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Digital Sky

Concept of Operations

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Definition of Terms

ADC	Air Defence Clearance
AGL	Above Ground Level
ATC	Air Traffic Control
AUT	Airspace Use Token
BVLoS	Beyond Visual Line of Sight
CA	Certifying Authorities
C-UAS	Counter UAS
DGCA	Directorate General of Civil Aviation
DHE	Ephemeral Diffie-Hellman
DSC	Digital Signature Certificate
DSSP	Digital Sky Service Provider
ECDHE	Elliptic Curve Diffie-Hellman
EVLoS	Enhanced Visual Line of Sight
FCMP	Flight Controller Module Provider
FIC	Flight Information Clearance
GNSS	Global Navigation Satellite Systems (GPS, GLONASS, Galileo, IRNSS/ GAGAN etc)
GoI	Government of India
HSM	Hardware Security Module
IAF	Indian Air Force
IST	Indian Standard Time
MoCA	Ministry of Civil Aviation
PII	Personally Identifiable Information

PKI	Public Key Infrastructure
RFCM	Registered Flight Controller Module
RFM	Registered Flight Module
RPA	Remotely Piloted Aircraft
RPAS	Remotely Piloted Aircraft System(s)
SSP	Supplementary Service Provider
UA	Unmanned Aircraft
UAS	Unmanned Aircraft System(s)
UASPC	UAS Promotion Council
UFII	Unified Flight Information Interface
UIN	Unique Identification Number
UTM	Unmanned Air Traffic Management
UTMA	Unmanned Air Traffic Management Agency/ Authority
UTMSP	Unmanned Traffic Management Service Provider
UUID	Universally Unique Identifier
VLoS	Visual Line of Sight

Introduction

1. Civil aviation has, traditionally, been based on the notion of a pilot operating the aircraft from within the aircraft itself and commonly with passengers on board. Rapid technological innovations have enabled pilotless aircraft which can be designed for specific applications that require precision or long duration which have been considered near impossible hitherto. These aircraft also enable applications considered dull, dirty or dangerous, in other words, tasks that entail monotony or hazard for the pilot of a manned aircraft. Such pilotless aircraft make use of ground based or pre-programmed automatic controllers to manoeuvre the aircraft in flight and are generically termed as drones.

2. Drones had been limited to military use due to high costs and technical sophistication. Their limited numbers and highly controlled use also implied that they could be allowed to operate alongside conventional manned aircraft without significant changes to the methods for management of airspace.

3. Rapid innovations in drone technology over the past about a decade; especially in areas of miniaturisation of electronic components, control systems, navigation systems and energy storage; have provided consumers with suitably small-sized cutting-edge products that are easy to operate and maintain at affordable prices. Today, consumers can purchase drones for less than a thousand rupees. Even sophisticated drones with advanced cameras and sensors are available for under fifty thousand rupees. This has challenged conventional systems for control of the production and operations of these pilotless aircraft; and enabled mass-scale production of these very small and compact flying machines which can support specific functions at a fraction of the cost of conventional methods for doing the same job.

4. Already drones help farmers prioritize where to apply fertilizer, or help energy companies monitor their infrastructure, or even enable emergency response teams to quickly map the extent of damage after natural disasters. Drones also deliver packages, streamline resource management, enable detailed surveys for infrastructure planning, and even are reinventing human mobility through small flying taxis. On the other end of the spectrum, large aircraft manufacturers such as Boeing and Airbus, are spending billions of dollars developing pilotless aircraft considered safe enough for long-range intercontinental flights by passengers.

5. However, this new paradigm has also brought in a host of challenges for not only existing users of airspace but also for uninvolved life and assets on ground. Drones in the air need

to ensure adequate separation from not only each other but also terrain and obstructions while ensuring that they do not adversely impact conventional air traffic.

6. Drones also differ from conventional traffic on the ground (road vehicles) in that there is no scope of continuing to hold the drone in the air as in the case of a 'traffic jam' with engine switched off or parking the vehicle by the side of the road and thereafter recommencing at will. Drone flights need to be planned and the traffic managed from the word go so as to avoid scary scenarios of drones falling out of the sky onto uninvolved and unsuspecting life and property on the ground because of drones running out of their available onboard energy.

7. It becomes incumbent not only upon drone designers and manufacturers but also all drone users to be cognizant of these basic limitations of drones and therefore be ready to accept a few limitations in the operation of these technological marvels so as to enable greater public confidence and acceptance in the use of drones. Such acceptance will also provide enhanced efficiency in the use of the finite resource of airspace and enable multifarious drone applications to be implemented thus strengthening the overall drone economy.

8. Given that the spectrum of pilotless aircraft ranges from a small toy weighing a few tens of grams to airplanes weighing several hundreds of thousands of tonnes, it becomes near impossible to be meaningfully able to regulate all of them with the same rules or standards. In order to overcome this formidable challenge, the International Civil Aviation Organisation has unambiguously categorised pilotless aircraft and associated systems into two broad categories[1] as follows: -

    a. Unmanned Aircraft (UA) – an unmanned aircraft which is not permitted to operate alongside manned aircraft by airspace restrictions.

    b. Remotely Piloted Aircraft (RPA) - an unmanned aircraft, actively piloted from a remote pilot station, which is allowed to use the same airspace as manned aircraft subject to meeting the same safety standards as manned aircraft. In other words, RPAs act like and are treated like manned aircraft.

9. It, therefore, follows that UAs are permitted to operate only in 'segregated' airspace or airspace that is not permitted for use by manned aircraft except in case of emergencies.

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[1] https://www.icao.int/safety/UA/UASToolkit/Pages/FAQ.aspx#Q1

This airspace is the very low level airspace below 500 ft (150m) AGL since 'Rules of the Air' prohibit flight by manned aircraft below this level without special permission except for the purposes of take off and landing. Globally, the accepted convention is to add a hundred feet of safety buffer and accordingly, UAs are required to fly below 400 ft AGL (120m).

10. It is fairly obvious that the challenges in managing both these kinds of unmanned aircraft (or drones) can be expected to be very different. The challenges of integrating RPAs alongside manned aircraft imply that they need the same levels of operational response to air traffic control instructions as manned aircraft which in turns implies significant cost, comparable to the cost of manned aircraft, thus limiting the numbers of such pilotless aircraft. However, the small and extremely low cost of UAs implies immense and rapid proliferation thus obviating suitable air traffic control through conventional means. Thus, traffic management for UAs requires a radically new and highly automated approach for UAs which, by definition, are segregated from conventional manned aircraft through airspace restrictions.

11. This approach does not discount the need for those airspace users which may straddle both the types of airspace e.g. small drones needing to fly higher for survey purposes. However, since the challenges for such uses are more complex, it is preferable to optimise the existing needs and find easier implemented solutions for the larger number of users. The edge cases are best taken on once the bulk of the new category of airspace users (UAs operating in non-segregated airspace) stabilise in their operations.

12. Digital Sky puts in place a seamless and secure technology to integrate UAs into the low level segregated Indian airspace. It enables a proactive approach for enforcement of safety and security guidelines by ensuring that no UA takes-off without ensuring an adequate amount of safety for other users of the airspace.

13. We envision a future, when millions of UAS are flying across the country, without significantly impacting public safety and security or increasing the regulatory burden. Thus, Digital Sky can be extended in the future to function as an automated UAS traffic control enabling autonomous flights, air taxis, inter-city cargo drones etc besides use-cases discussed above. It is thus envisaged as the single air traffic management system for various users of very Low Level airspace.

Mission

14. The mission of Digital Sky is to create a completely digital, automated and real-time process of on-demand seamless air traffic management for UAS while ensuring the highest degree of public safety, national security and operational efficiency.

Vision

15. The vision is to create a digitally enabled state-of-the-art air traffic management system which will support safe, efficient, and secure access to Indian airspace for millions of UAS while also ensuring the rights of the conventional airspace users. The system will be based on principles of autonomy, scalability, efficiency and provide equity of opportunity to airspace users. This system is christened Digital Sky.

Digital Sky

16. Digital Sky is the digital public infrastructure that enables seamless unmanned traffic coordination between all categories of UAS and can also provide information to ATM service providers on a need basis. It manifests through the Digital Sky Service Provider (DSSP) portals that would be operated by any entity authorised for the purpose by the GoI.

17. Digital Sky is thus not a single system but rather a system of interdependent services some of which are essential or core services whilst others are supplemental services. All UAS users would need to enrol themselves with the core services but would have the option of using the supplemental services. All these services are collectively termed Digital Sky Services.

Digital Sky Services

18. There would be several elements or kinds of services that would be required to provide comprehensive UTM. These may include core services focussing more at the active traffic control and supplemental services providing the necessary support for making the complete UTM safe and efficient. These services are described in the trailing paragraphs.

Registration Service

19. This is the initial step for registration of all users of the UTM services viz UASs, pilots, owners, manufacturers, law enforcement agencies, DSSPs etc. Registration Service is thus a core service.

20. Registration of individual UAS in the system is key to effective UTM. Since most UAS have large number of small replaceable components, it may not be feasible to identify the UAS from its physical components like the registration plate in conventional aircraft or vehicles. It is proposed to identify the UAS by an electronic identification on its flight controller module like the IMEI chip in mobile phones. The entities enabling the linking of the Flight Controller modules with the physical drone would also need to ensure that the modules cannot be tampered with. These Flight Controller Module registration services are described in more detail later.

Terrain Database Service

21. This is the service for maintaining an updated localised terrain database which can then be used for flight planning as also providing terrain deconfliction. This service would also

capture the airspace availability including the green zones, yellow zones or red zones - temporary or permanent. Alternatively, this service would also be used for applying airspace restrictions as needed. However, only the airspace availability feature of this service would be the core element with the terrain services being optional.

Flight Planning Service

22. This is a core service for users to plan their flights. This service would generate the appropriate 4D airspace requirements for any flight that is planned to enable strategic and dynamic traffic deconfliction.

23. Although most UAS today have integral flight planning features, this service would define the standards for the identification of 4D airspace. Therefore, even if the UAS pilot initially uses the integral planning software, the final submission of any flight plan for authorisation would need to be through this service in order to ensure adequate levels of flight safety. However, in case the UAS' integral flight planning software can demonstrate compliance with the 4D coordinates generated through this service, this service could be considered optional for such UAS.

Flight Authorization Service

24. This is the core service which would enable authorization of the planned flights and then provide the Airspace Use Tokens (AUTs- described in greater detail later in the document) based on confirmation of the user components from the registry service, planning from the Terrain service and payment of requisite charges. This would also act as the strategic traffic deconfliction service by ensuring that the proposed flight plans are approved based on 4D traffic separation with the specified margins.

25. Since traffic deconfliction is at the heart of the Digital Sky UTM, entities providing this service are also referred to as UTMSPs. However, it needs to be clearly understood that any UTMSP is not sufficient in itself to provide comprehensive UTM - it is at best the first among equals as far as DSSPs are concerned.

Identification/ Surveillance Service

26. This supplemental service would track all UAS airborne in the designated geographical area at any given time for activating any immediate airspace restrictions or temporary red zones for dynamic airspace management. This would also be responsible for providing information to the UAS, pilots and operators in case of any sudden requirements for suspending operations or any other significant operational information e.g. change in weather status/ law enforcement requirements/ traffic emergencies etc.

27. These restrictions would be implemented through the UAS ground stations. Thus it would need to have reliable communication with the UAS ground stations in order to achieve its objectives. In the future, its scope could be expanded to assess any potential traffic or terrain conflicts and provide tactical deconfliction directions to the UAS and pilots, thus forming a safety layer for dynamic traffic deconfliction in addition to onboard dynamic deconfliction features such as 'detect and avoid'.

Meteorological Service

28. This service would track and forecast local weather around the clock to provide inputs to pilots and operators at the planning stage. As Digital Sky matures, data from this service could also become central to the Authorisation service for approval of flight plans. Further, this would also provide inputs to the surveillance service for onward information to operators and pilots in case of any change in weather status.

Risk Analysis Service

29. This supplemental service would be used at the planning stage to quantify and assess risks associated with each flight. Based on data, certain common flight patterns could subsequently be classified as 'low risk' and not require a detailed analysis. Data from this service could also be used for the airspace planning including route planning and earmarking of green or yellow zones.

30. As Digital Sky matures, this service could also be mandatory for higher risk UAS such as air taxis.

Compliance Service

31. This service would be focused at assessing whether the operations have adhered to plan and analyse data to assess variations with a view to streamline future operations and authorisations. This service would also provide information for accident/ incident analysis, enforcement actions, renewal of registrations etc

Public Information Service

32. This service is for providing information to the general public in response to specific queries as an initial step for dispute resolution.

Stakeholders

33. In order to align with the mission and vision of Digital Sky, it is imperative to identify the key stakeholders.

Central Government

34. MoCA is the central ministry responsible for the overall growth and regulation of civil aviation in India. It thus is the primary agency for stipulating policies and laying down rules for civil aviation including UAS and UTM in India.

35. However, considering the use of very low-level airspace for UAS operations and associated challenges, the MHA and MoD also become important government stakeholders in defining restrictions on the use of airspace.

36. Finally, MeitY being the nodal central ministry in defining technical standards and promoting technological solutions, has an inherent stake in specifying technical standards for not only UTM but indeed even the UAS.

DGCA

37. As India's primary aviation regulator, DGCA has a key role to play, especially at the policy level, for the Digital Sky. The DGCA will be actively guided and monitored by the MoCA in its approach.

38. DGCA is also responsible for stipulating the rules of the air for low level unmanned air traffic as also the certification standards of UAS in India. These standards will be the primary means of ensuring that UTM services can have effective communication between the various stakeholders through a common information exchange protocol called the Unified Flight Information Interface (UFII - described in greater detail later in the document).

UTMA

39. UTMA is proposed to be a government designated agency for designing and implementing UTM procedures in the airspace segregated exclusively for UAS operations.

40. It will effectively be responsible for the selection and monitoring of DSSPs and allocating them areas of responsibility, both geographic and functional, through a method of licensing or similar onboarding mechanism.

41. The UTMA would work in close coordination with the Airports Authority of India, the Indian Air Force, Indian Navy and any other Air Navigation Service Providers designated for management of national airspace by the Central Government for coordination between manned air traffic needing to use UAS airspace in emergent conditions and vice versa. It would also be aided by the inputs from the industry through the UAS Promotion Council (UASPC) which would inform the UTMA of relevant and updated technologies for UTM functions as also help establish market rules for selection of DSSPs.

42. The UTMA has not been envisaged in the National UTM Policy Framework. However, UTM and UAS have a significantly different approach in the use of airspace as compared to conventional manned aviation e.g. the airspace use is expected to be much denser and technology dependent for active control/ regulation as compared to conventional systems. Thus, UTMA, in conjunction with UASPC, is considered essential to enable adequate assimilation of the new-age and rapidly evolving UTM, UAS and related technologies into the legacy aviation environment while ensuring that conventional airspace use is not adversely impacted.

43. UFII will be the information exchange protocol that enables seamless information exchange between various stakeholders with varying levels of access as finalized by the UTMA.

IAF

44. The Air Defence Authority of the Indian Air Force is responsible for monitoring all manned and unmanned aircraft operations in the national airspace.

45. The IAF and other air defence entities shall, through the Digital Sky platform, provide Air Defence Clearance for unmanned aircraft operations where stipulated by the UTMA.

46. They shall also be able to rapidly distinguish between legitimate and illegitimate UAS as needed to initiate C-UAS actions. IAF will be responsible for the stipulation of C-UAS standards and infrastructure for implementation of UAS red-zones.

47. These C-UAS systems will need to be interfaced with the UTM ecosystem for identifying whether the UAS is flying in an authorised manner or not and for subsequent enforcement action as required.

AAI

48. AAI is the primary Air Navigation Service Provider in India and is responsible for air traffic management across all of Indian airspace except airspace designated for military use. Any segregation of airspace for exclusive UAS use would require close coordination with AAI. More importantly, UAS transiting from segregated airspace into non-segregated airspace or manned aircraft movement transiting through UAS airspace would require active coordination between the concerned ATC and the UTMSPs.

Law Enforcement, Disaster Management and Emergency Medical Services

49. Use of UAS for law enforcement or emergency medical services or disaster management places additional system demands for UTM as such UAS operations are expected to take precedence over routine operations.

50. In order to ensure that demands for priority use of airspace are generated only by validated entities and when other constraints (e.g. UAS capabilities or UAS pilot training) have already been catered for before such requests for precedence can be initiated, such stakeholders will need to be specially identified and authorised in the UTM ecosystem.

Digital Sky Service Providers (DSSPs)

51. Effective implementation of Digital Sky services would hinge upon entities authorised by the UTMA to provide such services at the pan India level or within designated geographical zones (a concept akin to telecom service providers). Such authorised entities are collectively called DSSPs. As already highlighted, DSSPs undertaking traffic deconfliction are also referred to as UTMSPs.

52. While the final decisions for defining critical processes such as UAS/ manufacturer/ operator onboarding or Flight Plan approval, etc. would rest with the UTMA, UTMSPs would act as the active Air Traffic Control in their delegated airspace.

53. Alongwith the core UTMSPs, DSSPs would provide a valuable intermediate layer between airspace users and UTMA by: -

    a. enabling digital platforms for onboarding of UAS/ manufacturer/ operator/ pilots; and

    b. informed flight planning by providing terrain, airspace availability & weather data; and

c. providing real-time information about constraints, directives, notifications; and

d. safer operations through risk assessment tools.

54. Supplemental DSSPs would also provide the means for -

a. safety assessment in case of unintended violations; and

b. facilitate investigation by providing data and operational information in cases requiring such investigation; and

c. enforcement actions in case of violations by helping map and locate the errant users of the UTM system; and

d. establishing channels for public feedback or incident reporting.

55. DSSPs may provide any or all of the services listed above as authorised by the UTMA. Thus, DSSPs would combine the functions of UTMSPs and SSPs as envisaged in the National UTM Policy Framework.

UAS and Equipment Manufacturers

56. All UAS operating in India's UTM airspace would need to have onboard systems that will enable effective implementation of UTM procedures as decided by the UTMA. UAS manufacturers will therefore need to ensure that the UAS and related equipment whether flight control modules or communication equipment are manufactured in accordance with the certification standards stipulated by DGCA.

Flight Controller Module Providers

57. In order to ensure the authenticity of drones being used legally in the ecosystem, the firmware of every flight controller is required to be verified and tamperproof. The accepted method is to encrypt the firmware using public key infrastructure. The providers or certificate authorities of the key pairs are termed as the Flight Controller Module Providers (FCMP) in the Digital Sky ecosystem.

58. The FCMP should be a legal entity registered in India and is responsible for certification, key management (as per this specification), and any security or other responsibilities set forth by UTMA or any other regulator appointed for the purpose by the GoI.

NOTE: In this document, the term “FCMP” is used to refer to a UAS manufacturer or any agency who has partnership with the manufacturer to manage certification and related software/security aspects of registered flight controller modules:

a. One provider may serve many UAS models

b. One provider may have many versions of the Registered Flight Controller Module (RFCM) service

c. One RFCM service may handle many models

UAS Operators

59. UAS operators are entities that exercise control over the UAS by virtue of their ownership. Thus UAS operators are owners or lessors of the UAS but may or may not be the UAS pilots. They could also be legal entities other than individuals such as companies or corporations etc

60. All UAS operators would need to register themselves and their UAS on the Digital Sky portal in order to be able to obtain the AUT as per laid down procedures. They would also need to ensure that not only are their operations compliant with regulations but also do not pose any hazard to any uninvolved persons or property.

61. At the same time, the operators would need to apprise the UTMA in case of any shortcomings in the services of DSSPs or any system failures and therefore would also need direct communication channels with the UTMA.

UAS Pilots

62. UAS pilots are people exercising functional control of the UAS for the duration of its flight. Thus they could be owners of the UAS or could be employees of the UAs operators. They could be actively controlling the UAS or merely be responsible for the programming of autonomous UAS flights.

63. UAS pilots will effectively be the most operationally active human element of the entire UTM ecosystem. They would need to ensure that the operations undertaken are not only safe and efficient, but would need to provide requisite feedback to overcome any systemic deficiencies.

General Public

64. The general public may use DSSPs to report issues in case they may suspect that a particular unmanned aircraft may not be flying as per the regulations or may be breaching their privacy, as per guidelines stipulated by the UTMA.

Infrastructure Prerequisites

65. Several key infrastructure elements that would constitute an efficient, viable and robust UTM system can be identified.

Navigation Infrastructure

66. Navigation infrastructure is essential for UAS to move between desired points and along desired paths. Most current UAS systems utilize GNSS for navigation information. GNSS infrastructure is being widely used for multiple applications and therefore no special/ additional infrastructure is envisaged for UTM systems. However, the standards of service viz signal monitoring for integrity and reliability would need to be undertaken by the DSSPs. Further, navigation information may be supplemented by cellular mobile networks etc.

Communication Infrastructure

67. Various airspace users, especially users within the UTM network, are required to securely and reliably communicate with each other in order to achieve the requisite degree of position awareness and safety of operations. The technologies used would need to suit low level airspace as UTM will be focussed in this airspace. The communication infrastructure requirements would be dependent on the expected UAS traffic density and spectrum sharing with other applications. Thus, adequate communication infrastructure would need to be carefully planned for UTM systems. The technologies employed would also need to employ minimum appropriate encryption methods so as to ensure integrity of individual UAS as well as the entire UTM system.

68. The availability of existing mobile communication network especially 4G/ 5G networks would be one of the major considerations in this context as they enable readily usable infrastructure with minimal cost. However, reliability of the networks would play a decisive role in regulatory acceptance as unreliable communication networks can upset the entire premise on which airspace sharing is based.

Surveillance Infrastructure

69. Surveillance or independent position confirmation is essential for ensuring safe and reliable UTM. Surveillance infrastructure needs to provide for cooperative and non-cooperative traffic with different technology solutions, surveillance reports and tracking information about airspace users to build a complete situational awareness of traffic.

Typically, radars may not be suited for UAS surveillance considering the small size of UAS and multiple obstructions in the low level airspace.

70. However, other surveillance sources such as Network remote ID, ADS-B, mobile telecom networks, need to be considered as possible means for surveillance. These technologies would also be significantly dependent on the integrity and reliability of the communication networks.

Geo-Spatial Data Infrastructure

71. There is an essential requirement for having updated terrain/ geographic information with the required level of detail so as to ensure adequate separation from terrain/ obstructions. As can be well appreciated, geo-spatial information is continually evolving and so dedicated infrastructure is required for the same including maintaining and disseminating updated databases.

Meteorological Infrastructure

72. Similarly, there is an essential requirement for infrastructure to predict, monitor and provide updated weather information for safe and effective UTM. A significant portion of this infrastructure requirement would be fulfilled by the existing meteorological infrastructure already existing for various applications including conventional aviation/ agricultural purposes/ disaster management etc. However, considering the rather localised nature of UAS operations compared to the above-mentioned applications, additional infrastructure for enhanced local meteorological information would need to be considered.

Very Low Level Airspace Use

Types of Airspace Users

73. UAS users of airspace range from hobby fliers undertaking Visual Line of Sight (VLoS) operations within a few tens of metres to advanced commercial users providing Beyond Visual Line of Sight (BVLoS) logistics and survey applications beyond several tens of kilometres. Somewhere in between these two extremes would be agricultural or similar operations which may be conducted using Extended Visual Line of Sight (EVLoS), wherein the UAS pilot who may not be direct visual contact with the UA is assisted by an observer who maintains visual contact with the UA and provides situational awareness to the pilot.

74. Users may also vary based on the commercial nature of their operations wherein on one end are the purely recreational users and on the other end of the spectrum could be video photographers covering live events for whom the entire value is dependent on being at the right place at the right time. There could also be non-commercial users providing disaster relief or performing law enforcement activities for whom the rights to the airspace become equally critical in time and space.

75. A third factor to define the type of airspace users could be related to the nature and scale of operations. On one end would be recreational users or small-time commercial users having a single UAS akin to the pilot-owner category of manned aviation. On the other end would be large corporations using a huge number of UAs to propel their business especially in the field of logistics.

76. It follows from these categories of airspace users that any UTM system should be able to take cognizance of the nature and scope of operations and be able to cater to multifarious users without providing undue advantages to any category of users. The system has to not only be fair rather than user agnostic but also cater to dynamic demands on the airspace while ensuring public safety and other social needs such as privacy and noise restrictions.

Airspace Requirements

77. Apart from the above mentioned nature of operations, airspace requirements can be essentially divided into two types based on the duration they are likely to occupy an airspace. These are:

a. Area Use. These flights would require reserve polygons of airspace for UAS applications such as agricultural use, survey, mapping, aerial photography etc. The airspace for such applications would need to be spatially segregated from that identified for UAS transit routes.

b. Transit Flights. These are flights transiting from one place to another along a specified route. The routes could be categorised based on characteristics of UAS expected on the route – viz size of UAS, average speed of traffic, safety considerations for uninvolved public etc and other factors such as droneport availability etc.

78. Considering the differing characteristics of the two types of flights, the traffic management criteria such as separation, height band, flight monitoring standards etc would need to be different. Thus the airspace planning would need to take into account these factors with transit flights likely taking precedence in urban or high population density areas.

Safety Considerations

79. It is important to understand the concepts of VLoS, EVLoS and BVLoS operations with a view to understand how safety of operations and all stakeholders would be attained in each of these categories. There would be some inherent risk with any UAS operations for uninvolved third parties. However, this risk cannot be eliminated but can be mitigated through ensuring safe UAS design features whereby the UAS operations can be considered to have minimal impact on uninvolved third parties.

80. The basic requirement for safe operations therefore is that the UAS maintains adequate separation from other UAS(traffic) and obstacles in its vicinity (terrain). Although many UAS provide features wherein the UAS can be controlled remotely through position displays, such systems may not fully account for presence of terrain or traffic in the vicinity of the UAS.

81. VLoS operations are operations wherein the primary responsibility of ensuring that the UAS remains at a safe distance from terrain and traffic is that of the UAS pilot. This concept is imbibed in the very term Visual Line of Sight which means that the UAS pilot always has the UAS in its sight and can therefore manoeuvre it maintain adequate separation. Some underlying factors defining the distance till where such operations can be conducted would include the cross-sectional profile of the drone for visual acuity, atmospheric clarity for easy visual tracking of the drone and presence of obstructions.

82. BVLoS or Beyond Visual Line of Sight operations on the other hand are operations wherein the UAS is expected to be operated at long distance where it cannot be visually tracked. Separation from terrain in such operations can be attained with the help of detailed flight planning based on accurate geo-spatial data. Separation from traffic is obtained strategically by earmarking separate airspaces for various kinds of UAS (e.g. higher height bands for faster or bigger UAS) and then supplemented through approval of flight plans which provide 4D separation from other traffic. A final safety net in such flights would be the onboard detect and avoid systems that could initiate last minute evasive drone manoeuvres if essential.

83. EVLoS or Extended Visual Line of Sight operations are operations wherein the UAS pilot relies on another human observer who is visually tracking the UAS at all times and providing timely inputs to the UAS pilot for suitable separation from terrain or traffic. These operations enable greater ranges as compared to VLoS operations without the need for detailed flight planning or costly onboard systems but can only be undertaken in low UAS density areas.

84. It follows from these safety considerations that a single standard for safety separation would lead to avoidable inefficiencies in the system. A system with minimal margins and low safety requirements catering largely to VLoS kind of operations would imply larger losses of property especially for BVLoS operations due to resultant accidents. BVLoS operations would also be compromised as small inexpensive UAS could become the main cause for accidents of larger and costlier UAS hiking the cost of operations. On the other hand, very high safety standards and related compliance costs would encourage smaller operators to find ways and means to bypass the regulations (as in the case for NPNT proposal). The prudent approach would be to follow a graduated approach wherein the safety and operational flexibility balance each other such that those operators seeking minimal compliance costs (VLoS Ops) are afforded minimum flexibility through geo-fencing of available airspace. More commercially critical operations needing more flexible use of airspace are required to maintain higher standards and therefore bear higher compliance costs.

Traffic Deconfliction

85. In addition to the segregation of airspace users based on VLoS, EVLoS and BVLoS, there still exists a need for traffic deconfliction amongst the same category of users in the same airspace at the same time. Such deconfliction amongst VLoS and EVLoS users is baked into the system design through attributing the responsibility to the pilot – with or without the use of the external observer. However, in case of BVLoS flights, such

deconfliction would need technical solutions predicated on the concepts of Strategic and Dynamic Deconfliction.

86. **Strategic Deconfliction.** Airspace use deconfliction achieved at the planning stage is termed strategic deconfliction. Such deconfliction is aimed at attaining a state wherein the intended flight paths of various users are free of conflict. The intended flight paths are commonly called 'flight plans' for manned flights and increasingly termed as 'flight intents' for UAS in order to distinguish them from 'flight plans'. In turn this is attained at two stages :–

    a. Airspace design to address factors that influence the need and capacity of the airspace. The considerations include the availability of airspace which may be limited by factors such as terrain or obstructions, proximity of airports or vital security establishments, residential areas needing noise protection etc. This would also be impacted by anticipated user demand e.g. urban areas can be expected to have higher demand as compared to low population density areas. It could also be impacted by availability of drone infrastructure such as drone ports or suitable communication networks etc. Based on all of these factors, strategic deconfliction would be attained through steps such as establishing air routes for specific operations or limiting operations through operator/ drone registrations etc. In other words these are strategic steps for matching airspace demand and supply. Segregation of airspace into manned airspace and vertical limits of geo-cages for VLoS and EVLoS operations could be considered as steps in attaining this deconfliction.

    b. Flight Planning. Even with optimal airspace design, there would still be the need for deconfliction between UAS intending to use the same route at the same time much like flights of different airlines on the same sector intending to optimise on increased passenger demand at certain hours of the day. There would also be conflicts emerging from the criss-crossing of flight paths as drone operations could be expected between any two geographical locations and each operation would desire to use the shortest route. Flight Authorisation would help deconflict such needs by ensuring that there is no 4D conflict of flight intents and only deconflicted flights are authorised to operate. This would also help manage the quantum of UAS traffic at drone ports to make in commensurate with the drone port capacity.

87. **Dynamic Deconfliction.** Real life scope creeps would imply that even a very efficient system of strategic deconfliction would be impacted in execution as UAS may not be able to strictly follow their intended plans due to operational factors such as inadvertent

delays. Such delays could arguably be scoped in the 4D deconfliction of the flight intents at the authorisation stage . However, the execution of the authorised flight intents would also be impacted by real world uncertainties such as weather or even mechanical issues with the UAS impacting their performance. In order to contain the impact of such dynamics on other UAS and maintaining the overall safety of UAS operations, dynamic deconfliction would need to be resorted to. Dynamic deconfliction would be predicated on the Identification and Surveillance service monitoring the progress of UAS flights and taking proactive steps to limit traffic density to acceptable levels. E.g. a specifically out-of-sync UAS could be directed to a different drone port in order to avoid congestion at the originally intended drone port.

88. **Collision Avoidance.** BVLoS flights would need to have another final layer of safety predicated on onboard detect and avoid systems (e.g. using LIDARs) that would enable the UAS to make last minute flight path corrections to avoid heading into other traffic or even birds. However, there would also need to be defined limits on the corrective action that a UAS would take as unmitigated corrections would have a cascading effect on the overall airspace use. These limits could be in terms of the quantum of height/ direction changes as well as the duration for which the change is effected i.e. after how much time the UAS is required to regain its originally approved path.

Digital Sky Design

89. Digital Sky takes into all of the above factors in its design. The proposed Digital Sky design comprises Digital Sky Services that have already been described earlier. In addition it utilises the following major components that are described in detail subsequently: -

    a. UFII or Unified Flight Information Interface which is the common information exchange protocol between all services and users.

    b. AUTs or Airspace Use Tokens are flight authorisations accorded to legitimate flights that have assurance of 4D airspace availability except in the case of exigencies.

    c. Auto-geocaging or the automatic limiting of the extent of 3D airspace for VLoS and EVLoS flights.

UFII

90. The Unified Flight Information Interface is the communication protocol to integrate the services and users in the low-level segregated airspace for seamless information exchange. UFII will also supplement situational awareness by providing unmanned traffic status to ATCs/ manned airspace users on an as required basis. It shall also be the medium of enforcing restrictions on using airspace - temporary or permanent - within its jurisdiction. This interface would coordinate data exchange between the UTMA, various security agencies, the Air Defence Units and all other users of low level airspace. It would also provide information to all other communication networks exchanging aeronautical information such as the Aeronautical Telecommunication Network, the Aeronautical Fixed Telecommunication Network, etc.

91. The UFII will enable private innovators to provide services for unmanned air traffic management. Such innovators are termed as Digital Sky Service Providers (DSSPs). DSSPs would in their regions of operation coordinate with UAS manufacturers, operators and the UASs to ascertain conformance with policy and regulations. The UFII would also define the data exchange formats for communication between itself and DSSPs and in-between DSSPs for various scenarios to ensure interoperability.

Airspace Use Token

92. One of the major benefits of the use of the medium of air for transport is that there are minimal hindrances or obstructions for direct flights between any two places. Yet, in

order to allow this simple concept to manifest itself, there is a need to regulate the flow of air traffic. Equally important is the need to establish that the airspace users are legitimate and that illegitimate users, once identified as illegitimate, are not allowed to remain airborne.

93. Historically, this has been attained by a system of the users filing flight plans for their intended flights well in advance. The flight plans are required to be in accordance with well-defined rules of the air as well as designated routes. The designated air traffic control service then 'approves' the flight plan by providing the applicant with a flight and air defence clearance which are then used to identify the aircraft in flight. Aircraft which are unable to correctly identify themselves face the risk of being shot out of the sky as has happened in several cases. The approval also entails that the aircraft in air is actively monitored and controlled to maintain it at a safe separation from other legitimate flights. This system has evolved over the years and attained a significant level of efficiency for traditional manned flights.

94. However, this approach requires significant resources and can work efficiently only for a limited volume of traffic – it cannot be expected to work for the anticipated dense UAS traffic. In such a dense traffic environment the core requirements of identification of legitimate air traffic and also the regulation of flight path become even more accentuated. These twin requirements are proposed to be met through providing UAS with flight permits based on their intended area and type of operations. These permissions are termed Airspace Use Tokens (AUTs).

95. Every UAS must get armed through an AUT provided by the relevant DSSP, based on policies stipulated by the UTM Authority (UTMA), before it can get airborne. However, considering the variety of users and UAS operations, it is proposed that the token be valid for a single use or a prolonged duration based on the scope of operations. The specifics of the approval would be contained in the token itself.

Airspace Use and Restrictions

96. One suitable method of meeting the varying airspace requirements is through ensuring that only flights that are authorized after thorough vetting and traffic deconfliction are allowed to operate. This can be achieved through implementation of AUTs and geo-caging.

97. Similarly, safety and security concerns may demand that a certain volume of airspace is not permitted to be used for a certain duration or the usage is restricted to certain users

for a specific duration. These requirements would be dynamic and are enshrined in the concept of Red and Yellow Zones covered in the National UTM Policy Framework[2].

98. These concerns can also be met through the concept of arming the UAs through the AUT. The UTMA would deny issuance of AUTs for the restricted or Red Zone airspace as deemed operationally imperative.

99. Another necessity emanates from the need for financing the UTM infrastructure and services. Air Navigation Service Providers charge significant fees based on various factors such as distance covered, mass of the aircraft, level of service provided etc to decide on the route navigation charges payable by aircraft. The charges are required to be paid along with the flight plan. However, these charges generally form a very small fraction of the total cost of operating an aircraft.

100. In the case of UAs using UTM facilities as well, the AUT can become a means of ensuring that applicable fees, if any, has been deposited by the UAS operator. Although there is sufficient debate on whether UA operations need to be government funded, application of fees can have several positive effects including incentivizing UTMSPs for better services and disincentivizing UAS operators from filing infructuous flight plans. In fact, in a non-differentiated system wherein all users have equal rights, prioritizing use of the eventually limited resource viz airspace, would still prove to be a significant challenge. Introducing an associated fee would help bring in differentiation upfront besides helping in cross-subsidizing operational costs for the marginal users.

Auto-GeoCaging

101. This is automatic limiting of the extent of 3D airspace for VLoS and EVLoS flights based on the geographical coordinates at the time of the UAS powerup or bootup. These horizontal and vertical limits are hardcoded into the UAS firmware by the manufacturer but are dynamically imposed based on where the UAS is being started up. Thus, the UAS flight controller would acquire precise GPS coordinates of the location it is started up and then impose the limits dynamically. e.g. in case the auto-geocage limits are 300m horizontal and 100 ft vertical, it would mean that the UAS flight controller would not permit the UAS to go beyond a distance of 300m horizontally or more than 100 ft vertically from wherever it was started up.

102. The benefit of this concept is that very small drones intending to undertake only VLoS operations e.g. hobby flights or videography UAS are not required to be featured for

2 https://www.civilaviation.gov.in/sites/default/files/National-UTM-Policy-Framework-2021_24_Oct_2021.pdf

traffic segregation. It would also mean that they can be largely obviated from being able to interfere with UAS performing BVLoS operations. Further, operators of small UAS desiring minimal compliance costs e.g. drone hobbyists or videographers would not need to have UAS equipped with advanced safety features. Operators undertaking more commercially critical operations would be assured of availability of airspace as required, albeit at a cost. This concept is akin to the concept of toll roads vs public roads with the added feature that only certain vehicles can enter the tolled roads.

Suggested Model for AUT Requirements and Issuance

103. In view of the foregoing, the following model is proposed for AUT requirements and issuance: -

a. UAS airspace is limited to the green zones as envisaged in the National UTM Policy Framework and already notified by the central government. Presently, Green zone is the airspace upto 120 m (400 feet) AGL that has not been designated as a red or yellow zone; and upto 60 m (200 feet) AGL in the area located between 8-12 km from the perimeter of an operational airport.

b. Operators conducting operations only in VLoS using Nano or Micro category UAS need to activate the UAS with a one-time AUT based on providing the UAS registration, pilot and owner credentials. However, limits would be imposed on the operational envelope of the UA by restricting it to operation within a geo-fence setup automatically when the UAS is powered on immediately before commencing flight. The suggested limits for the geofence are 300 m radius and +30 m (100 ft) and- 15 m(50 feet) vertically. This approach would mean no additional cost and no prior flight plan requirements for the recreational fliers or even small time commercial videographers. The responsibility for ensuring separation from all other traffic/ obstructions/ safety of uninvolved persons and their property, in this case would be that of the UAS pilot. The creation of the automatic geofence would be based on the flight controller hardware and would need to be captured in the technical standards of the UAS for its type certification. In fact, such an AUT could be activated at the seller at the point of sale upon payment of the nominal registration fee. In case of direct sale between two consumers, the registration could be attained through a third party with the necessary equipment for activating the UAS i.e. feeding in the AUT into the UAS.

c. Operators conducting operations in VLoS/ EVLoS using Nano, Micro or Small category UAS operating within pre-defined geo-fence limits need to obtain a AUT which will be renewed after a defined time period, say six – eight weeks, subject to no airspace violations in the period so defined. However, UAS must be capable of providing an authenticated flight log to the UTMA for the validity of the existing AUT or at least one month, whichever is greater. The UAS would also set up an automatic geofence when powered on and before commencing flight which would again be a type certification requirement to be included in the UAS hardware. The suggested limits for the geofence are 1000 m radius and +45 m (150 feet) - 30 m vertically. This approach would also mean no additional cost and no prior flight plan requirements for the recreational or restricted use agricultural/ industrial users/ commercial videographers. The responsibility for ensuring separation from all other traffic/ obstructions/ safety of uninvolved persons and their property, in this case would be that of the UAS pilot. The rationale for periodic renewal of these relatively more potent drones is to maintain an updated database of the active UAS and operators for better traffic assessment and airspace planning activities. This information would also help in better compliance monitoring of these types of UAS which have a potential for impacting public safety and security, albeit in a limited manner.

d. All other users would need to obtain a AUT before each flight of the UAS which would be granted based on the following criteria: -

i. Nature of flight – transit or reserving an airspace for duration of flight.

ii. Preference for an airspace/ route and the time of its use; and prevalent demand for the same airspace – flexibility in route or low traffic density routes would attract lower charges.

iii. Category of UAS – higher categories will attract higher charges.

iv. Combination of the total distance planned to be covered based on the point of origin and destination (or the route length in case of a survey) and the flight duration - longer distances/ time will mean more charges.

v. Scale and complexity of operations of the operator – large corporations/ organizations will need to pay higher charges.

104. The AUT will be granted subject to: -

a. Submission of a flight plan by the user;

b. Payment of applicable charges;

c. No record of past violations of any operational regulations.

105. The responsibility for providing separation information from all other traffic/ obstructions/ safety of uninvolved persons and their property, in this case would be that of the UTMSP and the UAS pilot would use this information to ensure that the UA is operated within specified limits.

106. The AUTs would need to be obtained maximum one day and minimum 15 minutes before the intended flight unless the AUT is seeking reservation of airspace in which case there are no limits. However, a longer lead time may mean a higher charge.

System Design Principles

107. The guiding principles that form the design cornerstones of the digital public infrastructure of the Digital Sky implementation are listed hereunder.

Ecosystem Driven Approach

108. An ecosystem approach is necessitated such that the interfaces between the partners (like Digital Sky Service Providers and Application Service Providers) and systems (like Unified Flight Information Interface) are well defined and standardized. Hence, there must exist a technology backbone that would hold together this partner ecosystem. This backbone would be the Digital Public Infrastructure for the UTM Ecosystem and therefore the key proponent of the unique Indian approach to UTM.

Open Platform and Open Standards Based

109. The framework should use open technology and legal standards either already available in the country or evolved specifically for the purpose through consensus. It should be agnostic to applications, programming languages, and platforms. e.g. it should be DEPA complaint.

110. This approach would also enable data harvested through the UTKM application to be scaled for future design and growth of traffic corridors.

Universal Identity

111. The technical framework should leverage universal, authenticable, non-repudiable digital identities to allow interoperability across all users (pilot, FCMP, operator, UAS, etc) in the system. For example, Aadhaar for Individuals, GSTN for Businesses, etc.

Minimalist and Evolutionary Design

112. The design of the framework should be simple and minimalistic. It should not present adoption barriers for the ecosystem. The design of the systems should be evolutionarily - their capabilities should be built incrementally while allowing for rapid adoption. The essential technology components should be available to the end user as part of the DPI at nil or minimal cost e.g. AUT integration.

Ease of Doing Business

113. The framework should be designed by placing the operator in the centre, thus only adopting approaches that are convenient and easy for doing business.

Digital Enforceability

114. The framework should allow operators to set permissions and rights for airspace permission access at a fine-tuned level (for example, the ability to choose a route or a polygon area of airspace at a particular altitude and for a particular date and time) and the same must be enforced digitally through Airspace Use Tokens and generation of verifiable flight telemetry.

Safety by Design

115. In order to attain the desired level of UTM performance, every authorised UAS should be designed, manufactured, remanufactured, or rebuilt with safe design and manufacturing considerations. Improper design and manufacture can result in hazards to personnel if minimum industry standards are not maintained for the mechanical components, controls, navigation or communication equipment installed in any UAS.

Security by Design

116. The software and systems must be designed from the ground up to be secure. There must be end-to-end security of data using cryptographic techniques such as PKI, DSC, tamper detection, and other security measures like continuous monitoring, hunting, and response.

Privacy by Design

117. The following privacy principles must be embedded into the design:

a. Proactive not reactive; Preventive not remedial

b. Privacy as the default setting

c. Visibility and transparency – keep it open

d. Respect for privacy of all the stakeholders – keep it ecosystem-centric

Trust by Design

118. The system design will include the trust-building elements such as security, privacy and safety. Also, the fundamental assumption is that all public stakeholders viz operators, pilots, manufacturers, traders etc will be good actors who intend to follow the UTM rules.

Conclusion

119. The objectives of this ConOps are to present a vision and describe the associated operational and technical requirements for developing and operating within the UTM ecosystem. This ConOps does not prescribe solutions or specific implementation methods, unless for example purposes. Rather, it describes the essential conceptual and operational elements associated with UTM operations that will serve to inform development of solutions across the many actors and interested parties involved in implementing UTM. It is possible, and in fact, expected, that additional capabilities, services, and offerings, although non-essential, may be available within the UTM ecosystem. These should adhere to the principles and conceptual elements described here.

120. The ConOps document presents the following:

a. UTM operational concept, which provides the foundational principles around which UTM is based, a description of a conceptual architecture and associated UTM actors, and the concepts and operational requirements envisioned to provide a comprehensive set of traffic services,

b. Roles and responsibilities of the various actors and entities that interact with UTM,

c.

121. The key inferences of the document are :

a. UA should be regulated to achieve the same level of safety as manned aircraft;

b. UAS must be separated safely from each other and from manned aircraft;

c. UAS regulation must involve all the major groupings, e.g. UA pilots for safety and competence, UAS manufacturers for ATM innovation and flight safety, public interests for safety, security, privacy and environmental protection;

d. For safe UAS management in controlled airspace, consideration must be given to UA commercial value, UA usage goals and the current regulatory framework;

e. UAS airspace categorisation should be reviewed and defined with specific operational criteria (integration of UAS – low airspace limits);

f. UTM design must be predicated on robust DPI and make use of existing communication infrastructure to the best possible extent.

g. UTM design should cater for airspace equity and reasonable monetisation to enable economic sustenance.