Technical Evaluation Report

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EXECUTIVE SUMMARY

This report summarizes findings of the AVT-353 Workshop on "*Artificial Intelligence in the Cockpit of UAVs*". The Workshop took place in Torino, Italy on April 26-28, at the Italian Army Education and Training Command, and School of Applied Military Studies. The local coordinators were LtCol Moreno Proietti and Maj. Francesco Corso. The Workshop Chairs were Fulvia Quagliotti (Italy) and Afzal Suleman (Portugal). The Panel Mentor was Maj. Francesco Corso (Italy), and the Administrative Support person was Aurelie Bertrand (France). The Technical Evaluator was Kimon P. Valavanis (USA). AVT-353 included presentations from authors of the following countries: Belgium, Canada, Germany, Italy, Portugal, and the USA. The Lead Nation was Italy.

The report first states the mission, scope, and objectives of the Workshop, followed by a summary of the specific topics presented, as well as discussions that subsequently led to identifying challenges that need to be addressed and eventually overcome by the Member States. A list of key recommendations is presented, along with a relevant SWOT analysis, the aim being to avoid drawbacks that may delay fast progress.

It is emphasized that, based on submitted and presented research work, it has been obvious that UAV technology has advanced and matured, and it has been applied to a multitude of diverse applications. However, "integration" and "complementarity" at the NATO level is now required to pave the way towards establishing standards and introducing a common foundational framework that will allow for AI to be used as a tool to develop, implement and test high confidence autonomous and unmanned robotic platforms.

The aim of the report is to tabulate 'lessons learned' and to serve as 'guide', not as criticism, towards creating and implementing this much needed and common framework.

1. INTRODUCTION

The AVT-353 (type of activity, RWS), took place in Torino, Italy, on April 26-28, 2022. The meeting was open to NATO Nations, Finland, Sweden, and Australia. The lead nation was Italy. Authors who presented their research findings at the Workshop were from Belgium, Canada, Germany, Italy, Portugal, and the USA.

Meeting objectives focused on bringing together subject matter experts from civil and military organizations to share best practices for RPAS safe operations. Topics covered through presentations centered on regulations, risk-based safety assessment methodologies, procedures for mitigating operational risks, novel technologies for safety devices and risk mitigation, and insurance challenges.

Overall, all contributed papers and presentations were very detailed and reflected accurately the state-of-the-art in the chosen topics, and in the specific Member State. One may argue that one first (and perhaps cynical) observation, based on presented information, is that the Member States (may) have justifiably good reasons not to collaborate with each other. However, as this should not be the case, common ground must be found, and the NATO Headquarters must take the lead in developing a timetable with specific deliverables towards achieving UAV autonomous functionality.

2. AVT-353 SCOPE AND OBJECTIVES

The AVT-353 Workshop scope and objectives were to explore AI enhanced Guidance, Navigation and Control (GNC) of autonomous air systems with the aim to promote trust in autonomous decision making. Theory, mathematics, computational models, systems integration, and field applications provided the arsenal of tools and support technologies.

2.1 Topics of Interest

The Workshop advertised topics of interest included but were not limited to: AI algorithms and UAV Applications; Cooperative and non-cooperative systems; AI-enabled path planning, guidance, navigation, and control; Data fusion and deep learning; Data acquisition, storage, and processing; Big data and machine learning; Flight control and flight-assist technologies; Sensors and integration; Sense-and-Avoid; Human-machine interface, and Certification.

2.2 Benefits and Outcome

The meeting brought together experts from different disciplines. Through presentations and discussions, Workshop outcomes centered on: Identifying gaps and recommending a way ahead to the NATO S&T community; Promoting and continuing the dialog among NATO nations regarding unmanned and autonomous systems in support of future NATO military operations. A key finding and observation were that a roadmap and standards are needed to fully integrate AI into the cockpit of UAVs.

3. AVT-353 KEYNOTES

The Workshop included the following Keynotes:

- Responsible Innovation: Enabling the Alliance’s Future Advantage for Emerging and Disruptive Technologies
- Toward Autonomy: Operational and Ethical Considerations
- Assuring Autonomy on the Battlefield

The Keynotes were informative, albeit starting from different vantage points. However, the following key challenges that need to be addressed and overcome emerged as immediate next steps:

- Define and apply “Ethical AI”
- Enable and implement autonomy taking advantage of what AI offers
- Define, levels of autonomy, trusted, assured, and long-term autonomy

- AI is a force multiplier for autonomy.

Overcoming the specific challenges the Keynotes presented, will lead in a giant step forward allowing for the technical and scientific community to demonstrate UAV cockpit autonomy and decision-making.

4. AVT-353 TOPICS OF INTEREST

The Workshop presentations spanned a very wide and diverse list of challenging topics. This may be indicative of the advantages AI, when appropriately used as a tool, offers as a force multiplier towards developing autonomous aerial platforms. The Workshop presentations were on the following topics:

- Autonomy and Metrics of Autonomy
- Certification Challenges and Opportunities for UAS that Employ AI
- Scouting of AI algorithms for mission management of autonomous aerial platforms
- AI-Based de-Confliction and Emergency Landing Algorithm for UAS
- NAIS: Artificial Intelligence Powered On-Board Sensor Processing for UAVs
- One-to(o)-many: HMIs to enable multiple UAV control by single operators
- A Smart Autoflight Control System Infrastructure
- Intelligent Decision-Making Algorithms for Swarming UAVs in Defense Applications
- Adaptive and Evolutive Cyber Defence of Drone Teams in C4ISTAR Applications: DECyDO Project
- Non-cooperative UAV Detection: A DL Approach Using LiDAR and Camera Data
- Selective Classification for Learning-enabled CPSs based on Sequential Data
- Leveraging multimodal synthetic- and real-sensor data to enable safe flight operations in fair and degraded visual environments
- Online Planner based on Modified RRT and Trajectory Optimization
- Global Tracking Control of Quadrotor Based on Adaptive Dynamic Surface Control

Common themes among the presentations centered on: Advances in Systems Theory; Artificial Intelligence and Machine Intelligence; Computational Power and Evolutionary Computation; Complex Adaptive Systems (CAS); CPS; Learning (Machine Learning approaches, DL); Big Data and Data Analytics, and the wealth of available Support Technologies and Tools. Research and development in the underlying areas offers the backbone towards an integrated foundation for autonomy.

5. OBSERVATIONS AND RECOMMENDATIONS

The main observation that has surfaced from all presentations and discussions, the common objective that needs to be achieved is to design, build, implement and test high-confidence autonomous systems operating in dynamic and uncertain environments, which are capable of situation awareness, real-time adaptation, self-organization, and reconfiguration. Stated differently, but in engineering terms, the objective is to design autonomous systems for resilience (not just robustness).

However, for such complex engineering systems, autonomy is not just a set of capabilities achieved via software! The ‘physical system’ itself must be considered, and this requires at a minimum accurate modeling and controller design for robustness and resilience and with stability guarantees. On the other hand, when focusing on autonomy, autonomy must be defined and implemented with respect to a well-defined set of criteria; that is, ‘autonomy with respect to what?’. Desirable attributes of autonomy, and metrics of autonomy must be defined. Autonomy must be ‘measured’ to facilitate delegation of decision-making authority from the human to the machine. This is coupled with securing the trustworthiness of such systems against cyber-attacks.

a. Recommendations

The provided indicative list of recommendations is by no means exclusive. It only offers a starting point of topics that need to be considered when building autonomous systems. We have entered in a new era of unmanned aviation, where manned and unmanned aircraft will share the same airspace (eventually).

- Develop experimentally proven, certifiable, and reliable technology
- Use AI as a tool – apply ethical AI
    - Avoid ‘learning’ biases during ‘training’
    - What do you learn, why, how, and how do you use it?
    - Performance guarantees
    - Address safety issues through technology
- Address ethical, privacy, legal issues
- Develop standards, standards, standards!!!!!
- Create and implement a clear roadmap with specific milestones to accomplish

The above recommendations must be coupled by concrete:

- Requirements analysis
- Clear steps for progression of automation
- Gradual delegation of decision-making authority from the human to the machine
- When will the operator be part of the decision-making loop?

Building and testing autonomous systems is the epitome of current advances in technology. But to be successful, we need a framework, and this framework is currently missing.

6. SWOT ANALYSIS

S: AI is now matured technology. It is coupled with learning, big data analytics, and available computational power. AI can now be applied on complex systems, not only UAS (RPAS)

W: Lack of common framework; lack of acceptable definition related to autonomy and autonomous functionality, and levels of autonomy. Lack of a clear understanding of ‘autonomy with respect to what’. No roadmap, no standards, no timetable, no clear implementation steps. Gap between the military and civil/public domains.

O: Capitalize on available technology advancements, apply safe and secure AI, demonstrate acceptable performance of trusted and assured autonomy. Address safety and security, ethical, legal, privacy, and liability issues.

T: Don't make the same mistakes as in the 1970's and 80's – AI failed then and one of the reasons was that we overestimated what we can achieve. Times have changed, we have what we need to apply it, but we need to have a very clear plan. Currently, there are still many fragmented efforts, silo approaches among interested parties. There exist many/different regulatory approaches in different Member States limiting cooperation. Take China seriously!

7. SUMMARY AND NEXT STEPS

AVT-353 offered the opportunity to register current research efforts in AI and several aspects of autonomy from different considerations and vantage points. The meeting also offered the opportunity to representatives to find out what each one is doing in this emerging area of common interest.

AVT-353 also revealed different considerations to tackling almost identical or very similar problems – this is healthy and expected.

NATO must coordinate research and development activities and provide to member states a roadmap with specific timetable and milestones to achieve – scientists and engineers as well as military may work together to prioritize needs.

A follow up meeting is essential (to capitalize on the gained momentum) but with explicitly stated objectives and clear demonstrations of applicability using real robotic platforms.