Considerations for Unmanned Aircraft Systems Maintenance and Reliability

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Abstract: The proliferation of unmanned aircraft systems has introduced exciting new ways to conduct aviation operations. Much focus has been dedicated to best practices, mitigating human factors, and human-to-machine interface considerations while the aircraft is in one of the phases of flight. Far fewer resources have been dedicated to those topics regarding the maintenance of these systems. Unmanned aircraft systems have some unique challenges associated with their maintenance that must be accounted for and mitigated. On top of the challenges related to introducing personnel to new concepts and skills, we are also introducing new and very different equipment to our maintenance personnel while removing haptic and audio cues typically used to narrow system faults. Additional thought and foresight must be put into the engineering, specifically how maintenance personnel interact with these systems. Properly designed systems will lead to an improvement in system readiness and operational safety.

Keywords: unmanned, maintenance, training, aviation

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1. Introduction

Human factors play an essential role in all aviation disciplines but may affect unmanned aircraft (UA) personnel much more significantly than traditional manned aviation. The top three issues with unmanned system operations, that I chose to focus on, are the pace of changing technology, exacerbated imprecise fault symptoms from pilots, and a lack of engineering with maintenance in mind.

Anyone in the unmanned aircraft systems industry knows quite well that the technology is changing at an accelerated pace and has been for the last 20 plus years. While this is inherently a good thing, it also leaves gaps that must be filled to continue to conduct safe operations within the National Airspace System (NAS). While pilot training is continuously stressed, maintenance training does not always garner the same attention. Aviation maintenance personnel are a specific group that comes out of regulatory mandated training well behind the industry [1]. The Federal Aviation Administration regulates aviation maintenance training through 14 CFR Part 147. The topic areas and knowledge, skills, and abilities spelled out within Part 147 were last given a complete update nearly 50 years ago. The required curriculum still teaches component-level troubleshooting and does not address technology that has been ubiquitous for some time now. While there is an industry-led push to adopt new standards put together by the Aviation Technician Education Council (ATEC), the Mechanic Airman Certification Standard (ACS) has yet to be adopted. This new certification standard would allow wider latitude in training by Part 147 organizations, ensuring that students are trained to the standard that we have come to know and allow for the curriculum to shift to mirror current industry practices more closely. It will also help usher in a Competency-Based Education model (CBE) as hour requirements and static curriculum will be removed from the regulation.

Another problem that many in the maintenance world joke about is imprecise symptoms from pilots. An imprecise symptom is a symptom that is not well defined, for instance, "radio inoperative" or "funny sound coming from beneath the seat. "These maintenance write-ups leave room for interpretation or do not clarify the problem. Imprecise symptoms lead to prolonged maintenance actions, as the maintainer struggles to reproduce and fully define the problem. This can lead to aircraft being released for operations with the fault still in place, as a maintainer may find a problem and assume that the problem encountered was the same one that the pilot was referring to.

Finally, we will discuss the need for engineering to happen in close cooperation with maintenance personnel. Engineers typically work within tight budgets and requirements. Meeting some of those requirements sometimes means that maintenance on those products can be challenging. Maintainability tends to be considered, in a passing manner, during later stages of the manufacturing cycle. This can lead to unnecessary costs and missed faults.

2. Discussion

2.1 Keeping Up

Human error accounts for more than 50 percent of aviation accidents, with most of those incidents occurring in the early morning or evening hours during the start of a shift. Of that, nearly 12 percent cite maintenance as a factor and 50 percent of engine-related delays [2]. Human factors in maintenance are of growing interest [3] to the aviation community. Maintainers are more likely to commit a skill-based error in the early morning hours [4]. Unfortunately, newer concepts for operations are ensuring aircraft routing through the day to allow for maintenance at night [5]. From 1994 to 2004, maintenance factors were cited as a contributing factor to 42 percent of fatal airline accidents within the United States [6]. While awareness of the crucial role maintenance plays in keeping aircraft safely operating is expanding, training still lags. Maintenance personnel, straight out of their initial training, must be upskilled before becoming productive members of an aviation maintenance team. While there is some precedent, maintenance technicians are sometimes required to get system-specific training. This training has increased because technicians are missing foundational concepts that must be taught before the system-specific training even begins. This is where the introduction of the new 14 CFR Part 147 standard will come into play. The foreword of the Proposed Mechanic Airmen Certification Standard describes the Federal Aviation Administration's view of the ACS:

> *"The FAA views the ACS as the foundation of its transition to a more integrated and systematic approach to airman certification. The ACS is part of the Safety Management System (SMS) framework that the FAA uses to mitigate risks associated with airman certification training and testing. Specifically, the ACS, associated guidance, and test question components of the airman certification system are constructed around the four functional components of an SMS."*
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> **-Mechanic Airmen Certification Standards, Foreword [7]**

The new Part 147 will reference the Mechanic Airmen Certification standard [8]. This is a consensus standard document that can be a living document that changes in a way that does not necessitate Federal Aviation Administration (FAA) level action. While the FAA has a core mission of safety and is a great organization, large government regulatory bodies have always been slow to move and adapt. In addition, the pace of technological advancement in the last 30 years has increased, particularly in the previous ten years, leaving the regulatory language woefully behind the curve.

Further changes may be coming to how we train unmanned aircraft maintenance technicians. ASTM's F46 Aerospace Personnel Committee is working on a consensus standard to outline a pathway for unmanned aircraft technician training (expected Q1 2022). This will help standardize training for maintenance personnel working on unmanned aircraft systems. This will be an international standard that can easily be adapted to whichever regulatory agency has jurisdiction based on one's location. As more UAS and their manufacturers go through the type certification process, this standard will help them develop a qualified maintenance team.

By using the ACS [7] and the pending UAS Maintenance Technician standard, educational organizations, manufacturers, and repair stations will benefit by producing high quality and keeping up with the rapid changes we have seen in aviation technology.

2.2 Imprecise Symptoms

There are many running jokes in the aviation maintenance field. Most of them center around the descriptions by pilots of the faults they see within their aircraft during operations. Here are a few examples:

Pilot: Aircraft handles funny.

Maintainer: Aircraft warned to straighten up, fly right, and be serious.

Pilot: Target radar hums.

Maintainer: Reprogrammed target radar with lyrics

Pilot: Something loose in cockpit.


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While these write-ups are, in my opinion, hilarious, they tend to be funny because they contain a grain of truth. Pilots are not being properly trained on how to write up faults or oddities within the aircraft or understand the fundamental interconnectivity of their systems, allowing for more thorough write-ups for the associated maintenance personnel. This gets further exacerbated as we look at unmanned aircraft. Many faults on manned aircraft are something heard or felt by the pilot that was different than the last time they flew a specific aircraft. This lack of auditory and haptic cues limits the pilot's ability to understand what is happening in their aircraft [10].

Engine malfunctions are one example where sensory information plays a significant part. Visually, they may see the propellor stop spinning or slow down. At the same time, auditory cues tell the pilot that the sound has decreased or even stopped altogether [11]. Haptic feedback may come in the form of a reduction in vibration [12]. Unfortunately, these cues are denied to the pilot when flying from a control station on the ground.

Flight surface fluttering, landing gear movement, sudden changes in the cockpit smell, all these things provide signals to the pilot, sometimes even before the installed warning systems register the change and sound an alarm. Unfortunately, the effects of this run downhill to the maintainers responsible for keeping the unmanned aircraft system in a condition for safe operation.

This further complicates the maintainer's work, as the reported symptoms do not include any of the additional sensory input from the pilots. Coupled with the incidents of imprecise symptom reporting, this could lead to further failures during flight or additional time and resources to isolate and repair faults.

2.3 Engineering for Maintenance

During my career in the UAS industry, I have seen many examples of great ideas that are implemented that restrict maintenance or make it much harder for them to do their job. For instance, small access holes make getting your hand into or out difficult. Add in the need to clutch an object within that hole and the maintainer's hand is more difficult to remove from the hole, or the tools cannot be used in a way that allows for visibility of the component being adjusted, installed, or removed.

While this type of thing may seem trivial, the increased cost of man-hours will be exacerbated over the product's lifecycle. Maintenance is typically 10 to 20 percent of an aircraft's overall operating costs [13], so designing for maintainability can save a significant sum of money during the operational life of an aircraft. For example, a Boeing 787-8 has an hourly operating cost of nearly $10,200. At 10 to 20 percent, this means maintenance costs range from $1,024 to $2,040 per hour of operation [14]. This is more than $100,000 per 100 flight hours. If the initial design could reduce maintenance costs by 10 percent, this would be $10,000 savings over 100 flight hours. Typical aircraft may see more than 450 hours of operation through a year, making a potential savings of over $45,000 per year, per aircraft, a significant sum. Structures and systems should be built in a way that places critical items in a position to be rapidly accessible and easily replaceable [15]. Systems should have redundancy for essential parts. Built structures should allow for proper inspection, both inside and out.

Further consideration should be taken with access doors to compartments, making a single larger access door that easily opens and seals closed and placing it in a position that allows the best range of access. In addition, flanges or grommets should be built around the door to help with sealing and to minimize injury to maintenance personnel as they reach in and remove their hands and arms.

Routed cables and lines should allow for inspection and replacement of not just the connectors, but the cable lines themselves. Maintenance loops should be utilized for all installations. When a connector or wire termination fails, there should be enough slack left in the cable to provide the maintainer with enough cable to replace the connector and still provide slack for proper movement.

Test points should be provided [15], allowing measurements near the door rather than on the equipment itself. Wherever possible, automated, internal testing should be built into individual components, and this testing should also be able to isolate faults to specific components. Design products with the entire lifecycle in mind, and personnel from multiple departments, including maintenance, should be consulted early and often in the design phase of a project.

3. Conclusion

Adopting the new Mechanic Airmen Certification Standard [7] will go a long way towards bringing maintenance requirements up to date. Industry groups would influence the subject matter to keep it relevant and updated. Still, the Federal Aviation Administration will have to adopt the standards and a new bank of questions that reflect the norm. Keeping the exam questions and the practical, hands-on exams up to date may be a bit of a challenge. Still, even if they were updated every five years, it would be a significant improvement as the current regulations have not seen an important update in a much longer period. Hands-on examinations will likely be the biggest challenge where new technology is concerned. New technology, particularly in the aviation industry, tends to be expensive to acquire and maintain. A significant buy-in from the aviation community will be necessary to provide equipment to partner schools and training organizations to keep them relevant. The theory is relatively cheap and easy to teach. Practical applications require equipment and enough of it so that every student can train on the equipment.

Manufacturers and maintenance organizations will have to step up and provide this to have a workforce for the future of their business. The good news for them is that by partnering with a state school, their donations can be a write-off on their taxes, allowing them to recoup some of the associated costs.

Imprecise symptoms from pilots can be partially improved by incorporating more systems training on their aircraft. A pilot should not only understand how to use a piece of equipment in their aircraft, but they should also have a good sense of how that equipment works and how the systems work together. If the pilot better understood how the DME functioned and how their aircraft receives and processes the signal, they would be able to explain better what the system is doing or not doing. This will reduce maintenance costs as maintainers will have to spend less time trying to recreate an error on the ground to troubleshoot it. They may also have a better idea of what type of tools they may need before getting to the aircraft in question. Again, this will not likely save a lot of time on each job, but if each job can be completed one minute faster by each maintainer, a shop with 30 mechanics could see a significant change in throughput.

Finally, all aviation design teams should either have a qualified maintainer or at least have a skilled maintenance person to consult on the project during critical phases of the design process. This has the potential to reduce the number of times a concept must be refined before producing it. It would also lead to better, more accurate, and more easily accomplished maintenance tasks. All of which can show significant savings to an organization. Designing for maintenance has been shown to significantly reduce the time spent maintaining the airworthiness of an aircraft. This, in turn, leads to less downtime, sitting in the shop, and more time producing revenue for the organization.

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