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ABSTRACT

This paper will examine the political, policy, and regulatory barriers to the provision of STM as a global safety service. It will examine the concepts under development for airspace from 20km to 100km to accommodate new entrants in aviation and space and discuss how those concepts may provide a path forward for decentralized space traffic management.

1. Introduction

Space Traffic Management as a field of study represents a developing need to prevent collisions between objects in space, both operating in and transiting through shared orbital domains. The reliance on the vastness of space as a mitigation for collision risk is no longer viable given the current demand.

Researchers look to models in other domains, including air traffic management to provide a path forward. Certainly there are clear similarities in the emergence of air traffic management in aviation and the concerns of space traffic today. The early years of air transport did not require traffic management as the demand for airspace was low and the barriers to entry were high. However the declining cost of air travel, coupled with increasing competition between airlines, created a safety concern and the need for external controls; air traffic management. One can draw clear parallels between air traffic and space traffic in this regard. However, air traffic management is predicated on the legal authority of a state to exercise control over a sovereign volume of airspace. The space environment includes no such authority.

This question of sovereignty can be seen as an insurmountable barrier to the development of a functional space traffic management regime. However, by approaching the policy question of space traffic management as a decentralized safety service rather than a regulatory function, the question of sovereignty becomes less of a barrier.

2. Definitions

Discussions of Space Traffic Management are complicated when it is considered without a common agreement on what is meant by the term. For the purpose of this paper, terminology presented to the International Association for the Advancement of Space Safety is used [1]. The functional elements of space traffic management are defined as follows:

Space Situational Awareness (SSA) - the detection, collection and dissemination of information on the location and trajectory of natural and manmade objects in orbit around the Earth.

Conjunction Assessment and Alerting (CAA) – the evaluation of natural and manmade objects in Earth's orbit to identify potential collisions and notification of operators to determine if avoidance maneuvers are necessary.

Space Traffic Management (STM) – the control of the orbital environment by an appropriate authority responsible for the prevention of collisions between operational satellites and natural or manmade objects.

To facilitate a comparison of STM to ATM, it is useful to compare these terms to similar concepts in aviation.

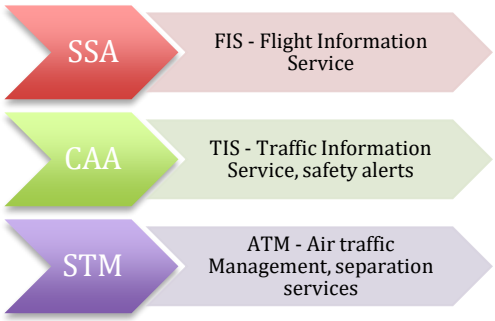

Figure 1: Comparison of terms between STM and ATM

Air traffic control systems provide different levels of service based on the airspace designation. At its most basic level, air traffic service is the provision of information to aircraft through a flight information service that includes information on meteorological conditions, aerodromes, and possible hazards to flight. It does not necessarily include separation services. A traffic information service provides information about active air traffic and can include safety alerts regarding a collision risk, but the decision on the avoidance maneuver lies with the operator of the aircraft. Air Traffic Management is the comprehensive application of air traffic control to prevent conflicts between aircraft to eliminate a collision risk through the positive control of aircraft by the air traffic service provider.

The primary distinction between air traffic services that are advisory (FIS and TIS) and where separation services are provided (ATM) is the authority and responsibility for the avoidance decision. At the level before separation services are provided, the decision to execute an avoidance maneuver lies with the operator (pilot). Where separation services are provided, the decision lies with the air traffic control service provider (ATC). Additionally, there is a distinction between separation and collision avoidance. Separation is the application of a specific separation standard to eliminate a collision risk. This depends on a regulatory requirement for the operator to comply with the instructions from the service provider.

While all levels are safety services, the transition from an advisory service where the decision to maneuver rests with the operator, to a separation service where the decision rests with the service provider, triggers the need for a common regulatory authority.

3. Barriers

If STM is defined as a service at the level of ATM where separation services are provided, there are considerable barriers to the implementation of a single space traffic management regime. One of the primary barriers is the question of sovereignty. In other models for managing traffic, particularly air traffic management, the model is predicated on a regulatory authority exercising positive control over a specified volume of airspace. The underlying premise is that an entity has the sovereign right to exercise or delegate that authority. This does not exist in the space regime and the outer space treaty clearly states that no claim of sovereignty can be made.

This is not to say that there is no regulatory authority in space, as each state of launch is responsible to exercise oversight and continuing supervision over the activities of non-governmental entities. The authorization to launch carries with it the obligation for the authorizing state to continually supervise the activities. This implies regulatory authority.

The transition from space situational awareness to space traffic management conjures images of a command and control structure similar to that of air traffic control, where an external entity exercises control over all operators within a given volume of space. It is important to recognize that the majority of collision risks in space involve a non-maneuverable object or debris. This makes STM modeled after ATM impossible. However, we can look to ATM as it developed systems to mitigate risks from non-maneuverable objects including obstacles, terrain, and weather.

3.1. Political

The political barriers to the implementation of a global space safety system to provide STM are not unique to space. The underlying intergovernmental questions of who benefits and who pays drive the political discussion. A free service provided by a single state, or even a coordinated effort of several states is not sustainable as changes in priorities within the providing state could compromise the availability of critical safety information for internal and external users. Political disturbances

in the providing state could have global consequences for STM.

Funding is ultimately a political question. A state funded service is only viable to the extent that it remains a sufficient priority over other state functions. Investment in new technologies and maintaining a state of the art system is a competition for resources against unrelated industries and priorities. This is outside the control of the space industry and the industry should consider a state funded "free" service as undesirable.

Conversely, an industry-funded service should not be used as a revenue stream to support other state priorities. For state-provided/industry-funded services it is important to develop structures that ensure revenue is dedicated to providing the services. This is also an area where STM can look to ATM for governance models.

3.2. Policy

With regard to policy, the absence of a common definition for Space Traffic Management is a fundamental barrier to developing a global policy. It is important to identify what is meant by STM. Is it the collection and distribution of space situational awareness data or does the process of STM begin with the conjunction analysis and alerting? Does STM require that an appropriate authority direct the actions of the space actors in an encounter, and if so, does it assume the liability for those actions? A common understanding of what constitutes STM is needed to shape a policy that can be implemented across space faring states.

3.3. Regulatory Authority

The absence of sovereignty in space precludes the establishment of a regulatory authority based on models established for ATM [2]. However, like aviation operations in uncontrolled airspace, operations may be uncontrolled, but are not unregulated. While aviation operations in uncontrolled airspace are subject to a "see and avoid" standard for collision avoidance, operations are subject to rules of the air and regulatory standards for determining right of way. The rules of the air apply to operations whether or not they are subject to intervention by air traffic control. Similarly, each state exercises regulatory authority over their space operators. While there is a specific obligation placed on the state of launch, some authorities have opted to exercise control over space operations conducting by citizens even when launched from another state. The US uses this model in both space and aviation. For aviation operators, US regulations apply outside US airspace to persons with a US aviation certificate and to aircraft under US registry, regardless of the location of the operation. The question of airspace sovereignty does not restrict the ability of the US authority to exercise oversight of the operations. It is important to recognize the distinction between the regulation of on orbit activities and the obligation for states to provide authorization and continuing supervision of ongoing activities in space under article VI of the Outer Space Treaty.

Prevention of collisions in space is a continuing obligation of states under articles VII and VIII of the treaty. As this obligation applies to each state as a party to the agreement, it is necessary to create a model for STM that reflects that distributed obligation. A decentralized approach to space traffic management requires a view of regulatory authority that moves away from an air traffic management model, that controls operations within a volume of airspace, to one that considers the enforcement of a common set of rules of operation, including right of way, similar to the concept applied in uncontrolled airspace.

3.3.1. *Rules of the Air*

If we consider the evolution of collision avoidance in aviation and the manner in which obstacles, terrain, weather, and other hazards to flight are mitigated, a rule based approach to STM augmented by SSA becomes possible.

Figure 2: Evolution of ATM Collision Avoidance

In comparing STM to ATM, the presumption is that there is a need to jump to an end state that models current air traffic management. This approach overlooks the value of the transformative stage in ATM where rules of the air were developed to govern actions of

individual operators in order to prevent collisions, augmented by the use of advisory services to support the operator's decision making. Requirements like operating right of the centerline of an airway, hemispheric altitudes for direction of flight, and requirements to maintain specified distances from clouds were all developed for the purpose of collision avoidance. The operators were obligated to comply with the rules, however the individual responsibility for collision avoidance remained with the operator.

Rules of the Air were established, on an international basis, through the Convention on International Civil Aviation [3]. This rule-based approach relies on contracting states to ensure compliance but does not interfere with their sovereignty. This led to the development of air traffic separation services as traffic congestion warrants and eventually the systems of air traffic management currently in place. While services are provided at different levels and utilize different funding mechanisms based on the determination of the providing state, the rules, standards, and recommended practices are consistently applied around the globe. Agreeing to a common set of rules for the purpose of collision avoidance in space, where the state of launch has the obligation to ensure compliance, could provide a path to decentralized space traffic management by creating a common regulatory framework without impinging on the sovereignty of the state.

4. Concepts for "Near Space" traffic management

The evolution of ATM in the high-altitude/near space domain is considering many of the same issues as STM. In many ways, this domain has more similarity to space operations than other aviation domains. Most operators in the region above 20KM (60,000 feet) are unmanned and may be long duration operations. While the totality of the airspace is low density, growth in the market is increasing demand. The airspace has a mix of high performance and low-maneuverability aircraft. In most of the world, the airspace above 20KM is either uncontrolled or undesignated. Developments in this area include concepts of cooperatively managed airspace. These ideas, while still in the development stage, may create opportunities for the space community to consider different models under development and leverage any safety cases that are developed.

Concepts for near space traffic management include a shared situational awareness picture, where all operators have knowledge of the traffic and hazards in the airspace and are subject to rules of the air, including right of way. This approach requires participation from all operators in the airspace. The participation requirement is tied to the ability to access the airspace. While the operator is responsible for determining the avoidance maneuver, the decision is supported by common information with known fidelity.

5. Policy Model for Decentralized STM

In building a decentralized model for STM, consideration should be given to developing advisory services that leave the decision making process for collision avoidance maneuvers with the operator. This allows for multiple providers of advisory services and moves beyond the sovereignty question as no state as exclusive authority over the domain. However, in order to go beyond the current system where a conjunction message is issued, the operator evaluates the level of risk, takes into account maneuvers, and decides whether to perform an avoidance action and the operational constraints [4], an agreed upon set of rules that prescribes action to be taken, including right of way, and a requirement for operators to share information on the maneuver is needed.

This creates a structure that allows for the collection and distribution of situational awareness data and a requirement that operators react to conjunction risks in a predicable manner. Governments, industry, academia and other entities with the capacity to collect space surveillance information are expected to continue to provide that data. Between the space situational awareness and the avoidance maneuver is the conjunction assessment and alerting. This is the opportunity for a decentralized service. The analytics used to determine whether a conjunction between a maneuverable and non-maneuverable object, or between two maneuverable objects will occur, need to be sufficiently reliable to form the basis for a required action under an agreed upon set of rules. In addition, maneuvers must be reported back into the shared situational awareness picture to ensure accuracy.

By decoupling SSA from CAA, there is a greater opportunity for competition in the field of STM. There is intrinsic value in encouraging conjunction assessment and alerting as a commercial service. It fundamentally transforms the satellite industry from user to customer of STM services. This has policy benefits in the ability to direct resources and incentivizes CAA providers to continually improve accuracy and quality of the alerts. There is often resistance to this concept due to the perception of additional costs because conjunction alerting is currently provided as a "free" service from government entities. However, the cost to the industry of processing hundreds of thousands of alerts that do not require an avoidance maneuver is substantial. As a user, rather than customer of the service, the industry lacks the ability to demand investment in improving alerts. The costs are born by the industry whether it is through processing false alerts or investing in more accurate predictive capability.

Steps needed to build a decentralized STM

1. International agreement on standards of behavior for the purpose of collision avoidance.
2. Processes and agreements for the collection and sharing of space situational awareness information, including space surveillance and operator information.
3. Expansion of market for conjunction assessment and alerting services.

The collection and distribution of space situational awareness information will always be subject to limitations from states that choose not to share information on national security assets. While the SSA does not require information on the purpose of a given space object, some states will seek to also conceal the position information. While space surveillance systems may render this effort moot, aviation provides a policy model to address this concern. The issue of state aircraft and national security was a similar concern in the development of the international treaty on civil aviation. The concept of "due regard" was established in the convention to allow state aircraft to operate outside the rules of the air provided they operated with "due regard" for the safety of other aircraft. This placed the full burden for the avoidance of collision on the state aircraft in exchange for the ability for those aircraft to operate outside the common rules, including the ability to be undetectable by other operators and service providers.

6. Summary and Conclusion

Decentralized STM requires the development of a set of enforceable standards of behavior and the decoupling of space situational awareness (SSA) and conjunction assessment and alerting (CAA) and allows the operator to determine avoidance maneuvers. This approach designs STM as a safety advisory service eliminating the sovereignty barrier that occurs with the development of a regulatory model that mirrors air traffic control or ATM. The regulatory authority to enforce a common set of rules of behavior for the purpose of avoiding a collision in space remains with the state of launch.

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