Adapting Existing Training Standards for Unmanned Aircraft

Finding ways to train staff for unmanned aircraft operations

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Abstract— **As unmanned aircraft are introduced into civil airspace, a framework for training and licencing of dispatch and operating staff will be required. This paper assesses existing pilot training unit standards and proposes a framework within which staff can be trained and licenced. The result is a list of useable unit standards, a list of new standards to be developed and a list of standards that can be used in modified form. Based on an analysis of South African, European and American licencing regimes, the FAA's Flight Dispatcher Certificate is deemed to be a suitable framework for licencing staff for autonomous unmanned aircraft.**

Keywords- unmanned aircraft; pilot training.

I. Introduction

Unmanned aircraft offer flexibility not found in manned aircraft. They can be made smaller and cheaper to operate. They offer payload advantages relative to small manned aircraft. They can also perform boring or dangerous missions ("Dull, Dirty and Dangerous") unsuited to human pilots. For these and other reasons, there is a strong incentive to facilitate unmanned aircraft (UA) operations in civil airspace.

In South Africa, UA operations are governed by the Civil Aviation Authority (CAA) under the terms of an interim policy[1]. This policy's paragraph 4.3 describes the process for obtaining a Certificate of Waiver or Authorisation. There is also provision for the issuance of an airworthiness certificate to non-state users.

To facilitate useful operations by UAs, future operations must be subject to no more than routine notification (e.g. an ATC flight plan), just like manned aircraft already are. Before such operations can be established, some form of personnel training and approval will be required. One possibility is a licencing system similar to that currently in existence for pilots.

This paper analyses both the requirements and the existing licencing arrangements. It then recommends adaptations to the existing framework to make allowance for UA operations.

Three distinct cases have to be analysed:

1. **Remote-controlled UAs:**
    a. **Command-directed:** The pilot directs operations, but only at the level of issuing commands (e.g. Fly Heading 270, 110 knots).
    b. **Control-directed:** The pilot provides control inputs, such as left bank, nose up, power increase.
2. **Autonomous UAs:** These aircraft may require no human intervention once airborne.

Although virtually all UAs are likely to be remote-controlled for the foreseeable future, the eventual goal must be to develop and operate autonomous aircraft, with or without ground supervision.

Autonomous aircraft will require planning and supervision. Autonomous aircraft may also have a remote-control capability which would require piloting. Most of these functions are not dissimilar from those for manned aircraft.

This article proposes a training approach for the required personnel, using existing training standards in a number of countries. Specific emphasis is placed on South African regulations. Existing South African unit standards are assessed for their suitability for UA personnel training. Proposals are made w.r.t. unit standards suitable for such training, unit standards that may require modification and unit standards that may be completely inapplicable to UA operations. A comparison is also made with international training regulations and standards.

The analysis is largely subjective, based on the first author's experience as Designated Flight Examiner for the South African Civil Aviation Authority, and on his three-year project to analyse the strategic development of required technologies to facilitate unmanned aircraft operations in civil airspace.

II. Sources of UA pilots

As UA operations become ubiquitous, a sustainable source of crew must be found.

Many current remote-controlled UA operations use ground-based licenced professional pilots. General Atomics, a major manufacturer of UAs for the USAF, employ former airline pilots, who relish the opportunity to maintain a relatively stable and predictable lifestyle close to home[2].

Pilots are attracted to their profession for a variety of reasons. Some are listed below:

- **Natural predisposition:** From a young age, some children are fascinated by aviation. The difference is noticeable in any group of children. When an aircraft passes overhead, some kids look up and stare. Some don't. Many pilots report having been drawn to aviation from pre-school age.
- **The enjoyment of flying:** Many pilots report feeling a sense of comfort and even euphoria in the cockpit that they do not experience in other environments.
- **Lifestyle benefits:** Many pilots enjoy travel, and use their flying as a way to see the world.
- **Perceived status:** Some pilots are attracted by the perceived glamour and lifestyle.

It is unlikely that a career as a UA pilot will satisfy most of these needs, except perhaps the last (perceived status), which may or may not eventually become associated with the function of a UA pilot.

If this assumption is indeed true, it will be difficult to attract enough UA pilots to satisfy the demands of the world-wide UA fleet. It may therefore become necessary to expand the pool of candidates outside of the current selection criteria.

One source of such candidates could be individuals that are keen to act as pilots, but are ruled medically unfit under current regulations because of impairment only of functions not essential to UA operations.

Although remote-controlled aircraft pilots have a similar function to on-board pilots in manned aircraft, some physical requirements (e.g. those relating to mobility, strength and both visual and aural acuity) could be relaxed. In the case of command-directed UAs, direct control inputs are not required, and some concessions could be made w.r.t. the reaction time, dexterity and coordination of the pilot.

Autonomous aircraft may require more rigorous planning and supervision, but personnel reaction time and coordination are not a factor. Support personnel may therefore not need to meet many of the requirements of current pilots. The requirements may in fact be better served by a flight dispatcher than by a pilot. Flight dispatchers are licenced in some countries, including the USA. They meet most of the theory requirements for pilots, but are not subject to flight training or the medical requirements for pilots.

It should be noted that some requirements of existing medical certification are not negotiable for remote pilots, specifically those that ensure some degree of resistance against incapacitation in flight. Examples include spells of disorientation or vertigo and seizures.

III. THE CAA INTERIM UA POLICY

South Africa's Civil Aviation Authority has taken some action towards introducing policies to govern UA operations. A Standards Working Group has been assembled and an Interim Policy[1] was published in 2008.

The salient points of this policy are:

1. One Pilot in Command (PIC) must be specified at all times. A distinction is made between external and internal pilots. The terminology refers to a requirement for a separate pilot with direct visual contact during takeoff and landing operations, with another pilot managing the remainder of the flight from inside a control station.
2. The PIC may not require a pilot licence under certain conditions:
    a. The aircraft must operate within 1500 m of the pilot and within 400 feet of the surface in Class F or G airspace. The area must be sparsely populated and not within 3 km of a public airfield or helipad.
    b. The PIC must have completed the theoretical training required for a Private Pilot Licence (PPL).
    c. The PIC must hold a Class 2 medical certificate (equivalent to that required for a PPL).
    d. Visual flight rules only.
3. Supplemental pilots, who may perform pilot functions under supervision of the PIC, must:
    a. Have completed the theoretical training required for a Student Pilot Licence (SPL).
    b. Undergo practical training in normal, abnormal and emergency procedures.
    c. Hold at least a Class 2 medical certificate (equivalent to that required for a PPL).
4. Observers, who may perform functions related to the payload or mission under supervision of the PIC, must:
    a. Have working knowledge of operational requirements (Rules of the Air, airpace classifications etc.).
    b. Hold at least a Class 2 medical certificate (equivalent to that required for a PPL).
5. All pilots must remain current (i.e. acquire ongoing experience) according to an operator-specific procedure approved by the CAA.
6. Provision is made for light UAs up to 150 kg, operating within visual range.

In other portions of the Civil Aviation Regulations (CAR)[7], some provision is made for potential UA operations:

1. Small UAs are exempted from many of the CAR's requirements under a dispensation intended for recreational remote-controlled aircraft.
2. Large UAs are not specifically excluded from pilot licence privileges. There is no requirement that the

PIC of any aircraft must be on board. This fact makes provision for remote pilots without the need to introduce further regulations for pilot licencing.

3. The Convention on which civil aviation is based, specifically stipulates that member states have an obligation to separate unmanned aircraft from manned aircraft to ensure the safety of such manned aircraft, and states that no restrictions on manned aircraft will be introduced to facilitate unmanned operations.

Although CAA published a second document in 2009[3], the regulation process appears to have ground to a halt, pending further progress internationally and in terms of technologies to support the reliable integration of UAs into civil airspace.

In the mean time, much work has been done locally with a view to identifying and developing the required technologies. Work is in progress at Universities (Cape Town, Pretoria, Stellenbosch[4, 5, 6] etc.), by UA vendors (Denel Dynamics, ATE) and by the CSIR (DPSS, MSM and Meraka Institute). The work includes redundancy, autopilots, airframe optimisation, regulatory frameworks, sensor development, conflict avoidance and even speech systems for air traffic coordination.

IV. Existing Pilot Licencing Arrangements

In South Africa, pilot licencing is controlled by the Civil Aviation Authority (CAA). The CAA is included under the umbrella of the Department of Transport, through which the Civil Aviation Regulations (CAR) are promulgated.

CAR Part 61[7] deals specifically with pilot licencing. Provision is made for the introduction of additional Parts in the range of 62 to 69 to cover requirements that may emerge. It is anticipated that a new Part will be created to regulate licencing of UA personnel. No such regulations currently exist.

South Africa already has a parallel licence system for recreational pilots, administered by the Recreational Aviation Association of South Africa (RAASA), described in CAR Part 62[7]. The contents of this Part clearly indicate that the licence system does not comply with standards prescribed by the International Civil Aviation Organisation (ICAO) and the licences issued cannot be used outside South Africa without the explicit consent of the nation in question.

Pilot licences are issued at different levels, commensurate with the privileges being excercised and the responsibility being taken. In general, pilots who take responsibility for others' safety are subject to much stricter requirements.

The licences applicable to aeroplanes are:

- **Student Pilot Licence (SPL):** Can fly solo under supervision, without passengers, by day and within the country.
- **Private Pilot Licence (PPL):** Can fly without supervision anywhere in the world, and can obtain night and instrument privileges.
- **Commercial Pilot Licence (CPL):** Can fly for remuneration.
- **Airline Transport Pilot Licence (ATPL):** Can fly as captain on multi-crew aircraft, including large transport aircraft.

Some licence holders are eligible for further ratings, affording instructor, instrument and test pilot privileges.

There are also specific qualification requirements applicable to the aircraft being flown. In general, these qualifications are issued in the form of category, class and type ratings (CAR 61.01.3)[7].

Categories are quite broad: Aeroplane, helicopter, airship, hot air balloon and glider are examples of different category ratings. Most pilots are confined to a single category. In South Africa, a completely separate licence is required for every category.

Class ratings normally encompass a number of variants or models. In South Africa, an example of a class rating is "Single Engine Piston Land", which includes any piston-engined light aircraft up to 5 700 kg with a single propeller. Pilots can move to other models within this class with relative ease, subject only to system ratings (tailwheel, constant-speed propellers etc.).

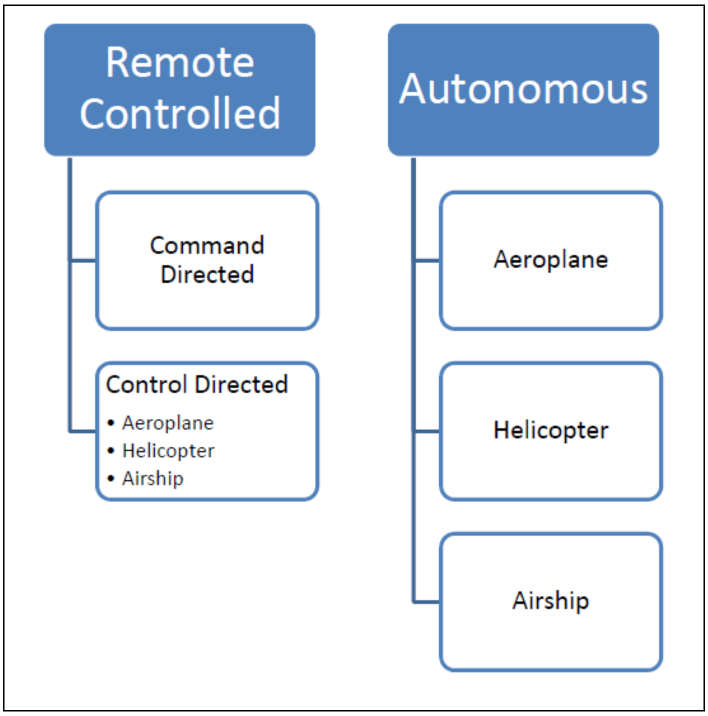
Type ratings apply to sophisticated aircraft, such as jet and large turbopropeller aeroplanes, as well as to helicopters. A pilot has to be trained and tested on a specific type before obtaining a type rating, and is generally subject to recurrent testing.

Unmanned aircraft could be included into the existing pilot licence structure with relative ease by defining a new category or categories (e.g. Unmanned Aeroplane, Unmanned Helicopter) and a structure of type or class ratings. Consideration would also have to be given to the inclusion of provisions for specific ground stations and uplink systems, as well as combinations thereof.

A structure of UA personnel licences could be based on the risk posed by different operations. High-risk operations must be managed by more experienced and knowledgeable pilots, just like with manned aircraft. Risk can be quantified in terms of threats to third parties, which in turn is closely related to the aircraft's kinetic energy, the terrain over which it operates, its proximity to other air traffic and the nature of the payload being carried. Additional restrictions might relate to the airspace being operated in and the flight rules (instrument or visual).

A possible classification of UAs for licencing purposes might be:

Figure 1: Possible UA category and class structure



The solid blue blocks may be construed as UA categories and the white blocks as UA classes within those categories, facilitating accommodation within the existing licence structure. In addition, airframes, payloads, ground stations and link types may all require type ratings.

Single ground control stations capable of controlling multiple aircraft types are not easily categorised. In the case of command-directed UAs, the differences can be made relatively transparent to the pilot, but in the case of control-directed craft, crucial differences in response of any system component might cause difficulties in controlling the aircraft. It is therefore not clear to this author how combinations of ground station and aircraft type could be licenced in anything but an onerous fashion.

In most respects, the licencing systems in various countries are similar. The reason is that detailed guidelines are provided by ICAO, and most countries adhere fairly closely to these recommendations. The introduction of UA personnel licencing is therefore not likely to be more or less complex than in other nations.

V. The National Qualification Framework

No further qualifications are required to exercise the privileges of a pilot licence. However, an effort has been made to harmonise pilot licensing with South Africa's National Qualification Framework (NQF)[8]. The NQF is administered by the South African Qualifications Authority (SAQA), with the intent of providing a uniform framework within which qualifications, education and training can be compared across different industries and fields. The NQF also provides for uniform and objective assessment of candidates, as well as recognition of prior learning (RPL).

Qualifications within the NQF also have a wider scope than a pilot licence, including some training material on life skills, general literacy, decision making, business skills and workload management. Such content is compulsory for all certificate, diploma and degree programmes.

Pilot training traditionally contains no content outside the aviation syllabus.

To achieve this harmonization, a set of Unit Standards has been established for aviation qualifications at different levels. Anecdotal evidence indicates that the strongest driver for this process was to comply with qualification requirements of the Civil Service, rather than to provide any real advantage in the context of aviation. However, personal discussions with training providers in large organisations have indicated that the Unit Standards have contributed greatly to the ability to prove fair and equitable treatment of employees while undergoing training, especially those that do not meet the required standard. Unit Standards provide a set of well-defined curricula, along with well-defined assessment standards.

Each Unit Standard is associated with a specific NQF Level. In general, qualifications up to Commercial Pilot Licence standard are at Level 5, representing an entry-level tertiary diploma, and the Airline Transport Pilot Licence is at Level 6, representing the next level up and comparable to a typical entry-level university degree.

In 2008, the original NQF Act was replaced by a new one. The NQF is being expanded to 10 levels[9], up from the eight levels in force until 2011. The expansion takes place in the upper part of the scale, leaving everything up to Level 4 unaffected. It appears that pilot qualifications may be placed in Level 6 and Level 7 under the new dispensation.

The process is being driven by the newly-established Quality Council for Trades and Occupations (QCTO), which will approve and moderate all future trade-related qualifications under the NQF in future. Unfortunately, pending finalisation of the implementation of the QCTO, level assignments within the NQF are preliminary and subject to change. All further levels referred to in this document are the preliminary levels currently assigned.

Relevant qualifications, in the form of National Certificates and National Diplomas, were identified in SAQA's framework, and investigated for potentially useful Unit Standards.

In some cases, a specific Unit Standard is applicable to more than one of these qualifications. In addition, a specific Unit Standard can be classed within a specific qualification as Fundamental, Core or Elective. As is implied by the names, some of these Unit Standards are compulsory within a specific qualification, while others are elective.

A list of these apparently relevant qualifications is provided below. For each qualification, its NQF level (under the old system) is indicated. It is likely that the NQF levels will increase by one in the new 10-level NQF.

Table 1: Qualifications potentially relevant to UA operations

National Certificates	
Aerodrome Control	NQF 5
Air Traffic Support	NQF 5
Aviation Support Operations	NQF 3
Communications, Navigation and Surveillance Support	NQF 5
Tourism: Cabin Crew	NQF 5
National Diplomas	
Aeronautical Information Management Practice	NQF 5
Aeronautical Surveillance Systems: Engineering Support	NQF 6
Air Traffic Control	NQF 6
Aircraft Performance Engineering	NQF 6
Aircraft Piloting	NQF 5
Aircraft Piloting	NQF 6
Communication and Navigation Systems	NQF 6
Flight Dispatch	NQF 5

The next step was to extract a list of 139 Unit Standards applicable to these qualifications and manually investigate each of these Unit Standards for relevance to UA operations. These Unit Standards are all published by the Aerospace Operations SGB (Standards Generating Body).

The result was a list of 19 unit standards that appeared useful:

- Four Unit Standards apply to on-board actions such as passenger care, and are therefore not applicable to UA requirements.
- Four Unit Standards will require modification to adapt them to the requirements of some UA pilots.
- Another two areas were identified that will require development of new unit standards.

The existing Unit Standards provide a good match to the requirements of UA pilots, especially for command-directed UAs. However, for control-directed UAs some modification of content will be required.

For dispatch personnel and for supervisors of autonomous aircraft, the usefulness of the existing Unit Standards is limited.

The discussion revolves only around the Unit Standards from the Aerospace Operations SGB. Many more Unit Standards will be included in a typical qualification, but they are not included in the discussion because they are generic in nature and will be dictated by the requirements of the NQF level rather than by the specifics of aerospace operations.

Unit Standards deemed useful to the requirements of UAs are listed below:

Table 2: Unit standards potentially relevant to UA operations

Title of Unit Standard	Applicability		
	Auto	**R-Cmd**	**R-Ctl**
Apply safety principles for flight operations	Core	Core	Core
Control aircraft by visual reference in normal flight		Core	Core
Manage aeroplane emergency situation	Elec	Elec	Elec
Manage flight environment	Core	Core	Core
Manage non-normal and emergency flight situations	Core	Core	Core
Operate an aircraft in the airport environment	Core	Core	Core
Perform advanced manoeuvres and procedures in an aeroplane		Elec	Elec
Perform aerobatic manoeuvres in an aeroplane			Elect
Perform low-level flying operations	Elec	Elec	Elec
Perform night-flying operations	Elec	Elec	Elec
Perform planning for an IFR flight	Elec	Elec	Elec

The applicability of each Unit Standard (Core or Elective) is as it is currently applicable to that qualification.

The following Unit Standards are deemed useful for Control-Directed remote control UAs, but will require modification for Command-Directed remote control UAs:

Table 3: Unit Standards requiring modification for Command-Directed UAs

Title of Unit Standard	Applicability		
	Auto	**R-Cmd**	**R-Ctl**
Demonstrate understanding of CRM	Mod	Mod	Mod
Perform aeroplane takeoffs, landings and go-arounds			Elect
Perform flying manoeuvres by sole reference to instruments		Mod	Core
Perform slow flight, stalls and spin recoveries in an aeroplane		Mod	Elec

"Auto" refers to autonomous UA supervisors.

"R-Cmd" refers to command-directed remote-controlled UA pilots.

"R-Ctl" refers to control-directed remote-controlled UA pilots.

"Elect" means elective content, mostly applicable only to aeroplanes.

"Mod" means unit standards that must be modified for applicability to the class of personnel indicated. In general, the detailed level of knowledge required for control-directed operations are not necessary for command-directed operations.

The modifications required are as follows:

- "Demonstrate Understanding of CRM" applies to Cockpit Resource Management, the term used to describe human factors in aviation. Typical CRM courses, including this one, focus on interaction within the cockpit to some extent. This focus may be applicable to multi-operator ground stations for remote-controlled UAs, but the more typical situation would require more emphasis on single-pilot decision making and the pilot's interaction with the outside world. Such doctrine exists in current pilot training, but will have to be adapted to the UA arena.
- "Perform flying manoeuvres by sole reference to instruments" and "Peform slow flight, stalls and spin recoveries in an aeroplane" can be simplified considerably for Command-Directed UAs, pilots do not have to understand intricacies such as non-linear flight characteristisc in the stall, control reversal, aileron drag and the wrong side of the drag curve. The UA can deal with these details automatically and can provide envelope protection to ensure that it does not deviate from the intended flight path.

In addition, Unit Standards will have to be developed to cover the following topics:

- **Link technologies and limitations:** Every link type has different behaviours, limitations and advantages. Pilots will have to deal with latency, line of sight, range issues, interference and a plethora of other technicalities that are not covered in current pilot study material. Examples include susceptibility to jamming and limited situation awareness ("drinking straw effect", the tunnel vision which causes the pilot to be completely unaware of anything outside the camera's field of view).
- **Jurisdiction issues:** Such issues are potentially fraught with difficulty, as the control station and aircraft could be made by different manufacturers in different countries. These components and the pilot might all be of different nationalities and based in countries different from their origins. As many as a dozen countries could be involved in a single flight in one way or another.

Once all the relevant Unit Standards are available, they must be combined, along with a number of generic Unit Standards, into a new qualification or series of qualifications for UA personnel.

None of these interventions will happen in the short term, as all approvals of qualifications have been frozen pending the establishment and functioning of the QCTO.

VI. Flight Training for UAs

Because no visual context apart from displays in the ground station is provided to pilots of UAs, simulators can provide near-perfect realism. The pilot may indeed not even be aware that he or she is not controlling a real aircraft!

As such, ground stations could easily include built-in simulation capability that would facilitate zero-time flight training. If insufficient visual fidelity is provided in the camera link simulation, limited flight training with the actual UA may be required.

For external pilots, those controlling takeoff and landing operations, simulation is harder, but given the duration required to master those skills, training on the aircraft appears feasible. The required skills overlap to a great extent with the skills required to pilot recreational radio-controlled aircraft.

VII. FAA Flight Dispatcher Qualifications

South African flight dispatchers are not licenced formally. There is no provision in CAR for such licencing and the National Diploma: Flight Dispatch contains content mostly not germane to the duties of UA personnel. The syllabus includes much emphasis on basic life skills including learning methods, maintaining relationships and teamwork. The qualification might prove useful for staff support UA operations, but does not include enough specific information about flight performance to allow direct supervision of a flight.

However, in comparing South African licencing provisions with those elsewhere, it became evident that the US Federal Aviation Administration's Flight Dispatcher Certificate, as regulated by 14CFR65C (Title 14 of the Code of Federal Regulations[10], Part 65, Subpart C) is eminently suitable.

The following requirements apply to applicants for the Flight Dispatcher Certificate:

- **Age:** At least 23 years.
- **English:** Proficient in English.
- **Training Course:** Attended a course with a minimum duration of 200 hours.
- **Experience** over two of the past three years in aviation, such as an Air Traffic Controller (ATC), Meteorologist or flight support member.
- **An examination:** Regulations; Meteorology; Information collection, dissemination, collection and use; Use of charts, reports etc.; Weather service; Windshear and Microburst; IFR operations; ATC; Aircraft loading and performance; Aerodynamics; Human factors; Decision-making and judgement; CRM.
- **A practical test:** Flight planning and dispatch release; Preflight, takeoff and departure; Inflight procedures; Arrival, approach and landing procedure; Post-flight procedures; Abnormal and emergency procedures.

In comparison, the National Diploma: Flight Dispatch is much broader and does not contain the same depth of aviation knowledge that the US FD does. It is therefore not regarded as suitable for this purpose.

The development of a qualification within the NQF is not necessary for licencing of UA personnel. As such, the CAA could relatively easily adapt the requirements of 14CFR65B to local requirements and implement a licence through a suitable CAR Part in the 60 to 69 range.

VIII. Questions to be Answered

1. **Are currently-proposed medical standards realistic?** Overly-strict medical requirements could deny an entire pool of suitable candidates access to the UA world. Many of the requirements for dexterity, vision and balance could be construed as being irrelevant to the specific requirements of UA operations.

2. **Should passenger handling be included in the UA licencing framework?** Probably not. Passenger transport in UAs will not happen any time soon. Existing CAA requirements also already address this requirement. However, thought must be given to building a licencing structure that will not require a major re-think once passenger services are introduced.

3. **How must the liability issues be addressed?** UA operations are fraught with difficulties associated with liability. The control station, aircraft, operator, passengers and pilot might all be of different nationalities, different from that of the country where the aircraft is operating. What happens if errors occur with a handover from one ground station to another? How should link hijacking and Denial of Service attacks be handled?

4. **How do we cultivate new pilots?** Some airlines now use an apprenticeship programme with a duration of up to 15 years. How do we cultivate mature commanders in sophisticated operations without this mentorship? Can the requirement be addressed purely through simulation?

IX. Contextual Remark

The feeling is often expressed in UA circles that work on personnel licencing and regulation of UAs in civil airspace is premature. While it is likely that it will take many years before unfettered UA operation in civil airspace is a reality, the regulatory processes take many years.

If these regulatory processes are not initiated timeously, we could end up with mature technology and potent aircraft, still unable to fly because of regulatory constraints that have not remained abreast of developments.

X. Conclusion

Existing pilot licencing regulations and standards can be adapted to the requirements of unmanned aircraft with relatively little modification. The article provides specific guidance on work that needs to be done to implement such changes, at least for the requirements of unmanned aeroplanes. A similar approach can be adopted for unmanned helicopters and other aircraft.

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