

**Aircraft Wiring and Inert Gas Generator Working Group
(AWIGG)
7-8 March 2001**

MINUTES

The ninth Aircraft Wiring and Inert Gas Generator (AWIGG) Working Group meeting was held on 7-8 March 2001, at the Delta Air Lines Training Center, Atlanta, GA. Sincere appreciation is extended to the staff at Delta Air Lines for being such exemplary hosts.

Mr. Richard Healing, Director, Navy Safety and Survivability, founder of AWIGG, introduced the opening speaker, Mr. Mac Armstrong, Executive Vice President of Operations for Delta Air Lines. Mr. Armstrong welcomed the attendees, and gave a brief overview of the mission in aviation. He stated that the mission is to provide serviceable aircraft that are ready when customers are ready, manned by qualified aircrews, and that depart on time, with safety being the highest priority. Mr. Armstrong said that any initiative to support safety cannot really be assigned a value, and that Delta Air Lines is dedicated to initiatives like AWIGG for the enhancement of safety.

Mr. Healing then addressed the group, summarizing activities that had taken place since the last AWIGG meeting in September 2000, including the Congressional hearing on Aircraft Electrical System Safety and the UK RAF Aging Aircraft Wiring Symposium, both in October 2000. Following a background summary of AWIGG, he stated that the forum's success was founded on both government and industry support, with over 400 individuals currently on the AWIGG distribution list. He emphasized the importance of continued *open* sharing of information. Mr. Healing informed the group that further testing of fire suppression and electrical system safety technologies is planned as a series of follow-on tests to the water mist and aerosol generator proof-of-concept tests completed in May 2000.

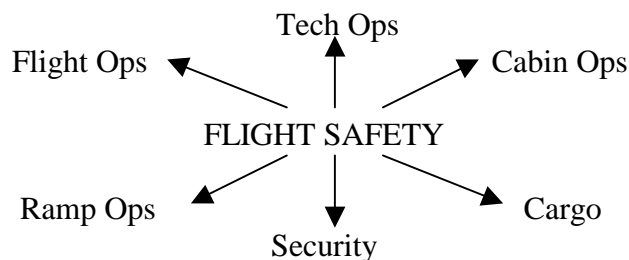
He then gave an overview of technologies and methodologies introduced at AWIGG since the group was founded. With growing reliance on aircraft electrical systems to reduce weight and increase reliability, Mr. Healing stated that wire insulation type, installation, inspection and husbandry are all important. AWIGG has addressed aircraft wiring inspection methodologies, wire protection technologies, new wire insulation materials, potential wire replacements, and miscellaneous wire related topics. Fire suppression technologies introduced include inert gas, nitrogen, water mist, and aerosol, as well as fire resistant materials. He added that AWIGG will continue moving forward with fire suppression technologies.

Mr. Healing stated that the future of AWIGG includes continued information sharing and more proof-of-concept tests for water mist and aerosol fire suppression systems, arc fault circuit breaker technology, and wire testing methodologies. He added that changes in the focus of future AWIGG meetings can be anticipated, with future meetings likely to focus either on wiring or fire suppression topics, as opposed to a combination of both. Following a review of the agenda, Mr. Healing introduced the next speaker, Mr. Ray Valeika, Senior Vice President of Technical Operations, Delta Air Lines.

Mr. Valeika, who has been involved with aircraft maintenance since 1965, expressed a concern with committees that try to solve large, complex problems at once; he emphasized that problems must be fixed one at a time. He would like to dispel the idea of “aging” wire; Mr. Valeika said that a wiring problem is a wiring problem, and such problems are random. In his view, the biggest aircraft wiring problem is with clamping, adding that there have been no changes in the way wires are attached since he began working with aircraft in 1965. He believes the second largest problem is with circuit breaker protection. He stated that circuit breakers used today are not protecting electrical circuits; the technology is available, so why is it taking so long to be incorporated? Mr. Valeika would like a method developed to attach wiring so the insulation is not worn through or broken; if such damage does occur, however, better protection is needed.

He advised the AWIGG group to not try to solve all problems at once; instead solve them one at a time so efforts do not become too diffused. The public’s confidence in aviation safety must be restored. Maintenance is very serious business, and Delta Air Lines takes it very seriously. The key is to translate this commitment to all employees.

The next speaker was Mr. Jim Anderson, Director Flight Safety, Delta Air Lines. He said that the mission of his Flight Safety Department is to support Delta’s commitment to safety, which is their first priority. The Department’s key functions include investigations, data collection/analysis, risk management, interdepartmental coordination, internal/external activism, and communication with all personnel. The safety culture includes awareness of corporate safety goals, reporting (very important), working relationships, respect, and a proactive attitude. The following figure represents the interaction of Delta’s Flight Safety office with the airlines’ other departments:



Delta Air Lines has a Safety Event Team, which includes Flight Safety, Quality Assurance and Technical Operations, that oversees risk analysis and monitors safety actions. Delta’s strategy is to prevent the “big” accident (e.g., mid-air, CFIT, loss of control in flight, high-speed runway collision, etc.) by focusing on precursors (e.g., altitude deviations lead to mid-air collisions). The airlines has an active Flight Operations Quality Assurance program to manage risk. The program incorporates the collection of data that are compared with other data for trends. Precursors are identified and classified, and risks are quantified. Activities are prioritized, countermeasures developed and fixes implemented. A case study for an MD-88 departure event was then reviewed. Shortly after takeoff, flight attendants reported a sulfurous odor, and an emergency return to the airfield was begun. A passenger reported a glow below the floor. A flight attendant discharged a Halon fire extinguisher and the flight returned to the field without incident. It was found that the alternate static port heater had had an arcing event that had propagated through the insulation covering; the circuit breakers did not trip and the heater

continued to work. The NTSB began an investigation, whereas Delta took immediate action that night by inspecting static port heaters on other aircraft. Delta subsequently did further testing to determine the root cause. Inspection procedures for the area were revised and insulation around the area was cut back to eliminate the possibility of fire. Delta, in conjunction with Boeing, went back to the manufacturer to resolve the problem. Another arc occurred later, but there was no fire because the insulation had been cut back. The component that arced is now changed on an approximate six-year interval during a heavy maintenance visit. The NTSB subsequently released the results of their investigation. An AD was issued to inspect the primary and alternate heaters on MD-80/90 and DC-9 aircraft. A design review was initiated to reduce the potential of arcing, and an AD was issued to remove/replace the metalized Mylar insulation.

Mr. Anderson was asked if this type of information is shared with other operators, and if there is a problem sharing this type of information. He replied that there are various forums for the sharing of this type of confidential information, adding that there are no barriers between safety organizations. He also added that the external connectivity that exists allows for action to be taken on safety issues before any regulatory direction is given to do so.

The next speaker was Dr. Chris Smith from the FAA Technical Center who gave an overview of the "Intrusive Inspection Project Report to ATSRAC." The draft implementation plan, to be released in the near future, includes recommendations from his intrusive inspection working group that the group's members strongly believe should be implemented. By the nature of the earlier ASTF non-intrusive inspections, it was not possible to collect certain data necessary to fully assess the state of wire in aged aircraft. The objectives of the Intrusive Inspection Working Group led by Dr. Smith were to assess the state of wire in aged aircraft and assess the adequacy of visual inspections. The group followed a rigorous protocol addressing 14 characteristic locations across several aircraft types, and conducted enhanced inspections to assess the electrical properties of wiring insulation, insulation mechanical properties and other degradation related parameters. Dr. Smith reviewed the specimen types of interest, which included wiring from the interior and exterior of the pressure vessel, bilge and crown areas, high/low maintenance locations and installations, bundles exposed and in conduit, straight runs and complex harnesses, small and large bundles, and small and large gage wire. Six aircraft were inspected: A300, B-747, L-1011, MD-10, and two DC-9s. The aircraft were selected by wire type, not by aircraft type. Dr. Smith expressed the caveat that the statistics presented are a starting point for analysis and not a conclusion.

Seven findings of the visual inspections, which varied in locations, findings and possible causes, were forwarded to the OEMs for follow-up. The findings from the intrusive inspections supported/paralleled many of those from the non-intrusive inspections. Nothing really stands out among the visual findings by aircraft type. Included in the tests conducted by the group was the DelTest, which had findings mostly of physical breaches. The DelTest, by Lectromechanical Design Company, applies voltage to one end of the wire, saturates the wire with water, and then checks for stray voltage; for breaches to be detected they must go all the way through to the conductor. Dr. Smith commented that because of the small sample size, specific conclusions cannot be drawn. Another test conducted on four of the aircraft was by Eclipse, using that firm's special test equipment and methodology. The DelTest, which is simple, objective and accurate, is limited to breached insulation. The Eclipse testing is subjective, and requires detailed knowledge of the installation, a baseline for comparison and sophisticated interpretation of results, but is potentially indicative of failure precursors.

Laboratory testing was also conducted at the macroscopic and microscopic levels by Sandia Laboratories and Raytheon, including mandrel bend testing, modulus profiling (looking at the hardness of insulation) and infrared spectroscopy (to some, not all, wire samples). Findings from the laboratory tests include various age related conditions. Wires with cracking insulation (breaches in wire insulation that do not include breaches resulting from direct physical contact or traumatic force) were found that indicated wire does age, with most anomalies and the rate of aging attributed to handling. Other age related conditions include heat damage or burnt wire, evidence of arcing, chafing, delamination, and breaches at hot stamp areas. Based on frequency of findings, the most common wire condition anomalies are heat damage or burnt wire, vibration damage/chafing and cracked insulation. Signs of characteristic degradation included instances of delamination of Polyimide wire, cracking and thermal degradation of PVC/Glass/Nylon wire, and radial cracking of Poly-X wire.

Based on the results of the inspection group's efforts, there are a number of characteristic indicators of the state of wire in aged aircraft. At least one problem was observed with mixed wire types in an improperly installed bundle; there was no physical evidence of chafing on properly configured bundles but the data and analysis are insufficient to reach a firm conclusion. Breaches in insulation were often co-located with hot stamp marks. Although not a wire degradation issue, the frequency of cut-off wires found was noteworthy. Also, all wire types performed as expected during flammability tests; their performance was equivalent to new wire of the same type.

Visual inspection was assessed to be an effective tool in the management of wires subject to heat damage, burning and chafing; however, in high-risk situations, visual inspection must be combined with other means of preventing or mitigating failure. Visual inspection was assessed as not adequate for the detection of degraded repair, cracking, arcing or delamination. Where these conditions may occur, and where the consequence of wire failure is unacceptable, other means for prevention and mitigation must be used. Dr. Smith also reviewed some indirect indicators of potential wire insulation degradation, including discolored wire, blue water contamination, chafing, and delamination. He also reviewed examples where flaws were imperceptible during visual inspections or inaccessible such as wire inside conduit.

For the threat assessment by the inspection group, flaws were categorized as unique, infrequent or common, with each class handled separately. For all but unique flaws, the group used a formal threat assessment procedure for plausible, hypothetical situations of interest to ATSRAC. In judging the threat, consideration was given to aggravating or contributory factors, wire insulation type and estimated probability of existence. In making recommendations, consideration was given to visual detectability and efficacy of other inspection or testing. The final report included 28 general recommendations or options for action, and more than 100 for ATSRAC to implement where appropriate. Research and Development (R&D) recommendations, currently being implemented by the FAA, are:

- The FAA should fully support its commitment to its wire degradation assessment project to begin this year (including analyses of the effects of wire-to-wire chafing and effects of common contaminants of wire, and be fully consistent with and build upon the work presented in the Intrusive Inspection Working Group Report).
- The FAA should aggressively pursue and promote arc fault circuit breaker development.

- The FAA should aggressively pursue and promote the development of nondestructive test equipment for aircraft wiring.
- The FAA should investigate the physical and functional integrity of any electrical interconnect system component whose failure could hazard the aircraft (including connectors, circuit breakers, relays, switches, shielding, grounds and wire installation hardware).
- The FAA should determine the frequency and significance of non-environmental splices, and assess their potential impact on flight safety.
- The FAA should conduct research to assess the significance of unacceptably high resistance connections.

Dr. Smith stated that the report is fully supported and endorsed by all participants in the Inspection Working Group's final meeting, December 12-14, 2000, except for one dissenting opinion.

The next speaker was Mr. James O'Bryon, Deputy Director, Live Fire Test and Evaluation (LFT&E), for the Department of Defense. Mr. O'Bryon presented an overview of "DoD's Live Fire Test Program: Impact on Safety and Survivability in the Civilian and Military Sectors." He stated that the Director, Operational Test and Evaluation (OT&E), reports directly to the Secretary of Defense and that LFT&E is required by law; in 1986 legislation was passed requiring realistic survivability testing of DoD weapon systems. Among his many responsibilities, the Director oversees the Joint Technical Coordinating Group (JTTCG) for munitions effectiveness and aircraft survivability initiatives. One of their office's objectives is to enable the Secretary of Defense to make informed decisions regarding DoD systems.

In a comparison of Congressionally mandated civilian versus military testing, Mr. O'Bryon referred to the NHTSA and its Office of Crash Avoidance and Office of Crash Worthiness. The military's focus includes susceptibility, operational testing, vulnerability and live fire testing. The military's interest in vulnerability was paralleled to the objectives of NHTSA's Office of Crash Worthiness.

Mr. O'Bryon emphasized that Live Fire Testing is a process, within which he works on a variety of threats: ballistic threat types include small arms, fragmenting projectiles, shaped charges, kinetic energy rods, high explosives, etc., and non-ballistic threat types include lasers, incendiaries, blast/fuel air explosives, charged particle beams, high-powered microwaves, etc. The LFT&E oversight list includes 101 total systems.

In the LFT&E planning process, considerations include what it will cost to test versus what it will cost not to test. 1/3 of 1% of a program is the maximum ever spent on LFT&E, which is conducted and funded by the military Services, with the Director, OT&E, responsible for independent reporting. Mr. O'Bryon stated that wire bundles are among the more significant components in both aircraft and tanks susceptible to threats, and a major source of DoD accidents. The DoD has a repository for all survivability related test reports, data, analysis, etc., from which this type of information can be obtained, known as SURVIAC located at Wright-Patterson Air Force Base; Mr. O'Bryon would like to have the SURVIAC data combined with safety data for a more complete information source.

There are currently those in the Test and Evaluation area that believe simulation should replace LFT&E. However, Mr. O'Bryon presented arguments to justify the need for full-up systems tests. LFT&E represents how systems and their operators/crews fight; recent experience

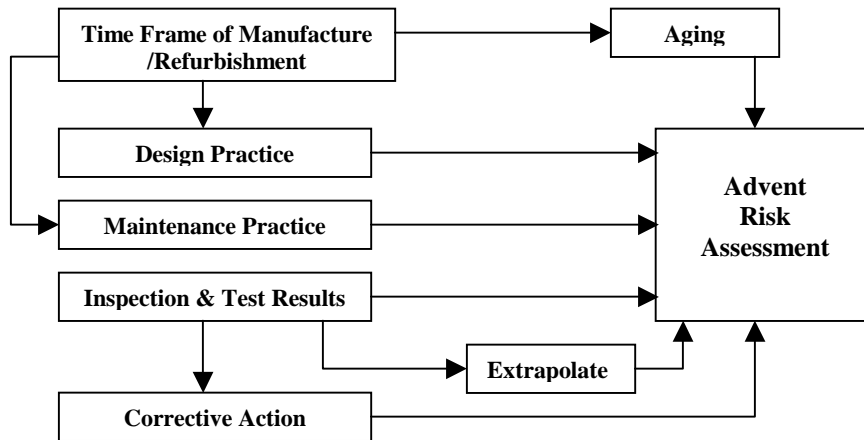
revealed surprises when LFT&E was conducted. During LFT&E secondary effects are revealed that are not seen in smaller-scale tests, synergistic effects are discovered that would have otherwise been unknown, and unexpected system degradation is exposed. Without full-up systems tests, it is difficult to obtain crew casualty estimates or realistic Battle Damage Assessments (BDA) and corresponding battle repair issues. LFT&E also provides insights into operational doctrine, and provides for on-board ordnance tests neglected in other testing. Fire spread and fire suppression capabilities are also realistically evaluated. Besides being legally required, LFT&E helps identify the “unknowns.”

Among the risks involved with weapon systems programs are risk of program failure, risk of technology obsolescence and risk of life and limb. Although most of the programs under the purview of the Director, OT&E, are classified, Mr. O’Byron cited survivability features of the F/A-18C/D and major ballistic vulnerability reduction features for the V-22 as representative of the types of results from LFT&E. He added that it will not be possible to do away with physical testing in the near future, and that statistical significance is not necessary for a significant test. The bottom line is LFT&E saves lives! Mr. O’Byron’s web address is <http://www.dote.osd.mil/staff/obryonbio.html>.

Mr. Vince Press, Lectromechanical Design Company, and Mr. Doug Wood and Mr. Dave Horvath with Advent Engineering Services, Inc., briefed the forum on Risk Assessment of degraded wiring, the next step after flaw detection. The methods presented should be applicable to any inspection methodology. Lectromechanical Design Company, Advent Engineering Services, Inc., aviation underwriters and aircraft operators were involved in the development of the risk assessment methodology.

There may be a number of potential dangers associated with wiring faults, but it is estimated an electrical fire occurs every two or three days in the aviation community. Like aircraft structures were a few years ago, aircraft wiring is now considered at high risk. For each anomaly found, the associated risk decreases; but there is no one answer for the problem. By utilizing a process flow chart, it is possible to conduct a risk analysis for wiring flaws, taking into account such factors as the likelihood of other flaws and likelihood of future flaws occurring. The matrix for this type of analysis includes a variety of factors; e.g., orientation of wire may affect the severity of polyimide arc tracking, and when assessing the flammability factor, structural destruction must also be considered. The methodology for determining risk includes questions, perhaps 10 or 12, to be addressed by an operator. Examples of the types of questions asked are “How many in-flight smoke or fire events do you experience?”, “How many instances of burned, charred or damaged wiring are discovered during the course of maintenance activity?”, and “Do you have an idea how many instances of damaged wiring are not discovered during the course of your maintenance activity?”.

The overall risk assessment process, presented below, is based on the background of Advent Engineering Services, Inc., in the nuclear power industry.



This type of process provides improved safety, reduced downtime, increased reliability, prioritization of resources, and design improvement recommendations. It structures data to quantify faults. Event trees (diagrams that map scenarios from initiating events through combinations of system successes and failures) and fault trees (diagrams that go backwards from events or failures to determine what causes events) are employed. By using this methodology, both qualitative and quantitative results can be achieved. Qualitative results include identifying wire faults of concern, defining results of multiple faults, improved future designs, and improved maintenance practices. Quantitative results include prioritizing problems by risk, assigning risk significance to as-found problems, and finite resource activity prioritization.

The next speaker was Mr. Tom Kowalski, from the Naval Air Systems Command (NAVAIR), Lakehurst, NJ, who has been involved with both Navy and commercial aircraft. He gave a presentation on the NAVAIR “Aircraft Wiring Support and Maintenance Program” and began with an overview of NAVAIR, and commented that there are over 4,100 active aircraft in its inventory. The Electrical Power Systems Division, Air 4.4.4, under NAVAIR’s Research and Engineering Program Executive Office, Air 4.0, is responsible for wiring related engineering support, science and technologies, and wiring assessments for the Navy. The Avionics Supportability Branch, Air 4.8.1.7, also under the Research and Engineering Program Executive Office, provides oversight for the Aircraft Wiring Support Equipment Commodity (AWSEC) team to which Mr. Kowalski is assigned.

The AWSEC team is responsible for all aircraft wiring Support Equipment (SE) issues, common and peculiar aircraft wiring SE issues, and is proprietor of the Aircraft Wiring Information System (AWIS) database. Over the past 15 years, NAVAIR has taken a number of steps to achieve standardization in addressing wiring issues. It established the Intermediate Maintenance Level Wire Repair Work Center in 1980, the Connector and Wire Harness Repair and Manufacture Program in 1990, and the Cable Harness Repair Or Manufacturing Equivalence (CHROME) Program in 2000. It has three main publications and processes for getting standardized information to technicians:

- NA01-1A-505 – Installation practices, aircraft electric and electronic wiring (publication)
- NA01-1A-23 – Electronic Assembly Repair (publication)

- N88-NTSP-A-50-8512B/A – Cable Harness Repair Or Manufacturing Equivalence (CHROME) Program (training plan).

The Electrical Power Systems Division, Air 4.4.4, is leading a number of science and technology initiatives. These include “smart wire”, arc fault circuit breakers, wiring diagnostics, advanced insulation, accelerated aging testing, fiber optics and new components. In-service engineering efforts include installation assessments, the Naval Aerospace Vehicle Wiring Action Group (NAVWAG), fleet support/investigations, training, tool development and failure tracking. The Division’s current component improvement program includes qualification, engineering support, failure analysis, FAA/NTSB support, and DoD/FAA/NASA/Industry coordination.

The AWSEC mission is to provide technical, logistic, production, procurement and in-service support to NAVAIR, relevant to organizational and intermediate level aircraft wiring support equipment. It was established in 1988, and is the Designated Procurement Activity (DPA) for all aircraft wiring SE, including Common Support Equipment (CSE) and Peculiar Support Equipment (PSE). The AWSEC objectives are to ensure system reliability, identify failure locations, identify proper repair tooling requirements, ensure technicians know how to use the equipment properly, repair failures, ensure repairs are effective, avoid maintenance induced failures, maintain records of failed items, reduce maintenance turn-around time, increase repair reliability, and reduce maintenance costs. The AWSEC team is the sponsoring activity for the Cable Harness Repair Or Manufacturing Equivalence (CHROME) Conference, which is the only known forum dedicated solely to aircraft maintainers. It has resulted in improvements in support equipment development and delivery. Mr. Kowalski extended an invitation to all commercial aviation maintainers to attend the CHROME meeting to be held in Norfolk, VA, 15-17 May 2001.

Following a review of some of the maintenance and testing equipment developed by the AWSEC, Mr. Kowalski presented an overview of the Aircraft Wiring Information System (AWIS) relational database management system that serves as a comprehensive repository for all major aircraft wiring system component and associated repair tooling data. Future plans for the database include integration with the Navy’s NA01-1A-505 publication (installation practices, aircraft electric and electronic wiring) to improve convenience and availability for maintainers. Additional growth includes expanding AWIS to include fiber optic data, video training, failure rate data, SM&R (source maintenance & recoverability) codes, and closed-loop technical assistance.

In addition to the AWSEC CHROME Conference, AIR 4.4.4 are the sponsors of the Naval Aerospace Vehicle Wiring Action Group (NAVWAG). NAVWAG is another NAVAIR forum established for Navy industrial activities to improve wiring systems. Coordination is effected with other Service’s maintenance depots and foreign agencies to develop standards and share information. NAVWAG has contributed to limited improvement of overall readiness and safety of Naval aircraft.

Mr. Ray Johnson, Electrical Systems Project Leader for the E2C2 Engineering Fleet Support Team at the Naval Aviation Depot (NADEP) North Island, San Diego, CA, presented a brief on “Naval Aircraft Wiring System Repair” that addressed how his organization developed during the past 12 years. NADEP North Island implemented processes which address aircraft wiring as a system.

NADEP North Island provides in-service support engineering for the US Navy's E-2C Hawkeye, Airborne Early Warning Command and Control aircraft which contains nearly 40 miles of high density wiring in a relatively small airframe. Also supported is the C-2A Greyhound Carrier On-Board Delivery (COD) aircraft.

The E-2C contains power systems which operate under high potential in-rush inductive current of up to 325 amps. Wiring system configurations in the E-2C fleet range between Poly-X, Polyimide and Crosslinked-Tefzel wiring. Presently new production aircraft, repairs and modifications have transitioned to all Crosslinked-Tefzel. The Navy fleet of C-2A aircraft currently contains an all Polyimide wiring system configuration.

NADEP North Island has implemented a Wiring Reliability Centered Maintenance, or RCM, program that addresses wiring as a system. RCM is a life cycle process for establishing and adjusting preventive maintenance requirements for aircraft wiring systems. It ensures that preventive maintenance requirements are based upon a platform's wiring system failure characteristics and allow it to realize its inherent reliability. Only applicable and effective tasks are used to prevent failures. If an appropriate task does not exist, preventive maintenance is not performed. The equipment or condition will be redesigned to eliminate the failure mode if the failure is of a safety consequence. As the equipment experiences changes such as mission, modifications, etc., RCM will adjust all of its preventive maintenance requirements.

RCM methods develop standardized inspection and reporting techniques, document accurately and systematically, provide continuous training and awareness, establish and maintain open communication between all levels of personnel, and continually refine processes. Wiring system RCM has drastically reduced man-hours, inspections and mishaps.

Mr. Johnson reviewed the C-2A wiring RCM process (the E-2C RCM process is currently being developed) and the C-2A Hazard Risk Matrix Logic. The Risk Matrix Logic was generated to assist the E2C2 Fleet Support Team in prioritizing work efforts and was modeled after ones set forth in MIL-STD-882C. It will be used to assign priorities for all maintenance efforts. Hazards that fall into the acceptable category will be worked according to their numerical risking order.

Other initiatives at NADEP North Island include the implementation of new Work Unit Code and Malfunction Code structures devoted to geographically documenting wiring discrepancies in the aircraft, providing more accurate and complete reporting. Training and awareness have also undergone significant improvements. Classes have been developed which provide a basic overview of E-2C/C-2A wiring systems awareness for all personnel, both maintenance and aircrew, and include a live flashover demonstration. Wiring systems training emphasizes that everyone within the community is responsible for recognizing wiring problems and taking proactive measures to correct them. Students receive training in the ability to recognize wire types and wiring problems in aircraft relative to wiring system configuration.

Even Supply personnel receive training in the ability to identify wire types which provides an additional screening process. This action aids in ensuring undesirable wire types are not mistakenly installed in an aircraft during modifications or repairs.

Another benefit of the training is improved accuracy in the reporting of wiring related discrepancies. Mr. Johnson closed his presentation by emphasizing aircraft wiring is a system unto itself, which deserves the same respect and attention given to any other aircraft system.

Mr. Pall Arnason, NAVAIR, presented a "Wire System Safety Interagency Working Group" brief on behalf of Mr. Robert Swaim, NTSB, who was unable to attend. The Gore

Commission, which was established in February 1997 following the TWA800 accident, addressed a number of issues including aging wiring in aircraft. Following NTSB findings and the Gore Commission recommendation to the FAA, aging wire programs were initiated by the FAA, NASA, and DoD.

Electrical problems also occurred in subways and power delivery systems. Deciding that the wiring related problems should be investigated further, the Office of Science and Technology Policy (OSTP, established to serve as a source of scientific and technological analysis and judgment for the President with respect to major policies, plans, and programs of the Federal Government), initiated the National Science and Technology Council Interagency Wiring Group and formed the Wire System Safety Interagency Working Group (WSSIWG). The WSSIWG includes representatives from a spectrum of federal agencies.

The mission of WSSIWG was to:

- Determine whether a hazard exists.
- Define processes for federal agencies to collaborate on S&T initiatives in wire system safety.
- Provide mechanisms for federal agencies to collaborate with industry, national laboratories, and academia.
- Provide strategic direction for federal investment in wire system safety.
- Accelerate development of advanced technology in wire system safety.
- Ensure that the results of federal S&T initiatives are communicated in a timely way to facilitate their rapid implementation with the goal of improving public health and safety.

The IWG developed a report that was presented to the President in November 2000, and can be found at <http://scitech.dot.gov/polplan/wirerpt/index.html> and http://ostp.gov/html/wire_rpt.pdf.

The report was organized to address whether or not a problem exists with electrical wiring. In the report it was stated that home wire systems caused over 40,000 fires in 1997, which resulted in 250 deaths and over \$670M of property damage. It also included a breakdown summary of electrical components that have contributed to USAF aircraft mishaps. Potential wire safety issues were identified, including environmental stress (chafing, embrittlement, and corrosion), improper installation, mishandling of wiring during maintenance, and accumulated damage as wire ages.

Current practices with regards to wiring include:

- Conformance with existing regulations, codes, and standards and revisions to them.
- Training of inspectors and mechanics.
- Inspection, assessment, and maintenance of wire.
- Engineering improvements.
- Safety investigations.
- Analysis of wire system data.
- Exchange of technical information.

The report identified current S&T initiatives to address wiring concerns:

- Diagnostics: Non-destructive evaluation (NDE) techniques, inspection and detection technologies, and monitoring sensors for identifying wire system defects.
- Failure Mechanisms: Identification of causes and modeling of wire system failures, as well as analysis of maintenance data.
- Interconnection Technologies: Improvements in development include components (such as circuit breakers); systemic issues (such as training and management tools); and advanced distribution approaches with existing materials (such as modular wiring, fiber optics, and wireless technologies).
- New Materials: New conductors, new insulation, and new approaches, such as application of microelectronic machine technology.

Common findings delineated in the report include:

- Faulty wiring poses a risk to public health and safety; it may lead to failure of essential functions, smoke, or lead to fire.
- Managing aging wire systems is expensive and time-consuming.
- Inspection, testing, and maintenance of wire systems are technical challenges on a national level.
- Most diagnostic procedures can detect only “hard failures” that result in serious deterioration of electrical integrity.
- Knowledge about how wire systems age and how they fail is limited.
- There are limitations to electrical codes and standards.
- Wire systems are becoming more complex with increasing computerization of operations and of information about those operations.
- Wire system maintenance is expensive and proactive actions to prevent failures are not common.
- Current practices flow from—and are limited by—the current state-of-the-art of wire systems technology in terms of design, installation, diagnosis and maintenance.

The conclusion stated in the report is that wire system safety is a national public health and safety issue that transcends government agencies. The recommendations included four basic strategies to improve wire system safety:

- Alter the perception of wire systems.
- Increase collaboration between industry, academia, and the government.
- Improve the management and functionality of wire systems.
- Improve wire system technology.

Currently ongoing are ideas for the National Wire System Safety Strategy (how the report will be implemented) and the development of a communications and coordination plan between federal agencies and government – industry – academia.

Mr. Arnason also presented a brief on the Naval Air Systems Command’s “Aircraft Wiring Code System” discussing how the Navy deals with its wiring code system. The Navy has three levels of maintenance for aircraft: Organizational, or “O” level, which is on-aircraft maintenance; Intermediate, or “I” level, which is off-aircraft maintenance and occasionally on-

aircraft maintenance when required; and Depot, or “D” level, which is industrial based “heavy” maintenance and overhaul. All three levels of maintenance are governed by one document, the Naval Aviation Maintenance Program (NAMP), which is a 4790.2 series Navy Instruction.

The NAMP establishes a central maintenance data system to record equipment/material/system related data from which many combinations of reports can be generated pertaining to equipment maintenance and reliability/capability, as well as related costs and logistics information. The maintenance data system requires the establishment of codes for the recording of data on maintenance action forms. The Work Unit Code (WUC), assigned and controlled by the Naval Air Technical Data and Engineering Service Command (NATEC) under the direction of the Commander, Naval Air Systems Command, is a one, three, five or seven character numeric or alpha/numeric code that identifies a system, subsystem, set, major component, repairable subassembly, or part of an end item. There are three categories: (1) aircraft, missiles, and drones; (2) aircraft trainers; and (3) aeronautical support equipment. Each aircraft type has an independent WUC manual, and each WUC identifies the system in the first two positions and subsystem elements in the third, fourth, fifth, etc. For example, 42XXXXX identifies electrical systems, 428XXXX identifies aircraft wiring, and 428W0 identifies warning and emergency wiring (C-9) and 428W1 identifies fire detection wiring (C-9).

Multiple codes are employed for recording maintenance transactions data. The cumulative data set describes each maintenance transaction in detail. These codes include the Work Unit Code, Malfunction Description Code, When Discovered Code, Action Taken Code, Type Maintenance Code, Transaction Code, and Type Equipment Code. All codes and data are entered in specified fields on the Visual Information System/Maintenance Action Form (VIDS/MAF) including data entry before, during and after maintenance actions. The Navy has transitioned to an electronic format for VIDS/MAF known as NALCOMIS, which permits maintenance activities to track VIDS/MAF information from cradle-to-grave and communicate with supply activities electronically. NALCOMIS data are backed up on tapes, which are forwarded to Mechanicsburg, PA, for entry into the Navy’s central logistics database known as NALDA. Before NALCOMIS everything was done manually, there were multiple copies of forms to track, maintenance data were unavailable to NALDA for six months, and human error was a major factor. After NALCOMIS was implemented, a more user friendly electronic format was used, there were no more paper copies to track, data became available to NALDA within days of receiving data tapes, and human error was reduced.

Multiple reports can be generated through NALDA to provide analysis information for virtually all aspects of maintenance. NALDA data are used to identify the top ten readiness degraders for Naval aviation. Also, the Navy Safety Center tracks hazardous material reports by Work Unit Code. The wiring codes lessons learned by the Navy include commonality in reporting does not extend beyond the 428XXX and sometimes 42XXXX codes. There are few safeguards to prevent the entry of the wrong code. The use of miscellaneous Work Unit Codes is far too frequent when proper codes are difficult to locate. There is lack of consistency in the number of wire codes relative to the number of systems; e.g., the C-2A aircraft has significantly more wire codes for wiring than the E-2C aircraft, but significantly less systems and wiring. Training is always an issue; garbage in = garbage out.

The need for change is clear. The Naval Air Systems Command does not know faulty wiring component failure rates, the actual costs to support wiring systems, costs related to lost/reduced missions, or the adequacy of fleet training and tools. However, it is known that wiring systems are consistently in the top five mission degraders. The problems with current

reporting methods include Work Unit Codes identify subsystem wiring but give no indication of zone or area of failure, generic or “not otherwise covered” codes are used too often, and Malfunction Codes do not provide adequate information to determine actual failures occurring.

The Naval Air System Command is changing its approach towards documenting malfunctions. Malfunction Codes will be sought first, and Work Unit Codes will be changed to a zonal system across the fleet and separate criteria for wiring within the Work Unit Code guide will be created. The Malfunction Code changes, which have been agreed to by members of the Naval Aerospace Vehicle Wiring Action Group (NAVWAG), will allow specific issues to be identified, unnecessary codes to be deleted and others clarified, and codes to be broken out by Conditional Group (no failure) and Functional Failure Group. The Work Unit Code changes, also agreed to by NAVWAG members, allow for the sharing of ideas with other agencies, identify wiring by location using common fleet terminology, quickly highlight troublesome areas of the aircraft, and treat wiring as a system. The challenges to implementing these changes include advertising, training, addressing changes in Work Unit Code management, and tying failures back to the original problem.

Mr. Arnason was followed by Mr. Massoud Sadeghi, FAA, who presented an overview of the FAA’s “Enhanced Airworthiness Program for Airplane Systems” (EAPAS), which was implemented to enhance the existing airworthiness programs in place at every transport manufacturer, operator and repair facility. An implementation plan has been developed that includes results and recommendations from reviews and studies that have been performed regarding aging related issues, inspections, tests, etc.

Areas for possible improvements include:

- Training
 - Wiring Practice Interactive Training for FAA engineers, inspectors, designees and others
 - New training requirements for Operational Specifications
 - Rulemakings
- Maintenance
 - New maintenance requirements for Operational Specifications
 - New inspection requirements
 - Rulemakings
- Design
 - Correction by AD, if necessary
 - New policies for approving wire installation drawings
 - Development of standards for enhanced circuit breakers
 - Rulemakings
- Research and Development
 - Wire separation/segregation investigation
 - Development of non-destructive wire inspection tools
 - Development of enhanced circuit breakers (arc fault circuit breakers, etc.)
- Wire Reporting
 - Guidance for completing wiring problem reports
 - Development of tools for trend analysis
- Information Sharing

- Information sharing among industry and other regulatory agencies
- Promote voluntary step-up
- Workshops

The EAPAS implementation plan includes both near and longer-term actions. Near-term actions include enhancements that can be made to existing airworthiness programs by the end of this year (2001). Longer-term enhancements, for example required rulemakings, are planned to be accomplished by mid-2004.

On day two, Mr. Jim Shaw, Manager of the In-flight Fire Project for the International Air Line Pilots Association, provided an overview of this project, which was initiated in response to several in-flight fire incidents in recent years including Swissair 111, Valuejet 592, and FedEx 1406. The goal of the project is to reduce the risk of having an in-flight fire and increase the odds that passengers and crew can survive an in-flight fire if it occurs. This is a huge and complex project that encompasses operations, design and certification, and fire detection and suppression.

Recent accomplishments include an industry negotiated consensus submitted to the FAA regarding a tripped circuit breaker reset policy, which after some rewording was released by the FAA as FSAW 00-08, FSAT 00-07, and FSGA 00-04. (Mr. Shaw commented that he knows of no circuit breaker that he would have to reset in-flight because of system redundancies that exist in today's transport aircraft.) The project is also aiding arc fault circuit breaker development efforts. Other accomplishments include an SAE paper analyzing Service Difficulty Reports (SDRs) for in-flight fire and smoke events, participation in forums such as the Aging Transport Systems Rulemaking Advisory Committee (ATSRAC) and AWIGG, and crew vision enhancement initiatives. Participants in the project include the FAA, JAA, IFALPA, Boeing and Airbus, with several other organizations, such as ATA, IATA and AECMA, maintaining communications and liaison with the project. Participants discuss individual positions on relevant topics, and foster the understanding of others concerns and issues. There are some significant changes in work regarding the de-powering of non-essential systems and addressing design issues.

The project group extracted smoke and fire event related data from the FAA SDR database for the period 1 January 1999 to 2 November 1999, which yielded 1,089 records for the approximate ten-month period. Following analysis and review of the data, the group assessed that the FAA incident database under reports significant events, there is more than one unscheduled landing per day due to smoke or fire, there are an average of three smoke events per day, 82% of high temperature events were related to aircraft electrical systems (11% wiring), crews had limited ability to recognize, control or have access to the malfunction area, and resetting tripped circuit breakers can be extremely hazardous. The general conclusions were that there is a significant number of smoke and fire events occurring in-flight, and efforts must be undertaken to reduce the risk of an in-flight fire occurring and to mitigate those risks if a fire does occur.

Following a synopsis of some recent smoke and/or fire events (ATF Flight 913 DC-9 and Continental Flight 1579 MD80 electrical fires), Mr. Shaw stated that there have been many existing problems identified and possible solutions developed. Industry concerns were taken into account, but were not a litmus test for the validity of the group's perception of what corrective action is needed. Numerous issues are being, or have already been, worked on by industry

working groups. The more viable solutions promulgated by the In-Flight Fire Project group can be grouped into the areas of operations, design and certification, fire detection and suppression, and miscellaneous.

Within the area of operations, a universal checklist should be prescribed for crews to follow immediately in the event of a smoke and/or fire event – 1) Don protective devices, 2) Establish communications, 3) Begin divert, followed by an all inclusive single checklist including all steps through evacuation/ditching. The checklist needs to be the proper font and color, easy to locate, and kept as simple as possible. Also, consideration should be given to de-powering non-essential electrical systems. Mr. Shaw stated that during a smoke and/or fire event a flight attendant should be the primary fire fighter, even in the cockpit, due to the cockpit crew's workload. The cockpit door should remain closed. He added that due to the need for effective communications, an inoperative interphone should be a no-go item. The flight crew's oxygen supply should be commensurate with the theater of operations, and they should have full-face single piece smoke masks (new performance standard from SAE-A10 forthcoming within the year), an alarm device for quantity depletion, and a hot mike automatically when donning masks. In addition, vision enhancement systems for smoke-filled cockpits, improved crew training for smoke and/or fire events, and a "no reset" policy for tripped circuit breakers (only reset if necessary for the safe completion of the flight per Captain's discretion) are needed.

In the area of design and certification, the group identified the need to separate the power supplies for the Captain's and First Officer's instrumentation. To reduce the risk of loss of multiple essential electrical systems, increased compliance with FAR Sec. 25.1353 (Electrical equipment and installations) is needed. The flight crew must be able to easily switch off electrical power to non-essential systems, such as galleys and IFE systems, from the cockpit. Future aircraft design should incorporate a "de-powered" mode for non-essential equipment in which only critical equipment will be powered. Arc fault circuit breakers are needed for all circuits capable of starting a fire; Mr. Shaw added that they must be dual trip capable. A checklist for ensuring compliance with ALPA recommendations during the certification process is needed, as well as more stringent oversight of the STC regulatory process.

Aircraft need 100% fire and smoke detection and suppression protection. Systems must be reliable and crews need the ability to monitor the progress of the event. Cargo depressurization and hazardous material issues also need to be addressed. Mr. Shaw stated that reporting of smoke events in the US should be mandatory, and that the feasibility of providing personal breathing equipment for passengers should be explored.

Mr. Shaw said that the In-flight Fire Project team will be working with industry in the future to improve communications, improve understanding of all sides to an issue, achieve faster results, and achieve a well-rounded product that everyone can live with. He emphasized that industry cooperation is critical to the successful implementation of the team's recommended solutions. ALPA's goal is to reduce the risk of having an in-flight fire and increase the odds that passengers and crew can survive such an event if it occurs.

Mr. Bill Larsen, FAA/NASA Technical Field Office, gave a presentation on "Susceptibility of Polymer Based Insulation to Water Sorption May Affect Electronic Circuit Stability." Mr. Larsen stated that there is not a common set by application of performance specifications for wiring that is being installed in aircraft. To date there seems to have been little success at assessing overall systems performance; instead individual component issues are addressed. A significant amount of testing is done when aircraft are built, but when highly

complex integrated systems are developed some of the needed tests that represent operational conditions on aircraft are not being conducted. This leaves the field repairman without intimate knowledge of the system to solve the problem by trial and error. As a result, problems must later be unnecessarily dealt with in the field due to systems not being properly built to address fielded/operational conditions.

An example is the case of a false warning from a TCAS system that occurred when coax cables became wet. One coax cable of a set of four between the antenna and LRU may have experienced electrical instability (transmission line unbalance) from water intrusion at the antenna connector. This allowed moisture wicking between the center conductor and insulating polymer, resulting in the loss of display blanking and the appearance of “ghost aircraft” on the display. Such events justify that components be checked out in the laboratory under both wet and dry conditions and attempts made in methods of keeping polymer insulations dry. Another concern is high-speed digital communications in the field where cables get wet, which changes their electrical properties. For example, in one test sample the conductivity of wet Polyethylene was found to be six orders of magnitude higher than dry Polyethylene. At the same time the permittivity (dielectric constant or capacitance; for a dielectric material it is that property which determines the electrostatic energy stored per unit volume for unit potential gradient) increased only a few times. These parameters play in the stability calculations for the cabling and must be considered for reliable systems performance. Mr. Larsen stressed the need to look at the performance of cables to better address these types of problems. Inexpensive cables or poor sealing between connector and cabling will create problems later in the field and are a poor investment.

Wires are used for electrical power, signal flow, control system and transmission line (coax) applications in aircraft. If some polymer insulations get wet, problems can arise almost immediately. There are no good measures commonly in use today for the electrical parameters of polymer wire insulation. Increased emphasis in this area is needed. Polymers have an affinity for hydrolysis. If related problems are to be successfully addressed, and maintainers are to be assisted with wire repairs, a better understanding needs to be developed of the insulation characteristics at the repairman level. There is also a need to better understand the performance of electrical and electronic equipment at the systems level and during field conditions. Mr. Larsen expressed a strong interest in conducting laboratory tests of cabling to assess their stability of performance when they become wet vs. dry performance measures as relating to standard measures used for transmission line performance measures.

Mr. John Brooks, International Aero Inc., and Mr. Gary Scott, Schneider Electric, presented an overview of their firms’ combined efforts at developing an arc fault circuit breaker (AFCB) for aircraft applications. Their focus has been in two areas – determining when and where an arc occurs, and how to tell the operator/maintainer where and when. Also, Mr. Brooks and Mr. Glenn Lacey, Phoenix Aviation and Technology, presented a brief on the use of the ARCMAS system (Time Domain Reflectometry (TDR) based technology) for a hidden fire detection system that would identify the exact location of a fire within the airframe and monitor its progression.

International Aero Inc. addresses aircraft operators’ problems in such a way as to reduce costs. Current initiatives include thermal acoustic insulation blankets, AFCBs, hidden area fire detection, fire proofing of aircraft cabin interiors, low pressure dual fluid cabin water mist fire suppression, solid propellant aerosol generator (Pyrogen) fire suppression, Halon replacement

extinguishing agents, and a non-fluorine replacement AFFF foam. Mr. Brooks said that since the last AWIGG meeting in September 2000, there have been six fires onboard commercial aircraft, and presented a brief review of each.

Mr. Gary Scott then briefed the forum on recent AFCB development efforts. The AFCB is designed to mitigate a series arc with bifurcated wire. In July 1998, the Square D Company (now Schneider Electric) released the first residential arc detector circuit breaker. Subsequently, a representative from the FAA Technical Center saw a demonstration of the technology and requested more information. In early 1999 a residential size AFCB was built and provided to the FAA for evaluation. Two of the problems with developing an AFCB for aircraft applications are miniaturization and defining the level of arc detection required on aircraft. The new AFCB methodology demonstrated utilizes a unique <power source – breaker – electrical load> configuration that proves to be more accurate and reliable. The new AFCB works with AC and DC circuits, and both single and multi-phase circuits. It also works on varying frequencies, and has a less likelihood of false trips. Mr. Scott then demonstrated that there is no change in load when current flow varies due to a series fault, but the circuit breaker is opened providing protection. The AFCB is designed to look at two half-sized wires. For a multi-phase application a sensor is needed for each phase. Two disadvantages with this AFCB design are the requirement to add an additional wire for each retrofit and the length of wire and number of connections must be doubled for each protected circuit (the total weight, however, will not necessarily be doubled because lighter wire can be used). Advantages include faster (near instantaneous) protection than with digital methods of signature analysis, simple circuit design that minimizes failure modes, thermal protection is retained in the event the arc protection fails, with wires run in same bundles the effect of inductive loops should be minimal, protection is available for AC/DC/single/multi-phase circuits, analog parts are used, and the AFCB can prevent the formation of serious arcs.

Mr. Glenn Lacey then presented an overview of recent developmental efforts by Phoenix Aviation, International Aero, and Securaplane, for a hidden fire detection system using Phoenix Aviation's ARCMAS TDR technology. Approximately four weeks prior to the AWIGG meeting, the firms began work on a system (using prognostics and reactive impedance) that would provide information to an aircrew when an event such as a fire is starting to occur. The system design does not require manufacturers to redesign aircraft, retrofit problems are not anticipated, and the system requires only 20-30 milliamps. Securaplane, the only firm certified by the FAA for wireless applications, provided the linkage for getting the information to the crew. The system maps out impedance characteristics of wire, which varies with temperature. Although wire temperature is constantly changing in flight, if there is a rapid change in temperature, the system can not only detect it but also locate it within 1mm. Using the "map" of the wiring, the system monitors temperature rate changes to alert the crew of rapid heat buildup. Key to the system is the selection of the proper type of conductor that responds as needed. The fire detection system not only alerts the crew where the rapid heat buildup is occurring, but also changes in conditions. To conserve backup power sources, if the main electrical power source is lost, the system pulses the circuits to detect changes; if detected, the system automatically powers up and begins monitoring and analysis. Mr. Lacey expects that a single hybrid conductor will eventually be utilized for the hidden area fire detection system, called AFDAMS (Automatic Fire Detection and Monitoring System).

Mr. Dick Lukso, Securaplane General Manager, added that because of wiring issues being identified on aircraft, his firm has developed wireless smoke detection and fire suppression

systems technologies. The firm's efforts have involved approximately \$1M in software development and flight tests on each aircraft which has their system installed. There are more than 1000 airliners with the Securaplane system, using dual point sensors. Mr. Lukso added that the biggest problem encountered has been with water.

The next speaker was Mr. Tom McKinnon, with the Department of Chemical Engineering, Colorado School of Mines, who presented "Microgravity Testing of Fine Water Mist Fire Suppression." The goals of the water mist project are to understand the water mist/flame front interaction at the fundamental level, obtain fine water mist fire suppression design parameters based on sound data, and work with the fire suppression industry to design systems optimized for given applications. Recent achievements for the project include the delivery of space flight hardware to SPACEHAB at Cape Canaveral for the upcoming STS-107 mission, completion of fire tests using Mist Commercial Sponsor, EEC, 10 μm atomizer nozzles, and numerical modeling of the droplet size and concentration effects tested.

The motivation for the fine water mist project is that no effective and environmentally acceptable chemical fire suppression agent has been identified to replace bromine-based chemical fire suppression agents (the manufacture of Halon was banned at the 1995 Montreal Protocol due to its high ozone depletion potential). The oldest fire fighting technology – water – is emerging as a promising contender for many applications. Water mist is an inexpensive agent, is non-toxic and poses no environmental problems, suppresses a wide variety of fires (solids, flammable liquid pool, spray fires), utilizes water quantities a tenth or lower as compared to sprinklers, may be electrically non-conductive, and provides total flooding capability making it a possible replacement for Halon 1301.

Mr. McKinnon stated that marine applications are the most advanced earth-based applications for fine water mist, citing International Maritime Organization regulations and work conducted by the Naval Research Laboratory. The FAA has an extensive testing program to improve crash survivability (increased escape time) and protection of cargo compartments. He said that mists are more effective than sprays for pool fires, with less water reaching the pool and more attacking the flame. He also commented that it is effective on electrical components in telecommunications racks.

The Colorado School of Mines is a member of the Center for Commercial Applications of Combustion in Space (CCACS), which is evaluating space-based applications for fine water mist for spacecraft fire suppression systems. On a per unit-mass-basis, water is as effective as Halon 1301 and more effective than carbon dioxide for surface and deep-seated fires. More of the water mist agent could be delivered per unit volume of extinguisher as compared to current International Space Station designs. In addition, fine water mist is non-toxic and readily available on spacecraft, agent cleanup may be achieved with dehumidifiers in the ventilation system, and deionized water may be used for electronic equipment. Water can suppress fires through several mechanisms including thermal (gas phase cooling through sensible and latent heats), physical (oxygen depletion by steam expansion, fuel/oxidizer dilution, wetting surfaces, reduction in radiative transfer of energy), and chemical (enhance radical recombination – gas-phase third body and liquid droplet surface).

Well characterized experiments are difficult to carry out in a normal gravity environment because gravity causes the mist cloud to settle and prevents the formation of uniform mist. Under microgravity conditions, by removing settling and flame distortion effects, fundamentals of droplet size, critical concentration, and flame/mist interaction can be more cleanly studied,

and under long periods of high-quality microgravity conditions, experiments can be carefully set up and monitored.

The objectives of the space-based project are to characterize flame front/mist interaction by mapping out the effects of droplet size distribution and concentration, and evaluating the thermal, chemical and physical effects of water mists. The research approach incorporates the propagation of a premixed laminar flame inside a tube under microgravity conditions; lean, stoichiometric, and rich propane (C₃H₈)-air mixtures; flame interaction with a quiescent, uniform gas/water mist mixture; use of flame speed and shape as a measure of fire suppression efficacy; and numerical modeling studies to determine the effects of droplet size distribution and concentration and the relative importance of thermal, physical, and chemical mechanisms.

There have been a number of ground studies completed in support of the upcoming STS-107 mission. Numerical simulations have been conducted to determine the effect of droplet size and concentration on laminar flame speed using full chemical kinetics, thermodynamic, and transport data. Combustion experiments under normal gravity conditions were completed, as well as drop tower experiments with a 1.5 second freefall. In addition, more than 200 low gravity tests were performed on NASA's KC-135 aircraft, which provided 20 seconds of reduced gravity ($\pm 0.01g$) conditions for each experiment. Results from these efforts indicate that small droplets are more effective than large droplets at fire suppression because of more rapid vaporization, a higher surface to volume ratio, and the requirement for less water. Regarding thermal effects, Mr. McKinnon stated that with 5 micron droplets, heat of vaporization is not as important as sensible heat, and dilution is not as important as heat of vaporization. During low gravity testing aboard the NASA KC-135, it was learned that the flame speed actually accelerates for undetermined reasons.

The STS-107 water mist research objectives include a total of 36 tests to assess the effects of water concentration and droplet size distribution on flame propagation, to assess the effect of water-mist addition on different premixed flame propagation modes, and to investigate the "water mist enhanced flame propagation mode." The test hardware will be configured in the SPACEHAB, a bus size package in the cargo bay, and the tests will be controlled from the ground.

In concluding, Mr. McKinnon stated that fine water mist is a promising alternative to Halon fire suppression systems for many applications. The field can be advanced by more fundamental knowledge about all aspects of fine water mist fire suppression, and tube tests and large-scale tests show definitive efficacy of mists. In addition, models show that small droplets are the most effective; however, transport and momentum are not considered in the models used. Mr. McKinnon closed by announcing a Water Mist Fire Suppression Workshop will be held at the Colorado School of Mines Campus in Golden, Colorado, and advised the forum that additional information, including registration instructions, can be found at <http://www.mines.edu/research/ccacs>.

The last guest speaker was Mr. Tim Reilly, Stonestreet One Inc., who gave a presentation on Bluetooth technology. Stonestreet One, Inc., established in 1996 in Louisville, KY, offers Bluetooth developer kits, Bluetooth protocol stacks, and Bluetooth development services. The firm has already created Bluetooth solutions for medical devices, warehouse automation, and others. Additional information can be found at www.stonestreetone.com.

Mr. Reilly presented an overview of possible benefits of Bluetooth wireless technology relative to wiring reduction in aircraft. Bluetooth is not a product, idea or company, but a

technology with open specification that supports better customer acceptance, a larger overall market, and the freedom to license products that successfully complete the Bluetooth qualification process (2.4 GHz license free band). It is a short-range wireless technology that can be used for both voice and data worldwide, and employs spread spectrum and frequency hopping methodologies. Mr. Reilly stated that Bluetooth technology is inexpensive (\$11 per unit for one million quantity procurement), reliable, resilient, and requires low power. It can potentially reduce an aircraft's weight by reducing the amount of wiring required and reduce maintenance requirements for wire testing and inspection.

Among the issues to consider are possible interference with other onboard and ground-based systems (by specification, maximum output is 100 mWatts with an approximate range of 300ft), regulatory issues (any Bluetooth device is considered an intentional radiator or transmitter), and the security of the data/information transmitted. Possible aircraft applications include equipment/system health and usage monitoring systems, wireless PA systems (onboard and outside the aircraft), onboard entertainment systems and Internet connectivity, wireless connectivity with digital fire/heat/smoke detectors/sensors, secondary cockpit voice and/or video recording, wireless internal communication systems, and real-time recording and transmission of flight related data to an external transmitter for relay to remote ground stations.

Mr. Healing closed the two-day meeting by thanking Delta Airlines for their exemplary support, and announced that the dates for the next AWIGG meeting would likely be in the late July or early August timeframe. He also reminded attendees of the 10-11 October 2001 Water Mist Fire Suppression Work Shop to be held at the Colorado School of Mines in Golden, Colorado. Following a brief review of AWIGG related accomplishments over the past year, he said that AWIGG will be focusing on new applications for technologies such as low pressure water mist, aerosol generator fire suppression systems, AFCBs, and others.

Delta Airlines' responses to the questions submitted prior to the meeting will be forwarded as an attachment at a later date.

{Please forward questions/comments to Joel Walker, Quadelta, Inc., at 703-354-0700 or jwalker@quadelta.com.}