Maintenance Ecosystem of Small Unmanned Aircraft System (sUAS) in Military Aviation

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India's commercial drone industry is growing and the drone market is expected to become a multi-billion-dollar industry over the next decade. In this drone era, the smaller drone systems, that is, small Unmanned Aircraft System (sUAS) are also gaining traction in Indian armed forces for use in Intelligence, Surveillance, Reconnaissance (ISR) and as armed sUAS for kamikaze role.

The robust sUAS is technology-dependent and capable of autonomous operation in highly challenging, contested and congested environments. The technology verticals like Artificial Intelligence and Machine Learning may induce wide applications of sUAS to perform tasks that normally require human intelligence like making predictions or taking action.

Considering the future of aviation and its implications on the Indian armed forces, great challenges are being seen in the sUAS operations and maintenance aspects. Even though the operations are heading towards automation with lesser human intervention, maintenance of these systems is likely to remain human-centric for a long period of time. Maintenance ecosystem depends on its skilled tradesmen and the technical infrastructure. As the maintenance philosophy of sUAS is different from the traditional maintenance of conventional aircraft and of bigger UAS, a study is essential in this initial stage itself, to suggest measures for a robust maintenance ecosystem that can adapt to the technological disruptions and strengthen maintenance safety.

Keywords: *small Unmanned Aircraft System (sUAS), UAS, Maintenance Philosophy on sUAS, Indian Industry*

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'*If we're trying to build a world-class News Feed and a world-class messaging product and a world-class search product and a world-class ad system, and invent virtual reality and build drones, I can't write every line of code. I can't write any lines of code*.'

– Mark Zuckerberg

Unmanned Aircraft System (UAS) are usually referred to as Unmanned Aircraft/Aerial Systems (UAS), Unmanned Aerial Vehicles (UAVs), Remotely Piloted Aircraft Systems (RPAS) and drones by manufacturers, experts and in publications. UAS means an unmanned aircraft or airborne platform and the equipment to control it remotely. Drone is an airborne platform without an on board human aircrew. The drone may fly automatically or with pilot input from a distance. UAVs for both commercial and military objectives are frequently spotted flying around the world for operations like C4IR, logistics, traffic surveillance, agricultural survey, surgical strikes on targets respectively.

In India, drones are operated by the Armed forces and in the civil sectors. The armed forces follow the guidelines as per Technology Perspective and Capability Road (TPCR-2018) defined by the Ministry of Defence that broadly covers use of Remotely Piloted Aircraft and Systems/ UAS. In the civilian applications the Ministry of Civil Aviation, vide Drone Rules 2021 classifies drones based on its maximum all-up weight (with payload). Drones fall into one of five categories:- Nano, Micro, Small, Medium and Large Platforms. The nano drones are less than or equal to 250 grams the micro drones are greater than 250 grams and less than or equal to 2 kgs, the small drones are greater than 2 kgs and less than or equal to 25 kgs, the medium drones are greater than 25 kgs and less than or equal to 150 kgs and Large drones are greater than 150 kgs respectively. Drones with maximum all-up-weight of more than 500 kgs fall under the provisions of the Aircraft Rules, 1937.

Recently, Small Unmanned Aircraft Systems (sUAS) due to their operational and tactical advantages are gaining traction across various services in the Indian armed forces. These are the small drones between 2 kgs and 25 kgs (AUW: All-up weight) and are a technological feat in modern military aviation. sUAS procurements were seen in the last two years. In January 2021, the Indian Army signed a contract with ideaForge for Switch UAVs in a deal worth US$ 20 million. It placed a repeat order to procure an undisclosed number of Switch UAVs to augment surveillance along the LAC. According to the company, it has fulfilled

the first order as per contractual obligations. Other deals signed by the Army recently include deals for swarm drones with Indian start-ups, Bengaluru-based New Space Research and Tech and Noida-based firm Raphe. The drones from New Space Research and Tech can hit targets with 5–10 kgs explosives while mR-20 drones of Raphe can carry cargo of up to 20 kgs in high-altitude areas. In the second half of last year, the Army had also placed orders for 'SkyStriker' drones to be manufactured in Bengaluru by a joint venture between Israel's Elbit System and India's Alpha Design Technologies, which is now a part of the Adani Group.[1]

It is a known fact that the operational preparedness of armed forces depends largely on its men and their fighting equipment. As the saying goes that the man behind the machine is crucial in winning the war, however; to aid the warriors towards victory the machines or the equipment should be available and reliable when put for use. The availability for defence equipment to meet India's security objectives are evidenced by the periodical defence procurements through routes like the Arms Imports, procurements through Indian industries in collaboration with foreign industries and through 'Make in India' -indigenisation routes respectively. Presently, 'Make in India' has been given much impetus by the government to boost design, develop and manufacture of defence equipment in India. On the other hand, the reliability and maximum yield of the costly defence equipment is largely dependent on an effective and robust maintenance ecosystem.

With the rise in sUAS, popular publications and research papers show that maintenance of sUAS is becoming challenging compared to maintenance of large UAS. More so, the maintenance challenges of UAS will rise exponentially with the ongoing projects of integration of manned and unmanned aircraft in each country's national air space.

In this evolving aviation dynamics where technology imposes great challenges in the operations and maintenance domains, the aim of this article is to carry out analyses of emerging sUAS in armed forces on the maintenance aspects and to propose measures to enhance the maintenance ecosystem.

UAS as Force Multiplier and a Game-Changer

Conventional aircrafts since the invention by Wright Brothers have been conquering the skies for more than a century. Tremendous progress in aircraft design and aviation operations has been seen over a period of years despite experiencing setbacks due to accidents, incidents,

political and economic factors. Evolutionary and revolutionary aircraft development are in the road-map for 2050[2] in the commercial sector with the number of air passengers expected to nearly double globally to 7.8 billion annually by 2036 respectively. In this monopoly of the manned aircraft industry, it is also interesting to see the UAS market rising exponentially.

History shows that UAS have been touching the sky with glory along with the manned aircraft ever since Elmer Sperry experimented with manned aircrafts in 1913 with the introduction of the auto pilot. The technology of those days restricted the use of UAVs mostly as fire and forget one's and therefore UAVs found more applicable in the defence arena than the commercial sectors. Presently with technological developments, global competition and situational threats, UAVs/ drones along with ground support systems are evolving as an undisputable war machine, thus gaining more importance in the future of warfare. It is seen from a few developed countries that armed drones, Unmanned Combat Aerial Vehicles (UCAVs) and swarm drones are disrupting air superiority and act as force multipliers along with the manned aircraft.

The world is now witnessing technological innovations as well as its disruptions in all domains like agriculture, automotive, aviation and aerospace, business administration, computers, digital technology and communication, data analytics, defence, engineering, drones and unmanned systems and so on. These diverse dynamic changes are seen transforming from erstwhile traditional manual operations to fully automated environments with minimum human intervention. Presently, drivers like Artificial Intelligence, Machine Learning, Big data, Internet of Things (IOT) are spiralling the technology, interlinking all the above domains for a formidable future.

Noticeably, the aerospace industry is one of the most dynamic and ever-changing industries in the world. In this regard, the ambitious infrastructure project by the US that is, The Next Generation Air Transportation System (NextGen) by Federal Aviation Administration (FAA) using new technologies and procedures to increase the safety, efficiency, capacity, flexibility, predictability and resilience may dramatically improve the operation of the National Airspace System (NAS) by managing air traffic through Trajectory Based Operations.[3] NextGen is expected to revolutionise aviation philosophy and management in the future. UAS promise to dramatically change the

face of commercial aviation, enabling whole new markets and potentially spurring economic growth and job creation. According to industry forecasts, UAS operations will increase exponentially once they are fully integrated within the national airspace system.

Next-Generation UAS Management and its Challenges

UAS has been accepted as one of the promising niche entities in the Aviation and Aerospace Sector. The types of Drones like Nano, Mini/ Micro, Small, Medium and Large Drones are being explored widely for civilian air transportation and aerial studies. The challenges in UAS management are discussed next:

(a) **Aerospace Project Management:** Considering the demand, economic factors, affordability, pilot training and risks, small category drones have wider applications in limited environments within specified towns or cities. Larger drones for Urban Air Mobility and Advanced Air Mobility are also gaining traction. In the contested air space wherein manned aircrafts and unmanned aircrafts are to co-exist and operate, the anticipated drone proliferation and growth analysis, evolving congested airspace with air traffic are few challenges to be taken into account in the future.

Integrating drones in Next Gen Traffic Management to have an ecosystem for seamless operation, robust infrastructure set-up, cost-effective innovative delivery methods, hiring of talent manpower, facing the competition-business and technology are going to be major project management programmes. Further advancements in Artificial Intelligence, Machine Learning and Big data will have a huge impact on integration of UAS projects in the national airspace.

(b) **Next Generation Maintenance on UAS:** Maintenance philosophy varies with respect to manned aircraft and UAS, more so in sUAS due to the absence of systematic scheduled maintenance tasks.

- Manned aircrafts usually have common scheduled maintenance like 1st line, 2nd line, Out of Phase Servicing (OOPS) and Major depot level 4th level servicing in addition to unscheduled maintenance and snag rectifications. In UAS, certain scheduled maintenance for large UAVs like Medium Altitude Long Endurance (MALE) and High Altitude Long Endurance (HALE) have periodic maintenance (O, I and D Level) similar to manned aircraft with maintenance tasks and tradesmen earmarked for airframe, engine, radio, radar, instrumentation

and electrical systems respectively. However, in sUAS, in the absence of clear maintenance schedules, the technician do not tend to make clear distinction and most of the maintenance is unscheduled maintenance.[4]

- In conventional aircraft the tradesmen's responsibility is limited to aircraft maintenance only and the ground support systems are looked after by other ground staff. However, in case of UAS, the maintenance consists of interactions with the aircraft, ground-based components and whole-of-system. Thus, the technician or operator is responsible for the complete system, comprising the aircraft and a diverse set of ground-based equipment.
- Repetitive assembly and handling of spares in sUAS is similar to the 'grandfather's axe' problem, that is, similar to frequent change of handle in an axe. The frequent modular change in major components imposes difficulty in life component monitoring.

(c) **Policy and Regulations:** The UAS growth curve is seen exponentially and universally accepted as a game-changer in future aviation. Small UAS are gaining attraction in transportation of consumer goods, food, medicines, etc., in addition to numerous other purposes. Though all endeavours are meant to accommodate UAS in Automated Unmanned Traffic management along with conventional aircraft, the policy and regulatory framework for UAS operation/ management in congested environments, i.e., low altitude of flying (defence and civil) is seen as a challenge.

(d) **Human Resource Management (HRM):** HRM in the UAS domain will remain challenging as the talent pool (after required training) is tailored specifically for UAS. In this primitive stage of commercial UAS global expansion, multi-skilled training of personnel with knowledge of aircraft and ground systems, capturing data for all contingencies with added sUAS are seen as a challenge.

(e) **UAS Flight Safety and Hazard Management:** Aviation flight safety and hazard management is one of the important areas in UAS especially in the smaller drones that are for loitering at low altitude. Due to malfunction of the UAS, sensor and data link failures or pilot/ operator error, there are chances of unmanned aircrafts colliding with other airborne platforms or on property in the ground. While stringent maintenance and training procedures can reduce these hazards to a large extent, building an ecosystem

with all stakeholders in automated theatre for zero error is seen as a challenge. Risk management of UAS in evolving non-segregated airspace is one of the areas for research too.

Maintenance Philosophy on sUAS

Traditionally, medium and larger UAVs are operated/flown by separate teams mostly by aircrew experienced in flying manned aircraft and the maintenance is undertaken by separate teams, in most cases with maintenance exposure in manned aircraft. Accordingly the maintenance documentation in such UAVs were derived from aircraft documentation. The maintenance control on documentation in terms of preventive maintenance, snag rectifications, lifed component monitoring, demand procedures, storage and servicing, etc., were systematic and very effective. Aviation assets in defence are intended to be serviceable at all times with minimum downtime.

Also, these assets are expensive and foreign origin in most cases and therefore it is imperative to have high serviceability. Maintenance by skilled manpower, adhering to laid-down procedures and infrastructure set-up are the backbone of operations in defence units.

sUAS maintenance differs greatly in maintenance compared to conventional aircrafts. There are differences in the equipment that needs to be maintained, the procedures and paperwork and the traits of the maintainers themselves. Maintenance documentation for many UAS is either non-existent or of a poor standard. sUAS generally have rudimentary operating documentation and many are delivered without maintenance documentation. Users usually develop their own maintenance checklists and procedures to guide system assembly, perform scheduled pre-flight checks, and record defects. In most cases, sUAS technicians lack guidance to assist with unscheduled maintenance such as troubleshooting and repair. In the absence of such documentation, technicians must rely on their own system knowledge and problem-solving skills. Procedures performed without documented guidance are more prone to error than documented procedures. Studies shows that the sUAS are being maintained by generalist operators and maintainers who may not have a background in aviation maintenance.[5]

The diversity and rapid pace of change in the small UAS sector make it difficult to specify in detail the skill and knowledge requirements for maintenance personnel. It is clear however, that UAS maintenance personnel require a significantly different skill-set to their counterparts

in general aviation. Components such as laptop computers, modems, and radio communication systems are critical to the safety of unmanned flight. Future requirements or guidance for UAS maintenance training or qualifications must go beyond the traditional curriculum for aircraft maintenance mechanic training, to include topics such as electronics, radio communications, computer maintenance, and software updating and troubleshooting.

The regulatory approach currently applied to the maintenance of conventional aircraft is not likely to be suitable for small UAS. Most notably, a specific profession of 'UAS maintenance technician' is unlikely to emerge. Instead, maintenance and ground support activities are likely to be performed in the field or operator's workshop by multi-skilled personnel, with specialist personnel only becoming involved when components are sent away for major repairs or overhauls. In addition, many of the maintenance tasks performed on UAS fall well outside regulations that were designed for earlier generations of conventional aircraft.[6]

Challenges in sUAS Maintenance

The following are the few challenges that are seen in the sUAS maintenance in commercial sectors:

(a) In 2019, during 126 Annual Conference and Exposition, the American Society for Engineering Education published a paper wherein it brought out that one of the biggest challenges in sUAS is airworthiness assurance. It states that a commercial operator needs to inspect the vehicle for airworthiness before flight but since the airworthiness is not clear for sUAS, the pre-flight inspection in this regard is generally not given importance. This is a sUAS because there is no human on board the vehicle, and many of these practices are ignored.[7]

(b) The sUAS maintenance tradesmen are responsible for the entire system comprising the aircraft and a diverse set of ground-based equipment, unlike conventional aircraft where tradesmen vary based on the nature of job. Dedicated maintenance person like seen in manned aircraft cannot be available for sUAS and hence they are typically maintained by groups of multi-skilled workers that carry out all necessary ground operations, including assembly, flight planning, and in-flight operation.

(c) sUAS-associated laptops and desktop computers are treated as airworthiness items and their serviceability has a direct impact on sUAS. UAS maintainers should learn various technologies used to communicate with and control the sUAS such as software and hardware components.
(d) Repetitive assembly and replacement of components are part of sUAS maintenance unlike conventional aircrafts. The frequent connection and disconnection of cables, conduits, etc., can increase the chances of damage and introduce errors.

Survey with Indian Industries on sUAS Maintenance Concepts

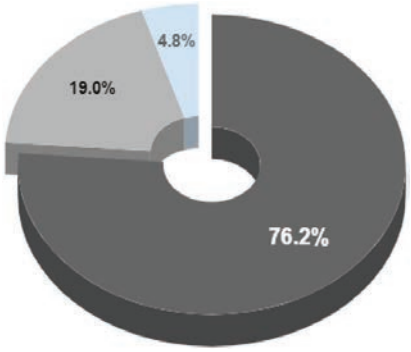
As discussed in the previous section, the maintenance and management of sUAS differs greatly from the manned aircraft and also imposes a few challenges. Multi-skilled individuals are an ideal fit to handle both operations and maintenance activities.

The maintenance philosophy in defence in sUAS was studied analysing the pros and cons of the system with respect to the commercial sector in consonance with defence manpower and infrastructure set-up. Thus, in the initial stages of sUAS in the defence sector, a study was attempted to assess the maintenance philosophy in sUAS and to streamline procedures and ways to optimise resources for long-term benefit.

The perspective of Indian Industries on sUAS maintenance

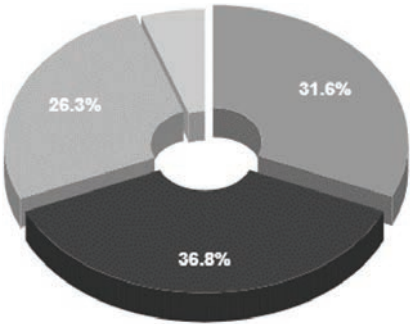
The sUAS operated by the defence forces are relatively new and are usually maintained as per OEM maintenance instructions tailored with individual services operational environment and ethos. Since these systems are relatively new, their serviceability state may be high with less snags/unserviceability reported. A survey was carried out with Indian drone manufacturers to find out their perspective on sUAS maintenance. Studies focused on knowing the maintenance instructions for complete product life cycle that comprises O, I&D level activity and skill level requirement. A total of 10 questions were asked, broadly keeping airworthiness, maintenance documentation, and expertise level of technicians as key areas. The survey questionnaire and responses are shown in the figures.

With the rising prominence of small Unmanned Aircraft/Aerial Systems (sUAS) in the defence sector, there is an increasing need to maintain safety. One of the biggest challenges in sUAS in civil sector is airworthiness assurance. Do you agree with it?



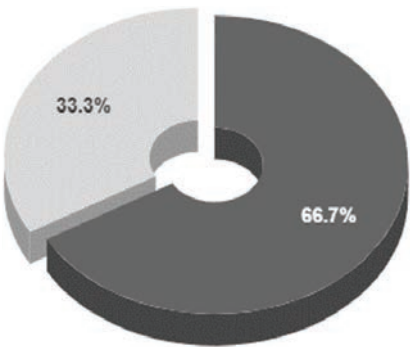
- Agreed as airworthiness assurance is a challenge (76.2%)
- Not agreed as airworthiness assurance is not a challenge (19.0%)
- Not sure whether air worthiness assurance is challenge or not in sUAS (4.8%)

There is no detailed airworthiness assurance or tracking requirement for sUAS as required for certificated manned aircraft.



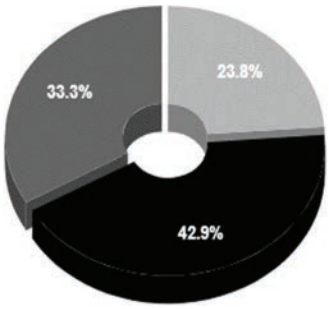
- Effective procedures like manned aircraft is not available (31.6%)
- Effective procedures like manned aircraft are being taken by manufacturers (36.8%)
- Effective procedures like manned aircraft are already available with manufacturers (26.3%)
- No idea (5.3%)

Proper maintenance of sUAS includes more than just using the right tool or the right replacement parts, it also includes the proper documentation. Proper documentation allows operators to track repairs, alterations and calibrations.



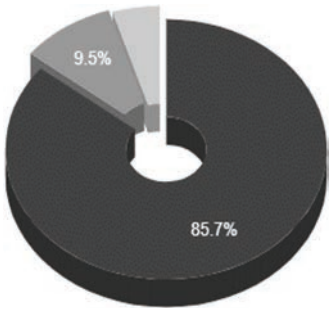
- Fully agreed as effective documentation enhances maintenance safety (66.7%)
- Agreed to certain extent as documentation is required for maintenance activities (33.3%)

In many cases, small UAS are maintained by generalist operator/maintainers who do not necessarily have backgrounds in aviation maintenance. The diversity and rapid pace of change in the sUAS sector make it difficult to specify in detail the skill and knowledge requirements for maintenance personnel.



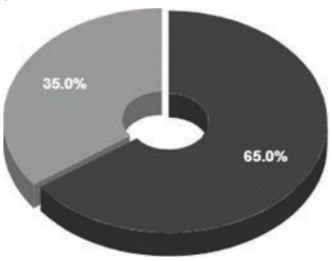
- Not sure whether aviation experience will have any effect in sUAS maintenance (23.8%)
- Aviation experience is not required for maintenance of sUAS (42.9%)
- Aviation experience is required for maintenance of sUAS (33.3%)

Future requirements or guidance for sUAS maintenance training or qualifications must go beyond the traditional curriculum for aircraft maintenance training, to include specialisation in areas such as electronics, radio communications, computer maintenance, and software updating and troubleshooting.



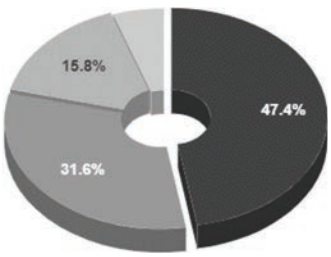
- Yes, specialised training in ground support systems additional to unmanned aircraft is required (85.7%)
- No, it is not important and training are not required. They have less impact on flight safety (9.5%)
- No idea on specialised training requirements and its effects (4.8%)

Conventional aircraft, medium and larger UAS generally are maintained by individual tradesmen like radio, radar, instrumentation, airframe, engine, etc. Further, the aircraft is operated by different set up like pilot/operator. Do you think such tradewise maintenance is required for sUAS?



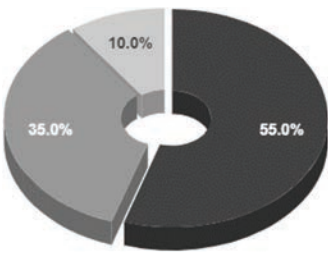
- Dedicated maintenance and operator team are not required. Individuals can be multiskilled for both tasks (65.0%)
- Yes, dedicated maintenance team and separate operator set up is required (35.0%)

Estimates of component reliability and schedules for preventive maintenance, depend upon predictive data as well as historical data for failure rates, including accident and incident data. OEMs of manned aircraft provide predictive data for maintenance, but OEMs of sUAS generally do not, either because failure data is not available, or because competitive pressures discourage disclosure of this information.



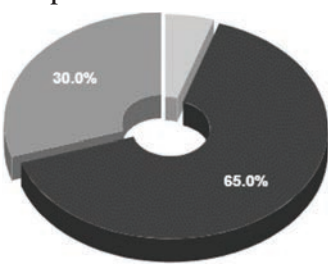
- Partially agree in this regard (47.4%)
- Agree in this regard. Failure rates not available or due to competitive pressure (31.6%)
- Not agreed, OEM and sUAS provides all relevant maintenance predictive data to customers (15.8%)
- No comments as not much failures are seen in sUAS (5.3%)

Smaller manufacturers of sUAS do not generally use part numbers or serial numbers on components. This makes it difficult to track the maintenance history of these components. A lack of serial numbers may increase the probability of errors resulting from misidentified parts, mistaking an unserviceable component for a serviceable one, or fitting non-compliant components.



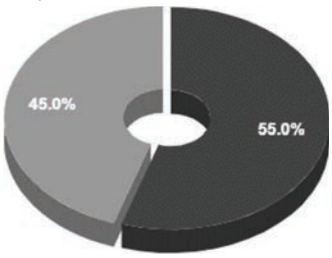
- Agreed, part numbers are not given for many components by manufacturers (55.0%)
- Disagree, all components have part/serial numbers (35.0%)
- No comments (10.0%)

Compared to a manned aircraft, a crashed sUAS is less likely to be located and recovered, making it more difficult to identify maintenance errors like component failures on the basis of physical evidence.



- No idea and not thought off (5.0%)
- Agreed and component failures cannot be ascertained (65.0%)
- Disagreed, the failure of individual components of sUAS can be ascertained (30.0%)

sUAS do not generally have on-board meters to record airframe or engine flight hours. If this flights history information is not recorded by the ground station, the timing of hours flown must be recorded manually for maintenance purposes and the scheduling of inspections. The modular construction of many sUAS means that different flight hours may be accumulated by different components on a single aircraft. For example, the wings, engine and fuselage may each have their own history of hours flown.



Survey Insights

The survey had brought out informative insights on sUAS maintenance concepts as seen by Indian industries. The drone OEM/ Indian industries' perspective match significantly with the global sUAS operational and maintenance philosophy as highlighted in research papers. The insights derived from the survey are as follows:

(a) Indian industries accept the concept that the biggest challenge in sUAS in civil sector is airworthiness assurance.
(b) The detailed and systematic maintenance procedures as seen in manned aircraft are not available in sUAS. Presently, the comprehensive procedures are not available and are being taken up by the industries.
(c) It is seen from the experts' viewpoint that proper documentation is the one of the grey areas in sUAS maintenance. The industries feel the same and agreed that effective documentation would enhance maintenance safety and is important.
(d) It is also seen that equally specialised training in ground support systems additional to the airborne platform or aerial vehicle training is very much required as ground support or ground systems is intrinsic to sUAS.
(e) Unlike the manned aircraft or larger UAS that depends on aviation specialisation/ technical training specific to the system on maintenance, many industries feel that in sUAS the aviation experience is not required for maintenance of sUAS. The industry is

of the opinion that flight-level maintenance (daily inspection card) on daily basis is simple and followed as per laid-down procedures.

(f) Industries feel that dedicated maintenance and operator team as seen in manned aircraft/ large UAS are not required for sUAS. The reason may be due to size, role, etc. Individuals can be multi-skilled for both tasks.

(g) Most of the OEMs of sUAS usually do not provide predictive data like manned aircraft because failure data is not available or because competitive pressures discourage disclosure of this information.

(h) sUAS do not usually use part numbers or serial numbers on components as seen in conventional aircraft.

(j) Crashed sUAS are less likely to be located and recovered, thereby making it more difficult to identify maintenance errors like component failures on the basis of physical evidence.

Aviation Maintenance Ecosystem at Defence Establishments

The Indian armed forces have a robust maintenance set-up to maintain its assets at high serviceability. Noticeably, there are various legacy systems still in active service and many have contributed beyond their life-span and aged gracefully. Maintenance activities therefore have been the backbone for the longevity of these systems and efficiency remained the same in spite of financial and economic constraints.

Traditionally, the maintenance aviation ecosystem, for example in the Air Force, consists of technical-trained maintenance team like airframe, engine, radio, radar, instrumentation, armament fitters on an aircraft, Missile fitter's with different trades for missile systems and so on. There are adequate infrastructure set-up like aircraft hangar, maintenance labs, supply chain management (logistics) set up, weapon storage areas and major serving sectors like base repair depots, etc. The servicing schedules are derived on the basis of a number of factors, the most important being OEM recommendations, climatic conditions, overhauling set-up, operating environment, etc. There are dedicated teams to conduct operations (aircrew) like flying the manned/unmanned aircraft and deploy system. Maintenance team is the dedicated team that supports operations through periodical maintenance activities.

The technology developments in aviation are imposing challenges to continue with traditional maintenance set-up. The software developments have given more automation in the systems such that all the aircraft systems are seamlessly interconnected with each other.

System specialisation along with a fair knowledge on interlinked systems is essential. Multiskilling of technical teams becomes imperative and further new systems such as sUAS also demand talented individuals capable to handle operations and maintenance simultaneously. sUAS will be on rise in defence establishments and simultaneously will need to be operated in airspace overlapping within defence establishments and with civil operators.

As per the opinions of experts seen in research papers and the views of Indian industries, the maintenance philosophy is unique for sUAS. Therefore with technological challenges on the rise, the maintenance team also needs to be suitably geared up and keep up the pace. The following are the areas of importance to strengthen maintenance ecosystem at defence bases/units:

(a) sUAS will be managed by a multi-skilled dedicated team. The team will be responsible for operating and maintaining airborne as well as ground systems. The team may be different within services and may comprise trades/ranks who may vary in skill levels, qualifications, training and technical acumen. As sUAS require multi-skilled teams to fly in all terrains (including high altitudes) as well as maintain a technological intensive system, the challenge comes in *identification of such talented individuals*.

(b) To have zero error in sUAS operations where airworthiness assurance is a challenge, maintenance documentation and procedures are to be refined to desired standards to cover lifed and non-lifed components, insights on accident and incident data are not adequate (because competitive pressures discourages disclosure of this information by OEM), crashed sUAS do not give much information on material failures and so on, hence there is a need to *devise a comprehensive maintenance philosophy* that covers these nuances.

(c) Larger drones like manned aircraft are expensive and have longer life-span. OEM assistance on maintenance in terms of contractual obligations and follow-on support contracts are prepared accordingly to yield maximum return on investment. The sUAS on the other hand may have a short service life unlike bigger drones. The sUAS market is dynamic and competitive with various models on rise. Many sUAS are manufactured by start-ups and MSME. In these conditions, there is a need to leverage the cost of investment by reducing OEM dependency

by *strengthening maintenance set-up at units including facilities for major repairs*. Effective maintenance set-up can handle new future sUAS inductions and be less dependent on OEM.

(d) On new procurements, the suppliers or OEM of sUAS need to be emphasised to give comprehensive maintenance documents that are found wanting as shown in the survey insights. The need for life component monitoring is one such area that needs more attention.

(e) Though many industries feel that aviation experience is not required for sUAS operations and management, it is felt that since sUAS is in the infancy stage in the armed forces it will be useful to employ individuals with some aviation background who broadly understand the environmental ecosystem. In a non-segregated airspace where manned, larger UAS and sUAS are required to operate, aerospace safety will be enhanced with such individuals.

The Future

'The rise of India's drone industry has been a fascinating development over the past 2 years. Currently, the Indian drone market is seeing a great increase in demand which will likely lead to the creation of a multi-billion-dollar industry over the next decade. Drones already started generating curiosity within Indian youth. We should see a drone in every house over the next decade'.[8] Drone technology is rapidly evolving and days are not far-off where unmanned aircraft of various sizes (like conventional aircraft) are seen hovering in the skies delivering pizzas at doorstep, transporting goods, for calamity aid, assisting law and order and surveillance purposes.

The countries around the globe are focusing on automated Air Traffic Management for seamless operations of both manned and unmanned aircraft in the integrated airspace. Technologies such as Artificial Intelligence, Machine Learning, data analysis and its algorithms are seen as crusaders for these activities with minimum human intervention in traffic control management. Technology disruptions are seen in the world across all industries with automation gaining importance. These developments demand knowledge and skill level in defence personnel to progress hand-in-hand with the world since future military aviation of UAS may rely more on civilian airspace during peacetime.

Although there are important differences in operational realities between manned and unmanned aircraft, the fundamental fact is that sUAS share airspace with manned aircraft and safe operations of one affect the safe operations of the other. Even though the intent of unmanned traffic management is to segregate most sUAS and manned aircraft activities, altitude and airspace restrictions may not prevent sUAS from entering airspace reserved for manned aircraft. In spite of this shared airspace, design and manufacturing standards, aircraft systems, and maintenance tasks all differ considerably between manned and unmanned aircraft. These differences affect UAS maintenance and airworthiness, which may in turn affect safety.[9] Thus the civil–military fusion in sharing of airspace is inevitable with growth in sUAS.

sUAS are gaining traction in India for use in Intelligence, Surveillance, Reconnaissance and Logistics and also as armed UAS in the military domain .As seen from the survey with Indian industries, the maintenance philosophy of sUAS is different from the traditional maintenance of conventional aircraft and of bigger UAS that is, above medium category. The operations and maintenance activities will be intertwined with each other such that one domain may influence the other domain. Hence, as the operations increase, so does the maintenance.

With the proliferation of sUAS in the armed forces in India, there is a need to carry out research on the maintenance philosophy specific to sUAS since it is unique and different from traditional aircraft. The cost associated with sUAS procurements can be leveraged through multi-skilled and talented team that may differ from existing trade structures by evolving maintenance ecosystem thatis dynamic to adapt to technological disruptions and last but not the least strengthening the maintenance safety by adhering to correct maintenance practices for sUAS.

Notes

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