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USE CASES FOR VEHICLE-TO-VEHICLE COMMUNICATIONS FOR UNMANNED AIRCRAFT SYSTEMS

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VEHICLE-TO-VEHICLE (V2V) UNMANNED AERIAL VEHICLE (UAV) COMMUNICATION BASED ON USE CASES

ABSTRACT

The proliferation of unmanned aerial vehicle (UAV)[1] usage in today's airspace creates unique challenges for coordinating movement of a multitude of different UAVs with different roles and responsibilities to ensure safe, secure, and efficient management in an ever-increasingly crowded airspace. The purpose of this paper is to look at the various use cases for UAVs and how these different cases impact the ability of UAVs to communicate with other UAVs. This paper expects UAVs to be complementary to ground communication (General Aviation Manufacturers Association [3], executive summary) to fulfill their operational missions. More specifically, this white paper examines how the detect-and-avoid or collision avoidance use case can be used to form the basis of a vehicle-to-vehicle (V2V) communication protocol and message format. The proposed solution is intended to meet the needs of regulatory requirements, such as the Federal Aviation Administration's Remote ID [2]), and other industry standards organizations, such as ASTM and RTCA, working on the Airborne Collision Avoidance System for Unmanned Aircraft (ACAS Xu) solution for UAVs, aerospace original equipment manufacturers (OEMs) building UAVs, and operators of UAVs. While security requirements and frequency usage were considered, the paper does not propose any detailed solutions in these areas as they will be offered by other sub-groups in the IEEE P1920.2 working group.

[1] UAV is considered "unmanned" in the context of this paper due to flying without a human pilot onboard, resulting in autonomous, semi-autonomous, or remotely piloted flight.

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1. INTRODUCTION

The usage of UAVs has become more prevalent as the technology incorporated into them has become more proficient. The capabilities were initially pushed by military needs and have crossed over to the commercial realm. UAVs of today have greater capabilities and expanded missions as their technology and performance have increased. This has led to a natural desire for communication between UAVs so they can work safely and in a coordinated fashion to accomplish their respective missions.

The working group's first step in evaluating the possible communications between UAVs was looking at all possible uses for UAVs. These initial use cases where evaluated from the perspective of how they might impact the UAV's ability to communicate while being deployed. This allowed the group to evaluate what specific issues a UAV may encounter when attempting to communicate to other UAVs with respect to their use case scenarios.

It was quickly determined that the most prevalent communication usage would be collision avoidance or the detect-and-avoid scenario. This was deemed to be the primary driver of communications between vehicles. With this in mind, the operating environments were considered along with the unique challenges that each different environment may include. For instance, a UAV operating in the confines of a major city would be prone to encounter more stationary man-made obstructions and other moving objects at a greater density than would be encountered in a rural location, such as a farm. All scenarios have a need to detect and avoid obstacles in the UAV flight path and could benefit if one UAV could communicate this information to other UAVs to aid them in avoiding obstacles that they may not yet have detected.

The next step was to consider any proposed or existing regulations, such as the FAA's Remote ID regulation, and the minimum requirements needed to comply. The Remote ID regulation stipulates certain broadcast features, operating frequencies, and other specific informational data to be broadcast by UAVs. It also includes a distinction between UAVs operating under Code of Federal Regulations Title 14, Chapter I, Subchapter F, part 91 and part 107 [2]. The Remote ID regulation has a clear prohibition against usage of either ADS-B OUT or transponders for UAVs flying under part 107. Therefore, the working group proposed that if the V2V standard was compatible with Remote ID, it might be able to be used for a less-sophisticated form of collision avoidance. In any case, this means there are two distinct classes of UAVs: those operating with traditional transponder capability and those without it. The proposed communication solution is intended to be compatible with other proposals being produced by other standards issuing organizations.

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The next step was to consider the role of various types of UAVs in operation and how the size of the craft would impact their capabilities. It was quickly surmised that the smallest UAVs would be limited in both capabilities and missions, being unable to match the capabilities of much larger UAVs. In addition, it was perceived that the capabilities and missions would scale up in proportion to the size of the craft. Larger UAVs would be able to carry more sensors, payload, and have better handling and range than smaller craft. The realization that craft size would dictate capabilities led to the development of categories or levels of UAVs.

The working group initially created three UAV levels based on vehicle size: small UAVs (less than 55 lb., no cargo, no passengers), medium UAVs (more than 55 lb. and less than general aviation aircraft), and large UAVs (equal to general aviation aircraft or larger). After further discussion, additional categories were added, such as vehicle type (fixed wing, rotorcraft, etc.) and vehicle usage (reconnaissance, cargo delivery, etc.), to provide a more fulsome description of the vehicle and its capabilities and limitations. It was determined that the safety and security requirements would be based on the UAV's mission or primary usage. For instance, more safety considerations would be required if cargo or passengers are being carried. The UAV communications are much more critical if the craft is a cargo UAV carrying valuable cargo, an air taxi loaded with passengers, or is acting as an emergency vehicle such as an air ambulance.

By setting up a UAV type designation based primarily on vehicle size, flight capabilities, and primary usage, it was determined that this would be useful in helping organize V2V communication but could also have the added benefit in situations where UAV congestion is heavy by allowing for prioritization of craft movements using the UAV type designation in conjunction with current position and flight path information.

This paper also looks at the different sensor and computational architectures that may be included on a UAV. The purpose is to highlight how the differences in capabilities, or the limitations due to a lack of certain sensors or computational architectures, may impact a UAVs role and/or ability to communicate to other vehicles. This effort is intended to provide guidance on minimum capabilities that the V2V communication standard should support.

Further topics discussed in the paper include the following:

- UAV sensors and how they impact UAV flight capabilities and performance, enable tasks, or affect mission complexity. Their output is integrated into V2V communications.
- UAV computational limitations due to craft size, system architecture and technology, and novel uses.
- UAV communication methods, message formats, and usage.

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2. UAV SENSORS REQUIREMENTS

2.1. OVERVIEW

One of the key features of UAVs used in industry is the availability of a wide range of sensors with different functionalities for unmanned operations. Employing advanced sensors together with high-tech navigational and communication devices onboard a UAV makes it capable of carrying out different missions without risk to human operators. Apart from military use cases, UAVs are utilized for many commercial use cases such as parcel delivery, precision agriculture, fire detection and fighting, industrial inspection, maritime surveillance, and medical equipment transport. Considering the exponential increase in UAV applications in recent years, it is expected that UAVs will be a common element in airspace in near future.

2.2. UAV PAYLOAD SYSTEM ARCHITECTURE

UAVs are usually equipped with a set of monitoring and data-gathering sensors and devices such as cameras, infrared sensors, and thermal sensors that collect different information to be processed on board the UAV or transmitted to the ground base station for further analysis. The systems architecting process consists of aggregating, partitioning, integrating, and finally validating systems architecture. The architecting process is the one by which standards, protocols, rules, system structure, and interfaces are created in order to achieve the requirements of a system. In other words, it is the planning and building of structures to respond to a given need. For this purpose, first, the system components should be classified according to their degree of autonomy and cognitive functionality. From another perspective, the system components are categorized into low-level and high-level components, as shown in FIGURE 1. The low-level components are in charge of the perception and cognition, data fusion, and flight control of the UAV. These components can provide reliable autonomous flight and navigation, providing an interface between human operators and high-level components. In addition, situational awareness and mission-planning functionalities are provided via the high-level components.

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