Safety Management for Unmanned Aviation

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Abstract: *In Air Traffic Management (ATM), Safety Management Systems (SMS) provide the principal vehicle for implementing safety policies, practices and procedures in accordance with internationally agreed Standards. In a constantly changing operating environment, it is essential to maintain SMS effectiveness to maintain and enhance levels of ATM safety. Research at the University Politehnica of Bucharest (UPB) has analysed the major, fast-rising threats to ATM safety emerging in the field of unmanned aviation. After considering the operating environment in terms of control arrangements and unmanned vehicle types, the relationship between ATM and Unmanned Traffic Management (UTM) is examined. It is concluded that the SMS supporting ATM requires enhancement to address the risks arising from the emergence of unmanned aviation and relevant enhancement measures are therefore proposed. Further, research shows that detailed safety management arrangements to support UTM are not yet defined. Indicative SMS requirements for UTM are therefore derived and presented.*

Key Words: *Air Traffic Management, safety, Safety Management Systems, unmanned aviation, Unmanned Traffic Management*

1. INTRODUCTION

In Air Traffic Management (ATM), Safety Management Systems (SMS) are the principal vehicle for implementing safety policies, practices and procedures in accordance with internationally agreed Standards [1]. In a constantly changing operating environment, it is essential to maintain SMS effectiveness to maintain and enhance levels of ATM safety. Research at the University Politehnica of Bucharest (UPB) into the future development directions of SMS has identified a range of new safety approaches and methods designed to ensure that safety performance keeps pace with increasing industry challenges and pressures and thus avoids a progressive decline in aviation safety.

Six development paths for enhancing the effectiveness of SMS have been identified, including three in the category of "**Opportunities**" - self-initiated proactive measures as part of SMS management and development - and three in the category of "**Threats**" - protective measures required to respond to external factors which have the potential to degrade ATM safety levels. For each development path, enhancement measures are proposed, designed to contribute to an overall increase in levels of SMS effectiveness over the next decade, thus countering the effects of increased pressures and threats in the ATM system over that time. In the "Threats" category, Unmanned Aviation is targeted as a major area for action, with a particular focus on

Unmanned Aircraft Systems (UAS) as viable forms of commercial and recreational civil aviation. This also includes consideration of the control arrangements for UAS.

2. UNMANNED AIRCRAFT SYSTEMS

Recent times have seen the rapid emergence of UAS as a viable form of commercial civil aviation, as well as a major recreational pursuit. Both these forms of operation need to co-exist with all sectors of current and future manned aviation in a safe and visible way. In this context, the term UAS includes unmanned aerial vehicles (UAV's) which both:

- fly autonomously i.e., with no form of external control, and
- fly under the remote control of an external agency (e.g., remote pilot). In this case, the term UAS includes not only the UAV itself but also its control agency, including personnel and procedures, as well as any communications links or other means of connection between the two [2].

The range of sizes of UAV's is considerable – far greater than for manned aircraft. UAS design is determined directly by the intended function, and includes, (but are not restricted to):

a. **Larger Unmanned Aircraft Systems (UAS) -** operating over significant distances and with operating and performance characteristics similar to those of manned aircraft. The UAV's involved typically require ground infrastructure equivalent to that for commercial passenger carrying aircraft;
b. **Small UAS -** typically weighing below 25Kg and operating at relatively low levels – below those of most other forms of aviation. They can operate beyond the visual line of sight of the pilot and, typically, do not require significant ground infrastructure.
c. **Urban Aviation** -involving a mixture of operating characteristics by using very low-level airspace but also using passenger carrying vehicles to provide on-demand Urban Air Mobility (UAM) services. Vehicle designs can include unmanned or optionally piloted variants.

Commercial pressure for UAS use is already large and growing rapidly – ref. Figure 1– and includes demand for the operation of UAS at all altitudes and in all forms of airspace. This includes in non-segregated airspace – i.e. airspace which is currently used by, and allocated to, manned commercial and recreational aviation [3]. The operating capabilities of the UAS will need to ensure compliance with the regulations applicable to the airspace of operation.

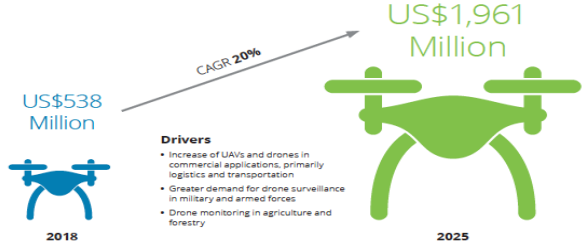

Fig. 1 – Assessment of Global UAS Market Development 2018 – 2025 (source Deloitte)

3. THE UAS OPERATING ENVIRONMENT

In Europe, EASA has defined three categories of UAS which are now embodied in EU legislation [4], [5], and may be summarised as follows:

- **Open** – for low-risk drone operations and requiring minimal regulatory intervention. Under EASA Regulations effective 30th December 2020, Vehicles are classified by type

and weight into one of five Classes. Vehicles heavier than 25Kg fall into the Specific or Certified categories.

- **Specific** – UAS operations presenting a higher risk and requiring a dedicated risk assessment. The UAS operator is required to obtain an operational authorisation by the Competent Authority specific to one, or a specified number of operations, and which may have specific limitations.
- **Certified** – operations of higher risk and subject to certification rules and safety oversight by the appropriate Competent Authority. Such operations can include operation over assemblies of people, the carriage of passengers, and transportation of dangerous goods.

In all three categories, the UAS (including its control agency, procedures and other technical constituents) is required to comply with the operating rules of the airspace within which it operates.

The EASA-EUROCONTROL Operational Concept for UAS-ATM Integration has defined three types of operation based on flight rules, which may be summarised as:

- **LFR** – Low-level Flight Rules - Applicable to Very Low Level (VLL) operations below the lowest Visual Flight Rules (VFR) altitude. Yet to be fully defined, LFR will encompass the rules of the air for UAS operations within Visual Line of Light (VLOS) and Beyond Visual Line of Sight (BVLOS). These will have to be compatible with VFR since VFR traffic uses this airspace.
- **IFR/ VFR** – Airspace currently defined for manned aviation. All UAS operating as IFR/VFR traffic within airspace classes A-G will be required to comply with relevant airspace requirements in the same manner, and with the same capabilities, as manned aircraft.
- **HFR** – High-level Flight Rules - Yet to be fully defined, these will apply to Very High Level (VHL) operations (above FL600) and cover all operations on manned and unmanned aircraft operating in this airspace. These rules must be compatible with IFR (as HFR traffic will need to transit through IFR airspace).

To include all forms of UAS operations within the above airspace volumes, it has been necessary to define seven classes of UAS traffic. Table 1 shows the way in which the differing types of UAS operation inter-relate with the UAS categories and the new range of airspace definitions that is necessary to encompass all UAS traffic. ***Together, this provides a basis on which manned and unmanned traffic may be integrated*** [6].

Table 1 – UAS Traffic Classes in all Airspace Types and Volumes (source material EASA-EUROCONTROL)

Airspace Type	UAS Traffic Class	UAS Category	Traffic Type	Airspace Limits	Operations	Purpose
VLL	I	Open	Recreation	Ground to 120m/400 ft	VLOS	Recreational
	II	Specific/ Certified	Specific/ Certified	Ground to 500 ft	VLOS/ BVLOS	Surveys, filming, search and rescue, and similar
	III	Specific/ Certified	Medium/ Long Haul Traffic	Ground to 500 ft	BVLOS, Free flight or route structure	Mainly transport
	IV	Specific/ Certified	Special Operations	Ground to 500 ft	VLOS/ BVLOS	Special Operations

IFR/ VFR	V	Certified	UAS not meeting pan-European performance requirements	500 ft to FL600 including uncontrolled aerodromes	IFR/VFR outside the pan-European network. Not flying SIDs and STARs	Mainly transport or military
	VI	Certified	UAS meeting pan-European performance requirements	500 ft to FL600 including aerodromes	IFR/VFR within the pan-European network, including SIDs and STARs	Any
HFR	VII	Certified	Very High Level IFR operations transiting non-segregated airspace	Above FL600 with transition through lower airspace	IFR/VFR	Stratospheric commercial operations

In the European context, the operation of UAS is encompassed within the European Community's U-Space concept, which coordinates the UAS vehicular requirements and specifications and the airspace structures which facilitate UAS operation and integration.
In the US, the same development challenges exist, but applied to an airspace system which is different in some respects to that in Europe. The FAA Concept is referred to as Unmanned Traffic Management (UTM) but this title is now in wider use to refer generically to a number of other traffic management applications now being marketed worldwide.
Overall, this analysis shows a complex and multi-dimensional operating environment in which the management of traffic, and the assessment of associated risks must be conducted.

4. UAS MANAGEMENT SYSTEMS

U-Space and UTM are two specific implementations of UAS management systems. Examination of these two operating concepts shows considerable similarities between the approaches – as might be expected when faced with broadly the same direction of industry development. Further generic issues which are fundamental in assessing future safety needs are also revealed. These include:

- **Formal Systems for Traffic Management** – forecast levels of UAS traffic are very large and cannot be accommodated under present-day ATM arrangements. Separate management systems are required for the airspace within which UAS will operate.
- **Levels of Automation** - in view of the traffic density to be handled, high levels of automation will be required.
- **Flight Services** – a range of automated pre-flight and in-flight services are required to enable UAS operations to proceed smoothly, including vehicle registration, flight planning, and flight approvals and authorisations.
- **Data and Information Management** – automated, network-supplied data services to support flight preparation and execution, including protection of airspace zones, weather information and air situation notification.
- **Airspace and Traffic Management** – services which control the management of traffic to optimise safety and airspace utilisation, including airspace management, conflict alerting, strategic de-confliction, dynamic re-routing and conformance monitoring (to detect deviations from planned/intended route).

For manned aviation, all of these functions are provided within the scope of ATM. Many involve human intervention and decision-making which will not be present for unmanned aviation involving U-Space/UTM concepts. While UAS traffic management will be "ATM-like" to some extent, it will involve traffic volumes, technologies and levels of automation not

currently used in ATM. Where UAS are integrated into non-segregated airspace, especially within ATM-controlled operations, some of the services will be provided within the ATM system while a proportion will be automated. Whatever the specific arrangement of flight services, or the type of UAS operation being considered, the UAS Traffic Management System will have an important interface with the ATM system within which the operations take place and, specifically, with the relevant ATM provider organisations. This is captured within the U-Space Concept of Operations accordingly:

"UTM provides services in its area of responsibility. Some of these services are similar to ATM services. Such services must have a high-level of coordination with ATM. Therefore, for these services, UTM is part of ATM."

5. EFFECTS OF UAS ON AVIATION SAFETY

All forms of unmanned aviation need to operate, and be seen to operate, in a manner that does not cause risk at a level beyond the safety limits that are viewed as tolerable today. This implies, among other measures, a system of UAS traffic management where safe and orderly operation can be assured, and levels of safety can be both measured and regulated. To establish the effects on aviation safety, it is necessary to assess the risks – potential and actual - that derive from the operation of UAS. These fall into the following areas:

Current Risks

In the current operating environment, all UAS operations are kept separated (segregated) from manned commercial aviation through the application of suitable airspace separation enforced by regulatory safeguards. This is an effective method of risk containment, especially with regards to the ATM system. In this context, therefore, a principal risk is the unauthorised penetration by UAS into non-segregated airspace occupied by other forms of aviation, including commercial aviation in controlled airspace. This is particularly evident in the specific (but not unique) example of small UAS in the vicinity of other aviation activities, such as airports. In this case, infringements by small UAS (or drones) into controlled airspace at airports have risen dramatically, one illustration of which is shown in Table 2. A number of collisions with commercial aircraft have also been reported in this period, including in Mexico, Canada and Argentina [7].

Table 2 – Reported UAS Incidents - UK and US. (Source – UK Airprox and FAA)

	UK	US
2014	6	57
2017/8	132	2124

Mitigation measures have been applied in the form of strengthened regulatory protection areas as well as "geo-fencing" capabilities on board the UAS designed to prevent flight into prohibited zones, including all controlled airspace.

However, some operations by operators with malicious intent, including using UAS without geo-fencing, or with geo-fencing that has been deliberately disabled, can cause major commercial disruption.

UAS can therefore already represent a potential threat to civil aviation safety which must be managed with effective countermeasures if levels of safety are to be protected. The ways in which such a threat may be identified and mitigated are as follows:

Risks from UAS

In this context, the major concern is the capability of the UAS to meet the operating requirements of the types of airspace in which they may operate.
This requires UAS, *as a minimum*, to replicate the performance of manned aircraft in that same airspace in terms of its ability to 'detect and avoid' increased-risk situations – including collisions with other aircraft, and with the ground (with the potential to cause collateral injuries on the ground).
The ability of UAS to operate to this level of performance is determined by their technical capabilities in respect of:

- Communications – the ability of the UAS to inform the agencies controlling the airspace of its status, and to respond to any changes necessary to its flight path. This may include communication with an external agency (such as a remote pilot);
- Navigation – the ability of the UAS to position itself with required accuracy, respond as required to fluctuating navigational demands and to comply with applicable navigational performance criteria (such as RNP specifications);
- Surveillance – the need for UAS to see and be seen. This includes the ability to remain electronically visible, to sense the surrounding operational environment adequately and fully as well as to comply with surveillance criteria applicable to the airspace of operation.

In the case of UAS, comparison with manned aircraft performance in respect of the above criteria is made more difficult by:

- The different types of UAS vehicles, differences in aerial performance and piloting arrangements;
- The differences in control arrangements for the airspace within which the UAS will operate – e.g. ATM or UTM
- The different technologies that will be used to achieve performance in the above C, N and S areas.

The European Commission and the European Aviation Safety Agency (EASA) have implemented comprehensive qualification and certification regulations applicable to all categories of UAS in three defined categories of operation.
These will continue to be updated as the operational contexts of these operations continue to develop [8].

Risks from Airspace and its Control Arrangements

Current airspace arrangements require an Air Navigation Service Provider (ANSP) to identify and mitigate safety risks through use of a SMS. In turn, the ANSP's operation of the SMS is subject to safety oversight by the National Supervisory Authority (NSA). The key risk-related issue is therefore how these service-provision arrangements are affected by the advent of UAS. The main effects are in three critically important areas:

For ATM –

- The integration of a proportion of UAS traffic into non-segregated airspace;
- The operation of UTM volume(s) of airspace within national airspace;
- The interface and consistency between the safety arrangements for ATM and UTM;
- The allocation of safety responsibilities between ANSP and UTM operator(s);
- Additional safety oversight arrangements by the NSA to cater for the addition of UAS operations.

For UTM –

- The need for the establishment of effective arrangements for the management of safety – a form of SMS designed for the type of traffic control arrangements within UTM airspace;
- The interface and consistency between the safety arrangements for UTM and ATM;
- The establishment of adequate safety oversight by the NSA.

For National Safety Oversight –

- The need for adjustments in the safety oversight arrangements by the NSA of the ANSP to address the additional risks posed by UAS operations;
- The need to introduce appropriate standardised processes for the safety oversight of UTM operators.

Figure 2 illustrates the safety arrangements and inter-relationships that need to exist when UAS are fully operational as envisaged: -

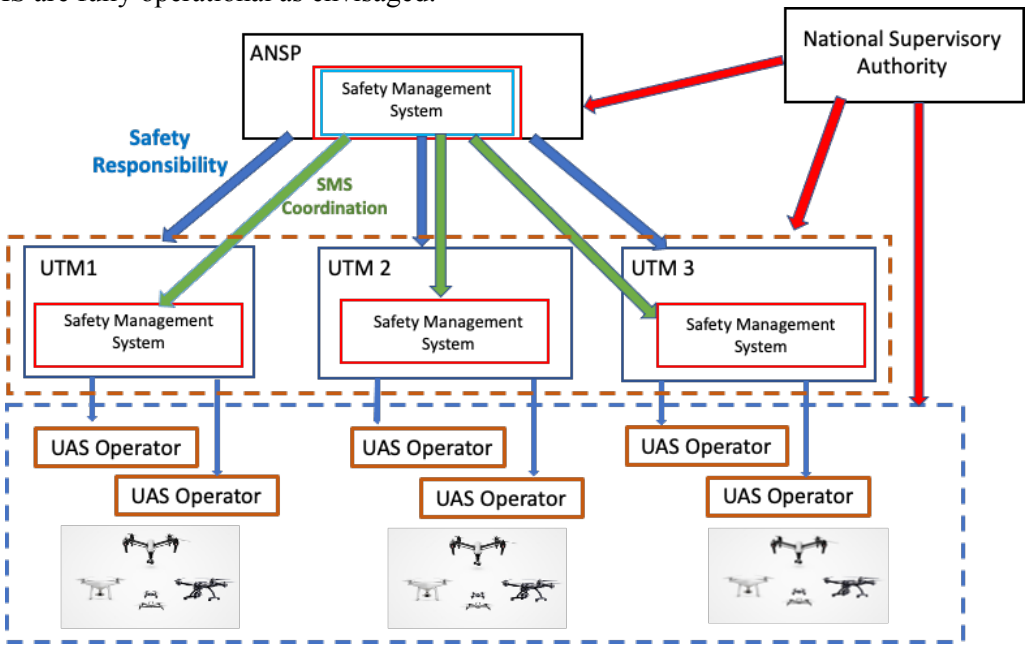

Fig. 2 – Safety Arrangements for Airspace Involving UAS Operations

6. UAS MANAGEMENT SYSTEMS

In addressing the severity of these risk areas, it is necessary to consider the regulations and requirements that currently exist at global and regional levels.

Any regulations specific to, or implemented due to, the introduction of UAS must be consistent with existing applicable rules for safety, and specifically for safety management. The market for UAS introduction is global. An overview of the application of existing global safety management standards to UAS operations reveals: -

- ICAO Standards and Recommended Practices (SARPs) for Safety Management – Annex 19 – applies in respect of the operation of all aircraft, to the providers of ANS [1].
- ICAO Document 10019 - Manual on Remotely Piloted Aircraft System (RPAS) – applies only to RPAS. RPAS is a subset of UAS but does not include autonomously operated UAS [9]. In addition, this Manual contains guidance, and not Standards.

- Current global safety management standards are generic to all aviation but do not introduce any SARPs specifically relating to additional risks due to the introduction of all categories of UAS operations.

At the European level:

- Regulations for the safety management of the provision of ANS, and for their certification, oversight and enforcement, are embedded in EU law [10]. As with their ICAO equivalents however, these are generic in nature in that they relate to the provision of services to all aircraft. The common requirements do not take account of the introduction of UAS, or new UAS services, and the risks they may bring.
- In addition, the European Community has enacted three further Regulations: -
  - European Commission Delegated Regulation (EU) 2019/945 - relating to the product compliance, manufacture, sale, importation and operators of UAS [4], and
  - Commission Implementing Regulation EU 2019/947 relating to the rules and procedures for the operation of unmanned aircraft [8] (and amended by Commission Implementing Regulation EU 2020/639 as regards standard scenarios for operations executed in or beyond visual line of sight) [11].
  - Commission Implementing Regulation EU 2021/664 on a regulatory framework for the U-Space [12].

Regulation EU 2019/947 does lay down requirements for the conduct of operational risk assessments, the rules relating to the competency of remote pilots, and requirements for UAS operators to "*report to the competent authority on any safety-related occurrence and exchange information regarding its UAS"*. These are all important elements of an SMS, but do not add up to a full SMS *per se*. This Regulation also contains the concept of a Light UAS Operator Certificate (LUC). A LUC is compulsory for operations in the "specific" category of operations and requires a: -

> *"safety management system corresponding to the size of the organisation, to the nature and complexity of its activities, taking into account the hazards and associated risks inherent in these activities"*.

The accompanying specification for an SMS is comprehensive and replicates the SMS requirements for an ANSP. However, the variable application of the SMS requirements leaves the nature of the final SMS somewhat unclear, the safeguard being that whatever is ultimately demanded, it must be to the satisfaction of the Competent Authority – i.e the National Supervisory Authority or equivalent. This therefore places a task on that Authority to judge compliance with the Regulation – one of a significant range of responsibilities placed upon the Competent Authority in the oversight and enforcement of the Regulation. For UAS operations in the 'certified' category, through circuitous cross-references to a significant number of EU Regulations, it can be taken that the SMS requirements of ANSPs would also apply to UAS operators [13], [14], [15].

This leaves open the question of what a UAS operator's SMS would comprise in practice. Commission Implementing Regulation EU 2021/664 refers to UTM Operators and places upon them the same requirements for safety management as laid down in Commission Implementing Regulation (EU) 2017/373 which are applicable to ANSP's and other ATM Network Functions.

These requirements are generic in nature and do not address the more specific aspects needed to cater for UTM operation. Given the current regulatory environment, it is therefore necessary to consider the need for further enhancements to current standards and regulations governing safety management to deal with the risks posed by the introduction of UAS operations. It can be concluded that: -

- In respect of UAS design and achievement of technical performance as outlined above, aviation authorities have laid down new certification criteria that are making their way into European legislation and related guidance material.
- In respect of airspace and its control arrangements, the issues identified above need to be satisfactorily resolved. Specifically, three main issues need to be addressed:-
    - The need for enhancements to current regulations governing SMS in ATM to deal with the risks posed by UAS operations;
    - The safety management criteria – requirements and guidance - that should apply to UTM operations;
    - The need for changes to the NSA's safety oversight process.

Paragraphs 7, 8 and 9 deal respectively with these issues.

7. MANAGING UAS RISKS IN ATM USING SMS

Global Standards require that ANSPs implement SMS. The key question is the extent to which SMS can deal with the new risks posed and can identify the measures required to enable safe UAS operation. Further, while SMS can support the process of risk identification and mitigation, is current SMS design sufficiently comprehensive to provide what is needed? The requirements for mitigating the risks posed by UAS operations must satisfactorily address:

- Risk identification and assessment;
- Identification and implementation of mitigation measures;
- Monitoring and recording of UAS-related safety experience, including occurrences (accidents, incidents) and deviations from applicable regulations;
- Informing and training organisational personnel who may manage or deliver air navigation services involving UAS.

An examination of the SMS arrangements in current use by European ANSPs is necessary to identify whether SMS design can meet these requirements as it stands, or whether further enhancement is necessary [16]. Figure 3 shows the SMS architecture developed jointly by the Civil Air Navigation Services Organisation (CANSO) and EUROCONTROL. It is in use throughout Europe and elsewhere globally, and is entirely consistent with ICAO SARPs. A review of the applicable European legislation, which is also consistent with global Standards, shows that all major components and elements of SMS are already mandatory. The key need for enhancement is in the adaptation of these elements to include the measures to effectively mitigate UAS-based risks.

Fig. 3 – Current CANSO/EUROCONTROL SMS Framework (source CANSO/EUROCONTROL)

With reference to the SMS Framework shown in Figure 3 therefore, Table 3 examines key SMS elements in ATM to specify the extent to which, in the context of current and future UAS

operations, those elements can meet the above requirements. It also examines shortfalls in current SMS functions, and proposes measures (initial and high-level) to be applied to enhance SMS effectiveness.

Table 3 – Proposed Measures to Enhance ATM SMS Effectiveness in Providing Services Involving UAS

SMS Elements	Potential Shortfall in Current SMS Capability to Deal with UAS-based Risks	Proposed Counter-Measures for SMS Enhancement
Safety Policy	Organisation insufficiently aware the nature and scale of proposed UAS operations, and the consequential risks.	Incorporate the need to reinforce the SMS to support awareness and preparation for providing ANS involving UAS, as well as the necessary interface with UTM.
Risk Management Process	Need to identify and categorise risks to safety posed by UAS operations and identify necessary mitigation measures.	Include identified and categorised risks deriving from UAS operations within the safety risk assessment and mitigation process.
Safety Interfaces	Need to ensure that actions taken in respect of UAS operations are fully coordinated and acted upon within the entire SMS and the organisation at large.	Implement procedures to ensure full coordination between SMS actions in respect of UAS operations and wider organisational functions. This applies especially in respect of UTM operations.
Safety Performance Monitoring	All threats to ATM safety posed by UAS operations need to be monitored to establish the scale and nature of the threats, as well as longer term trends.	Update performance monitoring procedures to include the effects of UAS operations on ATM safety performance.
Continual SMS Improvement	SMS must be kept current in terms of known or anticipated threats to safety.	Updated assessments of risks deriving from UAS operations to be taken into account as part of regular SMS effectiveness reviews.
Safety Reporting ***(see note 1 below re UTM)***	Need to achieve full visibility of UAS-related safety occurrences and their effect on safety performance.	Introduce further categorisation within the safety reporting system to take account of UAS-related events, including severity classification (in terms of safety impact).
SMS Audits	To ensure that measures to mitigate UAS-related risks are in place and functioning effectively.	To include SMS measures to mitigate UAS-related risks in regular SMS audits.
Safety Communication	UAS-related issues and events need to form part of normal organisational communications (internal and external) on safety matters.	To improve organisational awareness by including UAS-related information within normal communications methods on safety matters. Establish lines of communication with UTM operator(s).
Training and Education	A key need is awareness of UAS-related risks and defences at all levels of the organisation.	To formalise awareness of UAS-related safety issues by inclusion in organisational training programmes.

Note 1*– Applicable legislation requires safety events to be reported by the UTM operator to the Competent Authority (NSA). While this is essential, it can leave the ANSP out of the loop and potentially unaware of safety events occurring within the airspace for which they have responsibility. It is therefore proposed that a system is implemented whereby ANSPs can be equally and directly aware of any safety event reports being raised.*

8. SMS REQUIREMENTS FOR UTM

The Context of UTM Safety Management

Given the UTM concepts envisaged, from a safety viewpoint several issues need to be considered: -

- The volume of traffic expected means that ATM providers are unlikely to provide UTM services directly. Current proposals suggest that UTM services will be provided by separate commercial agencies and will be reliant on considerable levels of automation using technologies that are not currently part of ATM;
- A number of UTM services may be operated within the airspace managed by a single ANSP;
- Each of these services will become a delegated operation under the overall operational control of the ANSP;

- The Safety Management System (SMS) of the ANSP will need to be enhanced to provide safety assurance in respect of the UTM operations in airspace for which it remains responsible (as proposed in paragraph 8) and subject to safety oversight (ref. paragraph 9);
- A corresponding set of safety management requirements are therefore needed to apply to the UTM providers – in effect, an SMS for UTM - including appropriate connections to, and coordination with, the ANSP's SMS.
- The ANSP will remain under the safety oversight of the appropriate National Supervisory Authority (NSA) and will continue to be responsible for the safety of all services within their airspace, whether provided directly or as a delegated operation. This therefore includes UTM services.

In March 2020, EASA issued a formal Opinion (for adoption by the European Commission) addressing the *"High-Level Regulatory Framework for the U-Space"*, along with draft Acceptable Means of Compliance and Guidance Material [17], [18]. This resulted in the implementation of Regulation (EU) 2021/664 which does not become applicable until January 2023. As observed in paragraph 6, this Regulation applies to UTM providers the same safety management requirements that currently apply to ATM. This implements the SMS framework shown in Figure 3 but does not cater for the adaptations necessary to address the risks specific to UTM. Hence the derivation of further, or supplementary, SMS requirements for UTM service-providers is a necessary and urgent next-step in fully addressing the safety aspects of unmanned aviation. Given the publication of Regulation 2021/664, these further "requirements" may serve as guidance material, and assist the National Regulatory Authorities in assessing whether the legally applicable (and generic) SMS requirements have been sufficiently met to ensure the provision of safety UTM services.

Deriving Additional UTM Safety Management Requirements

In deriving SMS requirements for UTM, current formal ATM SMS requirements provide a suitable and stable platform, because they are: -

- The result of development and refinement over an extended period - more than two decades - of ATM operations;
- Derived from basic safety concepts and policies which are accepted industry-wide;
- Applicable to an industry sector that is sufficiently analogous to the UTM context in which they will apply.

All the safety criteria which apply to ATM also apply to UTM, so the same safety management framework may be used as a basis for the formulation of UTM equivalents. However, the nature and extent of application may be different in each case due to differences in operating procedures, the degree of automation and the technologies used.

It is therefore necessary to examine each SMS element individually to establish the extent of adaptation needed, and what the resulting UTM safety requirements may be. These requirements would be placed upon the providers of UTM services and overseen by the appropriate National Regulatory Authority.

Using the current SMS arrangements as shown in Figure 3 as a basis, Table 4 analyses the transformations, adaptations and/or additions required to the generic global Standards for safety management in aviation (as laid down in both the CANSO/EUROCONTROL Framework and in ICAO Annex 19), which should also apply to UTM.

The result presented in Table 4 is a set of 'Indicative' UTM SMS Requirements - 'indicative' meaning that they have not been worded or specified here as formal standards, regulations or guidance material but, nevertheless, the requirements are intended to be: -

- indicative of areas or topics where further SMS provisions are considered necessary, and
- supplementary to the applicable SMS Standards for ATM, which should also apply.

Table 4 – Indicative SMS Requirements for UTM

SMS Element	Differences in a UTM Environment (when compared with ATM)	Indicative UTM SMS Requirements
Safety Policy	To establish public confidence and acceptance of UAS operations, the safety policy will need to be made more explicit and backed up by demonstrable safety results. A robust policy will be required in the face of hard commercial strategies deployed by UAS operators.	• The UTM service-provider should set safety policies which: – Clearly state how the service will operate and interact with the surrounding services being provided to manned and unmanned aviation. – ensure that UTM services do not present any additional risks to the manned aviation alongside which they will operate. – must apply to the full range of the UTM services being provided.
Organisational and Individual Safety Responsibilities	Safety responsibilities will be more complex than in ATM due to higher levels of traffic, increased system automation and less human intervention. The potential for hidden system failure modes is even greater. The safety management expertise required will be wider than in an ATM equivalent.	• The UTM service-provider should allocate: – overall safety responsibility for the service provided as well as – specific safety responsibilities for the major service functions. • Specification of the responsibilities should take account of the wide variety of safety functions involved in UTM service-provision, including flight planning, authorisation and approvals and data management, in addition to strategic and tactical control of traffic.
Compliance with International Obligations	International Standards and Regulations do not exist for all aspects of UAS operations, and not for UTM. National regulatory authorities will exercise safety oversight to ensure compliance with national rules. National approaches could vary until harmonised standards have been agreed.	• The UTM service-provider should comply with the national standards set by the NSA (which will ultimately be developed to reflect internationally agreed rules). • Arrangements should also be in place to comply with safety oversight processes, including demonstration of compliance with applicable standards.
Coordination of Emergency Response Plan	In a UTM environment, the types of emergencies requiring response planning can be significantly more varied than those experienced in ATM (e.g Urban Air Mobility).	• Emergency response planning should: - – take account of all possible response scenarios based on a full risk assessment. – Include details of alternate means/locations for service-provision [19].
SMS Documentation	The UTM operating system may involve increased complexity which must be documented. This will include different and/or additional operating procedures and interfaces and increased scope of safety occurrence reporting.	• For UTM service-provision, SMS documentation should include: - – SMS regulations under which UTM services are provided – Operating procedures specific to UTM – Enhanced safety occurrence reporting (to take account of new occurrence types) – Organisational arrangements for safety responsibilities.
Risk Management Process	Operational Risk Assessments are a key requirement for UAS operations and are a principal element in the EASA UAS-ATM Concept of Operations [5].	• The risk assessment requirements for UAS operations should apply in the case of UTM operations. • The risk assessment function should be integrated into the overall SMS framework for UTM to provide complete SMS functioning.
Safety Interfaces	Key external institutional safety interfaces will be with the relevant ANSP and NSA. Operating interfaces will include ANSP for flight information and airspace status, UAS registration bodies, data providers including meteorological data. Effective internal interfaces will ensure that the SMS operates as a complete system – not a collection of elements.	• The UTM service-provider must establish and maintain effective interfaces: - – With the ANSP relevant to the airspace within which the UTM service is being provided, and – with the providers of all data relevant to the vehicle registration, planning, authorisation and operation of UAS flights under its control. – Internally within the provider organisation to ensure comprehensive operation of the SMS.

Safety by Design	Safety by Design ensures that all parts of the operation – the whole system, people, procedures etc. - are considered and managed from a safety viewpoint. For UTM, this could involve certain elements not usual in ATM (e.g. vehicle registration).	• The service-provider should ensure that operation of the SMS captures all elements of the UTM operation. • By its operation, the SMS should provide all relevant safety performance data to support further UTM system improvements.
Fatigue-Related Risk Management	In ATM this refers to the alertness of personnel performing safety-critical tasks. In UTM, with increased automation, fewer humans in the system have to be even more vigilant to avoid fatigue-related problems. In addition, the areas where alertness becomes a high-risk issue can be different from ATM (e.g. data handling).	• An assessment should be conducted of high-risk tasks with the potential to be subject to fatigue-related problems. • Appropriate mitigations, safeguards and procedures should be built into the operation of the UTM SMS.
Safety Performance Monitoring and Measuring	UTM service-provision may involve additional safety criteria that need to be measured and monitored. New additional safety performance indicators and targets may be needed.	• The UTM service-provider should define the structure of the reporting scheme to be used to measure safety performance. • Specific safety performance indicators and targets need to be established and agreed with the regulator.
The Management of Change	The generic Standards in Annex 19 apply equally to the safety management of UTM. This will require a highly effective risk assessment process as timescales for changes may be compressed during initial UTM operations.	• The UTM service-provider should: - – clearly document all aspects of the current operation as the definitive basis for identifying where changes are occurring, – establish a regular change review process using staff and stakeholder inputs as well as formal risk assessment processes.
Continual Improvement of the SMS	Ongoing SMS improvement is supported by structured data gathering and exchanges of information, both inside the organisation and between organisations. UTM will throw up new areas of data gathering which must be assimilated into the SMS structure.	• A system should be implemented of regular assessment of SMS effectiveness and updating of the operation of the SMS. • The system should be based on professional expertise and judgement as well as support through safety data collected in SMS operation and information interchange.
Safety Reporting Investigation and Improvement	In ATM, this requires a system which reports, records and analyses risk-bearing events. including safety occurrences. In UTM, the requirements will be the same, but the range of events will be partially different, encompassing new areas and risks, leading to new types of risk mitigation.	• The UTM reporting system should: - – encompass all types of safety occurrence identified by the risk assessment process and by professional judgement. – operate on an organisation-wide basis. – be consistent with, and integrate where necessary with, the corresponding system in ATM service-provision. – provide for joint UTM-ATM occurrence investigation and performance review.
Operational Safety Surveys and SMS Audits	The requirements in ATM for internal and (independent) external SMS audits apply equally to SMS in UTM. However, both the audit process and the expertise of audit personnel need to take into account the processes and key risk factors in UTM service provision.	• The UTM service-provider should make provision for periodic internal safety surveys and external SMS audits. • The scope of the surveys and audits should address the full range of safety activities in UTM service-provision, including relevant external interfaces with ATM. • The survey/audit personnel should be equipped with expertise corresponding to the scope of the systems under review.
Safety Communication	In UTM, communication on safety matters is vital, both internal and external. A wide range of communications methods are involved, especially as much data exchange will be automated (more than in ATM). External communications will also need to deal with issues surrounding the public acceptability of unmanned aviation.	• A communications system should be established which: - – Uses all available and appropriate communications media – Ensures that appropriate safety information is disseminated internally to staff and externally to stakeholders – Takes account of public awareness and interest in UTM and UAS matters.
Training and Education	Training on safety matters, and on SMS in particular, is an essential pre-requisite for ATM service provision. It is equally	• A structured training programme is required which embodies fundamental concepts of SMS, but also takes

	essential for UTM service-provision, but the training syllabus will include new aspects, as well as training on ATM to UTM service-providers.	account of the new systems and organisational features in UTM service-provision. • A competency review system is required to monitor proficiency in the context of UTM safety management.

9. SAFETY OVERSIGHT REQUIREMENTS

With the introduction of unmanned aviation, Safety Oversight has a crucially important role to play in ensuring safety. In the operational concepts being proposed, the number of major actors makes the task of oversight far more complex than for the (present-day) ATM situation. Specifically, regulatory bodies will need to have effective oversight of: -

- ATM service-provision, including integrated unmanned aviation within non-segregated airspace, and relevant interfaces with UTM service provision;
- UTM service providers, including relevant interfaces with ANSPs;
- UAS operators;
- UAS manufactures and suppliers.

In this context: -

- "Oversight" refers not only to the verification of compliance with applicable rules, but also establishing rules where none currently exist, and
- "Relevant interfaces" would include effective communications between the organisations, consistency of operating plans and procedures, and equivalence of safety standards. In this context, and in partial support of this need, Article 19.1 of Regulation (EU) 2019/947 (as amended) specifies:
  "The competent authorities of the Member States and market surveillance and control authorities referred to in Article 36 of Delegated Regulation (EU) 2019/945 shall cooperate on safety matters and establish procedures for the efficient exchange of safety information" [4], [8].
- Additionally, EASA Opinion 01/2020 and its related Guidance Material addresses the need for *"Competent Authorities to perform certification, oversight and enforcement tasks in respect of the Common Information Service (CIS) providers and USSPs"* [15], [17]. Further, Regulation (EU) 2021/664 establishes *a certification and continuous risk-based oversight programme*. As these documents relate to a 'High-Level Regulatory Framework', no further detail on safety oversight requirements or provisions is given.

Accordingly, the further articulation of safety oversight provisions for unmanned aviation, and especially for UTM service provision, emerges as an urgently needed next step.

The current regulatory baseline may be used as the start-point for identifying further enhancements in this area, as shown in Table 5: -

Table 5 – Enhancement of Safety Oversight Provisions Required for Unmanned Aviation

Subject of Oversight	Current Applicable Regulatory Provisions *(See Note 2 below)*	Sufficiency / Enhancements Required
ATM Service Provision	ICAO Annex 19 ESARR 1 *(see Note 3 below)* Reg (EU) 2017/373	No further enhancements required, but current provisions should be applied to enhanced SMS (as per Para 7).
UTM Service Provision	Reg (EU) 2021/664 *(from Jan 2023)*	Generic provisions for SMS (ATM-based) requiring enhancement - See proposals at Para 8.
UAS Operators	IR (EU) 2019/947 IR (EU) 2020/639 Reg (EU) 2017/373	Sufficient for operations in the Specific category by specification of operator's SMS requirements. Certified Category operations appear to be covered by ANSP requirements.
UAS Vehicles & Systems	Del.Reg (EU) 2019/945	Sufficient for oversight of UAS. Many of the additionally-invoked regulations apply to all aircraft – whether manned or not.

***Note 2**: In the case of EU Regulations, only the principal reference is quoted here. In almost every case, the principal Regulation cross-refers to, and invokes, provisions in a number of further EU Regulations. In addition, only Regulations are stated here – not guidance or supporting material which, in themselves, may not be legally binding.*

***Note 3**: EUROCONTROL Safety Regulatory Requirements (ESARRs) form part of the European safety regulatory baseline for those States who are not subject to European Community Law through EU membership or through other treaty obligations.*[20]

While the regulatory baseline for UTM can be established on the basis shown above, Industry pressures exist for or the rapid introduction of UAS. As a result, certain sections of Industry may be pushing for 'lighter' regulation in view of the limited extent of many UAS operating environments. However, in the context of Urban Air Transport, a major international conference – Global Urban Air Summit (GUAS 2019) - concluded that, regarding safety: -

"if Urban Air Mobility Systems (UAMs) are to be used for transporting people, they will have to meet the safety standards and approvals as are required for manned aviation" [21].

This logic does not stop at UAMs, which are only one of many types of UAS. Even UAS that do not carry passengers have the potential to cause damage to those outside the air vehicle and, arguably, can have the same likelihood of vehicle or system failure. Though the consequences may be different in some respects, they could nevertheless be potentially just as dangerous. Wider still, it can be argued that all service-provision environments within which UAS operate should *as a minimum* be subject to the same safety principles and levels of safety as those for manned aviation. Indeed, the European Union's Intermediate Concept of Operations for U-Space observes that, for small UAS ('drones'): -

"There are currently no specific rules governing drones other than those that regulate all aircraft. In order for the manned and unmanned operations to be compatible, there need to be clearly defined flight rules…" [22],

… and, in this case also, this logic applies in respect of UAS outside the 'drone' sphere of operations.

A review of current legislation therefore shows that, in the European context,

- Sufficient regulatory provision exists for regulatory authorities to exercise effective safety oversight in the fields of ATM service-provision (with enhancements as per paragraph 7), UAS operators and UAS vehicles and systems, and
- In respect of UTM service-provision, the application of SMS requirements for ATM is a necessary but insufficient basis for ensuring adequate UTM safety. Additional safety management provisions are necessary (as per paragraph 8) with corresponding enhancements to safety oversight. The proposals in paragraph 9 and Table 5 should therefore be implemented in an appropriate form.

10. CONCLUSIONS

UAS represent a fast-emerging sector of civil aviation but can also present additional risks in the provision of ANS to civil aviation. In both Europe and the US, the major Concepts of Operations for UAS are under advanced development, but the consequential effects on safety management have not yet been fully addressed in legislation and published guidance. This paper therefore seeks to rectify this gap and make necessary proposals to reinforce SMS effectiveness. The principal means for identifying and controlling risks is the organisation's SMS. However, an analysis has been necessary to assess whether ATM SMS has the capability to adequately address UAS-related risks. This has shown that, while current SMS design encompasses the scope and the major functions needed to achieve this objective, specific

enhancements are required to a wide range of these SMS elements to make the control of UAS-derived risks fully effective. A range of risk countermeasures are proposed which, if implemented, would enhance SMS to increase its effectiveness in mitigating risks arising from UAS operations. In addition, the currently proposed concepts of operation for UTM demand a similar, but parallel, approach when specifying safety management requirements applicable to that sector. Lessons are transferrable from ATM (as now captured in EU legislation) but some adaptation and extension are necessary to fully address the specific features of UTM operations. Accordingly, a set of initial and indicative SMS requirements for UTM is proposed. Finally, the current situation regarding safety oversight of ATM has been reviewed in the context of the arrival of UAS operations, and recommendations for enhancements made accordingly.

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