

SCI-269 Flight Testing of Unmanned Aerial Systems Technical Evaluation Report

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ABSTRACT

A two day symposium on Flight Testing of Unmanned Aerial Systems (UAS) was held in Ottawa, Canada on 12 and 13 May in support of the Systems, Concepts, and Integration (SCI) Panel business meeting. Ninety-Six participants from 15 nations heard 21 technical presentations and two keynote speeches on UAS flight testing topics ranging from use of multicopters for medical support operations to development of high altitude long duration unmanned vehicles and the technical challenges associated with such operations. Areas of interest also included flight test education and training approaches using manned UAV surrogate vehicles and collection of UAS performance data for simulator development. A requirement to follow established manned flight test methodology or to establish UAS unique processes based on existing flight test methodology was a common theme throughout the symposium. An additional high priority topic was the integration of UAS and UAV operations into the airspace structure of NATO nations while preserving safe skies for manned flight. The presentations were well received and produced vigorous questions and discussion which should lead to additional future technical exchanges and collaboration between participants and improvement in NATO's UAS flight testing capabilities.

1.0 BACKGROUND

The SCI-172 Flight Test Technical Team (FT-3) 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. In the three years leading up to the symposium, 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 unmanned aerial systems (UAS) flight test activities. 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

Ultimately the two day symposium was held in the John G. Diefenbaker building in Ottawa, Canada from 12-13 May 2015. The symposium featured 21 technical papers and two keynote presentations involving six NATO nations and hosted 96 participants representing 15 nations. All but two 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.

2.1 Symposium Organization and Facilities

The SCI-269 symposium organization was well structured with a full schedule of presentations and appropriate breaks to facilitate discussion and interchange between participants and presenters. FT3 event organizers maintained good schedule control and no briefs extended beyond their allotted time on either day. The John G. Diefenbaker facility was appropriately sized to comfortably seat the symposium participants with dining facilities in the building and coffee break areas immediately adjacent to the lecture room. The acoustics were good with few distractions as were the audio-visual presentations with the exception of a few embedded video incompatibilities which did not significantly affect the value of the presentations. The visual presentations could have been improved by the incorporation of a second screen as the far left side of the audience did not enjoy a head-on view of the video screen. This was acceptable for the size of the audience participating in this symposium but would have been an issue for a larger group of attendees.

Registration was quick and friendly with pre-made badges on hand for all attendees and presenters with CSO staff on hand to address any emergent issues. The John G. Diefenbaker building was accessible and host-provided bus service from the Ottawa hotel area provided quick and ready transportation to and from the event.

2.2 Introduction and Keynote Speeches

The symposium began with welcome speeches by the SCI-269 Symposium Chairman and SCI Panel Chairman who both outlined the origins of the event as well as the importance of the topic to NATO and its affiliated nations. These opening remarks were immediately followed by the first keynote speech detailing the approach taken and challenges faced in reviving the EUROHAWK program and operating a large UAV in the European airspace environment covering issues ranging from flight in icing conditions to the changing NATO focus from early Cold War surveillance needs to today's more global reach missions. This first keynote presentation served to provide a good foundation for the morning's follow-on papers on high altitude long duration UAV and UAS flight testing, many of which addressed UAV unique flight test items such as autonomous operations, loss of flight control links, and operational coordination issues.

The second keynote speech opened the first afternoon session with a comprehensive overview of Canadian and other national bodies' efforts to address operation of UAVs in a national airspace system involving both controlled and uncontrolled airspace. Air traffic control, sense and avoid traffic de-confliction options, and weather minimums issues were introduced and discussed with a general sense that, while all nations were working vigorously to establish a working environment for co-use of airspace with manned aircraft, concerns are high that the regulators cannot keep up with the rapidly expanding roles and increased numbers of UAS in operation. Additionally, the rate of innovation in UAS development is outpacing government efforts to adapt comprehensive regulations to accommodate that development. Later technical presentations further highlighted this issue and stressed that integration of UAVs into all national airspace systems and management of their safe co-use with manned aircraft may be the biggest challenge facing both civil and military use.

2.3 Technical Presentations

The 21 technical papers accepted for this symposium were all successfully cleared for release and every paper had at least one author in attendance for the symposium. No back-up presentations were required to complete the two day schedule. Topics ranged from testing of small direct control UAVs such as quadcopters and small radio control aircraft to autonomous operations of large UAVs, shipboard operations, emergency relief applications, and UAS test range considerations. These presentations were divided into four sessions with loosely grouped topics and interrelated subjects.

2.3.1 Session 1 – Flight Test of High Altitude Long Endurance Vehicles

This first session focused on flight testing associated with the development and technical challenges faced in flight testing High Altitude Long Duration (HALD) UAVs. Many of these challenges stemmed from basic air vehicle issues such as high altitude effects on internal combustion engine ignition systems, cold temperature effects on air vehicle mechanical systems, structural challenges encountered with very high aspect ratio wings constructed from lightweight materials, and special concerns related to the storage and use of exotic fuels including liquid hydrogen. Additional topics included crew resource management aspects of multi-shift test operations dictated by the long endurance use of these vehicles and regenerative propulsion system applications to minimize power plant requirements and maximize mission system utilization.

2.3.1.1 Session 1 Presentations and Speakers

- Revival of the EUROHAWK (Keynote speech), H. Weiss, Germany
- Flight Test Report on the Global Observer UAS, A. Thurling, United States
- Phantom Eye System and Test Review, J. Lenander, United States
- Multiple Shift Test Operations for Long Endurance Unmanned Aircraft, B. Brierty, United States

2.3.2 Session 2 – Flight Test of Specific Vehicles

The second technical session featured presentations focused on unique aspects of flight testing different unmanned aircraft and systems ranging from rotary wing vehicles to high speed targets. Each air vehicle and system type discussed posed its own set of challenges and flight testing demands depending on the basic airframe's level of maturity as well as that of the on-board mission system (or simulator) paired with it. Though numerous unique technical aspects of control law development, autopilot gain adjustment, or adaptive software workload sharing were discussed in different briefs, an underlying message supporting strict adherence to flight test methodologies and procedures emerged from this session. Basic adherence to test planning, thorough test team briefings, detailed data collection, rapid data analysis and reasonable test point build-ups along with a described need to document and report test findings were present in each brief and formed a common element between the different tests.

2.3.2.1 Session 2 Presentations and Speakers

- Integration of UAS in Civil Airspace (Keynote Speech), M. Wuennenberg, Canada
- A Research Perspective on Flight Testing of an Unmanned Aircraft System, J. Dauer, Germany
- ANKA Unmanned Aircraft System Flight Testing, S. Sergen, Turkey
- MQ-4C Triton UAS Mission System Trainer, A. Judy, United States
- Testing of the SIMSEK High Speed Target Drone, Y. Cetin, Turkey
- Flight Testing and High Fidelity Modelling of the Aphid Unmanned Helicopter, K. Hui, Canada
- A Toolset for Mission Level UAS Flight Testing, M. Schmitt, Germany

2.3.3 Session 3 – Training and Analysis

Wednesday's morning session began with several surrogate and optionally manned air vehicle platform presentations detailing various methods to facilitate UAV and UAS development by conducting flight testing of their control systems with a rated safety pilot onboard the test vehicle. Various protocols for emergency disconnects of the UAV control laws and transfer of air vehicle control to the live pilot were presented along with rationales supporting the test risk management process that led to selection of control transfer criteria.

These criteria included proximity to air vehicle operating limits (airspeed, acceleration, pitch attitudes, etc.), safety limits pertaining to the operating environment (altitude and terrain, visibility), and traffic de-confliction (collision avoidance). Both actual tests such as inflight refuelling control law development and test pilot school education and training schemes to teach UAV/UAS flight test techniques were covered and the merits of using an on-board test pilot as the primary safety feature highlighted for each.

The second half of this session shifted to simulator and mathematical modelling of vehicles and systems including parameter identification data collection and assessment as well as algorithm development for on-board systems. As was noted for the previous day's presentations, use of classic flight test methods and the need for accurate and consistent recording of flight test data were presented as key components of successful programs.

2.3.3.1 Session 3 Presentations and Speaker

- Surrogate UAV Flight Testing, K. Prosser, United States
- Unmanned Air Systems Flight Test Training Using an engineering Simulator, P. Vitsas, Canada
- Remotely Piloted Vehicle Flight Test Technique Development and Training, R. Olsen, United States
- Time and Frequency Domain Identification of a Fixed Wing UAV, S. Haser, Turkey
- Large Unmanned Aircraft Non-Precision Aggressiveness Quickness Criteria, K. Greene, United States
- nEURONUCAV Development and Operational Assessment Campaign, J. Piccinotti, Italy

2.3.4 Session 4 – Flight Testing, Flight Test Centers, and Training

This final session addressed flight testing considerations for UAS operations in a wide variety of environments, scenarios, and conditions. Shipboard operations posed a highly variable and often unpredictable set of operational test conditions where application of manned helicopter test methods formed the best first approach to developing UAS specific test processes while civil medical emergency relief practice missions provided the opportunity to prove UAS benefits in a time critical situation. Once again, established manned flight test concepts were either applied or adapted to UAS needs with consideration given to unique aspects of UAS operations and the need for intelligent risk management. Development of UAV and UAS specific test ranges was raised with the predominant issues of frequency allocation and protection of UAV control transmissions from interference discussed in addition to risk mitigation options offered by overflight of low (or no) population density areas during early test operations.

2.3.4.1 Session 4 Presentations and Speakers

- Selection and Training of Test Event Directors for Advanced Unmanned Aircraft, M. McDaniel, United States
- Development and Flight Test of a Multicopter for Medical Operations, L Novaro, Italy
- Development of a RPV Demonstrator for ATM Research, M. Kreienfeld, Germany
- How to Safely Flight Test a UAV Subject to Cyber Attacks, M. Heiges, United States
- Centers for UAS Flights in Spain, A. Sierra, Spain
- Dynamic Interface Testing of Unmanned Aircraft Systems, J. Nelson, United States

2.4 Closing Remarks

The two day symposium was concluded with remarks by the Technical Evaluator and Symposium Chairman. The technical evaluator provided a brief summary of the presentations and keynote speeches pointing out that all of the presenters had stressed a common need for strong adherence to flight test discipline and processes in order to gain useful technical data from their testing and to ensure that risk was minimized. Though much personal risk was removed from the flight test evolution by eliminating on-board personnel, technical and programmatic risk remained and the safety risk to non-participants was actually increased for UAV testing. Five basic tenants of manned flight testing; intimate knowledge of the system under test, thorough test team briefings, operator/pilot proficiency, respect for the “no” vote or test veto, and the need to record and report test results were restated as applying just as much to UAS and UAV flight test evolutions. Attendees were encouraged to expand upon lessons learned and relationships established at the symposium and continue to communicate with each other and collaborate on future flight test efforts. This future sharing of UAS flight test knowledge can improve the process and UAS products across programmatic and national boundaries in support of NATO missions and needs.

3.0 CONCLUSIONS

The SCI-269 symposium of flight testing of UAS was a successful venture that presented a representative sampling of UAV and UAS flight test efforts from across a broad spectrum of technical interests. Numerous NATO nations were represented and offered presentations proving the technical challenges faced in flight testing UAS were shared across national boundaries and not unique to any one country or region. Small multi-rotor vehicles demanded the same test rigor as large high altitude vehicles highlighting the need to document and report test results so as to communicate data and lessons learned to future test teams and test operations were highlighted.

The presentations encompassed a vast field of UAS concepts and uses including small drones, extended endurance aircraft, UAS test ranges, adaptive software development, medical emergency support, and university research platforms. Military applications relevant to NATO were addressed through topics such as shipboard interface and target drone testing while operations outside of restricted airspace were shown to not only pose regulatory problems but also to provide opportunities to use manned surrogate UAVs to reduce schedule and improve risk management and safety.

In all cases, the high value of applying disciplined flight test techniques and data collection methods to UAV and UAS operations was clearly shown based on the same technical and safety risk issues that promoted development of these techniques many years ago for the manned test community. Some test techniques could be applied directly from the manned experience while others needed unique development to be fully applicable to the UAS testing. Source material such as NATO/CSO’s own *SCI-105 Unique Aspects of Flight Testing Unmanned Air Vehicles* were cited as providing valuable baseline information for planning and conduct of UAS specific testing along with UAV test operator courses provided by Test Pilot Schools.

The fact that flight testing still forms an important and vital part of air vehicle development was strongly stated throughout the symposium. Flight testing proves system performance, collects critical data, and serves to manage risk. Though the risk to vehicle occupants is removed from UAS operations, technical and programmatic risk remain and the potential risk to non-participants is actually increased by the lack of an on-board sense and avoid decision maker. The choice of mission termination or loss-of-control-link protocols for UAV test operations has a critical impact on test safety which warrants close consideration when pairing a vehicle or system’s state of maturity and reliability with a test range or site to limit the potential of endangering ground personnel or manned aircraft. Most importantly, the symposium presentations showed that a disciplined and professional test approach is needed to obtain necessary data and effectively manage risk in a UAV or UAS test program whether manned flight test methods are applied or whether new test

methods are developed specifically for that assessment.

The high number of papers cleared for publication will greatly expand the availability of the symposium material beyond the symposium participants and enable greater sharing of UAS flight testing lessons learned between NATO nations and partners. This will not only enhance the value of the symposium material but should encourage further collaboration within NATO for future UAS testing as relationships established at the symposium are nurtured and built upon in later communication.

SCI-269 provided a well-organized opportunity to share valuable information about flight testing of unmanned aerial systems and unique developmental issues affecting those tests. Operations of unmanned aircraft in unrestricted national airspace alongside manned aircraft remains the largest obstacle to full utilization of UAS but both technology and regulatory guidance are working vigorously to address this issue. Symposium participants should have gained additional tools and references to use to improve their future UAS test efforts and increase the value of their programs to NATO as UAS applications in support of NATO missions are almost unbounded. This symposium was held at a very timely and important period of UAS development considering the incredible pace of UAS technical growth and the emergence of national policies and regulations affecting their use. The success of SCI-269 should prove valuable in promoting future collaboration between NATO members and partners on UAS flight test issues.

4.0 RECOMMENDATIONS

It is recommended that future symposia consider incorporating additional video screens to widen the field of view of the visual presentations and allow better sight angles for the audience. It is also recommended that symposia incorporate a feedback questionnaire to be sent to attendees after the completion of the symposium to gauge the effectiveness of the program, the facility, and the material.

Finally, it is recommended that NATO/CSO/FT3 consider undertaking a comprehensive assessment of the UAV and UAS flight testing processes and references available to determine if expansion of the 300 series AGARDOgraph SCI-105 *Unique Aspects of Flight Testing Unmanned Air Vehicles* may be warranted in order to include new test techniques and accepted procedures.