An Essay on Unmanned Aerial Systems Insurance and Risk Assessment

Jason Knight
Southwestern Law School
Los Angeles, California 90010
Email: jknight@swlaw.edu

Brendan Smith, *Student Member, IEEE* and YangQuan Chen, *Senior Member, IEEE*
MESA Lab, University of California, Merced
Merced, California 95343
Email: bsmith24@ucmerced.edu, ychen53@ucmerced.edu

***Abstract*—UAV technology has begun to integrate into the National Airspace (NAS), at an accelerated rate. Coupled with a high demand for civilian UAS applications and decreasing component prices, more UAS researchers, commercial operators, and manufacturers begin to fly. Despite a lack of government mandated insurance requirements and mission profiles deemed dull, dirty, and dangerous, the UAS industry is gaining momentum. However, as the UAV industry matures, unmanned aircraft will inevitably crash. In anticipation of these growing pains, insurance carriers must be ready. Unmanned aircraft present a unique matrix of risk endemic to the challenges of flight in the NAS. Underwriters and actuaries will be able to provide peace of mind to pilots and bystanders alike. Insurers must design policies to properly allocate liability and provide a safety net. UAS-tailored coverage will identify and quantify the unique characteristics of unmanned aircraft. Underwriters have just begun to adapt insurance products to suit the needs of the nascent sector. This analysis will outline the process of insuring UAS. Further, it will highlight how insurance companies should cope with the dynamic forces within the UAV market.**

I. Introduction

UAS risk management is a large sector in flux. Though the FAA has not moved to impose minimum insurance requirements, underwriters are rushing to fill the void. Though UAS risk assessment may seem trivial, the obvious risks of personal injury and property damage loom. Like manned aircraft, UAS are sensitive and subtle instruments that carry hefty repair and replace costs. Therefore, insurance companies must consider UAS to be comparable to small or ultra-light aircrafts. Since several factors make up the UAS risk matrix, underwriters will take into account who is liable for when a mission fails or causes injury. Problems should be initially divided into two categories of fault, Pilot-In-Command (PIC) and manufacturer (hardware/software malfunction) liability. As the FAA and local legislatures develop a concrete legal framework for these risks, the insurance industry must remain ready and flexible.

II. What Makes Aviation Insurance Different

Aviation risk is not like other types of risk. Insurance in other sectors use actuaries[1] to identify and manage risk. For example, in the automotive industry, actuarial classes are used to determine what level of coverage is necessary for a prospective policyholder. Currently, automotive underwriters use two classes, vehicle and driver, to determine coverage. Vehicle data points include the manufacturer, model and value. Driver data points are comprised of gender and driving record among other factors [2]. An underwriter then plugs in the respective client information and a tiered coverage package matrix is generated. The underwriter then applies relevant minimum coverage requirements, usually mandated by the local legislature. Finally, the policyholder chooses a well suited package and coverage ensues. Unfortunately, this model is not universal to all industries. However, this model may be adapted to the UAS sector.

Insurance companies rely on a portfolio of risk to mitigate cost. Those policyholders engaged in risky activities or inexperienced operators must meet higher certification standards and pay higher premiums. Conversely, those who operate in a noticeably safer manner and have greater experience are rewarded with lower premiums and potentially better coverage. A pool of diversified risk allows underwriters to organize and prioritize future clients. Insurance companies can then absorb automotive or marine accidents that lie within coverage constraints. Firms can then assess risk with some degree of certainty based on historical data. However, in the aviation industry, this pool is so small, that actuarial classes and policyholder risk matrices are considerably less relevant [3].

Risk management in the aviation industry is unique because of the endemic nature of flight. Insurance policies are generally written based on aircraft airworthiness; available accident data; area of operation and pilot certification. These factors are deceptively similar to actuarial classes in the automotive industry. However, unlike the relatively consistent variables drivers face on the highway, flight conditions change every time the propellers start to turn. Each mission profile should be analyzed independently and within the aircraft envelope [4].

Another differentiation from other sectors is that the federal government does not generally require pilots and aircraft owners to carry insurance. Though there is an exception, it will be discussed later in this paper. The rationale behind the lack of a federal insurance mandate is the stringent scheme for pilot certification and aircraft airworthiness as well as oversight from air traffic control (ATC) at airports across the country. Under FAA regulations, a pilot must complete a rigorous training regiment to obtain a pilot's license [5].[2] Subsequently, certification maintenance requires that a pilot who wishes to transport passengers must complete three takeoffs and three landings every 90 days, in the same category, class and type for the certification issued [7]. Furthermore, a pilot must maintain minimum health requirements for a biannual medical examination.

Aircraft airworthiness is also subject to strict scrutiny. Any defects that may affect performance of an aircraft must be documented, reported and repaired for continued airworthiness [8]. Underwriters have responded to this rigid structure by issuing policies with strict exclusions. Courts have held that

[1] a person who compiles and analyzes statistics and uses them to calculate insurance risks and premiums [1]

[2] An applicant must complete a specified number of hours of ground school or class room training for a certain type rating. The applicant must then complete the relevant written test for the rating. The applicant must then complete a specified number of hours of flight instruction and pass a practical flight exam to receive a certificate [6].

978-1-4799-2280-2/14/$31.00

policies with exclusions that withhold coverage for accidents caused by certification and airworthiness issues are valid [9], [10]. Insurance firms enforce such exclusions and argue that forfeiture of coverage due to faulty pilot certification or airworthiness is not an exclusion. Instead, the coverage never existed in the first place [11].

Unmanned aerial vehicles and systems occupy an even smaller pond in the risk pool. Currently, underwriters do not have a legal framework to rely on. Because so few UAS and UAV operators have approval to fly in the United States, insurance firms must innovate to accommodate them.

So far, insurance firms that write policies for UAS rely on two methods to mitigate risk for pilots. The first method is to require the PIC to maintain a minimum private pilot's license (PPL) certification rating. The second is to require the PIC to attend a mandatory FAA private pilot ground school, as to ensure education on the consequences of flying in the National Airspace (NAS) [12]. However, some speculate that the FAA will require a baseline ground school for both PICs and Visual Observers (VO) (individuals who are critical to mission operation through communication with the PIC, but do not directly control the aircraft). However, until this requirement emerges, underwriters must rely on the existing general aviation certification scheme.

Furthermore, insurance firms face a challenge for UAS aircraft airworthiness. The FAA requires that all airworthy aircraft have a serial number [13], also known as a tail number. The serial number allows manufacturers, pilots, and the government to monitor accident data and reliability. This challenge intensifies in the small UAS (sUAS) market because many (sUAS) are either homebuilt or are not issued serial numbers due to a lack of regulation. As of 2014, the FAA has only issued 127 tail numbers. A large portion of tail numbers are assigned to government contacted entities [14]. In addition, there is an overwhelming and inaccurate assumption that all sUAS fall under Model Aircraft. Consequently, there is currently no standardized way to track accident data to determine what different makes and models carry more or less risk. Some firms have begun to assign serial numbers to insured UAVs in an attempt to track reliability internally [3]. A logical inference is that the FAA will eventually require all commercially operated UAVs to carry serial numbers.

Moreover, as the FAA proceeds with UAS integration, insurance companies must act strategically. The industry has begun to set its own standards and criteria for evaluating the complicated risks of flying UAVs. Additionally, some commercial entities may choose to fly hobby-level UAS to cut costs [15]. However, this decision is misguided. Current standards for airworthiness for hobby-grade UAS are sub-par or non-existent. Unforetunately, many hobby-grade operators adhere to the adage, *If it flies, it will work*, which is unacceptable from a legal and engineering standpoint. Thankfully, no major UAV accidents or injuries have occurred, but the future is still unclear. If and when it does happen, the risk management industry must react, as society will not tolerate machines that injure humans.

III. FAA Commercial Aircraft Insurance Requirements

The FAA does not maintain a general aviation insurance scheme. However, the FAA does require insurance for certain manned commercial aircraft [16]. These requirements apply to direct air carriers[3] or when "a person who provides or offers to provide air transportation and who has control over the operational functions performed in providing the transportation" [17]. As required by FAA CFR 205.5(a), "these requirements apply to bodily injury or property damage, resulting from the carrier's operation or maintenance of aircraft in air transportation..." [16].

TABLE I. Air Carrier - Minimum single limit of liability with 16 passengers

$3,600,000 $= [(16 \text{ passenger seats}) \times (.75)] \times \$300,000$ (Liability Per Occurrence)
$+ \$2,000,000$ (property damage per occurrence)

$= \$5,600,000$ Minimum Coverage Requirement

TABLE II. Air Taxi - Minimum single limit of liability with 16 passengers

$900,000 $= [(16 \text{passenger seats}) \times (.75)] \times \$100,000$ (Liability Per Occurrence)
$+$ $300,000 (non-passenger liability per occurrence)
$+$ $100,000 (property damage per occurrence)

$= \$1,300,000$ Minimum Coverage Requirement

FAA minimum requirements are calculated based on commercial aircraft capability and capacity. Under 14 CFR 205.5(b), the FAA discriminates between aircraft that can transport 60 people or more then 18,000 pounds of cargo [16]. The minimum requirements for coverage is illustrated above in Table I. The FAA maintains a different scheme for air taxis [16]. An air taxi is an aircraft that transports passengers, property, or mail in small aircraft [18]. The minimum requirements for air taxi coverage is illustrated above in Table II.

Although the manned aircraft scheme may not be directly translated into the commercial UAS context, there are a few takeaways. The first aspect is that coverage minimums are segregated and calculated by capacity and commercial use. UAS should also be segregated in this manner.

UAS come in different sizes with different payload capabilities. Like the size limitations of 60 passengers or 18,000 pound cargo, UAS minimums should be split by weight capability. Small UAS (sUAS), 55 pounds or less, differ greatly from large UAS. Like air taxis, sUASs are smaller and cannot lift heavy payloads. Thus sUAS may be required to carry extra coverage similar to that of non-passenger liability. Since sUAS do not have the ability to carry passengers, the extra requirement will be focused on the nature of sUAS operations. In comparison to larger UAS, sUAS have the ability for low altitude flights and operations in close proximity to buildings and structures. A separate requirement may be imposed for certain proximities, for instance, cities, buildings, structures or gatherings.

Furthermore, the typical software and guidance systems on sUAS and large UAS are different, radio control (R/C) and satellite navigation respectively. Although many sUAS operate via radio control and have the ability to perform beyond-line-of-sight (BLOS). SUAS tend to operate within line-of-sight, due to radio control capability constraints and to maintain adequate separation with surrounding aircraft. In addition, lost link procedures should be firmly in place for enhanced safety [19]. Further, the FAA Modernization and Reform Act of 2012, mandates as part of UAS integration into the NAS, the FAA must provide specific recommendations on ensuring sense and avoid capability is equipped on any civil UAS [20]. For example, during manned aircraft operation, the FAA requires the maintenance of three visual flight rules: Visual Flight Rules (VFR), Special Visual Flight Rules (SVFR) and Instrument Flight Rules (IFR). In addition, depending on the airspace of operation, there are different degrees of necessary separation. It is the opinion of the authors that the FAA will enforce an equivalent or higher level of separation for all UAS. In contrast,

[3] "an air carrier or foreign air carrier directly engaged in the operation of aircraft under a certificate, regulation, order, or permit issued by the Department of Transportation or the Civil Aeronautics Board." [17]

large UAS controlled via satellite may operate BLOS and for longer durations. This capability relates full-scale UAS more to the direct air carrier aircraft described above and therefore need higher minimums to match the enhanced level of risk.

The second parallel to manned aircraft is mission classification or profile. UAS can be deployed for a wide array of missions from low risk precision agriculture flights, to high risk disaster relief missions. As manufactures and operators dream up more creative mission profiles, underwriters must be able to categorize mission characteristics. Mission profiles may be divided into basic columns. For example, some of the elemental mission profiles include, entertainment and news gathering; search and rescue; delivery; industrial; etc. As use categories come into focus, the FAA will be faced with new risks to people and property. In response, the FAA may impose different required minimums for different uses. However, this may place a high financial burden on UAS operators who utilize UAVs for a variety of missions. Nonetheless, the FAA will most likely find a way to incorporate use into potential insurance minimum legislation.

As new commercial operations and regulatory framework becomes clear, the insurance industry must be proactive. UAS are already flying under COAs, Certificates of Waiver and Special Airworthiness Certificates in the US. Further, UAS are in the skies of Europe, Asia and Australia. Inevitably, an incident will occur and operators need coverage now.

IV. Types of Aircraft Insurance

The insurance industry has developed several insurance products for the aviation industry. In general, three main areas occupy the aviation risk product spectrum. These areas are owner's liability, non-owner liability, and manufacturer liability. A policy is typically written per category and considered on a case-by-case basis.

A. Owner's Liability

Owner insurance encompasses policies written for bodily injury and property damage. This category also covers damage to the aircraft and its components, known as 'hull damage'. Third party insurance may be covered under owner's insurance, which would cover pilots in addition to the owner, depending on the policy. Owner's liability in the UAS context can be tricky. Currently, UAS underwriters focus on the use of the UAS [21]. Each mission profile presents unique risks and may require levels of coverage that vary wildly. Furthermore, some underwriters focus on the individual physical parts of the UAS. In addition, personal injury, property damage, and 3rd party injury must also be considered in writing a policy for owner's liability.

Hull damage is a significant area of interest. Hull damage on a UAS pertains to the loss or damage to the UAV and associated equipment on an agreed value basis [21]. Typically, damage to the UAV refers to the landing gear, fuselage, wing, stabilizers, control surfaces, and avionics. Associated equipment however, refers to a myriad of hardware and software. On the hardware side, associated equipment includes the control station, any transmission equipment, and any other equipment necessary to use of the UAS [22]. Hull damage coverage is usually be calculated based on the established value of the UAV and equipment. On the software side, a UAS operator may seek to cover any loss of code or protected UAS software-related intellectual property in the event of a catastrophic loss. Coverage limits are typically written for $1,000,000 [23], unless otherwise negotiated. Coverage applies to both risks incurred on the ground and in flight [21].

Furthermore, UAS are not insignificant in size or mass and have the ability to cause injury or property damage. A UAS operator should consider coverage for personal injury, property damage and 3rd party injury. Though this liability will be discussed further in this article, UAS owners are potentially liable for harm caused during UAS operation. So far, underwriters cover these risks with a combined single limit, implemented with a minimum of $1,000,000,000 [21]. The limit amount is the most the insurance company is obligated to pay for damages because of bodily injury or property damage or both resulting from a single accident.

B. Non-Owner Liability

The next type of insurance is non-owner insurance. Non-owner insurance is akin to renter's insurance. This type of coverage applies to a pilot who is an employee of a corporation, rents aircraft or regularly borrows aircraft. Non-owner insurance follows the pilot and not the aircraft, which manifests in two ways, for individuals and for corporations.

Non-owner insurance for individuals applies to several parties of UAS operation. Coverage applies to for-hire PICs, VO, and UAS operator customers. Whether one of these parties needs coverage generally depends on two factors. The first is whether the owner's policy maintains adequate limits for protection. Due to potential exclusions and the possibility of catastrophic injury or damage, any non-owner connected to the UAS operation should assume the owner's policy does not offer protection. The second, is the degree of connectivity to the UAS operation. Connectivity to the operation depends on whether the party influenced the arrangement or control of UAV operation. Though the question of connectivity obviously applies to those who directly control the UAS like the PIC and VO, connectivity becomes unclear for those outside the radius of the control station. Depending on what level of participation to the mission or operation a party contributes, the party may or may not be covered by the owner's policy. Despite the liability analysis, any party not directly a part of the UAS operation must assume she is not covered by anyone else's policy. The effect is that even indirect participation may impute liability. Therefore, all parties without an ownership interest should consider non-owner coverage [12].

Non-owner coverage for corporations is broader and is reserved for commercial UAS operation. Corporate non-owner policies are similar to those carried by commercial manned aircraft. Employees and pilots are protected under this type of policy. Coverage depends on the PIC's certification and aircraft airworthiness required for the UAS type. Further, since the customer does not usually influence the airworthiness of the aircraft, the PIC is exempt from any hull damage liability [12].

Another form of non-owner policy is a non-owner hull policy. Hull damage is excluded from non-owner policies. Known as Liability Coverage for Damage to Non-Owned Aircraft, this type of protection is usually not included in non-owner liability policies [12]. However, in the context of UAS insurance it is imperative to have hull damage coverage, especially during UAS operator training missions. Without this policy, a non-owner is exposed to liability every time the operator or the operator's agents crashes the UAS. Unless the non-owner is prepared with extra parts or is proficient in aircraft repair, a small crash could amount to a big repair cost.

C. Manufacturer Liability

The third type of policy is product liability or manufacturer's liability insurance. These types of policies apply to those who fabricate aircraft and aircraft components. Since

TABLE III. sUAS CATEGORIZATION IN THE NAS [25]

Group	Gross Take-off Weight
I	$\leq$ 4.4 lbs or 2 kg
II	$\leq$ 4.4 lbs or 2 kg
III	$\leq$ 19.8 lbs or 9 kg
IV	$\leq$ 55 lbs or 25 kg
V	lighter than air (LTA) only

UAS design errors can lead to catastrophic injury and property damage, all producers of UAVs and relevant components should carry manufacturer liability policies to protect against potential product failure in the field.

V. UAS Risk Factors

Many modern commercial airline flights are performed under the control of autonomous operations. These aircrafts are fully capable of roll stabilization, heading control, altitude control and even autonomous landing [24]. Despite the similarity with semi-autonomous manned aircraft, most insurance policies exclude UAS because the UAVs are not covered under the definition of a traditional aircraft. Regardless, underwriters must quantify the amount of coverage needed. So far, underwriters have taken each UAS client on case-by-case basis. However, as more UAS firms start up, insurance companies will find it difficult to constantly re-invent its polices. Therefore, the insurance industry needs to set several parameters. First, is to define UAS. Second is to fashion a set of standard and quantifiable risk factors. Third is to determine risk allocation and mitigation.

A. *UAS Defined*

A legal definition of an unmanned aerial system is critical for an insurance firms because it is deeply vested in the legal defense of themselves and their clients. Currently, if a vehicle does not fall within the definition of an insurance policy, that vehicle may be excluded. In response, insurance firms struggle to define what a UAS is and what items are included or excluded. The effect of a legally undefined UAV or UAS is that vehicle or system is *running bare* or without any applicable protection.

The dispositive question for UAS is whether a UAV, is a model aircraft or indeed an aircraft. In the wake of *Huerta v. Pirker* [26], the FAA definition of an aircraft is, "a device that is used or intended to be used for flight in the air" [17]. The FAA has and will stand by this definition, which allows for an all-inclusive control over all U.S. NAS. In response to many questions regarding the blurred line between sUAS and hobby/recreational aircraft, the FAA released an interpretation of Congress' SEC. 336 of the FAA Modernization and Reform Act of 2012 [27]. In this interpretation, the FAA attempts to clear the ambiguity by presenting clear examples of when an aircraft is functioning for recreation or commercial gain [20]. Regardless, insurance firms must act in light of the real world effects of uncertified unmanned flying machines, despite the lack of a legal framework.

An adequate definition of a UAS is currently the FAA definition:

> A UAS is the unmanned aircraft (UA) and all of the associated support equipment, control station, data links, telemetry, communications and navigation equipment, etc., necessary to operate the unmanned aircraft. The UA is the flying portion of the system, flown by a pilot via a ground control system, or autonomously through use of an on-board computer, communication links and any additional equipment that is necessary for the UA to operate safely. [25]

According to this definition, a UAS is not only the vehicle, but includes all associated critical components involved in flight operations. Furthermore, Congress defines UA as, "... an aircraft that is operated without the possibility of direct human intervention from within or on the aircraft." This broad definition clearly encompasses Model Aircraft, however SEC. 336. Special Rule for Model Aircraft of the same document aims to protect the hobbyist by further defining the characteristics of recreational and hobby use. Moreover, the definition for a Model Aircraft is stated:

> A sUAS used by hobbyists and flown within visual line-of-sight under direct control from the pilot, which can navigate the airspace, and which is manufactured or assembled, and operated for the purposes of sport, recreation and/or competition. [25]

Nevertheless, this definition is merely a recommendation by the FAA Small Unmanned Aircraft System Aviation Rulemaking Committee and cannot be held as a strict definition. However, the council of sUAS experts has provided a general categorization for sUAS, found above in Table III (without additional operational limits and capabilities information). This matrix may guide underwriters to quantify sUAS more effectively. According to Table III, UAS 55 lbs. or less is classified as an sUAS, allowing for a slightly less ambiguous line drawn between small and full-scale UAS. Further still, an alternative exists to the above definitions. An underwriter could categorize a sUAS as a Model Aircraft type under the Academy of Model Aeronautics (AMA). These classification types include radio control (R/C), control line (CL), helicopters [28]. Though these UAV types are cumbersome, they are solid definitions until the government acts.

B. *UAS Risk Factors*

As with any new technology venture, there are inherent risks associated with the operation of a UAV. When an underwriter decides to insure or reinsure an operator, he or she must understand how the UAV will be used and what operations will be conducted. So far, the industry has been conservative as to which operators receive coverage. Underwriters tend to insure a scant 3% [3] of applicants. The rationale is simple, UAS operation is risky. The Congressional Research Service described UAS, "flight missions considered to be 'dirty, dull, or dangerous' are regarded as prime candidates for the use of unmanned aircraft" [29]. Further, the cited mission profiles for UAS is a laundry list of dirty jobs. Naturally, insurance providers are a bit cautious. However, insurers are concerned with providing effective coverage while minimizing unknown and unacceptable risk.

Risk is composed of two forms, identified and unidentified. Identified risks are further split into two subcategories, acceptable and unacceptable [30]. Insurance agencies make an attempt to limit the amount of unknown risk, while exempting unacceptable risk from coverage. Underwriters cope with UAS operation risks by quantifying these relevant risk factors and adjusting rates accordingly. To better identify and assess these risks, the industry employs questionnaires. The appendix presents a questionnaire from a licensed UAV/UAS underwriter [31]. These questions are posed to UAS operators prior to coverage allocation and serve as a first step in the underwriting process.

As demonstrated in the appendix, underwriters are meticulous in terms of aircraft specifications and proposed mission profile as to decrease the amount of unknown risk. The questionnaire was adapted from a standard aircraft questionnaire with a few key areas in mind: who is control of the UAV; what are the essential elements of the mission; and operator safety procedures. Further, payloads must be considered. The payload is at the heart of every mission flown and the UAV is merely a means to an end for payload implementation. In cases where multi-spectral imagers are utilized, current technology costs thousands to tens of thousands of dollars. Therefore, payload risk assessment is critical. Overall, each of these areas aids the allocation of risk and the determination of what aspects of the mission can be refined to mitigate known risks. Consequently, UAS risk factor determination may lead to an early form of UAV/UAS actuary data.

C. Risk Allocation & Mitigation: Early UAS Actuarial Data

Once an underwriter has identified the key risk factors, she can begin to allocate and mitigate. Currently, there is no UAS actuarial data officially on record for civilian UAS flights. An underwriter may instead rely on three basic areas to gather enough data to determine coverage price. The main areas appear similar to actuarial classes and include: who is in control of the UAS; what is the mission or use of the UAS; and what measures have been taken to ensure the safety of the mission. Further, once an underwriter has a better picture of these aspects, he or she can then portion out potential liability.

1) Who is in Control?: There is always a human in the loop who has a higher *authority* than the autopilot during the flight. The PIC should have the ability to override any autonomous mission and have the ability to safely operate the UAS remotely. Currently, there is no obligation for a sUAS operator to hold a pilots license or be trained in an FAA flight school. However, some allocated COAs require a private pilot to be present during the operation of a UAS. Although it is still unclear as to where the liability falls during the operation of a UAS, an underwriter can allocate PIC liability by way of analogy. The FAA provides a clear definition for manned aircraft PIC. According to 14 CFR 1.1 [17], the PIC holds full responsibility and liability over the aircraft:

> Pilot in command means the person who:
> (1) Has final authority and responsibility for the operation and safety of the flight;
> (2) Has been designated as pilot in command before or during the flight; and
> (3) Holds the appropriate category, class, and type rating, if appropriate, for the conduct of the flight.

It is required for the PIC to log these hours accordingly and denote PIC flight time. While this definition may seem bullet-proof, liability tends to be fluid when it comes to aircraft because of how aircraft command can shift in the cockpit or control station [32]. In typical civilian UAS operations, there are at least three personnel in communication: UAS operator, spotter (VO), and GCS operator. Accordingly, any one of these operators can be considered PIC at any point of the flight. That is if UAS are held to the same standards as manned aircraft [32]. Though this procedure may seem slippery, underwriters and actuaries are familiar with this procedure if they currently insure manned aircraft.

2) What is the Mission?: Insurers aim to create plans that are inclusive and specific. While UAV mission profiles are varied, mission planning and execution determines where and with whom the risk lies. Coverage may change according to: operation terrain such as over populated cities, over forests, over desert, in high winds, etc.; mission altitude, flight envelope and takeoff weight; and LOS or BLOS. Most recently, the FAA approved five mission profiles. In June of 2014, the FAA implemented the Certificate of Waiver (COW) process under Sec. 333 of the FAA Modernization and Reform Act, which granted exemptions to a handful of industries. The industries include the film and television industry; precision agriculture; power line and pipeline inspection; oil and gas flare stack inspection; and mining. These mission profiles occupy very different points on the risk factor spectrum and present unique risk matricies. Film and television missions are the riskiest profiles. On the polar opposite, precision agriculture flights present the least amount of risk.

Furthermore, it is in the best interest of the underwriter and actuary to require a concept of operations (CONOPS). CONOPS outline any and all operations, including those in the occurrence of certain failures during a mission [19]. As outlined by the FAA, CONOPS completely and concisely relays mission specifics, stakeholders and liability for missions to be performed using the aircraft [33].

3) Is it Safe?: Safety is a concern in any flight operation, but is particularly sensitive in the UAS industry. The history of UAS is not typically associated with safe and reliable flight. Rather UAVs are crucial tools in warfare or as aircraft prone to accidents. This is a concern particularly in the face of rising with availability of affordable UAS, commercially off the shelf (COTS). While there are a few systems that are reliable, many systems on the market are unreliable and all are unsafe when placed in untrained hands.

While there is currently no civil UAS insurance data available, there are a fair amount publications that detail statistics associated with risk and UAS accidents. The FAA and many other national airspace administrations, allow for Equivalent Level of Safety (ELOS) for aircraft that do not meet current FAA standards, or when no safety standards exist. Details of ELOS for current manned aircraft are explored in [34], where accidents are categorized into three primary accident groups: ground-based, mid-air, and early flight termination. Ground-based accidents are associated with taxiing and ground crew interaction. Mid-air collisions can involve two UAS or a UAS and a manned aircraft. Early flight termination end in collision with ground or water and may be controlled or uncontrolled. The research creates hypothetical case studies where historical manned flight accident data is analyzed and extrapolated to accommodate current military UAS of a range of sizes.

In a similar manner, Beyer et al. analyze U.S. Airforce unmanned aircraft Class A mishap reports for fiscal years 2004 to 2013, where a Class A mishap is defined as, "...a noncombat accident that results in a death, a permanent total disability, or damage of at least $1 million" [35]. Their findings revealed that during this period, there were a total of 72 reported accidents of which 27.5% were due to pilot/human error and 57.9% were caused by hardware issues [36]. These statistics can be used by underwriters to estimate where liability should be placed, and in turn accurately create premium's accordingly. It should be noted, however, that these aircraft are typically not categorized as sUAS which have a maximum takeoff weight (TOW) of 55 lbs.

Conveniently, a human is at the top of the hierarchical structure for liability distribution. But, there is no human in the cockpit of a UAV. Rather, multiple stakeholders collaborate to fly a single aircraft on the ground. In the case of sUAS, the operators main control view is 'third person' to the aircraft and in some cases a 'first person' view from the front of the aircraft. This method of operation is too prone miscommunication and human error. Therefore, tolerance controls must be carefully tightened [19] and the human factors [37],[38],[39] cannot be forgotten.

VI. Conclusion

As UAS integrate into the NAS, insurance firms must take a proactive approach to identify and quantify the risks presented by UAVs. Underwriters will face a steep learning curve as new uses and unmanned aircraft types are released into the market. Underwriters must innovate to tailor liability products and policies to adapt to the fluid landscape of who is flying and where the mission transpires. However, despite the ebb and flow of market forces, allocating risk and safety guide the future of the UAS insurance industry.

Though there is not sufficient empirical data of civil UAS and sUAS in the NAS, there is much to be taken from academic research on risk factors, human factors, fault tolerant control and case studies on UAS accidents. Interesting to watch are the insurance groups such as Overwatch and TransportRisk, whom are taking high risk in trail blazing insurance for UAS both in the NAS and abroad [21] , [40]. Future work will be a series of papers that will delve into the topic of insurance regarding the various categories of UAS individually, including: UAV size rating; operations of civilian hobbyist, private commercial, public/government and international; and pilot.[4]

Acknowledgment

The authors would like to thank Brandon Stark and Cal Coopmans for useful discussions. The authors would also like to thank David Goldberg and Michael D. Scott. Additionally, Vikki Stone, Senior Vice President, Poms & Associates Insurance Brokers, Inc., for thoughtful insight and guidance.

References

[1] H. H. Panjer, *Insurance Risk Models*, 2nd ed. Society of Actuaries, 1992.

[2] R. H. Jerry, *Understanding Insurance Law*, 5th ed. Matthew Bender & Company, Inc., 2012.

[3] S. Spangler, "Insurance and the future of commercial drone operations."

[4] J. Roskam, *Airplane flight dynamics and automatic flight controls*. DARcorporation, 1995.

[5] US Code, Title 14, section 61.15, "Offenses involving alcohol or drugs," 2014. [Online]. Available: http://www.ecfr.gov

[6] US Code, Title 14, section 61.3(c), "Requirement for certificates, rating, and authorization," 2014. [Online]. Available: http://www.ecfr.gov

[7] US Code, Title 14, section 61.57, "Recent flight experience: Pilot in command," 2014. [Online]. Available: http://www.ecfr.gov

[8] US Code, Title 14, section 21.3, "Reporting of failures, malfunctions, and defects," 2014. [Online]. Available: http://www.ecfr.gov

[9] *Eastern Aviation & Marine Underwriters, Inc. v. Gilbertson*, Northwestern Reporter, 2nd Series, p.570, 1985 (US Court of Appeals for the District of Minn.).

[10] "*Ideal Mut. Ins. Co. v. Last Days Evangelical Ass'n*, 783 F.2d 1234, 1237 (5th Cir. 1986)."

[11] D. J. Hahn, "General aviation aircraft insurance: Provisions denying coverage for breaches that do not contribute to the loss," *Air Law & Commerce*, vol. 64, p. 675, 1998-1999.

[12] TransportRisk, "Non-owner UAS insurance." [Online]. Available: http://www.transportrisk.com/nonowneduavinsurance.html

[13] US Code, Title 14, section 45, "Identification and registration marking," 2014. [Online]. Available: http://www.ecfr.gov

[14] A. Domain. (2014) Unmanned aerial vehicles (UAV) tail number listing. [Online]. Available: http://www.aircraftdomain.com/reports/uav.html

[15] B. Stark, B. Smith, and Y. Q. Chen, "A guide for selecting small unmanned aerial systems for scientific research applications," in *Research, Education and Development of Unmanned Aerial Systems*, R. Lozano, Ed., vol. 2, no. 1. The International Federation of Automatic Control (IFAC), University of Technology of Compiegne, Compiegne, France, 2013, pp. 38–45.

[16] US Code, Title 14, section 205, "Aircraft accident liability insurance," 2014. [Online]. Available: http://www.ecfr.gov

[4] Appendix is removed due to space limit. For the full version of this paper, visit: `http://mechatronics.ucmerced.edu/droneinsurance`

[17] US Code, Title 14, section 1.1, "Definitions," 2014. [Online]. Available: http://www.ecfr.gov

[18] US Code, Title 14, section 298.3, "Classification," 2014. [Online]. Available: http://www.ecfr.gov

[19] B. Stark, C. Coopmans, and Y. Q. Chen, "Concept of operations for personal remote sensing unmanned aerial systems," *Journal of Intelligent & Robotic Systems*, vol. 69, no. 1-4, pp. 5–20, 2013. [Online]. Available: http://dx.doi.org/10.1007/s10846-012-9710-9

[20] M. P. Huerta, "Interpretation of the special rule for model aircraft," FAA and DOT, Tech. Rep. Docket No. FAA-2014-0396, June 2014.

[21] TransportRisk, "UAS UAV drone insurance." [Online]. Available: http://www.transportrisk.com/uavrcfilm.html

[22] H. Chao, A. M. Jensen, Y. Han, Y. Q. Chen, and M. McKee, *AggieAir: Towards Low-cost Cooperative Multispectral Remote Sensing Using Small Unmanned Aircraft Systems*, G. Jedlovec, Ed., http://www.intechopen.com/books/advances-in-geoscience-and-remote-sensing/aggieair-towards-low-cost-cooperative-multispectral-remote-sensing-using-small-unmanned-aircraft-sys, 2009.

[23] V. Stone, "UAS coverage limits," January 2014, Unpublished.

[24] D. Haddon and C. Whittaker, "Aircraft airworthiness certification standards for civil UAVs," *UK Civil Aviation Authority*, August 2002.

[25] Small Unmanned Aircraft Sys. Rule Making Comm., "Comprehensive Set of Recommendations For sUAS Regulatory Development," *FAA*, 2009.

[26] *Huerta v. Pirker*, National Transportation & Safety Board, CP-217, 6 March 2014.

[27] U.S. House, 112th Congress, 2d Session. (2012, Feb. 1) *Rep. 112-381, FAA Modernization and Reform Act of 2012*. [Online]. Available: http://www.gpo.gov/fdsys/pkg/CRPT-112hrpt381/pdf/CRPT-112hrpt381.pdf

[28] Academy of Model Aeronautics, "Newcomer's guide." [Online]. Available: http://www.modelaircraft.org/files/education/docs/newcomerguide.pdf

[29] B. Elias, "Pilotless drones: Background and considerations for congress regarding unmanned aircraft operations in the national airspace system," *Cong. Research Serv*, no. R42718, p. 6, 2012.

[30] M. Baser, S. Yorulmaz, and S. AkgüL, "The role of unmanned aerial system in decision process by operational environment's risk level," in *Unmanned Aircraft Systems (ICUAS), 2013 International Conference on*, May 2013, pp. 160–166.

[31] V. Stone, "UAV/UAS underwriting questions," January 2014, Unpublished.

[32] A. German, "Logging pilot-in-command time," FAA document. [Online]. Available: http://www.faa.gov/about/office_org/field_offices/fsdo/sdl/local_more/avsafety_program/media/LOGGING%20PILOT-IN-COMMAND%20TIME.pdf

[33] FAA, "Develop CONOPS and preliminary security requirements (b)." [Online]. Available: https://www.faa.gov/about/office_org/headquarters_offices/ato/service_units/operations/isse/items/b%20-%20CONOPS.cfm

[34] K. Dalamagkidis, K. Valavanis, and L. Piegl, "UAS safety assessment and functional requirements," in *On Integrating Unmanned Aircraft Systems into the National Airspace System*, ser. Intelligent Systems, Control and Automation: Science and Engineering. Springer Netherlands, 2012, vol. 54, pp. 91–123. [Online]. Available: http://dx.doi.org/10.1007/978-94-007-2479-2_5

[35] The Air Force, *Air Force System Safety Handbook*. Air Force Safety Agency Kirtland AFB NM 87117-5670, July 2000.

[36] D. K. Beyer, D. A. Dulo, G. A. Townsley, and S. S. Wu, "Risk, product liability trends, triggers, and insurance in commercial aerial robots," in *WE ROBOT Conference on Legal & Policy Issues Relating to Robotics*. University of Miami School of Law, April 2014.

[37] C. Johnson, "The hidden human factors in unmanned aerial vehicles," in *Proceedings of the 2007 International Systems Safety Society Conference*, 2008, isbn: 0972138587. [Online]. Available: http://eprints.gla.ac.uk/40049/

[38] M. Cahillane, C. Baber, and C. Morin, *Human Factors in UAV*. John Wiley & Sons, Ltd, 2012, pp. 119–142. [Online]. Available: http://dx.doi.org/10.1002/9781119964049.ch5

[39] T. B. Chen, D. A. Campbell, G. Coppin, and F. Gonzalez, "Management of heterogeneous UAVs through a capability framework of UAV's functional autonomy," in *15th Australian International Aerospace Congress (AIAC 15)*, Melbourne Convention Centre, Melbourne, VIC, March 2013. [Online]. Available: http://eprints.qut.edu.au/58670/

[40] Overwatch, "A division of avalon risk management," 2014. [Online]. Available: http://www.avalonrisk.com