Technical Evaluation Report

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1. INTRODUCTION

1.1 Background

Deployment of Global Positioning System (GPS) satellites by the US in 1960s has provided (almost) ubiquitous opportunity to provide accurate position, timing and navigation (PNT). Following by the US, many other nations have deployed their own satellite constellations for PNT, which led to the coining of a more general term, namely Global Navigation Satellite System (GNSS). While, the GNSS is the most commonly used source of accurate PNT information, its vulnerabilities yield in performance degradation or denial of GNSS availability. It is instructive to consider what is meant by GNSS degraded and denied environment. The following explanations can be used:

GNSS works on the time of arrival of signals from each satellite in the constellation, thus, line of sight (LOS) becomes an important issue. High mountains and especially high rise buildings in urban areas hinder LOS and reduce GNSS availability especially when satellites are at low elevation angles. This causes GNSS degradation.

GNSS signals have a very well-known frequency/modulation and structure and travel a long way before they reach the receiver rendering the signal become rather weak. This makes GNSS vulnerable to jamming and spoofing and this results in GNSS denial.

Hence, techniques/systems/approaches are needed to provide reliable PNT information in GNSS degraded or denied environments. Cooperative/Collaborative Navigation Approach that allows information sharing between interoperating PNT systems helps address the problem caused by the absence of GNSS support. The approach, also called all source PNT, exploits capabilities of diverse PNT sources (sensors and/or systems) to produce improved PNT output in a GNSS degraded/denied environment. All source-PNT, as the name suggests, could also use GNSS as a source if the GNSS signal available in the environment is deemed reliable. Most commonly used complementary PNT technologies can be listed as follows;

- Multi-constellation (or multi-frequency) GNSS
- Signals of Opportunity
- Vision-based Navigation
- Beacon Referenced Navigation
- Magnetic Anomaly Referenced Navigation (MARN)
- Gravity Gradient Anomaly Referenced Navigation (GGARN)

- Gravity Anomaly Referenced Navigation (GARN)
- Network Collaborative PNT

Accurate PNT knowledge is of utmost importance for maintaining situational awareness and several efforts within NATO towards addressing the challenges presented by GNSS degraded/denied environments have been made. SET-229 on "Cooperative Navigation in GNSS Degraded and Denied Environments" was the latest one to explore technologies that will enhance NATO military effectiveness, particularly in challenging indoor and urban environments, through the use of advanced, cooperative/collaborative navigation sensor technologies and integration techniques. With the advent of autonomous systems, the topic has also attracted great attention from researches worldwide for non-military applications as well.

1.2 Objectives

SET-275 the symposium on Cooperative Navigation in GNSS Degraded and Denied Environments was aimed at bringing together specialists and researchers in the field of navigation, sensors, integration & communication technologies from universities, military and non-military research institutions and companies to trigger discussions and identify state-of-the-art technology and R&D results. The two-day symposium was proposed to see the current results on:

- Cooperative/Collaborative PNT Technology Trends – PNT Sensors and techniques
- Alternative (complementary) sensors and techniques used in Cooperative PNT in GNSS degraded/denied environments
- PNT Architectures
- Time Transfer & Synchronization
- PNT Fusion Algorithms
- Cooperative PNT Communication Architecture
- SET-229 Cooperative Navigation Demonstration Results
- PNT Cooperative Multi-Sensor Navigation across different platform types: Ground, Air, Sea, Underwater, Space & Dismounts

2. REVIEW OF SYMPOSIUM PAPERS, PRESENTATIONS AND DISCUSSIONS

2.1 SESSION 1 - Cooperative/Collaborative PNT Technology Trends – PNT Sensors and Techniques

KN1 SET-229 Cooperative Navigation in GNSS Degraded and Denied Environments Demonstration and Results
Mikel M. Miller, Integrated Solutions 4 Systems (IS4S), USA

This keynote address was dedicated to convey the motivation, background, details and findings of the demonstration on Cooperative Navigation in GNSS Degraded and Denied Environments that took place on 16 August 2019 in the UK. The demonstration was a joint effort by 7 nations (Croatia, Italy, Singapore, Sweden, Turkey, UK and USA), where each nation contributed with their available resources and technologies in a search and rescue mission scenario in which the operation area was jammed to block GNSS signals. The adverse conditions created by the absence of GNSS support were overcome by first, mapping the overall S&R mission area using Cooperative Arial Mapping and Modeling and second, mapping the interior of the buildings where the hostage was being held and where the overwatch teams would conduct their missions. Through the successful outdoor/indoor mapping the overwatch teams were able to locate

themselves in the operation area without the help of GNSS receivers. The address concluded with key-findings and lessons learned from the demonstration. This keynote address was particularly important to see the practical implications of a cooperative positioning in a realistic scenario.

KN2 Current PNT System/Sensor Challenges
Murat Eren, Aselsan, TUR

The second keynote address presented the journey of positioning sensors/systems starting from pre-GNSS days and provided an overview of challenges that had to be overcome for a more accurate PNT information. The address also focused on the enormous dependency on GNSS for PNT information both in the military and in civilian life. Efforts to modernize GNSS both in terms of software and hardware were also covered with an emphasis on no modernization effort can help with the inherent vulnerabilities of the GNSS. The keynote address also provided a coverage of alternative positioning systems and possible benefits of integrating those system for a GNSS-less PNT and concluded with presenting the need to have a plug-and-play type open architecture cooperative PNT solution for a faster, time/effort conserving and more efficient development process.

Paper 1 The Performance Analysis Of Tactical And Navigation Grade Land Inertial Navigation Systems Aided With Hypothetical Measurements
Lisan Ozan Yaman, Roketsan Missile Ind., TUR (***Virtual Presentation***)

GNSS is the main tool to provide positional fix to the Inertial Navigation System (INS) in order to reduce INS errors that accumulate over time. The paper presented an alternative way to provide positional-fix like correction to the INS. The method included introducing hypothetical measurements such as Zero Velocity Update (ZUPT), Zero Angular Rate Update (ZARUPT) and non-holonomic constraints (NHCs) in aid of both tactical and navigation grade INS employed in a land platform. In the study, ZUPT and ZARUPT were used during vehicles stationary period whereas NHCs was used to improve navigation performance during platform motion. The proposed method was tested both via simulations and with a field test using two different inertial measurement units (IMU) on five different platform trajectories. The conclusion was that the hypothetical measurements can help improve navigation performance by reducing INS errors in the absence of GNSS signals.

Paper 2 Independent Testbed for Positioning, Navigation and Timing in GNSS-degraded/denied environments for Military Applications
Stefan Baumann, IABG, DEU

This paper was not presented.

2.2 SESSION 2 - Alternative (Complementary) Sensors and Techniques Used in Cooperative PNT in GNSS Degraded/Denied Environments

Paper 3 An Application of Relative Node Positioning Using Ultra-Wideband Distance Estimates
Serkan Zobar, Aselsan, TUR

This paper discussed the problem of node positioning for an indoor wireless sensor network. Node

positioning in wireless sensor networks is of great importance as it determines the performance of the system while monitoring, tracking and controlling/directing people/objects both in military and civilian applications. The proposed method, in the paper, is based on classical Multidimensional Scaling (MDS) and Procrustes analysis. The methodology includes a distance-based positioning scheme and pairwise distance estimates between nodes where the distance information is obtained by observing the roundtrip time-of-flight (ToF) measurements of Ultra-Wideband (UWB) signals. Mathematical model of the proposed solution was derived and the system was tested in a laboratory setup where two types of nodes were considered. One type of the nodes was assumed to have no communication limitation with the other nodes where the other type node was forced to communicate with the other type of node. Experimental results revealed that while the MDS approach helped with creating the local relative maps of the nodes, Procrustes analysis provided a global map displaying relative positions of all nodes.

Paper 4 State of the Art in Visual Localisation for UAVs in GNSS-denied environments
Michael Schleiss; Fraunhofer FKIE (DEU)

This paper explored the performance of two recently proposed visual localization techniques in a GNSS denied environment based on data collected as a benchmark by an aerial vehicle. The data represented an hour of flight data, over 130 km long trajectory, collected at an altitude of 300-600m above ground. The paper did not include any technical discussion of the compared techniques, namely, ORBSLAM3 and NetVLAD that are representatives of relative and absolute visual localization approaches respectively and compared the localization performance as applied to the collected data. The results showed that ORB-SLAM3 suffers from drift over time, however, the combination of ORB-SLAM3 and a geo-localization technique NetVLAD aligned rather well with the ground truth. On the other hand, the performance is dependent on the scene and deteriorates significantly if the platform is flying over an area where there are no discernable landmarks, such as forests. One important point is that the visual data set has been made available to all researchers and it can serve as a benchmark either in full or parts of it.

Paper 5 Geo-matching with simultaneous altitude measurement for SAR-aided navigation systems
Majiec Wielgo, Warsaw Univ. of Technology, POL

This paper aimed to provide a navigation solution in a GNSS denied environment based on SAR-imaging. The approach involved matching SAR images to an ortophotomap where longitude and latitude shifts were estimated and corrected utilizing altitude measurements. Altitude measurements were matched to SAR images through algorithm proposed by the authors that is based on cumulative minimum square distance matching. Localization using SAR images is a relatively recent approach compared to the techniques using day-time or IR camera images. Unlike day-time or IR cameras, SAR systems can perform well in adverse weather conditions as well and research into SAR-aided navigation could provide additional advantages in visual localization.

Paper 6 A Novel Approach for Pedestrian Positioning Using Inertial Sensors
Taylan Keles, BITES, TUR (***Virtual Presentation***)

This paper addressed the issue of pedestrian tracking in a GNSS denied environment based on measurements obtained from a single inertial sensor. Inertial sensors are good source of providing continuous motion information but they suffer from accumulated errors. This paper proposed a solution where a combination of nonlinear estimator, namely extended Kalman filter (EKF), and zero velocity detection was employed. For a foot mounted inertial sensor zero velocity occurs when the subject is in stance phase and this phase has to be

detected. Therefore different thresholds have to selected based on the size (heigh and weight) and of the subject and the nature of the motion (walking or running). The paper proposed a threshold-less method to detect the stance phase based on general likelihood ratio test so that positioning of the subject is independent from his/her size/weight and/or the type of the motion. Extensive field tests were carried out to display the performance of the proposed method and it was shown that a consistent and bounded positioning errors were obtained across different subjects both for walking and running motions.

Paper 7 Vehicle Dynamic Model Assisted Inertial Navigation
Oguzhan Ciftdaloz, Cankaya University, TUR

This paper presented a methodology where vehicle dynamics were taken into account while determining its position using an inertial sensor during operation in a GNSS denied environment. In aid to the inertial sensor, vehicle dynamic model was used to determine both zero velocity and zero turn instants so that the accumulated errors by the inertial sensor could be reduced in the absence of a positional fix provided by the GNSS. The study is still at early stages and only Kalman filter solution to vehicle position under linear conditions using zero velocity and zero turn updates were studied.

Paper 8 Micron-precision distance measurement using mmWave radars
Niksa Orlic, Geolux d.o.o (HRV)

This paper presented a high scan rate radar distance sensor to provide positioning data for the autonomous vehicles operating in GNSS degraded environments. The radar operates in the mm-Wave band and provides 25 μm accuracy in distance measuring. Such accuracy is of utmost importance in order to safely navigate in an environment where other platforms are present avoiding collision. It is also important to follow a pre-defined or calculated path with precision. Some technical aspects of the design process of the narrow beam antenna were also discussed in the paper. Such equipment could also prove useful in a search and rescue mission similar to the exercise performed under SET 229.

Paper 9 275 Day 1 Summary
Mikel M. Miller, Integrated Solutions 4 Systems (IS4S), USA

Symposium Chairman Dr. Miller provided a very good overview of the presentations made throughout the first day and opened the floor for discussions on the first day papers. Audience unanimously agreed on the quality of the information content of the papers.

2.3 SESSION 3 - PNT - UAS / Drone PNT and Location

Paper 10 Cooperative Navigation For UAV And Ground Units
Jonas Nygards, Department for C4ISR FOI, SWE (***Virtual Presentation***)

This paper presented results from the NATO demonstration on Cooperative Navigation in GNSS Degraded and Denied Environments during NATO SET-229. In SET-229 FOI had been the provider of a visual localization system where the camera was mounted on a UAV. UAV estimated its position by comparing images from an onboard camera to a georeferenced orthographic photo of the environment, while the ground units use foot-mounted IMUs. Ground units were tracked by the UAV upon detection and their position estimates along with covariances were passed on the ground units improve their own navigation accuracy., The paper detailed the positioning systems utilized on the ground units and on the UAV and the algorithm developed for fusing the data both from the ground units and the UAV was described. Results from SET-229

were also reported showing the potential contribution of cooperative navigation in reducing the position error significantly.

Paper 11 Cognitive and Collaborative sUAS Swarms in Urban Environments
Maarten Uijt de Haag, Technical University Berlin, DEU

This paper presented a very interesting approach to navigation of swarm drones. Inspired by the Nature, the proposed approach aspires to utilize the behavior of animals in nature in order to cognitively and collaboratively produce navigation decisions for localization as well as situational awareness. Urban areas were the choice of operational field in order to observe the performance of the approach. Navigating through urban areas, even with the help of GNSS, is rather difficult asthe high-rise manmade structures create adverse conditions causing multipath, shadowing and/or scattering of GNSS signals. The paper studied several cases where the swarm members carried different sensors ranging from GNSS receiver to radar altimeter, from barometric altimeter to beacon receiver. Different combinations of sensor availability were studied where a leader or leaders were assigned for the others to learn from them. Conclusion was; with the help of basic principles of swarm navigation in nature the leadership and social learning principles do apply nicely and by evaluating the necessary constraints filters can be defined that allow some of the swarm members to operate in GNSS-challenging environments . Also, in addition to the accuracy performance, integrity and continuity of the navigation solution for swarms were identified as future work.

Paper 12 Collaborative Navigation – Using Relative Sensor Measurements between Swarm Members to Aid and Synchronize Absolute
Tobias Neuhauser; Airbus Defence and Space GmbH (DEU)

This paper presented an approach for the Collaborative Navigation of a swarm in order to provide the members of the swarm with consistent absolute navigation estimations both when GNSS is available and not available. The approach aims to fuse the relative navigation information with the absolute navigation of the swarm memmbers. The fusion process was employed by establishing a common knowledge within the swarm through exchanging absolute state estimations, state uncertainties and relative measurements. Based on this, the proposed Consistent INS Drift Algorithm calculates a new position for each member that would be optimal for the whole swarm. The approach employs a main filter where the measurements from the sensors are processed to produce absolute navigation information and the Consistent INS Drift Algorithm is housed. There is also a backup filter to track swarm members to produce relative navigation. Benefits of the proposed architecture and approach is discussed via simulated scenarios and the general expexted performance based on the availablity of inputs is explained in the paper. The conclusion was; with the proposed approach INS error build up is slower and stops to remain bounded if positional fix from an external source such as terrain aided navigation is available.

Paper 13 Relative Navigation and Docking of an sUAS and an UGV
Maarten Uijt de Haag, Technical University Berlin, DEU

The paper addressed the problem of joint operation of an UAV and UGV as well as the docking of the UAV onto the UGV during or after the operation. Such a scenario requires both platforms estimating their own position along with the docking platform estimating the relative position with respect to the docking station. The fact that both platforms are in motion complicates the situation. Once the UAV detects the UGV, it will have to take into account the dynamics of it so that a successful docking can be accomplished. Both platforms are assumed to be equipped with a number of sensors, namely, the UAV with GNSS, IMU, camera, range radio and altimeter whereas the UGV with IMU, fiducial marker, range beacons and GNSS. Several scenarios, in which the availability of sensors was changed, were studied and performance bounds

were obtained through simulations and real life field tests have been identified as future work.

Paper 14 Detection and Classification using an Acoustic Camera
Sanja Grubesa, University of Zagreb, (HRV)

The paper gave a summary of the challenges involved in the development of a prototype 4D Acoustic Camera. 72 MEMS microphones were used to form a microphone array in the shape of a hemisphere. 4 different categories, namely, noise, human walking, human talking and flying drone were used as sources to detect and classify. The paper also discussed the preparation of the data set used and classification results of the aforementioned categories. “Delay and Sum” approach was used to focus on the signal coming from a particular direction and attenuate signals coming from other directions. Convolutional neural networks were used in the classification process. Initial results revealed high levels true positive classification for the studied categories (87% for noise, 89% for walking, 85% for speech and 92% for a flying drone). This is a promising outcome for further development of the prototype and using acoustic cameras as a sensor.

Paper 15 Radar-assisted relative location of multiple targets and collaborative sharing of location information between multiple radars
Tomislav Grubesa, Geolux, HRV

This paper presented the application of small size mm-Wave FMCW radars in order to determine relative locations for multiple targets without drift over time. The radars were used during the search and rescue mission demonstrated under SET 229. Static reference points were utilized to translate target’s relative speed, distance, and position to absolute position. The testing also included using multiple radars on the same platform and sharing position information between multiple radars and multiple platforms. Such a setup yielded improved the accuracy of absolute position and reduced location drift. The paper also discussed the challenges in designing and manufacturing the hardware of the radar. The main advantage of the radar was presented to be its ability to precisely measuring the distance and speed without drift and concluded that with electronic beam steering it is possible to scan the surveillance area quickly to produce precise maps to assist UGVs and/or UAVs with navigation information.

2.4 SESSION 4 - PNT Communication Architectures

KN3 SET-309 NATO PNT Open Architecture Vision
Dr. Adam Schofield and Dr. John Raquet, USA (***Virtual Presentation***)

This keynote was dedicated to explaining what PNT open architecture was, how it could be achieved and its possible contributions to developing effective navigation systems that are able to operate in GNSS denied/degraded environment. The keynote emphasized that, collaborative PNT requires a collective multinational effort, NATO would provide the perfect cultivating environment for this purpose and open PNT architecture allows multiple parties working on the same cause without having to let on individual contributing technology. The presenters also talked about the PNT-OS development efforts that had been going on for a while within the US Air Force. PNT-OS is a plug and play architecture with modules set as plugins where the input-output structures are standardized. Such an architecture will elevate the efforts to develop an all source PNT system through multinational collaboration. The keynote also informed the audience about the upcoming NATO RTG event, namely, “SET 309 -NATO PNT Open System Architecture & Standards to Ensure PNT in NAVWAR Environments” dedicated to developing a modular open PNT system that uses plug-and-play modules for sensors, integration algorithms, hardware, and

integrity monitoring and invited the audience to take part in this effort.

Paper 16 A Cooperative Navigation Simulation Framework for Designing Robust Navigation Systems
Murat Efe, Ankara University, TUR

This paper presented the details of a simulation framework that had been developed to support open architecture PNT studies. The framework is accessible through a graphical user interface where sensors, navigation systems and integration algorithms can be parametrically designed. The simulation environment supports two different approaches to the collaborative PNT designs. The distributed design integrates the outputs of different navigation systems using the selected fusion/integration approach whereas the INS-centric design allows INS to receive error correction from individual sources and/or from the integration/fusion center. The framework has been developed as part of an ongoing project where different parties are working on different navigation systems. Hence, the framework aims to support and effectively integrate the outputs of these systems. It was reported that the framework would also serve as a testbed, use field data and with some effort could provide the means for hardware-in-the-loop testing of individual subsystems. The paper also opened the floor for discussion if distributed decision making would contribute to better navigation solutions in the all source PNT effort.

Paper 17 Modular Sensor-Fusion TOPS to Achieve Accurate And Reliable Time And Position Information
Danny J. Maat, TNO, NLD

The paper proposed a modular sensor-fusion framework, namely as the authors call it, TOPS, that combines sensor/system information to provide more accurate. To assure the availability of a navigation solution under GNSS denied conditions, TOPS was reported to combine a wide variety of alternative navigation (Alt-NAV) sensors, such as Inertial Navigation Systems (INS), land-based radio navigation systems, database matching navigation systems, odometry and velocimetry based systems, etc. The paper provided two example scenarios, one with a land platform and the other with an Autonomous Underwater Vehicle (AUV) where the framework was used. The paper also discussed possible extensions to the framework

Paper 18 Overcoming GNSS Degradation by Cooperative Networked Localization of Autonomous Vehicles
Mattia Brambilla, Milano Politechnical University, ITA (***Virtual Presentation***)

This paper proposed an algorithm for cooperative self-localization to overcome the problem of GNSS absence. The proposed approach exploits both inter-vehicle communications and information obtained from the estimation of the position of detected stationary or moving targets. The combination of cooperative self-localization of vehicles and multi-target tracking (MTT) was proposed a solution utilizing the sum-product algorithm. The sum-product algorithm is a message-passing algorithm working on a suitable devised factor graph. The general formulation for the proposed methodology was also to enable tor work on any multi-static network configuration, with multiple transmitters and receivers. The paper also presented the validation of the proposed approach in a simulated urban environment as well as in a real maritime surveillance use case with a dataset collected by NATO STO CMRE.

Paper 19 Correlation-agnostic Fusion for Improved Signals of Opportunity-based Navigation
Clark Taylor, ANT Center, USA (***Virtual Presentation***)

This paper addressed the problem of correlated inputs to a fusion process and proposed an approach that does not need to consider the correlation. Since correlation between fusion inputs can lead to overly optimistic estimations, it cannot be ignored and must be taken into account. The way the correlation is handled in the literature is mostly limited to determining the amount of correlation and depending of the expected amount different techniques or same technique with different is used. The paper proposed a method based on probabilistic constraint that is indifferent to whether the inputs are correlated, or how much if they are correlated. The proposed method was applied to signals of opportunity based navigation where the velocity was estimated using GNSS signals from different satellites. The clock information is required in the described scenario which created correlation. Simulation results indicated performance improvement in comparison to commonly employed techniques. Testing the algorithm on real life system has been identified as future work.

Paper 20 Resilient Collaborative All-Source Navigation
Jonathon Gipson, AFIT, USA (***Virtual Presentation***)

This paper described the Autonomous and Resilient Management of All Source Sensors with Stable Observability Monitoring (ARMAS-SOM) framework that fuses collaborative all-source sensor information in a resilient manner with fault detection, exclusion, and integrity. The main focus of ARMAS-SOM is to provide assurance that the integrity information is valid and warn the user when it might not be where the additional goal is preservation of integrity in response to a single simultaneous sensor failure. An addition to the ARMAS frame work was also presented where the proposed approach aims to maximize efficient use of network resources, limit the propagation of unknown corruption to a single donor, prioritize high fidelity donors, and eliminate double counting normally associated with recursive Bayesian fusion of collaborative information. Numerical simulation results were given to demonstrate the effectiveness of the approach using the ARMAS-SOM framework.

2.5 SESSION 5 – Final Discussion and Closing Remarks

Mikel Miller opened the Session by giving an overview of the second day as well as a short brief on the first impressions of the Symposium.

This was followed by the co-chair Murat Eren and event host Tomislav Grubesa giving their thoughts on the completed event and the importance of all source PNT with future directions and topics of research. The most important future topic is identified as the open architecture all source PNT studies as it will provide the means to consolidate individual efforts on more accurate PNT information in GNSS denied/degraded environments.

All presenters concluded that SET 309 on NATO PNT Open System Architecture & Standards to Ensure PNT in NAVWAR Environments study will be the most important medium for developing the architecture and laying the groundwork for this open architecture to become a NATO standard and invited all participants to take part in SET 309.

3. CONCLUDING REMARKS AND RECOMMENDATIONS

SET-275 Symposium on “Cooperative Navigation in GNSS Degraded and Denied Environments” was a successful event with interesting papers presenting cutting-edge technology on cooperative navigation and its components.

Keynote addresses were comprehensive opening the floor for discussions and stimulating brainstorming amongst the participants.

Papers were a good mixture of theory and practice from researchers that are members of institutions ranging from universities to defense companies and to military research laboratories yielding a good balance of academic and application content.

Presenters were keen to address any questions from the audience which further elevated the level of information sharing.

The symposium provided a good forum for discussions of findings on navigation solutions in GNSS denied/degraded environments. It was important to see, through the symposium, that almost all NATO countries consider the problem of GNSS unavailability (intended or unintended) as a major problem to be addressed and have some kind of government supported program where state-of-the-art technology is being researched. Researchers also get together at academic conferences but it was observed that NATO symposiums attract more technology users from the military which is of utmost importance. It is recommended NATO symposiums are held more often to bring together technology users and developers so that the technology developed better meets the needs.

Also It was indicated that the symposium was the first in-person NATO event since the start of the covid pandemic restrictions being in place. Online participation (as audience or author) was also permitted for those who could not travel and/or cautious to travel due to covid. The hybrid (in-person and online) set-up allowed increased participation and discussions among a wider audience. Although the bandwidth availability at the symposium venue was somewhat limited, apart from a few number of incidents the online contribution went virtually problem-free. Thus, it is recommended that online participation be made available in events even after the pandemic.

With different technologies being studied by different NATO and/or allied nations, it is clear that an enabling technology to seamlessly and (virtually) effortlessly integrate these technologies is essential. This fact highlights the importance of SET 309 on NATO PNT Open System Architecture & Standards to Ensure PNT in NAVWAR Environments study.