Weather Information Communications (WINCOMM) Project: Dissemination of Weather Information for the Reduction of Aviation Weather-Related Accident Causal Factors

Michael Jarrell, NASA Glenn Research Center
Thomas Tanger, Ohio Aerospace Institute

Abstract

The Weather Information Communications (WINCOMM) Project at the NASA Glenn Research Center is an element of the Weather Accident Prevention (WxAP) Project within NASA’s Aviation Safety and Security Program (AvSSP). The goal of WxAP is to develop enabling technologies, which if implemented, will reduce weather-related accident causal factors and turbulence-related injuries by the year 2007. WxAP’s efforts include; increasing airborne meteorological sensing that improves weather forecasting accuracy, maximizing data link capacities for dissemination of cockpit weather products, and providing on-board turbulence detections and warnings. WINCOMM’s goal, as an element of WxAP, is the development of advanced communications and information technologies enabling the high quality and timely dissemination of strategic weather information between the flight deck and ground users. In addition WINCOMM is responsible for the transfer of tactical turbulence hazard information between relevant aircrafts. WINCOMM is focused on; the definition of weather information communications requirements, assessments of current communications infrastructure, the application and/or development of communications systems addressing technology shortfalls and gaps preventing use and/or implementation.

Advanced weather communication data links and networks are being developed to achieve these WINCOMM goals. Airborne atmospheric sensors and Electronic Pilot Reports (EPIREPS) of tactical turbulence hazard information require; on-board networks for the processing and display of own-ship information, air to air data links for hazard awareness from other relevant aircraft, and air to ground data links for the dissemination and formatting of weather data to the data collection centers. This is required to improve both the weather forecasts and products. Ground networks/stations must also provide ground to air data link capabilities enabling the efficient dissemination of weather products and warnings to the cockpit, increasing the situational awareness of pilots and alerting them to potential hazards during the en-route phase of flight. This must be done while not impeding other more critical traffic on the links.

The overall development challenge to WINCOMM is the diverse airborne communications platforms for General Aviation, Business Jets, and Commercial Transport/Cargo Aircraft. This challenge is not limited exclusively to physical attributes but includes considerations of policy including future direction of policies, current/planned equipage, real estate availability and weight augmentation restrictions. The specific challenges to WINCOMM are; the establishment of weather information requirements, cost reduction of the data link for aviation weather, and integration of solutions into the current/future NAS structure.

This report will discuss how WINCOMM is developing advanced communications and information technologies enabling the high quality and timely dissemination of strategic weather...
information between the flight deck and ground users, as well as the dissemination of tactical turbulence hazard information between relevant aircraft. Present data link requirements for the dissemination of weather products are being addressed through the utilization and leveraging of existing aviation data links through a multi-use and/or multiple data link solution. Innovative use or enhancement of this existing equipage, as well as influencing future use and/or design of these data links is the approach being pursued. The report summarizes the weather dissemination communications architectures for General Aviation/Regional, Commercial Transport, and International/Oceanic operation scenarios that have been selected for flight evaluation as well as the future looking advanced data link research and development being performed.

**Introduction**

Early success and stimulation of the market by WxAP and WINCOMM providing weather information to pilots have resulted in first generation systems being commercially available today. The significance of these systems in the ongoing process of weather dissemination research and development is significant and should be applauded. It must be noted that these impressive milestone accomplishments though significant are not the end goal/state. These systems are predominantly broadcast systems, broadcasting the information to the cockpit from the ground via satellite or ground stations. Due to the one way nature of these links, they fail to support dynamic pilot requests of weather products or information beyond the prearranged suite. In addition, direct transfer of sensor and/or hazard information between aircraft, air to air, is not supported by these implementations. Weather dissemination in first generation systems within the aviation community provide limited bandwidth restricting product sets to provide reasonable latencies. Currently available cockpit data links, if combined, would fail to realize the capability an average user would expect over a 56kbps ground modem. This makes providing capabilities comparable to mobile users to aviation neither light nor straightforward.

The methodical process of selecting aviation datalinks to demonstrate dissemination of weather information included the following:

- Weather Dissemination Concept of Operations
- Communications Datalink Requirements
- Selection of Candidate Architectures
- Current and Planned Equipage
- Current Use Restrictions
- Policies Affecting Future Datalinks
- Datalink Cost
- Modeling and Simulation
- Flight Validations

This report describes the aviation data link architectures selected for demonstration and/or validation for the dissemination of weather information in a combination of laboratory and relevant flight environments. The validations will demonstrate the ability of the selected data links to disseminate weather information during the en-route phase of flight from ground-based weather information providers to the flight deck (ground to air), from airborne meteorological sensors to ground users (air to ground), and weather/turbulence hazard information between relevant aircraft (air to air). Ground networking includes; routing of airborne sensed weather
data from ground stations to data collection centers, weather information from providers to
ground stations for transmission to aircraft. Information within this report includes; selected data
links, disseminated weather information, laboratory configurations and flight configurations.

WINCOMM has targeted three distinct operational architectures for the development and
validation of weather information dissemination based on aircraft class and operational airspace.
The WINCOMM organization is aligned with the four major deliverable products which are:
• National Capability for Regional/General Aviation (GA) Weather Dissemination
• National Capability for Commercial Transport Weather Dissemination
• Global Capability for Weather Dissemination
• Advanced Data Link Technology Candidates for Weather Dissemination

The role and focus of WINCOMM is on the identification and subsequent validation of any
required modifications to enable weather information dissemination over these data links. It is
not the intent or responsibility of WINCOMM to perform characterization of these existing data
links as any activity of this nature would duplicate the efforts of the data link creators and
equipment manufacturers. Modifications will not be made to the basic message structure or
physical layer of the data link, insuring that other (non-weather related) traffic remains intact and
unaffected by the inclusion of weather information.

WINCOMM is not responsible for sensor or display development or testing. However, actual or
representative sensors and displays are required to validate weather information
communications. Emulations are used to accomplish these objectives for two basic reasons.
First, actual hardware requiring modifications may be delayed in manufacturing or within other
display or sensor development projects. The second reason for emulation is to insure that a
representative data set utilizing an actual flight profile is used and sent over the data link,
especially for the laboratory environment. Finally, the adequacy or effectiveness of the weather
information communicated is not addressed by WINCOMM.

Validation in laboratory and relevant flight environment of all but advanced data link technology
candidates must occur before the project scheduled completion of September, 2005. However,
the option exists should any advanced data link technology reach an acceptable level of maturity
suitable for lab or flight validation.

Laboratory and selected flight validation/demonstration of weather dissemination technologies
are aligned with the product deliverables. Validation of data links are separated into the
following three en-route flight scenarios:
• Regional / General Aviation
• Commercial Transport
• International / Oceanic

The data link validation goals are as follows:
• Perform Successful Transmission and Reception of Weather Information
• Show that Weather Information flow does not impact “Normal” Traffic
• Demonstrate the Feasibility of an Operational Implementation
• Lay the Foundation for Future Data Link Development
The validation of data links is accomplished through partnerships between WINCOMM, FAA, industry, and academia. WINCOMM coordinates with the Aviation Weather Information (AWIN) and Turbulence Prediction and Warning Systems (TPAWS) project elements, also within the WxAP Project, to assure mutual goals and benefits are realized.

**Regional / General Aviation**

The specific goal of the Regional/GA task area is to develop a weather dissemination capability for general aviation and regional aircraft within a national network that includes:
- On-board sensor and telemetry information to ground users and between aircraft. (air-ground, air-air)
- Broadcast of graphical weather products to the cockpit. (ground-air)

The objective of the Regional/GA task area is to demonstrate a path to implementation for the following value added objectives:
- Cockpit display of own ship sensor information.
- Broadcast of data from an onboard sensor to other aircraft and ground users.
- Receive and display information from other airborne sensors.
- Receive and display ground-air Flight Information Service Broadcast (FIS-B) weather products.

The architecture selected for development of a Regional/GA weather dissemination capability uses the Universal Access Transceiver (UAT) system under development for the FAA. UAT will be utilized to satisfy requirements for ground to air broadcast of weather information, air to ground delivery of atmospheric data from airborne sensors, and air to air reporting of weather hazard information to aircraft within coverage of the transmitting aircraft.

- Weather information from an appropriate weather service provider is routed to the Ground Based Servers (GBSs) via the UAT network hub located at the FAA Tech Center in Atlantic City, New Jersey where it is then broadcast by the Ground Based Terminals (GBTs) to aircraft. Airborne sensor data is processed for display onboard the aircraft and broadcast to other aircraft within range for possible hazard alerts/warnings. The GBTs will also receive these messages, providing required formatting and routing for successful delivery to the appropriate data collection center.

**Commercial Transport**

The specific goal of the Commercial Transport task area is to develop a weather dissemination capability for commercial transport aircraft within a national network that includes:
- On-board sensed turbulence information to ground users and between aircraft. (air-ground, air-air)
- Broadcast graphical weather products to the pilot. (ground-air)

The objective of the Commercial Transport task area is to demonstrate a path to implementation for the following value added objectives:
• Dissemination of data from own ship turbulence events to other aircraft and ground users.
• Receive, process and deliver valid turbulence warnings to the cockpit from other equipped aircraft.
• Receive and display Flight Information Service Broadcast (FIS-B) ground-air weather products.

The architecture selected for development of a Commercial Transport weather dissemination capability uses the FAA Very High Frequency (VHF) Data Link Mode 3 (VDLM3) and 1090 Extended Squitter (ES) Automatic Dependent Surveillance Broadcast (ADS-B) data links. VDLM3 will be utilized to satisfy requirements for ground to air broadcast of weather information and air to ground reporting of turbulence hazards. VDLM3 will also accommodate pilot requests for specific weather information not included in the basic broadcast (ground to air weather information). The VDLM3 ground network will provide routing on the ground of turbulence data to the appropriate data collection center. 1090ES will satisfy the requirements for the air to air delivery of Electronic Pilot Reports (EPIREPS) of turbulence alerts and warnings to other aircraft within coverage.

Weather information from an appropriate weather service provider is routed to the VDLM3 Ground Stations where it is then broadcast to the aircraft for display in the cockpit. Pilot requests from the aircraft for specific weather information not included in the basic broadcast set is routed to the weather service provider and delivered to the aircraft via an augmented broadcast message.

• Airborne turbulence data is broadcast via 1090ES to all aircraft in the vicinity as limited by the radio frequency (RF) range determined by the antenna configuration and transmitted power of the sending aircraft and the antenna configuration receiver sensitivity of the other aircraft. Turbulence data is also sent to the ground via the VDLM3 air to ground data link and routed to the appropriate data collection center.

International / Oceanic

The specific goal of the International/Oceanic task area is to develop a global weather dissemination capability for commercial transport aircraft that includes:
• On-board sensed turbulence information to ground users and between aircraft. (air-ground, air-ground-air)
• Broadcast graphical weather products to the pilot. (ground-air)

The objective of the International/Oceanic task area is to demonstrate a path to implementation for the following value added objectives:
• Dissemination of data from own ship turbulence to other aircraft and ground users.
• Receive, process and deliver valid turbulence warnings to the cockpit from other equipped aircraft.
• Receive and display Flight Information Service Broadcast (FIS-B) ground-air weather products.
The architecture selected for development of an international/oceanic global weather dissemination capability is the SWIFT 64 Multiple Packet Data Service (MPDS) utilizing the Inmarsat satellite constellation. This satisfies the requirements for air to ground and ground to air dissemination of weather information and reporting of turbulence hazards.

Swift-64 packet mode currently provides only cabin services. These services are not available to the cockpit due to the level of certification and the best effort basis delivery of messages. Cockpit solutions to date have focused on implementations that address these issues through expensive hardware solutions providing separation or through use of circuit switched mode of operation that provides guaranteed message delivery of all messages.

Advanced Data Link Research and Development

Advanced data link research and development is being performed within the WINCOMM project element. Due to the nature of research, validation testing will depend on the technology progress achieved. Advanced data links are included in this document for completeness and to elevate the awareness of the aviation community to these enabling technologies. Detailed information for these activities can be made available upon request and will be included in future publications and presentations.

Aviation Cellular Data Link

The objective of this effort is to leverage existing and future cellular networks and technologies for use by aviation. Existing implementations have failed to provide the required capabilities, capacity and or cost benefit possible through leveraging of the considerable investment and efforts in the development and reuse of existing public cellular networks/infrastructure. This research will develop a Proof of Concept (POC) plan for an aviation cellular capability extending the existing commercial 3G through 5G cellular networks, enabling enhanced data link capabilities and performance while minimizing recurring cost to the aviation user.

Re-configurable Antenna 800 MHz - 2.6 GHz

The objective of this effort is to design and fabricate a wideband electronically scanned reconfigurable antenna for airborne use in the 800MHz to 2.6 GHz spectrum. A key element of this program is to design and develop a Proof of Concept (POC) ASIC chip and incorporate it into a half element, whole element, and array.

In partnership with Honeywell Labs, this activity seeks to demonstrate an antenna technology that will address the issues of today’s airborne cellular market and simultaneously provide for aero capacity in tomorrow’s next generation wireless infrastructure.
Application of a VHF Radio Transceiver ASIC to VDL mode-3

The objective of this research and development is a custom designed VHF radio ASIC in a demonstration transceiver for VDL Mode-3 data communications. The transceiver ASIC to be used was developed within the current project with the intent of creating a highly integrated radio chip for low cost avionics applications.

This effort will demonstrate a highly integrated, low cost transceiver ASIC providing data communication using VDL Mode-3 in the capacity of an electronic flight bag application.

Three-dimensional Weather Information Gridding and Compression

The objective of this effort is to develop the general design, theoretical framework, and necessary models for compression algorithms. The output of this task will be an integrated compression toolkit for use in meteorological data dissemination.

SUMMARY

WINCOMM has achieved early success as evidenced by the commercial offering of first generation systems providing weather information to the cockpit. WINCOMM is on track to demonstrate a clear path to implementation for second generation weather dissemination by coexistence with other traffic via current, near term, and next generation datalink technologies. Advanced data link research and development is expected to establish a foundation for development beyond the WINCOMM project scheduled end of September 2005. Unfortunately, aviation datalink limitations will keep us from realizing any far term goal of true interactive weather decision aiding or other proposed safety enhancements that rely on ground-air, air-air, or air-ground weather information dissemination. With the possible advent of security encryption overhead and traffic loads, weather information could be displaced on the current and near term links. Weather datalink research must continue and be coupled and relevant to the entire weather community. It should also focus on overcoming the two greatest aviation datalink challenges: lowering the cost and increasing the capacity.
WINCOMM Project Overview

ICNS Conference, 2004

Mike Jarrell
WINCOMM Project Manager
NASA Glenn Research Center
Cleveland, OH
(216) 433-8102
Michael.A.Jarrell@nasa.gov

Tom Tanger
WINCOMM System Engineer / Research Lead
Ohio Aerospace Institute
Cleveland, OH
(440) 962-3129
ThomasTanger@oai.org
WINCOMM Goals

WxAP: Weather Information Communications

Aviation Safety & Security Program

Air

Weather Hazard EPIREPS

Weather Hazard EPIREPS

Tactical Information

Air

Cockpit Presentation & Decision Aids

Airborne Weather Sensor Information

Strategic Information

Air

Ground

Aviation Wx Information

Forecasters & Weather Product Developers
Data Link Decision Factors

- CONOPS
- Flight Region
- Existing Links
- Phase of Flight
- Equipage
- Aircraft Class
- Planned Links
- Wx Information
- Connectivity
- Costs
Data Link Decision Factors
Datalink Architectures
(weather information dissemination)
Datalink Validation Goals

- Perform Successful Transmission and Reception of Wx Information
- Show Wx Information flow does not impact “Normal” Traffic
- Demonstrate Feasibility of Operational Implementation
- Lay Foundation for Future Data Link Development
Product Deliverables

- National Capability for Commercial Transport Weather Dissemination
- National Capability for GA/Regional Weather Dissemination
- Global Capability for Weather Dissemination
- Advanced Data Link Technology Candidates for Weather Dissemination
WINCOMM Structure

Weather Information Communications Project (WINCOMM)

- Commercial Transport En-Route
- General Aviation / Regional En-Route
- International / Oceanic En-Route
- Advanced Datalink Development
Commercial Transport En-Route

WxAP: Weather Information Communications

Air to Air (1090ES)
Turbulence Alerts/Warnings

Ground to Air (VDLM3)
• Graphical Turbulence
• Weather Products

Air to Ground (VDLM3)
Aircraft Systems
• Sensor Data
• Aircraft Telemetry

Ground Station

VDLM3 Ground Stations & Network
Regional/General Aviation En-Route

WxAP: Weather Information Communications

Air to Air
- Atmospheric Sensor Data
- Aircraft Telemetry

Ground to Air
- Graphical Wx Products
- Textual Wx Products

Air to Ground
- Atmospheric Sensor Data
- Aircraft Telemetry

40,000 AGL

5,000 AGL

Ground Station

FAA – UAT Ground Stations & Network
**International/Oceanic En-Route**

**WxAP: Weather Information Communications**

**Air to Air**
(Air-Ground-Air Routing)
- Turbulence Alerts/Warnings

**Air to Ground**
Aircraft Systems
- Sensor Data
- Aircraft Telemetry

**Ground to Air**
Ground Systems
- Reports & Forecasts
- Alerts / Warnings

**SITA – Inmarsat Swift 64 & Network Service Provider**

**National/Commercial Weather Providers**

**AOC, Dispatch, ATC**

**Aviation Safety & Security Program**
Advanced Data Link Technologies

• **Aviation Cellular**
  – Investigation of 4G and 5G cellular systems leading to the development of a Proof-of-Concept (POC) aviation cellular system data link solution utilizing existing public infrastructure (Briefing at WxAP Annual Review – Las Vegas, NV on June 2\textsuperscript{nd}, 2004)

• **Reconfigurable Antenna (Honeywell – ESCAN)**
  – A Proof of Concept reconfigurable aero antenna spanning 800 MHz to 2.6 GHz will be developed

• **Radio on a Chip (Honeywell – ASIC)**
  – Size and cost reduction enabling compact radio designs with capability and flexibility through programmability to all VHF aviation NAV/COMM bands
Weather Information Datalinks

Where we are.

Where we need to be.
Enabling Role of Datalinks

**Datalinks: the Critical Gear in the Information Sharing Process**

- Safety
- Security
- Capacity
- Efficiency
Total System Solutions Required

Weather Information

+ 

Delivery to Key Decision Makers
  • Forecasters
  • Controllers
  • Pilots
  • Automated Control Systems

+ 

Resultant Action

________________________________________

Safety Benefit
Aviation Data Link Capacity

WxAP: Weather Information Communications

Legacy Systems
- Limited throughput
- Limited bandwidth

Planned Systems
- Limited Wx
- Shared bandwidth

Graphical Wx

Limited Use of Commercial Spectrum

Assigned FAA Spectrum

Reallocation
Aviation Data Link Cost

Equipage = Safety Improvements
Aviation Data Link Development

**WxAP: Weather Information Communications**

1st Generation (FY 00–02)
- G–A Broadcast
- Private Networks
- Weather (Wx) Only
- Limited Capacity
- High Relative Cost
- GA

- FISDL (Terrestrial)
- WSI (Satcom)
- XM (Satcom DARS)

2nd Generation (FY 03–05)
- G–A, A–G, A–A
- Private Networks
- Multi-Aviation Use
- Additional Capacity
- Increased Value
- GA & Com Transport
- EPIREPS
- A/C Wx Sensors
- Dynamic Requests

- UAT & VDLM3 (Terrestrial)
- Swift 64 (Satcom)
- 1090ES (Air-Air)

3rd Generation (FY 06–10)
- Full Mesh Networking
- Public Infrastructure
- Information Pipeline
- Broadband
- Low Relative Cost
- All Aircraft
- Crosslinks
- Data Processing
- Routing

- Aviation Cellular
- High-Value Satcom
A vision without a plan may be a hallucination.