Technical Evaluation Report

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INTRODUCTION

This broad-scope, flight-test symposium was jointly sponsored by NATO's Research and Technology Organization (RTO), Systems Concepts and Integration Panel (SCI), and the Society of Flight Test Engineers, European Chapter (SFTE(EC)). The SFTE (www.sfte.org) is a fraternity of engineers and associates, whose principal professional interest is the flight testing of aircraft, fixed and rotary wing, and missiles. The objective of the Society is the advancement of flight test engineering throughout the aircraft industry by providing technical and fraternal communication among individuals, both domestic and international, in the allied engineering fields of test operations, analysis, instrumentation and data systems.

The symposium, hosted by the Polish National Delegates of the RTO at the Ministry of Defence Conference Centre, Warsaw, was an unclassified event with participants from 24 countries. This was the first NATO symposium since the formation of RTO to deal comprehensively with aircraft flight test and evaluation (T&E), and the first SCI symposium to be conducted jointly with an organization outside of NATO. Two previous SCI symposiums included significant aspects of flight test: "Integration of Simulation With Systems Testing," October '01, Toulouse, FR and "Aircraft-Stores Certification Testing," September '98, Chester, UK. The last NATO symposium to broadly review international flight testing was conducted by AGARD in Norway in the mid 90's.

The symposium was developed and conducted, in partnership with SFTE(EC) and the RTO Research and Technology Agency, by the SCI Panel's Flight Test Technologies task group (SCI-172, FT3). The FT3 mission (which was well matched to the symposium) is to: (1) disseminate information through publication of AGARDographs on flight test technology derived from best practices which support the development of concepts and systems critical to maintaining NATO's technological and operational superiority; (2) enable advancements in flight test technologies to be discussed in open forum within the NATO community by identifying and distributing flight test training opportunities, and through proposing and facilitating symposia, short courses, lecture series, etc., and (3) serve as the focal point for flight test subjects and issues with the SCI Panel while ensuring the vitality and continuity of the network of flight test experts within the NATO community.

THEME

The symposium objective was the sharing of flight-test related information between the international community with a purpose of improving flight test practices worldwide. Flight testing is the ultimate and most realistic proof of aerospace systems performance. It is an expensive and time-consuming activity with safety implications. Three aspects (safety, time, and cost) imply that there is a high pay-off to NATO aviation in learning from the experience of others, avoiding the repeat of past errors and having access to the best practices of other flight test organizations.

PURPOSE AND SCOPE OF THE SYMPOSIUM

- Flight test safety management
- Operational systems instrumentation for safety investigation
- Flight testing of new capabilities
- Flight testing of Unmanned Air Vehicles (UAVs), focusing on the specific differences from conventional piloted vehicles
- Flight testing of form, fit & function replacement capabilities on legacy platforms
- Status of recent research & development flight test programs
- Flight test instrumentation challenges
- Practical aspects of flight test programs and subsequent lessons learned

The symposium included 2 ½ days of presentations, a summary review by Session Chairmen and others, and a visit to and briefings by Poland's Air Force Technical Institute & Military University of Technology. The technical content of the symposium was communicated via Keynote Presentations and sequential Sessions of presentations as follows (the Programme of Presentations, attachment 1, lists the presentations, authors and organizations):

- **Sessions 1 & 6 – Programme Operations**
- **Sessions 2, 7 & 8 – Test Methods**
- **Session 3 & 5 – Programmes Overview**
- **Session 4 – Facilities & Flight Test Instrumentation**

SYMPOSIUM EVALUATION

General

This Technical Evaluation Report summarizes significant developments in aircraft test and evaluation (T&E), considerations for the NATO and flight test communities and lessons learned from recent flight test participants. Within each Session of the Symposium, a synopsis of each of the presentations is made which includes specific lessons and considerations applicable to the broad range of flight test and related professionals. Summary views of key individuals including Session Chairman are then listed, followed by overall Conclusions and Recommendations. Three Keynote Addresses and 22 papers were presented (in total, 35 abstracts were submitted from which 24 papers were selected.). Significantly, many of the primary NATO-country aircraft test and development organizations were represented by the speakers: Airmacchi, AIRBUS, Arnold Engineering Development Center, BAE Systems, Boeing, DEU, EADS, Eurofighter, FMV, Joint Strike Fighter, Lockheed Martin, NASA, NLR, Polish Military University of Technology, QinetiQ, SAAB Aerosystems, SSC/Esrange, US Airforce Flight Test Center and US Naval Air Systems Command.

The Symposium was introduced by Mr. J. Wickes (GBR), SCI Panel Chairman, and Mr. K. Karlsson (SWE), SFTE(EC) President. Mr. Karlsson noted the close tie between the theme of this symposium and the purpose for SFTE – the sharing of flight test lessons and experience. Mr. Wickes pointed out the uniqueness that this first NATO RTO symposium with SFTE provides and the frequent utilization by the military of aircraft developed for civilian purposes that need to be tested from a military perspective.

Keynote Addresses

***KEYNOTE ADDRESS #1, POLISH AVIATION HISTORY*:** The history of aircraft development in Poland was presented by Andrzej Witczak, DR INZ, from the Polish Military University of Technology. His address showed that Poland was a participant in aircraft development from the beginnings of aviation until the present. The Polish Aircraft industry developed a wide range of aircraft for military and civilian purposes, before and after WWII. These included a variety of fixed-wing aircraft (including fighters and bombers), helicopters, gliders, seaplanes and agricultural aircraft. Jet trainers developed by Poland are in use multi-nationally today. Contributions to aviation and international aircraft development include the V-tail (like on the F-117) and the tandem cockpit concept and design. Poland recently became a manufacturer of the F-16 by means of the Offset program from the US Company that develops and builds the F-16 tactical aircraft.

***KEYNOTE ADDRESS #2, T&E IN A MULTI-NATIONAL PROGRAMME*:** The T&E leader for the Eurofighter, Group Capt (retired) L. Hilditch, focused on test management and methods, and shared lessons learned, on this major aircraft development program. The Eurofighter program uses 12 test aircraft, and many primary and sub contractors which must be taken into account throughout the flight testing. This program is important to NATO with its net-centric, multi-nation and multi-service applications (and implications). This leads to a certain reality: The more complex the aircraft and the development program, the more difficult is the testing. The method used is “combined flight testing,” which integrates planning and execution between involved nations and the developer. About 10% of the flights are allocated to individual nations. Flight test and test aircraft are also used to develop flight operating and training procedures. Missile separation considerations – like missile plume effects on the aircraft – required test thermal couples that measure quickly changing temps in the airplane environment, and that can be bonded to the engine intake (new bonding techniques become an important instrumentation consideration).

Lessons:

- A metric for a complex program: Eight successful flights (meaning, the specific goal was accomplished) per aircraft per month.
- Flight test managers may tend to hold up programs; they need to communicate with all the players. Development flight test “is not a science project to continue investigating interesting areas” – need too focus on getting it developed and into military operations.
- “Risk analysis, though important, is only a helpful tool – accidents are real.”
- Testing limitations and communications challenges quickly arise when portions of tests are planned offsite.
- Money “saved” at the beginning “often isn’t” in the long run.

***KEYNOTE ADDRESS #3, THE JOINT STRIKE FIGHTER – AN INTERNATIONAL ENTERPRISE*:** Mr. Paul Metz, Vice President, Integrated Task Force JSF, explained the history, multiple missions, capabilities, collaborative arrangement and testing challenges for this, the largest ever fighter-aircraft development program; and for the United States, the most complex teaming arrangement ever. While the

United States has engaged in numerous co-assembly and co-production programs, it has been only recently that they have engaged in co-development efforts similar to the successful European ventures like the Jaguar, Tornado, Eurofighter and Airbus. Design, test and fielding of the F-35 involve 9 nations, including several NATO countries. Testing is challenged by complex aircraft and avionics, and net-centric, multi-role, multi-national, multi-service aspects of the program involving ship-based and land-based operations.

Lessons:

- Communicate, communicate and communicate, including rapid communication.
- With very little room inside the airframe for wiring, innovative instrumentation methods are required.
- With the F-35's mission-systems data collection now up to tera-bytes level, transport and review of the data becomes an issue.
- Manage to offset the high intensity work efforts with some occasional "fun".

Presentations

Lessons learned, significant results and common findings are summarized in each of the following Sessions paragraphs and important results and lessons from individual presentations are included.

SESSIONS 1 & 6 – PROGRAM OPERATIONS: The Session's objective, "Survey current procedures for and results from flight test operations," was accomplished. The presentations described testing in unusual and dangerous situations and shared the knowledge gained from those experiences. The disciplined step-by-step path from test planning through test execution is consistently used and innovative methods employed. Several examples of methods used to improve safety were described, with applicability to future programs. Rehearsing planned test procedures prior to flight improved effectiveness and safety. Increased UAV testing is noted, including research applications. Impacts of reductions in an organization's core flight test competence requires careful management. Noted were: integrated and empowered teams, extensive use of cockpit video, application of data-generated images and Computational Fluid Dynamics (CFD) and learning from past tests / events.

Presentation (P)1. T-45 Stability Augmented Steering System: The T-45 Goshawk is a US Trainer variant of the British Hawk. Tests were conducted to develop a solution to loss of directional control and/or runway departure during landing. Part of the challenge was to conduct test maneuvers in a manner representative of a student in early flight training. Instructor pilots were brought in to validate the test maneuvers used to determine gains to be incorporated in the augmented system. Included were tests in crosswind and wet runway conditions. Effectively used were the experience of a race car company, support from NASA's special ground test vehicle and cockpit video. The tests were specifically tailored to the situation and integrated with development of the augmented steering.

Lessons:

- Clear the airfield in the vicinity of potential departures.
- Determine whether to build up or build down in speed (tests at increasing speeds was chosen).
- Add a 2nd pilot in the airplane as an observer and radio communicator.
- Set predetermined ejection criteria.
- Take advantage of lessons from past tests and landing incidents.

P3. High Angle of Attack Flight Control Design & Testing of the F/A-18: The challenge was to resolve the re-occurring instances of out-of-control F/A-18 losses/incidents in the fleet – as many as 20 over a period of years. Testing was effectively integrated with design and development of the flight control fix. Cockpit video and data-generated images were among the test tools used. Sideslip was not measured, but calculated from other parameters. Substantial pre-test analysis allowed testing without a spin chute.

Lessons:

- Expect unexpected effects (like the unpredicted departure mode).
- Following test completion, the control modifications were installed and flown in the test squadron's F/A-18s prior to fleet introduction, to further validate their suitability.
- Listen closely to the test pilots for key information during the design, development and test cycle.
- Allow the integrated design and test team a long leash to innovate.

P17. The Flight of the Phoenix: A scaled-down version of a future reusable re-entry vehicle was tested on the North European Aerospace Test Range (NEAT) to verify the performance of the Phoenix test vehicle, including its flight control and navigation systems, by auto-landing on the runway. The program was conducted by a test organization that had been reduced in capacity. Collaboration between different organizations within and outside the test organization resulted in a successfully completed mission. Specialist competence was acquired externally, but worked within the team. The customer participated throughout and had access to all documentation and test results. The developer was responsible for airworthiness certification on the range and had to define a hazard zone such that risk of injury would be less than 1x10-6. This required a destruction system which would be activated if the vehicle exceeded its small runway approach window. Airworthiness certification for helicopter carriage of the UAV was done with a wooden mockup. The Swedish version of the CH-46 helicopter equipped with video cameras was used to carry the Phoenix. Innovative methods for carrying the under-slung loads included an instrumented T-bar which contained a gas-operated ejection release unit borrowed from a fighter airplane. A ballasted drop tank was used during initial tests and wind tunnel tests preceded actual flight tests.

Lessons:

- Identify unusual requirements such as specialized ground crew and unique training with sufficient lead time prior to test conduct.
- Design and advanced flight test is feasible in a substantially reduced capacity organization if: a core of experienced personnel is still available; competence from other organizations is added to the team, including the customer; and reduced capacity issues are resolved prior to start of tests.
- In an integrated team, everybody must have access to all relevant information and each member made to feel they are a part of the team.
- Celebrate the successes.

P18. Flight Test of the Autonomous Takeoff and Landing Functions of the SHARC Technology Demonstrator: The demonstrator was a UAV equipped with an onboard camera and a GPS (for horizontal location). Following a comprehensive risk assessment, and analysis sufficient to obtain airworthiness certification, it was landed successfully on a civilian runway. The test program was accomplished by a very small group of professionals, empowered to work on their own. Prior to flight test, they followed a disciplined test planning and test approval process. In addition to flight tests, the program included simulation, lab-based subsystems evaluations and hardware-in-the-loop verifications.

Lessons:

- If you buy commercial off-the-shelf test equipment, check it out first – compensation or modifications may be required for your specific application.
- Have a back-up pilot in place during flight operations.
- Steel reinforcing bars in runways may cause magnetic effects on the system under test.
- Small, empowered teams are effective.

P19. Separation Flight Tests of a Small UAV from a C-130 Transport Aircraft: Launch methods for UAVs have been primarily ground based. This concept-demonstration program determined the feasibility of launching a small (80lb maximum) UAV from a larger surrogate air platform, and to determine if once launched, it would be stable enough for wings deployment and be flyable by a programmed profile or remote pilot. The UAV, XPV/GL Hawkeye, was designed to be launched from the host aircraft's wing or fuselage hard-points. Results from previous tests and limited simulations provided guidance to the test team for the actual test launchings from the cargo ramp of the C-130. Three main challenges: enough predictive analysis to determine a safe start for flight test, design and build a launch system to enable safe separation, and constrained within a limited budget. Ground tests including practice and mock launches were used to develop in-flight procedures. Mass properties and moments of inertia were measured and compared with MIL-HDBK-1763 for store certification tests (method as used for air-launched ordnance programs). C-130 computational and visualization studies and USAF Academy flow vector plots were used to create a simulation to predict launch trajectories. The simulations showed that launch separation was sensitive to UAV weight with less separation distances at lighter weights. Flight tests were thus conducted by building down from heavier to lighter weights.

Lessons:

- With modern predictive tools like CFD, this type of testing can be accomplished with fewer test points and be started at higher risk conditions. Caution must be exercised to compare actual results at every step with predictions to avert dangerous trends.
- Review results of previous related tests.
- Practice maneuvers and procedures prior to flight.

SESSIONS 2, 7 & 8 – TEST METHODS: The Session's objective, "Review techniques being used to safely evaluate system performance in challenging technical environments," was accomplished. Communication, and information access and organization were shown to be of increasing importance. Noted were: new T&E tools and methods; more use of simulation; integrated use of numerical methods, data-based animation, modeling, simulation; the need to focus attention on ground testing; and impacts of UAV automation on the pilot's situation awareness and response. The human as part of the UAV system was evaluated. Methods and lessons from manned flight and air traffic control should be considered when planning UAV tests. **Issues: (1)** Who should "pilot" UAVs – during tests, during operations. What training and skill set is needed? Is manned flight experience needed? **(2)** Telemetry (TM) needs are exceeding frequency spectrum capacity.

P4. Flight Test Verification of a Wake Vortices Model: The problem: Wake vortices from a leading aircraft impact a trailing or crossing aircraft during "dog fights" and other events. If these effects can be measured and accurately predicted, then methods for responding to the effects can be developed. The presentation described development of a method for measuring the effects and the flight tests that were part of the development. Flight tests used a Swedish Viggen as the lead aircraft to generate the vortices.

Lessons:

- Data-based animation was used to show trailing aircraft movement through the vortices.
- Conventional vortex models have not been adequate for the real world. This one worked. It allows validated vortex simulations to now be used for design and testing.
- Innovative use of smoke generators on the lead aircraft was used to enable the trailing aircraft pilot to locate and close on the target airplane.

P5-1. UAVs: A New Age in Human Factors Evaluations: Even in today's complex manned aircraft**,** pilots control with manual inputs and receive physical / direct feedback, or at least have a cockpit with a range of feedback instruments to monitor, and when needed, respond to. Most of the physical and cockpit stimuli are absent in the remotely-operated UAV. This presentation addressed evaluation of the UAV operator in his environment, compared that to tests in manned flight and described effective and similar "Measures of Performance" used in both cases. Test devices included expert observation, audio and video recording, physiological recording, and eye and head trackers. Stated that "Pilots are still the best UAV operators."

Lessons:

- Flight simulators provide high fidelity for human factors tests of UAV operators.
- The human factors Measures of Performance are nearly the same between manned and unmanned situations.
- UAVs use much more automation, which, compared to manned aircraft: leads to reduced pilot workload and task complexity, reduced situation awareness of the UAV location, decreased emergency response performance, induced complacency and degraded piloting skills. The workload was more mental than physical with related fatigue and complicating interaction with the UAV's automated features.

P5-2. Assessing Human Factors in UK Military UAVs: This presentation reinforces the message that the human operator is part of the UAV system. With experience of conducting safety assessments on a number of different UAVs, the authors discuss some of the major issues that must be considered in evaluation of UAVs. The UK UAVs must be certified as safe prior to fleet release. The certification process is based on a rigorous safety assessment. This safety assessment must evaluate the potential for human error in the operation of the UAVs and assess the mitigation against such error offered by the system's design and by proposed operational procedures. With respect to test or fleet operations, a "yes" answer to the following is required: Can the human mitigate problems when required? Does he have the right information at the right time, along with access to the right communications facilities?

Lessons:

- Lessons from manned-aircraft piloting and Air Traffic Control often apply.
- Open for consideration is what piloting skills are required: navigator, model airplane flyer, air traffic control background, some manned flight aspects, etc?
- UAV-type automation: may surprise the operator with an unexpected aircraft reaction, can mask problems and cause difficulty in maintaining situation of the UAV versus terrain or other aircraft.

P6. Telemetry Band Augmentation: An Agenda Item at the Next World Radio Communication Council: This presentation by authors from three countries is about a critical tool of flight testing: TM, the means by which data is transmitted real time from the aircraft to ground stations. The capability is no longer sufficient due to encroachment of commercial users and the increased demand (increased quantity of data required by the aeronautical community). The TM frequency bands, located between 1400 and 2450 MHZ, are vital to military and commercial flight test activities. Capacity limits have already impacted some NATO-country development/test programs. Encroachment from the non-aerospace communities, in some cases legislatively approved, in areas like wireless web, cell phones, digital audio and video entertainment has markedly limited the spectrum available for aeronautical telemetry. Several research efforts have increased TM efficiency by decreasing the amount of spectrum needed to transmit a bit of information. These techniques, promising a 2-3 fold increase, still can't address the needs for future wide-band TM transmissions, which are growing exponentially. The need for additional spectrum is shared by the international community and has generated an agenda item for the next meeting of the World Radio Communication Conference. **Issue:** Without international attention and support for increased TM capacity, future aircraft development and flight test programs will suffer delays, be more expensive and have increased risk. www.telemetry.org

Recommendations:

- Protect existing TM spectrum.
- Promote new methods to improve spectrum efficiency.
- Research to find TM capability outside the existing spectrum.

P21. US Air Force Flight Test Center (AFFTC) Experiment in Experimental Design: Increasing flight test costs, decreasing resources to conduct flight tests, and the war fighters' rising expectations to rapidly deploy and employ operationally ready weapon systems into the battlespace have forced the flight test community to more effectively and efficiently conduct flight tests. Design of Experiments (DOE) is rapidly gaining interest within the United States Air Force flight test community for developing test plans, executing tests, and analyzing results. This paper addressed the DOE experiment currently underway as a possible test strategy for developmental T&E flight test programs. Among other benefits, DOE could help handle the huge quantity of data being generated by today's flight tests. AFFTC engineers have completed training on DOE and statistics. Trained engineers have applied the techniques to three test projects at the USAF Test Pilot School. Although tests are still underway, positive results have already been confirmed.

Lesson:

- Design of Experiments and related statistical methods, used in applicable T&E situations, will reduce test cost and improve test efficiency.

P22. Simulations and Reconstructions of Aircraft Flights and Accidents Performed at the Institute of Aviation Technology During the Last Years: Described are numerical simulations and accident reconstructions conducted over the last seven years, some of which has been verified by data recorded during flight test. The Polish-designed trainer TS-11 crashed in 1998 during routine flight operations. Since the TS-11 was not equipped with a Flight Data Recorder, a time history of flight velocity, taken from ground radio-location data, was the only objective data available describing the flight path. Reports of eyewitnesses were the other source of information about the critical phase of flight. On the basis of all available information two hypotheses were formulated: the aircraft was in operational working order and the pilot made a mistake, and an icing phenomenon was the main cause of the crash. These hypotheses were verified with a standard 6 degree-of-freedom model of airplane flight dynamics. An investigation of control limits during nap-of-the-earth maneuvers for the Polish-designed *Sokol* helicopter was also conducted. Test flights were conducted after numerical simulations of each maneuver. Resulting analysis enabled improvement in piloting technique for nap-of-the-earth maneuvers.

Lesson:

- Numerical simulation with math models verified by flight test is effective for accident investigations and flight control investigations.

P23. Knowledge Gained from F/A-22/F119 Propulsion System Ground and Flight Analysis: Described is the teaming strategy between Arnold Engineering Development Center (AEDC) and the AFFTC, to evolve new ways for sharing cost and knowledge in the development of aero-propulsion systems. The AEDC is responsible for the ground-based altitude development of current and future propulsion systems, and the AFFTC is responsible for in-flight development testing of installed propulsion systems. With the long-term goal of developing joint ground/flight propulsion modeling and simulation (M&S) capabilities, AEDC and AFFTC have teamed to apply these data analysis tools to two major propulsion flight test programs: F/A-22 and JSF. Propulsion system M&S techniques and automated M&S-based analysis of test results were explained. Included were example results in which the engine model-based technique correctly identified errors in test measurements used for calculation of in-flight thrust. The model-based approach enables simultaneous validation of test data and calibration of the engine model while helping the test engineer interpret predicted and measured responses, and effectively use additional measurements available during ground and flight testing.

Lessons:

- Installed-engine pressure ratios can be better characterized with methods like CFD.
- Installed-engine flight profiles need to be evaluated during engine ground test; include the use of simulators.
- Communicate to combine M&S, wind tunnel, and flight testing into one coherent propulsion evaluation.
- Ground-based and in-flight propulsion testers should develop standardized data analysis tools together.
- Use M&S during testing.

P24. Introduction of a Workflow Tool in Support of Information Management within a Flight Test Organization: Flight testing is a complex endeavor with crucial related information that is often independently organized. The speaker described the integrated, automated data base that was systematically developed to document, access and coordinate test information. In support of the test team, it brings together primary test information into a single, organized set. Up-to-date booking of Test Task, Plans, Flight Cards Aircraft Configuration Control and Work Orders were included. Restructure of the flight test organization was made to comply. Typical software like Microsoft Word and Excel was used. Results were positive and successfully applied to the Eurofighter program.

Lessons:

- Implementation of a work-flow tool project is a sophisticated change-management task requiring management attention and commitment throughout.
- Organizing flight test information into a disciplined, automated and readily accessible data base improves flight test efficiency.

P25. Transient Temperature Measurements during In-Fight and Wind Tunnel Investigations and Icing Phenomena: Described is a study following a crash in Poland in preparation for an Independence Day air-show which deals with transient temperature measurements performed on the airfoil exposed to icing conditions. Aircraft icing is among the least understood phenomena in aviation, effecting both manned and unmanned aircraft. The experiments were performed both in-flight and in ground-based labs. The temperature changes of the airfoil surface were investigated during test flights in all kinds of atmospheric conditions in March. Special attention was paid to icing conditions in flights through clouds. Crucial parameters included air temperature, liquid water content and airspeed. Flight tests were conducted with a Polish TS-11 airplane equipped with temperature measuring apparatus. Special attention was given to understanding the relationship between wing surface temperatures and fuel temperatures. Large wing temperature decreases were noted when the wing was out of the sun (under a cloud). Experiments were performed on the NACA0012 model airfoil in a small-scale icing research tunnel. In this case, a multi-channel temperature measurement system of a different type was applied. It enabled investigations of the dynamics of ice formation and was used to validate and expand flight tests. Fuel temperature effects on wing icing were thus determined to be negligible. The in-flight and lab results were consistent with theoretical predictions.

Lesson:

- Actual or potential icing should be given special attention for military and civilian, manned and unmanned, aircraft; especially those who may need to operate in all weather conditions.

SESSIONS 3 & 5 – PROGRAMS OVERVIEW: The Session's objective, "Assess the status of recent research and development test programs," was accomplished. Noted was the multi-nation/NATO-countries involvement, joint teams with technical areas well integrated, similar planning and testing elements and test execution roles, and risk assessment and mitigation. The importance of ground testing and ground-based pre-flight rehearsals was emphasized, as was the need to adapt test methods to address future NATO-country ship and air applications. Good examples of today's flight test process and key roles were shown. UAVs: can safely operate in civilian and military aviation environments, some manned-aircraft piloting skills are required and manned-flight test operating rules should be used as a starting baseline.

P7. Ship Suitability Testing – Preparing for the Future: Involves interaction with several NATO countries, US Naval Sea Systems Command and US Coast Guard. Substantial testing is to be conducted with the JSF during 2007 – 2009, including UK and US aircraft carriers along with ongoing fixed-wing, rotary-wing and tilt-rotor tests. Navy plans call for a diverse set of new and modified aircraft and air-capable ships. Ship compatibility testing will be required on aircraft ranging from the two variants of the JSF to the Fire Scout unmanned helicopter; and from C-130 cargo aircraft to small unmanned seaplanes. Conversely, aircraft compatibility testing will be required on ships ranging from the Littoral Combat Ship to the DDX destroyer, and from a new amphibious assault ship to the latest in nuclear carrier technology, CVN-21, which will incorporate all new electric catapult and arresting gear equipment. Determining aviation compatibility with electromagnetic launch and recovery systems and with the new "fast ship" will require changes to T&E methods. Provided were examples of testers helping developers develop software via flight test, validating models with test, an increasing number of wind tunnel applications and using CFD and M&S. Current and future UAV ship-interface T&E challenges include innovative launch and recovery, measures of safety and performance specification.

Lessons:

- Learn to test in areas without a history and from past examples of unique testing like ski-jump and C-130 shipboard tests.
- The most challenging area in aircraft/ship compatibility is the integration of the unmanned aircraft in the shipboard environment. Everything must be reconsidered.

P8. A Year of Bomber Test – Legacy and Lessons Learned: Testing and the test process for developmental testing of the B-1B, B-2A, and B-52H were described including the training, development and roles of Operations Engineers, Test Conductors, and Test Directors who coordinate the efforts of the entire flight test team. The Operations Engineer translates engineering requirements into test cards, assigns specific test points to a mission objective summary, outlines the prospective test mission, and schedules and de-conflicts resources and mission requirements. The Test Conductor leads the mission planning activities and acts as the mission focal point, ensuring overall quality of the test planning process leading up to a mission. This includes conducting the mission readiness review, control of the test mission from the control room, and drafting the "quicklook report" which documents the test, including what worked and what didn't. The Test Director acts as the squadron commander's representative during a mission and has authority to cancel a mission at any time whenever anything fails to meet test criteria, test discipline or violates test safety. Communications procedures were standardized between the mission control room, the aircrew, and the range. Several flight test programs took place on all three airframes over the past year. The B-1B integrated the Joint Standoff Weapon and Joint Air-to-Surface Standoff Missile to the platform. The B-2A completed regression testing to validate the newest software update and added a new tactical Link-16 terminal to improve pilot situational awareness during combat. The focus of B-52H testing has been upgrading the offensive avionics system.

Lessons:

- Step through test cards in a "dress rehearsal" with each player reading his or her part. This has eliminated confusion during the final minutes of a complicated and expensive weapons test.
- Ground test planning procedures were defined to mirror, as much as possible, the rigorous planning required of flight test; to avoid the "it's only a ground test" mindset.
- Configuration control procedures were implemented to prevent test hardware from this project inadvertently affecting future tests or airplane operations.

P9. Flight Testing the Nimrod MR4A: Provided was an overview of the Nimrod MRA4 flight trials which highlighted innovative flight test methods. Though drawing on the airframe configuration of the existing Nimrod, the MRA4 is essentially a new aircraft; 95% new design and a new fully integrated mission system. The lead development aircraft, which is the principal air-vehicle test aircraft, recently started its flight test program involving handling trials, flutter and systems testing. The build up to first flight was an intense period of activity with low and high speed taxi trials taking place immediately prior to flight. In order to prepare for this busy period, taxi and flight rehearsals were conducted by linking the flight deck assessment rig to the flight test TM ground station. This allowed the aircrew and flight test engineers involved to practice and refine the planned testing. The second development aircraft will be the first mission systems aircraft to fly. To expedite the flight test program, much of the mission systems testing will be conducted simultaneously with air vehicle trials. The third and final development aircraft will fly in mid 2005 and will be dedicated to avionics and mission systems testing. The flight trials are being conducted as a Joint Trials Team with QinetiQ, the Defence Procurement Agency and the RAF. Trials support can be provided both onboard (using flight test observers) and/or via a TM down link to the test ground station. Concept of operations for high risk air vehicle tests: TM mandatory, crew emergency escape system enabled, testing over land only, minimum crew, entire flight test team including safety pilot in TM ground station with invited designers, and test direction by the TM ground station controller. Explained was a web-based Flight Trials Management System. Instrumentation included 2000 transducers.

Lessons:

- Flight test rehearsals improved flight testing (Flight Test and Flight Ops team received Award for Innovation).

- Emphasis on risk assessment and mitigation.
- Split-site operations offer the strengths of the sites but involve communications and test management challenges.

P13. Early Flight Achievements with the Aermacchi M-346 Advanced Trainer: Briefed were the successful ground and flight test planning, preparation and execution with a collaborative and integrated test team including members from the Italian MOD. All testing participants were included: operations, flight line, test conduct, instrumentation and data processing; and design, lab and manufacturing representatives were directly involved. The first part of a demanding 800 flight, 3 prototype-aircraft flight test program has been completed. Young engineers with two to five years of flight-test experience were brought together to create communications linkage with designers and others. Ground tests were organized and expedited by a Flight Test Manager. Weekly meetings and daily contacts with specialists and managers paved the way for a smooth transition to flight-test. Ground tests were conducted on facilities specifically designed for equipment, subsystem and system performance verification and functional integration. Flight test engineer training emphasized data processing and analysis, and real time data interpretation. Flight test was supported by inter-connected automated data bases which included: configuration change documentation, aircraft software configuration updates and integration results, test requirement documentation, test documentation, flight test cards and flight test analysis documentation. Risk mitigation included simulation models set up in advance of flying.

Lessons:

- Flight test is a process with the Flight Test Manager being the process owner.
- Involve flight test teams early in the subsystem ground lab test process to enable team integration to move through each development phase.
- The success of this program was largely attributed to the well-integrated team structure, in place before and since first flight.

P15. Swedish Evaluation of a MALE UAV System in Civil and Military Airspace from a Civilian Airport: Test flights were performed in both civilian and military airspace within the NEAT range, over Lapland. The evaluation was a pre-demonstration for civil and military customers and was required by airworthiness authorities, leading to a Flight Test Permit. Takeoffs and landings were at the Kiruna Airport, the second airport in Sweden to receive the new VDL mode 4, GPS-based, transponder system; so the UAV was equipped with this system. Clearance for flight test included determining what other aviation operations (air ambulance, forest fire reconnaissance and aircraft with extended separation) could occur at the same time. Risk assessments with regard to inhabitants, aircraft and facilities were made, mitigations were applied and tolerable risk levels were set. The pilot was always to have full knowledge of the UAV's position, and the UAV system had to prevent flight outside restricted airspace, and be able to immediately and safely abort the flight. These arrangements allowed UAV flights in civilian controlled airspace for the first time in Sweden. A number of No Flight Zones around populated areas and Emergency Landing Spots in open areas were established. Prior to flight tests, three ground tests had to be performed with acceptable results: Map control test to verify that the translation of the Swedish maps in the system didn't generate positioning errors. Radar illumination test to verify that the air defence radar at Kiruna airport did not cause electromagnetic interference. Taxi test to verify functionality of the system and familiarize the pilot with the runway.

Lessons:

- Some but not all manned-aircraft piloting skills are needed for UAV flying.
- Consider manned-aircraft rules as a baseline, then modify for specific UAV flight tests.
- UAVs can safely operate from civil airfields and within civil and military airspace, so don't restrict UAV operations to areas without aircraft.
- The NEAT range proved to be excellent for UAV testing.

SESSION 4 – FACILITIES AND FLIGHT TEST INSTRAMENTATION: The Session objective, "Determine the latest applications of instrumentation methods, aviation facilities, test tools and resources" was accomplished by this and presentations in the other Sessions. Noted in this Session were: optimized means of acquiring flight data onboard the aircraft; T&E tools, systems and instrumentation; current instrumentation systems tailored to specific needs and considerations for future applications. Optical air flow measurement systems and instrumentation provide improved options for test airspeed determination and other future avionics applications. Self-contained TM units are now an option for weapons captive carriage and separation testing. Insufficient TM frequency spectrum required installation of special test provisions.

P10. A380 Flight Test Engineer Station and On-Board Data Processing: The first flight of this largest ever civilian aircraft occurred two weeks prior to this presentation. The A380 has the first flight-test installation conceived completely around a redundant Ethernet network interconnecting the acquisition, storage and onboard computing systems. The flight test onboard crew is limited to two pilots, one flight engineer and one or two flight test engineers (FTE). The FTE leads the flight test program and conducts and validates the test sequences. To perform theses tasks, a dedicated station is installed onboard the aircraft. Because of the reduced flight-test crew, Airbus developed the TM to provide dynamic message adaptation to the test sequence, and allow deferred data transmission when the aircraft is outside the coverage area. To minimize flight test data reduction time, a dedicated set of computers has also been installed to execute automatically many pre-processing tasks. Flight tests rely on extensive instrumentation (6000 parameters). TM frequency in France is limited to only 5 mega-bytes (up to 80 would be required if all the parameters need transmitting). Thus selective transmission of parameters is managed per test, along with temporary storage of data onboard. Fault-tolerant architecture enables essential functions to always be available. The onboard data system is UNIX (which is also used for ground data processing), along with a dedicated LINUX distribution on all portable computers, with standard extensions to insure near real time performance. Center of gravity for test purposes is managed with a water balance system.

Conclusion: The A380 onboard flight test data system:

- Provides reliable validation tools necessary to speed up the test cycle by detecting instrumentation, aircraft or test method problems.
- Provides ground engineers with fully validated onboard results to speed up data reduction.
- Uses standard off-the-shelf software which allows easy upgrades.
- Can be scaled down for use in lightly instrumented A380 aircraft.

P11. Optical Air Flow Measurements for Flight Tests and Flight Testing Optical Flow Meters: This presentation, determined by many in the audience as the most interesting of many interesting presentations, described optical air flow measurement techniques applied in flight, and ideas on what could be achieved with the techniques for flight test. Uses include aircraft flight test, in-flight investigations of the atmosphere, and applications for flight-safety avionics and air-data systems. Reference was made to the AGARDograph on this topic, written by the authors, and recent advancements were discussed. Flight tests were used to qualify these instruments for the flight environment. In-flight optical airflow velocity measurements use light scattering (light scatters on air molecules and aerosols entrained in the air). Measurement of airspeed in three directions provides important flight test data. Measurement of airspeed and density was demonstrated. Results apply to both fixed-wing aircraft and helicopters (measuring helicopter airspeed by conventional means has always been difficult). Velocity distributions in boundary layers can be measured. Optical air flow measurements contribute to the remote detection of atmospheric phenomena such as wind shears, mountain rotors, wake vortices and clear-air turbulence. In avionics systems, measurements are developed for air-data systems (airspeed, angle of attack and angle of sideslip). The safety systems generate a warning if a wind shear, clear air turbulence or wake vortex is detected in front of the aircraft. Recently NASA acquired new data on mountain rotors and the hazard to the aircraft was indicated by measured wind shear strength. NLR recently installed a laser anemometer on a Cessna Citation II research aircraft which detected wake vortices.

Conclusions:

- Applications: Measures in undisturbed air around the aircraft: speed, angle of attack, sideslip, wake vortices, wind shear and clear air turbulence.
- Advantage: Nose-booms or other appendages and calibrations are not needed.
- Additional tools for the flight tester can be developed with this technology.

P12. Adding New Instrumentation to Aircraft Platforms: Presented were low cost alternatives called "6 DoF" and "Captive Carriage Miniature TM" (CCMT). When a weapon is to be integrated on a tactical aircraft, flight testing is needed to confirm that it will be carried and deployed safely. Conventional but expensive ways to collect the test data include photogrammetrics, cinetheodolites and fully instrumented aircraft**.** Often legacy aircraft, and some new aircraft, have little space or budget available for extensive installed instrumentation systems. Recent advances in technology have allowed instrumentation systems to greatly shrink in size and cost. Some are designed to fit inside a MK 80 series fuse well and to look like existing bomb components. One of these is a small form factor instrumentation system named "6 DoF" because it transmits six-degrees-of-freedom information to a ground station. The 6 DoF is self-contained, requires no aircraft interface to operate and is capable of capturing and transmitting over 6,000 samples per second. The 6 DoF has provided a low cost data collection device for weapon separation test programs for the last couple of years. The question was raised: could a similar system be used for captive carriage loads and flying qualities test programs. To meet this need, a new low cost, under $30K, instrumentation system has been developed and is designed to take external strain gauges and accelerometers. This new system is a block upgrade of the 6 DoF system that has had the internal sensors removed, and has had plugs installed to take inputs from external sensors. Now instead of having to instrument a specific aircraft for a test program, a store could be instrumented to collect the same data. This system is designed to not only allow the instrumentation to be moved from one type of aircraft to another, but also to allow the instrumentation to be moved from one type of store to another. Various test applications included successful tests on a 20 year old AV-8; then removed and installed for other applications.

Conclusion:

- Six degree of freedom TM units and captive carriage miniature TM units have proven to be valuable low cost, low impact tools for evaluating weapons separation and captive carriage.

***SYMPOSIUM SUMMARY VIEWS OF SESSION CHAIRMEN, HOST FROM POLAND, SFTE(EC) PRESIDENT AND SCI'S FLIGHT TEST TECHNOLOGY TASK GROUP CHAIRMAN*:**

- Symposium was effective for sharing knowledge within the Flight Test and related communities.
- Breadth of symposium shown by the range of subjects and presentations from UAVs to the A380 and participation involving 24 countries.
- Was worthwhile for the host country, Poland.
- Quality of the papers and information was impressive.
- Shows flight testing personnel are indeed an international community.
- Innovative ideas in the areas of test methods and instrumentation.
- A good fit with the SCI's flight-test AGARDographs (developed and arranged by the Flight Test Technology task group).
- Emphasis on the need for teaming.
- Importance of multi-national test programs, jointness, integration, team size and safety.
- UAV impacts of the symposium were significant.
- Be careful to retain core skills and capabilities as retirements, downsizing and re-organizations occur.
- Presented today's challenges in testing complex systems – technical and managerial.
- Informative look at today's challenging test operations.
- Much knowledge was also shared by individuals communicating during breaks between Sessions.

CONCLUSIONS

Meeting the Symposiums Theme and Objectives:

1) The symposium was successfully executed and was very worthwhile, as determined by the attendees and myself.

2) Those attending this symposium certainly left with an improved understanding of the state-of-the-art in flight testing.

3) The Theme "Sharing flight-test related information between the international community with a purpose of improving flight test practices worldwide" was exceedingly well met, as were each of the eight previously mentioned symposium objectives.

4) The many examples of multi-national involvement and international applications increase the importance of flight test to NATO. Current flight testing experience on most of the major aircraft development programs in NATO countries was reported.

5) The health of the flight test discipline in NATO countries is good, in fact better than 10 years ago.

6) The benefits were enhanced by the symposium being jointly organized with and supported by SFTE(EC).

Significant Findings, Lessons Learned and Common Threads: Many lessons learned and significant results have been previously mentioned in the respective Session and individual presentations summaries. The following conclusions resulted from the Sessions summaries and several presentations or have special significance.

1) Test techniques, the disciplined step-by-step path from test planning through test execution, test tools and challenges were amazingly similar regardless of the nation or organization involved.

2) Today's concept of operations: teaming and collaboration, often internationally; co-location; flight-test integrated with design and development, simulation, CFD, numerical methods and M&S; and flight test efforts integrated with wind tunnel, hardware-in-the-loop, net-centric, ground-based propulsion aspects and ground testing.

3) The most frequently mentioned lesson learned was to communicate a lot, accurately, clearly and fast, given the broad-scope and multi-disciplined team structures and the need to use off-site locations.

4) The substantial amount of presented UAV applications indicates how rapidly they have become an increased and important part of NATO aviation.

5) Even though more complex, today's testing appears much safer given that the number of related aircraft crashes is substantially reduced. Credit goes to disciplined in-flight, ground and ship-based test planning; risk assessment, risk mitigation, and pre-flight mission readiness reviews; along with pre-test rehearsals and well-managed test coordination.

6) Innovation was frequently noted, with regard to: instrumentation and test-tailored tools, the use of data generated images and animation and learning how to test where no history exists.

7) Several flight test organizations have developed an automated, readily accessible data base of organized test planning and execution information for each test program, resulting in efficiency improvement.

8) The October '01 SCI symposium "Integration of Simulation With Systems Testing" showed that simulation and testing were then interdependent and mutually beneficial for aircraft development, but not well integrated. They now seem to be effectively integrated by organization and process.

9) Cockpit video is now used extensively for both manned and unmanned flight tests, and GPS is being used in UAVs.

10) Pilots are now evaluated as part of the system, especially with UAVs. The extensively automated UAVs result in pilots having reduced workload during flights which in turn has the tendency to decrease awareness of the UAV's location and to decrease rapid response performance.

11) UAVs can now safely be flight tested from civil airfields and within civil and military airspace while in proximity to other aircraft.

12) In addition to the large scope, complex, major developmental T&E programs, several combined flight test and design efforts have resolved important operational problems including accident/incident causes.

RECOMMENDATIONS

1) NATO-country aircraft developers and testers, with military and civilian aircraft operators, should determine who should "pilot" UAVs – during tests, during operations. What training and skill set is needed? Is manned flight / air traffic control experience needed? How much?

2) Support initiatives to expand the decreasing amount of TM frequency spectrum available for flight testing. High data quantity from today's complex systems is exceeding frequency spectrum capacity. Without international attention and support for increased TM capacity, future aircraft development and flight test programs will suffer delays, be more expensive and have increased risk. Also, the flight test and TM communities need to determine ways to better handle and evaluate the huge volume of data available today.

3) Empower small, integrated teams and give them a long leash to innovate.

4) Keep an eye on and carefully manage impacts of reductions in your organization's core flight test competence.

5) Practice maneuvers and procedures prior to flight with ground-based rehearsals.

6) Consider adding a back-up / safety pilot for applicable manned and unmanned tests.

7) Manage to offset the high intensity work efforts with some occasional "fun" and "celebrate the successes".