The COURAGEOUS project efforts towards standardized test methods for assessing the performance of counter-drone solutions

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ABSTRACT

Confronted with an ever-increasing amount of professional and non-professional airspace users, European Law Enforcement Agencies (LEA's) are given the new task of policing the lower airspace. In order to enable them to take up this task, a large amount of Detection-Tracking-Identification (DTI) tools is being offered to them by commercial suppliers. However, for LEA's it is extremely difficult to assess the capabilities of all these Counter Unmanned Aircraft Systems (C-UAS) tools for their specific use case scenarios. To remedy this situation, the European Union decided to fund the COURAGEOUS project that brings together end-user organisations from across Europe with a number of renown European Research and Technology Organizations (RTOs), to gather lessons learned in order to build a common understanding of the capabilities of DTI C-UAS systems. This paper will outline how the COURAGEOUS project is working on developing a standardised test methodology for DTI C-UAS systems, allowing for the qualitative and quantitative evaluation of commercial C-UAS systems according to a series of user-defined standard scenarios. Within the COURAGEOUS project, the developed standard test methodology will be iteratively improved in close collaboration with end-user stakeholders. The test methodology will be applied to a batch of commercial DTI C-UAS systems during three field validation events, spread around the EU. As a direct result of the COURAGEOUS project, EU LEA's will be able to select the optimal DTI tool for the UAS threat that they have identified and by doing so, they will be able to reduce the risks for the population and the infrastructure and increase the general level of security in the society

Keywords: C-UAS, quantitative evaluation, standardization, validation, Countering small UAVs.

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1. INTRODUCTION AND PROBLEM STATEMENT

Unmanned Aerial Systems (UAS) or drones cannot be ignored in our society. They are easily available and relatively cheap. Their applications vary from toys to inspection, from observation to delivery and agriculture [1]. However, their potential as a criminal asset is also recognized. Drones are frequently used for drug smuggling, to mention the US-Mexican border, and their ability to disrupt airport operation is demonstrated [2]. Technological development in the drone arena is fast, they become more and more sophisticated at an affordable price. Hence, the possibilities for criminals using drones increase as well.

Counter UAS (C-UAS) systems do exist and are available, however, often at substantial costs [3]. Due to the lack of common functional requirements, each of the systems has their own virtues and functions. Their performance claims are mostly not supported by evidence and there is no commonly accepted standard to compare their effectiveness. Consequently, acquisition of C-UAS systems is risky both in functional and budgetary respect.

The lack of standards will hold back industrial development of C-UAS solutions, given the absence of objective means to prove the capabilities of such systems. Well-chosen performance requirements and proper tests allow industry to show C-UAS improvement and will fuel development.

The European Union (EU) has started a holistic C-UAS approach to create an effective and affordable mitigation of the UAS threat [4]. It has initiated an initiative to provide regulations for safe and appropriate cooperative drones, adhering to those regulations might indicate a drone has no bad intent. Malicious drone users however might try to hide their intent by acting as cooperative drone.

A malicious drone needs to be countered and hence, an effector is inevitable. Given that the use of effectors is bound to national regulations that differ from country to country, there is no basis for a common standard in this respect. The detection, tracking and identification (DTI) of the drone will however benefit from standards and common testing strategies.

The most important function of the DTI is providing decision support to the operator. Future developments will focus on this issue. Programs like ALFA [5] have highlighted that knowledge about the probability of malicious intent of a drone is highly beneficial to the operator.

An undisguisable parameter for DTI systems is the reliability of its output. Birds or small aircraft might be mistaken for drones, as distinguishing between them is no easy task [6]. The same might happen to a cooperative drone. Effector action in this case might lead to collateral damage that is totally unacceptable in a civil context.

In order to tackle all these problems, it was decided by the EU Directorate-General of Home Affairs (DG-HOME) to fund the project COURAGEOUS [7], tasked with providing an adequate set of operational, performance and interoperability requirements for DTI systems, as well as a suitable test methodology that is validated in practice. This paper will explain the methodology followed within the COURAGEOUS project. Emphasis is on the adequacy of the DTI output as decision support, and on the accuracy of the track information in order to effectively guide effectors. COURAGEOUS will define the performance requirements for DTI systems in close collaboration with the Law Enforcement Agencies. As C-UAS systems might be complex, the test methodology is suitable to both system parts and integrated systems.

The COURAGEOUS approach is tailored towards requirements for and functions of DTI systems. This enables testing of any kind and any make of DTI systems, irrespective of the underlying technology. COURAGEOUS concept is designed such that it is future proof and any new technological development can be accommodated including run-time adaptive DTI systems coping with smart UAS.

The COURAGEOUS consortium involves relevant end users from EU ministries of interior, justice, defence and police forces, in order to ensure a broad acceptance of the proposed approaches.

2. PREVIOUS WORK

Research related to the C-UAS domain focuses often on technical development of novel C-UAS solutions. Notable examples are the projects H2020-ALFA [5], H2020-ALADDIN [8] and H2020-SafeShore [9] that all developed drone detection systems for specific use cases. There are in general two main difficulties related to the development of an efficient drone detection system. First, the cross section / detection baseline for these systems is in general very limited, whatever sensing technology is used [10]. Indeed, drones have a small RADAR cross section, a small acoustic signature (from a relevant distance), a small visual / infrared signature, they use common radio signal frequencies, etc. Moreover, the signature of many drones is quite close to the one of birds, so it is difficult to filter out these false positives [6]. Sensing modalities that can be used to solve the drone detection problem are typically RADAR [11], acoustics [12], visual [13], IR [14] (thermal and short-wave), sensing of the radio spectrum [15], LIDAR [16], etc. However, as the problem is so difficult to solve in realistic operating conditions, most of the existing solutions rely on a mix of different sensing methodologies in order to solve the drone detection problem [10] and use a mix of traditional detection and tracking methodologies [17], [18] originating from computer vision to achieve multi-sensor tracking

In relation to the development of standardised test methodologies for evaluating the performance of drone detection systems, two contrary requirements can be identified [10]. On the one hand, drone detection systems most often rely on complex data fusion and processing of sensor data, which means that it is required to carefully control the test conditions in order to single out the limits of the system under test. On the other hand, drone detection systems need to be operational 24/7 and under all weather conditions, meaning that it is required to assess their performance within a wide range of environmental conditions. These constraints are in contradiction with one another and a standardised test methodology must therefore seek a careful compromise between these two types of requirements.

The objective is therefore is to find a validation methodology that satisfies both the request of the end-users towards a qualitative operational validation of the system and the platform developers of a quantitative statistically relevant validation [10]. Such qualitative and quantitative validation methodologies have been proposed before, e.g. by the U.S. National Institute of Standards and Technology (NIST) in the field of robotics [19]. In [20], a qualitative and quantitative validation methodology was proposed, based on the work performed at NIST and this technique was validated in [21]. Also in Europe, a large number of tests of C-UAS equipment have been performed by EU LEA and other government actors [22]. An aim of COURAGEOUS is to maximally make use of work being done in different countries (which is why the consortium is composed of LEA's from all over the EU) by incorporating available and relevant results and insights into its scenario, requirements, and test development processes.

In the USA, research towards developing a C-UAS testing and evaluation methodology was performed by the United States Department of Energy's National Nuclear Security Administration [23]. This test approach described identifies test strategies, performance metrics, UAS types tested, key variables, and the necessary data analysis to accurately quantify the capabilities of C-UAS technologies, but never really made it into a real standard. In Europe, the most important relevant action towards standardisation of C-UAS tools is the work being performed within EUROCAE WG-115 [24], which was established to develop standards to support the safe and harmonised implementation of C-UAS Systems into airport and Air Navigation Service Provider systems. While EUROCAE-WG115 focuses on airports, the C-UAS capability can be extended to operations in other environments, such as urban areas.

Another important actor for standardizing C-UAS test methodologies is NATO. The NATO C-UAS WG is working on aspects as i) building a C-UAS community; ii) Policy, Concepts, Doctrine, Tactics, Techniques and Procedures; iii) Development of standards; iv) Research, Development and Operation efforts. An important example are the yearly TIE exercises that aim to foster the interoperability between different C-UAS assets [25].

An important aspect to consider besides the development of the standardised test methodology is also the integration of this concept in the standard operating procedures for police forces with respect to C-UAS. Relevant in this context are the projects SkyFall [26] and DroneWise [27], studying different C-UAS systems, integrating the best systems on the market in a training for law enforcement organisations and delivering a series of practical end-user focused measures to improve the response to UAS terrorist attacks.

From this overview of the state of the art, it is clear that there is no existing standard for testing C-UAS systems. COURAGEOUS therefore clearly fills a capability gap., making it highly relevant, not only for the end users (acquisition agencies that can make better informed decisions on the optimal system to choose for their specific use case), but also for the C-UAS system designers (who can use the standard test protocols to better quantify and thereby iteratively improve the performance of their systems).

3. PROPOSED SOLUTION TOWARDS STANDARDISED TEST DEVELOPMENT

3.1 Global overview

The COURAGEOUS project has six main objectives:

1. Identify and develop a set of standardised UAS threat scenarios

2. Define the performance requirements of C-UAS systems
3. Develop a standardised C-UAS testing methodology
4. Test the performance of different C-UAS systems with the developed test methodology
5. Sharing of tests results between all relevant authorities
6. Pre-standardisation of the developed test methodology

These different objectives translate to project activities that are highly inter-related, as the project follows an iterative and incremental spiral development process [28]. That process starts with the COURAGEOUS system definition, consisting of requirements extraction, initial scenario definition and the preparation of the evaluation methodology. In a following system development phase, an iterative refinement of the scenarios requirements and evaluation framework and test methodology takes place, as the initial assumptions are iteratively improved upon by taking into consideration results from the validation phase where field tests are organized and systems are C-UAS evaluated using prototype evaluation methodologies. The standard evaluation methods are still being developed and will be presented at a later stage. This paper therefore outlines the general approach in the following sections.

3.2 Standard scenario development

The conceptualization of standard UAS threat scenarios is a primary condition required for achieving a common understanding of the capabilities of C-UAS systems. Therefore, COURAGEOUS develops a set of standard scenarios, representing the needs of all relevant stakeholders and, where possible, find common scenarios. These standard scenarios cover the drone-threat spectrum to the maximum possible extent, against different types of infrastructures, open spaces, etc., under different situations, covering the needs of different stakeholders across EU Member States. Primary action points that are carried out to derive these standard scenarios are:

1. Better perceive the overall framework of the threats by reporting on previous drone related incidents
2. Identify gaps and needs in the security systems and methodologies
3. Report the current C-UAS technologies and methodologies available on the market and those applied or tested by organisations.
4. Define high-level threat scenarios by reflecting on the security needs and gaps per operational environment
5. Identify the risks per individual scenario and also define the relevant metrics

3.3 Performance requirements

In order to find a common agreement on the performance requirements of these systems, COURAGEOUS investigates the operational needs of the end users and the corresponding development of functional and interoperability requirements. From that knowledge, COURAGEOUS develops performance indicators for DTI systems, including an evaluation framework to measure them for known technology modalities.

Crucial in this work is linking the operational needs and performance requirements of civilian law enforcement/security stakeholders with counter-UAS responsibilities now and in the years to come. Therefore COURAGEOUS takes into account both the current and future threat landscape in Europe, as well as anticipated advances in both UAS and C-UAS technologies. Primary action points that are carried out to derive these performance requirements are:

1. To provide a general set of operational needs for detection, tracking and identification systems, including integrated systems;
2. Develop C-UAS system functional requirements;
3. Develop C-UAS performance requirements and metrics;
4. To create a common framework by which Member States working in coordinated, voluntary fashion can test and share data regarding the performance of different C-UAS systems with one another;
5. To create a common baseline understanding amongst Member State authorities concerning the effectiveness of different C-UAS solutions;
6. To provide the commercial C-UAS industry with a clear understanding of the common C-UAS needs and expectations of different authorities around Europe.

3.4 Test methodology development

A common understanding of the effectiveness of C-UAS tools can only be achieved when a common, standardized test methodology is adopted to compare different solutions to each other. Therefore, COURAGEOUS develops a test environment that is subjected to functional and integral testing in order to serve as a baseline for the qualitative & quantitative evaluation of C-UAS systems. A major constraint is that the methodology should enable testing of complete DTI systems under realistic conditions and scenarios. The methodology also covers testing of DTI functions and sub-functions. The methodology is both future proof and able to accommodate future developments. Primary action points that are carried out to derive the test methodology are:

1. Generation of a test environment, describing and generating the stimuli that are needed to test DTI systems. These stimuli comprise on one hand of stimuli generated by the UAS following a specific flight trajectory as described in the used scenario. In addition, these stimuli are dependent on the type of UAS, for example fixed wing or rotor, its size, and also on its way of control and communication.
2. Based on the operational needs as well as functional and performance requirements a functional decomposition is drawn up for the DTI system. Each of these functions is analysed to obtain a functional input-output relationship. This allows for sensitivity analysis of these functions, as well as for their false positive and negative behaviour. Sensor functions are in this respect often straightforward, they compose of adaptivity towards maximum clutter suppression.
3. A method is drawn up to test the full functionality of the DTI, given the DTI constitutes of a set of (sub-)functions that perform as required. The developed methodology takes the presence of the DTI operator into account. The method supports full DTI operation either with simulated data in a modelling environment, with real data in a real environment or a mixture of those. Thereby the integral test methodology is well suited to reveal compliance with the operational requirements.
4. A sensitivity analysis is performed to reveal the validity of the developed test methodology, thereby showing the sensitivity of the test method for the used KPI's. A multi-stage approach is used.

3.5 Performance testing

In order to validate the developed methodologies, and in order to allow for an iterative design review, COURAGEOUS organizes 3 field validation campaigns, geographically spread over the EU, in order to ensure maximum attendance by industry. The overall aim of this performance testing is to show that the evaluation methodology developed within COURAGEOUS produces quantifiable, documentable, and evaluable performance data on systems under test and also produces comparable evaluation results. In addition, the evaluation results from each test constitute actionable information for stakeholders in the sense that they show how well the specific systems under test address the user needs.

In order to validate the methodology and C-UAS systems in different meteorological conditions and in order to ensure a varied response from the C-UAS industry to attend the COURAGEOUS tests, three different and geographically spread trials are organised:

1. A first one in spring 2023 in Athens, Greece
2. A second one in autumn 2023 in Nieuwpoort, Belgium
3. A third one in spring 2024 in Seville, Spain

All of the field trials have – next to the pure technological validation aspect – also an important user engagement dimension, as user workshops is attached to these events for building awareness among the end-user base of the COURAGEOUS developments.

3.6 Results dissemination

Responsible sharing of research findings is a key element of the COURAGEOUS project, which is a delicate exercise. Indeed, the sharing of COURAGEOUS outputs is confronted with contradictory constraints from different perspectives:

1. In order to arrive to open standards, an open dissemination of the research results is required
2. From a security point of view, it is not possible to share openly the weaknesses of operational threat detection systems like C-UAS DTI solutions
3. From industry point of view, it is also not possible to share openly detailed system performance assessments with competitors

In order to strike this balance, COURAGEOUS adopts a multi-layered dissemination strategy, sharing outputs on four different levels. Specifically interesting for COURAGEOUS are the possibilities to share data:

With the global Law Enforcement Community, through the INTERPOL network

1. With the EU Law Enforcement Community, through the Counter-UAS Interest Group of the European Commission, via the CIRCABC platform
2. With the global Law Enforcement Community, through the INTERPOL network

3.7 Standardisation

COURAGEOUS fosters the standardization of its developed test methodology through bodies as EUROCAE, ETSI & CENELEC. At the present time, there are no agreed-upon international civilian standards for UAS countermeasures. That being said, at least one standardisation body, the European Organisation for Civil Aviation Equipment (EUROCAE), is currently engaged in work aimed at assessing and establishing operational, performance and interoperability requirements for C-UAS systems deployed within the context of airports. COURAGEOUS focuses on collaboration with the European Standardisation Organisations in order to cover all LEAs' needs and to provide additional clarity to industry, which stands to benefit from having a clear understanding of the shared C-UAS needs and expectations. At this moment, COURAGEOUS is mostly focused on the interaction with the European Committee for Electrotechnical Standardisation (CENELEC). Thanks to the involvement of the Romanian Standardisation Organisation ASRO, COURAGEOUS works towards a CENELEC Workshop Agreement (CWA), which will drive the standardisation of COURAGEOUS outputs.

4. LONG TERM SUSTAINABILITY AND CONCLUSIONS

This paper discussed the current work performed within the COURAGEOUS project on the development of standard test methodologies for C-UAS solutions. Major outcomes of the project are:

1. A set of standard UAS threat scenarios that will be disseminated as standard "vignettes" for use when testing the performance of different C-UAS systems by Member States,
2. A set of performance requirements for C-UAS systems will be defined in the frame of COURAGEOUS with the aim of facilitating the performance evaluation as well as the smarter purchase of C-UAS systems after the conclusion of the project.
3. A standardised test methodology, providing a common evaluation method for C-UAS performance testing by interested parties where the results will be comparable.

The above COURAGEOUS results will be system/sensor agnostic to the maximum possible extent in order to account for future developments in C-UAS technologies. As such, upcoming DTI technologies like run-time adaptivity will be covered. Additionally, the standardisation actions will play an important role as drivers for ensuring the longevity of the COURAGEOUS results.

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