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ADDRESSING LIABILITY OF AUTOMATED SYSTEMS IN AIR TRAFFIC MANAGEMENT

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Abstract

In the current operational scenario of Air Traffic Management (ATM), liability is mainly allocated to the operators who are responsible for air traffic control and air navigation. However, this scenario will rapidly change: the adoption of new technologies with high automation levels is likely to raise new legal issues related to liability. The paper presents an outline of the issues of liability in relation to automation, focusing on the concept of autonomy and on the delegation of tasks to automatic systems or to hybrid human-machine systems. Finally a proposal to handle such issues is presented, based on a model of ATM as a socio-technical system, where the allocation of liabilities may be seen as a governance mechanism enabling the enhancement of the functioning of ATM.

Keywords

Liability, automation, delegation of tasks, socio-technical systems, air traffic management.

Giuseppe Contissa
Max Weber Fellow, 2010-2011

Introduction

In the current operational scenario of Air Traffic Management (ATM), liability is mainly allocated to the operators who are responsible for air traffic control and air navigation (e.g. controllers and pilots).

However, this scenario will rapidly change: the SESAR concept of operations, in the context of the development of the Single European Sky,[1] is defining a new high-performance air traffic management system, involving the adoption of new technologies, devices, and high automation levels, which will enable the future development of air transport. Advances in automation and technology may bring about drastic changes from the legal and regulatory perspective, questioning the allocation of liability mainly to operators. Innovation and automation run almost parallel in ATM and the more innovation progresses, the more the theme of liability attribution will be crucial.

Automated systems in ATM

The current legal framework in the ATM domain[2], despite involving the applicability of different models of liability (fault-liability, organisational liability, design liability), does not contemplate the specific issues concerning the relationship between humans and automated systems which will become more and more relevant in the future of ATM: the issues, for instance, related to highly automated systems that perform actions without explicit human intervention; delegation procedures that dynamically transfer responsibility from controllers to pilots or to other technical systems; and functional airspace blocks involving new allocations of tasks.

Such technological changes question the very notion of individual agency, and require a critical revision of the actual human contribution to the performance of ATM, and consequently of the criteria for the allocation of liability.

Several questions are prominent in this context. The first is that of the extent to which the use of new automatic tools may shift liability for accidents from operators to technology, that is from operators to manufacturers, organisations and system developers. In this respect, various issues could be analysed from the legal perspective: (a) balancing individual liability and organisational liability, (b) determining how different degrees of autonomy of agents and machines shape the liability of the different actors (operators, controllers, manufacturers designers), (c) analysing dynamic transfers of responsibility due to forthcoming operational concepts and procedures (e.g. business trajectories, self separations, variable separation minima depending on aircraft performance).

A second question concerns how to properly manage this shift in order to achieve an optimal allocation of liabilities. This will imply reconsidering the role of liability, not only as a tool to redistribute risks and allocate sanctions for errors and accidents, but also as a means to prevent those accidents and to increase levels of safety and performance in ATM, fostering the development of a safety culture within organizations[3]. Thus, it will be essential 1) to identify tasks and roles of operators (managers, ATCOs, pilots, etc) and automated tools; 2) to identify the expected level of performance for each task; 3) to consider different kinds of errors (unintentional rule violations, reckless behaviours, intentional violations); and 4) to define the appropriate legal and disciplinary sanctions and/or safety incentives in relation to different errors, risks and accidents[4]. A third question regards the extent to which the realisation of such a system requires a change in the law in force, the extent to

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[1] SESAR Consortium (2008). The Concept of Operations at a glance.
(http://www.eurocontrol.int/sesar/gallery/content/public/docs/ConceptofOperations_02.pdf)

[2] For a deeper analysis, see Diederiks-Verschoor I., Butler. M. (2006). An introduction to air law. Kluwer Law International, Alphen aan den Rijn; Van Antwerpen N. (2008) Cross-border provision of air navigation services with specific reference to Europe: safeguarding transparent lines of responsibility and liability. Kluwer Law International, Alphen aan den Rijn; M. Chatzipanagiotis. (2007). Liability aspects of air traffic services provision. Air and Space Law, 32, pp. 326–357; Leloudas G. (2009). Risk and Liability in Air Law. Informa Maritime and Transport, London.

[3] Reason J. (1998). Achieving a safe culture: theory and practice, Work & Stress, 12(3), pp. 293-306.

[4] Calabresi G. (1970). The costs of accidents: A legal and economic analysis.Yale Univ Press.

which public regulation is required as opposed to self-regulation, coupled with contractual mechanisms.

The Current Legal Framework of ATM

Multilateral conventions are the primary source of air law. The Chicago Convention[5] (1944 Convention on International Civil Aviation) established the International Civil Aviation Organization (ICAO), a specialized agency of the United Nations in charge of coordinating and regulating international air transport. The Convention defines rules of airspace, aircraft registration and safety, and details the rights of the signatories in relation to air transport, grounding liabilities in the Contracting States, and obliging them to create regulations which provide for the liabilities of further private and public actors, such as Air Navigation Service Providers (ANSP) – organisations that separate aircraft on the ground or in flight in a dedicated block of airspace on behalf of a state or a number of states. Article 28 governs air navigation facilities and standard systems, providing that

> each contracting State undertakes, as far as it may find practicable, to: a) provide, in its territory, airports, radio services, meteorological services and other air navigation facilities, in accordance with the standards and practices recommended or established from time to time, pursuant to this Convention; b) adopt and put into operation the appropriate standard systems of communications procedure, codes, markings, signals, lighting and other operational practices and rules which may be recommended or established from time to time, pursuant to this Convention […].

Annex 2 of the Convention, entitled "Rules of the Air", specifies that an aircraft commander must follow the instructions of the control tower. However, it also states that the ultimate responsibility for a flight rests with the same commander.

While the Chicago Convention governs regulations between States, it does not give cause of actions to private persons to claim compensation for damage caused by ATM; liability for international carriage by air is governed by the 1999 Montréal Convention[6], which deals with airlines' liabilities in respect of the carriage of passengers, baggage and cargo. The scope of the Montréal Convention was extended to domestic transport within each single EU Member State by virtue of Regulation (EC) No. 889/2002. However, the Montréal Convention only gives responsibility to airlines for damage "sustained in case of death or bodily injury of a passenger upon condition only that the accident which caused the death or injury took place on board of the aircraft or in the course of any of the operations of embarking or disembarking." (Article 17). Article 21 of the Convention provides that the carrier is strictly liable for compensation in the case of death or injury of passengers. The strict liability is limited to 113,100 special drawing rights (SDR)[7]. For damages in excess of this amount, the airline may avoid liability by proving that the accident which caused the injury or death was not due to its negligence or was attributable to the negligence of a third party (including the ANSP). The carrier is not responsible in the case that the damage derives from an act of God/force majeure. In the case that the damage is attributable to the ANSP, no relevant rules exist permitting the victims to recover damages.

Despite the fact that air traffic management relies largely (and will rely even more in the future) on the use of sophisticated automated system, the convention makes it clear (see article 21) that an air carrier's liability may be invoked as a consequence of the action (or inaction) of his aircraft's pilot or other human agents such as air traffic controllers.

Nevertheless, there can be little doubt that all the automated devices implemented in ATM in recent years have reduced the burden of the captain's (and controller's) responsibilities. This may be better clarified by examining the particular nature of these systems.

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[5] Text of the Convention available at: http://www.icao.int/cgi/goto_m.pl?/icaonet/dcs/7300.html

[6] Text of the convention available at: http://untreaty.un.org/unts/144078_158780/3/5/11624.pdf

[7] 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 concept of Autonomy

The salient feature of automated systems is the fact that they possess a certain degree of autonomy. In computer science, the concept of autonomy has been traditionally linked to the study and development of particular software artefacts called software agents. Wooldridge[8] gives the following definition of a software agent (SA):

> An agent is a computer system that is situated in some environment, and that is capable of autonomous action in this environment in order to meet its design objectives.

Wooldridge pinpoints three crucial elements in the definition of an agent. First, an agent is related to a computer system. Second, this computer system can act autonomously. The notion of autonomy relates here to the principle that an agent can make decisions and take actions on its own, without the guidance of humans or other systems; roughly speaking, this means that control lies inside the agent and not outside. And third, an agent is designed for specific purposes known as design objectives.

The features of agents, as described by Woolridge, make them suitable for application in many industrial sectors where decisions have to be made quickly, and in volatile or conflictive environments where it is necessary to handle great complexity. Moreover, agents are scalable: they can work with a huge array of data sources and detailed information, taking into account the preferences of other agents and those of the entire organisation, and on this basis make the best resource-allocation decision. These properties meet most needs in the industrial and commercial sectors.

This has sparked a growing interest in the application of agent technologies, mainly in three sectors: telecommunications and networks, manufacturing, and transport.[9]

In all of these applications, software agents usually come as quite complex systems, so it is often difficult to predict and discuss their behaviour in terms of instructions or sets of connected programs. One common alternative when discussing agents is to conceive of them by using the mentalistic notions more typically applied to humans, such as knowledge, belief, and intention[10]. In fact, a user will normally have little knowledge of the internal functional mechanisms of an SA, and not even the programmer who built the SA will be able to view the SA's present and future behaviour as the execution of the computational processes which it consists of. The overall interpretation of the SA's behaviour will be based on the hypothesis that the SA is operating "rationally," by adopting determinations appropriate to the purposes that have been assigned to it, on the basis of the information available to it, in the context in which it is going to operate.

Liability and Automated Systems

Manufacturers of automated systems may be held liable for harm and damages caused by, or through, their products. Regarding product liability, a first distinction can be made between intentional torts (harms intentionally caused by an actor), negligence (when an actor omits to exercise reasonable care), and strict liability for defective products. The latter focuses on the product rather than on the conduct of the manufacturer, who may be held liable even in the absence of intent to injure or negligence[11].

[8] Wooldridge, M. An Introduction to MultiAgent Systems, John Wiley & Sons Ltd, 2002.

[9] Agent-based applications have been developed for aerospace applications and training, process control, air-traffic control, traffic and transportation management, information filtering and gathering, business-process management, resource management, human-capital management, skills management, mobile workforce management, network management in utilities networks, user-interface and local-interaction management in telecommunication networks, schedule planning and optimisation in logistics and supply-chain management, control-system management in industrial plants (such as steelworks), defence, entertainment, and medical care.

[10] See Dennett, D.C. The Intentional Stance. MIT Press, Cambridge, Mass. 1987.

[11] Within the EU, the regime of strict liability for defective products was created by The Product Liability Directive, formally Council Directive 85/374/EEC of 25 July 1985 on the approximation of the laws, regulations and administrative provisions of the Member States concerning liability for defective products.

An essential component of every automated system is the software. Therefore, from the legal perspective, all the issues related to liability for software defects are relevant here[12]. As is well known, the use of software always implies the possibility of a failure, since not all software defects can be detected during the development and validation phases, and therefore it is impossible to guarantee that a piece of software will be absolutely error-free.

This is a crucial issue whenever software is the core component of a safety-critical system (such as those implemented in Air Traffic Management); that is, a system in which a malfunction could result in death, injury or illness, major economic loss, mission failure, environmental damage, or property damage. The cast of characters involved in the development, implementation and use of software makes the assignment of responsibility a problematic task, so it is often very difficult to pinpoint exactly what went wrong and who is responsible. For these reasons, software development contracts and licenses usually include strong liability limitations or even exemptions of the developers/providers for damages caused by their products. However, these limitations are not effective with respect to third parties. In these cases strict liability is usually imposed on the producer/manufacturer, in order to cover the necessity of assigning the risk to someone who can be considered to be in the best position to prevent defects in the products, and absorb or spread losses in cases in which a person might be held responsible, even if no negligent action was performed. However, it has been argued that this is an excessive burden on software producers, a burden which could hinder the development and deployment of useful programs.[13]

Of particular interest in this context are the "aeronautical charts" cases (Aetna Casualty and Surety Co. v. Jeppesen & Co[14;] Saloomey v. Jeppesen & Co[15]; Brocklesby v. United States[16]; Fluor Corp. v. Jeppesen & Co[17]), where the courts have routinely held that the charts are products for purposes of product liability and that strict liability can be applied. In Aetna Casualty and Surety Co. v. Jeppesen & Co, Jeppesen published instrument approach charts to aid pilots in making instrument approaches to airports, based on specifications prescribed by the FAA in tabular form. Jeppesen acquired this information in FAA form and portrayed it on a graphic approach chart. Aetna (the plaintiff) contended that the chart for the Las Vegas Airport was defective, not in the information contained in itself but in its graphic presentation, and that this product defect was the cause of the crash.

The trial judge found that the Las Vegas chart "radically departed" from the usual presentation of graphics in the other Jeppesen charts; that the conflict between the information conveyed by words and numbers and the information conveyed by graphics rendered the chart unreasonably dangerous and a defective product. In these cases, the courts categorized information (provided in a chart, or by analogy in a software system) as a product, assuming that a nautical chart or an airline chart is similar to other instruments of navigation such as a compass or radar finder which, when defective, can prove to be dangerous. This provides at the same time the best analogy to software and the fullest analysis and supporting arguments for why software should be subjected to strict liability. Usually, to mitigate this approach the concept of misuse is also introduced, so that a user might be held partially or fully responsible whenever he/she uses the software in an incorrect or improper way, and as a consequence

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[12] For an overview of the evolution of different approaches to software liability, see Zollers F.E., McMullin A., Hurd S., and Shears P. (2004). No more soft landings for software: Liability for defects in an industry that has come of age. Santa Clara Computer and High Technology Law Journal, 21, pp. 745-782.

[13] For an analysis of the relationship between Product liability and innovation, see Morrow R. (1994). Technology issues and product liability. Product liability and innovation: managing risk in an uncertain environment, pp 23 – 29.

[14] Aetna Casualty & Surety Co. v. Jeppesen & Co., 642 F.2d 339, 342-43 (9th Cir.1981), available at:

http://openjurist.org/642/f2d/339/aetna-casualty-and-surety-company-v-jeppesen-and-company

[15] Saloomey v. Jeppesen & Co., 707 F.2d 671, 676-77 (2d Cir.1983), available at:

http://openjurist.org/707/f2d/671/saloomey-v-jeppesen-and-co-c-halstead-f

[16] Brocklesby v. United States, 767 F.2d 1288 (9th Cir.1985), 439, available at:

http://openjurist.org/767/f2d/1288/brocklesby-v-united-states

[17] Fluor Corp. v. Jeppesen & Co., 170 Cal.App.3d 468, 475, 216 Cal.Rptr. 68, 71 (1985)

of a negligent action. Finally, another interesting issue concerns the analysis of those cases in which software is supplied and used as a service rather than a product (product liability, and therefore strict liability, may not apply in the case of services[18]).

In addition, automatic and automated systems add additional layers of complexity with respect to traditional software/hardware artefacts, since they may possess (in different degrees depending on the capabilities of each system) autonomous cognitive states and behaviours that are relevant from a legal perspective[19]. In these cases, the reason why the effects of what an automated system does will fall on the user is not that the user has wanted or has predicted its behaviour, but rather that the user has chosen to use the automated system as a cognitive tool and is committed to accepting the results of its cognitive activity. Thus, since the user intends to rely on the automated system's cognition, the fact that the user is responsible (in the sense that he will bear the rights and duties resulting from the automated system's activity) does not exclude, but rather presupposes, the legal relevance of the system's cognitive states and processes: the liability of the user would be similar to the liability of the employer for the employee (vicarious liability), rather than the liability of a custodian of a thing. Vicarious liability, in fact, is not based upon the assumption that the employer can foresee the behaviour of the employee, but rather on the fact that the employee may accomplish a tort when acting in the course of his employment.

Even further complexity may emerge when hybrid man-machine units are implemented: in these cases, agency does not pertain only to human or to machines, but to the hybrid itself[20], so that human machine interaction and trust play a decisive role in assessing and allocating liability. Under this perspective, a relevant (and still open) question is that of how to deal with cases in which, as in the Ueberlingen accident[21], conflicting information is provided to pilots by humans (controllers) and automated systems, and more generally what kind of priorities should be given to different signals, and when humans may override automatic devices.

A proposal: a Modelling Framework for ATM

An Air Traffic Management system can be viewed and described as a socio-technical system (STS), namely a system that involves a complex interaction between technical, social and organisational factors, as well as human factors[22]. In STSs, both the technical and the social aspects (the latter including humans and norms) are crucial to their design and functioning: at the core of such systems is a technical infrastructure, designed to serve a specific purpose, coupled with human operators that continuously monitor and modify its state during the operational process. In the perspective of focusing on the legal implications of automation, exploring the relationship between automation and liability in ATM as fundamental issues in human-technology interaction, it is feasible to address the issues of liability in ATM in the context of a socio-technical system, where the allocation of liabilities may be viewed as a governance mechanism enabling the enhancement of the functioning of ATM,

Thus, a comprehensive theory of ATM – as an STS – should be developed, which would integrate: 1) an ontological model of ATM nature and structure, covering its technical, social and legal

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[18] Brannigan V.M., Dayhoff R.E., Liability for Personal Injuries Caused by Defective Medical Computer Programs. American Journal of Law & Medicine 1981; 7(2):123-144

[19] See Sartor G. (2009). Cognitive automata and the law: electronic contracting and the intentionality of software agents. Artificial Intelligence and Law, 17(4), pp. 253-290; and Bing J., Sartor G. (eds) (2003). The law of electronic agents, Unipubskriftserier, Oslo.

[20] Teubner G. (2006). Rights of Non-humans? Electronic Agents and Animals as New Actors in Politics and Law. Journal of Law and Society, 33, pp. 497-521.

[21] Bennett. S. (2004). The 1st July 2002 mid-air collision over Ueberlingen, Germany: a holistic analysis. Risk Management, pp 31–49.

For a complete description of the accident, see the EUROCONTROL Review of the BFU Ueberlingen Accident Report, available at: http://www.dcs.gla.ac.uk/~johnson/Eurocontrol/Ueberlingen/Ueberlingen_Final_Report.PDF

[22] Baxter G., Sommerville I. (2011) Socio-technical systems: From design methods to systems engineering. Interacting with Computers, 23(1), pp. 4–17; Kroes P., Franssen M., Van de Poel I., Ottens M.(2006). Treating socio-technical systems as engineering systems: some conceptual problems. Systems Research and Behavioral Science, 23(6), pp. 803–814.

aspects; 2) a declarative model of ATM, based both on standard conceptual modelling languages (such as UML) and computational logic-based approaches suitable for dealing with the dynamic aspects of STS.

On the basis of the ontological and declarative models thus developed, it would be possible to provide a methodological tool to support the introduction of any technology in complex systems, particularly in ATM, ensuring that all the relevant legal aspects are taken into consideration at the right stage of the design, development and deployment process. The methodological tool, built on the lines of the EUROCONTROL “Safety Case”[23] and “Human Factors Case”[24], would be of use to those who need to understand how to behave in order to prevent accidents and avoid liabilities, and also to those who need to make inquiries into compliance and liabilities.

In building such a system, the following ideas should be taken into account: 1) the most recent theory of argumentation[25] should be used for building visual argumentation graphs, showing how exemption from liability results from compliance with all legal norms and technical requirements. Argument schemas should be used to categorise the grounds for liability for different agents or exemptions from it; 2) recent AI work on arguments for the automatic evaluation of argument graphs should be incorporated to establish whether all conditions have been fulfilled and in the case of accident who is liable[26]; 3) appropriate links to sources (according to established document standards) should be embedded in the graphs, for accessing additional information, such as cases and guidelines; 4) information concerning burdens of proof should be included, to help in assessing liabilities when factual information is missing.

[23] EUROCONTROL (2008). Preliminary Safety Case for Enhanced Air Traffic Services in Non-Radar Areas using ADS-B surveillance, available at: http://www.eurocontrol.int/cascade/gallery/content/public/documents/CASCADE%20ADS-B-NRA%20Preliminary%20Safety%20Case%20v0.9.pdf

[24] EUROCONTROL (2007). The Human Factors Case: Guidance for Human Factors Integration, available at: http://www.eurocontrol.int/humanfactors/gallery/content/public/docs/DELIVERABLES/HF42%20%28HRS-HSP-003-GUI.01%29%20Released-withsig.pdf

[25] Walton N. D., Reed C., Macagno F. (2008). Argumentation Schemes. Cambridge University Press, Cambridge, Mass.

[26] Prakken H., Sartor G. (2009). A logical analysis of burdens of proof. Legal Evidence and Proof: Statistics, Stories, Logic, pp. 223–53.

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