THE DEVELOPMENT OF THE UAS TRAFFIC MANAGEMENT (UTM) AN AIR NAVIGATION SERVICES PERSPECTIVE

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1. Introduction

The Unmanned Aircraft Systems (UAS) sector is evolving quickly. The number of devices, commonly known as "drones", produced and launched annually is expanding widely, and new applications are constantly being developed. Although it is to be expected that not all such applications will be successful from a business perspective, it is undisputable that these new entrants will have a major effect on the air transportation system.

It is becoming apparent that because of the numbers and the diversity of applications involved, some sort of infrastructure will be required to support the safe operation of drones in those parts of the airspace that are opening to UAS operations. That future infrastructure is coming to be known as UAS Traffic Management (UTM), based on the model under development by NASA.

The development of the UTM is a bottom-up process conducted by an extremely dynamic and innovative industry. However, it remains a loose and uncoordinated process, without any visible structured leadership, building on a multitude of specific projects launched by individual organisations. In theory the shape, functions, and components of the future UTM could emerge from the combination of the most successful initiatives, in a way similar to the process that led to the emergence of the Internet.

The development of the UAS is though not occurring in a vacuum, and powerful external factors will need to be accounted for, which will influence the future of UTM. The main such consideration is that the UAS business is arising alongside an incumbent industry, namely manned civil aviation. The airspace open to civil aviation is presently managed by established air navigation services providers (ANSPs) in accordance with Air Traffic Management (ATM) rules produced by the International Civil Aviation Organisation (ICAO). To the extent that UAS will share the airspace with manned aircraft under the responsibility of incumbent ANSPs, it is difficult to imagine the development of a UTM in full isolation from the existing air navigation services (ANS) system.

One of the main challenges for the establishment of future UTM will be to define a strategy that reconciles two worlds operating on the bases of fundamentally different business models. The purpose of this paper is to offer an ANS perspective of future UTM with a view to support the development of a UTM strategy that is pragmatic and realistic and that capitalises on emerging opportunities while managing all safety-related issues without complacency.

2. Air navigation services and the integration of unmanned aircraft

Acknowledgment by the ANS community of the emerging UAS sector is overdue and remains surrounded by a sense of confusion. Whereas the fact that the advent of UAS will have a major impact on the civil aviation system is recognised, the exact nature of that impact still needs to be understood. The attitude of the ANS providers (ANSPs) and regulators towards this new business reflects an intuitive mixed feeling of still undefined

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threats and opportunities. The position of the ANS industry consequently remains cautious, as ANSPs would not want to miss the potential opportunities offered by this new segment of activity but, at the same time, need to ensure that new entrants do not compromise the performance of their historical business, especially from a safety perspective.

The incumbent ANSPs have ruled unchallenged over the airspace open to civil airspace ever since the need for such services was first identified. The first requests to share the airspace used by conventional aircraft with unmanned aircraft have come from a little number of vehicles, mostly military, which need to transit through the civil aviation airspace or to conduct a specific, often single, mission in that airspace. The regulatory effort and attention for the integration of drones have originally focused and still remain largely concentrated on such particular operations.[2]

But the numbers and applications for drones have largely grown outside of that airspace, relatively unnoticed by the regulators and the ANSPs. Drones have begun to multiply in the thin airspace layer immediately above the Earth's surface, which, except for the odd low-flying helicopter, remain largely unused by manned aviation. More recently, new possible applications for drones have targeted the high levels of the atmosphere, well above the operational ceiling of conventional aircraft. It becomes apparent that the real game-changing operations along with the densest levels of drone activity, are likely to arise from applications used outside of the airspace presently open to civil aviation activities.

From an ANS perspective, drone operations can presently be divided in three categories, which are well captured in the preliminary regulatory work performed by the European Agency for the Safety of Aviation (EASA):

1) Drones that will commonly share the airspace used by civil aviation users;
2) Drones that are not intended to fully integrate into the civil aviation airspace, but that may occasionally need to operate within that airspace or in close vicinity thereof (this includes UAS that need to climb through the civil aviation airspace to reach a high altitude mission level);
3) Drones that will commonly operate outside the airspace used by civil aviation users, either in the very low altitude or in the very high altitude range.

Consequently, from an ANS point of view, future framework objectives for the operation of drones should be to:

1) Ensure that drones that will share the airspace with manned aircraft can be safely integrated in that airspace;
2) Ensure that those drones that cannot be safely integrated are effectively excluded from that airspace;
3) Clarify the features of the future airspace structure, the needs in terms of infrastructure to support the operations of drones in those parts of the airspace that are not employed by civil aviation users and the organisational arrangements needed to deploy and operate that infrastructure.

3. A clash of cultures

Drones have had a relatively minor impact on conventional aviation as long as manned and unmanned aircraft were operated in a segregated manner. However, both worlds are moving closer to each other, with an expanding operational interface and in an increasing number of overlaps. The projected paths of these two separated environments could ultimately result in a fully seamless environment.[3] The convergence of the two business models is however not without risk. Conventional manned aviation and drone operation

[2] ICAO's regulatory approach is still largely focused on such applications.
[3] Most of the early regulatory work performed by ICAO and EASA assumes the integration of UAS as ideal.

belong to two distinct worlds, governed by fundamentally different cultures and business models.

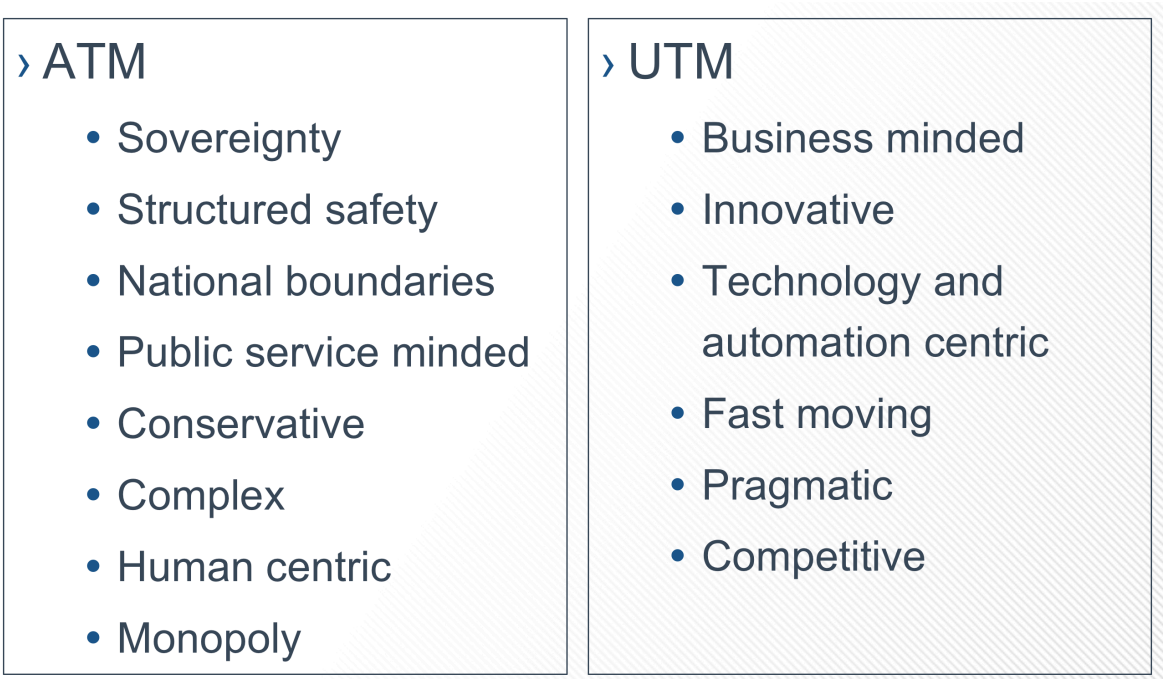

Figure 1. A Clash Of Culture

The incumbent manned civil aviation world is an environment heavily influenced by principles such as state sovereignty and politics. For various reasons, it is a monopolistic activity strongly constrained by national boundaries and, in most states, it operates in accordance with the rules of public service. ANS is a heavily regulated activity subject to top-down development processes in which states retain ultimate decision-making authority. Safety stands as the core value of the industry and constitutes its main strength. Based on decades of at times painful practical experience, the manned aviation community has developed a robust and comprehensive safety management system. However, in part because of the complexity of its safety certification processes, it is also an extremely slow moving environment. Finally, the incumbent ANS system is human centric in the sense that the air traffic control operational procedures rely heavily on human interaction, and automation still plays a limited role in this domain.

The drones' world, for its part, is a much more dynamic sector driven primarily by business processes for whose purpose national borders are largely irrelevant. The regulatory framework lags far behind technology. The UAS domain is highly innovative and fast moving, in part thanks to extremely limited certification processes. Safety is certainly not ignored by the UAS community, but that industry still lacks a comprehensive and systemic approach to safety management that would allow drones to blend into the air transportation system as a whole with the same level of safety performance as that of the current manned aviation system. The UAS industry operates in a lightly regulated competitive environment, the development of which builds on bottom-up initiatives. Finally, contrary to the manned aviation sector, the UAS industry capitalises fully on the use of technology to favour automation instead of human interaction.

Recognising and managing the differences of cultures will be a critical success factor in avoiding a clash between two business models currently set on a collision course for shared use of the airspace.

4. From a threat to an opportunity

From an ANS perspective, the advent of drones could be viewed either as a threat or as an opportunity.

The defensive attitude takes the view that the airspace open to civil aviation is about to be invaded by millions of undisciplined drones. Because the UAS domain is driven by business opportunities outside the formalised safety management framework for manned civil aviation, such development is feared to put the safety of the occupants of manned aircraft and of third parties on the surface at risk. Although the reality of this threat must be acknowledged and urgently addressed in light of recent incidents, its magnitude needs to be put in context. For the foreseeable future, only a marginal number of UAS are expected to be authorised to share the airspace with conventional airspace users. These will be mainly large and sophisticated devices that can be safely integrated into the flow of air traffic or less conspicuous vehicles that may need, for the purpose of a specific mission, to cross an airspace open to civil aviation. The genuine imminent threat currently stems from devices operated by irresponsible owners and that are flown close to manned aircraft (in particular, in the vicinity of airports) in spite of the fact that they are not allowed to do so. But the overwhelming majority of UAS will be required to remain well clear of manned aviation operations, either at very low altitude or in the higher layers of the atmosphere. Assuming compliance, these UAS will not constitute a significant risk for civil aviation. A more interesting perceived threat is that the rise of UAS could challenge the incumbent ANS business model. This paper takes the view that such a development should be welcomed and seen, on the contrary, as an opportunity.

The opportunistic attitude is presently primarily focused on the prospect that drones could open new business areas for ANSPs. However, such business opportunities remain undefined and seem still to reflect declarations of faith rather than a well-constructed business analysis. This paper takes the view that the most promising opportunity for the ANS community is that the UAS industry could help the incumbent ANS world make a performance breakthrough at system level. There is growing recognition that the legacy ANS will need a disruptive factor as a springboard to take the next measurable step to improve its performance. Many see innovative technologies as such a disruptive factor. It is true that technology alone is not the full answer to a breakthrough, as overcoming many of the current ANS environment's limitations will above all require a major change of business mindset, but the lack of available technology will no longer be a valid excuse to justify the status quo.

Drone technology, and especially for those that operate at the lowest altitude, could constitute such a disruptive factor. Because of the specific features of the UAS operating model, that sector offers a unique framework to design, test and validate traffic management tools and functions that can hardly be developed in the legacy ANS system. Once such tools and functions have been successfully validated in the UAS environment and have gained the maturity required, they can be exported back into the manned civil aviation context to improve the ANS system's performance. In that, ANSPs could have much to gain from supporting the safe development of the drone sector.

5. Designing the UTM

The need for a formalised UTM has not yet been universally recognised. For some, the UAS industry can thrive in a self-contained framework based primarily on common technological standards. The filing of a flight plan and the operation of drones in accordance with a set of regulatory provisions, possibly within predefined airspace corridors, would constitute the minimum requirements. Such a view is supported by the preliminary trials performed by some UAS operators with the assistance of national aviation authorities. But the positive conclusions of such trials only stand in an environment with extremely little UAS activity. In the event that the numbers of UAS operations should reach

the presently predicted levels, such arrangements would become impracticable, and it is increasingly recognised that the safe and efficient operation of drones, especially at low altitude, would require some type of infrastructure to play a role comparable to the ICAO-based ATM in place for civil manned aviation activities.

It appears that individual states will develop their own provisional UAS frameworks to address the most urgent aspects (such as keeping drones away from landing and departing aircraft) as interim solutions before a definitive framework emerges from the work undertaken at the regional and global levels. The future infrastructure is now known as the UAS Traffic Management (UTM) in the terminology of the American NASA who is developing the concept for the specific US context. However, the American authorities are wisely sharing their thoughts, and other entities are finding inspiration from that model, as common national and regional approaches can hugely facilitate the emergence of a common and consistent global framework.

The shape, content, role and components of the UTM remain unclear. It appears that the term itself remains to be defined. Although it is commonly envisioned as an equivalent for the incumbent Air Traffic Management system, it will probably encompass a broader range of elements. The ATM system comprises essential operational and technical functions to prevent collisions between aircraft, expediting the flow of air traffic and providing pilots with information to support air navigation safety and efficiency. The UTM, however, as it is presently discussed, seems to cover the entire UAS framework, including components such as the maintenance of a drone registry, which falls outside the ATM system[4].

Some guiding principles can nevertheless already be intuited. The main objective of the UTM must be safety, with a view of preventing collisions between drones and manned aircraft and from one other along with preventing drones from colliding with buildings or obstacles and from falling on third parties on the surface. One of the principal challenges to successfully launching the UTM will consequently be demonstrating that drones will not constitute a new safety threat. That reassurance must be brought to the manned civil aviation world but also to a much broader public, as social acceptability will be a fundamental success factor for UAS operations.

5.1 UTM strategy

The features, components and organisational structure of a future UTM are not ends in themselves and must be the result of a UAS strategy. That strategy cannot address the management of UAS in isolation. To be successful, it must reflect a common approach supported by all manned and unmanned aviation stakeholders. This paper takes the view that the UTM strategy should include two components: a robust airspace strategy and a technology strategy.

From an airspace strategy perspective, the UTM could be considered a mere extension of the legacy ANS system as new types of aircraft enter airspace sectors that were not used by manned civil aviation aircraft. This approach would address the airspace as a seamless continuum, assuming the full integration of drones and the sharing of the airspace as a whole by all airspace users, whether manned aircraft or not. Much of the work of regulatory activities involved in this matter aspires to achieve that ideal objective as a long-term vision. But a full integration strategy does not appear to be realistic for the foreseeable future considering the major differences between the business models and cultures that need to be bridged. With a mid-term view, the major risks will remain located at the interface between both worlds. As such, some intermediate steps seem to be necessary before a full integration and a seamless airspace can be imagined. For that reason, some actors, such as Amazon, wisely recommend that in a first phase, the airspace reserved for low-

[4]States maintain a civil aircraft registry, but it does not form part of the ATM system.

flying drones should be strictly segregated from the airspace open for civil aviation applications. That segregation should include an appropriate buffer between the airspace blocks assigned to the various user categories. The thickness of that buffer still needs to be defined. It will need to guarantee a sufficient separation between UAS and manned civil aircraft, but the buffer will be smaller than the 3 NM or 5 KM distance applied in different parts of the world. This structural measure would serve a dual purpose. It would protect civil aviation users from the intrusion of unauthorised drones and, at the same time, allow the UAS industry to mature in airspace sectors governed by regulations that reflect that segment's specific requirements and capabilities.

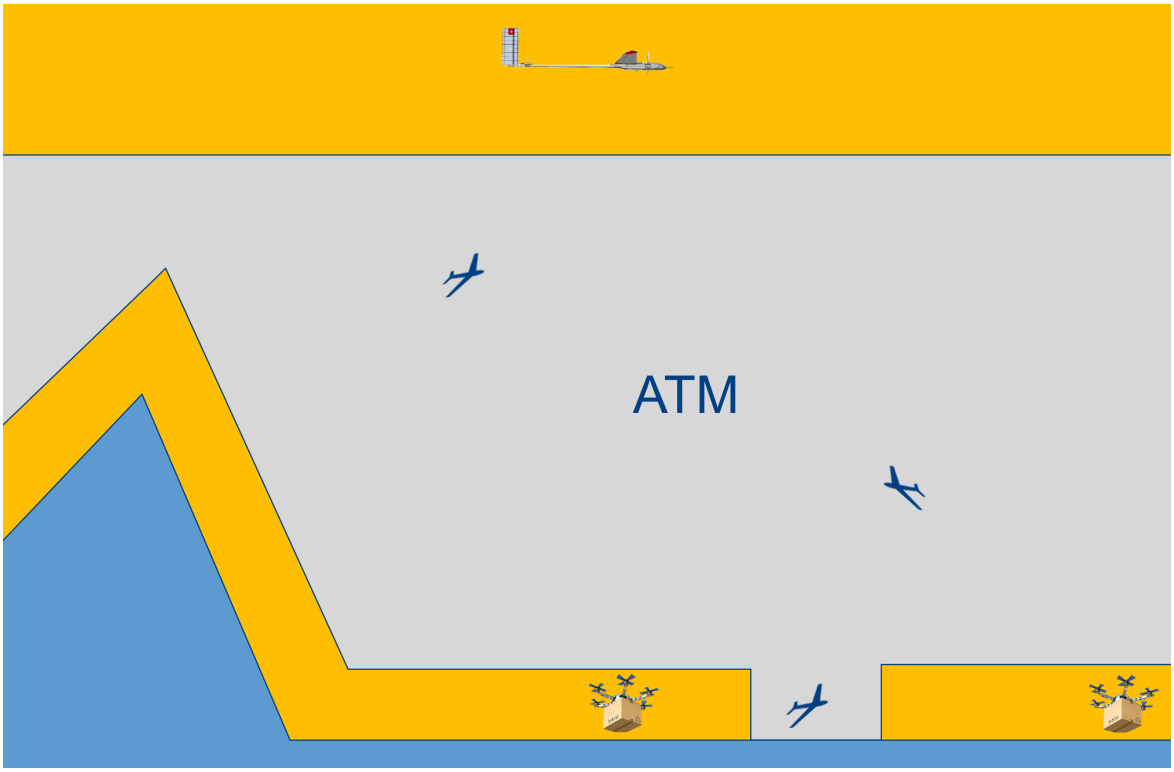

Figure 2. Designing The UTM

Airspace segregation should not be absolute, but crossing the boundary between the UTM and ATM airspace should be subject to strict conditions. All UAS penetrating the ATM airspace sectors will need to be albe to behave as ordinary aircraft or be able to self-separate from manned aircraft. Penetration by UAS that do not have such capabilities could be allowed, subject to an operational concept presented by the UAS operator, which explains how the safety risks involved will be mitigated and approved by the civil aviation authority and/or the competent ANSP. However, such flights should remain exceptions, as specific operations supported by an ad hoc safety case can be envisaged for a small number of isolated flights but will prove impracticable on at a larger scale.

An airspace strategy based on segregation will not be sufficient in mitigating the safety risks involved. Measures need to be put in place to avoid the UAS that are meant to operate strictly within specific airspace sectors escape from the boundaries of such sectors, whether inadvertently or wilfully. Geofencing technology offers a powerful means to keep drones outside the airspace open to civil aviation users and can even overrule a lack of discipline on the part of a UAS operator. Such technologies exist, and initial regulatory measures should focus on their mandatory embedding in all drones that could constitute a threat to civil aviation users. In addition, even within airspace reserved for low-flying drone operations, where such devices should be allowed to fly relatively freely, some limited and often unplanned civil aviation activity is likely to take place, for instance, in the form of low-

flying helicopter operations. In the UTM domain, conspicuity is exacerbated because of the small size of most UAS. The operation of manned aircraft in the UTM sectors should consequently be subordinated to mandatory carriage of equipment designed to ensure that such aircraft can be easily detected by UAS and that the latter can autonomously take appropriate action to avoid a collision. Because of the comparatively low level of conspicuity of drones, the responsibility for avoiding collisions with manned aircraft should in effect reside with the UAS.

5.2 Regulating the UTM

A regulatory framework will need to be developed to support future UTM deployment and operations. This paper takes the view that 'if technology is right, then regulation is light.'. The unique features of the UAS environment should allow for a relatively light regulatory environment where technology can act as an effective substitute for cumbersome regulation. This philosophy should apply to all UAS operations, whether they operate in airspace sectors reserved for drone operations or whether they share the airspace with other operators.

Relying on technology instead of on detailed regulatory provisions is consistent with a 'performance-based' regulation model. That model, which is opposed to a 'prescriptive' regulation regime, has generated a great deal of debate but has remained a nebulous notion to date, with few concrete applications. A performance-based regulatory framework focuses on the definition of objectives that need to be met and leaves it largely to the industry actors to determine the means to achieve these objectives and to demonstrate that such means are appropriate for the intended purpose. A performance-based regulation shifts a significant amount of the regulatory burden from the regulatory authorities to the regulated community.

Translated into the UAS environment, a performance-based regulatory framework would include high-level regulatory requirements such as:

- the need for UAS operating in the UTM to have the embedded ability to remain outside airspace sectors where such operations are prohibited;
- the need for UAS entering the airspace open to civil aviation to have the capability to operate as ordinary aircraft or to self-separate from ordinary aircraft and from each other;
- the need for the operation of any UAS that cannot comply with the above requirement to be based on a concept of operation prepared by the operator and approved by both the competent regulatory authority and ANSP;
- the need for any manned aircraft flying within the UTM airspace (e.g. low-flying helicopter) to carry equipment making it fully conspicuous to UAS so the latter can self-separate from the manned civil aircraft;

How these objectives are met and what specific technological tools should be developed for that purpose should be left to UAS manufacturers to determine.

5.3 UTM infrastructure

A UTM based on the assumption of an initial segregation from the civil aviation airspace should allow for the development of an infrastructure and services that respond precisely to the UAS sector's needs while simultaneously preserving the interests of manned airspace users. A fundamental assumption is that the future UTM cannot emulate existing Air Traffic Management (ATM). The UTM certainly can gain enormously from the systemic safety management framework in place in the manned civil aviation—to ensure that safety matters are properly addressed. This would greatly help the UAS industry achieve the required level of social acceptance. But the features, operational procedures and technical tools that characterise the legacy ATM model appear to be ill fitted to support UTM deployment. In particular, contrary to ATM that relies heavily on human interaction, the

specific features of that sector require very different tools and processes that reflect the fact that numbers in the UTM clearly speak for automation.

It is beyond the ambition of this paper to offer a detailed presentation of the various possible components of a UTM infrastructure. These will be primarily determined by the UTM strategy pursued by individual sstates and international aviation policy bodies. But assuming that that strategy foresees segregated operations as a first step, the initial UTM framework will likely comprise a UAS register similar to the existing manned aircraft register, containing UAS owners' identities. Among other purposes that data will be useful for investigating incidents. The framework will also include a UAS positioning function possibly using the mobile phone network, which will allow UAS to determine precisely their position (as a complement to GNSS) and to share that information across the UTM. Conspicuity enabling and enhancing devices and self-separation applications will also form crucial elements of a future ATM infrastructure.

5.4 UTM organisation

The UTM will require an organisation to be designated and mandated to deploy and operate the necessary infrastructure. That organisation can take many forms. The theoretical models range from entrusting the responsibility to the legacy ANSP in place, as an extension of its monopoly mandate, to mandating another operator or network of operators to be established as private law companies operating in accordance with competition rules. Hybrid models could foresee the national ANSP delegating the function to one or several third-party operators. The organisational model will also depend largely on the UTM strategy pursued.

As long as the UTM operates in a segregated environment, the UTM's technical features offer much better prospects for a multiple-operator competitive environment. In such an environment, the future UTM operator need not be a monopoly. The monopoly status of the existing ANSPs in charge of ATM provision to civil aviation users is the consequence of a combination of political choices and economic factors. As far as 'competition for the market' is concerned, incumbent ANSPs enjoy a legal monopoly because they are primarily designated by their parent states to operate the ANS system on an exclusive basis within the national borders of that state. From a 'competition in the market' point of view, in the present context, historical ANSPs respond to the definition of a natural monopoly in the economical sense of the term. As long as they operate based on current ATM processes, it still costs more to have several providers operating within the same airspace block than to entrust a single entity with that responsibility, chiefly because of the cost of coordination involved. The economic figures will probably look different in a UTM environment where innovative technology and common standards can drastically reduce coordination costs. Then a segregated UTM airspace would make it easier for an incumbent ATM provider to outsource the UTM provision to a third-party provider should an ATM provider's state mandate be extended to UTM provision with a view to concentrating the overall service provision within a single entity. Conversely, in the event that states should opt for a strategy that assumes a non-segregated UTM environment, or for a UTM sector with a very active interface with the legacy ATM environment, a multiple-service operator model or even the delegation of responsibility to a third-party UTM provider would become difficult to imagine.

6. Conclusions

The UAS domain is enjoying massive development. Whereas a number of these devices will share the airspace with conventional manned aircraft, for the foreseeable future, the overwhelming majority will operate in airspace sectors with currently very little or no civil aviation activities (e.g. very low-level or very high altitude). A framework needs to be defined to support the conduct of UAS operations and, more specifically, to prevent collisions between manned and unmanned aircraft and among UAS themselves. That framework is becoming known as UAS Traffic Management (UTM). One major risk at the

moment relates to the loose and informal framework supporting UTM development and the absence of an authoritative UTM strategy whether at a national, regional or global level.

The UTM cannot be developed in full isolation, as the UAS industry is developing alongside an incumbent ATM system. The biggest challenge for the successful deployment of UTM will be to reconcile two worlds that operate based on fundamentally different business models and cultures. Both worlds have much to learn from each other. The UAS industry should find some valuable inspiration from the robust integrated safety management framework that emerged from decades of practical experience in the manned aviation domain to ensure that the safe integration of drones is managed without complacency. The incumbent ATM community, for its part, should make use of the opportunities offered by the UTM to validate disruptive innovative technological solutions that can only be tested with difficulty in the manned aviation domain. Recourse to such technologies could help the ATM industry reform the legacy business model and achieve the next performance breakthrough.

The development of the UTM is becoming an urgent task, primarily because of the need to manage critical safety aspects arising from the promiscuity between manned and unmanned aircraft. It is this sense of urgency that should drive both process and strategy for defining the UTM.

It is likely that the first measures for establishing a UTM will be taken at the national level. National policies will be more effective in taking rapid action in this domain. But these domestic frameworks are expected to remain transitional measures to govern UAS operations until a common regime is developed at regional and global level.

The full integration of UAS in the airspace has been the implicit ideal aspiration of many early studies dedicated to the UAS industry. That vision should remain the long-term objective. But considering the urgent need for action, a practical and realistic UTM strategy will need to include several steps. The first step should assume that the airspace sectors open to manned civil aviation should be segregated from those reserved for UAS operations. Geofencing technology should ensure that UAS do not operate outside the boundaries of the airspace sectors reserved for such operations. The regulatory framework supporting the UTM should remain light and performance oriented, reflecting the assumption that in the field of UAS, technology can act as a powerful substitute for hard regulation.