ACCIDENTS PAST, ACCIDENTS FUTURE: SAFETY IN THE AGE OF UNMANNED AVIATION

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September 5, 2019

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Introduction

The theme of the 2019 ISASI Annual Seminar is “Future Safety: Has the Past Become Irrelevant?” This is a timely and necessary issue to take up in the context of unmanned aviation. There are few directly relatable lessons learned upon which to base a path forward for the certification and operation of remotely piloted aircraft systems (RPAS).(1) Still, countless analogies can and should be drawn to the evolution of *manned* aviation and the history of major aviation accidents to date in considering how RPAS should join and participate in the greater flying community. At the same time, the historical record is extremely important as a means of avoiding repeating in the unmanned domain errors first identified in manned aviation.

Throughout the first century of powered flight, aviators and engineers constantly ran afoul of what they did not know about the flying environment, the demands it put both pilots and aircraft, and the complexities of keeping ever-faster and more numerous aircraft safely separated from one another. Painful but essential lessons were learned through accidents and their investigations. Perhaps most important, the speed with which aviation expanded and evolved tended to reduce the likelihood that important preventive measures, once implemented, subsequently would be abandoned. Lessons learned throughout aviation’s brief history for the most part have *stayed* learned.

Against this backdrop of hard-won experience, it seems reasonable to assume that new entrants into the aviation environment would seek all available information to understand its hazards, and regulators would ensure that the rules under which new entrants are granted access would be applied fairly and uniformly. Indeed, this has been the case for generations as the framework for allowing experimental and homebuilt aircraft and less comprehensively trained pilots has evolved to incorporate all safely into the overall aviation system.

At its core unmanned aviation is just another form of aviation, and unmanned aircraft are just a different breed of aircraft. However, the "unmanned aviation sector" is a very different collection of interests, with very different priorities, than the pioneers of manned aviation. Its proponents and practitioners have consistently sought to operate as free of regulatory constraints as they can.

Two seemingly conflicting arguments regarding unmanned aviation frequently are raised in advocating for widespread expansion of the unmanned sector. The first is that RPAS can safely be employed in support of a wide range of "integrated" operations, including those currently carried out by manned aircraft. The second is that unmanned aircraft should be allowed to operate at will in any class of airspace, with minimal obligation to adhere to existing rules governing pilot qualification, system certification, aircraft equipage, or even the conduct of aviation operations themselves.

In consideration of these two contradictory perspectives, this paper seeks to re-emphasize the importance of history in the growth of unmanned aviation by addressing two key questions with respect to the relevance of past experience:

1. Should lessons from past accidents, or even very recent accidents, involving manned aircraft be applied to making unmanned aviation safer?
2. Are past accident scenarios in danger of being repeated due to the expansion of minimally regulated unmanned aircraft operations in the midst of manned aircraft?

Safety Developments in Manned Aviation: A Brief Overview

The successful growth of aviation always should be looked at through the prism of the advances in safety that supported its progress. The viability of *commercial* aviation itself is directly traceable to public confidence in it as a safe and reliable form of transportation. If aircraft accidents continued to occur at the rates seen during the 1930s, the commercial airline industry itself never would have been more than an expensive and risky niche instead of an integral part of global commerce.

It always is appropriate to revisit how the current level of safety in aviation has been achieved, including *why* we do some of the things we do in certifying aircraft and regulating their operations. Many accidents that led to new rules and preventive measures have themselves receded into the past, so it is valuable to be reminded from time to time that little in the body of rules governing aviation is arbitrary or capricious

Consider how aviation and aircraft benefited from examination of safety needs identified through crashes and their investigations. There always has been overlap among these issues, of course, but the challenges to be dealt with moved forward along the following general lines:

1. Make airframes strong enough to withstand the stresses of flight.
2. Make engines as reliable as possible.
3. Find ways of making operations at night and in adverse weather practical and safe.
4. Find ways of protecting the occupants of aircraft from harm during normal and adverse conditions.
5. Develop means of managing growing numbers of aircraft in the vicinity of airports.
6. Develop means of monitoring aircraft movements over large distances and long routes.
7. Identify areas requiring surveillance to keep aircraft separated.
8. Identify environments within which civil and military operations might come into conflict and develop rules and procedures applicable to both.
9. Establish requirements for IFR and VFR operations that protect the former while enabling the latter.
10. Establish requirements for airspace based on the control and safety challenges different densities and complexity of traffic can create.

Each of the above has seen incremental and occasionally revolutionary improvements over time, often resulting in both safety *and* economic benefits. For example, aircraft construction techniques have become steadily more sophisticated, increasing strength and occupant protection while reducing weight. The incorporation of turbojet, and later fanjet technology into airliner design allowed maximum gross takeoff weights and corresponding cabin and cargo revenues to increase, even as their relative simplicity increased their reliability and, eventually, their efficiency. Communications, navigation and surveillance capabilities have evolved – sometimes individually, sometimes in parallel – to make air traffic management steadily more efficient while providing both greater system capacity and safe separation.

Sharpening the focus on safety, new aircraft are certified in consideration of experience accumulated over time. Those incorporating new materials or manufacturing processes are subject to close review of their novel attributes and have to prove their safety against long-standing standards suitably adjusted to gauge <u>performance</u> as opposed to conformity to possibly outmoded guidance. This is a realistic approach to balancing the need to minimize risk with the need to encourage innovation, again developed through careful consideration and years of experience adjusting certification standards as needed in response to both identified hazards and new technology. **The past matters.**

Are Manned and Unmanned Aircraft Different?

As we move from the development of manned aviation toward the blossoming of unmanned aviation, this would seem to be a purely rhetorical question with an obvious answer. Unmanned aircraft are dependent on either extensive and inflexible pre-programming or a two-way datalink allowing a "remote pilot in command" (RPIC) to control and maintain situational awareness in the operation of the unmanned aircraft. Unless an unmanned aircraft is explicitly designed and expensively equipped to clear its own flight path, it *must* have either a functioning datalink or totally segregated or protected airspace to allow the RPIC to avoid in-flight conflicts or even midair collisions with other aircraft. Clearly, unmanned aircraft are different from manned aircraft… right?

The real-world perspective on these differences – each of which represents a limitation that is not necessarily compatible with how the current aviation system works – is more nuanced, seeking to accommodate unmanned aircraft despite their limitations. However, such a supportive approach also provides potentially unwarranted latitude to unmanned aircraft for shortcomings that would be completely unacceptable for manned aircraft.

In many States, an unmanned aircraft simply is, by definition, "an aircraft." Various qualifiers often are added to that fundamental proposition to account for the limitations mentioned above, but the idea behind starting with the same basic definition is that existing operating rules and certification standards rules can (and should be) applied equally, regardless of whether an aircraft has a pilot aboard the aircraft or on the surface of the Earth.

This ideal environment has yet to be achieved. There is little motivation on the part of the unmanned aviation sector to pursue it, especially to the extent that mandatory equipage associated with specific classes of airspace would cost them money to install, and more money to make operate through satellite-based datalinks or terrestrial networks. It also would reduce range, endurance, useful payload, or all of the above. To them, "integration" often is seen simply as an alternate term for "access to desired airspace," not participation in the xisting aviation system.

One of the major advantages of unmanned aircraft systems is that they cost less to build, less to maintain and less to operate than manned aircraft. These savings often are achieved at the expense of being significantly less capable than the manned aircraft whose airspace they share. However, in facilitating more widespread operations of RPAS regardless of their differences, there is the not inconsequential precedent of permitting some activities that are known to be more hazardous than others based on "societal benefits" asserted to justify them.

As the ICAO *UAS Toolkit* observes, "As a regulator, recognizing the societal benefits of UAS and the need to facilitate operations in a safe manner are key and include: humanitarian efforts, search and rescue, firefighting, infrastructure monitoring and research and development (R&D). Operations limited to VLOS operations may limit benefits obtained by carrying loads or discharging substances (e.g. crop dusting, insect control). (2)" Of course, this perspective sidesteps such practical implementation considerations as both manned and unmanned aircraft performing the same operations in the same airspace at the same time, and is essentially silent on the larger question of *risk*.

In 1962, ISASI's esteemed founder, Jerome Lederer, presented a lecture on "Perspectives in Air Safety" on his receipt of the Daniel Guggenheim Medal from ASME. He asked a number of questions about risk throughout this talk, all of which resonate in the current debate about unmanned aviation. For example, when considering instances where a production aircraft is found to need a safety-related modification:

> The aviation industry resents and protests over-regulation and is prone to combat detailed regulation of the nature that would have overcome [such a] deficiency. But what is the FAA to do when it finds good safety practices developed by one organization not adopted by others, yet both comply with the regulations?...
>
> Should the government, in such cases, step in retroactively to correct a known hazardous situation by changing the regulation, making it more specific? One should be careful not to discourage original thinking, imagination, and ingenuity, which may lead to improved practices. Should the public, therefore, be asked to assume some risks for the sake of progress?... The solution to such problems should not lie entirely in the domain of government regulation in a free society." (3)

It is important to acknowledge that a very high-level risk decision already has been made regarding unmanned aircraft operations: <u>they are permissible and will be allowed to continue</u>. From a "prevention" perspective, this is by no means an inconsequential part of the landscape.

There is no doubt that some types of aviation operations undoubtedly are safer to carry out using unmanned aircraft than is the case with manned aircraft, even using relatively simple RPAS. It also is undeniable that the lack of a human life at risk aboard an unmanned aircraft allows a different perspective on how and from what platform such operations should be carried out. To date only a bare handful of accidents have been attributed to manned and unmanned aircraft sharing the same airspace while operating under different rules. However, such occurrences are easy to envision as UAS operations become more common as long as manned and unmanned aircraft are regulated and operated differently.

Thinking About the "Manned" Past to Prepare for the "Unmanned" Future

At this point, it may be best to restate the first of the two questions asked at the start of this paper as, "In what ways do unmanned aircraft systems need to be more or less the same, in terms of capabilities and operating rules, as manned aircraft in the interests of aviation safety?" To date, there is no generally accepted answer to this question. This is fertile ground for exploring through the lessons of manned aviation and historical accidents.

To start with, consider two propositions:

1. What has come to be considered a shared perspective on aviation safety – a common basis for a "safety culture" – is *not* shared by the unmanned aviation sector except to the extent they are obliged to conform to it.
2. A complex system like aviation is only as safe as its least safe component.

The first proposition might be hotly contested by the more professional operators and manufacturers of unmanned aircraft systems. They could argue, rightly, that they do whatever is asked of them to gain access to airspace. This is true but somewhat disingenuous. Unmanned aircraft cannot conform to many rules of certification or operation currently in force, meaning they must seek permission to operate that is conditioned by mitigations for their various limitations (or simply accepts the increased risk associated with them). Since unmanned aviation business models and risk calculus are quite different from those of manned aircraft manufacturers and operators, they tend to seek to avoid complying with any requirements not explicitly for the safety of the overarching aviation system and all of its stakeholders.

Manned aircraft pilots are rational actors; they have never been big fans of dying. Aircraft manufacturers are rational actors; they never have been interested in seeing large judgments against them for unreliable designs that have led to losses. Commercial air carriers are rational actors; they will not engage in operational behavior that is likely to place their passengers in jeopardy, or even to make them uncomfortable in flight.

In unmanned aviation, risk decisions are driven by different considerations, and the priorities of the manufacturers and operators come from a significantly different direction. If one digs deeper it becomes clear that, from a regulatory perspective, there is a certain logic in placing less of a burden – a "price of admission," if you like – on RPAS operators willing to accept a certain amount of loss in the course of their operations, as long as those operations do not pose a hazard to the general public or to other users of common airspace.

However, problems arise when lessons from the past that speak to current or emerging hazards are not recognized as such, and a hands-off regulatory approach can result in minimally regulated operations interacting with those regulated on the basis of previously identified need. The present interest in enabling and encouraging the growth of unmanned aviation means RPAS are being regulated with as light a touch as possible, often with the regulators taking on more risk on behalf of the public than would be considered acceptable for manned aircraft and operations.

While this pattern of benign neglect may survive the first catastrophic accident directly attributable to an unmanned aircraft, it will be unlikely to survive a second. Public outcry for rapid, decisive and effective action will then place national aviation authorities in the difficult position of having to justify their previous risk decisions (economic benefit to the UAS sector versus risk to existing stakeholder operations).

More important, however, is the likelihood that the permissive *status quo* no longer would be acceptable to the general public. Identifying and implementing credible preventive actions will be essential to restoring public confidence in regulators and minimizing overreactions that actually could harm the unmanned sector more than the *laissez-faire* approach has helped it. This is where lessons learned from past accidents involving manned aircraft will have to be *re*-learned.

The Lessons of History

Since the aviation enterprise as a whole is notoriously slow to act on safety concerns until catastrophes force action, the air safety investigator community needs to be ready to highlight where unmanned aircraft system development and certification requirements have diverged from those of manned aircraft. Past accident reports will need to be dusted off and re-examined as "new" unmanned aircraft accidents, or those where unmanned aircraft are involved, occur where long-standing adjustments have been made to rules governing manned aircraft.

For this approach to bear fruit, however, it is crucial to consider *how* those manned aircraft accidents occurred, along with the specific changes made to aircraft, the regulatory environment, human-machine interfaces, and pilot training and certification that arose from their investigations and recommendations. The fundamentals – the nature of known risks and the detailed sequence of events documented in similar previous accidents – will be critical in such cases.

Both regulators and the general public often forget that many aviation-related rules have been written in blood and derived from accident investigation recommendations. In the aftermath of aircraft accidents, air safety investigators often are obliged to consider both previous risk decisions and prior accident investigations whose recommendations were not acted upon. It would seem prudent to do likewise in consciously addressing the latitude accorded unmanned aircraft in the same of "growing the sector" before the pressures and passions of a new investigation come into play.

ICAO's *UAS Toolkit* offers a good starting point for discussions between ASIs and regulators: "States will want to make key policy, technical, regulatory and programming decisions for UAS operations. A determination will need to be made as to what extent UAS regulatory proposals will need to adapt to conventional aviation rules, parameters, procedures and practices. Consideration should be given to whether existing standards and regulations which govern the operation of manned aircraft can be leveraged, while also addressing the specific and unique needs and characteristics of UAS. When building a regulatory framework for UAS, it is important to ensure that the new regulations do not contradict existing aviation regulations." (4)

If it is not possible to examine the course of unmanned aviation's growth in the greater airspace system prior to an accident, air safety investigators will need to have done at least a little advance thinking about how to proceed. The objectives of the accident investigation process can be summarized in two straightforward steps: identify causes, and make recommendations to prevent recurrence. Accidents involving unmanned aircraft – especially where loss of life occurs – will require two additional steps:

1. Determine whether the sequence of events might have been different had a manned aircraft been the subject of the investigation
2. Determine why any difference between manned and unmanned aviation requirements or rules identified in the sequence of events exists.

As observed above, it has been critical to accident investigations over time to identify instances where the act of flying itself has encountered unknown hazards and the expansion of aviation has created unrecognized hazards. In the past, the governing principle was, "You don't know what you don't know." In future investigations involving unmanned aircraft systems, it is likely that at least some of the accident sequence will be uncomfortably familiar, and the question to be answered might be, "Why didn't we see this coming?"

The Power of Analogy

In preparing this paper, it became clear that it sometimes can be difficult to align previous accidents and preventive actions involving manned aviation against the unmanned sector. It would be a relatively simple matter to inquire into an accident involving, say, an unmanned aircraft lacking required two-way communications and a transponder colliding with a properly equipped manned aircraft in controlled airspace. The ASI simply would ask why the former was operating under less stringent requirements than the latter and place the decision made and their consequences in their proper chronological perspective.

However, if one applies the principles of system safety in reverse, it is clear that rules and training typically are the *last* hazard controls to be imposed on a system. They typically are far less effective than those associated with earlier stages in the life cycle – developing warning systems, modifying a system to eliminate a hazard or, most desirably, designing the system to avoid encountering the hazard in the first place.

Many of the design decisions that have resulted in unmanned aircraft not having air traffic-related avionics, or in some cases lacking redundant controls, standardized pilot interfaces and other features commonly found aboard manned aircraft are a direct result of how UAS are certified (or not certified). In other instances, it is the nature of unmanned aircraft themselves (lacking a pilot on board who can assume control of an aircraft in an emergency, directly perceive the environmental conditions affecting it, etc.) that can result in an unmanned aircraft becoming unrecoverable, experiencing a progressively deteriorating condition or system failure, or otherwise operating in a manner counter to that intended. For these reasons, it is worthwhile to consider *outcomes* – some of which have been declining steadily for decades – against potential new sources of failures or initiating events that can lead to those outcomes.

Most categorization approaches to accidents have relied on identifying types of events that the aviation community wants to reduce or prevent. For example, the *CAST-ICAO Common Taxonomy Team* list of "Aviation Occurrence Categories" (5) lists more than 30 types of events. Only about half of these would seem to be of importance to regulators *or* RPAS operators simply because they do not have to worry about the lives of people aboard their aircraft (yet) and the latter's risk tolerance for certain types of losses is correspondingly higher.

At the same time, this taxonomy – like so much of the current aviation enterprise – is based on certain assumptions that have become embedded in aviation thinking through decades of experience and common practice, including some based on accident experience. As such, it does not readily highlight certain types of accidents whose underlying causes might derive from the uniqueness of unmanned aircraft systems, except in very general terms. Some creative thinking, and a fairly detailed understanding of how unmanned aircraft systems work, must be applied to "occurrence" based templates. This may be done prior to or in the midst of an accident investigation, but some preparation is needed to engage in such "what if" strategizing effectively.

As an example, the current emphasis of ICAO's *Global Aviation Safety Plan* is on improving runway safety, reducing controlled flight into terrain (CFIT) accidents, and reducing loss of control in-flight accidents. (6) EUROCONTROL maintains lists of exemplar accidents associated with each of the above that can be found on www.skybrary.aero. Interestingly, these three types of accidents have been quite resistant to preventive efforts over time, but not for lack of attention paid to them.

For Skybrary, EUROCONTROL had no difficulty assembling a representative list of fatal CFIT accidents solely from occurrences since the beginning of the 21st century. Their list of runway operations accidents is much longer and includes a number of events that fairly may be considered "landmark accidents," e.g. the Tenerife tragedy, a Boeing 737 landing on top of another aircraft at Los Angeles, and other accidents involving occupied runways and miscues by pilots and/or air traffic controllers.

CFIT accidents would seem to be unlikely in routine RPAS operations, especially those using platforms that are equipped with comprehensive position-tracking provided to their RPICs. Now, think about what happens if the command and control (C2) link fails and the aircraft reverts to a pre-programmed mode of operation ("lost link profile"). Terrain awareness and warning systems (TAWS) are neither typically provided nor mandated for any type of RPAS. So, given that a C2 link failure takes the RPIC entirely out of the control loop, and the aircraft might "decide" to take up a heading, airspeed and altitude from its present position that would take it to a pre-programmed point in space, regardless of the possibility of intervening terrain or surface features, how unlikely might an RPAS CFIT be?

Runway environment hazards pose a different set of challenges for unmanned aircraft. C2 links tend to be bandwidth-hungry, meaning only flight-critical functionalities might be in "protected spectrum" If the only camera aboard is part of an unmanned aircraft's payload, it may not be available for ground operations, or may not provide an adequate field of view for safe taxiing. If towed into position on an active runway, RPAS may interfere with other operations or require other aircraft to yield to them.

On final approach, an unmanned aircraft may directly observe its touchdown point, or it may fly in a more or less purely automated mode to a GPS-defined touchdown point. In other words, mixed UAS and manned operations at an airfield could result in a whole range of challenges distinct from those that have occasioned such concentrated attention on runway safety over time.

Perhaps most interesting from both historical and prevention perspectives in the context of unmanned aviation is the Skybrary recap of causes seen in a whole range of "loss of control – inflight" (LOC-I) accidents, which includes all of the following:

- Loss of situational awareness
- Low level wind shear or higher level Clear Air Turbulence (CAT)
- Structural or multiple power plant damage (including that suffered during midair collisions)
- Intended or unintended mishandling of the aircraft
- Attempted flight with total load or load distribution outside of safe limits
- Unintentional mismanagement of aircraft pressurization systems
- Takeoff attempts with ice contamination
- Airframe ice accumulation / significant loss of power attributable to engine icing
- Attempting to maneuver an aircraft outside its capabilities to resolve a prior problem
- In-flight fire
- Fuel exhaustion or starvation
- False instrument readings
- Wake turbulence
- Pilot-induced oscillation
- Malicious interference (7)

When one familiar with unmanned aircraft systems looks at this list, it is immediately obvious that UAS are vulnerable to many of the same conditions, albeit for many different reasons. Chief among them is the RPIC's inability to directly perceive what is happening to the aircraft from moment to moment. However, even as work continues apace on addressing these issues in manned aviation, it is clear that preventive or corrective measures that might be effective in that domain may be completely inadequate for unmanned operations.

One of the great virtues of unmanned aircraft is that many are inherently *more* stable than manned aircraft under normal conditions. On-board automation provided in many makes them extremely effective at stabilizing themselves, responding to transient conditions that might take them off their programmed course, etc. However, some of their design features – such as supercritical wings and satellite antennae subject to "fuselage blanking" in some attitudes – render them vulnerable to unexpected departures from controlled flight.

Experienced UAS pilots often can diagnose structural problems, inadvertent gear extensions and the like through close monitoring of the need for unusual throttle settings, higher than normal fuel consumption, or a constant need for heading or altitude corrections.

Summing Up

Current conversations about the effects of unmanned aviation on airspace include a significant amount of incompletely informed – and occasionally misleading – blurring of existing distinctions between "small" RPAS and larger unmanned aircraft seeking to operate side by side with other aircraft, especially in controlled airspace. There is a not inconsiderable amount of risk associated with those at the small end of the size and weight spectrum interfering with terminal operations at low altitude, especially when permitted to operate in that environment more or less at will and without the possibility of being "seen" either visually or electronically. Addressing the hazards those operations present mostly will be matter of looking at the history of midair collisions, rules (including mandatory equipage) developed over time to prevent them, and the deference such operations receive and should receive in that environment.

On the other hand, unmanned aircraft asserting a need or a "right" to operate amid other aircraft, whether receiving air traffic services or flying purely under some interpretation of "visual flight rules," represent an entirely different challenge. Current aviation stakeholders can and should consider the rules they are required to follow; regulators must take an objective look at how much relief from rules unmanned aircraft operating in shared airspace should enjoy, and how much is warranted. In making such determinations, the past will continue to matter.

Finally, attentive readers undoubtedly have noticed that the second question posed at the start of this paper has yet to be directly addressed: Are past accident scenarios in danger of being repeated due to the expansion of minimally regulated unmanned aircraft operations in the midst of manned aircraft?

The author's view is that the answer to this is a qualified "yes." The protections built into the present-day aviation system are far more robust than they used to be, although the foundation of RPAS "detect and avoid" technologies rests on understanding that it is not enough for unmanned aircraft to "see" only aircraft emitting transponder or Automatic Dependent Surveillance – Broadcast (ADS-B) Out signals; they must be able to actively detect non-emitting aircraft as well.

Current generation transport category aircraft use aircraft collision avoidance systems (ACAS) only can detect aircraft equipped with transponders. Therefore, it is possible to envision RPAS given relief from the requirement to be equipped such avionics on the basis of their not being designed or certified with them. The current architectures of both the Single European Sky ATM Research (SESAR) Joint Undertaking and the U.S. Next Generation Air Transportation System (NextGen) heavily rely upon participating aircraft being comprehensively equipped to serve as interactive nodes of trajectory information upon which optimal clearances for all aircraft may be based. Again, if equivalent equipage requirements are not imposed upon unmanned aircraft, they will be effectively invisible to all other aircraft in the system.

It is possible to envision a scenario similar to that seen in the tragic 1986 collision of an Aeromexico airliner and a general aviation (GA) aircraft over Cerritos, California. (8) The former was operating under instrument flight rules in the Los Angeles terminal control area (TCA), the predecessor to the current Class A airspace; the latter was operating legally under VFR, but strayed into the TCA. Most GA aircraft at that time lacked Mode C pressure reporting transponders, and the profusion of 1200 "VFR" targets flying under the TCA boundaries complicated the air traffic controllers' task immensely.

The Cerritos accident resulted in quite a few changes in the U.S., including creation of the "Mode C veil" concept and more stringent communications requirements for VFR aircraft flying in Class B and C airspace. However, it also highlighted the distraction inherent in having numerous transponder targets flying outside airspace for which ATC was responsible. The potential for repeat accidents led many facilities to suppress display of targets below a certain altitude to avoid clutter, which in turn may indirectly have led to the FAA's new guidance to controllers that air traffic services are not provided to unmanned aircraft below 400' AGL. (9)

Small unmanned aircraft bring with them their own unique issues, but also can be managed to some extent by keeping them as segregated as possible from manned aircraft. This approach cannot work for RPAS flown *among* manned aircraft. In those cases, history has taught many lessons that apply to all flying, regardless of the pilot's physical location. The aviation community would be wise to reflect on them as unmanned aircraft operations continue to expand.

ENDNOTES

(1) There is a lively debate taking place around the world regarding the proper nomenclature for aircraft whose pilots are not aboard or inside their aircraft. The terms "unmanned aircraft system" (UAS) and RPAS are used more or less interchangeably, along with the far

less precise term "drones." Even the International Civil Aviation Organization (ICAO) has created formal documents using both terms.

(2) https://www.icao.int/safety/UA/UASToolkit/Pages/Narrative-Background.aspx.

(3) Jerome Lederer, "Perspectives in Air Safety," Daniel Guggenheim Medal Award Lecture, ASME Aviation and Space Conference, Washington, DC, 1962, pp. 9-10.

(4) ICAO *UAS Toolkit*, para 2.2. (https://www.icao.int/safety/UA/UASToolkit/Pages/Toolkit-Operations.aspx).

(5) http://www.intlaviationstandards.org/Documents/OccurrenceCategoryDefinitions.pdf.

(6) ICAO Document 10004, 2017-2019 Global Aviation Safety Plan, paragraph 1.2.3. (https://www.icao.int/Meetings/a39/Documents/GASP.pdf)

(7) https://www.skybrary.aero/index.php/Loss_of_Control.

(8) http://libraryonline.erau.edu/online-full-text/ntsb/aircraft-accident-reports/AAR87-07.pdf.

(9) FAA Order JO 7110.65, *Air Traffic Control*, para. 2-1-1e.