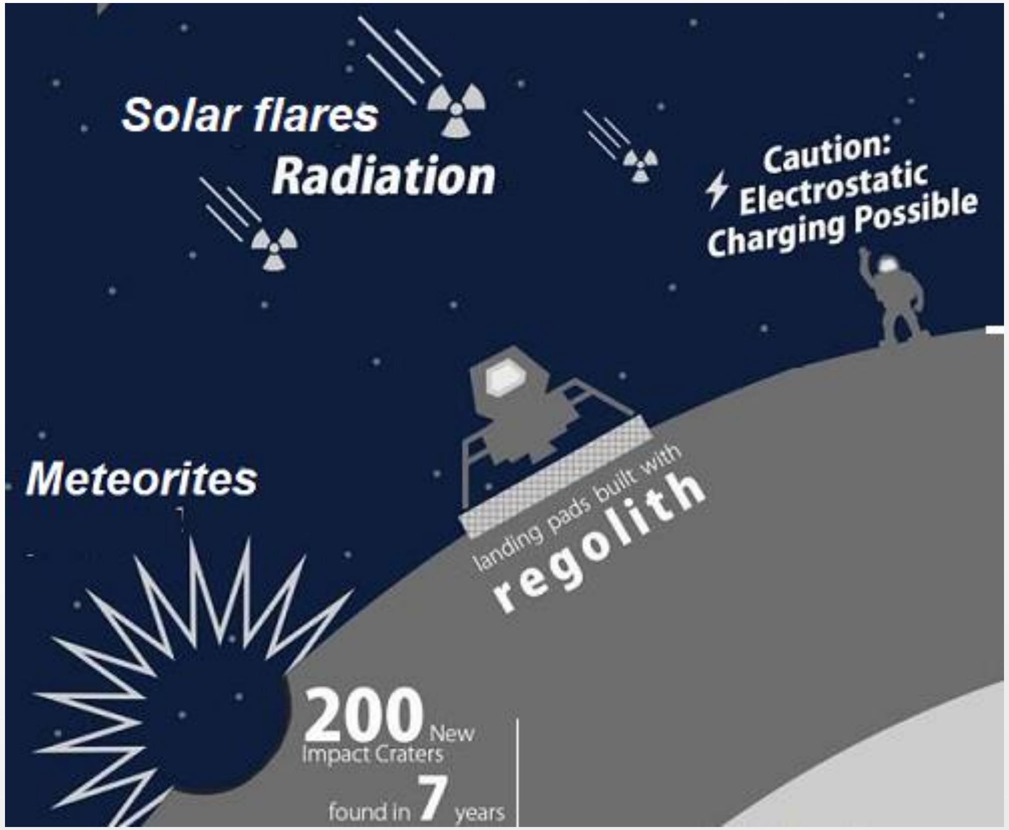
a) The first reason is that the Moon horizon is closer than on Earth and there is a general lack of landmarks. the Moon is about one quarter the size of the Earth and therefore the surface of the Moon is more curved than the Earth and the horizon is physically closer.

b) But there is a second reason everything on the Moon looks so close, there's no air. On Earth, when we look at objects far away in the distance, the air between us and them gets thicker the farther away they are. Now, it's not always hazy, but it's not always perfectly clear either. There's always at least a little haze, even on the clearest day, which makes the mountains in the distance look a little bluer. Not so on the Moon. There's absolutely no air, so there's absolutely zero haze, so everything on the Moon looks the same distance away, no matter how far it is.

Environmental hazards

The Moon's surface is exposed to solar wind and solar flares produced by the Sun, and to galactic cosmic rays. Solar flare's individual particles possess high energies. It is not yet possible to reliably predict solar flares and only very short reaction time is allowed. The radiation from a solar flare can be fatal for astronauts outside a protective shell/shelter.

Meteorites fall constantly on the Moon but differently from Earth they do not break and (partially) vaporize during entry because there is no atmosphere on the Moon.



The ejecta created by a meteorite impact can travel up to several kilometers due to low Moon gravity, and constitute themselves a hazard (e.g., puncturing EVA suit, pressurized system, etc.)

Moon dust hazards

Depending on whether it is from the equator or highlands or the dark side, Moon dust may look and behave differently. For example, the sun-facing side is constantly exposed to solar radiation. Because of that, dust on the day side has a positive electrical charge. This solar charging means that the dust clings to everything. `

Moon dust generate hazards of the three categories above.

- It is damaging to everything from lunar landers to spacesuits (*functional hazards*);
- can damage human lungs if inhaled (*environmental hazard*).
- can hamper visibility (*operational hazard*).

When astronauts enter a lunar habitat, dust can get everywhere. It can clog mechanisms, interfering with instruments, and cause radiators to overheat.

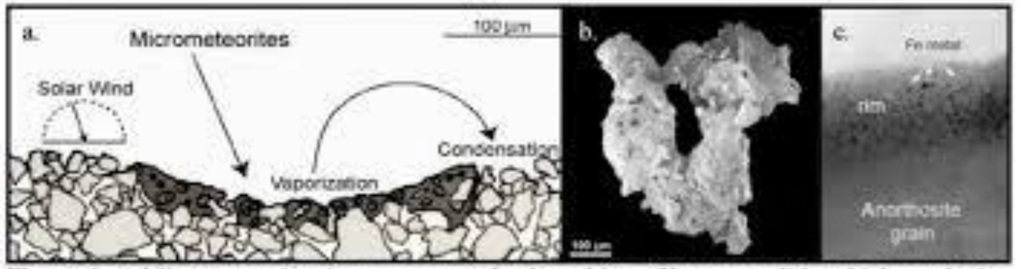


Figure 1. a) Micrometeorites impacts cause shock-melting of lunar regolith, which results in vaporization and re-condensation. b) Particle of lunar regolith showing sharp, jagged edges, as viewed by electron microscopy. c) Lunar dust contains nano-scale size deposits of metallic iron ("nanophase iron"). Images courtesy of Lawrence Taylor and David McKay.

NEEDED LUNAR SAR CAPABILITIES

Communication & Navigation

There is no magnetic field on the Moon, and therefore no simple instrument like a compass for orientation. A Moon global navigation satellite system (GNSS) is the obvious solution, but it is expensive, and the service should be non-monopolistic and cooperative.

Currently, NASA and ESA have conceptualized the initial framework for a Lunar GNSS. NASA is developing its own cislunar satellite-based communication and navigation network, LunaNet. ESA is implementing two projects, Pathfinder and Moonlight. ESA is exploring the feasibility of using the signal from the Earth GNSS for Lunar navigation. NASA is exploring a similar concept in cooperation with the Italian Space Agency.

Distress tracking and messaging

Lunar SAR capabilities must include a key system that enables automated distress tracking and notification to locate and help the crew in distress. Current development at NASA takes advantage of lessons learned in SAR's creation of terrestrial Advanced Next-Generation Emergency Locator (ANGEL) beacons, it includes distress messaging standard format definition.

The NASA Orion capsule will use the ANGEL beacons also for astronauts search and rescue at sea. In case after the capsule splashdown there is an emergency and the astronauts need to egress into the sea, they are equipped with ANGEL beacons to ensure their quick recovery by the responsible SAR service (the U.S. Coast Guard in the United States).

Surface Mobility

Surface mobility has been considered since the time of the Apollo program including systems developed and flown (Moon buggy) and concepts developed/tested but not flown (Moon scooter). Generally, the design drivers have been lunar geology, soil, and slopes for scientific exploration. With a top speed of about 11 km/h, and uncertainties about the paths ahead, such vehicles may not be ideal for Lunar SAR.

A specialized category of fast vehicles, including the capability of transporting injured astronaut should be considered, as well as the identification and maintenance using AI of safe paths (e-roads) between habitats and locations of interest.

International surface docking standard

Existing international docking standard allows the transfer of astronauts suited for internal activities (i.e., short sleeves) between spacecraft in flight. An evolution of such standard should be developed for docking on the Moon surface of pressurized vehicles.

EVA standardized access/egress to/from pressurized habitats

A major issue is that there are no standards to allow astronauts suited for EVA (Extra Vehicular Activity) access/egress to/from surface habitats (or to transfer EVA suited astronauts between vehicles in close proximity but not docked). The items that should be standardized are:

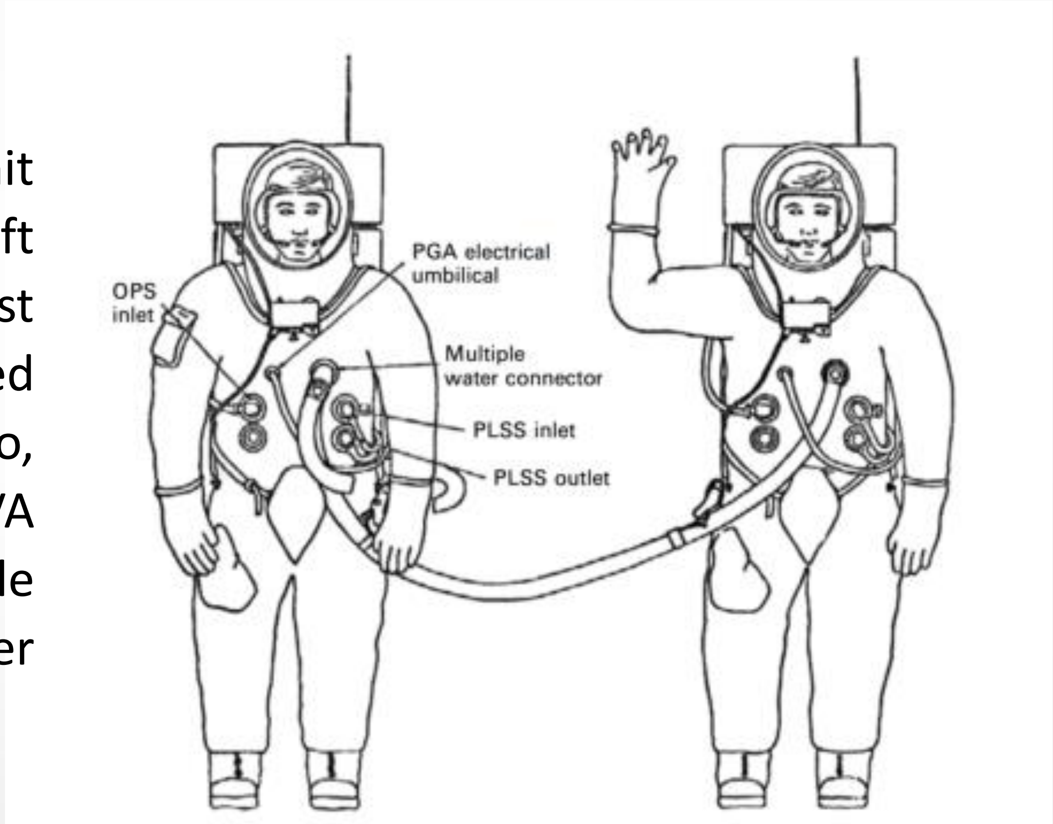
- Dust mitigation measures and protocols for dust removal
- Airlock hatch (minimum) dimensions
- Life support interface control panels and umbilicals interfaces
- RF communication between EVA crewmembers, spacecraft and ground

Pre-breathe protocols (to allow differently EVA suited astronauts to egress a Moon habitat at the same time).

Issues related to access/egress of incapacitated astronauts.

Standard EVA-to-EVA suits Interfaces

The EVA space primary function is to permit routine operations outside of a spacecraft pressurized environment. In addition, it must allow emergency support between EVA suited astronauts. In an international rescue scenario, interoperability is required such that an EVA space suit system of any national origin is able to provide emergency support to any other space suit system regardless of its origin.



Apollo Buddy System

LUNAR SAR WAY AHEAD

Lunar SAR elements

The implementation of Lunar SAR capabilities requires the development of the following elements:

1) Satellite-based communication and navigation systems.
2) Receivers and transmitters of distress radio signals. Processing, localization, and transmission of alert messages.
3) Development of international Lunar SAR Interoperability standards.
4) Performance of dedicated research and development activities.
5) Organization for coordinating and executing rescue operations.

Although the establishment of a single SAR organization for the development of the above five elements may seem the logical solution, the extension of the mandates of some existing international organizations to include Lunar SAR related activities may be productive and cost effective.

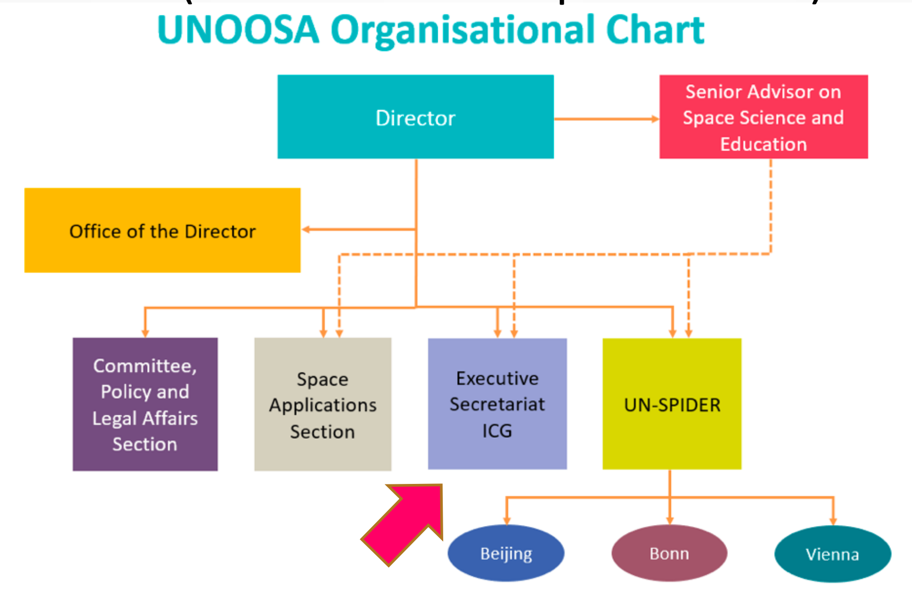
Point #1: Lunar SAR communication and navigation non-monopolistic and cooperative

NASA is developing its own cislunar satellite-based communication and navigation network, LunaNet. ESA is implementing two projects, Pathfinder and Moonlight. ESA is exploring the feasibility of using the signal from the Earth GNSS for Lunar navigation. NASA also is exploring a similar concept in cooperation with the Italian Space Agency.

Moon global navigation satellite systems are expensive to develop and maintain, and the service should be preferably **non-monopolistic and cooperative**. Therefore, the various Lunar communication systems should be compatible and interoperable.

Point #1: Lunar SAR communication and navigation non-monopolistic and cooperative (cont'd)

There is an ***International Committee on GNSS*** **(ICG)**, which has the mission to "facilitate compatibility, interoperability and transparency between all Earth satellite navigation systems", (service providers: USA, Russia, Europe and China) <u>The ICG mandate could be extended to include lunar communication and navigation systems</u>. **NOTE:** The executive secretariat of the ICG is provided by the United Nation OOSA (Office of Outer Space Affairs)



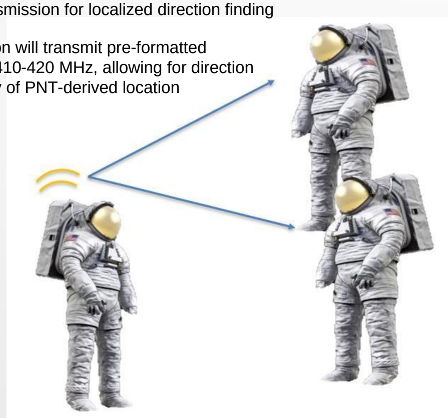
Point #2: Lunar SAR alert system part of Cospas-Sarsat Programme

The Lunar SAR alert system could become part of the current terrestrial Cospas-Sarsat programme because of commonality of technologies. **NOTE**: The NASA-GSFC Cospas-Sarsat team is currently working on the development of the LunarSAR system that uses a similar architecture and the same beacon technology and frequency of the terrestrial Cospas-Sarsat system.

UHF-Surface Transmissions
(Local Data Transmission & Homing)

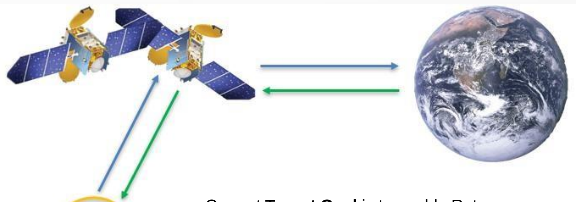
Current **Initial Goal** is to enable UHF point-to-point surface transferal of information as well as potential swept-tone transmission for localized direction finding

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

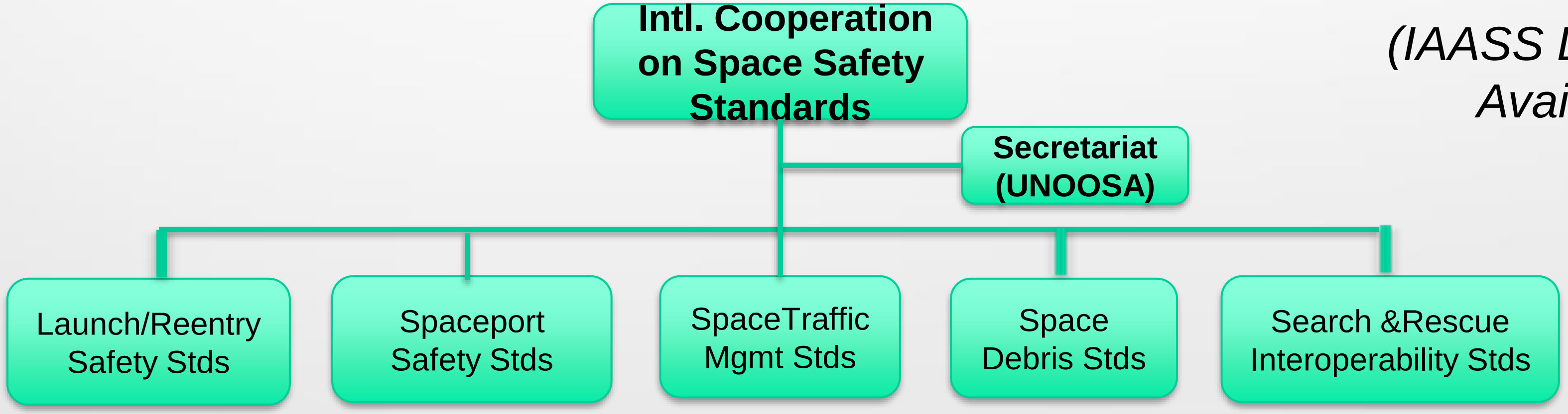
Lunar surface user could send pre-formulated "canned" messages via handset, and receive responses from Lunar or Earth-based SAR coordinators/responders

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

Point #3: Lunar SAR standards as subset of international space safety & sustainability standards

The development of Lunar SAR interoperability standards should be part of a wider space SAR standardization activity in consideration of the on-going expansion of the commercial human spaceflight industry. Furthermore, such standardization activity could be part of a wider international cooperation for space safety standards, including, launch and re-entry safety standards, space debris, ground space operations safety, and space traffic management. **The secretariat of such standardization cooperation activities it is proposed to reside at the United Nations OOSA** (Office of Outer Space Affairs).



(IAASS Draft MoU Available)

Point #4: Expand the IADC mandate to Include the Moon environment

In principle research in the fields related to space safety and sustainability is an institutional competence of space agencies. Moon hazards research would greatly benefit from international coordination and exchange of information

Currently there is a forum for the exchange of information and coordination of national research activities in the field of space debris, the IADC (Inter-Agency Space Debris Coordination Committee). **The scope of the IADC could be extended** to cover other space safety and sustainability topics of common interest, including **Moon hazards (manmade debris, meteorites, space weather, dust, etc.)**

Point #5: Lunar SSA & Lunar SAR collaboration

The establishment of a Lunar SSA (cislunar and on lunar surface) situational awareness is a necessary corollary of Lunar SAR. The countries operating crewed Moon mission will need to exchange information on their programs and have full awareness of any robotic spacecraft which approaches the lunar orbits or lands on the Moon. There should be also a catalog of location of any lunar systems, which has been disposed at the end of the mission.

The operational coordination of rescue operations, including plans for periodic training and exercises, should be established on the basis of bilateral or multilateral agreements between the interested countries. The agreements should include among others the principles and rules of rescue operations performance, for example roles and responsibilities of the parties during rescue operations, and all relevant legal agreements related, for example, to waiver of liabilities, costs, exchange of personal data, etc.

THANKS FOR YOUR ATTENTION