Chapter 23
Remotely Piloted Aerial Systems Support Considerations

Jonathan Pelham

Abstract Remotely piloted aircraft (RPA) also known as drones have in recent years become an essential tool for civilian and military users in finding out information about their environment in a cost effective way. Their uses at small scales have encompassed fields as diverse as crop monitoring through to safety critical inspection on oil rigs. Larger RPA have also found a wide variety of niches from scientific research to shipping monitoring and persistent surveillance of military targets. As these systems have seen wider use across a variety of users at various scales, and with a wide variety of uses a picture has started to emerge of how their unmanned nature offers unique challenges to their through life support and to the frameworks that can be used to assure safe operation through life.

23.1 RPAS (Remotely Piloted Aerial Systems)

Remotely piloted aircraft are aircraft that are intended to fly without a pilot on board. They consist of several main system elements. This section will introduce RPAS (Remotely piloted aerial systems) and discuss their use. Some of the difficulties of operating RAS and problems unique to RPAS will be discussed. A generic RPAS architecture is shown in Fig. 23.1. The individual elements of the RPAS shown in the figure are discussed within this chapter and the contribution of each to the through life health management of the system discussed. Briefly the chief portions of the system are the aircraft, the communication means, the GCS (Ground Control Station), the pilot or pilots, and the wider supporting system.

There are many different types of airframe used for the remote aircraft part of the RPAS. Some have become highly recognisable such as the MQ-1 Predator and some have become ubiquitous such as the increasingly popular quadcopters and octocopters. Each type of RPA has different missions to which they are suitable and

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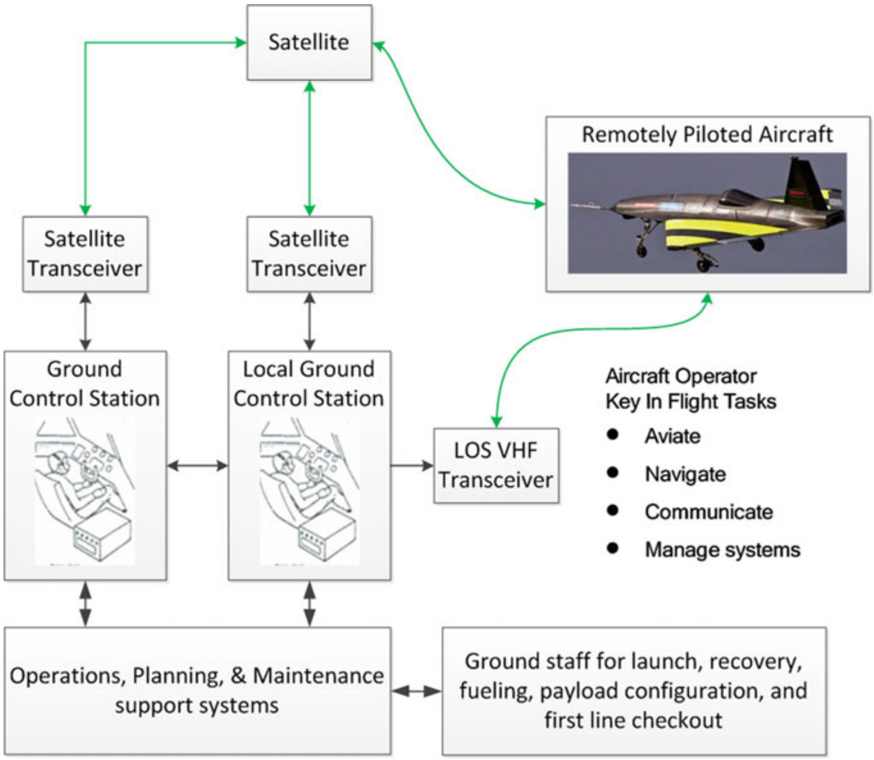

Fig. 23.1 RPAS architecture

different operational challenges caused by the design decisions made during their creation. Quadcopters are highly agile and able to get very close to assets for inspection but have limited payload capacity and endurance due to the high power requirements of hovering flight. Long endurance aircraft such as Predator are able to stay aloft for multiple hours and take very detailed pictures and collect other useful sensor data but are highly complex and require sophisticated support structures to be in place to ensure they are used effectively.

The ground control station is a long winded way of describing the way by which the remote pilot controls the aircraft. This can be done at various levels of control all the way from full control authority, through high level mission planning, to just supervisory control of the aircraft. Whatever level of control chosen the remote pilot remains responsible for the safety of the aircraft and the safe interaction of the aircraft with other airspace users and potential 3rd parties on the ground. The choice of a ground station is often rather limited as it is frequently supplied as part of the control system for the aircraft selected for use. There are however emerging standards for GCS and for communications between the GCS and the RPA. Particular attention should be paid to the Dronecode project which is creating a full stack of open source GCS software, aircraft flight management, and communications systems [1].

The communication system that connects the GCS and the RPA could be one of many different methods. Frequently quadcopters use radio in the 2.4 GHz band which can result in relatively short range. Every method to communicate with the aircraft will have some pros and cons that affect operations and must be understood. The USAF controlled the Predator through a combination of VHF radio for line of sight control during take-off and landing and satellite band radio for control during the cruise and mission phases of the flight. Control via satellite relay created large amounts of latency which reduced the ability of the remote pilots to understand potential aircraft issues. It did however allow control from almost anywhere in the world.

The operation supporting means of the RPAS is the entire team that manages, repairs, supplies, and supports the RPA. The team on the ground that prepares the aircraft for transport between mission locations are every bit as responsible for flight safety as the pilot despite a certain detachment from the immediacies of flight control.

23.2 RPAS Mishaps and Challenges

RPAS experience challenges in just the same way as manned aircraft but with some additional complicating factors. The average DoD UAS mishap rate has been claimed to be as high as 50 per 100,000 flying hours (DoD manned mishap rate claimed to be 1 per 100,000 flying hours) [2]. Figure 23.2 shows the mishap rates for the USAF (United States Air Force) MQ-1 Predator, RQ-4 Global Hawk, MQ-9 Reaper, U-2 Dragon Lady, F-16 Falcon, and F-22 Raptor. The U-2, F-16, and F-22 are all manned platforms and it can be observed how with increasing fleet hours the mishap rate of these aircraft decreases significantly. The initial conclusion could be that this shows broadly comparable mishap rates between manned and unmanned aircraft. However the F-16 and F-22 are both supersonic fighter aircraft and the U-2 has a notorious history of being a very difficult aircraft to fly. To put this in context the Boeing 737 has a class A mishap rate per hundred thousand flying hours of around 0.13 and that performance is more than an order of magnitude better than the best performance in the figure. If RPAS are to live up to the many potential opportunities for their use then their mishap rate will need to be substantially improved. There is very little data available for smaller platforms used by civil operators. There is anecdotal evidence that the mishap rate for small platforms is higher than that shown in Fig. 23.2. However without hard evidence it is difficult to come to further conclusions.

As of 2009 the USAF had accrued a total of 675,450 flying hours with the Predator, Global Hawk and Reaper. A study by Hartfield et al. [3] published in 2012 went through the mishap data for these aircraft. The mishaps were classified

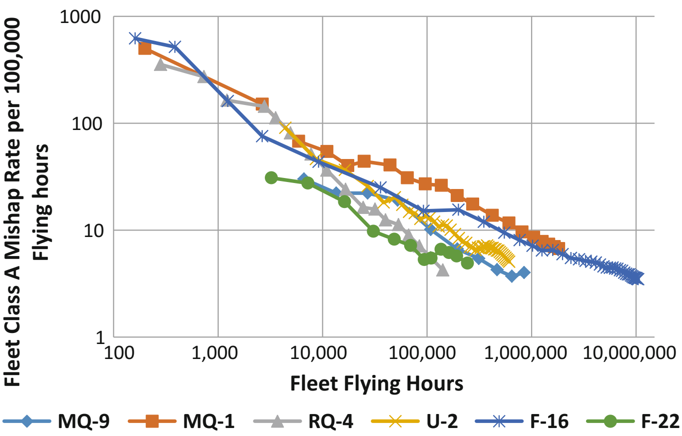

Fig. 23.2 USAF RPAS mishap rates

by the USAF [4] and the study further examined their data to identify mishap cause and system.

The total accrued mishap rate was 57.3 mishaps (A–E) per 100,000 h. The rates for Global Hawk and Predator B/Reaper are projected as during the period of the study the respective fleets did not exceed 100,000 flying hours.

Individual mishap rates (classes A–E, all categories) [3]

Predator	33.7 Mishaps per 100,000 h
Predator B/Reaper	64 Mishaps per 100,000 h
Global Hawk	53.8 Mishaps per 100,000 h

Accrued class A mishap rates (all categories) [3]

Predator	11 per 100,000 flying hours
Predator B/Reaper	18.8 per 100,000 flying hours
Global Hawk	12.7 per 100,000 flying hours

These three aircraft all share a number of common features as well as being unmanned. They all feature high aspect ratio wings, a single engine, satellite modem for beyond line of sight control, and long endurance. These aircraft cannot currently refuel in flight and thus this long endurance suggests a large take-off weight fuel fraction. Over the 10 years of this study (2001–2009) there were 79 Class A mishaps but only 11 Class B mishaps ($200,000 to $999,999 in Damages). There are also 61 class C mishaps over the period in question. This could suggest RPAS are more prone to complete write off or low damage than a manned aircraft.

It was suggested by Hartfield that these RPAS may be susceptible to single item catastrophic failure due to their design [3]. The largest single mishap cause identified was reliability at approx. 57% of class A mishaps [3]. This was dominated by power and propulsion reliability which should perhaps be expected as these are all single engine aircraft. It certainly shows the need for careful maintenance of RPAS.

The U-2 manned reconnaissance aircraft shares some of the features of these unmanned aircraft and also has a low rate of class B mishaps compared to its class A mishap rate [5]. The U-2 similar features include a high aspect ratio wing and a large fraction of its take-off weight is fuel. The very low wing loading during landing makes these aircraft increasingly susceptible to gusts as fuel is burned and contributes to difficulty during the final touchdown phase due to ground effect. RPA suffer more from this as their wing loading can be as low as a third of that expected for a manned aircraft [6]. The study revealed that these aircraft suffered 43 mishaps categorized as Heavy Landing during the period under study of which 15 were Class A mishaps. This demonstrates that the aircraft handling can be compromised by mission optimisation. RPAS operators would do well to consider that as well as the challenges due to remote operation they face the additional burden of aircraft with a very narrow margin of safety engineered to fly for as long as possible.

One of the most widely discussed RPAS mishaps was the crash of a US border patrol Predator near Nogales, Arizona [7]. In this incident the GCs console operating system experienced a crash and the remote pilot switched to use the camera operators console but did not follow console handover checklist. This meant they failed to check the position of the control levers and when the switchover was completed the lever positions caused the Predator engine fuel flow to be shut off during flight. The engine was starved of fuel and the aircraft crashed. This turned a slow problem with a crashed pc console into a quickly deteriorating issue with a crashing aircraft. It shows the core need for checklists when performing complex activities and also the need to avoid design decisions which can enable simple mistakes. Designing systems to be less brittle in their tolerance of unintended actions is a field of discussion out of scope to this chapter but worthy of further study.

Manning et al. [8] blames ground control station design for ongoing problems in the mishap rate of unmanned aircraft. This complexity of control is coupled with the checklists that sometimes get ignored to the detriment of safe operation. Not following checklists was identified as a contributory factor in several mishaps [9–12].

The key problems identified in Predator mishaps [13, 14]

- Skills and Knowledge
  - Checklist error
  - Task miss-prioritization
  - Lack of training for task attempted
  - Inadequate system knowledge

- Situational Awareness
  - Channelized attention
- Crew coordination

These are all relevant to operators of other RPAS whether military or civil operators.

RPAS Maintenance

A review of the studies into RPAS maintenance shows one of the most common recommendations found is the keeping of proper logs to record maintenance tasks performed on the aircraft or supporting systems. This ties in well with the more general need to document procedures and to make checklists to more conveniently enable staff to actually follow those procedures. See The Checklist Manifesto for further discussion [15]. Even the big ticket aircraft are sometimes developed in a rush. Figure 23.2 USAF RPAS Mishap Rates shows how the mishap rate of the MQ-1 was very high initially but has improved over time as the USAF has learned how to operate the Predator and the Predator has been improved based on lessons learned. One crucial part of this improvement was an improvement in the maintenance procedures and the maintainability of the Predator system. Prior to the Nogales Predator crash cited earlier there were several incidents of the GCS locking up but no maintenance action was taken to address this issue. The maintenance of the GCS and associated equipment is every bit as necessary as proper maintenance of the aircraft.

23.3 RPAS Through Life Support

The support of the RPAS through life consists of a process going from acquisition where the specifications for the required RPAS are determined, through operation, to disposal. The through life management of assets is discussed well elsewhere and here the focus will be on the management of the RPAS itself.

Figure 23.3 shows an illustration of the decision making process for RPA actions. Its intent is to show the need for data and information to be considered when setting strategy and also that the time available to make the decisions is different for different parts of the system. For example an aircraft may not be able to usefully discuss the relative merits of air safety policy chances but would be able to respond to a gust during flight in a much more timely and appropriate manner than the pilot on the ground. This difference in capability, role, and the need for an appropriate level of decision making is a key question for effective operations that to some extent will always be held in tension by the capabilities of operators, systems, and algorithms. The decision about how an operator will operate may be made by adopting a recognized framework and adhering to an operations manual of known provenance. It may also be made by working from first principles to choose

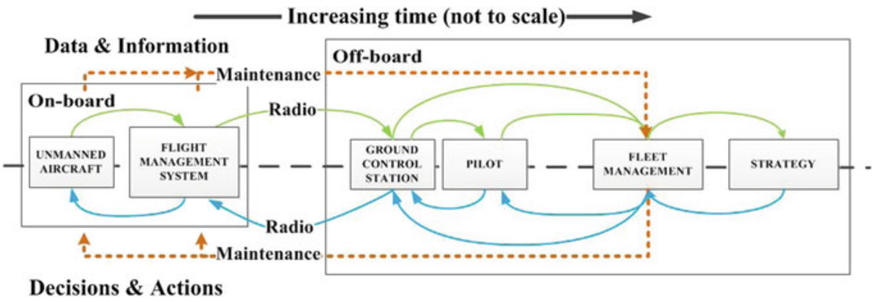

Fig. 23.3 RPAS decision timescales

appropriate processes, aircraft, and support for specific missions. In some circumstances the decision may be an unconscious one but the end result may not be desirable. In a bit more depth the right most box of the figure shows strategy whereby the strategy of the operator is considered, set, and applied to operations. The operator strategy must be informed by data and information from fleet management, from the pilots who conduct operations, and where possible from data developed from actual operations. Data mining can be used to review the flight data retained from previous missions to look for trends that could suggest a need for changes to operational procedures or training for personnel. This is the same in concept to FOQA systems used by large airlines [16, 17].

The strategic decisions taken have wide consequences and if a strategy is not set the operations may not reflect the culture desired or conform to local regulations. The absence of a safety management strategy still represents a choice albeit a negative one. Fleet management is informed by the strategic choices of the company and uses information from staff and systems in the day to day management of the fleet. Operational problems are reported and problems rectified in a timely manner. The time available for these decisions is less than those decisions taken at a strategic level and those making them may find themselves more able to understand fleet problems due to their involvement in fleet management. The next two boxes are the GCS and the pilot. These are shown as separate because the pilot will not automatically understand data the GCS is displaying for their attention. To paraphrase Billings et al. [18] data does not become information until it is understood in the mind of the pilot. In addition the GCS could be programmed to make automated mission decisions based on aircraft and other data in a timeframe that the pilot would not be able to match. In this type of decision the pilot would have to be aware of the procedures and able to supervise appropriately. The left most box represents the aircraft and its flight management system. The decisions and actions that can be taken by the aircraft can occur within time constraints that could not be matched by any off board system but will necessarily be limited in the amount of computational power available to make those decisions. Typical decisions made include flight stabilization and aircraft pitch required to achieve level flight at a requested speed.

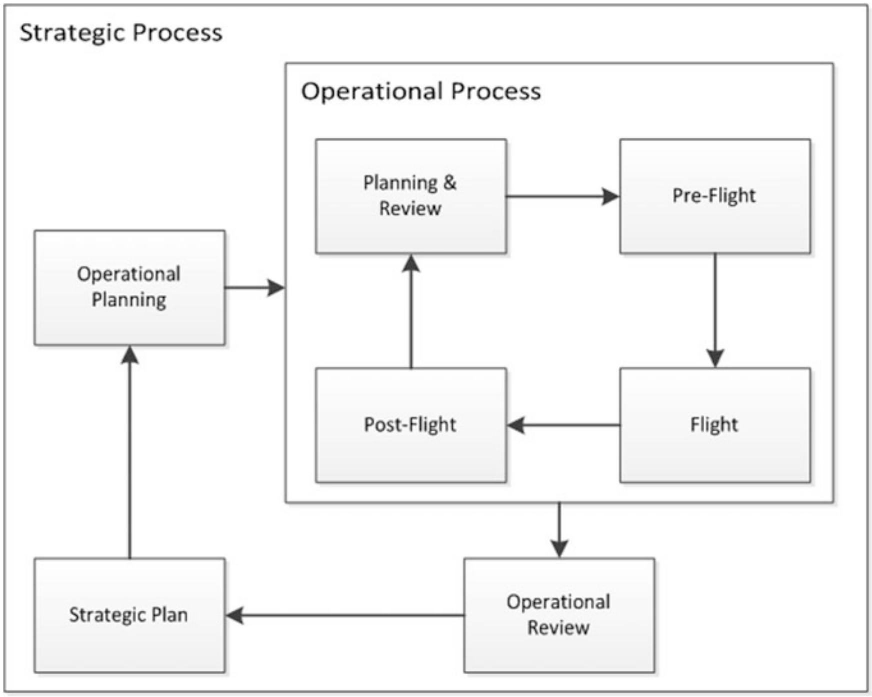

Fig. 23.4 UAS management

Figure 23.4 shows a generic UAS operator process to illustrate the different elements which contribute to the safe operation of the aircraft. To illustrate the application lets go through the typical operation of an aircraft within this scheme. It is agreed to go and do a survey of the land of a client. The operator consults the operational plan and makes any necessary modifications for this particular project. Required tools, parts, aircraft, and team members are accounted for and a plan made to get them all to the work site at the appropriate time. Experienced personnel may be able to do these items much more quickly as they readily understand what is needed from their experience but the use of a plan and a checklist reduces error and helps less experienced personnel contribute as they develop their own skills. When the team arrives on site the plan of work is examined and reviewed based on a site survey and any unexpected risks discussed and assessed. The aircraft is then prepared for flight and its performance checked in accordance with the operations manual of the operator. During flight the pilot and any supporting staff keep a sharp eye for problems and take any appropriate mitigating actions. After flight the aircraft is turned around to prepare it for the next flight and mission data downloaded. The site survey being performed may consist of several flights and it is appropriate between each one to check that conditions are still right for flight and that no new risks have emerged. The process of safe operations is performed through continual review of risks and the application of control measures to mitigate their likelihood or impact. This will be done internally by any experienced pilot but the risks and control measures should be documented to ensure they are retained and learned from instead of trusting to the vagaries of individual memory. After the operation to conduct the survey has been completed and all equipment packed and transported back to base it is appropriate to review and note down any lessons learned or interesting occurrences that can help guide the planning and preparation for future operations. These can be as mundane as discussing whether taking additional batteries would have sped up the completion of the mission to a review of whether guidance on weather restrictions for operations is appropriate or should be tightened. The through life support of RPAS is a process of constant review and decision making. It represent at its core the OODA loop discussed by Boyd [19]. Observing your environment, orienting the observation into context, deciding on your action, and then taking the action. This iterative loop of decision making and evaluation decision results is the constant process of a competitive business. It can also be expressed in a similar way to the evolutionary paradigm. There the expression would be that the fittest survive and in this context we can suggest that the best informed survive to thrive in RPAS operations. It is entirely possible to operate an RPAS in accordance with a manual you have adopted, to have no mishaps, and to have a successful business. If improvements in safety, efficiency, and cost effectiveness are desired however then not only will some thought be required but the also the experience and analysis of mistakes. If lessons can be learned from the mistakes of others then so much the better.

23.4 Conclusion

RPAS are complex even when consisting of a single aircraft and a single pilot. To manage these systems safely and effectively some amount of thought and methodical decision making is required. The use of checklists is an effective way to manage the performance of critical steps necessary for safe operation [15]. In order to consider how safety and usage can be improved through life RPAS operations and fleet management should undergo a consistent process of review and strategies for operations improvement discussed with operators and then set out to be followed. The consideration of how repairs will be conducted, spare parts will be found, who will fit them, and how the effectiveness of repairs will be assessed should be given consideration and plans put in place. The choice of an RPAS that cannot be repaired effectively can cripple the ability of the organisation to complete contracts in a timely and professional manner. The process by which an aircraft is deemed obsolete or unsafe must also be known so that when the aircraft reaches that state it can be removed from active status and either used as a parts source to keep other aircraft operational or responsibly disposed with. In conclusion even the smallest operator has the ability to make a checklist to aid their operations and if they wish to improve their operations and maintain a minimum standard then they would be well advised to do so.

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