Liabilities and automation in aviation

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***Abstract*— The adoption of increasingly automated technologies in ATM raises new liability issues that question the traditional approach on liability attribution. In this paper, we present some preliminary results from the ALIAS Project (Addressing the Liability Impact of Automated Systems). Firstly, a theoretical framework for liability attribution in aviation is presented. Secondly, the framework is applied to real air disasters and to hypothetical accident scenarios involving Unmanned Aircraft Systems (UAS). The results are briefly discussed.**

***Foreword*— This paper describes a project that is part of SESAR Work Package E, which is addressing long-term and innovative research.**

Keywords: liability; automation; ATM; accident; UAS

I. INTRODUCTION

In the time horizon of SESAR, that is over the next 30 years, a new generation of air traffic management systems will be developed. Such systems will be capable of augmenting today's capacity, while at the same time making traffic safer and more fluid, efficient and sustainable. To achieve this objectives, new technologies will be developed with increasing automation levels. Some of these innovations are likely to raise new legal issues related to liability for accidents.

The introduction of higher levels of automation will bring about a new allocation of the decision making tasks between the human and the machine. Tasks previously carried out by the human, for example the provision of separation, are supposed to be partially delegated to the system. Highly automated systems are expected to take over operators' repetitive tasks, while human role is expected to be focused on strategic planning, intervening on exceptions and monitoring the system's behavior. In general, rather than governing flight operations directly, pilots and controllers will supervise the automated systems doing the job. As operational tasks are increasingly delegated to automatic systems, the actual human contribution needs to be reconsidered, and human-machine interaction reengineered. This will require a critical revision of the allocation of tasks, roles and responsibilities in the context of complex socio-technical systems.

In this paper, we present some preliminary results from the ALIAS Project (Addressing the Liability Impact of Automated Systems), which is co-financed by EUROCONTROL on behalf of the SESAR Joint Undertaking as part of Work Package E. The project addresses the legal implications of the automation – exploring the wide spectrum of relations between automation and liability, focusing on Air Traffic Management (ATM), but also considering various domains that face similar issues, such as HealthCare, ICT, Train Transport, Navy, automotive industry, etc. The paper is articulated in three main parts. The first part presents a framework for addressing liability issues in the socio-technical systems, providing the description of the different types of liabilities and the list of the different kinds of actors that are likely to be held liable in case of accident. The second part presents a legal analysis of two air disasters: Uberlingen mid-air collision and Linate runway incursion. The innovative aspect of the approach proposed for the analysis deals with the integration of the socio-technical perspective [6][10][12] with the framework of liability in aviation, thus helping to identify which socio-technical aspects were involved in the accident, the way they reflect into issues of liability attribution and the actual correspondence with the outcomes of the legal trial. The third part presents the application of the legal framework to a hypothetical accident scenario [4] involving the flight of an Unmanned Aircraft System. Conducting the legal analysis on a technology still under design and development has the added value of offering a proactive methodology to address liability aspects, in order to help preventing them to act as showstoppers for the development and the deployment of the concerned device. This approach is crucial for the ALIAS Project because it will lay the foundation for the development of the Legal Case, the methodological tool intended to introduce the legal aspects as one of the Key Performance Areas addressed in the design process of highly automated systems.

II. FRAMEWORK OF LIABILITY IN AVIATION

Aviation accidents (and near misses) can engender different kinds of liabilities [5]:

- criminal liability, which presupposes a crime and involves the subjection to imprisonment or to a fine (plus reparation);

- civil liability, which presupposes a tort, and involves the obligation to repair the damage (possibly increased beyond the value of the suffered ham, in case of punitive damages);

- contractual liability, which presupposes a breach of contract;

- administrative liability, which presupposes the violation of a rule or regulation, is enforced by a civil court or a regulator and involves a penalty (fine or withdrawal of privileges);

- disciplinary liability, which applies to employees toward their employers for violations concerning work activities, and which may consist in the subjection of sanctions such as reprimands or dismissal.

One way to limit the impact of liabilities (with regard to compensation to be paid to the damaged persons) consists in insurance. In this regard we distinguish two types of insurance: 1st party insurance, which covers damage suffered by the insured party (e.g. the Air company's loss for damage to the aircraft), and 3rd party insurance, which covers the insured party's obligation to compensate the damage to a third party (e.g. the Air company's obligation to compensate the passenger).

The liabilities we have presented above can have different impacts on the different kinds of actors that may be involved in an accident. We have distinguished the following classes of actors:

- *Air service operators*. These are the individual who are directly involved in the provision of air services. In particular our analysis has focused on pilots, ATCOs or Managers of air services;

- *Air service providers*. These are the public or private bodies delivering air services. In particular our analysis has focused on Air companies, Air navigation service providers, Airport companies, Aviation authorities;

- *Supporting providers*. These are the public or private bodies supporting the provision of air service. In particular our analysis is focused on technology providers, maintenance providers, standard setters, States;

- *Insurance companies*. An important distinction must be introduced concerning the actors we just listed: while operators are individual human beings, air service providers, supporting providers, and insurance companies are organisations. This distinction has a huge importance [2]: only individuals are generally subject to criminal liability and their civil liability is based on fault. On the contrary various instances of no-fault (strict) liability is foreseen for organisations [3].

Let us first consider the liabilities of individual *operators*.

Pilots may be subject to criminal liability, not only when intentionally causing the accident, but also when this is due to their negligent behaviour. In particular when deaths results from the accident pilots may be criminally liable for manslaughter (non-intentional homicide). Pilots may also be subject to civil liability and in particular to professional liability, for not performing their tasks with the required skill and care. This involves the obligation to compensate all damages, though this obligation is usually excluded (or reduced) when pilots are employed by a third party (typically an air company). In the latter case, unless recklessness was at issue, only the employer may be liable (but this varies according to different legal systems). Finally, pilots may be subject to disciplinary liability towards their employers.

ATCOs are subject to in principle to the same liabilities of the pilots.

Managers also can be subject to the same liabilities as pilots and ATCOs. This can happen for having failed to take due care in organising the service, and in contributing to create a defective work-environment where accidents were more likely to take place.

Let us now consider the liabilities of the different categories of *air service providers*.

Air companies are subject to special regime for liability. They are subject to strict liability for damage to passengers and for damage on the surface. This strict liability is limited when the victim has culpably (contributory negligence). In addition Air companies are also vicariously liable (for faults of pilots and managers). This liability has no cap. Finally they may be liable for negligence even when no negligence is attributable to individual people working for or anyway representing the air company. This is corporate criminal liability, which only takes place in a few cases and systems.

Air navigation service providers are subject to a regime which is similar to that of air companies. They may be subject to strict civil liability (on the basis of national laws delegating the sovereign function of air space control from the State to the ANSP), to vicarious civil liability (for torts of ATCOs and managers) and they may, in some cases and jurisdiction, incur in corporate criminal liability.

Airport companies: As for air navigation service providers

Aviation authorities: As for air navigation service providers.

Let us now move to the *supporting providers*.

The first and most importance category of them are *technology providers*, who deliver goods of services (hardware and software equipment and infrastructure) to the Air service providers. They are contractually liability to the purchasers of their goods and services (failure to provide such goods and services up to standard may involve contractual infringement). They are civilly liable (tort liability) towards third parties. When delivering defective goods, they are civilly liable toward damaged third party, under the regime of product liability, which may be viewed as a kind of strict liability with additional excuses (in particular for design failures). They may also be liable for quasi-strict enterprise liability, when damages are caused by inadequate operational activities or processes.

Maintenance providers are usually subject to contractual liability towards the purchasers of their service. They are subject to fault (negligence) liability toward third parties.

Standard-setters may also be liable for providing wrong standards, compliance with which leads to defective products.

However, only a reckless behaviour seems to engender liability on standard setters.

States are the primary addresses of the responsibility to manage the air space. Thus they may be liable for its mismanagement, even when they have delegated this function to Air service providers (there is an ongoing debate on this issue).

Insurance companies may intervene to cover the damage suffered by one party (1st party insurance) or the damage that the party has to compensate (3rd party insurance. 3rd party insurance may be mandatory (up to a certain cap), and additional insurance may be purchased by the concerned actors (in particular Air companies).

The final impact of the liability regime is also determined by the possibility of *recourse*: a liable party may have the right to recover some or all of the paid sums from a third party, who caused the damage or contributed to its causation. This is the case in particular for Air companies, who have the obligation to compensate the passenger under strict liability, but have recourse against other actors (e.g. technology provider, or Air service providers) in case they had a role in the causation of for the damage.

As there are different kinds of possible persons and bodies liable, so there are different victims who may be entitled to compensation. The victims may be operators involved in the accident (pilots, crews, on-ground personnel), passenger, owners of carried baggage of goods, air companies, airports, third parties on the surface. All such parties, depending on the nature of the accident, may have claims to compensation towards the responsible agents.

III. Real cases

This section applies our approach to the analysis of accidents occurred in the aviation domain (in particular ATM) and involving automated devices. A larger set of examples is one of the main output of the ALIAS Project and it is contained in the deliverable D3.1. We analyse each accident starting from factual information such as accident dynamics, investigation report and outcomes of the legal trial. We then identify the role played by the automated system in the accident and the liability issues raised by the event. These cases allow us to identify the different ways in which technology can be involved in air accidents dynamics and how this reflects into processes of liability.

A. Mid-Air Collision, Überlingen 2002

The event: The Überlingen mid-air collision occurred on 1 July 2002 between a Bashkirian Airlines passenger jet and a DHL cargo jet, over the town of Überlingen in Germany. The air space was controlled by Skyguide (Switzerland). The Air Traffic Controller (ATCO) managing the air space was working in an environment below the prescribed safety standards and noticed only less than a minute before the accident that the two aircrafts were on the same course. Technology played a crucial role in the accident [8]. Both airplanes were equipped with TCAS (Traffic Collision Avoidance System), a device designed as a last-second safety net to prevent air traffic collisions. Unfortunately the ATCO was unaware of the instructions provided onboard by TCAS and his avoidance clearance to one of the two flights was in contrast with the resolution advice provided by the TCAS. The pilots of the cargo followed the ATCO's instruction while the pilots of the other flight followed the TCAS instruction. As a result both aircrafts descended. They collided and all 71 people on board the two aircraft died.

Let us first consider the liabilities of *air service operators* in Überlingen. Concerning *pilots*, both crews died in the crash. The behaviour of the pilots of the Bashkirian Airlines jet was questioned in a civil liability trial in Spain aimed at assessing the liability of Bashkirian Airlines. The judge sentenced that the pilots were not negligent. In the criminal proceedings started on 15 May 2007 before the District Court of Bülach (Zurich), the *ATC controller* that instructed the colliding flights was charged with criminal liability for multiple manslaugher and negligent disruption of public transport. However, he was acquitted by the Swiss judge. In the same trial, several *managers* of Skyguide were condemned by the Swiss judge for multiple manslaughter, on the ground that their failure to ensure safety within the ATM organisation was the main cause of the accident. In contrast with the large majority of proceeding before (and after) this trial, the judges did not focus on the last link of the chain, that is, the last human agent (the ATC controller), but rather on Skyguide managers. The managers were held liable not on the ground of the misconduct of the air traffic controllers (vicarious liability), but for their own failure to exercise sufficient care, and in particular for (1) not ensuring that the workstations were properly staffed at all times of the day; and (2) tolerating (over several years) the common practice that in time of low traffic at night only one controller operated two workstations.

Let us now consider the liabilities of the *air service providers* involved in the accident. Concerning *Air Companies***,** Bashkirian Airline compensated the families of the victims with a payment of 20,400 dollars per victim, according to the rules established by art. 22 of Warsaw Convention concerning strict liability of airlines (which is limited to such a maximum amount). In a civil proceeding in Spain, families of the victims demanded a compensation of $ 100,000 per victim. The plaintiffs claimed that (1) Bashkirian Airlines was responsible of gross negligence as referred to in Article 25 of Warsaw Convention, and therefore that the company could not benefit from the limitation of liability referred to in Article 22 of the Convention; that (2) Bashkirian Airlines had not fulfilled its obligations under both Article 3 of the Warsaw Convention and Article 6 the ECJ regulation 2027/1997, and therefore could not benefit in any way of a limitation of liability; that (3) Skyguide was responsible of gross negligence and reckless faults that was a direct cause of the accident; and that (4), consequently, Bashkirian Airlines and Skyguide was held liable jointly and severally, without any limitation of liability.

The Court dismissed the claims. The decision was confirmed in appeal and, lately, by the Supreme Court in Madrid (Judgment 564 of 18/07/2011). In 2003 Skyguide, the *Air navigation service provider* controlling the airspace above Überlingen, established a Compensation Fund, and between 2003 and 2004 reached agreements to pay compensation to most of the families of victims, including crew members. In 2010 the Swiss Federal Administrative Court rejected the claim from relatives of Russian victims aimed at increasing the amount of compensations. In 2011 the Federal Court in Berne confirmed the decision[1]. In the legal cases resulting from the Überlingen crash, liability of *Airport companies* and *Aviation authorities* was not questioned.

Let us now move to the *supporting providers*. Concerning the *technology providers*, Honeywell International, Inc. and Aviation Communication & Surveillance Systems (ACSS), manufacturers of the TCAS installed on the Bashkirian Airlines Jet, were found liable in a product-liability case in Spain[2], for not having provided appropriate information on the use of the TCAS. In particular, the court found that the TCAS Pilot's Guide did not clearly set forth the priority of TCAS advisories over conflicting air traffic control orders. Consequently, the two companies were condemned to pay damages to the familiars of the passengers. On the contrary according to the Court two further alleged defects of the TCAS were not sufficiently proven by the plaintiff: (1) a fault in the RA Reversal system; and (2) the defendants's failure to implement a new version of TCAS software, already available at the time of the accident, which corrected the problems of the earlier version. In deciding the case, the Court followed the 22nd Convention on the Law Applicable to Products Liability, signed in The Hague on October 2, 1973[3]. On these grounds the Spanish judges applied Arizona law to ACSS and New Jersey law to Honeywell, and awarded plaintiffs a total of $10,459,810.50 in damages for the deaths of 30 persons, including $6,723,639.45 as to ACSS and $3,736,171.05 as to Honeywell – an average of $348,660.35 per decedent. The decision is currently subject to appeal (as of June 2012). Concerning *maintenance providers*, in the criminal trial in front of the Swiss Court of Bulach, the ATSEP project leader was sentenced to a fine on the ground of fault liability: he was on leave at the time of the collision, but failed to inform the adjacent centres about the state of the maintenance of the communication lines. In the same trial, the technician on duty in the night of the collision was acquitted. Concerning the liability of *States*, on 27 July 2006, in a legal case resulting from the Überlingen accident, the District Court of Konstanz decided that the Federal Republic of Germany should pay compensation to Bashkirian Airlines. The court found that the delegation of air traffic control to Swiss authorities on the basis of an exchange of "letters of agreement" did not constitute a legally effective assignment to Switzerland, because such letters involved only technical arrangements, and they were not signed by competent bodies representing Germany and Switzerland. Therefore, since no bilateral treaty had been concluded between Switzerland and Germany, nor had there been a valid delegation of the exercise of German national competencies to Switzerland on the basis of international customary law, Germany was held liable towards Bashkirian Airlines for the damage resulting from the wrongful conduct of Swiss ATCOs and for the organisational shortcomings of Skyguide. Besides, the Court declared that Germany was under obligation to indemnify Bashkirian Airlines against all third-party claims brought against the same company in connection with the plane crash[4]. The latter claims included in particular the claims by Honeywell, having recourse against Bashkirian Airlines as a result of Honeywell being sued by familiars of the victims. No legal procedures against *standard-setters* resulted from the Überlingen accident. However, after Überlingen, studies were made to improve TCAS capabilities. Following extensive Eurocontrol input and pressure, a revised TCAS II Minimum Operational Performance Standards (MOPS) document was jointly developed by RTCA (the US Radio Technical Commission for Aeronautics) and EUROCAE (European Organisation for Civil Aviation Equipment). As a result, by 2008 the standards for Version 7.1 of TCAS II were issued and published as RTCA DO-185B (June 2008) and EUROCAE ED-143 (September 2008).

The Swiss Winterthur Group, as *insurer* of Skyguide, paid damages in the amount of 2.5 million of Euros to the families of victims. The District Court of Konstanz, in the Judgement of 18.09.2008, dismissed the action brought by Winterthur Group (AXA Insurance in the meantime) against the bankruptcy trustee of "Bashkirian Airlines" on pro-rata compensation amounting to the equivalent of 2.5 million of Euros.

B. *Runway Incursion, Linate 2001*

The event: On 8 October 2001 at Linate Airport in Milan, Italy, a Cessna Citation CJ2 business jet (callsign D-IEVX) collided with a Scandinavian Airlines Flight 686, a McDonnell Douglas MD-87 airliner, which was preparing to take off. The Cessna jet was instructed to taxi from the western apron along the northern taxiway (taxiway R5), and then via the northern apron to the main taxiway which runs parallel to the main runway, a route that would have kept it clear of the main runway. Instead, the pilot taxied along the southern taxi route (taxiway R6), crossing the runway toward the main taxiway. This error was due to a number of flaws in the organisation of the airport and in its equipment: the lack of a functioning ground radar; the absence of procedure to effectively replace the radar; the bad management of communication by the air traffic controller on the ground; the lack of a stop bar at the intersection between taxiway R6 and runway; the bad conditions of signalling systems and marking on the taxiway and on the runway. In the accident, all 114 people on board the

[1] Judgment 2C_287/2010 of 28 April 2011.

[2] Case 5. First Instance Court N. 34 of Barcelona.

[3] The Convention is currently in force in 11 European countries (Spain, France, the Netherlands, Croatia, Finland, Luxembourg, Montenegro, Norway, Serbia, Slovenia, and FYROM)

[4] The decision of the District Court was appealed by Germany and the trial is still pending (as of June 2012).

two aircraft died. Moreover, the crash and subsequent fire killed four Italian ground personnel in the hangar, and injured four more.

Let us now first consider the liabilities of *air service operators* in Linate accident. All the *Pilots* died in the accident. In the criminal trial involving ATCOs and other ground operators, the behaviour of the Cessna Pilots was considered by the judges "maybe not faultless, but certainly not decisive"[5] in causing the accident. Concerning the *ATCOs* and the *Managers***,** in the Italian Criminal Trial the first instance court of Milan decided as follows. (1) The Airport director was given eight years in prison, for negligence in activating himself in repairing the radar and restoring the markings on the runway, and for not issuing any rule restricting the operation in case of low visibility, and any other rule that could have avoided or limited the harm, (2) The Air traffic controller was given eight years in prison, since his behaviour was considered by the court "unquestionably negligent" in omitting to trace the position of the Cessna and authorizing its invasion of the runway. (3) The former head of ENAV (the air traffic controller's agency) was given six and a half years in prison for negligence in activating himself, given the duties and responsibilities related to his role, in order to update and maintain the technological devices and infrastructures of the airport. In particular, he was held liable for negligent behaviour for not having adopted the new radar, maintained the markings, and provided an updated cartography, consistent with the layout of Milan Linate Airport. (4) The same sanction (6 years) was given to the former head of the ENAC structure, who according to the judge had a role (and therefore duties) similar but hierarchically higher than that of the airport director. Concerning damages, the first instance court found all defendants "jointly and severally liable to the plaintiffs in sums to be established during future proceedings". In a separate and parallel summary criminal proceeding, the General Director of ENAV was held liable for negligence in fulfilling his institutional mission, and in particular for omitting to design, implement, deploy and verify an adequate system for the assistance and control of ground traffic in the airport in conditions of low visibility and high density of traffic. The manager of the ENAV flight assistance centre (CAV) of Linate, his local supervisor, and the central safety supervisor were also condemned. Partially changing the perspective, in the appeal trial (7 July 2006), the Airport Director and former head of ENAC were discharged. The pardon law issued by the Italian Parliament on 29 July 2006 reduced the remaining convictions by three years. On 20 February 2007 the Corte di Cassazione upheld the decision of the Appeal Court.

Let us consider the liability of *service providers***.** In March 2003, in a civil liability case, a complaint was filed against *Cessna Aircraft Company* (Cessna) in the Southern District of Florida by the King family, acting as personal representatives of the estate of Jessica King. Thereafter, 69 European plaintiffs brought suits against Cessna, (as the owner of the aircraft) which were consolidated with the King Plaintiffs' case. Plaintiffs asked the payment of damages from Cessna, alleging that the crash was caused by defendant's failure to properly implement policies and procedures in relation to demonstration flights. Plaintiffs' claims were later modified to allege that defendant was strictly liable for conducting the ultra-hazardous activity of flying an aircraft in dense fog, and that defendant was directly liable for the negligent hiring and supervision of the chartered flight crew. On October 21, 2005, the district court granted in part Cessna's motion to dismiss the case as to the European Plaintiffs on *forum non conveniens* grounds (excluding the jurisdiction of American judges with regard to such plaintiffs), denied in part the motion with regard to the King Plaintiffs, and stayed the King Plaintiffs' case pending resolution of Italian disputes relating to the European Plaintiffs. Both groups of plaintiffs appealed, but United States Court Of Appeals For The Eleventh Circuit confirmed the decision. Jack King lately received a total of EUR 333,628.97 and USD 73,026.50 from settlements, however he sought additional damages from Air Evex (as the operator of Cessna Flight). On June 21, 2010, the Court of Milan issued its judgment in the case, concluding that the sum Jack King already received were "amply satisfactory" to compensate him fully for his damages under Italian law. On 3 October 2002 the Italian *Aviation Authority* (ENAC), The Italian *Air Navigation Service Provider* (ENAV), the Linate *Airport Authority* (SEA), and the *Air companies* SAS and Air Evex, established a Compensation Fund, which reached agreements and paid compensation to the families of the victims. The parties agreed to equally contribute to the fund with deposits up to the limit of 25.000.000 Euro for each contributor. ENAC made a deposit of 25.000.000 Euro. The fund was managed by a Panel where each of the contributor was represented, and included a workgroup in charge of examining compensation claims.

Finally, let us consider the liability of the *supporting providers*. Concerning the *technology and maintenance providers*, the Former head of ENAV, the general director, the manager of the ENAV flight assistance center (CAV) of Linate, his local supervisor, and the central safety supervisor were held liable for negligent behaviour in relation to the adoption of the new radar, the maintenance of markings, and the provision of updated cartography for the ATCOs, consistent with the layout of Milan Linate Airport. Besides, the final ANSV report [1] highlighted that the Jeppesen navigation charts for Milano Linate provided on the Cessna jet contained several discrepancies with the effective state of markings on the ground. This was confirmed also during the criminal trial. However, judges did not considered such discrepancies to be relevant for the causation of the accident. Liability of *States* was not addressed during the trial, however, on 27 February 2003 the Italian Parliament enacted the Law 33/2003, "Measures in favour of the victims of Linate Air Disaster". Article 1 of the law assigned to the Prefect of Milan the sum of 12.500.000 Euro with the scope of fairly donating them to the relatives of the victims, taking into account also their state of effective necessity. Besides, the sum was also aimed at funding

[5] Court of Milan, Fifth Penal Section, sentence N. 4426/03 R.G. T of 16 April 2004

initiatives proposed by the "Comitato 8 Ottobre"[6]. Donations and funding were exempt from taxes, and were assigned to beneficiaries in addition to any other sum received by them in relation to the accident.

C. Analysis of the accidents

Let us now develop some general considerations that can be extracted from the above cases. Accepting accidents as organisational-made disasters [14] implies a view of them as a dynamic combination of human, social, organisational and technological failures. Each of these factors *per se* is not sufficient to generate the accident: only their interaction determines the tragic events. There were technological and organisational failures in both the accidents described above. In the Überlingen case, the technological component of the system had a primary role in the dynamic of the event. In the Linate case, a complex net of active and latent errors [11][12], combined in creating the conditions for the event to occur. In both cases human errors and/or technical malfunctions acted as triggers of the events, but had a disruptive effect only because of latent failures in the system, which allowed the errors to happen and propagate through the system.

Analysing more in detail the dynamic of the two accidents, we have identified two main categories of latent conditions: organisational latent conditions and technical latent conditions. The organisational latent conditions concerned the following aspects: failure to apply security protocols or procedures (e.g. Überlingen); lack of personnel, with regard to peaks in activity (e.g. Linate); lack of training (e.g. Linate); standard deviation from procedures within organisation (e.g. Überlingen); lack of response from organisations to accidents or risks (e.g. Überlingen, Linate). The technical latent conditions concerned the following aspects: absence of supporting instruments (e.g., land radar in Linate, TCAS in Überlingen); unreliable source of information (e.g. unreliable maps in Linate,); insufficient maintenance of essential safety instruments (e.g. markings in Linate, ATC systems in Überlingen); persistent technical malfunction (e.g. Überlingen); design defects (TCAS Überlingen); manufacturing defects (Überlingen).

We have also identified two types of active errors: technical active errors and human active errors. The technical active errors concerned the following aspects: deactivation of communication devices (e.g. Überlingen); malfunctions of safety devices (Überlingen, Linate); fault in software and/or hardware (Überlingen, Linate). The human active errors concerned the following aspects: application of inadequate procedures (e.g. Überlingen, Linate); misinterpretation or lack of human communications (e.g. Überlingen, Linate); inability to correctly identify causes of problems (e.g. Überlingen, Linate); failure to monitor malfunctioning devices (e.g. Überlingen, Linate).

Remarkably there appear to be some interesting connections between the different kinds of errors: (1) Organisational errors have provided in both cases latent conditions for technical errors to happen (e.g., the missing radar in Linate); (2) Organisational errors have provided the latent conditions for human errors to happen (e.g., bad management of safety procedures in Überlingen and Linate); (3) Technical errors have provided the latent conditions for human and organisational errors to take place (e.g. insufficient maintenance of safety devices in Überlingen).

Let us now consider how the different instances of accidents can be classified from a legal perspective. Human active errors may instantiate a violation of a task responsibilities of the concerned individual, or of a more general duty of care pertaining to persons. They may trigger the following legal consequences: (1) Criminal, civil, or disciplinary liability of the involved operators; (2) Vicarious liability or direct enterprise liability of their employer (the organisation in which the operator worked). However, as observed, usually only the employer will compensate the damage. Technical active errors may instantiate either a failure in the product itself of a failure in its maintenance. They may trigger the following consequences: (1) Civil liability on the product manufacturer (usually for design defects); (2) Civil liability on the maintenance provider; (3) Civil or disciplinary liability of the operator charged with maintenance; (4) Civil or disciplinary liability of the manager charged with the maintenance process. Faulty latent organisational conditions may lead to: (1) Criminal, civil, or disciplinary liability for the managers in charge of the organisation (it does not seem that there is a liability when no particular individual has the role responsibility for the organisation, and the bad practice emerges out of individuals' behaviours and shared rules); (2) Vicarious liability or direct enterprise liability of their employer.

The analysis of the accidents proposed highlights how the legal framework sometimes does and sometimes does not cope with this organisational dimension. We have seen how criminal liability often concerns operators, and sometimes managers, while civil liability usually concerns organisations rather than individuals, which are the object of disciplinary remedies. Further steps are to be made for the law to contribute to a safety culture, focused on prevention rather than repression. While the organisational theory of accidents leans towards a no blame safety culture (in virtue of the organisational nature of the accident) the legal framework attribute liabilities to individuals. The organisational theory of the accident is slowly entering into this context, particularly in some socio-technical domains (such as ATM) that are particularly advanced in safety culture diffusion. There are some illuminating legal cases, as the one concerning Überlingen accident, in which the organisation was blamed as the main responsible for the event rather than individual operators.

IV. Hypothetical Accident Scenarios

In the previous section we analysed real accidents that occurred in the ATM domain. On the basis of such analysis and of the Framework for Liability in Aviation, in this section we move forward proposing a similar approach for the

[6] "Comitato 8 Ottobre" is the association of relatives of the victims

investigation of legal issues that may be associated to the design of new technologies based on automation and to their introduction into operations. The approach proposed in this case is not retrospective, but proactive in the sense that potential socio-technical or legal issues are monitored throughout the system lifecycle. We believe that an iterative approach to the design of new technologies for ATM can be extended in order to include also the legal aspects of liability attribution. The purpose is to foster an early, proactive and iterative identification of legal issues that may emerge from the use of a new technology and that may also impact on its success (acceptability and/or sustainability). In the following we present an hypothetical accident scenarios related to the use of Unmanned Aircraft System (UAS). The scenario is freely inspired by a real accident.

A. Unmanned Aircraft System (UAS)

According to the ICAO definition [9] an Unmanned Aircraft (UA) is "an aircraft which is intended to operate with no pilot on board". By extension, an Unmanned Aircraft System is the combination of an UA and the associated elements enabling its flight, such as Pilot Station, Communication Link and Launch and Recovery elements. There may be multiple UAS, Pilot Stations or Launch and recovery Elements within a UAS. Currently Unmanned Flight is restricted within segregated and/or isolated airspace. There are two classes of UAS: Autonomous Unmanned Aircraft Systems (AUAS) and Remotely Piloted Aircraft Systems (RPAS). The ICAO regulatory framework focuses on RPAS, as the only UAS that will be integrated into the international civil aviation system in the foreseeable future.

In building a hypothetical scenario concerning UAS, we considered a future context in which RPAS are integrated in the civil airspace, and thus can fly along with civil traffic. They are equipped with reliable Detect & Avoid Functions that allow the detection and the avoidance of civil traffic in the vicinity of the unmanned aircraft. In case of risk of collision the UAS proposes an avoidance strategy to the remote pilot. If the pilot does not reply in a pre-defined lapse of time the UAS instructs an automatic avoidance manoeuvre, still maintaining the possibility for the pilot to return to a fully manual guidance. At the end of the manoeuvre, control of the unmanned aircraft goes back to the remote pilot. Moreover each RPAS is connected to one or more Pilot Stations, depending on the distance to be flown. Each Pilot Station is connected to one or more Air Traffic Control Sectors. They operate in BLOS (Behind Line of Sight) mode, meaning that the separation of the UA from both terrain and other traffic is based on instrumental support on-board.

In this scenario, a RPAS being used for commercial purposes to bring some materials from one airport to another is approaching the destination airport. A problem suddenly arises concerning the communication link with the Pilot Station: the remote pilot is able to download aircraft parameters but is not able to instruct the flight and to manage it. He tries to use the other Pilot Station as a back up, but the flight is too far from it and there is no connection between this Pilot Station and the UA. The remote pilot informs the air traffic controller of the ongoing problem. He is however confident in the safety of the operations as the UA Detect & Avoid System can separate the UA from the rest of the traffic, if needed. Moreover the UA is able to automatically follow the flight plan and manage landing. Although confident as well in the safe behaviour of the UA, the air traffic controller decides to apply a safety measure and moves the rest of the traffic in order to create a buffer around the UA and avoid crossings that might trigger unexpected behaviour of the UA. The UA proceeds automatically. When approaching the destination airport it applies the landing procedure to be used in case of radio communication failure. This is the behaviour expected by the Tower Controller. The Tower controller manages the traffic in order to dedicate one runway to the UA. In this way he reallocates the rest of the arriving and departing traffic to other runways for safety reasons. The UA lands perfectly, but after the landing, maintains a too high speed, goes out of the runway and finally stops against an airport building. The accident produces significant damages to both the UA and the building.

Let us now first consider the liabilities of *air service operators*. According to the ICAO Circular 328 / AN 190, the *remote pilot* of a UAS has the ultimate responsibility for the safe operation of the aircraft. However the pilot should be able to exclude his liability by proving that the damage was not caused by his negligent behaviour in the management of a technical problem (in this scenario, the communication link between the UA and the Pilot Station). To exclude his liability, he should in any case take all appropriate mitigation measures, and first of all signal the issue to the relevant actors of the air traffic management, so that they can manage the situation with the necessary counter-measures. Concerning the *air traffic controller*, he has the responsibility for the safety of air traffic. Therefore, in the present case, he should operate in an effective and prudent manner avoiding overtrust in technology. This is what happened in our scenario, since the ATCO redirects traffic in order to create a buffer around the UA. Such precautionary measure indeed allows the safe landing of the UA and prevents risk of both mid-air and landing collisions. On the contrary, if the air traffic controller had not taken these precautions in this critical situation, he could have been charged with negligence (for not having adopted the proper safety measures), caused by overtrust in technology or underestimation of the problem. In other words, the controller would have been responsible for faulty supervision of the air traffic, even if he could not interfere with the UAS's autonomous behaviour. Concerning the liability of other air service operators, such as *managers or other employees* of air services providers, we need to consider the organisation in place and the rules which are applied, so that we can determine (for the purpose of criminal liability) whether the operator could really be considered individually at fault.

Let us now consider the liabilities of *air service providers*..If the UAS was correctly performing at the moment of the accident, and it is not possible to detect technical defects (and therefore allocate the consequent liability to the technology or the maintenance provider), the responsibility would remain upon the entity who was in control of the UAS, unless a specific cause of the problem can be found, according to the rules concerning dangerous activity. This entity could be the *air company* who owns the UAS, unless the use and therefore the control over the UAS activity was transferred to another company or person. Concerning *air navigation service providers*, in any case of damage caused by an error of the ATCOs, the organisation running the ATC service would also be liable on the ground of (1) vicarious liability, in case the fault was due to the negligence of the operator; (2) strict liability in almost all the other cases (the main exceptions being that the failure was unavoidable, and the activity was uninsurable). The same solution would apply for liabilities of *airport companies* and *aviation authorities*.

Finally, let us consider the possible liabilities of *supporting providers*. As the damage occurred from the crash of the aircraft against the airport building is concerned, liability issues are directly related to the need to repair this damage which is caused by an automatic behaviour of the UAS on the ground. Since after the landing the aircraft could not reduce its high speed, the liability should be allocated according to the reasons why the aircraft missed the normal stopping procedure. If this error is due to a defect in the construction of the aircraft which was not known to the buyer at the moment of the purchase, *the technology providers* (seller or producer of the UAS) can be liable for failure to warn about the product's danger when used in its intended manner, since the proposed warning would have prevented the resulting accident. If this error is due to bad maintenance, *the maintenance provider* who failed to perform this task appropriately may be charged with liability (for negligence, or for contract infringement). Therefore, the company who owns the aircraft can be responsible for this, or the bad maintenance can be blamed on who was in charge of maintenance of the system (the user for instance), or on who effectively performed the maintenance tasks and guaranteed for their correctness.

Finally, concerning *insurance companies*, it should be remarked that current premiums for liability insurances related to the use of UAS are notably higher that corresponding premiums for manned aircraft. If such disparity would persist in the future, it may hamper UAS technological innovation and market development.

Our analysis is based on the current regulation of liability. In the future of the project we shall consider whether the current regulation is appropriate to the new situation generated by UAV, or if an update is needed, in particular to deal with cases where (as in our scenario) a technical problem implies a de facto evolution of the aircraft from RPAS to AUAV.

VI. CONCLUSIONS

The present research uses the human-factor and legal analysis of past accidents for a prospective purposes, namely, to identify liability issues that may be raised by new technologies, currently being prototyped. Thus the analysis of past cases is complemented by the generation of hypothetical scenarios highlighting critical interaction in the socio-technical system, accompanied by their legal implications. With this approach we expect to identify potential legal issues during the development process of new technologies, so that remedial actions can be taken concerning the design of such technologies, or their implementation and deployment in organisations. We also aim to provide useful indications to national and international decision makers (judges, legislators, actors involved in self-regulation) on how to deal with liability issues. This might even trigger new/updated aviation conventions and/or regulations within the broader established legal framework. Our research has led to the construction of a method for classifying liabilities according to the kind of actor involved and the kind of liability at issues, which has been applied to both past accidents and to scenarios. On this basis we were able to link liabilities to the different kinds of mistakes originating them. This will provide a basic framework for comparing and critically assessing the approaches adopted in different legal systems, and for the proposals and tools to be developed in our project. In particular we shall deploy this framework in the Legal Case, that will be developed in later stages of the project. It will consist in a methodological tool including recommendations and guidelines to ensure that relevant legal aspects are proactively taken into consideration at an early stage, during the design, development and deployment process of new technologies based on automation.

REFERENCES

[1] Agenzia Nazionale per la Sicurezza del Volo (2004), Final Report N.A/1/04, approved by ANSV Board on the 20th of January

[2] Bovens M.A.P. (1998), The quest for responsibility: Accountability and citizenship in complex organisations. Cambridge University Press

[3] Brüggemeier G. (2004), Common Principles Of Tort Law: A Pre-statement Of Law, British Inst. of International and Comparative Law

[4] Carroll J. M. (1995), Scenario-Based Design: Envisioning Work and Technology in System Development. Wiley

[5] Chatzipanagioti M. (2007), Liability Aspects of Air Traffic Management, in Air&Space Law, (32)

[6] Edwards E. (1972), Man and Machine: Systems for Safety, in Proceedings of British Airlines Pilots Associations, London

[7] Johnson C.W. (2006), Linate and Überlingen: Understanding the role that public policy plays in the failure of air traffic management systems, in Proceedings of the ENEA International Workshop on Complex Networks and Infrastructure Protection

[8] German Federal Bureau of Aircraft Accidents Investigation. Investigation Report AX001-1-2. 2004-05- 02

[9] ICAO, Unmanned Aircraft Systems (UAS), Cir 328, AN/190

[10] Perrow C. (1984), Normal Accidents: Living with High Risk Technology, Basic Books, New York

[11] Reason J. (1990), Human Error, Cambridge University Press, Cambridge

[12] Reason J. (1997), Managing the Risk Organisational Accidents, Ashgate Publishing Limited, Aldershot Hampshire

[13] Schubert F. (2010), Legal Aspects of Cross-Border Service Provision in the Single European Sky, in Air&Space Law, (35)

[14] Turner B.A. (1978), *Man-Made Disasters*, Wykeham, London,