The Social Acceptance of the Passivation of Misused Aircraft

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***Abstract*— One procedure under consideration to handle the threat posed by misused aircraft is passivation. In a passivated aircraft no more inputs from the cockpit are accepted and the aircraft safely lands in the nearest suitable airport without intervention from the pilots. Aircraft passivation is a procedure to be used in an emergency situation and would be handled as such by all stakeholders (air traffic control, airports, airlines, etc.). This paper attempts to address for the first time the social acceptability issues faced by passivation. It is assumed that the introduction of such a system in aircrafts will be a contentious issue expected to be met with strong resistance by pilots and the public in general. In this paper some of the technology under consideration is presented. This is followed by a discussion of the acceptance of similar technologies (unmanned aerial systems, driverless cars) before the social acceptance of passivation is discussed in more detail. Among the recommendations is the need to raise public awareness and familiarity with the technology. Pilots' acceptance is also seen as essential. Once society trusts the technology behind the system and the risks are deemed small enough, acceptance of passivation under some specific conditions should be possible.**

Keywords—passivation; social acceptance; misused aircraft

I. INTRODUCTION

This paper summarizes a concept study being done in GAMMA, an on-going FP7 research project. GAMMA addresses the full set of security threats and vulnerabilities affecting the ATM system and attempts to establish a framework to manage these, extending the scope of SESAR.

Several ATM Security objectives have been identified in GAMMA, among them the need to detect illicit use of airspace (a/c in exclusion zone, without ID or without known flight plan), to detect abnormal situations of identified flights (deviation of flight trajectory or procedure, unlawful interference on-board, renegade[1] aircraft) and contribute to airspace security incident management (contact authorities upon detection of abnormal situation and perform the relevant procedures).

To anticipate and mitigate main threats and risks to ATM, several procedures to the threats described above have been discussed by international organizations (including EASA, NATO) and national authorities. One such procedure is aircraft passivation. In a passivated aircraft all cockpit inputs are disabled and the aircraft safely lands in the nearest suitable airport.

At least three European-wide projects (SAFEE, SOFIA, PATIN) have looked into passivation systems, but mostly discussed the technical issues that need to be addressed before such system can be introduced in aircrafts. A common finding in these projects was the need to address society's acceptance of the passivation system.

A. The need for increased air travel security

In 2012 the air transport industry flew a total of 2.9 billion passengers, corresponding to 31 million aircraft departures [1]. Even though flying is one of the safest modes of transport, the events of September 11, 2001, raised several issues regarding aircraft security and the use of aircrafts to carry out terrorist acts. Ever since, civil aviation security became one of the greatest concerns not only for the industry, but governments and international organizations.

The misuse of civil aircraft is usually associated with hijacking, which traditionally involves the seizing of an airplane to collect some ransom, make certain demands or as a political statement. Before 2001 the crew of a hijacked plane was instructed to cooperate, land the aircraft and let the authorities handle the situation, as this was assumed to minimize the loss of life. The attacks in American soil, however, introduced a new threat: the use of aircrafts as weapons against targets in the ground, with the goal of causing as many casualties as possible. Hijacked airplanes can also be used to propagate biological or chemical agents, or to multiply the effects of the explosion of a weapon of mass destruction on-board. These different kind of hijackers usually act without warning, make no demands and are not open to negotiation, making it very hard for authorities to deal with such a situation. As a result new procedures and regulations were introduced, together with new information dissemination systems. For example, flight attendants and pilots now receive anti-hijacking and self-defense training. The number of air marshals has also increased dramatically, with an estimated 4000 working in the US Transportation Security Administration in 2013 (actual numbers are classified), from a pre-9/11 number of 33 [2]. Other countries, such as Australia, Canada and India, have also instituted new programs or strengthened already existing ones.

[1] For NATO, renegade aircraft is a civil aircraft used to carry out a terrorist attack.

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Currently, once an aircraft has been taken by terrorists, the priority is to reduce the number of civilian fatalities not only inside the aircraft but, most importantly, in the ground. Therefore, several countries (e.g., EUA, India, Russia, etc.) have enacted laws allowing the shooting down of hijacked commercial airlines should it be necessary. Needless to say, this is an extremely unpopular decision that no authority wishes to make. In addition, in 2006 the German Federal Constitutional Court ruled against the shooting down of hijacked aircrafts, deciding it was against the Constitution [3]. And even though the European Court of Human Rights has not legislated on the issue, it provides the same rights to life as the German Constitutional law. That is, both deny the right to take life in favor of rescuing others in normal legal conditions, that is, without first declaring state of emergency [3]. Hence the need to consider alternatives, passivation being one of them.

B. *When to passivate?*

The most obvious situation in which to use aircraft passivation is any September 11 scenario, i.e., with any aircraft hijacked with the intention of crashing it. Passivation can be seen here as the only way to save the aircraft and its passengers as well as to prevent fatalities in the ground and damage to infrastructures.

However, if the technology is installed, it could also potentially be used in other cases where the crew is incapacitated. For example, in 1999 a Learjet 35 suffered a loss of cabin pressure for undetermined reasons and all on-board are thought to have died of hypoxia. The engines eventually ran out of fuel and the aircraft crashed near Aberdeen in South Dakota. Before that happened, military jets intercepted the airplane and if there had been some risk of it falling in a populated area, most probably they would have shot it down. This option involves some risks as well, as the debris can hit people and cause damage in the ground. Passivation might not have prevented the death of the flight crew and passengers, but it would have made it possible to safely land the aircraft.

Another case of crew incapacitation occurred in Greece in 2005 with the Helios Airways Flight 552. In this case the crew also became incapacitated due to hypoxia and the aircraft crashed after suffering a fuel exhaustion only 33 km northwest of the Athens International Airport. Here, unlike in the previous accident, passivation might have saved at least one life, as two hours after ATC lost contact with the a/c, the F-16 pilot following it reported seeing a person entering the cockpit and trying, unsuccessfully, to control the airplane before it crashed.

In the two cases described above, the social acceptance of passivation would probably not be an issue as it would have been the only way to land both aircrafts. But what about those situations where the crew falls asleep or is so engaged in other activities that the pilots do not respond to ATC calls? As an example, in 2009 Northwest Airlines flight 188 did not communicate with ATC for over one hour, despite repeated attempts by the controllers to reach the pilots. The National Transportation Safety Board determined that the flight crew failed to monitor the radio and instruments after becoming distracted by activities unrelated to the operation of the flight. The pilots eventually established communication and landed the aircraft without further incident, but it is possible that passivation would have been activated shortly after all communications ceased.

The probability of the two pilots falling asleep in the cockpit is also a reality. A report by [4] summarized the results of several polls on fatigue carried out by member associations between 2010 and 2012. Depending on the country, 43-54% of the surveyed pilots indicated that they had fallen asleep in the cockpit without informing the other pilot. And in the UK, a third of the pilots said they woke up to find the other pilot also sleeping. In an incident in May 2012 the pilots of an Air Berlin flight requested an emergency landing in Munich reporting extreme fatigue.

In some cases, one can make a strong argument in favor of passivation (hijacking, crew incapacitation), whereas in some others, it is more of a grey area (lack of communications due to cockpit distraction or to unscheduled rest, etc.). The particular cases in which passivation would be used need to be stated, with clear procedures accepted by all stakeholders. Pilots in particular might not accept a system that takes control of the airplane from them while they are busy with other tasks (approved or not). The need for a lack of ambiguity is also of the upmost importance to the public. This and other issues will be further discussed below.

II. European Security Research Programs in Aviation

The issue of the social acceptance of aircraft passivation does not have a simple answer, as it depends on several of factors. One among them is the public perception of the technology involved and how it would change the way we fly. Therefore, this chapter presents a short description of some European research programs which directly investigated passivation and the new systems envisioned.

The NATO/EUROCONTROL ATM Security Coordinating Group (NEASCOG), was established jointly by the two organizations to ensure close coordination on ATM security activities in Europe [5]. The group also includes national and international stakeholders (e.g., ICAO, ECAC, EC, EUROPOL, IATA) that have a role in ATM security. One of the main areas of the NEASCOG work programme is to optimize the sharing of civil and military information. The goal is to provide ATM service providers (civil and military), NATO and national air defense units, national government authorities, intelligence agencies, police agencies, aircraft operators, airports and other units playing a part in aviation security, via encrypted links and in real time, with all the information needed to respond to acts of unlawful interference or suspected acts on-board an aircraft [6]. The available information would concern the flight, the route, the passengers and crew, the cargo, the alert state, threat assessment, the progress of the response by states and information handover between states. SAFEE [7], SOFIA [8] and PATIN [9], all to be described next, expect that the passivation system and/or the authorities in the ground have access to such an information dissemination system.

The EU project Security of Aircraft in the Future European Environment (SAFEE) [7] focused on the development of an aircraft decision support system, which would be able to deal with on-board security issues, including hijacking [10]. One of several new systems to be outlined was the On-board Threat Detection System (OTDS), which detects unauthorized access to the cockpit in flight, dangerous materials and goods, and suspicious behavior. Once an alert threshold has been crossed, a signal is sent to the Threat Assessment and Response Management System (TARMS) which has the capability of activating both the Emergency Avoidance System (EAS) and the Flight Reconfiguration Function (FRF) if it detects that the pilots are no longer in control of the aircraft. The EAS automatically takes over to avoid impact with the ground, whereas the FRF allows an automated landing at a secure airport. The EAS also disables all unauthorized inputs to the flight controls and aircraft systems, including electrical circuits, hydraulic systems and engine power.

One topic of concern was the way the new systems would change the interaction between the pilots and the aircraft in normal operations. Airline pilots who were interviewed about the automatic engagement of the EAS by the TARMS expressed concern about the conditions under which those occur. They were not comfortable with a system which could potentially take over control of the aircraft and urged the need for a clear engagement and disengagement philosophy. The acceptability study of the FRF revealed similar concerns. Even if most pilots agreed that such a system would decrease terrorist risk, many showed reluctance in accepting it. As stated in the final report (pp. 28 [7]): "This psychological obstacle needs to be addressed in further studies with proper consideration of the identified concerns".

The main goal of SOFIA (Safe Automatic Flight Back and Landing of Aircraft) [8] was to advance the work on the flight reconfiguration function (FRF). SOFIA also introduced a new authority, the Ground Security Decision Station (GSDS) at European level, to manage the emergency and coordinate with ATC, airports, ANSP, national authorities, etc.

Three operational solutions were proposed [8]:

- Flight planning with negotiation: The flight plan is generated by the GSDS and transmitted via a secure data link to the FRF. The FRF then needs to check the aircraft status (e.g., fuel left, condition of all relevant systems) and confirm that there are conditions to perform the plan. Otherwise, more information exchange is required. Once the new flight plan is accepted, ATC keeps the traffic away and the GSDS informs the authorities in the ground, including the airport where the aircraft is to land.
- Military aircraft relay: an intermediary step between the other two options. A specially equipped aircraft needs to intercept the hijacked airplane and connect to the FRF in order to ascertain the aircraft condition. This information would then be transmitted to the GSDS and the new flight plan broadcasted to the aircraft via the military jet. This is the most complex procedure and the one that requires the most time.
- Autonomous flight planning: If communications between the aircraft and ground are disrupted the FRF creates and executes a flight plan. ATC can use predicting techniques to anticipate the aerodrome selected by the FRF, a procedure similar to the one used today with an aircraft with R/T failure. The airplane conditions can also be simulated in the ground to anticipate the solution chosen by the FRF. The degree of uncertainty introduced, however, requires giving ATC time to close the affected sector. Therefore, a holding pattern of at least 15 min is necessary. Of the three solutions, this was considered the one in which the safety of the whole air traffic system was the least certain, but also the least complex and fastest to implement. This solution would also be the back-up solution to the other two.

SOFIA also assumes that TARMS or a similar on-board system is able to provide all the necessary information to the FRF, including up to date databases about the airspace (along with prohibited areas, such as large cities, nuclear reactors, etc.), aircraft status, weather conditions and location of the airports in the area (plus runways and navigation equipment available). If the data link is available these can also be provided from the ground by the GSDS, otherwise the system is dependent on ATIS to confirm the airport conditions. Weather information can also be obtained via the on-board weather radar.

The main goals of the third project, PATIN (Protection of Air Transportation and Infrastructure) [9], were to assess the key aspects of security in the whole transportation system, as well as to propose an overall warning and information system accessible by emergency response organizations. One of the aircraft in-flight protection systems investigated was passivation. As before, passivation would be monitored by a military interceptor aircraft (mid-term solution) or from the ground (long-term solution). Decisions would be made by the national authorities, connected through an information dissemination system with ATC and military operations centers.

The following functionalities were considered:

- Misuse detection capability through sensors in the passenger cabin and a secure communication path to the ground (as in SAFEE), or through the detection of deviations from the assigned flight path. Unlike SAFEE, decision on whether there is an emergency situation on-board is made by ATM/ATC.
- An ATM/ATC panic button that triggers a holding pattern in order to avoid collision with other aircrafts or with the ground, and to evade a forbidden area. The panic button would also block on-board manual flight controls. This would provide some time to review the situation and all available options. Also considered was an on-board panic button, allowing the pilots or cabin crew to react faster than ATM/ATC.
- Like in SAFEE/SOFIA, an FRF with autonomous flight, sense and avoid, landing and taxiing capabilities. This system calculates a new flight plan considering remaining fuel, weather, airport requirements, etc. These steps would be performed under the supervision

of a pilot on ground that can intervene at any time and remotely control the a/c.

PATIN dealt mostly with the need to detect abnormal events taking place inside an aircraft as soon as possible, since in Europe several major airports are located next to cities with important economic and technological centers. Therefore, the concept of a panic button was developed to allow ATM/ATC to confirm the emergency (i.e., to confirm the activation of the passivation system). But unlike in SAFEE, in PATIN the decision center remains on the ground.

In common all three projects acknowledged that modern aircrafts with full fly-by-wire capabilities can already fly an aircraft without human intervention. In fact, they concede that for safety reasons the passivation system needs to be prepared to come up with a flight plan in case communications between the a/c and the ground are affected.

Another important aspect is the need to avoid the inadvertent activation of the FRF. A high rate of false alarms in such a system would be unacceptable for pilots, airlines, air traffic services and the public. Thus the system will have to be made as fail-safe as possible, seeing that it is expected to run without direct human intervention on-board. Finally, it was also recognized that before such a system can be implemented, the acceptance of aircraft crew and the public is required.

As a side note, it should be pointed out that public reaction towards any accident involving new technology, especially if it occurs early in its operation, is likely to be severe [11].

Several technological solutions have been discussed and at this point it is not possible to decide with certainty which will be adopted, if any. But whatever the solution chosen, the passivation system is just one of several new systems under consideration in the growing trend toward increased aircraft automation.

III. Cockpit Automation

[12] defined automation as the execution by a machine of a function that was previously carried out by a human. The trend that emerged in the 1970s toward increased automation in the cockpit will continue through the next decades, as new and more powerful computers and technology are developed. One major step in this process was the reduction of the flight crew from 3 to 2, with the elimination of the flight engineer (FE). This was only possible due to the introduction of automated systems that took over most of the tasks traditionally assigned to the FE like, for example, the Full Authority Digital Engine Control, which monitors and has full control of the engines and related subsystems. Another technological enabler was the introduction of the glass cockpit which allowed for the replacement of physical dials and gauges with electronic displays. One of these is the EICAS (or ECAM), a centralized display of system alerts or warnings and engine indications. In recent years, several other systems were introduced with the goal of increasing security, such as the Airborne Collision Avoidance Systems and the Terrain Awareness and Warning System. These warning systems detect traffic and terrain, respectively, in close proximity of the aircraft.

Even more sophisticated is the Flight Management System (FMS), an on-board navigation, performance, and aircraft operations computer. One of its functions is to support automatic flight path control along the lateral, vertical, and longitudinal axes [13]. The FMS has three levels of automation; in the higher level of automation, called the *flight management mode*, the pilot programs a plan into the flight management computer, including route, speeds, and altitudes at different waypoints, and on some aircrafts, arrival time at the waypoints [14]. The pilot's role is to monitor the system and detect any discrepancy and failure. If all goes well, the pilot does not have to touch the controls.

Current Standard Operating Procedures and regulations in most airlines usually encourage the use of automation during cruise and, under some circumstances, for landing. Consequently, crews no longer fly the aircraft manually, unless they choose to do so. Pilots can usually override the computers, but there are some exceptions. For instance, the introduction of the flight envelope protection means that the pilot is prevented from making control commands that exceed the aircraft's structural and aerodynamic operating limits. In Airbus aircrafts, for example, the pilots can only fly outside the flight envelope by selecting a different "control law", whereas in Boeing aircrafts they are required to use excessive force. In review, airplanes can already fly without any input from the pilots and as technology evolves, they are expected to become more reliable and safe. A passivation system could then be seen as another security layer to the automated systems already in place.

IV. Unmanned Aerial Systems (UAS)

Originally called Unmanned Aerial Vehicles (UAV), Unmanned Aerial Systems consist of the unmanned aircraft and the ground station. Originally UAS were secret military aircrafts developed for reconnaissance and strike in war zones. They now range from small air vehicles that weigh less than 500g to aircrafts weighing over 40 thousand pounds. Today UAS development is undergoing a massive growth associated with the development of new technologies originally introduced to support pilots in the cockpit, like satellite navigation, autopilot, new systems to support navigation, etc. As the costs to build and maintain such systems become smaller, the range of potential civil applications increases: crop surveillance, wildlife monitoring, traffic monitoring, support of search and rescue activities, pollution detection, weather monitoring, airborne crime reconnaissance, etc. [15].

The only thing delaying the civilian applications of UAS are the certification procedures and regulations, including air traffic management procedures, currently under discussion by national and international airworthiness authorities, including the FAA, EUROCONTROL and ICAO. But by 2016 Europe expects to see civil airspace opened to UAS, just one year later than the USA.

One of the proposed civil applications of UAS include cargo transport. In one of the first studies to look at the social acceptance of UAS, [16] reported a survey where 51% of those interviewed were willing to accept cargo transportation by UAS after being provided with detailed information about costs, human error, reliability and availability. In a control group that did not have access to this information only 37% accepted cargo transportation by UAS. When the respondents were asked if they would fly in an unmanned a/c, there were no differences between the two groups in the number of positive answers. However, 35% (vs. 12%) of the "educated" group responded "Not Sure" which suggested that the information provided changed their attitude toward UAS. The author concluded that to increase society's acceptance, UAS information should be slowly provided to the public. Finally, another interesting finding was that only around 12% and 17%, respectively, of the respondents said they would fly in an unmanned a/c if prices were 50% cheaper.

Familiarity brings acceptance, and as people become more familiar with UAS, they will be more willing to accept them. As reported by [16], there is already some support to the use of UAS for cargo transportation. Once it becomes a reality, trust in the technology behind the system should increase and, once the risks are deemed small enough, society might be more willing to accept the transport of passengers by UAS. It is reasonable to assume, though, that passenger transportation by UAS is even more remote in time than aircraft passivation. A more realistic approach is that social acceptance of cargo transportation by UAS could pave the way for a system like aircraft passivation in commercial airlines which, in turn, could lead to a greater acceptance of UAS transporting passengers in the long-term.

V. LESSONS LEARNED BY THE AUTOMOTIVE INDUSTRY

Driverless cars are no longer a thing of the future. Currently several car companies are testing the prototypes of cars that do not require human intervention and it is expected that before 2025 they will be ready for the market [17]. Two of the arguments for the introduction of driverless cars is that it maximizes road capacity and reduces driver error [18]. [19], for example, reported that approximately 90% of all traffic accidents are caused by human error due to fatigue or inattention. Therefore, some argue that computers are actually safer than humans considering that they do not run red lights and do not go over speed limits, for example.

A survey of 407 drivers from 9 European countries conducted in SAVE [20], a EU project aimed to develop a system that takes over vehicle control in case of an emergency, showed that handing control to a device was evaluated as a negative aspect of such a system. Drivers expressed concern over "loss of control" and were only willing to hand over control in emergency situations, such as driver breakdown [20]. In a different study, [21] tested drivers' acceptance of an Adaptive Cruise Control system and found an almost unanimous objection to automatic braking, because it "crossed the red line that dictates who controls the vehicle". What the automobile industry has discovered is that systems that take over control are usually disliked by the public [22].

In CVIS [23], an FP6 EU project which evaluated intelligent transport systems for road transport, a survey assessed how acceptability changed if the public had to pay for these new systems. The authors found that the percentage of acceptance of new car technology decreases on average 25% when the drivers are asked about the willingness to pay for it [23]. Furthermore, the authors concluded that in order for society to accept these advanced technologies, they should be introduced concurrently with actions to encourage adoption and acceptance. These include, among others, emphasizing safety, economic growth and job generation.

VI. THE ISSUE OF SOCIAL ACCEPTANCE

The overall acceptability of a computer system can be measured in terms of social acceptance and user acceptance [24]. The former is determined by society's perception of the benefits vs. the risks or drawbacks of adopting such a system. The latter includes the evaluation of the ergonomics of the system, considering features such as cost, reliability, usability, compatibility with other systems, etc. [22]. A system can have high scores on user acceptance, but low on social acceptance and, thus, be rejected. Some aspects to consider are the moral issues involved and the social, political, economic, and institutional environments surrounding the technology [11, 25].

Technology seems to have reached a point where the most important question is not "can we do it?", but "should we do it?". And the public wants to have a say in the matter. With a few exceptions, nowadays people are less inclined than a few decades ago to enthusiastically and uncritically accept technology, even if it has a strong support from the government and scientists. The nuclear accidents in Chernobyl and Fukushima, the destruction of the ozone layer by the chlorofluorocarbons (CFCs) used in sprays and infant malformations caused by the drug Thalidomide, are reminders that sometimes innovation can go terribly wrong. Events like these also affect the level of trust that society has on its scientists and engineers. If science is considered objective, people will be more willing to accept the professional opinion of researchers. However, if science is seen as vulnerable to bias and prejudice, society will reject its conclusions [25], and thus dismiss scientists' assurances that a system is safe.

Several researchers consider that the most influential cultural dimension in determining technology acceptance and usage is Uncertainty Avoidance, or UA [26, 27]. As the name suggests, UA is a measure of society's tolerance for uncertainty and ambiguity. The higher the UA scores, the greater the resistance to change. Resisting change, however, is not the same as resisting technology. In fact, high UA societies are more likely to embrace technology as a means to reduce unstructured and unpredictable situations. The adoption will not occur immediately, though, as these countries will usually observe the experiences of other countries before adopting the technologies themselves. Low UA countries, on the other hand, tend to value innovation, risk and accept innovations more easily [27]. Japan, France and Germany are examples of countries with high UA scores, whether the US, the UK and Denmark are among the countries with the lowest UA scores in the World.

Nevertheless, even the data on uncertainty avoidance are not enough to allow us to make clear predictions regarding acceptability of new technologies. For example, unlike Germany and Italy, France's nuclear power program was accepted without much opposition [28] and all three countries have relatively high UA scores (especially France and Italy). More relevant seems to be the perceived transparency and degree of confidence in the decision-making process. In other words, the political and institutional specificities of each country explain people's behavior toward new technology better than the countries' UA score. As reported by [29], the public focuses on three main aspects when deciding if a new technology is acceptable:

- Is the decision-making process about the technology acceptable to those who would suffer the consequences of an accident?
- In case of an accident, is the process to decide responsibility and accountability accepted by those affected?
- Do people trust those making the decisions?

French society, for example, is in general more supportive of the decisions made by the state and public administration than the Italian and American societies [28], which suggests that there might be less opposition against a passivation system in France than in Italy or the USA.

Also important is the perceived risk associated with the technology, that is, the risk as judged intuitively by the public as opposed to that measured by the experts, which in most cases do not match. Risk perception is influenced by several related factors. For [28] the most important are the perceived benefits for the individual (the greater the benefits, the smaller the perceived risk) and the global feeling of security provided by society, which depends on the socioeconomic status, as well as on physical and mental health. For example, low income and lack of social relationships are associated with overestimation of risks.

Another important characteristic of risk perception is that accident magnitude is usually given more weight than probability of occurrence [29]. For example, in the eyes of the public, a failure in the technology that causes 300 deaths is unacceptable even if it occurs only once in 10 000 years, whereas for an expert this fatality rate might be acceptable considering the benefits.

Also, when society has no control over the outcome once in the risk situation, the less the level of risk it is willing to accept [29]. For example, people are more willing to accept the risks associated with skiing than with flying since they have much more control over the situation and are not dependent on the skill of others. Society also expects a higher level of protection from involuntary than from voluntary risks (e.g., the presence of a nuclear power plant in the area vs. riding a motorcycle) [11]. Finally, if the technology forces dependence upon small groups of technical elites, if it requires strict physical security measures or special police powers, or if it increases the power of big business, society will develop a negative perception of it [11].

A. *Social acceptance of the passivation of misused aircraft*

Assuming the passivation system is deemed to be safe and reliable by the regulation authorities, the stakeholders of the aviation industry will have a very important saying regarding its introduction in aircrafts. For aircraft manufacturers and airlines, a very important issue would be the costs associated with introducing the system in new aircrafts. Retrofitting of current aircrafts would probably not be economically viable given the technical complexity of the upgrades [7]. If it becomes more expensive to buy and maintain aircrafts, the airlines will attempt to cover the costs by increasing ticket prices. And, as with the driverless cars, passengers might not be willing to pay for it even if a strong case is made of increased safety, because aircrafts are already perceived as being quite safe. A more realistic possibility is that the new system would be introduced in a whole new generation of aircrafts.

The situation for the pilots is of another nature and one might expect the biggest opposition to come from them since they would be directly affected by the system. In the current environment, any system that reduces the pilot's authority in the cockpit will probably be met with some resistance. Here the major question is: Will the pilots accept a system that, under some conditions, might take control of the aircraft from them? Recall that the activation of the passivation system in an aircraft will ultimately be dependent on the pilots' behavior. If their behavior is erratic or raises red flags, the system might be activated. Therefore, several aspects will need to be clarified, including the Standard Operation Procedures and the system's engagement and disengagement conditions, an issue also raised by the pilots surveyed in SAFEE. If someone threatens to break into the cockpit, should the system be immediately activated (as a deterrent to further actions)?

Finally, pilots might also oppose such a system if they see it as one more step toward full cockpit automation and, thus, job loss. In a shorter-term there is some risk that regulations on working hours and rest periods could be loosened up. If a new safety layer is introduced, such that an a/c can land even if the pilots are incapacitated, airlines will most likely pressure the authorities to allow such a reduction.

In terms of public acceptance of passivation, one very important aspect is the need to introduce some mechanisms which define the conditions under which national authorities can passivate an aircraft, especially one from a different country flying over its territory. As discussed earlier, current ICAO conventions state that the responsibility for dealing with security incidents remains with the states that are dealing with the emergency. In theory, however, what would prevent a country from activating the passivation system of an a/c if authorities suspect that a fugitive is on-board?

The benefits of passivation should also be made clear, as they will greatly influence the public's willingness to accept the risks. Passivation needs to be presented as a countermeasure to terrorist actions that improves safety. And society might need to be reminded that currently there are only two approaches to deal with a hijacked aircraft: escorting it by fighters in order to force it to land, or destroying it in case a catastrophic event needs to be prevented [9]. Even dispatching military jets to meet the suspicious a/c can take several precious minutes as the time from flight path deviation to impact can be shorter than the start-up time for the fighter. Additionally, as already mentioned, one needs to consider the damage that the debris resulting from shooting down an a/c might have on the people and structures on the ground.

Earlier in the paper it was pointed out that the type of technology would also influence the degree of public acceptance. As seen in SAFEE/SOFIA and PATIN, there are two different decision-making procedures that need to be allocated. The first one is whether the decision to passivate an a/c remains in the a/c or on the ground. The second is where the flight plan is generated. To leave both decisions to aircraft systems means humans would be giving up control, which might lead to a greater resistance to their acceptance by the public. I suggest that we avoid the temptation to automatize the decision-making process and that humans should be kept involved whenever possible. In other words, total automation of the passivation system should be seen as a back-up plan when all else fails: it should not be the only solution.

In review:

- System should be safe and reliable with a low rate of false-alarms.
- Solicit and incorporate feedback from pilots.
- Decision-making process should be clear and transparent (who passivates and under which conditions).
- The more familiar people are with the technology, the easier it will be to accept it.
- Promote the benefits, point out the alternatives.
- Stress that the passivation system is to be used only in emergency situations when the pilots are incapable of flying the a/c.

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REFERENCES

[1] ICAO, 2013 Safety Report, 2013.

[2] M. Grabell, “History of the federal air marshal service”, Retrieved from http://www.propublica.org/article/history-of-the-federal-air-marshal-service, 2008.

[3] M. Tresselt, “Renegade flights and the tragic choice: must the State sacrifice innocent people?,” Paper presented in the Workshop of the 5th Berlin Roundtables on Transnationality, Retrieved from http://www.irmgard-coninx-stiftung.de/fileadmin/user_upload/pdf/archive/Matthias_Tresselt_III.pdf, 2006.

[4] European Cockpit Association, Pilot Fatigue. Brussels, Belgium: ECA, 2012.

[5] ICAO, Fifth meeting of the ALLPIRG/Advisory Group (ALLPIRG/5-IP/7), 2006.

[6] EUROCONTROL, Annual Report 2005, 2006.

[7] SAFEE Consortium, SAFEE (Security of Aircraft in the Future European Environment), Final Publishable Report (EC contract number AIP3-CT-2003-503521), 2008.

[8] SOFIA Consortium, SOFIA Final Publishable Activity Report (EC contract number AST5-CT-2006-030911), 2010.

[9] D.-R. Schmitt, H. Többen, and H. Philippens, “Passivation of Misused Aircraft to Protect Passengers, Airports and Infrastructure,” Proc. 27th ICAS, 2010.

[10] O. Laviv, and L.J.P. Speijker, SAFEE - Security of Aircraft in the Future European Environment (Report no. NLR-TP-2006-716). Amsterdam, The Netherlands: NLR, 2007.

[11] R.A. Clothier and R.A. Walker, “Determination and Evaluation of UAV Safety Objectives,“ In Proc. of the 21st Int. Unmanned Air Vehicle Systems Conf., pp. 18.1-18.16, 2006.

[12] R. Parasuraman, and V. Riley, “Humans and automation: Use, misuse, disuse, abuse”, Hum Factors, vol. 39(2), pp. 230–253, 1997.

[13] C. D. Wickens, “Aviation Displays,“ in Principles and practice of aviation psychology, P.S. Tsang and M.A. Vidulich, Eds. Mahwah, NJ: Erlbaum, 2003, pp. 147-200.

[14] S. Dekker, and E. Hollnagel, Coping with computers in the cockpit. Aldershot, UK: Ashgate, 1999.

[15] FAA, Integration of Civil Unmanned Aircraft Systems (UAS) in the National Airspace System (NAS) Roadmap. Washington, DC: US Department of Transportation, 2013.

[16] S.L. MacSween-George, “Will the public accept UAVs for cargo and passenger transportation?”, Proc. Aerosp. Conf. , vol. 1, pp. 1-11, 2003.

[17] C. Wüst, “Auto Revolution: A Promising Future for Self-Driving Cars,” Spiegel Online International, February 2013.

[18] D. de Waard, M. van der Hulst, M. Hoedemaeker, and K.A. Brookhuis, “Driver behavior in an emergency situation in the Automated Highway System,” Transp. Hum Factors, vol. 1, pp. 67-82, 1999.

[19] K.A. Brookhuis, D. de Waard, and W.H. Janssen, “Behavioural impacts of advanced driver assistance systems–an overview,” EJTIR, vol. 1, pp. 245-253, 2001.

[20] S. Petica, and E. Bekiaris, Driver needs and public acceptance of emergency control aids. SAVE (TR1047) EU Project Deliverable 3.1. Arcueil, France: INRETS-DERA, 1996.

[21] M. Hoedemaeker, and K.A. Brookhuis, “Behavioural adaptation to driving with an adaptive cruise control (ACC),” Transport Res F-Traf, vol. 1, pp. 95-106, 1998.

[22] J.D. van der Laan, A. Heino, and D. de Waard, “A simple procedure for the assessment of acceptance of advanced transport telematics,“ Transport Res C-Emer, vol. 5, pp. 1-10, 1997.

[23] J. Pauwelussen, M. Hoedemaeker, and L. Kistemaker, Utility, Usability and User Acceptance requirements (D.DEPN.4.1), CVIS Project, 2010.

[24] J. Nielsen, Usability Engineering, San Diego, CA: Academic Press/Morgan Kaufman, 1993

[25] R. Pool, Beyond Engineering: How Society Shapes Technology: How Society Shapes Technology, Oxford University Press, 1997.

[26] P.W. Cardon, and B.A. Marshall, “National culture and technology acceptance: The impact of uncertainty avoidance”, Issues in Inf Syst, vol. 9, pp. 103-110, 2008.

[27] T. Vörös, and J. Choudrie, “Uncertainty Avoidance and Technology Acceptance in Emerging Economies: A Comparative Study,” SIG Globdev 4th Ann Conf, Shanghai, China, 2011.

[28] S. Bastide, J.P. Moatti, and F. Fagnani, “Risk perception and social acceptability of technologies: the French case,” Risk Analysis, vol. 9, pp. 215-223, 1989.

[29] S. Rayner, and R. Cantor, “How Fair Is Safe Enough? The Cultural Approach to Societal Technology Choice1,” Risk Analysis, vol. 7, pp. 3-9, 1987.

[30] H. Otway, and D. Winterfeldt, “Beyond Acceptable Risk: On the Social Acceptability of Technologies,” Policy Sciences, vol. 14, pp. 247-256, 1982.