This project has received funding from the European Union's Horizon Europe Programme

RESEARCH PROJECT [EASA.2022.HVP.22]

[STAGE 3.1: REPORT ON MAIN RESULTS OBTAINED]

Detection of lithium batteries using security screening equipment

An Agency of the European Union

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DELIVERABLE NUMBER AND TITLE:	3.1 Report on main results obtained
CONTRACT NUMBER:	EASA.2022.HVP.22
CONTRACTOR:	Rapiscan
IPR OWNER:	European Union Aviation Safety Agency
DISTRIBUTION:	Public

APPROVED BY:	AUTHOR	REVIEWER	MANAGING DEPARTMENT
	Sophie Hibbin	Ben Wong Dean Smith	Rapiscan

DATE: 06 September 2024

SUMMARY

Problem area

Lithium batteries are becoming more and more ubiquitous in portable electronics devices. Their diverse form-factors and favourable energy storage characteristics make them a prime choice of batteries in many applications. Yet the high density of stored energy along with the combustion characteristics of lithium batteries can also constitute a safety hazard resulting in a thermal runaway fire. This hazard is particularly acute in the aviation field onboard the aircraft, and in particular the baggage and cargo hold, where fire hazards pose particularly severe safety risks to the aircraft.

For these reasons, the carriage of lithium batteries in checked baggage and cargo is tightly regulated and restricted by ICAO. Enforcement of this regulation would be aided by a means to detect the presence of lithium batteries. An opportunity lies with the use of imaging and detection equipment already deployed and required as part of aviation security infrastructure. With adaptations to its detection characteristics as well as operational adjustments, certain aviation security detection equipment can be made to also mitigate the specific safety risk posed by lithium batteries deemed non-compliant with the provisions for transport by air.

Description of work

In December 2022, EASA appointed a consortium to deliver this research study for the specific case of detecting lithium batteries in checked baggage. The consortium is led by Rapiscan Systems and supported by consortium partner UK CAA International. This project will consist of four technical tasks.

- Task 1: Review of state-of-the-art solutions, development of test plan and protocol and consultation with Stakeholders
- Task 2: Performance of tests, collection of data
- Task 3: Analysis of tests performed, consultation with Stakeholders
- Task 4: Conclusions and recommendations

In addition to the technical tasks, this project includes a fifth, non-technical, workstream:

- Task 5: Communication, dissemination, knowledge-sharing and stakeholder management

As per the tender specification, the objective of this fifth workstream is to identify the target audience and their different needs and support EASA in the planning and organisation of the stakeholder events as well as in the preparation of briefings and presentations. The project includes several consultations with the main Stakeholders concerned with the detection of lithium batteries at aerodromes. Two workshops are organised to present the results of Tasks 1, 2, and 3 and to facilitate this information gathering.

Toward the end of the project, the dissemination of the research results is to be structured in a way that allows the contractor and EASA to identify the best communication formats and means to transfer the knowledge gained according to the identified dissemination goals. The dissemination goals range from ***raising awareness of the research project*** to the final goal of ***establishing a long-term impact of the project results on its target group***. Such goals, as well as the audience to be reached will be identified jointly by the contractor and EASA and documented in the communication and dissemination plan. The plan shall also consider appropriate knowledge-sharing actions for the target group.

This report represents the deliverable for Task 3.1 – “Report on Main Results Obtained.”

Results and Application

The purpose of this overall study is to provide objective data and recommendations concerning the use of certain existing security screening equipment to detect lithium batteries in passenger checked baggage. By exploring this data, we will in turn assess the impact that detecting lithium batteries has on airport operations and screener performance. The results will be used to facilitate and underpin future discussions amongst stakeholders and regulators. At the time of writing, there is no plan to mandate the results of this study in European aviation regulation but to contribute to a discussion on a potential need to do so.

This part of Task 3 will report on the tests performed and collected datasets during the second phase of the project, the outcome of which is to evaluate the effectiveness of using current security screening equipment for the detection of lithium batteries, by analysing the datasets from Task 2.1. Additionally, an evaluation is undertaken into the representativeness of the tests and of limitations for the performance of such detection in the context of airport security procedures.

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ABBREVIATIONS

ACRONYM	DESCRIPTION
CAA	Civil Aviation Authority
DG	Dangerous Goods
EASA	European Union Aviation Safety Agency
EDS	Explosives Detection System
EU	European Union
FAA	Federal Aviation Administration
HBS	Hold Baggage Screening
IATA	International Air Transport Association
ICAO	International Civil Aviation Organisation
IED	Improvised Explosive Device
IT	Information Technology
Level 1 / L1	X-ray scanner, as part of the HBS process
Level 2 / L2	Human screener, reviewing escalations from level 1 as part of the HBS process
Level 3 / L3	Human screener, reviewing escalations from level 2 as part of the HBS process
Level 4 / L4	Human screener, reviewing escalations from level 3, typically where passengers are reconciled with the aerodrome operator/air operator representative and their bag
LiBAT	Lithium battery
OOG	Out-of-gauge, otherwise referred to as oversized baggage
RTTVis	Screener image viewing tool, or image enhancement function
TIP	Threat Image Projection
Wh	Watt hours

1. Introduction

1.1 Scope and Objectives

This project, and the analysis of results within this task, explore potential safety measures regarding the transportation of lithium batteries in aviation, specifically in hold baggage. Lithium batteries, while widely used in portable electronic devices, can pose a potential safety hazard due to their high energy density and potential for thermal runaway fires. The International Civil Aviation Organisation (ICAO) has established principles and standards that States must adopt pertaining to the carriage of dangerous goods, to mitigate these risks. These are outlined in ICAO Annex 18 and ICAO Doc 9284 Technical Instructions for the Safe Transport of Dangerous Goods by Air. Further detailed measures form part of the International Air Transport Association (IATA) Dangerous Goods Regulations.

The objective of the study is to understand the feasibility for detection of lithium batteries in hold baggage, using existing screening technology. In addition, procedures for dealing with non-compliant lithium batteries (a resolution process) are explored, including identification, reconciliation, and the necessary steps to be taken to ensure safety and regulatory compliance within the aforementioned framework.

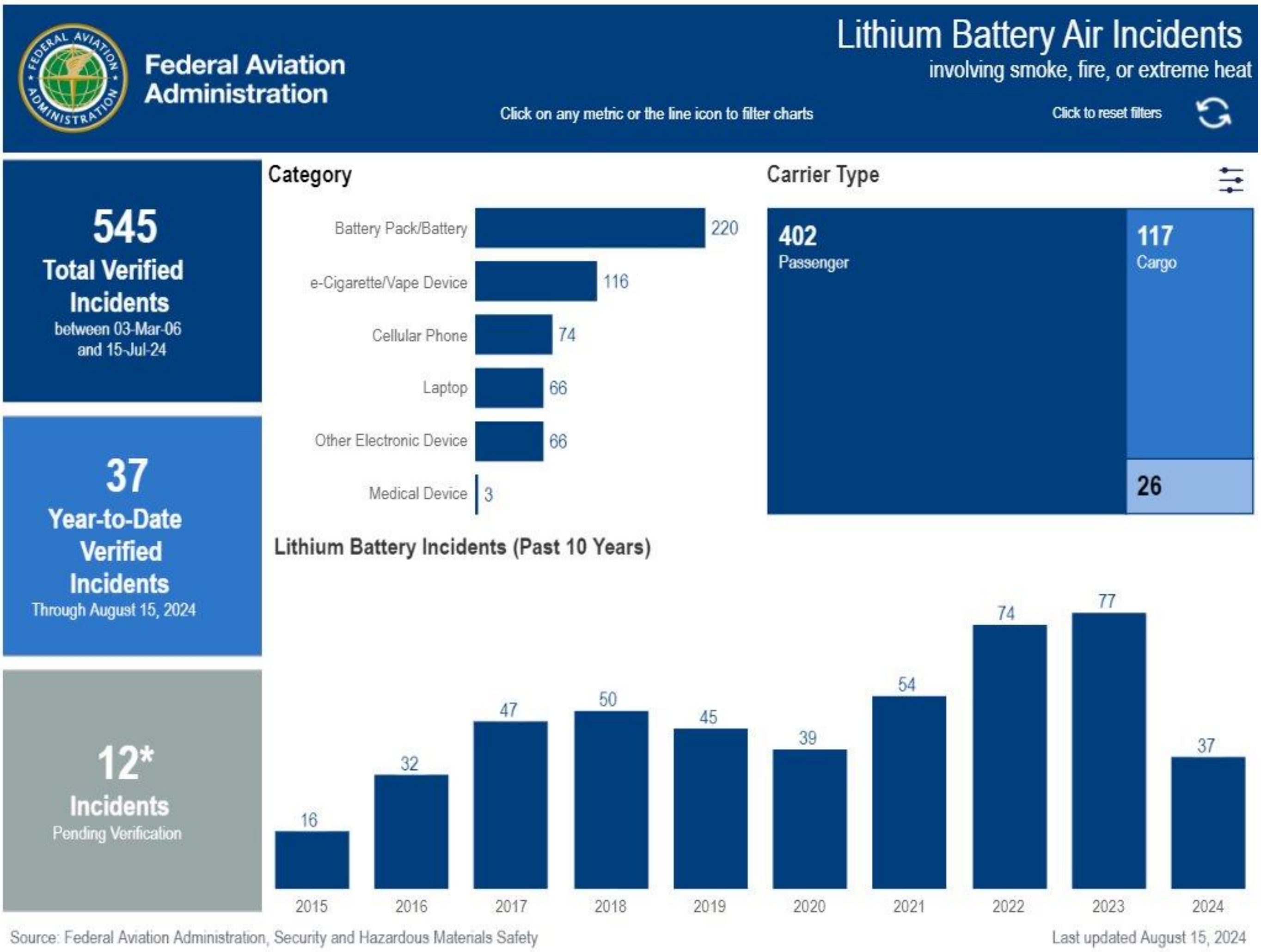
1.2 Rationale

Lithium batteries are considered dangerous goods, and regulations are in place on the carriage of such items by air. However, with the increased use of lithium batteries in everyday portable electronic devices it is inevitable that lithium batteries will end up being placed in hold baggage for carriage by air operators either contained within a device or loose.

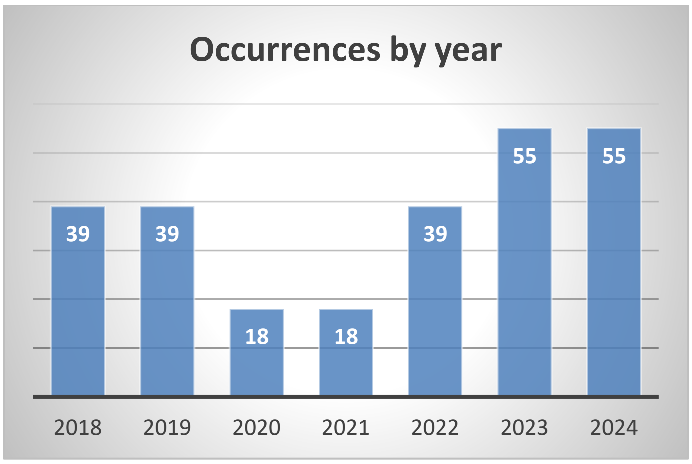
Forbes Magazine published an article in March 2023 (Forbes Magazine Lithium Battery Incidents) regarding the growing number of lithium battery incidents. The US Federal Aviation Administration (FAA) reported 64 lithium battery overheating incidents in 2022 compared to 54 the previous year. The article states that in 2014, only 9 incidents were reported all year, highlighting the growing use of lithium batteries and the risk associated with them. They are a serious safety risk to civil aviation: since their inception they have brought down a number of aircraft, for instance a UPS B747 Cargo freighter, in Dubai in 2010 – a lithium battery fire in the cargo hold caused the death of all crew onboard.

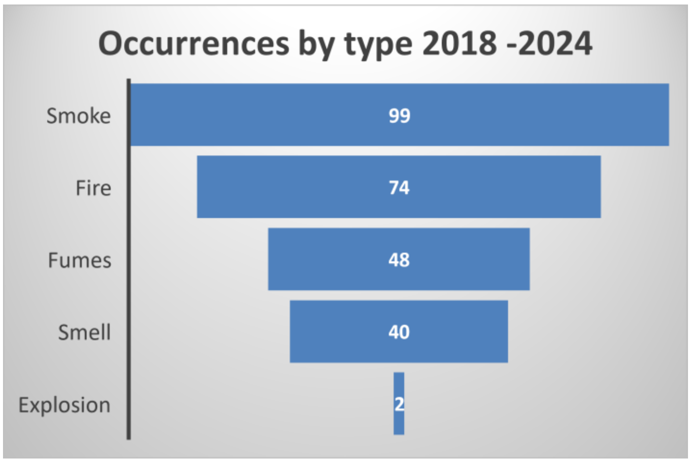
Generally, if the battery is under 30% charged, then it is deemed safe – this is how new iPhones are transported. ICAO technical instructions specify a 30% “state of charge” limit for lithium battery packing instructions. In addition to this, newer items have a safety cut off feature when they start getting hot. This safety feature cannot however be applied to spare or loose batteries. To address this, ICAO and IATA dangerous goods (DG) requirements are that spare batteries shall not be carried in hold baggage, and instead must be carried in cabin baggage (and even then in limited quantities). The reasoning behind this is that if the battery either starts to, or does combust, it will be more readily noticed, and can be acted upon in the cabin. However, the problem of undetected lithium batteries entering the aircraft hold still persists.

The FAA report below shows that battery packs, e-cigarettes, and vape devices are the leading causes of air incidents involving smoke, fire, or extreme heat.



The data below is from European Central Repository for the period 2018-2024 (Jan-Aug) and shows the total number of occurrences reported related to lithium battery incidents.





Source: European Central Repository

Aviation safety regulators and air carriers through IATA have been advocating for additional actions but a workable solution is yet to be found.

Without extensive research across multiple aerodromes, we will not know the extent of undetected prohibited lithium batteries making their way to the aircraft. However, during industry interviews conducted in the earlier phase of this project, one aerodrome operator found that just over 1% of hold baggage contained some form of prohibited lithium batteries (this figure is replicated in this trial). IATA report that, globally, there are ca. four billion items of hold baggage per year. Using 1%, this would equate to 40 million bags containing prohibited lithium batteries.

With this in mind, EASA commissioned this study to understand the feasibility of detecting lithium batteries using current screening equipment, to help drive change and mitigate the risk associated with the transport of lithium batteries in hold baggage.

1.1 Summary of Results

- The study was set up with a phased testing plan, involving development then deployment of a lithium battery detection algorithm to existing security screening equipment. The algorithm was tested in an offline environment, followed by a live operational environment.

- Test criteria (as outlined in task 1.2) required detection of power banks and spare batteries and any battery contained in Personal Electronic Device (PED) with capacity exceeding 100 Watt-hour.

- The lithium battery detection algorithm developed as part of this study proved capable of detecting in-scope lithium batteries in offline testing and in the live trial. The false alarm rate during the trial was relatively high, and if the algorithm were to be deployed again, would require refinement. A lower false alarm rate was observed during offline testing.

- Screeners adapted well to the new algorithm, and perceived no negative effect on their security screening process.

- As expected, lithium battery alarms took the longest to resolve by screeners, asserted to be caused by the novelty of the new alarm – it is to be expected that screeners take time to adapt to a new process.

- Decision times to accept and reject all types of threat were increased during the trial, when compared to the standard operating environment (i.e. no lithium battery detection algorithm running). This shows that the operational context of the trial was having an effect on the data.

- The prevalence of prohibited lithium batteries in hold baggage is estimated to be 1.34% during the trial period. This aligns with the one other fact-based data point for prohibited lithium batteries in hold baggage, gathered during the industry interviews.

- As to be expected, the reject rate was elevated during the trial, and without planning this will have implications for screener workload and have operational impacts.

- Limited data was available on the resolution process after a Level 3 reject, but observed searches of oversized baggage showed that the bag search can be efficient, whilst highlighting the importance of knowledge of the restrictions in both screeners and passengers.

- Any challenges with implementing such an algorithm would appear to centre on: operational processes such as screener training, process for increased rejects and decision time, and communications with passengers. Operational impact would also need to be looked at carefully particularly if the L2 screeners have limited decision time due to a short conveyor length.

2. Analysis of Results of Tests and Data Collected

2.1 Discussion

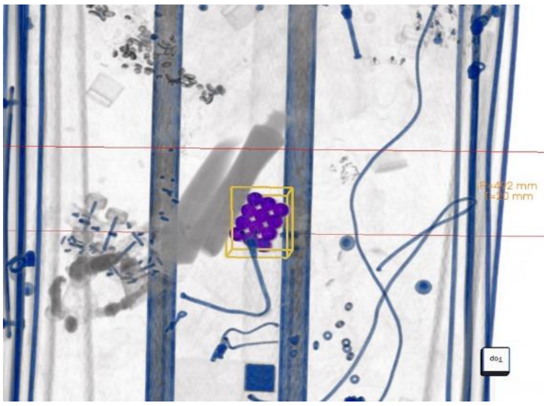
This section of the report will discuss the performance, capabilities, operational impacts, and limitations of the lithium battery detection solution, analysing the results from all streams of testing. Data was collected from two phases (prefaced by a development phase): offline testing and a live operational trial. The offline testing provided an initial indication of the prevalence of lithium batteries, as well as the performance of the algorithm, allowing an assessment to be made on the potential impacts of a live trial. The live trial provided verification of the performance and operation of the lithium battery detection algorithm, and insights into impact and implications of the resolution process for lithium batteries on the extant security processes.

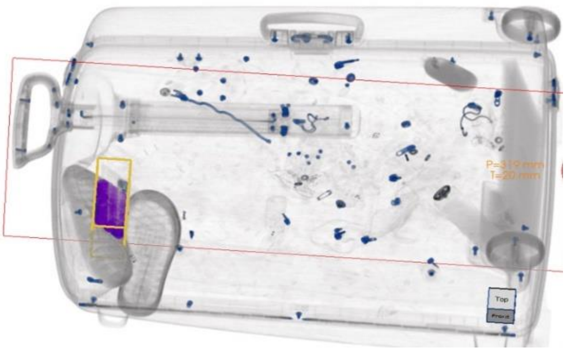
2.1.1 Algorithm Performance

The testing scope required an assessment of the baseline performance of the lithium battery detection algorithm. This performance can be defined in myriad ways, but the key element of a functional algorithm is that it identifies quickly, clearly, and accurately, the threat it is designed to highlight. This can be metricised through detection rates, false alarm rates, supported by qualitative image data, and further described by screener perception of the algorithm.

The offline data collection showed a 15% alarm rate, with 4.5% being verified as false alarms. From the 200 bags examined as part of this phase of testing, this represented a lithium battery prevalence of 10%, or 1 in 10 bags. This was deemed as an acceptable false alarm rate and prevalence for continuing the operational trial without the risk of the trial site's operation becoming overwhelmed. The algorithm performed efficiently at this stage, although it often detected lithium batteries with smaller power than the set threshold of 50 Wh. This meant that it was able to detect non-prohibited lithium batteries such as those contained in electronic items such as electric toothbrushes, but conversely this shows it can be capable of identifying most sizes and volumes of *prohibited* batteries. Additionally, it was alarming on bottles containing liquids (such as perfume bottles). It was clear, and to be expected, that further refinements to the algorithm would be required, however, these performance issues were not deemed to preclude the continuation of the operational trial.

During the operational trial, there was no observed or recorded delays in the functionality of the screening system when the lithium algorithm was deployed. The images were observed to render with the same speed





and quality when compared to normal operations. Observations by the researchers and comments by the screeners indicated that the alarms generated by algorithm were clear. Example images as would be seen by a screener is shown below:

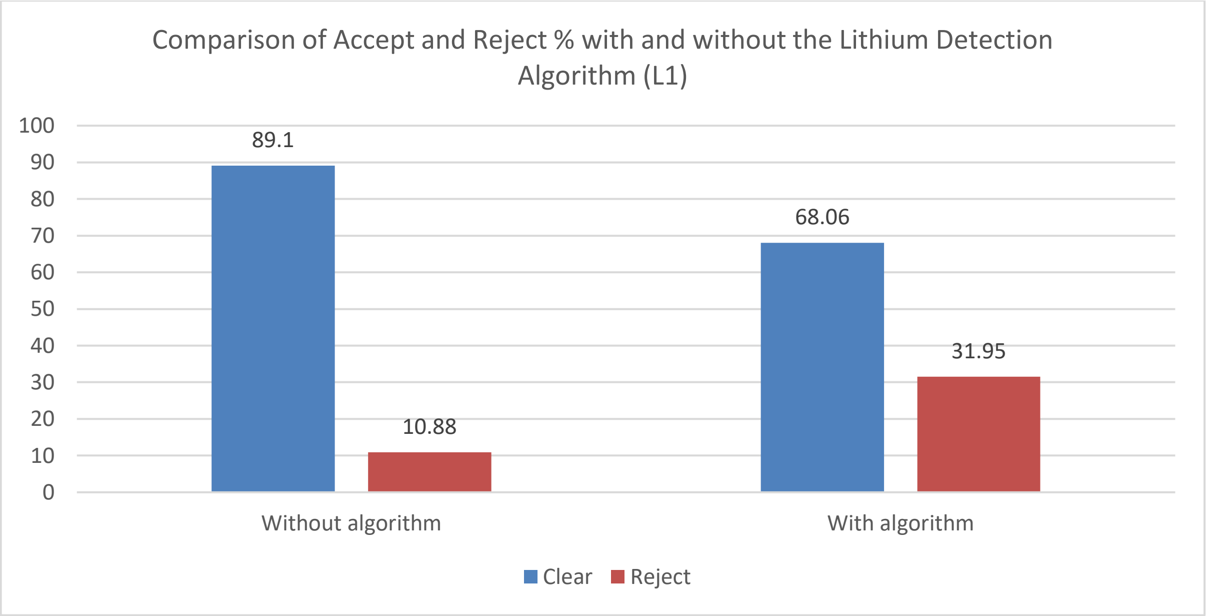
There was one instance, reported by a screener, where a potentially non-compliant lithium battery was identified which had not alarmed. The screener described the bag as being very cluttered, with numerous tools. The screener followed the normal operational procedure for escalating the bag to L4. Whilst the actual contents of the bag were, therefore, not verified as part of the trial, this is a potential indication of an instance in which heavy bag clutter could lead to a configuration causing non-detections. False negatives such as this are discussed further in the limitations.

In respect of accuracy of the algorithm, the false positive rate was higher than expected, and above the 4.5% false alarm rate seen in offline testing. It must be noted that this false positive rate includes all batteries identified from the algorithm, even those in a configuration allowed to travel in hold baggage, as well as items which clearly were not batteries. The 'true false positive' rate – where the lithium battery detection algorithm detects non-battery items – will be lower. And indeed, screeners during the trial were adept at identifying false alarms and cleared them efficiently and quickly, which means the operational impact of false alarms is mitigated by the screener's performance. Nevertheless, a high false alarm rate has significant implications for screener work rate, and this is discussed below.

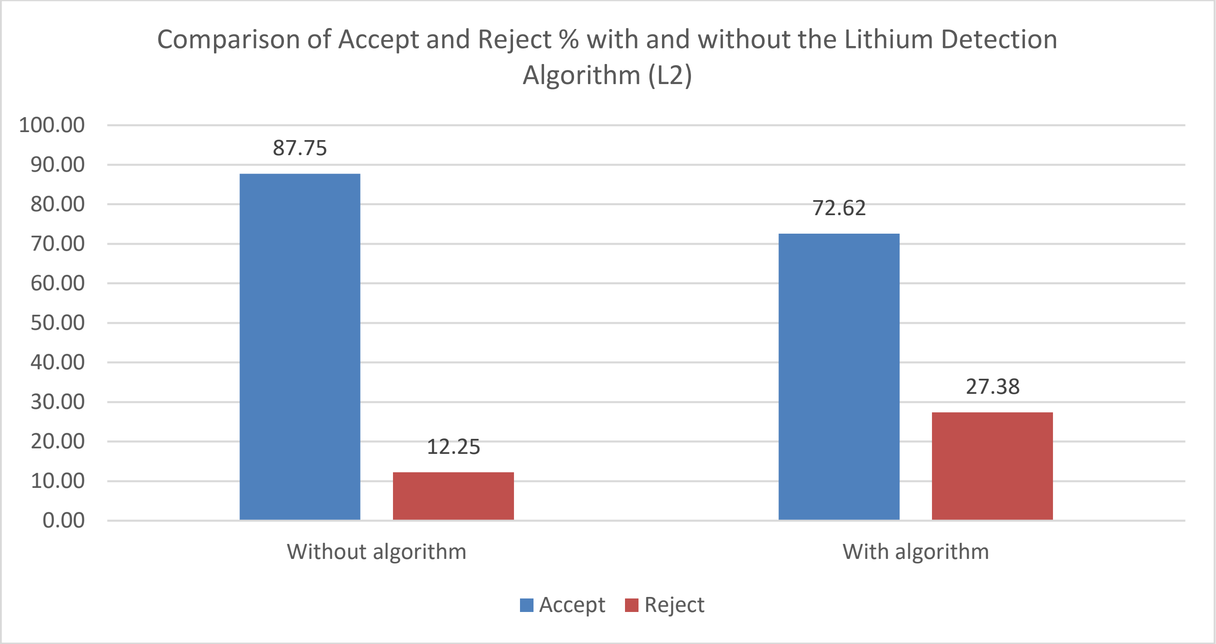
2.1.2 Operational Impact

The security system is comprised of two key parts in terms of threat detection: the EDS equipment and the human screener. Deployment of the algorithm had no observable impact on the functionality of the EDS equipment in terms of threat detection, so what remains to be assessed is the impact on the screeners and thereby the impact on the wider operational process.

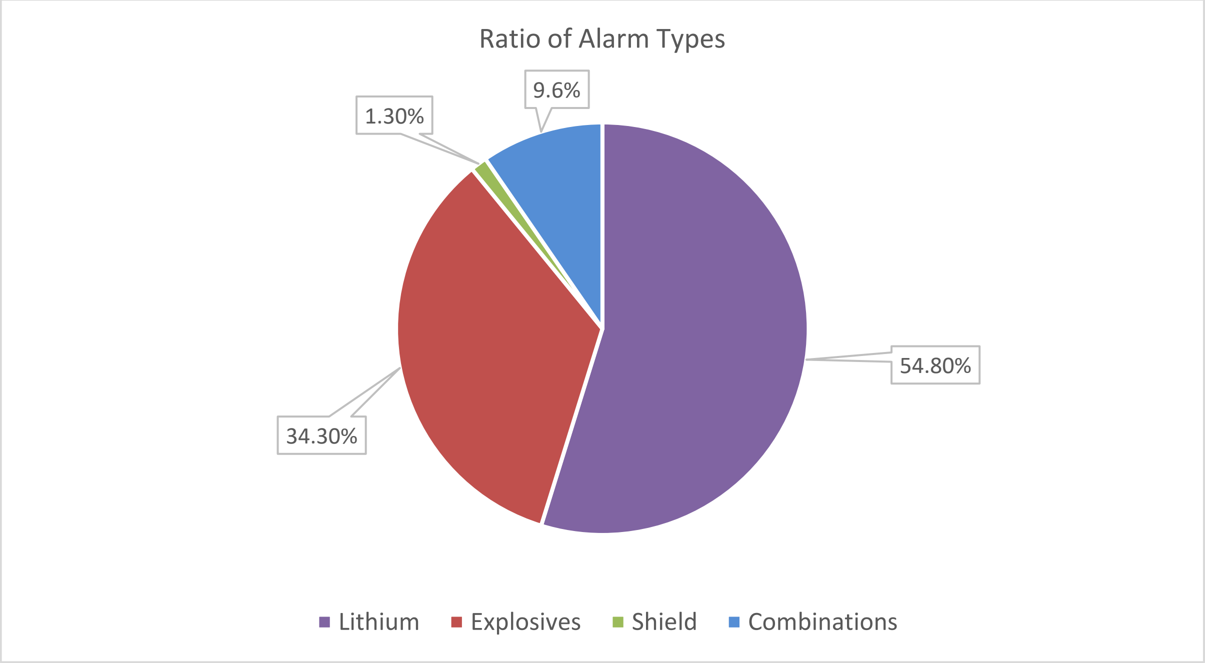
One method of assessing operational impact is by examining accept and reject rates – a higher reject rate leads to more work for the screeners reviewing images and more bags having to go through the resolution process. Of the 748 bags seen during the trial, 239 were rejected by the EDS equipment at L1 (all alarm types), representing a reject rate of 32%. This compares to a 11% reject rate at L1 as seen outside of the trial, during standard operating procedures.



Increases were also seen at L2 during the trial period; the reject rate was 27.38% with the lithium detection algorithm switched on, compared to 12.25% with the algorithm switched off.



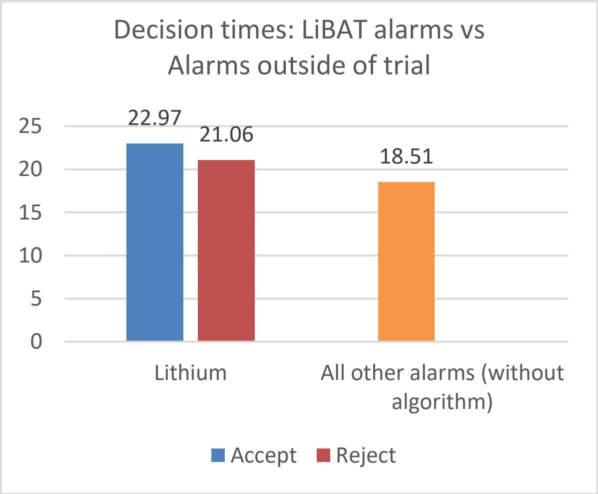
Additionally, most alarms during the trial were lithium battery alarms (overall lithium alarm rate of 21%).

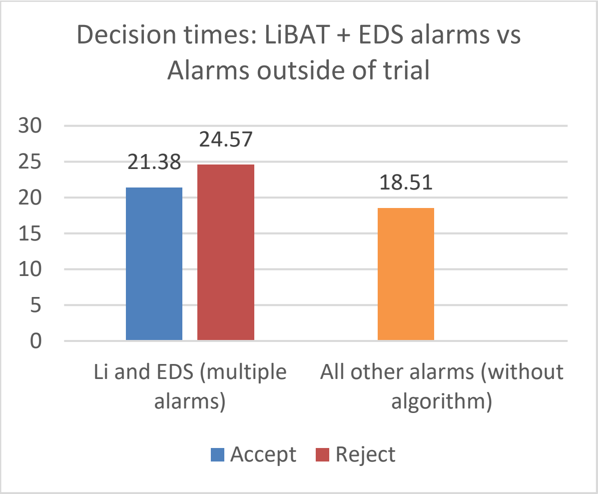


These increases show that the screeners had to review more images during the trial, and would potentially conduct more passenger reconciliation and bag searches – both of which would need consideration in terms of operational impact.

The trial showed a prevalence level of non-compliant lithium batteries as 1.34%. This is calculated from 10 bags observed on-screen to have potential prohibited batteries vs the total number of bags processed during the trial. This compares to a 1 in 10 prevalence observed during the offline data collection phase. This is a relatively low number when compared to, for example, liquids in cabin baggage, but higher than other prohibited articles in hold baggage. Further data collection would be needed to determine whether this prevalence level is robust. This data could also feed into a broader assessment of the risk posed by lithium batteries.

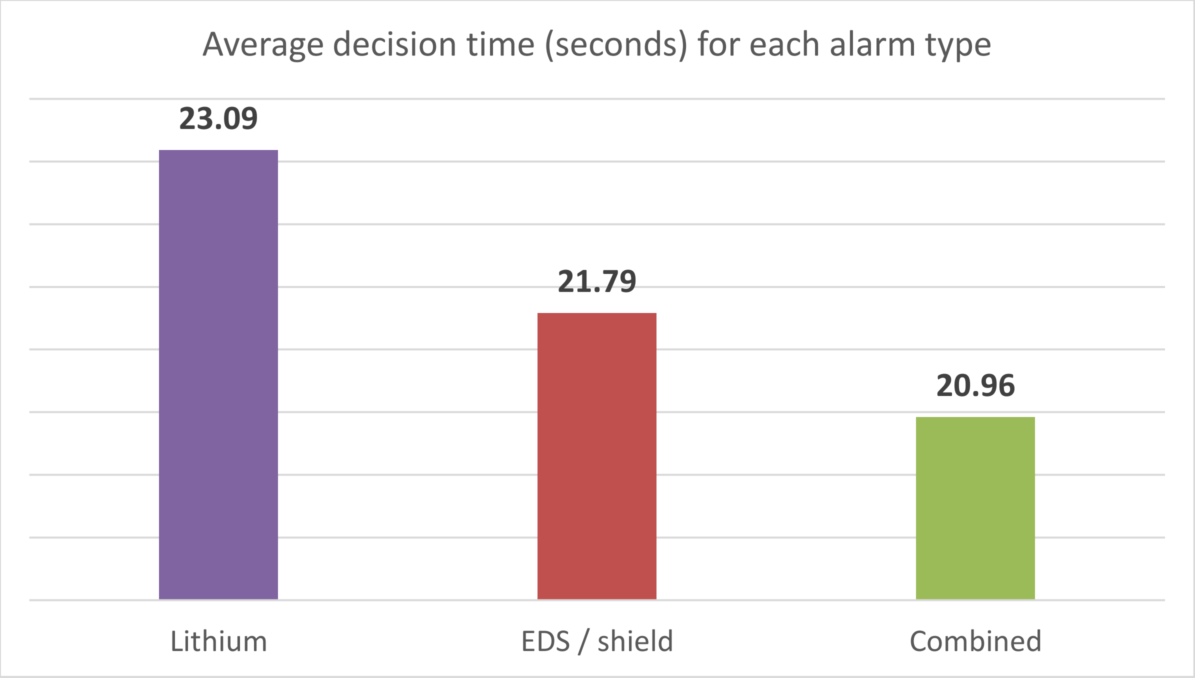
There was an observed increase in decision times, as shown in the following charts. Specifically, lithium battery alarms took longer to resolve when compared with alarms outside of the trial period, and when compared with other alarms during the trial. This is as expected, as screeners take time to learn and adjust to a new functionality.





Critically, it was observed that all decision times were increased during the trial period, so EDS alarms were taking longer to resolve than usual. Therefore, it can be concluded that the context of the trial was affecting the screeners, and indeed it was observed that interactions between researchers and screeners were lengthening the screening process (though never to the detriment of the security operation). It is a fair assertion, therefore, that after adapting to the new algorithm, and in a standard operating environment (or better controlled research environment) the increase in decision times would be seen to lessen, or regress to the mean. There is very strong evidence for this presented in the qualitative findings, with screeners reporting positive feedback on the algorithm and its ease of use. The screeners were observed to become more familiar with the novel algorithm relatively rapidly, even over the short duration of the observation periods.

A comparison has also been made of all decision times during the active trial period. This shows that lithium alarms take the longest to resolve (averaged at 23.09 seconds) followed by EDS/shield (averaged at 21.79 seconds) and then combined alarms (averaged at 20.96 seconds).



For reasons already discussed relating to the novelty of the lithium battery alarm, it follows that screeners would take longer to resolve these potential threats. It is unusual that the combined alarms are quickest to resolve, as multiple alarms are more complex and there is more work and time needed to look at more items. This is potentially explained by the sample size being very small (only 23 bags) and in seeing a very complex bag, a L2 screener may quickly decide to reject to L3, where a more detailed examination of the image is possible.

As the addition of another alarm category is likely to increase the number of images rejected at each level, and therefore the number of bags rejected, the impact on the baggage handling system will also need to be carefully considered. For example, the physical parameters of the level 3 reject lanes must have contingency to deal with multiple rejects – it is far more likely that multiple (real) lithium battery alarms are encountered than multiple (real) EDS alarms.

2.1.3 Resolution Process

Another critical aspect in assessing the operational impact is the resolution process at the end of the threat detection journey – when the bag is reconciled with the passenger and the lithium battery is either removed from the hold baggage or identified as a compliant item.

This process was only observed once during the trial, due to the low prevalence of non-compliant lithium batteries and the low throughput of bags. However, the researchers observed instances of bag searches at the out-of-gauge (OOG) screening area to supplement the findings from the algorithm. This additional observation was easy to facilitate as the OOG screening took place in the same area. There were at least three instances of non-compliant lithium batteries identified through the OOG screening process (via conventional x-ray) and in all cases, the screeners were confident of the regulations and the passengers were able to remove the batteries from their hold baggage and carry them on to their flight in their cabin baggage. Despite the limited occurrences, this process was efficient and did not add undue strain or complexity for the passenger or the screener. Indeed on one occasion, the passenger was grateful for the process as they perceived an increase in their own safety. Whilst a “full” reconciliation process would be more onerous, as the passenger needs to be brought to the relevant search area from the departure lounge, examining the OOG screening process does provide indications on how the full reconciliation might unfold, as the bag search and resolution process for the battery would be the same.

Whilst no conclusive data was obtained on the L3 to L4 process, the end-to-end resolution process was observed once. A power bank and some loose AA batteries were detected by the lithium battery detection algorithm, and were rejected at L2 and L3. The passenger was successfully reconciled with their baggage, and the search identified a power bank and loose batteries (these turned out to be zinc, rather than lithium, which highlights a potential limitation of an algorithm), in addition to two lithium batteries within a personal electronic device (compliant for travel in the hold). The passenger packed the prohibited batteries into their cabin baggage. There was some input from the researchers to the process in the form of referencing the regulations, but overall the process was observed to be efficient, and the screener was highly competent at conducting the search and dealing with the passenger.

From the observed removals of prohibited batteries from hold baggage, there can be a number of assertions made. Firstly, passenger behaviour is key to an efficient resolution. Although passengers behaved compliantly, there were instances where they exhibited confusion at the requirements. Furthermore, it can be asserted that *preventing* lithium batteries from entering the baggage handling system is more critical from an efficiency and safety perspective than detecting them once the baggage is checked-in. Making passengers aware of the lithium battery restrictions therefore, remains a critical process. It is beneficial where this information is clearly and consistently presented to passengers at check-in as per the defined responsibilities of the operator under ICAO requirements; observed signage was potentially ambiguous. One screener even reported that they do not believe passengers take much notice of signage on restrictions.

Secondly, variable levels of knowledge of the lithium battery measures were noted – the regulations themselves are quite complex, with different categories (power ratings) of lithium batteries being allowed or not allowed in various configurations and quantities, between cabin and hold baggage. In order to aid the search process, it would be valuable to have reference material available to the screeners to assist their resolution process. This would need to be embedded into a clearly defined operational process for lithium battery screening.

2.2 Screener Performance

This study also investigated the performance of the operator review component, or screener performance. Human performance incorporates a wide variety of themes; this research focused on the accuracy and speed of on-screen threat resolution, alongside self-perception of performance and other intrinsic performance values, such as motivation, in order to analyse the problem with sufficient breadth and depth (ICAO, 2021).

It was apparent during the trial that all 20 screeners appeared adept at identifying alarms within a bag, including batteries. Many of the screeners interviewed had upwards of 5 years screening experience. It was observed that some screeners reacted differently to the algorithm, with some taking longer to screen the novel alarms. To be clear, this is not a negative indicator of performance, it simply highlights the importance of having adapted training approaches to suit different learners when introducing new processes. Operationally, as screeners behave and adapt differently, there must be contingency (in on-job-training and implementation procedures, for example).

The evidence collected shows very little perceived negative impact on the screeners' performance, although their decision times were increased. All screeners observed remarked that the new algorithm did not inhibit their ability to screen, with some also recognising that it was a change they would have to get used to.

“I feel comfortable with the process.”

“It’s intuitive, and no extra effort.”

“It works. It is different.”

“It is another change to get used to, but would be ok.”

The latter quote touches on an important consideration for implementing a new algorithm; humans performing technical tasks have a finite ability to cope with multiple changes (Adler & Benbunan-Fich, 2012) and therefore the algorithm must be introduced with consideration to the operational context i.e. not loading security critical operatives with too much change. To note, during the trial screeners did not highlight any issues with identifying the lithium battery threats that were presented to them by the lithium battery detection algorithm.

Nevertheless, the threefold increase in rejections to L2, and the more than doubling of rejections to L3 clearly shows that the screeners work rate increased during the time the algorithm was running. Increased work rate increases cognitive load and risk of mistakes occurring (Galy et al., 2012; ICAO, N.d.). Although increased motivation could be posited as a mitigation to this more pressured environment (at least one screener reported that the algorithm made the screening process more variable and therefore added a different motivation) there must be considerations for managing this effect. However, it must also be noted that at no point were the screeners in contravention of the regulations requiring breaks after set periods of reviewing continuous images – the image flow never became continuous. Further to this, lowering the false alarm rate will mitigate increases in screener work rate.

Perception is a critical element of performance, with higher self-efficacy (defined as a belief in one’s competency to execute courses of action to manage prospective situations, put simply “self-belief”) linked to higher performance in the literature (e.g. Chen & Chen, 2014). The perceived performance of the algorithm by the screeners, and their own ability to screen using it, was positive overall. Screeners were asked if their process for identifying security threats (e.g. EDS alarms) was impacted by the new lithium battery alarm – they reported that they would examine the EDS alarms first, followed by the lithium battery alarm. This is indicative that the lithium battery alarm is not interfering with or distracting from the existing security threat identification process, and is merely slotting into the screener’s image review as an additional step (although one that does take more time per image).

In respect of enhancements used, all screeners used “zoom”, “rotate”, and “hide bag” functions to evaluate the lithium battery alarms. Other RTTVis (screener image viewing) functions used include “grow bag”, “slice”, “organic stripping”, and “metallic stripping”. The screening process taken by the screeners was not observed to change between screening for lithium battery alarms and EDS alarms, and the same range of enhancements were used screening at L2 when compared to L3, although screeners were observed to spend more time using enhancements at L3.

Interestingly, screeners also reported that the additional alarm was a beneficial tool, allowing them to identify potential components of an improvised explosive device (IED).

“The DG alarm is not a distraction – it has always been there, it would just normally be blue. I think of it as a useful indicator of something else to look at.”

“It is a useful tool for identifying the power source on an IED.”

"I am just screening as normal, as I would for an EDS alarm."

"It's no extra strain on the process. I would be looking at the whole bag anyway."

There was occasional observed uncertainty over the regulations defining the limits for lithium batteries in hold baggage, and what should or should not be rejected. This points to a requirement for further training to increase competency in knowledge of the regulations, and for the operational process for battery rejection to be well defined.

Overall, the addition of a safety screening process (for lithium batteries) was reported by users to aid the security screening process (for prohibited articles under the relevant regulations) during this trial, with no significant negative impacts on screener performance. This data gathered is representative of individual viewpoints, and therefore cannot be held as definitive, although it absolutely provides significant insight into the human element of the screening process.

2.3 Evaluation and Limitations

This research was subject to a number of limitations, which will be discussed in this section. It is important to note that where possible, these limitations have been considered and minimised, with data gathered from the research still deemed as sufficiently representative for an exploration of the problem.

The most significant limitation to this research comes from the sampling strategy. Due to constraints on resources and – critically – the availability of suitable aerodromes to conduct the trial, only one location and three consecutive days have been used for data collection. In an ideal scenario, the sampling strategy would demand that multiple airports were used, of varying sizes with varying passenger profiles, and that the trial is repeated both to verify the gathered results and to lessen the impact of any seasonal variation in passenger demographics. This would add greater weight to both the quantitative and qualitative data, although both are still valid as part of the research undertaken.

Necessarily, the low throughput of bags meant that the operational impact of the trial was minimised, and allowed collection of rich qualitative data from extensive time spent with screeners. However, the low volumes also meant that sample sizes for various datasets were relatively low and may not, therefore, be representative. Furthermore, no statistical analysis has been conducted on the quantitative data, due to the small sample size. Therefore it cannot be said, at any confidence interval, that the reported differences decision time – for example – are a real change or due to chance/sampling error. For the majority of the prohibited lithium batteries identified by the algorithm during the trial, there was no verification of the item through a bag search, which limits the confidence of conclusion on detection. This is the nature of conducting a live trial, without interfering with the operation – there has to be an on-screen resolution process. When viewed in parallel with the offline testing, confidence can be asserted in the detection ability. To give further insight to the detection accuracy, the images from the trial will be reviewed.

It would also have been valuable to set up a control lane (or at a larger aerodrome, a control terminal), whereby one screening system is running the lithium battery algorithm, and another is running standard operating procedures, with one set of screeners acting as controls and another set screening with the algorithm. This would have allowed isolation of causative factors in decision time increases, for example.

Although a large amount of valuable data has been produced, there was very limited observation of the passenger reconciliation process, owing primarily to the limited number of lithium batteries present within hold bags. There is also no reported data on L3 resolution times; L3 quantitative data was not taken forward as it is largely obsolete for this study, as the screeners were not solely focussed on screening the bag. It is therefore impossible to differentiate with the data obtained whether an increase in screening time is due to the algorithm or due to the screener attending to another task in the observation point (i.e. screening an out of gauge bag).

The screening environments were observed to be very pressured at times, and the data on resolution times and reject rates was no doubt affected by the operational context, however to what degree it is not possible to say.

There is also no data available on false negatives at this time. From the trial, it was clearly observed that laptops and similar PEDs in hold bags were not alarming under the Lithium battery detection algorithm. Although it cannot be ascertained for certain whether any or all of these devices contained lithium batteries (and indeed a lithium battery within a personal electronic device is permitted in hold baggage) it does show that not all lithium batteries were identified by the algorithm. The conclusion on the algorithm's accuracy would be made more robust with a detailed image level analysis on false negatives.

The execution of the trial itself was also subject to limitations. Owing to the setup of the screening process, there was no ability for a researcher to follow a bag from L2 to L3 in real time – the researchers were restricted to one level when positioned in each observation point. Although this has limited effect on the validity of the data, following a bag journey might have brought different insight. Furthermore, the timings of the data collection were not robustly planned to maximise the number of bags seen over the course of a day.

Finally, the deployed methods of qualitative data collection were not totally standardised. Whilst this approach allowed fully flexible and exploratory questions to be asked within the dynamic screening environment, future research would be strengthened by standardised questionnaires or interviews being implemented outside of the active screening locality. This could be further bolstered by gathering in-depth data on screener competency and experience (for example, specific certifications, TIP scores, time since last training, 6x6 currency, etc). This would give the ability to deepen the analysis on human performance.

2.4 Conclusion

The performance, capabilities, operational impacts, and limitations of the lithium battery detection solution have been successfully assessed during this research. The algorithm performs to a standard sufficient to detect prohibited lithium batteries in the live, operational environment, utilising existing security screening equipment and processes. The algorithm has demonstrated capability of detecting single, low-power, lithium batteries and hence capability of identifying non-compliant batteries, as defined by ICAO DG Technical Instructions.

The algorithm as deployed does have an impact on airport operations and screener performance. Current levels of knowledge of the relevant dangerous goods regulations amongst passengers and staff executing the screening function are variable. This would indicate that any deployed solution will need to take into account further training and procedural approaches to the full resolution process. Also, decision times for screeners were observed to increase for all threats, with lithium batteries taking the longest to resolve, though this can be balanced by the strong feedback received that the algorithm was an enhancement to the screening process; at least part of the increase was due to the context of the trial; and that it is predicted this decision time would come down with time as the operatives adjust.

Further research is needed to assess the limitations of the algorithm, specifically an examination of false negatives. However, any challenges with implementing such an algorithm would appear to centre around operational processes: adequate screener training, mitigations for the increased number of bag rejections, improved communications with passengers, and ensuring competency in the relevant regulations, rather than with the algorithm itself.

The broad questions asked by this project can be answered successfully by the trial data: The lithium battery detection algorithm *can* identify lithium batteries in the live, operational environment, and screeners *can* successfully perform the task of Lithium battery detection using the algorithm. The gathered data provides an initiation point for further discussions on the potential need to address the lithium battery threat through legislative means.

2.5 References

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European Union Aviation Safety Agency

Konrad-Adenauer-Ufer 3
50668 Cologne
Germany

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Mail EASA.research@easa.europa.eu
Web www.easa.europa.eu

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