Textual and Network Analysis of Title 14 CFR Part 107 Waivers

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Abstract—Context: The management of hazards in small unmanned aircraft systems (sUAS) operations is not as well defined as today's commercial operations despite sUAS widespread use. FAA Title 14 Code of Federal Regulations (CFR) Part 107 waived operations' provisions, which manage hazards for higher risk operations that require approval, can offer insight to organizations establishing UAS Programs in managing their own operation hazards.

Aim: We seek to understand how the Title 14 CFR Part 107 waived operations manage hazards.

Method: We used the constant comparative method to identify hazard mitigation textual categories from provisions and use networks to assess the dispersion of provisions and the identified categories across issued waivers.

Results: Eight mitigation categories and twenty-four subcategories were identified. Most provisions present in waivers are mostly reused in one waiver.

Conclusion: While there is a broad range of provisions to control for hazard mitigations in the Title 14 CFR Part 107 issued waivers analyzed regulations, they require case-by-case modifications.

Index Terms—part107, sUAS, drone, provisions, waivers, mitigation, network, coding, hazard

I. INTRODUCTION

Emerging aviation includes the use of small Unmanned Aerial Systems (sUAS) in novel operations. The sUAS are a relatively new addition to the National Air Space (NAS), and many of the remote pilots have only Title 14 Code of Federal Regulations (CFR) Part 107 training. They may not have been in aviation, nor have a specific concept of operations. The manufacture and operation of these sUAS are not as regulated as today's commercial operation, and their widespread use introduces new risks and hazards to the public.

Today, there are case-by-case approvals for sUAS operations beyond what regulations normally allow, particularly for emergency response operations in which the potential benefits of the use of sUAS are perceived to outweigh potential risks. These approvals include the issuing of Title 14 CFR Part 107 waivers, which are publicly available on the FAA's website¹.

¹We indexed the URL using the Internet Archive should the URL change in the future: https://web.archive.org/web/20240407061822/https://www.faa.gov/uas/commercial_operators/part_107_waivers/waivers_issued

We argue there is value in systematically understanding how the FAA is currently managing risk for UAS operations. For example, public agency UAS programs can benefit from checklists describing hazard mitigation strategies for operations when defining their own operational manuals and policies. In this work, we focus on the analysis of issued Title 14 CFR Part 107 waivers. We chose issued waivers because they represent higher risk operations (as they require waivers to be conducted), and also because they are publicly available.

While issued waivers do not include the description of operations described in their application, which are not public, they include a list of *provisions* which help the FAA manage risk for that operation. Provisions are enumerated operation limiting statements included in the waivers, and the basic unit of our analysis, as exemplified in table I and Figure 1. By analysing these provisions across waivers, we can therefore derive general mitigation concepts which may be useful for Title 14 CFR Part 107 pilots and agencies alike as to revise training material, policies and procedures for different types of operations. Towards that goal, we ask the following research questions:

RQ1: How standardized are the issued waiver mitigation strategies?

We examine this question by observing how often provisions are reused across waivers within and beyond a particular regulation. We would expect a more mature and standardized set of rules seldom requires variations, and would often be present across several waivers of at least the same regulation.

RQ2: What mitigation concepts are present in waiver provisions?

The issued waiver provisions are included as an enumeration of statements with little structure. By identifying broader categories among these unstructured provisions, our goal is to systematically understand what hazard mitigation strategies the FAA requires for waivable regulations that could serve Title 14 CFR Part 107 pilots and agencies alike.

RQ3: Do issued waivers with combined regulations "inherit" mitigation concepts from their individual counterparts?

Title 14 CFR Part 107.205 defines 10 types of regulations which can be waived. However, issued waivers can request multiple regulations to be waived in a single waiver. For example, an issued waiver may apply to regulation 107.29 (fly a small UAS at night or periods of civil twilight without anti-collision lighting), or 107.35 (fly multiple small UAS with only one remote pilot), or both 107.29 *and* 107.35. Operations which require multiple regulations to be waived would thus present higher hazard risk than issued waivers of individual regulations.

We are interested in evaluating how the provisions of issued waivers of combined regulations differ from those of waivers containing only one of them. For example, a natural expectation is that an issued waiver for both 107.29 and 107.35 would "inherit" mitigation concepts from waivers only waiving 107.29 and waivers only waiving 107.35, or otherwise this could present a safety gap in managing hazards. In the scope of this work, we examined three sets of waivers: Those requesting only 107.29, those requesting only 107.35, and finally those requesting both 107.29 and 107.35.

RQ4: Are the identified mitigation concepts consistently present across waivers?

Once we identify mitigation concepts, we can use them as a checklist to assess how consistently they are present throughout different waivers of the same regulation. An inconsistent presence of mitigation concepts could reflect safety gaps in managing hazards. By using the identified concepts as a checklist against waivers, we also demonstrate how they could be used to assess other materials, such as training and operational manuals.

Our contributions in this work are as follows:

- To the best of our knowledge, we provide the first study in analyzing provisions in Title 14 CFR Part 107 issued waivers to identify hazard mitigation strategies.
- A novel methodology using both textual and network analysis of statements is presented. This methodology can be used for other textual datasets with overlapping statements, such as Part 91 Certificate of Authorizations.
- Our proposed method provides full traceability between raw data (provisions) and mitigation concepts (analyst interpretation), reflected in examples throughout this manuscript, to improve the validity of the results.

The closest work to ours is by [1], where the authors analyze Title 14 CFR Part 107 waivers *Applications*, to aid the FAA in evaluating them in a more efficient manner utilizing machine learning. In analyzing data from waivers, a large list of acronyms are utilized from the source material, e.g. Pilot-In-Command (PIC) and Visual Observer (VO).Due to space limitations, we defer the reader to FAA's Appendix 3. Abbreviations/Acronyms for a reference of acronyms utilized in the source material².

II. METHOD

A. Dataset

We used the publicly available Title 14 CFR Part 107 issued waivers as the dataset for our analysis. In the scope of this work, we analyzed issued waivers from regulations 107.29, 107.35, and those requiring both 107.29 and 107.35 from 2/6/2020 to 10/4/2024. This resulted in a dataset of 60 waivers for 107.35, 2 waivers for 107.29, and 58 waivers for 107.29&107.35. Across all waivers, a total of 252 provisions were present. Of this total, 20 provisions applied to 107.29 waivers, 200 provisions apply to 107.35 waivers. Note the number of provisions of each individual regulation do not sum to the total number of provisions, as they can also be reused between regulations.

Because only PDF files were available, and the results of this work heavily rely on the analysis of its contents, we defined a data schema based on the type of information contained in the waivers, and manually transcribed the PDFs content into a spreadsheet using this data schema.

The data schema consists of tables enumerating the 10 regulations which can be waived, the waiver ids which were analyzed, and unique provisions which were used throughout the waivers. Additional relationship tables were created using these as basis. For example, the Waiver and Provision table identified provisions from our glossary and listed which provisions were used in which waivers. This process revealed provisions were reused, either with minor or major modifications, across different waivers. While we identified other information of interest that could also be analyzed, such as the waiver operation areas of the issued waivers, we decided to defer that to future work.

B. Network Construction

Two waivers are exemplified in Figure 1 in the form of a network. The fields for regulation, provisions and the waiver itself are mapped to three types of nodes. Waivers are connected to a a single regulation node if they requested the regulation to be waived. In the example, two waivers request the same regulation pair to be waived, and therefore, in the graph they are connected to the same regulation node. In the scope of this work, there are only three possible type of regulation nodes: 107.29, 107.35, and (107.29&107.35). Provision nodes are connected to waivers if they are included in the waiver. Since our analyzed dataset contains 252 provisions, a full graph will also contain 252 provision nodes, which may be connected to more than one waiver node if the provision is reused across these waivers.

²https://web.archive.org/web/20240407053838/https://www.faa.gov/air_traffic/publications/atpubs/aim_html/appendix_3.html



Fig. 1: Network Construction for Regulations, Waivers and Provisions.

By default, nodes are placed in random positions in the plane. We used Yifan Hu's Proportional Layout algorithm [2] in the Gephi tool [3], both which are publicly available³, to reposition the nodes in the plane. Yifan's algorithm "pulls" nodes that are more interconnected and "pushes away" nodes that are less interconnected. The resulting visualization, therefore, provide different types of insight in our data, depending on their relative position. We discuss in more detail our findings when answering RQ1 in sub-section IV-A.

C. Pre-Processing Provisions

To address RQ2, we must identify the overall mitigation concepts present in waiver provisions. In the screening phase, we observed that provisions could either be reused "as-is" or with minor modifications. Table I illustrates three patterns we identified when pre-processing provisions.

In the first two rows, the provision ids 69 and 70 found in different waivers and are almost identical other than the limit of sUA allowed in the operation. Therefore, we consider them to be effectively the same meaning and assign them the same "Provision Meaning ID". A second pattern appears on the subsequent two rows: The Provision ID 4 "extends" Provision ID 3, but the premise remains the same. In this case, we still considered them to have similar meaning, and therefore assigned the same Provision IDs 38, 39 and 222. In this case, Provision ID 222 combined both the other provisions ID 38 and 39. In this case, we chose to treat Provision ID as its own provision meaning ID 65.

³https://gephi.org

TABLE I: Provisions Pre-processing: Three Different Patterns of Provision Variation.

| Provision | Provision | Provision Text |
|-----------|---------------|---|
| ID | Meaning ID | |
| 69 | 26 | As described in the waiver application, operations using multiple sUA are limited |
| 70 | 26 | to no more than 12 sUA at a time; As described in the waiver application, |
| | | operations using multiple sUA are limited to no more than 2 sUA at a time; |
| 3 | 3 | Communication between the remote PIC and VO must allow for the remote PIC ground the sUA with sufficient time to yield right-of-way in accordance with \$107 37. |
| 4 | 3 | communication between the remote PIC and VO must allow for the remote PIC to light the sUA and/or ground the sUA with sufficient time to yield right-of-way in accordance with \$107.37 as described in the waiver application; |
| 38 | 14 | The sUAS must be equipped with the flight termination system described in the waiver application. Prior to operations subject to this waiver, the flight termination system must be tested and verified to operate as described in the waiver application; |
| 39 | 15 | A sUA geo-fence system must be pro- grammed and verified prior to operation; |
| 222 | 65 | The sUA geo-fence and flight termination system must be programmed and verified to operate as described in the waiver ap- plication; |

We used Provision Meaning IDs to reduce the number of comparisons we would subsequently perform when deriving conceptual groups in order to answer RQ2, while providing traceability to the original provisions at each step of the analysis. Specifically, the 252 provision ids were grouped into 82 provision meaning ids. We note, however, the networks represented in this work utilize the *Provision IDs* (as shown in Figures 1 and 3). We did so in order to assess how our conclusions following a text comparison methodology compares to one using a network methodology starting from the original dataset.

1) Semantic Grouping: With the 252 provisions now preprocessed into "Provision Meaning IDs", we randomly selected a provision meaning ID as representative provision. This table was then partitioned into three tables:

- Table 107.35: Provisions in 107.35 not in 107.29 (N = 69)
- Table 107.29: Provisions in 107.29 not in 107.35 (N = 19)
- Table 107.29&107.35: Provisions in both 107.29 & 107.35 (N = 33).

We applied the Constant Comparative Method by Glaser [4] to each individual table, in order to create categories and sub-categories representing the concepts of these provisions. The method consists of sorting segments of text into groups according to their meaning. Specifically, in the context of our dataset, each provision (text segment) was assigned a label, based on their interpretation, and subsequently given a category label.

These category labels were successively revised after multiple iterations of comparing the provisions, as our understanding of their meaning improved. These category labels were then broken down into sub-categories to differentiate the tables. Both category and sub-category labels were also given identifiers, such that category and sub-category ids could be traced to provision meaning ids, which in turn could be traced to provision ids, the original description of the text. In this manner, while the presented categories, sub-categories and pre-processing are subjective in nature, to alleviate threats to validity, we created a traceability map from provision ids, to provision meaning ids, and from provision meaning ids to categories and sub-categories.

While we are unable to provide the full mapping across of the provisions in this manuscript due to space limitation, we provide examples throughout our answer to RQ2 that illustrate our identified categories from provisions, where we present the identified categories and sub-categories for regulations 107.29, 107.35, and 107.29&107.35 waivers. The interconnection between provision meaning ids, sub-categories and categories, which extend the network representation in Figure II-B, is shown in Figure 2. The provision meaning nodes were discussed in the prior section II-C, while the sub-categories and categories method were discussed in this section.

III. COLORING NETWORKS WITH TEXTUAL CATEGORIES

To assess how our identified categories and sub-categories based on textual interpretation of the provisions are distributed across different waivers and regulations, we represent them as colored provision nodes in a waiver and regulation network as defined in section II-B.

The intuition behind this visualization lies on the Gestalt Laws [5] of Similarity and Proximity. Gestalt Laws describes how we visualize information. The Gestalt Law of Proximity states that objects that are near, or proximate to each other, tend to be grouped together. To construct our networks, we utilize a layout algorithm that attributes meaning to provisions being close together or far apart from one another (which is discussed in greater detail in answering RQ1).

The Law of Similarity states that people perceive elements that share similar visual characteristics, such as color, to be related. We therefore mapped to color the identified subcategories, to identify if any visual pattern emerges in our constructed network, as we will discuss in RQ4.

IV. RESULTS

RQ1: How standardized are the issued waiver mitigation strategies?

A. Title 14 CFR Part 107 Network

Figure 3 displays our dataset represented as provisions, waivers and regulations, using the construction method shown in Figure 1. This network does not include any categories created by interpreting the provisions, only the dataset "asis".

As noted in the method section II-B, the layout algorithm will position nodes (provisions, waivers, regulations) more closely as the number of edges among them increase. In Figure 3, we can observe the waivers (yellow) center around two of the three regulation (red) nodes. This makes sense, as the isolated red node represents regulation 107.29, which only two waivers in the dataset requested.

While the waiver nodes generally surround the regulation nodes, we can see two waivers standout in the visualization. This is because a large number of provisions (white) are unique to these waivers. In contrast, we can also see at the center of the graph, a set of provisions. These provisions are commonly reused across all waivers.

Between both extremes, we can also observe a number of provision nodes surrounding the middle-left red node for regulation 107.29&107.35, and even fewer surrounding the middle-upper-red regulation 35. These represent provisions that are often reused within waivers of the same regulation. Finally, we can see most of the provisions lie on the "periphery" of the graph, surrounding all waivers. These are provisions only found in one given waiver, but not along side a consistent set of unique provisions (or said waiver node would appear isolated as the other two waivers discussed).

We manually inspected the connections of each type of pattern discussed to ensure the relative position of the node



Fig. 2: Extended Network Construction for Regulations, Waivers and Provisions, Provision Meaning IDs, Sub-Categories and Categories.

was consistent with our interpretation. Our answer to RQ1 is therefore, that *the exact verbatim* of provisions are seldom reused, with most being used only once. This suggests the management of hazards reflected in these provisions still require operation-specific mitigations, and may not easily generalize as a set of 'one-size-fits-all' set of rules to not require a process to request waivers.



Fig. 3: Regulation, Waiver and Provision Network of the dataset.

RQ2: What mitigation concepts are present in waiver provisions?

While in RQ1 we focused only in representing the provisions "as-is", we would like to have a better understanding how the provisions in the issued waivers help manage hazards. In the method section, we defined how provisions were grouped into provisions whose meaning were very similar (i.e., by assigning "provision meaning ids"), subsequently grouping them into broader sub-categories, and finally categories. Each subcategory may pertain to one or more of waivers of regulations 107.29, 107.35, and 107.29&107.35. If the sub-category does *not* apply to all three possible combinations of regulations, we explicitly note the exception in the sub-category. For clarity, we also provide an example provision included in each subcategory.

B. Area Limitation and Monitoring

This category pertains to both limiting the area in which operations can take place at, and requirements of monitoring or observing the area for hazards or obstacles. The broader goal of the provisions in this category is to keep sUA in the operation within a safe area. Some of these provisions include monitoring of areas for hazards or non-participants, establishing a geo-fence to confine sUA in the area, or issuing a NOTAM for operation awareness.

1) Limitations to Operational Area: This subcategory imposes restrictions on the operational area. They may limit operations to specific locations, general locations meeting

a criterion, place a lower limit on altitude, or require a specific airspace for the operations. Waivers for 107.29 and for 107.29&107.35 mostly have a single similar provision limiting the specific location. 107.35 has many variations of provisions that address different topics like altitude or airspace restrictions. An example provision is: *Operations conducted under this Waiver are limited to the locations described in waiver application*.

2) Monitoring Operational Area: This subcategory requires the monitoring of the operational area for non-participants, obstacles, or hazards, such as aircraft entering the area. Some provisions explicitly mention the purpose of monitoring to prevent collisions or causing damage. In this subcategory, both 107.29 and 107.29&107.35 provisions require identification of hazards within the operational area. Waivers for 107.35 have provisions that emphasize the monitoring of non-participants. An example provision is: *During operations, the flight operations <u>area must be monitored</u> as described in the waiver application.*

3) Restricted Access to Operational Area (Not in 107.29): This subcategory requires restricted access to the operational area. Non-participants are to be prevented from entering the area during operations. This subcategory does not pertain to 107.29 waivers. All waivers for 107.29&107.35 have one identical provision under this subcategory, while 107.35 has several variations within different contexts or additional requirements. An example provision is: As described in the waiver application, operations are only permitted within a location closed to the general public, with a secured perimeter to prevent unauthorized or accidental intrusion into the area.

4) File NOTAM: This subcategory pertains to a NOTAM being filed. The NOTAMs are meant to alert nearby aircraft of the operation occurring and must include information about the operation. All waivers for 107.29 and 107.29&107.35 have the same provision, with some variations found in 107.35 waivers. The variations include additional requirements or stipulations. An example provision is: Not less than 24 hours prior to conducting operations that are the subject of this Waiver, a Notice to Airmen (NOTAM) must be filed. The NOTAM must include location, altitude, and/or operating area, time and nature of the activity, and number of sUA flying in the operating area.

C. Communication

This category emphasizes communication between participants, sometimes explicitly referring to the PIC and VO. There are no subcategories for Communication as there are only a few provisions with a similar purpose. Most require adequate communication to yield or halt operations. An example provision is: <u>Communication must be adequate for any person</u> directly participating in the operation to halt operations when an unsafe condition occurs.

D. FAA Knowledge and Management

This category pertains more to control, management, and understanding of operations by the FAA rather than the actual conduct of operations. These provisions involve reporting or logging information, giving the FAA authority over operations, or limitations so that the FAA will know with certainty how the operations will be conducted. The latter of these is seen in the restrictions regarding combining waivers. Most provisions in this category are common among all waivers and are broadly applicable to operations.

1) FAA Provided with Information/Reports: Provisions in this subcategory require logging information about the operations. In most cases, information or reports are to be given to the FAA. While this category is relevant to all three regulation combinations, it is unusual that 107.29&107.35 has the least provisions. Various 107.35 waivers have additional requirements of logging and/or reporting of sUA damages, test flights, and an operation manual. The 107.29 also presents a unique case regarding VO duties of recording operation information for the FAA. An example provision is: The Responsible Person listed on this Waiver <u>must maintain a current list</u> of small unmanned aircraft (sUA) by registration number(s) used in the Waiver holder's operations. This list must be presented for inspection upon request from the Administrator or an authorized representative.

2) FAA Management of Operations: This subcategory includes a variety of restrictions that appear more formal in nature. Restrictions give more authority to the FAA, clarify how different rules are to be followed for the waived operation, or refer to other documents. Some examples are restrictions on combining waivers or flying for compensation. Under this subcategory, 107.29 has two universally common provisions, while some 107.29&107.35 waivers additionally require remote identification and reference material. The 107.35 includes several additional provisions referencing documents, waiver limits and authorization clarifications. An example provision is: *The FAA has the authority to cancel or delay any or all flight operations if the safety of persons or property on the ground or in the air are in jeopardy or there is a violation of the terms of this Waiver.*

3) Notifying Other FAA Centers of Authority (107.29&107.35 Only): Provisions in this subcategory require notifying or receiving authorization from additional institutions before conducting operations. For instance, informing the Flight Standards District Office or receiving an Additional Security Waiver from Air Traffic Control. An example provision is: At least 72 hours prior to conducting operations that are subject to this waiver, the responsible person must notify the local Flight Standards District Office manager [...].

E. Failsafe Measures

This category deals specifically with potential failures that could occur during an operation. There are requirements for how to limit those failures or to have plans in place so that action can be taken in response to imminent or potential failures of systems and cascading hazards. This category is largely absent from 107.29 waivers, with only one subcategory, 4.3, having any provisions found in those them. Between 107.29&107.35 and 107.35, the subcategories are very similar overall with 107.35 having slightly more provision variations.

1) Flight Termination (Not in 107.29): This subcategory requires flight termination systems to be equipped and verified to be functioning. As this pertains to system requirements, it overlaps with the Hardware/Software category. It also includes general ceasing of operations in the wake of failure or hazards, in the case of one provision for 107.35. An example provision is: The sUAS must be equipped with the flight termination system described in the waiver application. Prior to operations subject to this waiver, the flight termination system must be tested and verified to operate as described in the waiver application.

2) Failure Causing Interference (Not in 107.29): This subcategory ensures that system failure will not interfere with other systems or further propagate errors like loss of control. This subcategory does not pertain to 107.29 waivers; however, it is highly similar between 107.35 and 107.29&107.35 waivers. The only notable difference is that a few waivers for 107.35 emphasize interference from tethers. An example provision is: An individual system failure must not interfere with the operation of any other sUA or cause incidents, accidents, or loss of control involving any other sUA that are subject to this Waiver.

3) Failure Notification: This subcategory requires alerts or notifications of errors or failures in the operation. It includes notifications for loss of control and for malfunctions. An example provision is: *The ground control station must audibly and visually notify the remote PIC of a sUA malfunction.*

4) Other Failure Measures (Not in 107.29): This subcategory includes two failure-related provisions that did not fit into any other categories. This subcategory does not pertain to 107.29. The waiver in 107.29&107.35 has only one provision, which requires emergency commands. An additional provision pertains to 107.35. An example provision is: At all times during operations, the emergency sUA commands described in the waiver application, must be available to the remote PIC.

F. Hardware/Software Restrictions and Requirements

This category refers to physical restrictions and requirements for the sUA, additional operation systems, as well as for material components. It also includes provisions that limit the number of sUA that may be flown simultaneously. Any physical system or software requirement is included in this as they pertain to having safe control and proper functions within the operation.

1) Limited Number of sUA (Not in 107.29): This subcategory includes various provisions that place a maximum number of sUA controlled at one time during the operation. Due to its nature, it pertains only operations waiving 107.35. An example provision is: As described in the waiver application, operations using multiple sUA are limited to no more than 3 sUA at a time. 2) Systems to Ensure Control (Not in 107.29): This subcategory covers various requirements of hardware and software intended to maintain control over sUA and ensures they function properly. It includes requirements for flight control, geofencing, and flight termination, among other systems. An example provision is: As described in the waiver application, prior to conducting operations that are the subject of this Waiver, the flight controller and the associated flight control system capability for each aircraft, operate properly.

3) Physical sUA Limitations (Not in 107.29): The subcategory includes physical restrictions and limitations on the sUA, such as the make and model or limits on sUA weight. It also requires compliance with manufacturer recommendations for the sUA. An example provision is: *The total weight of the sUA flown under this Waiver must not exceed 55 lbs.*

4) Other Hardware Requirements: Several hardware related provisions did not fall into a particular subcategory and were grouped together here. They include the topics of emitters, ADS-B out, and maintenance instructions. An example provision is: All emitters in the sUAS must be in compliance with all applicable FCC regulations and all provisions of the FCC authorization granted for the emitter. An FCC experimental authorization may be used as long as it serves no safety based or safety critical function in the sUAS.

G. Operation Knowledge

This category requires an understanding of the operations, including the environment, waiver requirements, general knowledge of sUA, and safety briefings. This category is similar in both subcategories across all three waiver types with several provisions being almost universal across waivers.

1) Information Available During Operations: This subcategory requires certain information to be available during the operation. An example provision is: <u>A copy of this Waiver must be accessible and available to</u> the Remote Pilot in Command (remote PIC) at the ground control station <u>during sUAS operations</u> that are the subject of this Waiver.

2) Participants Informed Prior to Operation: This subcategory requires the participants of the operation to be adequately informed. It includes requirements for safety briefings, ensuring participants are knowledgeable of aspects of the operation and Title 14 CFR Part 107, as well as clarifying the definition of participant and non-participant. An example provision is: Prior to operations under this Waiver, all <u>Direct Participants must attend a safety briefing</u> that addresses, at minimum, the following items as applicable [...].

H. Training and Planning for Operation

This category pertains to all sorts of requirements of preparation, training, and planning for operations. It also includes some provisions requiring knowledge of aspects of the operation. These all deal with ensuring the operation can be conducted properly and safely by preparing beforehand with various precautions. 1) Training and Testing for Participants: This subcategory requires the participants to undergo adequate training, testing, or to demonstrate their capability for the operation. PICs have particular focus in these provisions. An example provision is: Prior to conducting operations under 14 CFR 137 under the terms and conditions of this Waiver, the remote RPIC must pass knowledge and skills test in accordance [...].

2) Operation Planning (Not in 107.29&107.35 or in 107.29): One provision falls under this subcategory under 107.35, requiring dedicated plans for the operation. The example provision is: The remote PIC must ensure that routes are pre-planned prior to flight and aircraft are programmed to automatically follow the route

I. Visibility

Provisions deal with the visibility of the operation in some capacity. This includes maintaining visual line of sight with the sUA by ensuring it is easier to see or that there are sufficient participants to observe it. Some provisions also involve visibility of the operation or participants.

1) Lighting: This subcategory pertains to lighting requirements for visibility. It includes topics such as restrictions from night operations or requiring lights or visibility markings. An example provision is: The area of operation must be sufficiently illuminated to allow both the remote PIC and VO to identify people or obstacles on the ground [...].

2) Maintaining VLOS: This subcategory refers to more conventional visibility requirements in maintaining visual line of sight (VLOS) with the sUA, namely tracking the sUA or requiring a VO. VO requirements are universal for 107.29 and 107.29&107.35 waivers, while being almost universal for 107.35 waivers. An example provision is: All operations under this Waiver must use one or more VO(s).

3) Participant Visual Identification (Not in 107.29&107.35 or in 107.29): This subcategory requires participants to be easily identified visually. An example provision is: Individuals directly participating in the operation of the sUAS must be easily identifiable visually (e.g., apparel, safety vests).

4) Waypoint Confirmation (Not in 107.29&107.35 or in 107.29): This subcategory pertains to a rather unique provision. It requires the sUA to hold at waypoints for visual confirmation of the position. While similar to the Maintaining VLOS subcategory, this has a slightly different purpose and context. An example provision is: Prior to conducting operations under this Waiver, the Remote PIC must ensure that the sUA fly their predetermined route to specific waypoints and hold at those waypoints until visual confirmation that the sUA are at the routed positions.

5) Operation at Night/Twilight (Not in 107.29&107.35 or in 107.29): This subcategory restricts operations from being conducted at night and/or twilight. By its nature it will not be found in any operation waiving 107.29. While pertaining to one provision, several variations do exist for 107.35. An example provision is: Operations may not be conducted at night or civil twilight.

RQ3: Do issued waivers with combined regulations "inherit" mitigation concepts from their individual counterparts?

To answer this question, we first compared the categories and sub-categories we presented in RQ2 between regulations 29, 35 and (29 and 35) issued waivers. We chose to analyze the three categories of Area Limitation and Monitoring, FAA Knowledge and Management, and Hardware/Software Restrictions and Requirements due to space restrictions. Because regulation 107.29 contained fewer waivers, we assessed which categories and sub-categories in 107.35 were present or missing in issued waivers of both 107.29 and 107.35. Based on our annotations of which sub-categories were present in both 107.29 and 107.35, the following sub-categories were not "inherited" by waivers requiring 107.29&107.35: Operation Planning, Participant Visual Identification, Waypoint Confirmation, Operation at Night/Twilight. These subcategories were found only for 107.35 waivers and, with the exception of the last, they were found with only one provision. We therefore conclude these were operation specific cases, as reflected in their definitions. The last, Operation at Night/Twilight is not expected to be "inherited", as regulation 107.29 is also being waived in 107.35&107.29.

Although not specifically related to this RQ, we found noteworthy that the sub-category "Notifying Other FAA Centers of Authority" was only present in 107.29&107.35. We believe this additional sub-category reflects an additional precaution due to the combined risk of this type of operation. We also analyzed a subset of the categories in Figure 4, to observe if their provisions reflected any patterns in respect to their reuse across waivers. We can observe the colored provisions consistently appear on the outer portion of the graphs. As we discussed in RQ1, this visual pattern is associated to provisions that are only reused once in waivers.

Our answer to RQ3 is therefore that regulation 107.29&107.35 "inherit" most of the sub-categories identified in RQ2, and those which are not, are expected to be specific operation cases for 107.35.

RQ4: Are the identified mitigation concepts consistently present across waivers?

In this RQ, we utilize the defined categories of RQ2 as a checklist against the issued FAA waivers analyzed. Figures 5 and 6 display the percent of waivers that included the specified category and sub-category respectively. In addition to the defined categories, we also listed *overlapping categories*. Recall from table I, we noted in our third example of provision meaning ID, that some provisions combined existing provisions (in the table, this is exemplified by provision ID 222). These overlapping provisions result in overlapping sub-categories and categories, which are showcased in these Figures.



(a) Area Limitation and Monitoring

(b) FAA Knowledge and Management

(c) Hardware/Software Restrictions and Requirements

Fig. 4: Three out of Eight Categories of provisions in 107.35 not present in 107.29&107.35 waivers.



Fig. 5: Category presence across analyzed waivers. A waiver is considered to have a category if at least one provision of the category was included in the waiver.

We can observe in Figure 5 that most of the categories are prevalent across 100% of the waivers, with the exception of *Communication (55% of waivers)* and *Training and Planning for Operation of waivers (60%)* for regulations 107.29, 107.35, and 107.29&107.35. Note, however, in this case Communication co-occurs with Visibility provisions in approximately (95%) of the waivers. Figure 6 provides the breakdown of the categories into sub-categories, which also include overlapping sub-categories.

In Figure 7 we present a similar yet different perspective to the question. Instead of the percentual of waivers that contain a given sub-category, we instead ask the *percent of sub-categories* waivers include, which is displayed as a histogram. We can see from the Figure that approximately 45% of the

waivers include 100% of the sub-categories. However, the other half of the waivers analyzed vary widely on the number of sub-categories included.

V. CONCLUSION AND FUTURE WORK

In this work, we investigated how Title 14 CFR Part 107 issued waivers' provisions are utilized to manage hazards in operations. We found that although provisions covers a large variety of mitigation strategies, they are seldom reused in their exact textual form across waivers, reflecting the case-bycase nature of current hazard mitigation strategies. We also demonstrated how our derived mitigation concepts could be used to assess how often they are present in waivers, which





Fig. 6: Sub-Category presence across analyzed waivers. A waiver is considered to have a sub-category if at least one provision of the subcategory was included in the waiver.



Fig. 7: Percent of Waivers vs Percent of Sub-Categories utilized in the Waivers.

could then be used by other agencies' sUAS materials seeking to manage hazards, such as operational manuals.

In future work, we plan to examine the overlap (or lack of) between our identified categories and emergency response operational manuals. We also plan to identify strategies for semi-automated machine learning methods to pre-process categories, so we can scale the analysis to other regulations. A number of analyses can also be extended to this dataset, such as the evolution of provisions over time, operational areas of the issued waivers, and the interaction of waived regulations impact on provisions.

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