2-2016

Maintenance Implications for Unmanned Aerial Vehicles in Remote Locations

Ian R. McAndrew
Embry-Riddle Aeronautical University, mcand4f1@erau.edu

Mark Kaintz
Embry-Riddle Aeronautical University

Andrew Carruthers
University of Bradford

IOSR Journal of Engineering (IOSRJEN) **www.iosrjen.org**
ISSN (e): 2250-3021, ISSN (p): 2278-8719
Vol. 06, Issue 02 (February. 2016), ||V3|| PP 01-06

Maintenance Implications for Unmanned Aerial Vehicles in Remote Locations

Ian R. McAndrew FRAeS[1], Mark Kaintz MAS[2], Andrew Carruthers PhD[3]
[1](Embry Riddle Aeronautical University, UK
[2](Embry Riddle Aeronautical University, Italy
[3](University of Bradford, UK

***Abstract:* -** Maintenance in the aviation industry has evolved considerably since commercial and general aviation became a modern mode of transportation. ICAO has made maintenance a top priority by directing local National Aviation Authorities, NAA, to have implemented, robust and standardized training and qualifications for all maintenance personnel that work on any safety critical structure or component. There are rules, law and standards that are audited and the aviation industry is, perhaps, the most successful industry in maintaining standards and reliability. With the advent of Unmanned Aerial Vehicles, UAV, the role of maintenance is now needing to be reviewed to determine how and what is needed. This research paper reviews the concepts and importance of maintenance in this new and expanding industry and the complexity of having international standards for engineers to support continuous airworthiness.

***Keywords:* -** *Aviation, Maintenance, Procedures & Standards Unmanned Aerial Vehicles.*

I. INTRODUCTION

The maintenance aspects of aviation have been documented thoroughly since The Chicago Convention in 1944 started deregulate international air travel. Accidents and incidents are reported as well as the reasons for them regardless if fatalities occur or not. Nowadays as the likelihood of an accident reduces, data is collected according to incidents per 100,000 flying hours. Table 1, below, shows the reasons for accidents and incidents in the aviation sector [1]. Maintenance is not a major cause of an accident, it is a principal reason. These reasons vary, it must be emphasized the lower likelihood of maintenance causing such a concern is not by accident, but rather through detailed planning, training and re-training. For example, there are Human Factors involved that influence how a maintenance task is achieved successfully. Every two years the European Aviation Safety Agency, EASA, licensed engineers have to go through re-fresher training to ensure compliance [2].

Reason For Accident/Incident	%
Pilot deviated from basic operational procedures	33%
Inadequate cross-check by second crew member	26%
Absence of approach guidance	10%
Air traffic control/crew communication	6%
Maintenance Related Problems	25%
Total	100%

TABLE 1, Reasons for Accident or Incident.

This is not to say that maintenance is never a problem and issues still have occurred due to the Human Factors or protocols used. For example, the Air Transat Airbus A330-243 C-GITS, known as the Glider Airbus. On 24 August 2001, Air Transat Flight TSC236, an Airbus 330-243 aircraft, was on its scheduled flight from Toronto, Lester B Pearson Airport, Ontario, Canada to Lisbon Airport, Portugal with 13 crew and 293 passengers on board. The pilots noticed a fuel imbalance and then engine problems occurred. Inspection several weeks prior had noticed a build-up of metallic particles in the engine and a decision was made to replace both engines. An examination of the aircraft following the occurrence determined that both engines stopped due to fuel exhaustion, which was precipitated by a rupture of the high-pressure fuel pump inlet fuel tube on the right engine, which failed as a result of hard contact with the hydraulic line. The engine had accumulated 67.5 flight hours since the engine installation and in all aspects would not have been suspected to cause a problem. Flying over the Atlantic and losing all the fuel results in a need to glide to the nearest airport. In this case the Azores was fortunately near enough to reach. Unfortunately glide speeds are not a controlled descent and a fast and hard landing resulted, see Fig, 1.

Figure 1, result of the hard landing.

These incidents may be uncommon, but they do occur and in this case a maintenance error nearly resulted in the loss of an aircraft mid-Atlantic. It cannot be expressed more strongly that maintainers are needed to work at the highest of standards. With UAV there is now a new order of work and classification ranging from toys to advance aerospace vehicles which can be flown and controlled from thousands of miles away. No one argues that this is not a critical part of aviation and if the UAV are not maintained at its current level then more accidents and incidents are going to occur [3]. Thus, UAV maintenance is also going to be as detailed and effective to make these likelihood per 100,000 hours of flight to the same level.

II. MAINTENANCE

Within Europe the rules that govern the flying of Unmanned Aircraft Systems, UAV, is dictated by European Aviation Safety Agency. Their current dictate is Regulation (EC) No 216/2008, mandates the Agency to regulate UAS and in particular Remotely Piloted Aircraft Systems, RPAS, when used for civil applications and with an operating mass of 150 Kg or more. Below this weight if not used commercially the individual member states define their own policy, and the training needed for the remote pilots does currently vary within the European Union, EU, and indeed they differ from the U.S.A. Federal Aviation Agency requirements. It is worth noting that individual states within the U.S.A. have particular specific requirements. Within the U.K. for aircraft of 20 kg or less, these are referred to as a 'small unmanned aircraft', which the requirements are a less stringent and are covered within Articles 166 and 167. Nevertheless, a 20kg object flying at speeds of 60 mph can cause harm, injury and death if not controlled. This paper ignores the requirements of pilots and concentrates only on maintenance. Nevertheless, a UAV still flying within the line of sight can crash and cause property damage, personal injuries or fatalities. A personal UAV will be bought with a warranty, not a maintenance contract and who is even going to be aware of what is acceptable for airworthiness or acceptable levels of safety [4].

Currently, small UAV are limited to fly within the line of sight, larger ones may operate at extended ranges. These are generally low-tech devices with basic maintenance requirements. There are no regulations and nothing to stop unqualified personnel from undertaking or performing any level of maintenance. Implications could be catastrophic and far reaching if one was to collide with an aircraft taking off at the critical stage of flight. Currently, this emulates the pioneering days of aviation and it could be argued that the likelihood of accidents and incidents are high [5]. There are no agreed standards for airworthiness, pilot training, even classification of UAV by weight are misleading.

Clearly, it can be argued the regulations and requirements need to match expected use and applications. Maintenance will become more significant as their capabilities and technology increase. For now, the concern is in the long-term use of UAV and when expensive repairs are needed. In General Aviation, GA, they are subject to specific and less stringent requirements. UAV might already be more advanced than basic Cessna 152. The problem now is that UAV are used by the home enthusiast up to the military for precision bombing or observations. Potentially it is possible that every person in the world could be using a UAV or have access to one.

III. AIRWORTHINESS OF AIRCRAFT

Commercial aircraft need to be certified Airworthy before they are allowed to fly and especially flying into Europe or within European airspace. This is no different to U.S.A. of many regional airspaces. This is overseen by the regulations signed by all countries that are part of the United Nations, UN, and the aviation arm of ICAO, see Fig. 2 below. The top down approach is specified and implemented by National Aviation Agencies, NAA, throughout the world. Every time you fly on a commercial aircraft it will have a certificate of Airworthiness signed by an approved licensed engineer [6]. This certificate states all parts used were in accordance to the design and manufacturing requirements, fitted and checked by approved personnel and all required checks carried out as specified by the manufacturer.

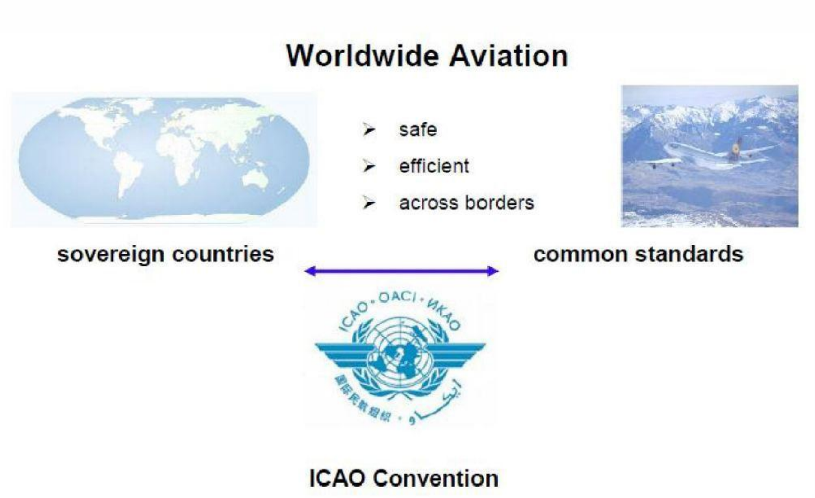

Figure 2, ICAO relationship with member states.

Airworthiness in the EASA region is classified as shown in Figure 3 below. Here the four branches are shown and their relationship to each other. An aircraft is sold as airworthy, then the operator is required to demonstrate continuous airworthiness on a continuous basis under the Basic Regulation 216/2008.

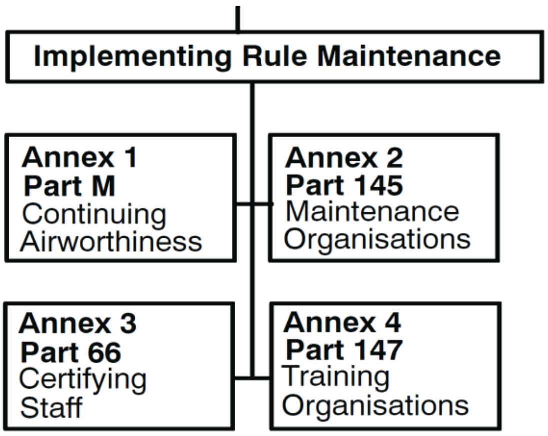

Figure 6, basic regulation 216/2008.

First, any training that relates to the safety or operational stability of an aircraft must be carried out by an approved maintenance training facility, classified as part 147. All licensed engineers in the EU are trained by part 147 originations. Any maintenance must be carried out within an approved part 145 organization by personnel that are certified under the part 66 standard. A passenger can take comfort in knowing these various organizations are audited and have to show compliance by regular and sometimes unannounced visits. The fourth and interesting part is part M. In this part M, it addresses the airworthiness of each aircraft and ensures all documented and recorded activities are planned, inspected and recorded. In case of an aircraft accident or incident these documented and recorded activities are the first documents investigators review [7]. There is a 'light part M for operators having 10 or fewer employees; generally these organizations operate small or few aircraft. It may be something parallel to this standard needed for UAV.

IV. UAV MAINTENANCE REQUIREMENTS

If the classification of UAV is made it can be argued that there are four distinct categories. First, military applications are separate to general and commercial activities. They have their own standards, requirement and deployments. This is not discussed or included in this research paper. Secondly, large (<150kg) and operate commercially. Thirdly, less than 150kg but greater than 20kg that operate commercially. Finally, less than 20kg and operate within line of visual sight. In this research the latter three applications are addressed and in particular, with remote location maintenance.

IV.I UAV greater than 150kg

These UAV are large scale and dimensions of over 3m in length and 4m in width are typical sizes. Such UAV are capable of flying distances of 150NM from take-off. They are, in effect, no different than two-seater Cessna 152 aircraft and as capable, if not more, to cause major damage if a failure where to occur. There are strong arguments to insist they are certified as airworthy with part M, light.

IV.II UAV less than 150kg but greater than 20kg

A category of this classification probable does not have a power plant to fly the distances of those mentioned above. Still, more than capable of flying beyond the line of flight and without correct flight paths, a danger to commercial and GA aircraft, even obstacles, e.g., Wind Turbines or tall buildings. This type of UAV is likely to be where maintenance and repairs need regulating. These can be generally classified into two sub-groups: Medium Altitude & Long Endurance, MALE, and High Altitude & Long Endurance, the MALE UAV are modelled a typical range of 125NM from take-off. Consider the implications shown in Fig. 4 below.

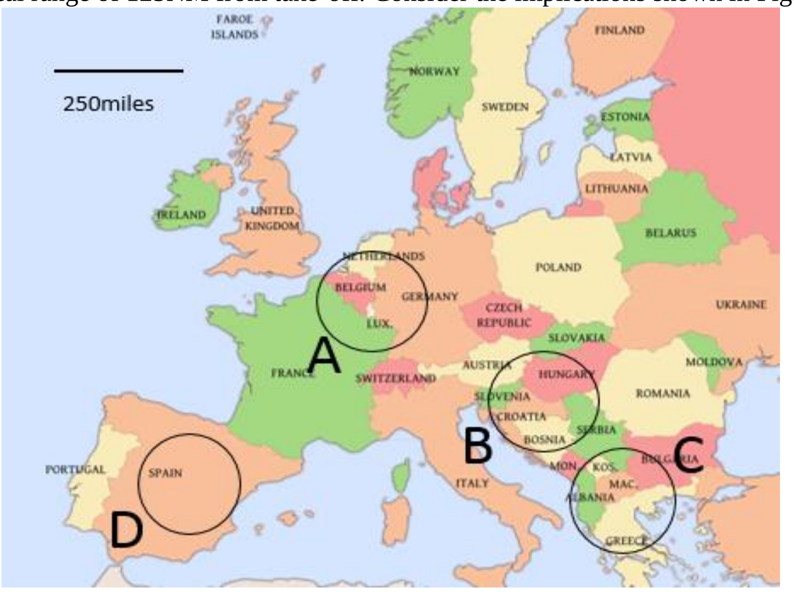

Figure 4, typical range for a MALE UAV.

Within the map are four circles representing various complexities. Circle A, A UAV that leaves a Luxembourg airport could fly into four different countries. Circle B, there ate seven different countries that can be classified as seven differen airspaces. Circle C, again seven different air spaces and also international waters. Finally, Circle D, where all within one airspace. Modern aircraft need maintenance at bases where they fly and land, these UAV are no exception. Routine maintenance is relatively easy to cover, fault diagnostics not. Given these are more complex and that there are far more different types of manufacures, then there will be many more specifically trained maintainers needed to sort problems and allow a UAV to be releassed back to service as in the commercial world of airworthiness [8].

IV.III UAV less than 20kg

Small UAV are by far the largest group when numbers are included. It has been estimated that by the end of December, 2015, that more than 1,000,000 drones had been sold. Amazon were reporting sales of in excess of 20,000 per month. Many of these would be classified as Small Unmanned Aerial Vehicles, SUAV, with a weight of less than 1kg. These, if broken, are unlikely to be repaired and the level of airworthiness can be ignored. Whilst these many be the significant number used, a failure, broken component or system and the operator can collect. It is probable that these UAV will not need regulations to maintain and only operate, not covered in this paper.

V. REMOTE MAINTENANCE

Remote maintenance in this sector can be defined as being when a UAV needs repairs, diagnostics of a fault or intervention before the UAV can be considered airworthy to fly again. In description this is easy, let us consider how this is achieved for commercial flights. As discussed earlier, training also is with a focus to ensure errors are minimized. Maintenance errors are classified into 12 groups, known as the Dirty Dozen, see Fig 5, below to summarize.

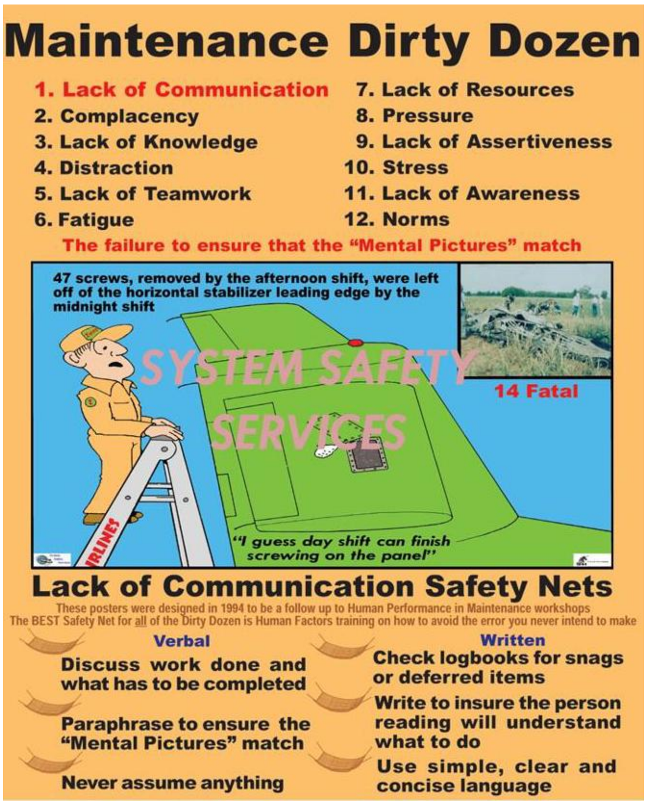

Figure 5, the dirty dozen Human factor Errors

At Frankfurt International airport the majority of aircraft are either Airbus or Boeing. Of these two types they are classified as A320 series, A 330, A340 & A380 with the A 350 soon. Boeing has the 737, 747, 757, 767, 777 and 787. An engineer, trained by a part 147, certified by a part 66 and working in a part 145 organization has a route to follow to be allowed to work on any aircraft. First, an engineer needs to pass the training for either mechanical or avionics; then they complete a type rating course. Thus, in theory, 11 type ratings and they could be cleared to cover ALL aircraft. Generally most are type rated for five on average. Now consider UAV, there are more than 400 international manufactures, 11 from Canada, 30 from China. Each with specific equipment, Power Plants, avionics, unique parts; coupled with manuals that have to be translated. The likelihood of an engineer to be experienced to work on a random UAV is low. Furthermore, many UAV need specific equipment and tools to work. It is not unlike modern cars, maintenance needs specific diagnostic software that is expensive to keep up-to-date. This is where the focus on UAV maintenance is needed and requires regulation.. Not anyone should be allowed to maintain any UAV. Even if they could, the engineer licensed to sign off airworthiness needs clarification and specific knowledge to verify [9].

VI. ANALYSIS

Failure and incidents will eventually lead to an accident. With UAV this carries the extra risk of the remoteness not aligning ownership to the incident and raising questions about how differently could be the result if a pilot. In this paper it has highlighted how current maintenance in the commercial sector is very effective. Ask anyone to state the last 10 aircraft crashes that happened in Europe or North America and most would struggle. Assuming that can automatically carried over to the UAV sector is not only unfeasible, but not practical. There are many facets that can be applied and used. For example, engineers trained and certified to EASA basic regulation 216/2008. It is then the type rating that adds a level of demand that is not possible. A UAV type rating course may take only a few days as opposed to 4 weeks for an Airbus, but, without currency (enough worked on in the previous 24 months) that license to practice expires.

Base maintenance, that is maintenance carried out at the operator's base, will have the equipment, tools, and software to carry out a full diagnostic evaluation when errors reported. It is the remote bases that the biggest risks occur. This is the principal point that needs solving and soon. Without an answer, universally agreed then international flights will only happen with military operators. This also needs exploring with the currency and experience for a Category C engineer (authorized to sign for release to service after maintenance) to undertake this task. Without these no airworthiness can be determined and should not be allowed to fly in that air space or any other countries air space.

VII. CONCLUSION

In conclusion UAV offer a unique advantage over other modes of flight or transport. Regardless of the manufacturer they will be sold as airworthy. The continuous airworthiness is the issue. Base maintenance can be sorted easily. Remote maintenance is the problem when the skills and equipment are not available. Without this solved UAV cannot fly a return leg of a journey. International agreement, regulations and approval is soon needed before UAV can be safely used.

VIII. FUTURE WORK

A next phase is planned and in this research it is to review all EU current regulations for each NAA and determine a framework for recommendations. Subsequently, to parallel the regulatory frameworks and recommend standards in components that will allow for remote maintenance.

IX. ACKNOWLEDGEMENTS

The authors would like to say a thank you to the faculty in their department that shared their concerns and offered advice to formulate the theory and demands that are likely.

REFERENCES

[1] Hawkins, F. (1993). *Human Factors in flight*. Ashgate: Aldershot, UK.

[2] Weibel, R.E. & Hansman, R.J. (2014, September). *Safety considerations for different UAVs in the NAS*. Paper presented at American Institute of Aeronautics andstronautics, 4th Aviation Technology, Integration and Operations (ATIO) Forum, Chicago, IL.

[3] Manning, S, D., Rash, C. E, LeDuc, P. A., Noback, R. K., & McKeon, J. (2004). *The role of human causal factors in US Army unmanned aerial vehicle accidents.* USAARLReport No 2004-11. US Army Aeromedical Research laboratory: Fort Rucker, AL.

[4] McCarley, J. S. & Wickens, C. D. (2005). *Human factors implications of UAVs in the National Airspace.* Technical Report AHFD-05-05/FAA-05-01. Federal Aviation Administration: Atlantic City, NJ.

[5] Munro, P., (2003). Reporting discrepancies: Informational needs of airline mechanics and pilots. Unpublished Master's Thesis, San Jose State University, San Jose, CA.

[6] O'Connar PD. (1994). *Practical Reliability*. 6th Ed. Prentice Hall. London.

[7] Bertin J and Cummings R. (2008). *Aerodynamics for Engineers*. 5th ed. Prentice Hall. London.

[8] McAndrew IR, Navarro E and Witcher K. (2015). *Drogue deflections in low speed unmanned aerial refuelling.* International Journal of research in Aeronautical Engineering & Mechanical Engineering, IJRAME. 3(1): 119-127.

[9] McAndrew IR, Godsey O and Navarro E. (2014). *Aerodynamics of drogue system refueling of unmanned aerial vehicles.* Advanced Materials Research. 1016: 349- 353