Liability and automation: Issues and challenges for socio-technical systems

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Abstract. Who is responsible for accidents in highly automated systems? How do we apportion liability among the various participants in complex socio-technical organisations? How can different liability regulations at different levels (supranational, national, local) be harmonized? How do we provide for accountability, while promoting safety? These and other questions are being addressed by the ALIAS (Addressing Liability Impact of Automated Systems) project. In this paper we present the outline framework of the project, its objectives, and some preliminary results: in particular, we present a framework for liability in aviation, an analysis of real accidents and of a hypothetical case involving UAS according to a methodology developed in the project, and finally, we introduce the Legal Case, that is a methodological tool (currently under development) aimed at identifying and addressing liability issues of automated ATM systems.

Keywords: Liability, automation, ATM, accident, UAS, legal risk management

1. Introduction

In the time horizon of SESAR (Single European Sky ATM Research), over the next 30 years, a new generation of air traffic management (ATM) systems will be developed. Such systems will be capable of augmenting the current capacity of air traffic management, while at the same time making traffic safer, more fluid, efficient and sustainable. To achieve this objective, new and much more automated technologies will be developed and some of them are likely to raise new legal issues related to liability for accidents.

In particular, highly automated systems will make choices and engage in actions, usually with some level of—sometimes even without—human supervision. For instance, aircraft will be able to automatically separate itself from the other aircraft, and some of them will fly without a pilot onboard. In general, rather than governing flight operations directly, pilots and controllers will supervise automated systems doing the job. This is why, 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.

The allocation of functions, responsibilities, and liabilities should be viewed as a governance mechanism enabling the enhancement of the functioning of ATM. In fact an ATM is a socio-technical system (STS), namely, a system that involves a complex interaction between technical, social and organisational factors, as well as human factors: at the core of an ATM is a technical infrastructure, but this technical infrastructure is coupled with human operators that continuously monitor and modify the ATM’s state during its operational processes. Thus both the technical and the social aspects (the latter including humans, institutions and norms) are crucial to the design and functioning of the ATM technologies of the future.

In this paper, we present some preliminary results from the ALIAS (Addressing Liability Impact of Automated Systems) project, which is co-financed by EUROCONTROL acting on behalf of the SESAR Joint Undertaking (the SJU) and the EU as part of Work Package E in the SESAR Programme. The project focuses on the legal implications of automation – exploring the wide spectrum of relations between automation and liability, focusing on ATM, but also considering various domains that face similar issues, such as healthcare, information and communication technologies, train and maritime transport, automotive industry, etc.

The paper is divided in the following sections: (1) an outline of ALIAS project’s aims and expected results; (2) the description of the framework of liability in aviation which connects different kinds of liabilities with the actors involved in ATM; a liability analysis of (3) selected real aviation accidents and (4) a hypothetical scenario, which have been analysed according to a methodology developed in the project; (5) the presentation of the Legal Case, that is a process which enables a proactive approach to liability and represents one of the main outputs of the project. Finally we will shortly summarise the outcomes obtained so far and provide some final remarks.

2. The ALIAS project

The ALIAS project argues that in order to ensure the efficient and safe use of automated technologies, an appropriate allocation of liability is crucial. Such an allocation should be designed on the basis of the most careful examination of the following issues.

The first issue refers to how automation changes the tasks and responsibilities of human operators, organisations, and technology providers, i.e., manufacturers and system developers. This requires addressing, in particular, the following aspects: (a) how different degrees of autonomy of agents and machines, in a complex organisational framework, shape the responsibilities of the different actors (operators, controllers, managers, manufacturers, designers), (b) what specific challenges forthcoming operational concepts and procedures (e.g. business trajectories, self separations, variable separation minima depending on aircraft performance) provide to the different actors and how these challenges impact actors’ responsibilities.

The second issue concerns, first of all, determining, how existing laws and regulations (national and international, public and private) regulate the allocation of liabilities in ATM, and, secondly, assessing whether such laws and regulations provide an adequate normative framework. We shall consider that automated devices implemented in ATM in recent years have reduced some tasks of the pilot in command and of the air traffic controller, or have transformed them from operational into supervisory tasks. This
change must be reflected in the allocation of responsibilities and, consequently, of liabilities for failures. We will also examine to what extent the current regulation, case law and internal practice contribute to fostering the development of a safety culture within organizations. For instance, the current allocation of legal liability, focused almost exclusively on the actions (or omissions) of pilots and controllers, contributes to attitudes and practices based on blaming individuals rather than going back over the chain of latent and active errors that occurred in the whole organisation. Such attitudes and practices may hinder reporting mistakes and near misses, and in general induce non-cooperative behaviour.

The third issue concerns how to optimally allocate responsibilities in present and future highly-automated STS. This implies viewing the allocation of responsibilities, not only as a way to distribute risks and sanctions, but also as a means to prevent accidents and to increase levels of safety and performance in ATM. For an optimal allocation of responsibilities, we suggest to: 1) identify tasks and roles of operators (managers, air traffic controllers, pilots, etc.) and automated tools; 2) identify the expected level of performance for each task; 3) consider different kinds of errors (unintentional rule violations, reckless behaviours, intentional violations); and 4) define the appropriate legal and disciplinary sanctions and/or safety incentives in relation to different errors, risks and accidents. On the basis of this analysis, we will suggest how to adapt existing normative frameworks and practices to forthcoming pervasive automation scenarios.

In order to address the above issues, ALIAS proposes a research plan that will combine theoretical investigations with an on-going online discussion with stakeholders, who share their experience and benefit from a collaborative effort on the project’s themes.

Two main outcomes are expected from the project:

- The development of the “Legal Case”, namely, a methodological tool (including recommendations and guidelines) to ensure that relevant legal aspects are taken into consideration at the right stage of the design, development and deployment process.
- The creation of a legal research network in STS with the purpose to set up a multidisciplinary community that will support knowledge construction and distribution, sharing of cases and best practices, discussion on the topics of interest, archiving of documents and references useful to develop this research area. The network is accessible from the project website www.aliasnetwork.eu.

The following article outlines some of the basic framework of analysis for liability in aviation developed in ALIAS. An actor-based approach to legal liability is combined with the socio-technical understanding of accident analysis in order to model the attribution of legal liability in the system of aviation. This framework is deployed in the Legal Case methodology, creating a process for the proactive incorporation of legal analysis in the early stages of technology innovation.

3. Framework of liability in aviation: Actors and liabilities

In the following we describe the framework developed by the ALIAS project which addresses liability in aviation by connecting different kinds of liability with the actors involved in ATM. Instead of taking the legal instruments as starting reference, the Legal Case purports to be an actor-based methodological tool.

Aviation accidents (and near misses) typically engender different kinds of liabilities:

- criminal liability, which presupposes an act (or omission) that violates national criminal legislation and is punished by an imprisonment or a fine;
tortious (extra-contractual) liability is based on the intentional or negligent breach of the duty of care, and involves an obligation to redress the loss or injury caused by this breach;
contractual liability, which presupposes a breach of contract;
State/administrative liability, which presupposes the violation of a rule or regulation by public officer who, while exercising his official powers, causes damages or harm.

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

- **Physical persons**: the individuals who are directly involved in the provision of air services, namely, pilots, air traffic controllers (ATCOs) or managers of air services.
- **Air carriers**.
- **Air navigation service providers (ANSPs)**: the public or private bodies exercising air service activities of sovereign function.
- **Other service providers and actors**: bodies which support the provision of air services, such as technology manufacturers, airport operators, maintenance service providers, certification authorities, national supervisory authorities.
- **States**.
- **Insurance companies**.

An important distinction must be introduced concerning the actors we just listed: while physical persons are individual human beings, airlines and ANSPs, other providers, and insurance companies are organisations [1]. This distinction is of relevance as 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) civil liability is foreseen for organizations [2].

Let us first consider the liability of individuals/physical persons.

Pilots or ATCOs may be subject to criminal liability when intentionally causing the accident or when the accident was due to their negligent behaviour. In particular when deaths result from an accident they are often charged with manslaughter (non-intentional homicide).

When pilots or ATCOs cause damages by not performing their tasks with the required skill and care, their employer (the Air company or the ANSPs) will have the obligation to compensate the damage on the basis of vicarious liability. This is why, as concerns the civil aviation, physical persons—in particular, pilots and ATCOs—are usually held liable to repair the damage only in connection with a criminal conviction, because in all other cases vicarious liability applies.

Finally, pilots or ATCOs may be subject to disciplinary sanctions towards their employers for violating their professional duties.

Managers may also be held liable. This can happen on ground of organisational liability, namely, for having failed to take due care in organising the service, and for failure to create an effective work-environment where the possibilities of an accident are reduced to a minimum.

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

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1Vicarious liability refers to the fact that an employer may be held liable for the wrongful act of his employee, performed within the scope of his employment. The French and the Italian civil code provide for strict liability of employers for the delict of their employees. While according to the German Civil Code (BGB), art. 831, the employer is only liable under the condition of own fault (but, in case of an employee’s delict, there is a rebuttable presumption of employer’s fault).
The regulatory framework for airline companies’ liability in the event of damage caused to passengers, baggage or goods during international journeys is today provided by the Montreal Convention of 1999, a treaty that supersedes the system of liability originally envisaged by the Warsaw Convention. The Montreal Convention provides a two-tier liability regime for damages in case of injury or death of passengers, comprising: (I) liability of the air carrier up to 113,100 SDR, irrespective of the carrier’s fault; (II) liability of the air carrier in excess of 113,100 SDR on the basis of negligence of the air carrier or its employees or agents. Air service providers may also be subject to national laws; this happens in those cases which are not covered by the Montreal Convention. In fact, the question concerning which cases are not covered by Montreal Convention is at the center of the international debate, as well as whether Montreal Convention preempts national laws. The scope of the Montreal Convention has been extended to domestic transport within each single EU Member State by virtue of the Regulation (EC) No 889/2002 amending the previous Regulation (EC) No 2027/1997 on air carrier liability.

Aircraft operators are also subject to a special regime of liability for damages on the surface of the Earth, according to the 1952 Rome Convention. For example, they are strictly liable below a specific liability tier, which varies according to the weight of the aircraft. Moreover, airlines are liable without limits under the same convention, if the damage was “deliberately” caused by the operator of the aircraft or its employees or agents. Personal injury claims are limited to 125,000 SDR.

The liability of air navigation service providers is governed by the national laws of the State over the territory of which the services are provided. In consideration of the sovereign nature of ANS, most national laws recognise the primary responsibility of the State, even if an independent body provides the services. A second approach places the service provider on the front liability line: in this case, the claims must be brought against the service provider but the ultimate responsibility remains on the State. A third approach is that, when the ANS functions have been entrusted to a privatised entity, the State remains liable only for damages caused by its own, direct fault.

ANSPs are also subject to vicarious civil liability (for torts of ATCOs and managers). Let us now move to other providers and actors that support the provision of air services.

The first and most important category of them are the technology suppliers. They are contractually liable to the purchasers of their goods and services (failure to provide them up to standard may involve

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3 Special Drawing Rights (SDRs) are supplementary foreign exchange reserve assets defined and maintained by the International Monetary Fund (IMF). They can be exchanged for Euros, Japanese yen, UK pounds, or US dollars. The current valuation (as of February 2013) of 1 SDR is 0.665 and 0.423 €.
4 Indeed, the courts have questioned the preemtiveness of the Montreal Convention (established by its art. 29): for instance in Serrano v. American Airlines (2008), the court argued that plaintiffs’ claims under the state law are permissible as long as they are in line with the liability conditions of Montreal Convention, and as long as “the local laws are in accordance with the rules of [Montreal] Convention” [3].
5 Regulation (EC) No 889/2002 applies the rules of the Montreal Convention to all flights, whether domestic or international, operated by Community air carriers. In particular, it added an Annex, specifying that there are no financial limits to the liability for passenger injury or death and that, for damages up to 100,000 SDRs, the air carrier “cannot contest claims for compensation”. Above this threshold, the air carrier can defend itself against a claim “by proving that it was not negligent or otherwise at fault”. Unlike directives, regulations have a direct effect in the Member States of the Union, therefore no risk of conflicting ratifications exists in the EU.
6 It is superseded by the 2009 Montreal Conventions (not yet in force). The Rome Convention has been ratified by a number of countries, among which several EU Member States (Belgium, Italy, Luxembourg, and Spain): If national law applies, it usually follows the lex loci damni comissi [4].
7 Currently no international or regional liability regime, comparable with the Montreal Convention for air carriers, exists to cover the liability of ANSPs.
contractual infringement). They may also bear tort liability towards both contractual and third parties.

When delivering defective goods, they are liable toward a damaged third party, under the regime of product liability, which may be viewed as a kind of strict liability with additional exemptions (in particular for design failures).

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

Certification authorities may also be liable for providing wrong standards, compliance with which leads to defective products. Certification authorities are usually State entities and their liability is a form of extra-contractual State liability: for instance, liability of EASA is governed by Article 31 (3) Reg. 216/2008.

States remain the primary addressees of the responsibility to manage the air space in accordance with Article 28 of the Chicago Convention. Thus they may be liable for its mismanagement, even when they have delegated this function to Air navigation service providers. In the absence of an international regime, adjudication would take place according to the place where an accident occurred [6].

One way to limit the financial risk of liability is insurance. Insurance companies may typically intervene to cover:

1. damages suffered in case of aviation hull insurance, which usually covers loss of or damage to the aircraft caused by fire, theft, collision loss (both in-flight and ground risks). In some countries loss or damage resulting from the insured’s own fault may be excluded from the insurer’s liability, in others the insurer may be still held liable;
2. the air carrier’s liability, including not only the liability of the carrier for passengers, luggage and cargo, but also
3. third party liability, resulting from damages (death, personal injury, loss or damage to property) to third parties [7];
4. flying and ATC personnel insurances, usually under collective personal accident policies.

In policies, liability caps are usually inserted. Liability insurance may be mandatory (up to a certain cap), and additional insurance may be purchased by the insured party. Insurers have a right of subrogation, i.e. a right to recover the amount from third parties (that is not the insured party) at fault.

The final impact of the liability regime is also determined by the possibility of recourse: a damaged party (or its insurer, if it has already paid the compensation) may have the right to recover some or all of the paid some from a third party, who caused the damage or contributed to its causation. This is the case in particular for Air carriers, who have the obligation to compensate the passenger, but have recourse against other actors (e.g., or Air service providers) in case they had a role in the causation of the damage.

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8Within the EU such regime has been introduced by the EC Council Directive 85/374/EEC of 25 July 1985 on product liability, implemented by all EU Member States.

9All ATM service providers operating in the EU internal market should be covered by a professional liability insurance, as established by art. 6 of Reg. (EC) No 550/2004. Concerning airline companies, after the 2001 terrorist attacks, the EU introduced a regulation aimed to strengthen aviation insurance coverage in order to foster consumer protection and avoid distortion of competition between air carriers. Reg. (EC) No 785/2004 of the European Parliament and of the Council of 21 April 2004, on insurance requirements for air carriers and aircraft operators, established minimum insurance requirements for air carriers and aircraft operators in respect of passengers, baggage, cargo and third parties, for both commercial and private flights flying within, into, out of, or over the territory of an EU country.
As there are different kinds of possible persons and bodies liable, so we may have different victims who may be entitled for compensation. The victims may be the flight crew, the ground crew, passengers, owners of carried baggage of goods, third parties on the surface. All such parties, depending on the nature of the accident, may have claims to compensation towards the responsible persons.

4. Real cases

This section contains some examples of the approach proposed for the analysis of accidents occurring in complex socio-technical domains (in particular ATM) and involving automated devices. A larger set of examples is contained in deliverable D3.1 of the ALIAS project, which will be available for download from the project’s website: www.aliasnetwork.eu.

The approach proposed for the analysis is retrospective and mainstream. We analyse each accident starting from factual information such as accident dynamics, investigation report and outcomes of the legal procedure in order to identify the role played by the automated system in the accident and the issues of liability attribution. These cases allow us to identify the different ways in which technology can be involved in accident dynamics and understand how this involvement reflects on the processes of liability attribution.

4.1. Mid-air collision, Überlingen 2002

The event: The Überlingen mid-air collision took place on 1 July 2002 between a Bashkirian Airlines passenger jet and a DHL cargo jet over the towns of Überlingen and Owingen in southern Germany. The air space was controlled by Skyguide (Switzerland).

The facts: The ATCO was working in an environment below the prescribed safety standards and noticed only less than a minute before the accident that the two aircraft were on the same route. The use of the technology played a crucial role in the accident dynamics. Both aircraft were equipped with TCAS (Traffic Collision Avoidance System), a device purposely designed as a last-resort safety net to prevent air traffic collisions. Unfortunately, the ATCO was not aware of the TCAS instructions provided onboard and his avoidance instruction to one of the two flights was in contrast with the resolution advice provided by the TCAS of the Bashkirian Airlines [8]: the pilots of the latter followed the ATCO’s instructions, while the pilots of the DHL aircraft followed the TCAS instructions.

As a result, both aircraft descended. They collided and all 71 persons on board the two aircraft died.

The outcome: Germany, having failed to delegate its responsibilities to Skyguide, was held liable towards Bashkirian Airlines for the damage resulting from the negligent conduct of the Swiss ATCOs and for organisational shortcomings of Skyguide. Three Skyguide ATC managers and one ATSEP (Air Traffic Safety Electronics Personnel) Project Leader were found guilty, while the ATCO in charge of the colliding flights was acquitted.

The legal issues: This case illustrates many legal issues related to the functioning of STS in general, and air navigation services in particular. The main issues are the following: delegation of responsibility for the provision of air navigation services; liability of organisations, in particular for tolerating emergent practices of deviations from rules within an organization; the difficulty to ascertain liabilities in a complex technological environment and especially to demonstrate the defectiveness of technology and its link with the causes of the accident.

Let us first consider the liabilities of individual persons in Überlingen. Concerning pilots, both crews died in the crash. The behaviour of the pilots of the Bashkirian Airlines jet was examined in a civil liability
trial in Spain, trying to assess the liability of Bashkirian Airlines. The judge ruled that the pilots were not negligent.

In the criminal proceedings started on 15 May 2007 before the District Court of Bulach (Zurich), the ATCO that instructed the colliding flights was charged with multiple manslaughter and negligent disruption of public transport. However, he was acquitted.

In the same trial, several managers of Skyguide were found guilty by the Swiss judge of multiple manslaughter on the ground that their failure to ensure safety within the organisation was the main cause of the accident. In contrast with the large majority of legal proceedings before (and after) this trial, the judges did not focus on the last link of the chain which led to the accident, that is, the last human actor (the ATCO), but rather on Skyguide managers. The managers were held liable not on the ground of the misconduct of the ATCOs (vicarious liability), but for their own failure to exercise sufficient care, and in particular for (1) not ensuring that the workstations were properly staffed during the day and night; and (2) tolerating (over several years) the common practice that in time of low air traffic at night only one ATCO operated two workstations. In particular, the judges pointed out that the one-man operation was not in accordance with safety requirements in air traffic services: “... the presence of two air traffic controllers could have prevented the disaster [and] staffing the entire ACC (Zurich air control) at night with only one controller goes completely against air traffic security principles...” and that the managers’ actions “had contributed to a climate of negligence” at Skyguide.

Let us now consider the liability of the air carriers involved in the accident. Bashkirian Airlines compensated the families of the victims with a payment of 20,400 dollars per victim, according to the rules established by Article 22 of the Warsaw Convention concerning strict liability of airlines. In a civil proceeding in Spain, families of the victims demanded a compensation of 100,000 dollars per victim. The plaintiffs claimed that (1) Bashkirian Airlines was responsible for gross negligence as referred to in Article 25 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 of Regulation (EC) 2027/1997, and therefore could not benefit in any way of a limitation of liability; that (3) Skyguide demonstrated gross negligence and reckless behaviour which directly caused the accident; and that (4), consequently, Bashkirian Airlines and Skyguide were to be held jointly liable, 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 July 2011).10

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 to increase compensation payments. In 2011 the Federal Court in Berne confirmed the decision.11

In the legal cases resulting from the Überlingen crash, liability of airport companies and aviation authorities was not examined.

Let us now move to the other service providers and actors. Concerning the equipment manufacturers, 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

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10Supreme Court of Madrid, Judgment 564 of 18 July 2011.
In deciding the case, the Court followed the 22nd Convention on the Law Applicable to Products Liability, signed in The Hague on 2 October, 1973. Article 6 of the Convention applies the law of the manufacturer’s principal place of business unless the claimant bases his claim on the law of the place of injury, while Article 11 establishes that there is no requirement for the Convention to be adopted by the country to which law Articles 6 points.

Concerning maintenance providers, in the criminal trial before 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 maintenance of communication lines. In the same trial, the technician on duty at 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 or 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 an effective assignment of right to Switzerland, because such letters involved only technical arrangements, and that these letters were not signed by competent bodies representing Germany and Switzerland. Consequently, there was no bilateral agreement 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 organisational shortcomings of Skyguide. Besides, the Court declared that Germany was under an obligation to indemnify Bashkirian Airlines against all third-party claims brought against the same company in connection with the plane crash. The latter claims included in particular the claims by Honeywell, having recourse against Bashkirian Airlines as a result of Honeywell being sued by families of the victims.

The Swiss Winterthur Group, as insurer of Skyguide, paid damages in the amount of 2.5 million Euros to the families of victims. The District Court of Konstanz, in the Judgement of September 18, 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 Euros.

Finally, no legal procedures against certification authorities 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 has been 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 have been issued and published as RTCA DO-185B (June 2008) and EUROCAE ED-143 (September 2008).

12The first instance court (Case 5. First Instance Court N. 34 of Barcelona) found that TCAS Pilot’s Guide failed to clearly set forth the priority of TCAS advisories over conflicting air traffic control orders. Consequently, the TCAS was considered defective (warning defect) and the two companies were condemned to pay damages to familiars of passengers. 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. In the Appeal, the court of Barcelona (Judgement n. 230/2012) considered the TCAS defective not only for warning defects, but also for design defects (the TCAS design was considered unreasonably dangerous, despite it was compliant with available standards) and manufacturing defects.

13The Convention is currently in force in 11 European countries (Spain, France, the Netherlands, Croatia, Finland, Luxembourg, Montenegro, Norway, Serbia, Slovenia, and Macedonia).

14The decision of the District Court was appealed by Germany and the trial is still pending (as of June 2012).
4.2. 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 facts: 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 beyond it. This error was due to a number of flaws in the organisation of the airport and in its equipment, such as the lack of a functioning ground radar, the absence of procedures to effectively replace the radar, bad management of communication by the ATCO on the ground, no stop bar at the intersection between taxiway R6 and runway, the bad conditions of signalling systems and marking on the taxiway and runway.

In the accident all 114 persons on board the two aircraft died. Moreover, the crash and subsequent fire killed four Italian ground operators in the hangar, and injured four other persons.

The outcome: The ATCO was sentenced to 5 year imprisonment, the head of ENA V (the air traffic controller’s agency) to 3 years, while the airport director and the head of competent structure of ENAC (the Italian Civil Aviation Authority) were acquitted.

ENAC, together with the other parties involved in the disaster, established a Compensation Fund, which reached agreements and paid compensation to the families of the victims. An attempt to obtain additional compensation through US courts had no success. The Italian Parliament enacted a law to donate additional sums to the families of the victims.

The legal issues: This case exemplifies how an accident is often reconnected to the missing or inadequate execution of specific tasks, and thus to the (natural or legal) persons which were responsible for the task (task responsibility) [9]. As a consequence of their failure to comply with their task-responsibilities, individual operators were subject to criminal liability. However, this case shows how a complex and fragmented legal framework, the uncertainty of the facts, and the complexities of organizations make the allocation of liabilities to individuals a difficult and controversial task [10].

Considerations: This is one of the most serious accidents on the ground ever occurred and it highlights a number of conditions that put the safety of the airport at stake. Besides crucial human errors, latent conditions and organisational problems contributed to the occurrence of this accident. However, it seems to us that the Italian legal system failed to take into account the importance of institutional-organisational aspects by allocating criminal liability mainly to ATCOs. This is one of the cases in which the results of our socio-technical and legal analysis challenge the actual outcomes of the legal trial.

Let us now first consider the liability of individual actors in the 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”¹⁵ in causing the accident.

Concerning the ATCOs and the managers, in the Italian Criminal Trial the first instance court of Milan decided that:

— the airport director should be sentenced to eight years in prison for negligence in taking actions to repair the radar and restore the markings on the runway, for not issuing any rule restricting the

¹⁵Court of Milan, Fifth Penal Section, sentence N. 4426/03 R.G. T of 16 April 2004
operation in case of low visibility, and generally, for not circulating any other rule that could have prevented or limited the harm;
— the ATCO should be sentenced to eight years in prison, and 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;
— the former head of ENAV should be sentenced to six and a half years in prison for negligence, in updating and maintaining the technological devices and infrastructures of the airport. In particular, he was held liable for negligent behaviour in relation to the adoption of the new radar, the maintenance of markings and the provision of updated cartography, consistent with the layout of Milan Linate Airport;
— the same sanction should be imposed on the former head of the ENAC structure, who, according to the judge, had a role (and therefore duties) similar but hierarchically higher than those 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 duties, 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, its local supervisor, and its 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 Court of Cassation upheld the decision of the Appeal Court.

Let us move now to the liability of air carriers. 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 related to the demonstration flight. 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 the United States Court Of Appeals For The Eleventh Circuit confirmed the decision.

Jack King lately received 333,628.97 euros and 73,026.50 dollars from settlements, yet he sought additional damages from Air Evex (as the operator of the 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 ENAC, ENAV, the Linate Airport Authority (SEA), and the airline SAS and Air Evex, established a Compensation Fund, which reached settlements 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 euros for each contributor. ENAC made a deposit of 25,000,000 euros. The fund was managed by a Panel where each of the contributors was represented and included a workgroup in charge of examining compensation claims.

Finally, let us consider the liability of the other service providers. Concerning the equipment suppliers and maintenance providers, the Former head of ENA V, the general director, the manager of CAY 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 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 consider such discrepancies to be relevant for the causation of the accident.

The 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 assigned to the Prefect of Milan the sum of 12,500,000 euros with the scope of fairly donating them to the relatives of the victims, taking into account also their state of their needs. Besides, the sum was also aimed at funding initiatives proposed by the “Comitato 8 Ottobre - per non dimenticare” (Committee of 8th October). 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.

4.3. Analysis of the accidents

Let us now work out some general considerations from the above cases. Accepting accidents as organisational-made disasters [12], implies to see them as a dynamic combination of human, social, organisational and technological failures. Each of these failures per se is not sufficient to generate the accident: only their combination produces the tragic event.

There were technological and organisational failures in both accidents above. In the Überlingen case, the technological component of the system had a primary role in the dynamic of the accident. In the Linate case, a complex net of active and latent errors [13] resulted in creating the conditions for the accident to occur. In both cases there were human errors and/or technical malfunctions that acted as triggers of the accidents. However they cannot be considered as the only cause of the accident itself, as a chain of latent faults (for instance the deviations from policies and procedures) created the silent conditions for the errors to occur. This chain of latent failures allowed the errors to happen and propagate through the system, thus entailing such disruptive effect. Latent failures [13] are those made by people in management, regulatory, designers’ roles, i.e. those people far from the sharp-end. They are defined latent as they may lie dormant or undetected for hours, days, weeks or even longer, until they are discovered or until they pose a threat to safety, thus contributing to the sequence of events resulting in an accident. Latent failures represent a hidden and unknown threat, that can reveal itself all of a sudden, thus leaving the system completely unprepared. Sometimes active errors can even be considered as symptoms of latent failures, as an active error is often caused by workplace problems, bad tools design, lack of procedures and so on.

16The Committee “8th October - Not to forget” is the association of relatives of the victims, officially constituted in Milan on 17 November 2001.
More in detail during the analysis of the accidents, we identified the following categories of latent conditions:

- organisational latent conditions;
- technical latent conditions.

The organisational latent conditions concerned the following aspects:

- failure to apply security protocols or procedures (Überlingen);
- lack of personnel, with regard to peaks in activity (Linate);
- lack of training (Linate);
- standard deviation from procedures within organisation (Überlingen);
- lack of response from organisations to accidents or risks (Überlingen, Linate).

The technical latent conditions concerned the following aspects:

- absence of supporting instruments (land radar in Linate, TCAS in Überlingen);
- unreliable source of information (unreliable maps in Linate);
- insufficient maintenance of essential safety instruments (markings in Linate, ATC systems in Überlingen);
- persistent technical malfunction (Überlingen);
- design defects (TCAS Überlingen);
- manufacturing defects (Überlingen).

We have also identified the following active errors:

- technical active errors;
- human active errors.

The technical active errors concerned the following aspects:

- deactivation of communication devices (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 (Überlingen, Linate);
- misinterpretation or lack of human communications (Überlingen, Linate);
- inability to correctly identify causes of problems (Überlingen, Linate);
- failure to monitor malfunctioning devices (Überlingen, Linate).

Interestingly we discovered some connections between the different kinds of errors:

- organisational errors have provided latent conditions for technical errors to happen (the missing radar in Linate);
- organisational errors have provided the latent conditions for human errors to happen (bad management of safety procedures in Überlingen and Linate);
- technical errors have provider the latent conditions for human and organisational errors to take place (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 or of the concerned individual’s—or a more general—duty of care. This violation may trigger the following legal consequences:

- criminal, civil, or disciplinary liability of the physical persons involved;
- vicarious liability of their employer.

However, as observed, usually only the employer has to compensate the damages.

Technical active errors may instantiate either a failure in the product itself or a failure in its maintenance. They may trigger the following consequences:

- civil liability of the product manufacturer (usually for design defects);
- civil liability of the maintenance provider;
- civil or disciplinary liability of the employee in charge of maintenance;
- civil or disciplinary liability of the manager in charge of the maintenance process.

Faulty latent organisational conditions may lead to:

- criminal, civil, or disciplinary liability of the managers in charge of the organisation (it does not seem that there is a liability when no particular individual has the responsibility for the organisation, and the bad practice emerges out of individuals’ behaviour and shared rules);
- vicarious or direct liability of their company.

The analysis of the two accidents highlights how the legal framework sometimes does and sometimes does not cope with this organisational dimension of the accident. We have seen how criminal liability often concerns physical persons, including managers, while civil liability usually concerns organisations rather than individuals, who are subject to disciplinary remedies.

Further steps are to be made for the law to contribute to a safety culture, which promotes 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 attributes liability 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 held responsible for the accident although there were also many (individual) errors which led to the collision as well.

5. Hypothetical accident scenario

In the previous section we analysed real accidents that occurred in the ATM domain. The innovative aspect of our approach is based on the idea to take into account and integrate both socio-technical and legal perspectives in this retrospective analysis of accidents. The result is a retrospective analysis of each accident, that shows the role of the technology in the dynamics of the accident, the causes (both active and latent) that contributed to the accident, the liability issues at stake and the correspondence of the outcomes of this analysis with the actual outcomes of the legal trials.

Based on this analysis, in this section we move forward to propose a similar approach for the investigation of legal issues that may be associated to the design and deployment of new automated technologies.
We now focus on scenarios as design and validation techniques [14]: the approach proposed for this case is therefore 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 the legal aspects of liability attribution, too. The purpose is twofold:

- to favour early, proactive and interactive identification of the legal issues that could emerge from a new technology and that could also condition its success (acceptability and/or sustainability), and
- consequently to support the design activities for the new technology in order to cope with any legal issues identified.

Doing so, we expect to make potential legal issues emerge during the development process of new technologies, so that remedial actions can be taken in the design process or in triggering new/updated aviation conventions and/or regulations within the established legal framework.

We are using a scenario-based design to generate hypothetical accidents to be then analysed with the same approach proposed in section 3 above. In particular, in developing and analysing the hypothetical scenarios, we started from the outcomes of the analysis of real accidents presented in the previous section: (1) we collected relevant information concerning the new technology (Concept of Operation, applicable standards, certifications, etc.) and its intended use within the ATM system (including information concerning the involved actors, their roles in relation to the use of the new technology, and related responsibilities), (2) on the basis of such information, we developed a scenario that highlights one or more potential risks associated to the new technology, and finally (3) we correlated potential risks to organizational, human, and technical failures, and to resulting liability, on the basis of the categorisation of failures and on the mapping of failures and associated liability resulting from the analysis of real cases.

The analysis of hypothetical accident scenarios allowed us to identify crucial issues concerning the current legal framework in relation to automation, in particular the different approaches that can be taken to attribute liability in contexts in which automation plays a crucial role, that is when relevant parts of cognitive functions and tasks are shared, or even totally transferred, to automated systems. Such issues have been taken into account in the development of the Legal Case.

Moreover, the proactive approach adopted in this analysis represents a cornerstone for the development of the Legal Case (presented in the following section).

In the following section we present a hypothetical accident scenario related to the Unmanned Aircraft System (UAS). The scenario is freely inspired by a real accident involving a UAS. The purpose of the scenario is not merely to analyse the event, but to identify legal issues that could feed the design process of the operational concept and technology under consideration.

5.1. Unmanned Aircraft System (UAS)

According to the ICAO definition (Circular 328 / AN 190) [15], 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 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 UASs: Autonomous Unmanned Aircraft Systems (AUASs) and Remotely Piloted Aircraft Systems (RPASs). The ICAO regulatory framework focuses on RPAS, because it is the...
only UAS that will be possible to integrate into the international civil aviation system in the foreseeable future.\textsuperscript{17}

In building a hypothetical scenario concerning UAS, we considered a future context situation in which RPASs are integrated in the civil airspace, namely, they can fly along with civil traffic in civil airspace. They are equipped with reliable Detect & Avoid Functions that allow the detection and the avoidance of civil traffic aircraft in their vicinity. 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 the automatic avoidance manoeuvre, while still maintaining the possibility for the pilot to return to a fully manual guidance. At the end of the manoeuvre the 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 they have to fly. Each Pilot Station is connected to one or more Air Traffic Control Sectors. They operate in BLOS (Behind Line of Sight) mode: the separation of the UA from both terrain and other traffic is based on instrumental support on board. In this context we developed a hypothetical case of accident, that, although invented by us, is nevertheless inspired by real events.

In this scenario, a RPAS 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 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 ATCO about the problem. He has, however, confidence in the safety of the operations, because the UA Detect & Avoid System should be able to separate the UA from the rest of the traffic. Moreover the UA is able to automatically follow the flight plan and manage landing. Although also confident regarding the safe behaviour of the UA, the ATCO decides to apply a safety measure and moves the rest of the traffic in order to create a buffer zone 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.

In summary, this scenario describes a case in which a RPAS has to perform some tasks in automatic mode with minimal or no pilot capability to intervene, due to technical problems in the communication link between the vehicle and the remote pilot. It raises the issues of how to attribute liability for an accident due to manoeuvres automatically managed by the aircraft. The case is particularly interesting for the active role played by the ATCO, who proactively mitigated the risk of a more serious

\textsuperscript{17}ICAO set up a study group in 2007, which studies the regulatory framework, in particular the Chicago Convention and the implications for UAS. Article 8 of the Convention currently addresses “pilotless aircraft.” “No aircraft capable of being flown without a pilot shall be flown without a pilot over the territory of a contracting State without special authorization by that State and in accordance with the terms of such authorization. Each contracting State undertakes to insure that the flight of such aircraft without a pilot in regions open to civil aircraft shall be so controlled as to obviate danger to civil aircraft.” UAS Circular 328 produced information for States developing regulatory frameworks. There were also RPAS related amendments to Annexes 13, 2 and 7. The ICAO activities foresee the development of an RPAS manual for 2014 and Standards and Recommended Practices.
accident managing the rest of the traffic in order to minimise the possibility of interactions with the UA.

With regard to this scenario, the first liability issue concerns establishing who is responsible for accidents due to UAS automatic tasks, and on what basis.

As the ICAO circular pointed out, the 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 ATM, so that they could manage the situation with the necessary counter-measures.

The ATCO also 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 was done in our scenario, since traffic was redirected in order to create a buffer around the UA. Indeed, this precautionary measure allows the safe landing of the UA and prevents risk of both mid-air and landing collision. On the contrary, if the ATCO had not taken these precautions in this critical situation, he could be charged with negligence for overtrusting technology or underestimating the problem. In other words, the ATCO would have been responsible for faulty supervision of the air traffic, even if he could not interfere with the UAS’s autonomous behaviour. To allocate responsibility to individual operators, however, we need to consider what kind of organisation is in place and what rules are applied, so as to determine (for the purpose of criminal liability) whether the operator could really be considered individually at fault. In any case of failure in the air traffic control, the organisation running it would be liable.

As to the damage occurred due to the crash of the aircraft against the airport building, 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, liability should be allocated according to the reasons why the aircraft failed in performing 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 seller or the producer 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 held liable (for negligence, or for contract infringement). Therefore, the owner of 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.

However, if the UAS was correctly performing at the moment of the accident, and it is not possible to detect reasons of—and allocate the consequent liability for—the technical problem occurred, 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 discipline for dangerous activity. This would be the air carrier performing the flight unless control over the UAS activity was transferred to an aircraft operator.

In the future of the ALIAS project we shall consider whether these answers, which we can extracted from the current regulation of liability, are appropriate to the new situation generated by UAS, in particular to cases where, as in our example, a technical problem implies a *de facto* evolution of the aircraft from being a RPAS to being a AUAS.

Note that the ICAO circular – focusing just on the introduction of RPASs in civil airspace – does not take into account this possibility: the aircraft, while being an AUAS, continues to be subject to the regulation
for RPAS. As a consequence, all the rules applicable to RPAS, and in particular the ordinary liability rules concerning technological failures (user and product liability) still apply, even though the aircraft started to act autonomously, outside of the control both of its operators and its technology providers. It will be interesting to investigate in future stages of the project if this approach is acceptable to the actors involved or whether an update of the regulation needs to be considered.

6. The Legal Case

On the basis of such analysis the ALIAS project is currently working on the definition of the Legal Case, that is a methodological tool to systematically identify and address the liability issues of automated ATM systems.

The Legal Case is meant to be used mainly in a proactive way, that is, to address liability issues that may emerge in the design of new technologies. The process includes the following 4 steps:

1. Understand the context. This step requires the collection of a set of background information about the object of the study (which may be an operational concept, a system, a service, or an accident).
2. Identify liability issues. This step defines the legal implications of the object of the study (operational concept, system, service or accident) on the basis of the understanding of its socio-technical aspects.
3. Perform the analysis. This step analyses the stakeholders’ acceptability of the legal implications defined in previous step, proposes ways to deal with all involved legal risks, and suggests possible mitigations and recommendations for the design.
4. Provide results and recommendations. This step presents the results of the study, highlighting the liability issues associated with the object of the study, the ways to deal with legal risks and further recommendations.

The analysis and modelling undertaken on real and hypothetical cases has been crucial for the development of the Legal Case. In particular, the safety and legal analysis of cases identified relevant models to better understand the ATM sector (as a STS) and the notion of automation. On the basis of several models deriving from human factor research such as the model by Reason [13], and the SHEL and SHELL [16] models, the analysis provided the conceptual grounds to understand automation, the conditions of technology failures, and how the human/technology interaction is developing. The development of a legal framework for liability, which distinguishes between civil and criminal liability, and the different actors involved in ATM, has been adopted in the Legal Case to develop conceptual tools that link failures and automation with legal liability. The goal is to represent different abstracted ‘mechanisms’ for imposing liability. In the Legal Case this is translated into three different levels of maps: description of the automation factor through the first level maps (e.g. types of failures), the liability type maps which view liability from an actor-based view, and the Legal Case maps for specific cases (the case selection presented here) in order to exemplify how courts have dealt with different liabilities and are hence likely to deal with them in the future (state of the law). Finally, the process of analysis followed for the cases, in particular the hypothetical case, has contributed to the definition of the 4 steps of the Legal Case.

Although the Legal Case is being primarily designed with the purpose of being applied to a single project, a transversal use of its results (its parallel application to multiple projects) is also feasible. This will constitute the transversal application of the Legal Case, that consists in combining the results of different Legal Cases, focusing on common elements. Thus, the process is being designed to be compliant with the Generic Transversal Areas Assessment Process, which the Transversal Areas of SESAR are required to follow in conducting assessments and building cases. Its adoption in the Legal Case corresponds to
the need to consider legal issues in a systemic and structured way across the innovation process in the same ways as safety, security, human performance, environment and cost-benefit issues.

Before designing the Legal Case, a close examination of the case-based approach and of the cases currently available (which are the Safety Case, the Human Factors Case and the SESAR Human Performance Case) has been carried out, in order to make the Legal Case coherent with them and to prevent redundant overlaps. The case-based approach has been proposed in the framework of the European Operational Concept Validation Methodology (E-OCVM), to provide key stakeholders with evidence constructed from targeted information. Initially, EOCVM proposed the development of the following five Cases to be applied in R&D: 1) the Safety Case; 2) the Environment Case; 3) the Human Factors Case; 4) the Standards and Regulatory Case; 5) the Business Case. However, only the Safety Case and the Human Factors Case have been developed so far and are currently available, while the Environment Case and the Business Case will be developed within the framework of the SESAR Programme. No attempt has been carried out so far to develop the Standards and Regulatory Case. The Legal Case presented will ideally be a way to bridge the gap.

7. Conclusions

The research illustrated in this paper has used the human-factor and legal analysis of past accidents for prospective purposes, namely, to identify liability issues that may be raised by new technologies. Thus the analysis of past cases is complemented by the generation of hypothetical scenarios which highlight critical interactions in the STS and their legal implications. With this approach we expect to make potential legal issues emerge during the development process of new technologies, so that remedial actions can be taken in the design process or in triggering 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 different kinds of liability according to the kind of actor involved, which we have applied to both past accidents and to hypothetical scenario. On this basis we could link liability to the different kinds of mistakes, which lead to them. This will provide the 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 is currently developed by the project. It consists of a methodological tool including recommendations and guidelines to ensure that relevant legal aspects are proactively taken into consideration early on, and during the design, development and deployment process of new technologies based on automation.

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