SCI-328 Flight Testing of Unmanned Aerial Systems (UAS)

Technical Evaluation Report

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ABSTRACT

A two day symposium on Flight Testing of Unmanned Aerial Systems (UAS) was held in Segovia, Spain on 12-13 May 2022 in support of the Systems, Concepts, and Integration (SCI) Panel business meeting. This was a follow up to a Symposium on UAS Flight Testing that was held in Ottawa, Canada on 12 and 13 May 2015. One-hundred-twenty participants, representing 17 Nations, registered for the symposium. Twelve registered participants did not attend. The twenty-three presentations were grouped into five sessions, Individually and as a whole, the information was highly relevant to the NATO mission and the utilization and development of UAS systems among the member nations. The presentations for the 2022 Symposium showed a significant maturation of the use of UAS, and a marked increase in rigor and development of the UAS when compared to the 2015 Symposium. There was a significant range and depth of the presentation Covering UAS developed specifically for research, UAS developed for Science application, UAS developed for military applications and commercial utilization of UAS. The full range of the development, test, and application of UAS was presented over the course of the seminar. This resulted in topics that spanned the spectrum of UAS development: use of Computational Fluid Dynamics, classical analysis, wind-tunnel testing, all software simulations, Hardware-in-the-loop, simulations, derivation of test objectives/plans from requirements, risk management, ground systems, crew resource management, certification, flight test Techniques and Flight Test Technologies. The results of this Symposium demonstrated an understanding among the NATO nations of the importance of integrating UAS systems into the overall NATO mission.

1.0 BACKGROUND

The SCI-172 Flight Test Technical Team (FT3) met in May 2012 and proposed an unmanned aerial vehicle and unmanned aircraft systems technical symposium focused on flight testing to be held in conjunction with a future Systems, Concepts, and Integration (SCI) Panel meeting. The SCI Panel approved this proposal and assigned the task as SCI-269 to be held in Ottawa, Canada in May 2015. The SCI-352 was approved as a continuation of the Flight Test Technical Team (FT3) and continues the core mission of the team - collection and dissemination of Flight Test Instrumentation and Flight Test Techniques to the NATO community in an acknowledgment of the rapid pace of change in the technologies, capabilities and operations of UAS proposed a follow on symposium to address the modern (2022) state-of-the-art of UAS Flight Testing. FT3 members concentrated on defining the symposium parameters, announcing the event, and selecting technical presentations that provided both appropriate technical depth and meaningful variety in terms of scope to cover the broad field of UAS flight test activities. These themes included (but were not limited to): UAS systems, and their usage, flight test practices, flight test lessons learned, risk management, ground testing, operational suitability modeling and simulation Session chairs were selected from active FT3 members, keynote speakers were identified and invited, and coordination with the host nation and the Collaboration Support Office (CSO) established and conducted.

2.0 SYMPOSIUM

The two day symposium was held in the Academia de Artilleria in Segovia, Spain from 12-13 May 2022. The symposium featured 23 technical papers involving six NATO nations and hosted 108 participants representing 17 nations. All but one of these papers were cleared for further publication and are available on the CSO website. The presentations themselves were created for use at the symposium only and are not available through the CSO but may be requested from the individual authors if desired. Presentations were limited to 30 minutes in duration with questions entertained as long as the 30 minute time allocation allowed. Further questions and discussion was deferred to break time or evening social events. Feedback from the participants indicated that the facility provided excellent support for the symposium. The comments from the participants were favorable about the execution of the symposium.

2.1 Introduction and Opening Remarks

The SCI-328 symposium began with brief introductory remarks and a presentation providing an overview of the roles and responsibilities of the Science and Technology Organization (STO), Collaboration Support Office (CSO), and the Flight Test Technical Team (FT3). The presentation highlighted and described the role FT3 has had since 1968 in gathering and disseminating the best practices, lessons learned, techniques and instrumentation for conducting flight test of piloted and Uninhabited Aircraft Systems. This outreach has been accomplished through AGARDographs, Meetings of experts, short courses, and symposia.

2.2 Technical Presentations

The 23 technical papers accepted for this symposium and all but one were all successfully cleared for release. Every paper had at least one author in attendance for the symposium. One back-up presentations was required to complete the two day schedule. Presentations covered the gamut of UAS from hand-held systems to commercial aircraft sized systems. Vertical Take-off and landing vehicles as well as conventional configurations were covered. Systems designed for a single use as well as UAS developed specifically to do high-risk flight research operations which would be inappropriate for a crewed vehicle. There was also discussion on the execution of flight test, development of test plans, and development of test teams.

2.2.1 Session 1: UAS Programmes

This technical session began with presentations of flight test to extend capabilities of existing flight system, the flight test planning for general UAS, discussion of certification of UAS for military use, and discussion of the use of Computational Fluid Dynamics (CFD) in conjunction with wind-tunnel testing. The concepts of build-up approach, requirements based test-planning, risk management, system-of-system testing, autonomy, and the cost/benefit trade-off of flight test instrumentation were introduced. Team training was addressed and included the discussion that team extends beyond the test pilot and flight test engineers.

2.2.1.1 Session Presentations and Speakers

- NOAA 'Hurricane Hunters' Flight Testing of Air-Launched UAS, A. Abitol, United States
- Skydweller Flight Demonstrations of Autonomous Aircraft for Development of an Unmanned Solar-Powered Aircraft , E. Babio, Spain
- Type Certification process for RPAS in the Spanish Air Force, G. Vazquez, Spain

- UAV Flight Test AGARDograph: Chapter 21 ‘Small UA. Testing’ and Chapter 22 ‘Highly Autonomous Systems’, D. Zyga, United States

- Numerical and Experimental Study of a Biomimetic UAV with Grids, E. Barroso, Spain

2.2.2 Session 2: UAS Operations and Applications

This presentations for the second technical session focused on flight testing for operational utility such as ship operations and , search and rescue missions. Also included were tests of subsystems intended to increase the survivability and reduce the cost of fielding UAS. These included defensive aids, environmental testing and improving subsystems sub as engines.

2.2.2.1 Session Presentations and Speakers

- AWHero Rotary UAS: Integration Activities and Flight Testing for Shipborne Operations, V. Bonini, Italy

- Feasibility and Testing of Defensive Aids Sub-Systems for Small UAS to improve their Combat Survivability, F. Cruz-Hernandez, Spain

- Development and Flight test of a UAV for Search and Rescue Missions, A. Niter Illescas, Spain

- Operation of Unmanned Aerial Vehicles (UAVs) in Icing Environments Activity, R. Hahn, Norway

- Flight Test Process for the Cooling of a Reciprocating Engine on a Remotely Piloted Aircraft System, D. Macor, Italy

2.2.3 Session 3: UAS Facilities and Training

This third technical session focused on the more formal aspects of training and managing a fight test team. both of these presentations relied heavily on the decades of experience of training pilots and flight test engineers at the various Test Pilot Schools. For UAS, it was acknowledged that the involvement of the entire engineering teams, operations team, as well as flight crew was required to test these systems. The presentations focused on the rigor required to execute flight test operations

2.2.3.1 Session Presentations and Speakers

- Training the UAV Tester, M. McDaniel, United States

- Crew Resource Management (CRM) in Flight Testing of Unmanned Aerial Systems (UAS), D. Gole, Turkey

2.2.4 Session 4: UAS Analysis, Validation, and Verification

The presentations in the fourth technical session tied the topics of analysis, verification and validation to the rigors of flight testing UAS. Topics that were covered in the session contain many of the elements required for meeting the symposium’s objective for UAS utilization by the NATO members. These included discussion of a user’s guide for flight testing, Values of Systems Integration Lab (SIL) testing including all aspects of the UAS including any ground station, the value of a properly trained team, risk and requirement based test planning, appropriate use of surrogate vehicles, and build-up approaches. Examples of actual vehicles included modeling for ship board applications, performance testing of long endurance autonomous systems, and the use of pure

research platforms for his advancement of UAS technologies. Looks at basic mathematical analysis and wind tunnel testing were also included.

2.2.4.1 Session Presentations and Speakers

- UAV Flight Test AGARDograph Status Update, M. McDaniel, United States
- Experimental Analysis of UAVs Operations on Military Frigates, J. Matias Garcia, Spain
- Analysis of the Longitudinal Stability of a Bio-inspired Morphing UAV, E. Barrosa, Spain
- Simulation and Flight Testing of an Algorithm that uses "RF DISTANCE" to guide UAVs to Home Position in GNSS-Denied Environment, K. Dogan, Turkey
- Performance Model Validation for Long-Endurance Unmanned Aircraft Using Mach vs. CL Test Method, B. Brierty, United States
- X-56A Flight Test Approach for Envelope Expansion Past Open Loop Flutter Instability, C. Miller, United States

2.2.5 Session 5: Future Systems and Regulatory Environments

This fifth and final technical session presentations discussed the regulatory environment for UAS and the contributions and path forward through flight testing of UAS systems. This included discussions on the processes for certifying individual platforms and future development for the testing advanced systems. A critical part of the discussion was the integration of UAS into the general airspace. The overview of what technologies have been matured, and what regulatory actions are required in order for UAS to fulfill the promise of future operations such as urban air mobility. There again was emphasis on the team required to test a UAS. In addition, it was further highlighted that these are just tests of a single vehicle, but of a system-of-systems. One unique aspect was getting the perspective of UAS testing from a trained research test pilot.

2.2.5.1 Session Presentations and Speakers

- Leonardo Aircraft Division UAS flight testing experience capabilities and future Developments , P. Chimetto, Italy
- Pilot Perspective of UAS Flight Test at NASA, S. Howe, United States
- UAV Airworthiness Certification, J. Willekens, Netherlands
- Unmanned Aircraft System Flight Test Approach Supporting the Development of Regulatory Recommendations for Integration with the National Airspace System, M. Vincent, United States
- Systems Integration and Operationalization: Supporting Unmanned Aircraft Systems Integration into the National Airspace System, M/ Rivas, United States

3.0 CONCLUSIONS

As stated in the call for papers, the purpose of this symposium is to share and disseminate the experience and lessons learned from flight testing of UASs among different NATO nations. The shared goals in this for NATO

members to improve the UAS systems acquisition process, shorten timelines for fielding, focus on a risk management approach to systems development and fielding and to deliver best value, capable and effective UAS systems to the operational units.

Overall, the two day symposium met the stated objectives. It is clear that UAS are being used as a game changing technology and a force multiplier for the NATO member nations with a very wide range of missions. The need of continued flight test rigor is essential in improving the reliability, usability and cost effectiveness of these system.

The practices and lessons learned shared through the symposium are applicable to the entire spectrum of UAS. The vehicles discussed covered small vertical takeoff and landing UAS weighing a few kilograms through systems as large as commercial airliners. System autonomy ranged from remotely piloted vehicles, to programmable flight profiles with autonomous return modes, to fully autonomous systems. All of these capabilities will be require as NATO member nations utilize these systems for such diverse missions as reconnaissance, delivery of supplies, and search and rescue

The increase in formal flight test principles in the UAS community over the the last decade was evidenced by the usage, adaption, and application of traditional crewed aircraft testing processes, techniques and constructs. The common flight testing themes included:

- application of wind tunnels and analytic methodologies such as computational fluid dynamics
- derivation of flight test plans from design requirements and operational users requirements
- treating the flight and ground hardware and software as a total system, including any ground control station or hardware
- robust build-up approach
- risk awareness and risk mitigation
- Software-In-the-Loop (SIL) and Hardware-In-the-Loop (HIL) testing
- the value of high fidelity simulators
- development of test techniques to advantageously use flight time
- crew resource management
- trained flight test operators (pilots), flight test engineers, engineering team, and ground crew
- inclusion of ground and flight safety in the planning processes
- the use of surrogate ground and flight vehicles to mature and validate technologies.

The recognition and utilization of these principles by the developer and user committee is critical to the integration of these UAS into the NATO inventory. By having formal processes and a set of best practices to follow, the development time, cost effectiveness, reliability and safe operations are directly applicable and of value to the NATO member nations.

Another important topic that received significant attention was the certification of the UAS and the inclusion of UAS into the National Air Space (NAS). Certification is required to get these systems into the NATO inventory. And routine operations will need to be world-wide for certain classes of UAS. Development and testing of the required technologies for situational awareness and detect and avoid of other aircraft is essential to the regulatory bodies such as the Federal Aviation Administration (FAA).

There was some discussion about specialized flight test instrumentation. While it was acknowledged that data collection was crucial in the test, evaluation, and certification of UAS, the cost and size often precluded the

inclusion of unique instrumentation. One of the factors that contributed to this was the installation of specialized flight test instrumentation on a low-cost single use system. There were excellent rationales for the decisions to use specialized instrumentation by the test teams. There were also some ingenious application of existing sensors and low cost data collection methodologies. It would seem that there would be value in having a broader discussion on this topic.

The symposium (SCI-328) was well organized and brought together a broad spectrum of NATO users and developers in an open forum for open sharing and discussion of UAS flight and ground test. The discussions validated the growth in utilization and testing of these system and the value to NATO to share and document the best practices and lessons learned. The compendium of the papers will also benefit NATO as a value document to share across the NATO flight community.

4.0 RECOMMENDATIONS

There has been a considerable change in the state-of-the-art of Unmanned Aerial Systems (UAS) since the 2015 Symposium. The applicability, utility, and value can be seen daily on the news. It is obvious that UAS systems will continue to be incorporated into NATO operations and become part of the baseline of systems used in the execution of the diverse NATO missions. It is expected that there will continue to be a rapid proliferation of UAS and further expansion of flight test activities. it is therefore recommended that a third symposium on the advances in UAS flight testing be conducted in approximately five years to continue the documentation of these activities and their impact on NATO.

In addition, feedback from the symposia has indicated that the current practice of allowing 30 minutes for the presentation is not adequate. for the next symposium it is recommended that the number of presentations be reduced and the allotted time increased to 45 minutes.

The presentations provided a number of best practices and lessons learned in the preparation for and execution of UAS flight and ground testing. In conjunction with the upcoming revision of the UAS testing AGARDograph, it is recommended that the FT3 go back to the flight test communities in their respective nations and gather these practices and lessons into a single AGARDograph. Providing lessons such as test card development, flight test execution, risk management examples, utilization of surrogate, flight test instrumentation for UAS, and similar items would be of considerable value to the growing UAS flight test community.