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# Integration of Aerospace Operations into the Global Air Traffic Management System

Martin Griffin

*Eurocontrol*, [martin.griffin@eurocontrol.int](mailto:martin.griffin@eurocontrol.int)

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## Sub-orbital Operations in the Air Traffic Management System

### Integration or Segregation

#### What needs to be done and who can do it?

#### SynopsusSynopsis

Commercial aerospace operations are a reality. Companies are already carrying out flight trials and will be carrying the first passengers and freight in the near future. The commercial development of more vehicles is underway. This situation can be equated to a similar stage in the development of Remotely Piloted Air Systems (RPAS) where technological advances took place at a far faster pace than envisaged leading to a fragmented regulatory and operational situation which is still not resolved at the present time.

This paper provides a timely catalyst to raise implications of the operation of commercial aerospace vehicles within the existing Air Traffic Management (ATM) system and to consider if the ATM system can safely include the integration of commercial aerospace vehicles into the existing system without a significant change in both the operational practices and technological standards of air traffic control. It also examines the feasibility of extending todays ATM system to encompass Space Traffic Management. More importantly that existing target levels of safety are not compromised and are maintained or improved in line with future system requirements

~~The paper will analyse the existing operations of aerospace vehicles in segregated airspace and consider if this is a long term solution for the development of the industry.~~

~~It will *inter alia* examine the implications of aerospace operations upon;~~

- ~~• Airports; runways, priority operations,;~~
- ~~• Air Traffic Control; operating procedures, separation standards, flight routings.~~
- ~~• Air Traffic Systems; flight data processing, system functionality, support tools, safety nets.~~
- ~~• Communications, Navigation and Surveillance; Performance Based Navigation, Automatic Dependant Surveillance and radar applications.~~

~~It will identify potential areas in which the existing system will require to be changed and/or upgraded to accommodate aerospace technology.~~

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**Comment [BM2]:** Is it worth saying you do not address airworthiness, certification and ops approval?

## **Introduction**

The Convention on International Civil Aviation dated the 7th December 1944 (The Chicago Convention) established the principles and arrangements in order that international civil aviation can be developed in a safe and orderly manner and that international air transport services can be established on the basis of equality of opportunity and operated soundly and economically

A specialized agency of the United Nations, the **International Civil Aviation Organization (ICAO)** was created to promote this safe and orderly development of international civil aviation throughout the world. It sets standards and regulations necessary for aviation safety, security, efficiency and regularity, as well as for aviation environmental protection. The Organization serves as the forum for cooperation in all fields of civil aviation among its 191 Member States.

Part 1, Article 1, of the Convention states;

*Sovereignty : The contracting States recognize that every State has complete and exclusive sovereignty over the airspace above its territory.*

Annex 8 of the Convention also defines an aircraft as;

*'any machine that can derive support in the atmosphere from the reactions of the air other than the reactions of the air against the earth's surface'.*

This paper will explore the issues that these statements have introduced together with the implications for a new generation of sub-orbital commercial craft operations. The paper will also consider the existing global Air Traffic Management system and the technology challenges that it faces together with the changes that this technology may require to accommodate sub-orbital operations.

## **Background to Air Traffic Management**

ICAO has 191 contracting States. Within these States there are frequently multiple Air Traffic Management systems operating in small different areas due to the political issues (*inter alia*, *security, social, financial, etc*) involved with maintaining control over sovereign airspace as provided for in the Chicago Convention. In the majority of cases these systems are capable of covering far greater areas than their actual area of operations thus providing the potential for fewer systems which, in turn, would lead to a more efficient ATM system and economic savings. In addition some States are allocated responsibility for aircraft operations over the high seas where Air Traffic Management Service provision may differ considerably from that provided over sovereign territory. Added to this complexity many other non-contracting States operate independently from the ICAO framework. This fragmented approach to the provision of Air Traffic Management Services has resulted in a largely inefficient system evolving in which technical interoperability cannot be presumed. Europe is a prime example of such a fragmented system development. Over 50 Air Traffic Control Centers (ACC's) operate within the European Civil Aviation Conference (ECAC) area -(note. ECAC consists of 44 member States). Aircraft may only be flying in the area of operation of these ACC's for as little as 3-5 minutes in some extreme cases.

The majority of these ACC's have their own individual Air Traffic Control Systems. There are a number of providers of these Air Traffic Systems and each provider offers different configurations of system depending upon needs and financial resources available to customers.

The problem of interoperability (the ability for systems to share data) has been evident for some considerable time. A number of bodies have been established to address the issue including the European Organisation for Civil Aviation Equipment (EUROCAE) and the Radio Technical Commission for Aeronautics (RTCA), [as well as of course ICAO via its Standards and Recommended Practices](#). However, to date, many interoperability issues remain.

Additional initiatives to address these interoperability issues have been commenced with the establishment of large research and development programmes such as the United State of America Next Generation Air Transportation System (NextGen), Europe's Single European Sky ATM Research (SESAR) and Japans Collaborative Action for Renovation of Air Transport Systems (CARATS). These initiatives are intended to provide new generation Air Traffic Control Systems, based upon satellite navigation capabilities, which are globally interoperable. [At regional level in the EU, the Single European Sky initiative provides an overarching regulatory framework of which the technical programme is a pillar.](#)

To provide a global framework for these initiatives ICAO has [revisited the Global Air Navigation Plan](#), introducing the notion of ~~an~~ Aviation System Block Upgrades ~~strategy~~ to ensure that aviation Safety will be maintained and enhanced, that Air Traffic Management improvement programmes (as mentioned previously) are effectively harmonised, and that barriers to future aviation efficiency and environmental gains can be removed at reasonable cost. The Block Upgrades incorporate a long-term perspective. They coordinate clear aircraft and ground – based operational objectives together with the avionics, datalink and ATM system requirements needed to achieve them. This overall strategy serves to provide industry-wide transparency and essential investment for operators, equipment manufacturers and Air Navigation Service Providers. Importantly the timescale of this strategy is 2028 and beyond.

### **Area of Application of Existing Air Traffic Management**

Aviation is a relatively young and rapidly evolving industry. When the Chicago Convention was agreed the extent of its applicability (in the vertical plane) was not established definitively. Rather, the definition of an *aircraft* “*any machine that can derive support in the atmosphere from the reactions of the air other than the reactions of the air against the earth's surface*” would seem to provide a limitation on the vertical application of ICAO's responsibility i.e to a height at which a machine stops deriving support from the atmosphere.

Modern commercial airliners typically operate at maximum altitudes of [4043,000 ft \(132,000m\)](#) with exceptions (notably the ex Concorde) operating up to 60,000 ft (18,000m). To accommodate the provision of Air Traffic Services the airspace is divided into Flight Information Regions (FIRs) defined as “An airspace of defined dimensions within which flight information service and alerting service are provided”. These FIRs are sometimes limited to a maximum altitude (commonly 66,000 feet) or in many cases [ares](#) described as- “unlimited” altitude. This raises the question as to what is the operational status of this area of ‘airspace’ above the area

of everyday air traffic operations. In the majority of cases an Air Traffic Control Service is provided within 'controlled airspace' up to a given level (which varies from country to country) above which no Air Traffic Control Service is provided. Services (-very rarely utilised due to the small number of aircraft operations in the area) are limited to Information and Alerting only.

The problem of delimitation of the boundary between airspace and outer space also raises questions as to the extent that the existing Air Traffic Management system can extend to. The issue is far from finding a common solution and is subject to extensive legal debate within the UNCOUOS Legal Sub Committee. It has been suggested that 100km (the Karmen line) is the beginning of outer space but this has never been fully accepted as this is, in effect, determining a national boundary. Therefore the area of applicability of the existing Air Traffic Management system is uncertain. For the area above 'airspace' no legal requirements yet exist for a 'Space Traffic Management 'system.

### **Technology and eOperations of Air Traffic Management**

The existing Air Traffic Management technology is still centred around the human Air Traffic Control Officer (ATCO). Automated system -support for the ATCO has been introduced gradually during the past 30 years but, in general, the system still relies to a great extent on human decision making.

There are three main technical components [in-supporting](#) the ATM system, communications, navigation and surveillance. These have been [evolving](#) over a number of years and developed to take into account technological advances in aircraft construction and operations.

- **Communications.** The main form of air/ground communication for critical messages is the use of Very High Frequency (VHF) voice transmission ([UHF over oceans](#)), this is foreseen to continue in the foreseeable future. Air/ground data link is utilised and will be more widespread in the future eventually replacing air/ground voice communications. In the long term higher capacity data link technologies are likely to be introduced.
- **Navigation.** Navigation capabilities traditionally have been based upon ground based navigation facilities (VHF Omnidirection Range (VOR), Non Directional Beacons (NDB), Distance Measuring Equipment (DME) etc in a predominantly point to point navigation infrastructure. To provide more flexible and economic routings the concept of Performance Based Navigation (PBN) is presently being introduced to provide a means of shifting from sensor based navigation to performance based navigation to facilitate global harmonisation based upon the gradual increase in reliance on satellite navigation. In the long term navigation capabilities will be based upon 4D trajectory management capabilities.
- **Surveillance.** Early forms of surveillance, many systems of which are still operating today, are primary radar which is the only existing independent/non-cooperative surveillance system. This is currently supplemented by Secondary Surveillance Radar (SSR) including SSR Mode S. Greater use is being made of Wide Area Multilateration (WAM) and Automatic

Dependent Surveillance Broadcast (ADS-B). All systems except for primary radar rely on signals being transmitted from equipment fitted in the aircraft.

These three basic components are supplemented by system functionality which can provide various support functions [enabling the ATCO to have a representation of the present and future traffic situation, supplemented by alert functions](#) such as Short Term Conflict Alert (STCA), Medium Term Conflict Detection (MTCD), Minimum Safe Altitude Warning (MSAW) and Approach Path Monitor (APM) to the ATCO.

In addition, equipment fitted into aircraft to provide information to the ground surveillance system is also utilised to give pilots information on other suitably equipped aircraft that may pose a threat to them. This is known as the Traffic Collision Avoidance System (TCAS). Crucially ICAO mandate the carriage of such equipment for aircraft with a maximum take-off mass of over 5,700 kg or authorised to carry more than 19 passengers.

ICAO provide a regulatory framework for these technical systems in Annex 10 Aeronautical Communications.

Air Traffic Control operating procedures have also evolved over the years from a procedural basis (where aircraft are separated by time, distance and level without the use of a surveillance system) to a system in which separation standards can be reduced by utilising more advanced technology (radar, ADS-B, Reduced Vertical Separation Minima RVSM etc). A regulatory framework for these operational procedures is provided by ICAO in Annex 11 Air Traffic Services, Annex 2 Rules of the Air and supplemented by Doc 4444 Procedures for Air Navigation Services.

### **Existing Aerospace Transportation Developments**

Since 2005 aerospace transportation systems have experienced rapid technological and commercial development. As these developments continue it is envisaged that aerospace vehicles could in the near future be used to regularly transport people and freight from point-to-point on the surface of the earth through airspace and outer space.

Traditionally space vehicles have been designed as rocket launch which requires limited lateral airspace restrictions. However many of the new generation sub-orbital space vehicles are designed, at least for part of their operation, as aircraft *any machine that can derive support in the atmosphere from the reactions of the air other than the reactions of the air against the earth's surface.* The USA space shuttle was an example of this type of operation as it was launched as a rocket but returned to earth with aircraft characteristics.

As technology has advanced the concept of different types of space launch vehicles other than the traditional rocket launch system are being exploited which are likely to lead to significantly reduced launch costs. These concepts include launches from "mother" aircraft ((Swiss Space System S3), high altitude launch station (Dark Sky) and "traditional operations" from airports (Rocketplane USA). The first company to commence operations, Virgin Galactic with SpaceShipTwo, successfully completed its powered tests during April of 2013 and the first fare-

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paying passenger flight is likely to occur within the near future. SpaceShipTwo is launched from a purpose built aircraft WhiteKnightTwo and flies the return leg as a glider.

The definition of an aircraft excludes rockets and capsules therefore the scope of interest for this paper is limited to winged vehicles which can be seen to be Sub-orbital Aeroplanes. If this is the case then Sub-orbital *aeroplane* operations, deriving support from the atmosphere for the largest part of their flight, are considered as aircraft therefore the legal framework of ICAO also applies to these vehicles.

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~~The first company to commence operations, Virgin Galactic with SpaceShipTwo, successfully completed its powered tests during April of 2013 and the first fare paying passenger flight is likely to occur in 2014. SpaceShipTwo is launched from a purpose built aircraft WhiteKnightTwo and flies the return leg as a glider. A number of other commercial companies will be ready to commence operations within the next few years including Swiss Space Systems S-3 with SOAR (pictured).~~

~~In addition to sub-orbital flights some aerospace vehicles intended to operate in earth's orbit are becoming more similar to aircraft and may be considered, at least for a portion of their flight, as an aircraft. The definition of an aircraft (above) excludes rockets and capsules therefore the scope of interest for this paper is limited to winged vehicles which can be seen to be Sub-orbital Aeroplanes. If this is the case then Sub-orbital *aeroplane* operations, deriving support from the atmosphere for the largest part of their flight, are considered as aircraft therefore the legal framework of ICAO also applies to these vehicles.~~

This then raises the question that, if they are aircraft operating in the legal framework of ICAO what operating procedures and technical requirements will be mandated for such operations and how will this fit into our existing ATM system?

These differing approaches to space launch technology will require radically different management than exists today.

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### **Integration or segregation**

To date most space launch operations have taken place in segregated airspace, in many cases in areas of low population or near the ocean. Future operations will, in several cases, take place at inland locations and as they grow in frequency will need to be integrated into the existing ATM system and, indeed, existing airports. Achieving a safe and efficient integration of sub-orbital operations into non-segregated airspace will require close coordination between numerous bodies and should seek to achieve a common regulatory framework.

A variety of launch licensing systems have been (or are being) put in place by countries including Malaysia, Russia, Sweden, Switzerland, United Kingdom and United States. They establish only system requirements and target levels of safety for ground personnel and for uninvolved public without differentiating between manned and unmanned systems except that in the former case no flight termination system is required for dangerous deviations from the flight path. This poses unknown risks on one side for the aerospace vehicle and its passengers, and on the other side for aircraft in its vicinity should a failure occur.

In the event of a catastrophic failure or, indeed, even the return to earth of space debris, there is an increased risk to aircraft as they are vulnerable to being hit by debris. The space shuttle *Columbia* re-entry breakup spread a wide trail of debris over major air traffic routes in the United States and raised safety issues with the possibility of an aircraft being hit by debris.

At present the number of launches of sub-orbital aerospace vehicles is limited and can be enabled by the use of segregated airspace and case by case flight authorisations. As previously stated some National Authorities have developed (or are developing) their national regulations and operational procedures which are not necessarily aligned and, in some cases may be contradictory. This is resulting in fragmentation of the system. The need for a common regulatory and operational framework is becoming more pressing. This was (and still is) a similar situation with Remotely Piloted Aircraft Systems (RPAS) developments which was subject to rapid technological advancement and operational use over the past decade. Delay in providing a global framework for these developments have resulted in an extremely fragmented system which is taking considerable effort to rectify the situation. As stated previously, no legal requirements exist for management of space traffic. In addition there are no global regulations relating to traffic management between aircraft and space flights. In some national space legislation there exist some procedures intending to ensure (as far as practical) safe operations of space activities and separation assurance. However these procedures were not developed for providing an integrated Air Traffic Management system.

If the sub-orbital aerospace industry is to grow segregated operations cannot be the long term solution. However, to integrate into the existing ATM system will require the development of a new regulatory, operational and technical framework. This must ensure not only the safety of the sub-orbital passengers but also of the other users of the ATM system.

### **Target Levels of Safety**

The establishment of a Target Level of Safety (TLS) for aviation in general has historically been influenced by the requirement of airworthiness authorities to establish quantified targets upon the contribution made by aircraft systems to aircraft accidents.

Current TLS vary a lot in terms of scope. Related applicability to the setting of safety minima and to the safety assessment of changes to the ATM system is therefore limited. Assumptions and related limitations (E.g., Route structure, assumed aircraft density, type, assumed phases of flight, etc..) related to each specific TLS are not always clear or well understood by the whole aviation community. There is a need to adopt a total aviation system perspective, top down, which would be complementary to existing practices while still enabling them to be put in context.

Given the current and anticipated future increase in the volume of air traffic over the next few decades, there is a growing concern that simply maintaining the current accident rate (in terms of flight hour) for existing air traffic operations will lead to an unacceptable increase in the number of incidents and accidents. If we now introduce additional variables such as aerospace vehicle operations into an integrated system there is a potential that the current accident rate

may increase. This will have significant detrimental consequences for civil air transport operations. It is therefore considered essential to achieve a decrease in the overall accident rate sufficient to offset the effect of rising traffic levels. This will require all contributors to the overall aviation risk, including aerospace vehicle operations, to decrease their contribution. This fact, in turn, raises the issue of the existing target level of safety being presently achieved (or planned) by aerospace operators.

Establishment of a target level of safety encompasses the complete ATM System which includes all aspects, operating procedures, technical equipment and human factors which together support the safe and expeditious management of civil air traffic.

ATM is intended to prevent the following accident types leading to the loss of one or more aircraft and/or multiple (fatal) injury to occupants:-

- a) collision between aircraft in flight or moving on the ground
- b) collision between aircraft and the ground
- c) impact between aircraft and other avoidable airborne object (e.g. missile, birds)
- d) impact between aircraft and other avoidable ground based object (e.g. vehicle, physical structure)
- e) loss of control/catastrophic degradation of aircraft ability to fly resulting from an avoidable external influence such as:
  - severe meteorological conditions (e.g. wind shear, turbulence, storms)
  - wake vortex or jet wash.

The integrated operation of aerospace vehicles has not been included in this process.

#### **Integration into the ATM system – Operational / technical issues**

Existing separations standards and operating procedures are based upon a number of factors including the height, speed and equipment of the aircraft in question. In the case of sub-orbital aerospace vehicles these will be significantly different than what we have today. If we are to achieve acceptable Target Levels of Safety many of these separation standards and procedures will require to be revised or new ones developed. Some issues *inter alia* that may need to be addressed are listed below;

Many Flight Information Regions (especially in Europe) are small and based upon national boundaries for political purposes. Existing aircraft remain in these areas for a very short time. Sub-orbital operations will be carried out at much higher airspeeds than existing aircraft operations and, therefore, will remain in the airspace for potentially only a few seconds. Present procedures involve handing responsibility from one ATC unit operating in an FIR to the next unit operating in an adjacent FIR and requires the aircraft to change frequency from one unit to the other. This will not be feasible in the case of sub-orbital operations.

Existing lateral and longitudinal separation standards are based upon the Target Level of Safety required to be met and the likelihood of an aircraft straying from its intended position in the lateral, longitudinal and vertical dimensional planes. In the case of sub-orbital operations existing separation standards are likely not to be sufficient.

The predictability of the ballistic trajectory will be extremely important as the future ATM system will be largely based upon 4D predicted trajectories.

The route network structure (especially in congested areas such as Europe) is defined based on ground based navigation aids and Performance Based Navigation. It is unlikely that this network will support Sub-orbital operations.

Many Sub-orbital vehicle operations are based upon an air launch of the aerospace vehicle from a mother aircraft. How are the separations standards going to be applied in this case?

Controller radar vectoring [and speed adjustments](#), especially in the vicinity of airports, ~~is~~ [are still](#) required to provide an efficient sequence of arriving and departing aircraft. [Vectoring-These](#) techniques for existing traditional aircraft may not be suitable for Sub-orbital operations.

Aerospace vehicles returning to earth for landing may also require priority landing as many designs apply a non-powered approach. The vehicle will have one opportunity to land as a “go around” is not an option. This has safety implications in the event that the approach is disrupted. In addition, the aerospace vehicles are likely to be operating at higher speeds than existing aircraft and also to be less manoeuvrable introducing potential safety issues. [In addition, this would raise issues regarding the efficient use of available airspace and airport capacity.](#)

Existing control procedures often require information/input from the equipment onboard the aircraft. This equipment is weight consuming and in many cases requires to have considerable redundancy capabilities. Sub-orbital operations are weight constrained and may not be able to be fitted with the appropriate equipment.

~~Surveillance data update rate.~~ [Our The](#) existing surveillance update rate and accuracy influence the separation standards to be applied within a particular airspace. Will the standards be suitable for suborbital operations at extremely high speeds and altitude.

Datalink and voice communications will need to be assessed for compatibility with Sub-orbital vehicle operations as will the navigation capability that these vehicles will be expected to meet.

### **Integration into the ATM system - Airport issues**

Space ports have traditionally be developed as sites for rocket launching but are now increasingly being designed with runways to accommodate Sub-orbital aeroplanes. ICAO provide design criteria for airports in Annex 14. It is uncertain is this criteria is applied at all space ports under construction or planned.

Many future operators of Sub-orbital aeroplanes are planning to operate from existing airports. This will raise a number of issues;

Runway length and characteristics. Existing runways are designed for conventional aircraft and may not be suitable for Sub-orbital operations due to dimensional and/or strength limitations.

Taxiway layout. Taxiways are designed for aircraft self manoeuvring which may not be the case for Sub-orbital operations. Equally, clearance distance between taxiways has been based upon the largest aircraft to use the airport. There have already been clearance limitation issues with the Airbus A380 at some locations (e.g. Heathrow Airport)

Landing aid facilities. Existing airports use both visual (Precision Approach Path Indicators) and electronic (Instrument Landing System) landing aids. Sub-orbital aeroplanes are likely to need to utilise the same facilities.

Passenger handling may need to be specifically for Sub-orbital aeroplane operations as passenger may require additional time and facilities to prepare for flight.

Dangerous goods. Many Sub-orbital operation will utilise rocket fuel which will require special handling at the airport and potentially upgraded fire fighting facilities established.

### **Pulling it all together**

A number of topics have been raised in this paper which will impact upon the development of Sub-orbital operations.

It is clear that the International Civil Aviation Organisation (ICAO) is charged with coordinating and regulating international air travel. However the contracting States have complete and exclusive sovereignty over the airspace above their territory. Many Sub-orbital vehicles will fall within the definition of an aircraft by deriving support in the atmosphere from the reactions of the air other than the reactions of the air against the earth's surface. Therefore falling under the remit of ICAO while they are operating in airspace.

The vertical extent of airspace and the boundary with outer space is unclear. In addition in many parts of the world the ATM system is fragmented. This is not an optimal situation for Sub-orbital operations.

ICAO have planned, in the form of Aviation System Block Upgrades, for future developments of the Air Traffic Management system which have not taken into account Sub-orbital operations. There are a number of questions both technical and operational relating to the operation of Sub-orbital vehicles in the existing ATM system.

Sub-orbital operations will have different characteristics and requirements than existing aircraft operations and will require to be integrated into the existing Air Traffic Management system and airports at some stage in the future.

Safety is paramount and airline passengers expect safety standards to be maintained or improved in the future. Sub-orbital safety standards will be expected to have no negative impact on the safety of other aircraft. Passengers on board the Sub-orbital vehicle will increasingly demand higher standards of safety than is presently proved. Target levels of safety will need to be established for Sub-orbital operations.

### **ICAO role**

The issue of Sub-orbital operations has been placed on the agenda of the ICAO Council during its 175<sup>th</sup> Session in 2005 and again at its 200<sup>th</sup> Session in 2013 receiving considerable interest.

ICAO is an established United Nations body which is already functioning and is already designated responsibility for setting standards and regulations for aviation safety. It is the obvious body to take on responsibility for Sub-orbital operations within the airspace.

Rather than develop specific regulations for Sub-orbital operations, existing Annexes and Documents may be revised complementing existing rules to capture the specific features of Sub-orbital vehicles. This “soft” approach allows new technologies to be accommodated and minimizes effort and risk while giving a sufficient framework for investment in Sub-orbital vehicle development.

As an initial step information and guidance material should be developed under the auspices of ICAO. Revision of Annexes can then be carried out over a period of time to ensure that the new industry is not constrained. However the clear objective should be to meet existing certification and operational standards.

Discussion should be commenced to consider airspace above what is commonly utilized today as similar to that over the high seas in order to avoid the fragmented system that exists in many locations today and which is not compatible with Sub-orbital operations.

### **Conclusion**

Sub-orbital commercial operations are a reality and will require integration into the existing Air Traffic Management system in the (probably near) future.

A number of issues need to be addressed now including political, operational and technical.

ICAO is the established body to provide standards and regulations for aviation. Sub-orbital vehicles are aircraft in many cases and therefore under the responsibility of ICAO while operating in airspace.

It takes considerable time to amend global documents, operational practices and technical specifications. We must commence this work now if we are to provide a timely regulatory, operational and technical framework for development