The Defragmentation of the Air Navigation Services Infrastructure

Legal Challenges of Virtualisation

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***Abstract*—The defragmentation of the European ANS system is leading to a fundamental change of the model for service provision. In particular, open architecture systems are slowly leading to a virtualisation of the technical infrastructure. While this development will improve the performance of the European ANS system, it also raises a number of legal issues, genuine or perceived, that will need to be addressed.**

Keywords-component; Air Navigation Services, infrastructure defragmentation, virtualisation, legal challenges

I. INTRODUCTION

The Single European Sky (SES) initiative is meant to establish a comprehensive and structured regulatory framework to overcome the failing performance of the European Air Navigation Services (ANS) system. The primary objective of the SES is to resolve the fragmentation of the current ANS landscape which consists of a patchwork of various systems that are strongly integrated at the national level, but do not operate as a seamless network at the regional level.

In particular, the technical infrastructures which support the activities of the European ANS Providers (ANSPs) are strongly shaped by national considerations. In most countries ANS equipment takes the form of highly customised monolithic systems, which operate in a relatively closed environment and limit the possibilities for the automation of ANS functions across the network. Defragmentation can be understood as any initiative towards seamless operation of the European ANS system. The SES program currently aims to achieve defragmentation by the means of 2 main measures, namely operational and technical interoperability and Functional Airspace Blocks (FABs). Technical interoperability intends to gradually open the ANS system architecture to facilitate the deployment of a seamless infrastructure and to increase the automation of ANS support functions. An open system architecture will facilitate the decoupling of the production of the data of all kinds that feed the ANS system from their use by individual ANSPs, paving the way to innovative ventures in the field of data management. This will result in increased sharing of data among service providers as well as to the emergence of a new market for specialised data suppliers.

Targeted developments in the field of ANS data management are slowly leading to a virtualisation of the ANS technical infrastructure. The full combination of interoperability, automation of ANS support functions, open system architecture and data sharing and integration offers a potential not only to improve individual functions within the ANS system but to reinvent the ANS industry model as a whole.

The defragmentation and virtualisation of the technical infrastructure of ANS opens promising avenues. But because of the manner in which these developments will fundamentally modify the underlying ANS industry model, they also raises a number of legal challenges that will need to be addressed and resolved.

1 TECHNICAL DEFRAGMENTATION

The fragmentation of the ANS technical infrastructure ranks high among the causes for the lack of performance of the European ANS system. The European Commission reported in this respect "*a low level of integration between national air traffic management systems and a slow pace in the introduction of new concepts of operation and technology necessary to deliver the additional required capacity*."[1]

ANS technical systems are highly complex and consist of many interlinked elements. Most legacy ANS technical systems are integrated at the level of individual providers. These systems are relatively closed. Full "off-the-shelf" systems are rare and, in spite of some coordination initiatives[2] meant to promote common specifications and procurement, ANS equipment is

[1] Regulation (EC) No 552/2004 of the European Parliament and of the Council of 10 March 2004 on the interoperability of the European Air Traffic Management network (the interoperability Regulation), as amended by Regulation (EC) No 1070/2009 of 21 October 2009, Preamble, recital 4.

[2] E.g. the Cooperation of ANS Providers (COOPANS) between 5 European ANSPs.

often designed to accommodate the particular needs or preferences of each individual service provider.

ANS systems rely on an enormous amount of data supplied by numerous different sources, which are translated into useful information for the controllers. Some, such as airspace structure and permanent obstacles are static, while many, such as flight plan, weather, surveillance, data are dynamic. Individual ANSPs acquires data from various sources, including their own CNS equipment, other ANSPs, aircraft, Aeronautical Information Service providers, Aeronautical Meteorological Authorities, and Aerodrome Reporting Offices. Further, the data supplier include not only civil organisations but also military authorities in order to ensure the proper integration of military requirements into the ANS system. Historically, the necessary data were supplied through discrete channels and introduced, often manually, into each ANSPs system. The data were either integrated within the boundaries of the equipment or displayed separately to the ATCOs. Whereas automatic data exchange tools have been deployed in the recent years, the full potential of data sharing and integration has not yet been fully exploited.

The current prevailing philosophy for the design and building of ANS system presents a number of disadvantages. Because these systems are relatively closed and highly customised, they tend to be fairly costly and the ability of these systems to interconnect efficiently with the equipment operated by other service providers is limited. Then each ANSP tends to procure and deploy full ANS infrastructures, ignoring the opportunities to share equipment upstream from the controllers working positions. At the level of data management each provider tends to produce and process its own instance of a same information, which leads not only to a costly multiplication of the effort but to a risk of inconsistent data across the network.

In order to defragment the technical infrastructure, the SES regulatory framework aims to achieve interoperability among the constituents of the European ATM Network (EATMN). The scope of the Interoperability Regulation is broad as it governs all "*tangible objects such as hardware and intangible objects such as software upon which the interoperability of the EATMN depends*"[3] and covers all systems used to support ANS operations. Full interoperability will promote the harmonisation of the European ATM working environment. It will ultimately require an open system architecture, where constituents operated by one ANSP will be able to connect through standard interfaces to constituents operated by other ANSPs, leading to a seamless flow of data across the ANS network. Such a development should enable exchanges not only between ANSPs themselves, but also with third party data suppliers.

In themselves, interoperability and standard interfaces to support the sharing of data among ANSPs are not new and there are numerous instances of concrete application which predate the SES regulations. For instance, ANSPs have been mutually exchanging radar data for several decades. The air traffic situation picture displayed to ATCOs is no longer an internal product of each individual ANSP, but a mosaic picture which integrates the data received from various internal and external sources. The coordination of flight transfer between ATC units has also been automated in a number of countries. This has required the development of suitable interface between the flight data processing tools used by the different ANSPs, in order to ensure the exchange of the relevant data.

2 THE VIRTUALISATION OF THE TECHNICAL INFRASTRUCTURE

As interoperability and the implementation of open architecture systems progress, in particular through the deployment of the Single European Sky Air Traffic Management Research and development (SESAR) program, the features of the ANS technological infrastructure are slowly being modified. The trend is fundamental and irreversible. The combination of data sharing and integration and the automation of data processing functions open prospects for a full virtualisation of the ANS infrastructure. For the purpose of this paper virtualisation is to be understood as a situation where a service provider no longer owns and operates a full data management infrastructure, but relies on data provided by a network of external independent data suppliers upstream from its own equipment. Where virtualisation differs from the instances mentioned above is in the scale and level of data sharing and integration, in the sense that full virtualisation does not address specific functions in isolation but reinvents the entire ANS industry model itself. A new model is slowly emerging under which "*[t]he ATM system can be seen as a complex, distributed real-time information processing community, populated by a large number of people and automated systems in the role of sensors, information providers, information users, and decision makers, all collaborating to ensure a safe, expeditious, and efficient flow of air traffic.*"[4]

The new European ANS technological landscape is characterised by two major features: the full integration of ANS data and the creation of a complex data management chain involving a large number of players and operating from many different countries.

Under a virtualised environment, the production, processing and distribution of data no longer remains an internal matter of a single ANSP or of a small group of ANSPs sharing a common network. The emerging framework will create a wide network of data suppliers upstream from individual ANSPs. It will be an added value multi-layered chain and establish complex relationships between these entities acting under a partnership

[3] Regulation (EC) No 549 of the European Parliament and of the Council of 10 March 2004, laying down the framework for the creation of the single European sky (the framework Regulation) as amended by Regulation (EC) No 1070/2009 of 21 October 2009, art. 2, definitions.

[4] Anna MASUTTI, "*Single European Sky - a possible regulatory framework for System Wide Information Management (SWIM)*", Air & Space Law, vol. 36, no. 4/5 (2011), p. 276.

approach explicitly supported by the European Commission.[5] The various players will collect data produced by one organisation, modify these data or parts thereof, before releasing them to the next entity which will further process the information for the next customer. Some will specialise in the collection and storage of data, while others will focus on their distribution. The data which will reach the ANSP, as final user, will be an aggregate information, resulting from the interaction of a multitude of players, each of which will have brought its contribution to the shaping of the final information.

Ultimately, the legal status of the data supplier will cover the full range of possible models. Individual ANSPs will act as suppliers to other service providers. But the framework will also include States agencies (e.g. for AIS or Aeronautical Meteorological Data) or international organisations (e.g. Eurocontrol) acting on behalf of their Member States. Finally the development of the technological landscape is expected to create a large community of commercial data suppliers.

Another important feature of the emerging European framework is that it will erase all political boundaries across the European ANS technological network. Some European ANSPs have been operating a system on the basis of the underlying principles of virtualisation for a number of years. Their technical equipment is built upon a single central data management infrastructure, which collects, processes, integrates and distributes the necessary information which is shared among their different ATC units. However, the model has been applied primarily at the domestic level. The actors involved in the emerging data management chain will be located in many different countries (even beyond the boundaries of the European Union) and providing information to other actors across national borders.

3 PIONEERING VIRTUAL INITIATIVES

Several recent conceptual or concrete initiatives have been launched that will capitalise on the basic principles of virtualisation

3.1 SWIM

The European System Wide Information Management (SWIM) program aims to reorganise the manner in which the data used for ATM purposes across Europe is produced and distributed. The ultimate goal is that each user of information should have access to the data needed in a timely manner and with the required level of quality. SWIM intends to reorganise the flow of data and to deploy the necessary distribution infrastructure. SWIM incorporates all the principles that will be necessary for an open system architecture. In particular, it operates on the principles of the separation of the data production from data consumption and the use of open standards. SWIM will become the backbone for a full scale virtual environment.

3.2 Centralised Services

Eurocontrol received the mandate from the European Commission in 2012, to investigate the concept of Centralised Services. A Centralised Service is defined as "*an ANS service or ATM function exercised at pan-European and central network level for harmonisation and cost-efficiency purposes. It is a means to foster the deployment of new ATM technologies and achieve unbundling of some of the ancillary services or functions, through implementation of market mechanisms and competition. It will allow centralised services processes to be provided on a pan- European level rather than on a national level.*"[6] The portfolio of Centralised Services envisaged by Eurocontrol currently includes 9 services. The proposal delivered by Eurocontrol foresees that Eurocontrol will issue a call for tender for each of the individual services. It will evaluate the bids returned and allocate the services. ANSPs will purchase the service on a competitive basis.

3.3 The Virtual Center Model

The Virtual centre model has been proposed as a conceptual alternative to the physical consolidation of ATS facilities. The virtual centre model is still in an exploratory phase and a common understanding of its exact features still remains to be achieved. In a paper which has pioneered the concept, a virtual centre has been defined as "*a group of air traffic services units (under the responsibility of one or several ANSPs) operating from different locations which use fully standardized methods of operation, information, procedures, technical means and equipment in such a manner that they are perceived as a single system from an airspace user's perspective*".[7]

Under the virtual centre model the participating ANSPs achieve a virtual defragmentation through arrangements which ensure the joint management of the airspace under their collective responsibility. Virtualisation requires full technical and operational interoperability among the participating ANSPs, which, in turn, allows sectors assigned to a specific unit to be temporarily transferred under the operational responsibility of another. For instance at times of low traffic, sectors from different units can be merged into a single, large block of airspace, which can be managed with the same level of operational performance, but at a lower cost for the participating ANSPs. Sectors can also be transferred to another unit in the

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[5] It is "*in the interest of all those involved in air traffic management to develop a new partnership approach allowing the balanced involvement of all parties and stimulating creativity and the sharing of knowledge, experience and risks; such partnership should aim at defining, in cooperation with industry, a coherent set of Community specifications that can fulfil the widest possible range of needs*". Interoperability Regulation, Preamble, recital 7.

[6] EUROCONTROL Proposal for a first set of Centralised Services to contribute to SES Performance Achievement Update to the European Commission, 25 March 2013, v 0.2

[7] "*The Virtual Centre Mode*l", Skyguide, April 2013, p. 1.

event that the necessary operational resources are missing with the unit normally in charge of it.

The model claims to deliver major benefits to the ANS industry which extend beyond economies of scale. It is also branded as a powerful concept to support the development of FABs. It offers an attractive option in terms of contingency facilities, as virtual centres will feature the redundancy required in the event of a failure of one of its constituent elements. Since individual ANSPs would no longer be compelled to purchase a fully-fledged system of their own, but will be able to acquire a service from a competitive supplier or share equipment with another provider, both investment costs and the overall costs of providing the services would be reduced.

3.4 The European Aeronautical Database

The basic principles of virtualisation have already been tested in practice in some areas outside the core Air Traffic Services and the experience acquired from pioneering ventures will be useful to support their application at a wider scale. The most compelling example is the European Aeronautical Database (EAD).

The purpose of the EAD is to provide for a common source of aeronautical information. The scope of the EAD covers the Aeronautical Information Service (AIS). The EAD is a centralised database of aeronautical data fed by participation AIS providers and other sources, which offer quality-assured aeronautical information to external customers such as airspace users. The EAD is managed by a consortium of ANSPs operating on behalf of Eurocontrol.

3.5 GNSS

The Global Navigation Satellite System (GNSS) offers an example of an infrastructure which is shared at a larger scale. The GNSS is slowly replacing a number of local ground based infrastructure as States rely on a jointly owned and operated system. Although this initiative differs in essence from data sharing ventures and relates to the provision of an alternative navigational service to airspace users, it belongs to the catalogue of measures that will defragment and virtualise the ANS technical infrastructure.

4 LEGAL CHALLENGES

The technology required to support the virtualisation of the ANS infrastructure exists and has been tested in other fields of activities. As often in the realm of ANS, the most significant challenges to be resolved are expected to arise from legal and institutional issues, genuine or perceived. These relate primarily to the large number of players that will be active in a virtualised framework and from the wide scale cross-border dimension involved.

Few of the anticipated legal issues are new, as most of them were raised and successfully addressed when the individual principles of virtualisation were tested by precursor ventures. A considerable amount of European legislation exists, that governs the interoperability of ANS system and the exchange and sharing of data in aviation. General requirements are expressed in the Interoperability Regulation as well as in Regulation (EC) 1108/2009 which governs EASA competences in the field of aerodromes, air traffic management and air navigation services. More specific regulatory requirements in respect of interoperability and sharing of data exist for instance in the field of automatic systems for the exchange of flight data, including those involving military units, civil and military coordination and Air Traffic Flow Management (ATFM) data. The combination of the existing pieces of legislation is slowly contributing to the creation of an overall framework to govern the virtualisation of the ANS infrastructure, although in a patchwork manner at this time. Whereas many of the instruments available will address a very specific aspect of the ANS technical infrastructure, or aspects that lay outside of the core ATS domain, the relevant provisions can serve as a useful source of legal inspiration for the drafting of the legislation that will be required to regulate those aspects of the technological virtualisation which are not yet covered in law.

This is particularly true of the legislation applicable to the management of the AIS aeronautical data. The early experience acquired with the EAD proves that effective legal solutions can be agreed to govern ambitious and large scale initiatives of data sharing in the ANS industry. The formal scope of AIS only covers a limited range of clearly defined applications known as the "upstream" part of the data management chain and including static and dynamic data published in the form of AIP, NOTAM, AIRAC, and AIC. However, the material scope of AIS is defined in a very broad manner as "*the object of the aeronautical information service is to ensure the flow of information/data necessary for the safety, regularity and efficiency of international air navigation*".[8] The definition of aeronautical data used for the purpose of AIM is also very wide since "'*aeronautical data' means a representation of aeronautical facts, concepts or instructions in a formalised manner suitable for communication, interpretation or processing*".[9] The similarities between the upstream part of the data management chain, which is covered by the scope of AIS and the downstream part, which is not, would justify that many regulatory provisions applicable to the management of aeronautical data for AIS purposes, such as Commission Regulation (EU) No 73/2010,[10] could extend directly or be applied by analogy to the management of the entire ANS data chain. Important developments in that direction are already occurring with the proposal by Eurocontrol to establish a European ATM Information Management Service (EAIMS) within its Centralised Services initiative. The EAIMS proposal explicitly builds on the experience acquired in operating the EAD, in order

[8] Aeronautical Information Service, Annex 15 to the Chicago Convention, 12th edition, July 2004, Chapter 1, Introduction

[9] ICAO Annex 15, Definitions.

[10] Commission Regulation (EU) No 73/2010 of 26 January 2010 laying down requirements on the quality of aeronautical data and aeronautical information for the single European sky.

to extend the management of relevant data to the full scope of information used for Air Traffic Management purposes.

4.1 Regulatory challenges

The virtualisation of the technological infrastructure raises crucial issues of regulatory nature.

4.1.1 Standardisation requirements

A first regulatory requirement relates to the need for rigorous standardisation in the infrastructure and data domains. A virtualised environment requires that the interfaces between the various elements of the infrastructure landscape are fully standardised, in order for these elements to be able to communicate efficiently with each other. This objective should be achieved within the work undertaken under the SESAR umbrella. It is equally important that the format used for data management processes are standardised across the network, to avoid the need for unnecessary reformatting and the risk of errors in the reading of the information.

4.1.2 Quality management requirements

The data which support ANS functions include elements which are both critical and essential from a safety perspective. A corrupted or missing data anywhere in the system raises a risk for the safety of air navigation. The safety of the ANS system also depends on the timeliness of the information. The tactical processes for Air Traffic Control leave little time margins for air traffic controllers to take safety critical decisions. The information needed by ATCOs must be made available to them at the time it is needed and in its most current form.

Further, the data management chain is not only exposed to safety risks but is also vulnerable to security threats. It must be protected from any harmful interference that may result in the corruption of data or the disruption of the distribution of data.

The safety and security aspects of the data management chain are addressed primarily by the means of regulatory measures. The regulatory framework includes requirements related to the quality of the data which support the ANS functions. It prescribes rigorous data quality requirements in terms of accuracy, resolution and integrity. These apply to all of the links within the data management chain, including "*…the origination, production, storage, handling, processing, transfer and distribution*"[11] of the data. The quality management framework requires the validation and verification of the data for each step of the process. Regulatory requirements apply to all constituents of the data management system and, beyond the data themselves, extend to the hardware and software that support data management. The data management equipment must be able to detect errors, both at source and introduced. An interruption in the flow of data puts the safety of air navigation at risk. This implies that the availability and reliability of the equipment must be guaranteed. In addition the same information will be made available to many actors, for final usage or for further processing. The consistency of the data becomes a critical issue, since it is necessary that a particular information used by one actor, such as a pilot, is consistent with the same information displayed to another (e.g. an air traffic controller) throughout the system.

Technological virtualisation significantly increases the need for a solid and comprehensive quality management framework. The risk of corrupted or inaccurate data multiplies with the complexity of the data management landscape. The large number of actors who will collectively produce, exchange, modify and distribute highly complex sets of data further exacerbates the necessity for rigorous performance criteria to be met by all participating entities. This is particularly true because it will become difficult to trace the origin of each specific alteration of the data. The traceability of the information consequently needs to be secured. The originator of raw data, as well as all intermediary instances that subsequently modify the data until it is delivered to the end user need to be clearly identifiable.

4.2 Legal challenges for sovereign States

4.2.1 States obligations under Art. 28 of the Chicago Convention

Independently from safety and security aspects, considerations related to the sovereign responsibilities of individual States in respect of the provision of ANS will further increase the need to a robust regulatory framework.

Under Article 28 of the Chicago Convention, each contracting State undertakes to "*provide, in its territory, airports, radio services, meteorological services and other air navigation facilities to facilitate international air navigation, in accordance with the standards and practices recommended or established from time to time, pursuant to this Convention*." It is commonly accepted that the Chicago Convention does not oblige States to provide the aforementioned services and facilities themselves and that they are free to entrust the responsibility for service provision to a third party. It is however also acknowledged that even when they avail themselves from this possibility, the relevant States continue to be responsible under Article 28 of the Chicago Convention.[12] The responsibility involved is essentially of regulatory nature and consists in establishing an appropriate regulatory and supervisory framework that will ensure that services are provided in accordance with the terms of the Chicago Convention. The purpose of the regulatory framework is to ensure the continuity, integrity and availability of ANS, even when the service is provided by a third party.

States remain particularly cautious when the service is offered not only by a third party, but by a service provider located across the national boundaries. The virtualisation of the ANS technological infrastructure may lead to the generalisation of such situations, for parts of the functions which support ANS provision. States may feel that their control over ANS, and consequently their ability to fulfil their obligations under the

[11] *Ibid.*, Article 2, scope.

[12] See ICAO Circular 284 AT/120.

Chicago Convention, are being diluted. It is primarily because the regulatory requirements for the EAD failed to convince them that their sovereign concerns were adequately addressed, that some States have still declined to adhere to this common initiative. The participation of military entities, either as supplier or as customer of the data only exacerbates the States' sense of caution.

4.2.2 National security issues

Whereas the accuracy and timeliness of aeronautical data is a prerequisite for the safety of ANS, these features are also essential for national security purposes. In order to safeguard their sovereign prerogatives, States have implemented measures to maintain a full and permanent oversight of all air navigation activities within their national airspace. ANSPs are normally required to support this function by ensuring a permanent monitoring of the airspace on behalf of their parent State, using the infrastructure deployed for civil ANS purposes. Specific regulatory action is necessary to ensure that all necessary data are made available when and as needed for that purpose. The timeliness of the information also acquires a particular sensitivity when data are provided from a foreign country in order to satisfy States that their designated ANSP can meet its responsibilities regarding the permanent monitoring of the airspace for national security purposes.

4.2.3 Dependency on foreign based facilities

Another crucial element regarding the acceptability of the virtualisation concept from a State perspective is that it may induce a situation of critical dependency for those ANSPs who renounce, partly or totally, producing and managing the necessary data internally and rely on information provided by external sources. A disruption in the flow of data, or a cancellation of the arrangements upon which data are supplied to ANSPs raise a serious risk for the availability of ANS. Reliance on foreign data is even more critical when an ANSP depends on such information to build a complete air traffic situation display for the purpose of national security. In order to comply with their obligations in respect of ANS, States will need to take measures to ensure the continuity of the data supply at all times and at the required level of quality, regardless of the arrangements taken for the provisioning of ANS data. Resolving the dependency concern is primarily a matter of redundancy and contingency. States will need to define the level of redundancy required for them to be able to maintain ANS operations in the event of a disruption of the data flow. A proper balance needs to be struck between a full duplication of the infrastructure which would only result in an increase of the overall cost of service provision and an insufficient back-up solution which would deprive the State of the possibility to ensure the continuity of the service. Any contingency plan must assume the stability of the data sharing arrangements as a rule, and the disruption of such arrangements as an exception arising from a crisis situation. The contingency arrangements should be dimensioned in such a manner that the State is able to maintain a defined level of service (which will not be the full level) until either the crisis which has led to the disruption has been resolved, or the State has regained its full ANS autonomous capability. The GNSS offers valuable references in respect of redundancy and contingency arrangements, as State are gradually decommissioning some ground based infrastructure as they gain confidence with the performance of the system, without moving into a situation of full dependency on the GNSS.

4.2.4 Institutional solutions

While the experience acquired shows that regulatory, redundancy and contingency measures are technically sufficient to address the States' sovereign concerns, the potential scale of the virtualisation concept may lead States to envisage additional safeguards in the form of institutional measures, at least as a transitional measure. The purpose of institutional solutions is to establish a framework which allows individual States to retain control over sovereignty sensitive services and facilities, when these are provided from, respectively located on foreign territory. They consist for States to establish a collective umbrella under joint management. In their heaviest forms, these take the form of an intergovernmental organisation which will be entrusted with the responsibility to operate the services or facilities on behalf of all participating States.[13] States may also mandate an intergovernmental agency to organise, manage and supervise the operation of a service outsourced to a third party.[14] Such institutional solutions allow States to influence the continuity and quality of service delivery through established governance bodies. But lighter forms of institutional solutions, such as accreditation schemes managed by a competent agency exist which serve the same purpose. Such schemes ensure that only entities which meet rigorous certification requirements, also in terms of permanent availability of the service, are entitled to perform a regulated activity under the strict supervision of the State or States concerned.

4.3 Liability implications

At first sight, the virtualisation of the technical infrastructure could result in a massive change in the liability regime applicable to ANS. In the historical situation when States operated a fully integrated national ANS system, the liability of ANSPs was essentially an internal matter for the State concerned. ANS liability was ruled by the legislation applicable to State liability. The separation of the regulatory and service provision functions has already required a clarification of the applicable liability regime. In most countries where the separation of functions was implemented, the liability regime has remained strongly influenced by the State liability rules, regardless of the legal status of the service provider and the State usually always retains a direct or indirect exposure.

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[13] E.g. Eurocontrol for the operation of the Central Route Charge Office (CRCO) or the Central Flow Management Unit (CFMU).

[14] Such institutional solutions would rely on the same philosophy as the EAD or the "Centralised Services" currently under consideration within Eurocontrol.

The virtualisation of the ANS technological infrastructure seems to be blurring the lines of the respective responsibilities of States and ANSPs. First, the virtualisation of the technological infrastructure will further break down the chain of ANS responsibilities between a large number of entities which will influence directly or indirectly the provision of services. Many of these actors upstream from the ANSPs will be private organisations operating on a commercial basis, which could result in a complex overlap of private and public responsibilities. Second, the philosophy of an open European system implies that actors involved in the data management chain will be operating from the territory of all European countries, and possibly outside of the region. Situations of cross-border service provision in ANS have traditionally been particularly difficult to regulate from a liability perspective. The multiplication of both the numbers of the actors involved and of the situations of cross-border service provision could consequently raise legitimate concerns about a major complication of the liability regime. However, under the condition that a pragmatic approach is pursued to formalise the framework that will govern the emerging technological infrastructure, the virtualisation development should impact the position of neither the States nor the ANSPs in respect of their responsibility for service provision and associated liability.

The main implication of virtualisation will be to create a separate market for the supply of data, upstream from the service providers. The relationships between all the actors involved in the data management chain should be formalised by the means of contracts which will detail all the aspects of these relationships. Suppliers providing data to ANSPs will also act on the basis of contracts which will include appropriate liability provisions. The liability regime governing the data management chain upstream from and up to the ANSPs will consequently be of contractual nature. The contractual framework will need to protect the ANSP against the risks involved in two possible scenarios. In the event that the law directly applicable to ANS liability in a specific instance should allow the concerned ANSPs to be exonerated from any liability if it can successfully prove that the damage was caused by the action of a third party (such as a data supplier), the contractual arrangements will need to prescribe that the faulty data supplier remains directly liable for any damage caused to third parties. In the event the applicable legislation should not allow an ANSP or its parent State to invoke the negligence of a data supplier upstream, in order to be relieved from any liability, the contractual arrangements will need to include an obligation for the faulty data supplier to reimburse any amount paid for the compensation of damage. It should be noted that contrary to instances of cross-border ATS service provision, the liability arrangements applicable to a failure in a cross-border data management chain should be easier to formalise within a contractual framework which is much closer by nature to an ordinary procurement arrangement.

Where the virtualisation of the ANS infrastructure could fundamentally modify the underlying principle of ANS liability, is in respect of the very nature of ANS liability. The challenges raised by developments such as the corporatisation of ANS and cross-border service provision are primarily related to the resolution of conflicts of rules and the allocation of liability among the various players. None of them, however is challenging the material principles of ANS liability to any significant extent. The virtualisation of the ANS infrastructure, on the contrary will not only add another level of complexity in the allocation of liability, but it will also impact the material nature of ANS liability. With very few exceptions so far, all existing cases of ANS liability have related to events caused by inappropriate instructions or clearances issued by air traffic controllers or by a failure to intervene to prevent an accident. ANS technology has rarely played a role in the occurrence of an accident. The main incidence of the digitalisation of aeronautical data will be a slow shift from a legal focus on human errors to a focus on technical failures. In the foreseeable future, an aviation accident caused by a failure of the ANS system is more likely to be directly or indirectly linked to an incorrect or corrupted digital data, than to a classical human error. Corrupted data can either directly cause an automated process to fail, or can indirectly lead a controller to issue an inappropriate clearance or to fail to deliver an instruction or information. The virtualisation of the ANS infrastructure raises a double challenge. First, it will be excessively difficult to trace the precise origin of a faulty data because the data management is embedded in a complex international network of data collectors, processors and distributors. Second, it will be equally difficult to demonstrate the existence of negligence when an incorrect data is the product of a piece of equipment and not the direct result of a human action. The aeronautical data management framework will extend over entire regions, and will possibly integrate inputs from actors from all over the world. Each of these actors will play a role in collecting, processing and distributing the data necessary for safe and orderly air navigation. It will prove extremely difficult, if ever feasible at all, to identify the location where data corruption has taken place especially since an incorrect data may be the result of several errors occurring at the level of different unrelated contributors. This will be made all the more difficult because computer networks render locations virtual. Also, the boundaries of data management frameworks will not necessarily be clearly defined. These frameworks may consist in a multiplicity of interconnected networks governed by different institutional arrangements. The notion of negligence, upon which the classical national ANS liability is based, relates by nature to the qualification of human behaviours. The application of this principle in a case involving the production and use of faulty data rapidly finds its limits. In the event a controller makes use of a corrupted information, negligence can only be demonstrated if it is proven that one could reasonably have expected that that controller should have noticed the faulty character of the data. Even in the case where it is possible to trace the origin of a data error to a specific actor in the data management chain, it remains extremely difficult to demonstrate that the corruption is the consequence of the negligent behaviour of a particular individual. In the context of accidents caused by a technical failure, a fault based liability regime often proves inadequate. A strict liability system, or at least a reversal of the

burden of the proof of fault (where it is for the defendant to demonstrate the absence of fault) is better fit for such situations.

4.4 Formal framework

The analysis presented above clearly emphasises the need for an appropriate legal framework to reflect the specificity of the emerging ANS technological landscape. The analysis also concludes that this framework should take the form of contractual arrangements to govern the roles, responsibilities and liability of the actors involved in the data management chain. Such contracts will need to be agreed not only between ANSPs and the entities which will supply them with data, but between all parties providing, acquiring or exchanging data. A similar approach is being pursued for the deployment of the SWIM initiative. It is foreseen in that respect that "*[r]ules, roles and responsibilities need to be defined, per stakeholder, taking into account the functional criticality of the information they handle. Data ownership, data provision and data usage rules will need to be redefined and possibly harmonised. Issues such as liability, charging and copyright principles should be proactively managed. In all circumstances, there is an increasing requirement for the definition and application of Service Level Agreements (SLA) between the different parties*."[15] The same applies to parties involved in the exchange of data in the specific domain of AIS as "*all parties within the scope of the ADQ IR that exchange aeronautical data and information shall establish a formal arrangement covering the transaction*."[16]

In addition to their ordinary purpose for the benefit of the parties themselves, these contractual arrangements will serve another fundamental specific purpose to reassure the States in respect of their own ability to secure the availability, continuity and integrity of ANS over their territory. This objective could be further supported by the establishment of a State managed accreditation scheme the purpose of which would be to limit the participation in the data supply chain to entities who are certified against strict criteria.

The contracts will prescribe essential requirements regarding the quality of the data supplied, in accordance with performance levels required by the competent State authorities. Among other provisions, the contracts will include requirements in respect of traceability of the information, which will make it easier to trace the cause of a data corruption of failure in the data delivery chain to its origin, and consequently to channel the liability for any resulting damage to the concerned party.

5 CONCLUSIONS

The measures initiated by the European Commission under the SES initiative in order to defragment the ANS technological landscape are slowly modifying not only the individual features of the technical infrastructure, but also the industry model as a whole. Interoperability and open architecture systems will lead to important new opportunities such as the virtualisation of the technological infrastructure. The emerging environment will witness the apparition of a new market for data suppliers upstream from individual ANSPs. This market will involve a large number of players, operating from different countries in Europe and beyond.

While these developments will contribute to the improvement of the European ANS system they will also raise sensitive legal challenges, genuine or perceived, that will need to be addressed and resolved. These challenges are related to the criticality of the data that will be produced, processed and distributed along the new data management chain, from a safety, security and sovereignty perspective. In order to ensure that the new operating environment does not jeopardise their ability to fulfil their obligations in respect of ANS under the Chicago Convention, States will need to ensure the establishment of a robust regulatory framework that will specify strict performance requirements in terms of accuracy, integrity, consistency, traceability and timeliness of the information. These requirements will need to be translated in contractual arrangements which will govern the relationship between all parties involved, including the liability regime applicable to them.

It is likely that performance requirements alone will not be sufficient to satisfy individual States in respect of their ability to fulfil their obligations under Art. 28 of the Chicago Convention, when the provision of critical data is outsourced to an external supplier, especially when that supplier is operating from a foreign territory. Balanced redundancy and contingency arrangements will need to be defined in order to avoid situations of critical dependency and an inability of States to ensure the continuity of ANS in the event the flow of data supplied from abroad is disrupted. In addition, institutional solutions, such as the establishment of shared State governance structure or an rigorous accreditation scheme can effectively complement the regulatory framework in order to reassure States in respect of the robustness of the operating environment.

The virtualisation of the ANS infrastructure also raises liability issues of two kinds, both of which are related to the multiplication of the actors involved and their distribution across national boundaries. From a formal perspective, this will require the establishment of a contractual framework among the actors involved, governing their exact obligations and liability. From a material point of view, a virtualisation will shift the liability focus away from human errors towards technical failures. The current historical regime of fault based liability is ill fitted to address such situations, because of the difficulty to allocate negligence in a virtualised environment. A liability framework based on strict liability for technical failures in ANS should be considered.

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[15] SWIM Fact sheet, SESAR SJU, 2011, p. 3

[16] Eurocontrol Specification for Data Assurance Levels, Eurocontrol, 15 March 2012, Doc 0148, p. 37.