Executive Summary

This report outlines the necessity and proposed concept for a Lunar Accidents, Incidents and Issues Reporting System (LAIIRS), a comprehensive multi-stakeholder community-led platform aimed at documenting and sharing knowledge about accidents, incidents, and issues associated with lunar activities.

The revival of lunar exploration, exemplified by the over 30 missions planned by various space agencies and private companies, underscores the urgency for a coordinated effort to ensure safe and sustainable operations on the Moon. Historical space missions, like the Apollo Program, have demonstrated the potential for accidents and incidents, highlighting the need for a systematic approach to capture and learn from these events. Plans to build shared community infrastructure on the Moon further emphasise the need for coordination to ensure interoperability. Navigating these risks is complicated by the diversity of actors planning to operate on the Moon, each with their own interests and reputational concerns.

We propose creating a community-led, voluntary, confidential and non-punitive accident, incident, and issue reporting system called LAIIRS which:

- Records verified accidents, incidents, and issues related to lunar activities in an anonymised format,
- Notifies stakeholders affected by reported events to ensure continued safe operation, and
- Analyzes gathered data to identify common issues and trends, providing valuable insights for hazard analysis, mission planning and standard development for lunar operations.

This platform will allow for transparent and accountable operations on the Moon. By creating a centralized database of lunar mission accidents, incidents, and issues, LAIIRS will facilitate the sharing of critical safety information and knowledge, reducing risks, and enhancing the overall efficiency of lunar operations. This proactive approach aims to prevent long-term damage to the lunar environment and ensure the sustainable development of a lunar economy.

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Introduction

This work explores the concept of a comprehensive multi-stakeholder reporting system that logs accidents, incidents and issues linked with activities on the Moon: The Lunar Accidents, Incidents, and Issues Reporting System (LAIIRS). This report will provide background on the needs for such a system, outline our proposed concept for the system and a potential governance model, and present a roadmap for the next steps to develop this system.

The Case for A Lunar Safety Reporting System

Background

Recent missions such as Peregrine Mission One [1] and Intuitive Machines 1 [2] are indicating the eventual return of humans to the surface of the Moon. Over 30 lunar missions to cislunar space and the Lunar surface have been confirmed involving 15 space agencies (representing over 35 countries) and over 20 private companies at the time of writing [3]. These missions are fueled by global plans to develop and deploy a variety of technologies and demonstrations on the lunar surface as exemplified by the Global Exploration Roadmap [4], ranging from lunar landers to nuclear power sources to roving vehicles to greenhouses. The end goal is to support long-term uninterrupted human presence on the Moon and cislunar space.

While most of these efforts have been led by governments (e.g. NASA's Artemis campaign [5], NASA CLPS [5,6], and the Chinese Lunar Exploration Program [7]), the private sector has consistently increased their role and explored the use cases for the lunar environment. The involvement of both public and private actors from different countries presents unique challenges in coordinating efforts which have not been seen during the age of low earth orbit operations.

Past space missions have shown us that there is potential for things to go wrong, despite the best efforts of the designers and operators of these systems. These risks arise due to the complexity of the systems, the large number of disciplines involved, and the uncertainty in our knowledge of the environment we have to operate in. The closest comparator to the type of lunar activities we are seeing today is the Apollo Program which faced over 700 accidents and incidents from 1963 to 1971 in all phases of the mission ranging from ground operations, and launch to operating on the Moon [8,9].

Long-term human presence on the Moon will not be the first time human explorers have attempted to create a long-term presence in a new and less-known environment. Our past experiences here on Earth have shown us two things:

1. **When humans have attempted to explore an environment, they have inadvertently damaged that environment.** Damage to the natural environment of New Zealand [10], deforestation of Easter Island [11], operations in Antarctica [12], the broader impact of colonialism on plant distribution in our world [12,13], and exploration of the Americas and the damage to the rich culture and history of this continent that resulted from this lucrative endeavour [14] are all examples of the impact human exploration activity can have on an environment. Even within the space sector, the catastrophic and dangerous rise in space debris threats [15] showcases the importance of thinking ahead and coordinating efforts to document best practices.

2. In the face of increased interest and growing efforts to gain a foothold in new environments, **we have made mistakes, learned from them and then eventually created standards and regulations to not repeat the mistakes.** Safety regulations in the aviation [16] and transportation [17] industries, or even something as simple as a building code [18] are the results of these trials and errors, usually fueled by disastrous consequences of bad past decisions.

These past trends highlight the importance of coordinating efforts among different actors, establishing accountability mechanisms for these actors, developing processes to document errors, and gathering insights and lessons learned from different activities which can form the basis of community guidelines, standards and regulations, and enable sustainable exploration and development in the highly sought environment.

However, this process has historically taken a long time. It took around 40 years to develop serious regulations in aviation and essential building codes were not created until the 1940s. Considering the fast-paced, harsh and high-stakes environment of the Moon, it is evident that humanity cannot wait decades to institute standards, regulations, and coordination. In fact, issues faced in lunar orbital and surface operations during the HAKUTO-R M1 Lunar lander [19], Astrobiotic's Peregrine [20], Intuitive Machines lander [21], Israel's Beresheet Spacecraft [22] and KARI's Korea Pathfinder Lunar Orbiter [23] missions show not only the importance of acting fast to capture the lessons learned from these incidents but also the opportunity for future missions and the space community to learn from these lessons and increase return on investment for future missions.

As activity on the Moon grows, an emerging source of likely issues is interoperability: think of how Tesla used different EV plugs compared to other EV manufacturers, which led to a need to standardize the plugs in North America over time [24,25]. With so many different technologies in development for the Moon, there is a need to identify points where interoperability issues may exist and facilitate coordination and standardization to help the community grow stronger and more resilient in the harsh environment of the Moon.

Overall, there is a need for a common system to document the knowledge and lessons learned by different actors, link them together and use this knowledge to inform decision-makers to reduce the risk of future missions, and the impact of missions on each other.

A Potential Solution

With these challenges in mind, the Open Lunar Foundation decided to build on its past work on the Lunar Registry of Objects and Activities [26] and investigate how accidents, incidents and issues could be leveraged as learning opportunities for the community of lunar actors. Our study resulted in this proposal for the creation of a community-led Lunar Accidents, Incidents, and Issues Reporting System (LAIIRS). Our proposed system will allow stakeholders to:

- Record verified accidents, incidents and other issues relating to lunar missions as reported by operators, and third parties in an anonymized format, complemented by public information scrapped from the internet,
- Notify actors whose operation may be affected by an accident or issue,
- Analyze trends in the gathered data to identify common issues, lessons learned and safety minutes that can be discussed as a community, and
- Map the information gathered to different mission phases, and different aspects of mission design or engineering to help mission planners in hazard analysis.

As a concept proposed to improve accountability, responsibility and transparency in lunar activities and safety on the Moon, LAIIRS may be considered the first step towards a Lunar Incident Management System, that can build on the information gathered in the LAIIRS database and help coordinate community efforts when an issue arises involving multiple stakeholders.

The Need for a Lunar Accidents and Issues Reporting System

The idea of recording accidents, incidents and issues is nothing new: in fact, it is part of most Quality Assurance processes, and we can see examples of the analysis we are proposing made available publicly in NASA's Manned Space Programs Accident/Incident Summaries [8,9], and NASA's Significant Incidents & Close Calls in Human Spaceflight [27]. However, these past approaches are focused on government missions and cases with strong regulation, and almost all involve manual compilation of information, a time-consuming approach. As more actors enter the arena of lunar explorations, there is a need to shift our approach towards accident, incident and issue tracking to meet the needs of these new actors.

While many lunar missions are still in their early stages, they are expected to ramp up dramatically in the next few years based on the 30+ planned lunar missions. We will likely see several developments in the coming years owing to this increase:

- Politically and legally, operations on the Moon are not currently fully regulated. Every actor will need to apply for radiofrequency spectrum allocation from their state as per ITU requirements [28]. Beyond that, other than a license to launch there are very few licensing requirements. This would have worked in the past where the Moon was the arena of government actors, but as more private actors enter the arena governments will likely increase licensing requirements to meet their international obligations. Part of this obligation is the liability for damage to objects owned by other countries under the Liability Convention [28,29], a feat that would not be possible without tracking accidents, incidents and issues.
- The technologies needed to develop the right infrastructure on the Moon are still in their infancy and there is a lot of research and development work ahead. The ability to share lessons among different actors and reduce risk to one's own mission and other operations on the surface is key to our collective development of a lunar economy.
- There are many concerns about the impact of operations on the Moon on the lunar environment (e.g. heritage sites, long-duration missions). A reporting system can create accountability in these contexts, and lead to the creation of best practices for operators.

Overall, the perfect environment currently exists where a reporting system focused on accidents, incidents and issues can slowly be developed and scaled to meet the needs of the growing lunar community.

Evolution of a Reporting System

Lunar Accidents and Issues Reporting System

Considering lunar activities are not yet regulated at an international level, a multi-stakeholder confidential voluntary reporting system of accidents and issues could be the right first step towards ensuring a safe and sustainable development of a lunar economy. This could eventually become a voluntary industry practice, and if done correctly could help pave the way towards an incidence management system on the Moon should the need arise.

In its basic form, a Lunar Accidents, Incidents, and Issues Reporting System will act as a database showcasing issues that have arisen in operating different missions. As more data is gathered, there will be an opportunity to identify common accidents, issues and safety concerns (we readily see this in the marine sector where a person falling off the boat is considered a common occurrence). Identifying common issues in various mission phases will enable the study of their root causes, and lead to improved hazard analysis and contingency for all missions. Insights from these common issues and their root causes could be used to develop lessons learned, standards, and mission assurance requirements that can improve the overall safety of lunar missions.

A multistakeholder system can enable different stakeholders to coordinate efforts on the Moon as well and operate more efficiently. Interoperability issues can range from using the wrong port for charging, to an accident on a particular pathway planned to be used by another actor. The system may also standardize, to an extent, how accidents and incidents on the Moon are investigated.

While not yet fully formed, in the coming years new regulatory and licensing requirements are expected to be put in place due to the large number of space missions at play. Part of these regulations will likely be some form of reporting of safety issues, with licenses limited to actors who can show compliance with reporting requirements. While there is no guarantee, the existence of a well-designed reporting system may entice regulators to transfer the burden of tracking accidents and issues to such a system, improving the utility of the system. Alternatively, involvement in the proposed voluntary confidential reporting system may be an indicator of good faith to regulators.

While national, agency or licensing requirements may motivate actors to share data, it is evident that voluntary sharing of the data by actors will be essential for a safe and thriving lunar economy. With the exploration of this system, we hope that the benefits of access to open data and lessons learned from various missions are a compelling value for most actors and entice them to use the system and help the formation of the next generation of standard practices for design, manufacturing and operation on the Moon.

Best Practices in Learning From Accidents, Incidents and Issues

Our survey of best practices in different industries has shown several approaches to capturing lessons learned from accidents, incidents and issues:

- **Project and program management, and systems engineering:** In this context, it is well accepted that deviations from plans should be captured as part of nonconformance tracking activities. Within the space sector, an example of such an effort is ESA's Non-conformance Tracking Tool [30]. Our conversations with several lunar space companies revealed that they do follow nonconformance tracking either as part of their project management processes or using a separate nonconformance tracking system. As most actors are tracking nonconformance within their processes, there does not seem to be a need for us to focus on these issues.

- **Community Safety:** In the context of communities, past experience has shown that there is a need for a system to help coordinate efforts by different stakeholders. A good example of this is the Ontario Incident Management System [31] which allows different levels of government and municipalities to coordinate efforts in the context of natural disasters. While we foresee the need for an incidence management system on the Moon as the number of actors and operations on the surface increases, we have many years to get to the right level of activity for such a system.

- **Regulator-mandated reporting:** In highly regulated industries such as aviation and transportation, regulators run reporting systems that can capture safety issues, and openly communicate them. Operators are required to use the reporting system and the information gathered may lead to legal action. Examples of such a system include the Transportation Safety Board of Canada's Air, Marine, Pipeline and Rail reporting systems [32], the Federal Aviation Administration's Aviation Safety Information Analysis and Sharing (ASIAS) System [33], and the International Civil Aviation Organization's Accident/Incident Data Reporting [34]. The latter may be used by different agencies to create their own compliant reporting system.
  While regulatory-mandated reporting systems have been very effective at improving safety in many industries, the lack of similar international regulations for lunar activities makes creating a similar system unfeasible.

- **Voluntary confidential reporting:** While regulatory-mandated reporting systems have helped improve safety, they are ineffective at highlighting unsafe practices (what may be considered a near miss or close call), as regulators usually set a high bar for what may lead to a report. As such, over time voluntary confidential reporting systems were developed which allow operators and any other stakeholders to confidentially report safety issues. Examples of these systems include the Aviation Safety Reporting System (run by NASA) [35], the NASA Confidential Close Call Reporting System (C3RS) (focused on railway operations) [36, 37], Canada's Securitas Program [38] and EUROCONTROL voluntary ATM incident reporting [39]. While these voluntary reporting systems are linked to regulators, the entity running the system is usually an independent third party to reduce the likelihood of retaliatory use of the information against operators. Confidential reporting is a best practice recommended by many international organizations such as ICAO [39–42].

Considering most players are internally tracking accidents, incidents and non-conformances in compliance with internal policies and local regulations relating to occupational health and safety or funding requirements, there is not much to be done there. Yet, it seems a voluntary confidential reporting system which is community-led could help better coordinate among actors and allow for knowledge sharing and better operations on the lunar surface. In the next section, we explore this idea further and propose how it could be implemented.

Proposed Lunar Accidents, Incidents, and Issues Reporting System (LAIIRS)

In this section, we will present the vision for our proposed Lunar Accidents, Incidents, and Issues Reporting System (LAIIRS). The proposed concept was informed by the review of literature, and consultations with over 15 individuals (1 from government, 2 from academia, 4 nonprofit, and 8 from the private sector) over 6 months.

Mission

The main goal of LAIIRS is to help lunar stakeholders (government, private, and academia) improve the safety of their operations in the cislunar and lunar environment by providing a means of documenting and tracking verified accidents, incidents and issues faced by various missions. With no other similar reporting system existing at this point, LAIIRS will fill a unique and important gap in our current ability to share knowledge and improve the safety of lunar activities.

Beyond the core goal of capturing safety information, LAIIRS will aim to harness recent advances in natural language processing and data analytics to generate custom, automated reports from these records which can help the broader lunar community operate more safely, and reduce the impact of operations on the lunar environment.

Finally, as a community-led project, LAIIRS will allow the coordination of activities among community members and the sharing of safety and interoperability information that may impact other missions operating on the surface.

LAIIRS also acts as somewhat of a glue that connects several Open Lunar projects, as outlined in Figure 1. The system can build on the existing OL Registry of Objects and

Activities [26] to reduce the data entry burden on users. The gathered data could be used to extract lessons learned documents which may form the basis for standards and best practices (for example the Open Lunar Power Standards [43] and Landing Pad [44] Projects), and support the Open Lunar Payload Review project [45] with tools to flag likely issues in proposed payloads. Overall, a third goal for LAIIRS is to help inform the development of new lunar standards and practices.

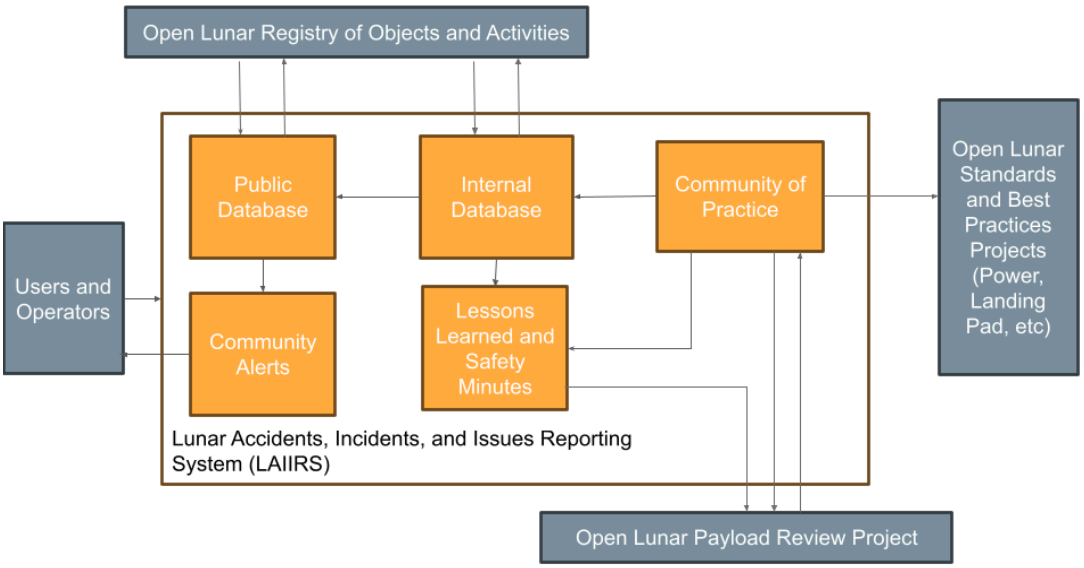

Figure 1: Relationships between the Lunar Accidents, Incidents, and Issues Reporting System, and other Open Lunar Foundation initiatives.

Principles

LAIIRS exists to build trust, safety and accountability in lunar exploration. Best practices in developing voluntary reporting systems [46,47] and conversations with stakeholders have pointed to the following core principles which will be adopted in developing LAIIRS:

1. **Multistakeholder-led and Community-focused:** Considering the large number of actors (ranging from employees to infrastructure companies to users and governments), the views of multiple stakeholders need to be considered in developing the system and a means should be provided to these stakeholders to share feedback and enable the community to learn and grow together.

2. **Voluntary:** The decision to use the system should be up to the stakeholder.

3. **Confidential and Anonymous:** Most reported information should be kept confidential and may be anonymized to reduce the likelihood of damage to

the organizations reporting. On a case-by-case basis depending on the situation LAIIRS may decide to make an anonymous case public to help other actors improve their operations.

4. **Intellectual Property Protection:** Some accidents and issues may involve the intellectual property of actors. It is important to protect this knowledge, while also generating actionable insights for all stakeholders. User access controls and a traffic light protocol may be necessary.

5. **Nonpunitive/No prosecution:** Reported information should not be used as a means for the prosecution of actions.

6. **Urgency:** The system should take into account the urgency of information when communicating with stakeholders. While a widget commonly failing may be a low-level risk and does not need immediate communication, two rovers crashing together and blocking a commonly used pathway required immediate communication to stakeholders.

7. **Verified and Documented:** Considering the reports may come from entities who do not own or operate the object or mission the report is about, the submitted information needs to be verified and validated for accuracy before inclusion in the system.

8. **Up-to-date and Tracked until Resolved:** For any accident, incident or issue reported, the system will maintain the latest information regarding issues. All efforts should be made to follow progress on the reported event until it is resolved and include information regarding resolutions in the system.

9. **Easy to Use (Low Barrier to Participate):** The system should minimize the need for stakeholders to process data for submission. Simple user interfaces should be provided to allow data portability between a stakeholder's existing system and LAIIRS.

10. **Scalable:** Past efforts to gather information regarding accidents, incidents and issues in the space sector have been manual, while, once again enabled by recent advances in computing, the system we foresee will be mostly automated with user intervention only used for verification purposes.

11. **Transparent and Accountable:** Sources of funding and management processes will be made accessible publicly and audit mechanisms with respect to principles exist to ensure unbiased decision-making. LAIIRS users will be asked to follow a code of conduct which includes transparency as a core value.

12. **Knowledge Shared to Improve Safety and Sustainability:** The system should provide a mechanism for the dissemination of knowledge gathered regarding accidents and incidents to enable different actors to improve their operations.

These principles will be further detailed in each phase of LAIIRS development to ensure compliance with the core value system enshrined in this effort.

Defining Accidents, Incidents and Issues

There are various terms used to refer to what may be considered an accident, incident or issue in the industry (*mishaps* and *close calls* being common language used in the space sector) [8,9,48,49]. In order to ensure consistency, we will be using the following definitions for LAIIRS:

- **Accident or incident:** An occurrence associated with the operation of one or more objects on the Moon that leads to:
    - Loss of life, loss of consciousness, physical or mental illness, or injury requiring medical treatment beyond first aid
    - Loss of property or structural damage
    - Loss of mission/object preventing mission/activity goals to be met
    - after which the object in question is classified as being missing
    - Loss of funds
    - Major delays in activities

- **Near miss or close call:** An occurrence associated with the operation of one or more objects on the Moon that leads to:
    - Unsafe conditions
    - Unsafe behaviour
    - Event with the potential to lead to an accident
    - Minor incidents and injuries that had the potential to be more serious
    - Events where injury could have occurred but didn't
    - Events where property damage could have resulted but didn't
    - Events where potential environmental damage could have resulted but didn't

- **Anomaly:** Any issue that is not an Accident or Incident, but is a deviation from normal behaviour:
    - Hazard: Predicted anomaly or expected deviation from normal behaviour with hazardous consequences, for which mitigation plans have been put in place.
    - Non-hazard: Anomalies that were not predicted, but could be resolved before reaching an accident or incident state.

    - Pre-existing conditions aggravated by the lunar environment
    - Conditions making it difficult to operate on the Moon

- **Other issues:** Considering the variety of scenarios, any other issue of interest to the community may be tagged and tracked. For example, an interoperability issue involving a mismatch between connector ports used for charging may not fit in any category above but may impact other missions or activities.

General Workflow of LAIIRS

The LAIIRS system has been drafted based on an extensive review of reporting systems and stakeholder research. The concept flow for baseline operations is outlined in Figure 2. This process was modelled around the process followed by the Aviation Safety Reporting System [46] and relevant fields of information gathered about accidents, incidents and issues outlined in Appendix A: List of Fields Used in LAIIRS Database was inspired by the Manned Space Program Accident Incident Summaries [8,9], Transportation Safety Board of Canada Incident and Accident Investigation Process [50], and NASA Procedural Requirements for Mishap and Close Call Reporting, Investigating, and Recordkeeping [51].

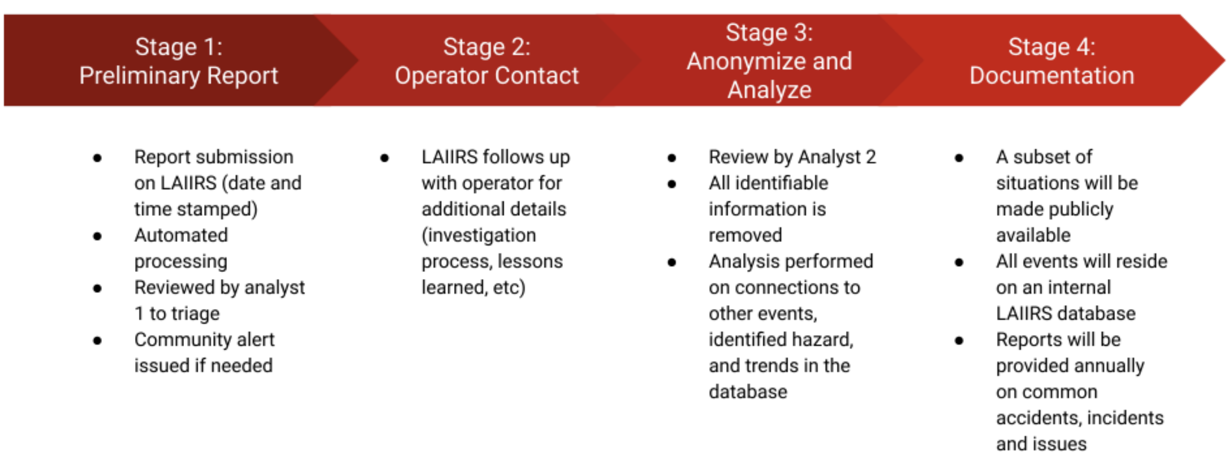

Figure 2: General workflow of LAIIRS baseline operations.

Stage 1: Preliminary Report

The process starts with a confidential preliminary report submitted to the LAIIRS by:

- An authorized user: An operator or owner submitting information pertaining to their activity or impacting their activity.
- An anonymous user: Anyone who would like to report something.
- Automated web scraping: The system will regularly scrape online sources from which additional preliminary reports may be generated.

The preliminary report will include critical information as outlined in Appendix A: List of Fields Used in the LAIIRS Database.

Upon receiving a submission, the system will perform automated processing of the data, assigning a priority and linking to any existing information in LAIIRS. An analyst reviews and approves the outcome to move to Stage 2. If needed, the analyst initiates a community alert, warning other users or operators of the incident and its impact on their operations.

Stage 2: Operator Contact

Based on the priorities assigned to different reports, LAIIRS will follow up with the relevant operator to verify the report and request additional information to be shared with the system. The relevant information requested is outlined in Appendix A: List of Fields Used in the LAIIRS Database.

Upon receipt of additional information, or if no information is provided after a pre-defined time frame, an analyst will recommend a next step at this point:

- Keep the file active to reconnect with the operator for additional information
- Archive file (if enough information has been gathered and the event is no longer impacting operations)
- Consult experts as needed

Stage 3: Anonymize and Analyze

When a case is archived at Stage 2, it will move to this stage. Here, a separate analyst will review the case and, after consultations with the community of experts, make a decision:

- In cases where the information is useful for many stakeholders or of public interest, anonymize the case and make it public

- In cases where the reported issue is not one faced by multiple stakeholders, keep the case private, in which case the case file will be anonymized with the information added to an aggregate dataset for trend analysis

For cases at stage 3, an automated algorithm will regularly check for trends in the data within the LAIIRS database. If a trend is identified or the information from Stage 2 warrants additional investigation, the analyst may decide to submit the case for review by the community of experts to generate lessons learned and safety minutes for the community.

Stage 4: Documentation

Per the decisions in the previous step, the information will be documented accordingly. This process involves:

- Updating the internal database (anonymize data and add any missing information)
- Updating the public-facing database
- Releasing any lessons learned documents created based on the Stage 3 efforts

Stakeholders and Incentives

Through consultations with the Open Lunar Community, the following stakeholders were identified whose involvement in developing LAIIRS would be key owing to their interest in and impact on lunar activities:

- The scientific community and academia
- Government Space Agencies: NASA, JAXA, CSA
- Standard organizations: ISO, ECSS
- International Organizations: ESA, ISECG
- Licensing: ITO, FCC, FTC
- National security and defence: DARPA
- Insurance companies
- Commercial space companies
- Quality assurance programs within space agencies

While LAIIRS will make some of the gathered information public, stakeholders may get access to additional benefits owing to their involvement with LAIIRS. Different access tiers may be defined based on stakeholders' interests, but we foresee the following forms of engagement and benefits:

- **Consultative mechanism:** Operators and other stakeholders who formally and regularly use the system will be included in a consultative assembly that may provide advice on future development and new features of the system.

- **Regulatory requirement for licensing:** Some national regulators may require the use of the system to reduce risk and encourage knowledge sharing. Currently, similar reporting systems are run by government entities as a requirement for their mission operations but trends in other industries show that at times a system run by an independent third party (be it a nonprofit or international organization) may be of interest to state actors as a means of increasing transparency.

- **Improved hazard analysis and risk assessment:** The information gathered by LAIIRS could help operators improve their hazard and risk analysis. At the same time, the insights can be valuable for funders, insurance companies and other entities who require a better understanding of mission risk in their decision-making processes.

- **Risk reduction consultations:** The information in the system and analysis performed will form the basis of annual risk reduction meetings focused on sharing lessons learned and improving the safety of lunar activities.

- **Access to the Community of Experts:** Access to the community of experts of LAIIRS may help actors when reacting to or investigating accidents, incidents and issues.

- **Validation of Claims:** As LAIIRS involves a validation process, this enables operators to have an opportunity to share their side of the story before information about their operation is made public.

In the next section, we outline elements of a governance structure which enable the delivery of the above values to stakeholders.

Proposed Governance

We explored 4 different governance models for LAIIRS:

1. **Government-run:** The majority of the reporting systems similar to LAIIRS are run by a government entity (either a regulator or a third party on behalf of the regulator). For example, NASA runs both the Aviation Safety Reporting System [35] and the Confidential Close Call Reporting System (C3RS) focused on railway operations [36]. This approach is not suitable for lunar activities, due to the international nature of these missions involving various stakeholders. Moreover, as the liability convention [28,29] holds states liable for activities, governments are incentivized to enforce strict regulations and mandatory reporting which will not only take years to develop but also disincentivize public data sharing.

2. **International organization:** Another model is a form of international organization, similar to the International Civil Aviation Organization (ICAO), funded through contributions of member states or national agencies. While this would ensure that the state liability issue is addressed and is the most suitable model considering existing space legal frameworks, creating an international organization is a lengthy process taking many years. We believe that the end goal may be to reach such a status, but the immediate governance cannot follow this model.

3. **Philanthropist-led:** In this model a third-party, philanthropic organization funded by those with an interest in safekeeping the Moon and lunar activities runs the reporting system. While this model creates the largest independence and impartiality for the initiative, it is unclear how open different commercial actors would be willing to engage with such an initiative in which they have minimal say or control.

4. **Nonprofit association:** In this model, different actors become part of an association which runs LAIIRS. Funding for LAIIRS is provided by its members, while LAIIRS' constitution and audit mechanisms ensure that the right level of transparency and impartiality is maintained throughout operations. A good example of this approach is the National System for Incident Reporting (NSIR) run by the Canadian Institute for Health Information [52].

Based on our initial analysis and consultations, the last model in the form of an organization where individual actors may apply for membership, similar to an industry association, seems to be most suitable at this point in time. In this model, different stakeholders may join as members by paying a nominal fee which is used to support LAIIRS activities. These member organizations will have voting rights enabling them to guide the activities of LAIIRS, with particular aspects of the organization (such as impartiality, public sharing of data, and the core principles outlined in the previous sections) being coded into its constitution and not modifiable through voting.

We expect LAIIRS governance structure in this model to include the following organizational elements to maximize benefit for its members:

- An **Executive Committee** made of individuals nominated and voted by the Members will direct the day-to-day activities of LAIIRS.

- An **Advisory Committee** composed of individuals representing different categories of stakeholders and independents will provide insight into operations, engagement, and new features to the Executive Committee.

- **Independent auditors** will regularly review the operations of LAIIRS to ensure it stays true to its core principles and follows its mission of gathering safety information and generating knowledge to enable the community to operate safer on the Moon. This audit is made public upon completion.

- An **Experts Consultative Committee** was formed by pooling subject matter experts from representatives of LAIIRS. Experts (without any connection to the operator and under strict confidentiality requirements) are consulted regarding finding and recommended actions for each case with their time being an in-kind contribution to LAIIRS. This will also help create communities of practice around particular topics which may lead to the development of standards in the long run, or support accident and incident investigations.

- A **Secretariat** will perform the day-to-day operations of the platform and will consist of a director, project managers and analysts. At this point, we foresee the following activities being led by the LAIIRS secretariat:
    - Maintaining the LAIIRS reporting platform and implementing the review process for reports
    - Maintaining the LAIIRS Public and Private Databases
    - Generating Community Alert Messages, and TLDR pages (public lessons learned)
    - Maintaining a Hazards and Risks Navigator (with issues linked to mission phases)
    - Generate Focused Studies with the help of the Experts (on topics identified as high risk by LAIIRS)
    - Generate annual report on submissions to LAIIRS highlighting statistics and trends in the data
    - Organizing an Annual Risk Reduction on the Moon Meeting
    - Generating the Organizational Annual Report, Financial Statements and Strategic Plan

Next Steps

This whitepaper lays the foundation and was a first step towards improving the tracking of accidents, incidents and issues associated with lunar activities, which would in turn lead to better-informed missions in the future. While it lays out the concept in some detail, there is much more that needs to be done to come to a final operational system.

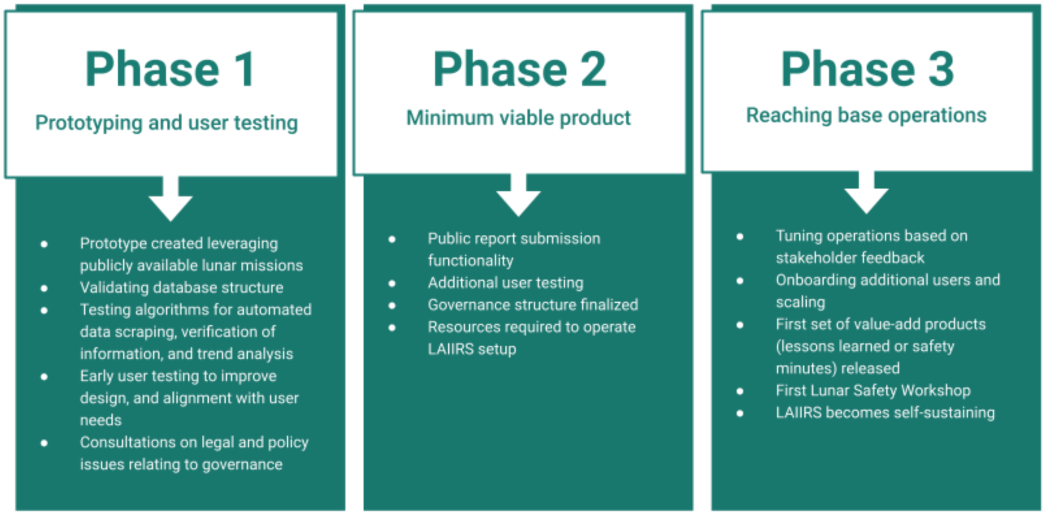

Figure 3. Next steps in developing LAIIRS/

At this point, we foresee the following next steps to develop LAIIRS as summarized in Figure 3:

- Phase 1 (6 months to a year): Prototyping and user testing
  - A LAIIRS prototype will be created based on publicly available information about lunar missions. This will create a tool that, even without reporting features, may be of use to stakeholders. The prototype will allow for the testing of algorithms for scraping data, and automated validation of information along with trend analysis. Moreover, this will act as a validation of the fields proposed for the LAIIRS database.
  - In conjunction with prototyping, user testing involving various stakeholders will take place to gain a better understanding of the needs of different stakeholders. The aim is to verify our hypothesis that such a system is feasible and useful. In addition, user research will provide valuable insights into the governance needs of the system.
  - Additional consultations with representatives of each stakeholder group identified in the previous section will be held in order to explore other value propositions of interest, incentives for using the system, and transparency and confidence-building measures needed to operate and govern LAIIRS.
  - Additional analysis will be performed on the legal and policy ramifications of a platform like this. Particular areas of interest identified

include Whistleblowing laws, the potential for legal action by operators, cybersecurity considerations and reputational risk for actors.

- Phase 2 (1 year): Minimum viable product and pilot testing
  - Building on the prototype and results of the user testing, a minimum viable product will be created that has all relevant functionalities, particularly user-submitted reports.
  - A pilot test with representatives of different stakeholder groups will be used to validate the design.
  - Concurrently, the governance structure and resources required to operate LAIIRS Will be set up.

- Phase 3 (1+ years): Reaching base operations
  - LAIIRS setup and processes will be tuned during this phase as additional users are brought on board to scale the system.
  - A focus will be creating the first set of value-add products (lessons learned or safety minutes), along with the first annual Lunar Safety Workshop.
  - By the end of this phase, the aim is for LAIIRS to become self-sustaining and new features will be identified for future development work.

Conclusion

As lunar activities ramp up, there is a need to ensure safe operation on and close to the Moon. This document presented the case for a Lunar Accidents, Incidents, and Issues Reporting System (LAIIRS) as one of the tools to tackle this challenge in a community-driven manner. The core principles for such a system were presented along with definitions and concept of operations for the system and its governance. Yet, there is still much more to explore. The next step would be to rely on past space missions and verify that such a system will be feasible, and will create useful insights for the different stakeholders involved.

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Appendix A: List of Fields Used in LAIIRS Database

Preliminary report (Stage 1)

- Source Name
- Source Type
  - Owner
  - Operator
  - Informant
  - Public
- Event Date and Time
- Event Category
  - Accident
  - Incident
  - Issue
- Event Location
- Mission Activity/Phase
- Involved Parties
- Owner
- Operator
- Stakeholders
- Purpose of Impacted System
- Nature of Damage/Loss/Anomaly
- Highest injury level
- Highest mission impact
  - Access to confidential information or IP
  - Cybersecurity
  - Environment
  - Property
  - Technology anomaly
- Preliminary Narrative
- Urgency (How fast the information is shared with others?)

Upon submission, the system tags the report with the following information:

- Unique ID
- Tags (to link to common categories of issues identified)
- Links to Lunar Registry of Objects and Activities
- Type of Mission/Activity
- Similar Incidents
- Priority level

Detailed Report (Stages 2 and 3)

- Categorized by organization as
    - Mishap
    - Close-call
    - Accident
    - Incident
    - Other:
- Abstract
- Factual narrative
- Causation
    - Task
    - Material
    - Management
    - Environment
    - Personnel
    - Design
- Environmental conditions
- Nature and circumstances of the occurrence
    - Provide details of what happened, including a description of the circumstances immediately prior to the occurrence, and any machinery, equipment, process or procedure involved. *
- Post Incident Activities
- Timeline
- Was the issue identified in hazard analysis?
- Hazardous material released
- State of Hazardous material
- Class of hazardous material
- Other Hazards created
- Equipment State
- Fatal injuries
- Nonfatal injuries
- Cost of damage
- Time lost
- Analysis narrative
- Root Cause
- Hardware Deficiencies
    - Material Failure
    - Design Deficiency
    - Materials Incompatibility
    - Malfunctions
    - Other

- Software Deficiencies
    - Procedural
    - Planning
    - Work Control
    - Management/supervisory
    - Training
    - Inspection
- Likelihood of future repetition
- impact
- Risk Assessment
- Investigation report
- Safety Recommendation/Lesson Learned
- Outcome/Impact
- Status
    - Incorrect report
    - Ongoing
    - Closed
- Steps taken to prevent a recurrence (Mitigation)
    - What action has been taken so far to prevent a similar incident from happening?