This presentation describes final test results for the Weather Information Communications (WINCOMM) program at the NASA Glenn Research Center on flight testing of the 1090 Extended Squitter (1090ES), VDL Mode 3, and Universal Access Transceiver (UAT) data links as a medium for weather data exchange. It presents an architectural description of the use of 1090ES to meet the program objectives of sending turbulence information, the use of VDL Mode 3 to send graphical weather images, and the use of UAT for transmitting weather sensor data. This presentation provides a high level definition of the changes made to both avionics and ground-based receivers as well as the ground infrastructure used to support flight testing and future implementation. Summary of results from flight tests of these datalinks will also be presented.
Flight Test Results of VDL-3, 1090ES, and UAT Datalinks for Weather Information Communications

ICNS Briefing
May 3, 2006

James Griner
NASA John H. Glenn Research Center
(216)433-5787
jgriner@nasa.gov
Outline

Commercial Transport
- 1090ES
- VDL-3

General Aviation
- UAT
Transmission of on-board sensed turbulence information to ground users and between aircraft.

1090ES for Air-to-Air
VDL-3 Air-to-Ground

Broadcast graphical weather products to the pilot.

VDL-3
added objectives:

1090ES
Turbulence Alert Message

• The turbulence alert message consisted of the following parameters:
  1. Time
  2. Latitude
  3. Longitude
  4. Altitude
  5. Processed Normal Load
  6. Processed Aircraft Constant

• Standard ADS-B messages already contain the first four parameters, it is only necessary to broadcast two additional parameters. These two additional parameters are each eight bits long, totaling an additional 16 bits to be transmitted. The additional parameters will be formatted as a payload to a standard ADS-B message, in compliance with DO–260.
• In compliance with DO-260, with a
downlink format (DF) of 17 (standard
for ADS-B messages over 1090ES).

• Uses the test type code (23), and
BDS codes 4 & 5 (already designated
in ICAO Annex 10, Volume II, as
Meteorological Hazard Report).

• The messages are sent as
encountered turbulence exceeds one of
three thresholds, but is never
transmitted at a rate greater then once
per 60 seconds. (For testing purposes a
message is sent every 60 seconds.)
N616NA and N933NASeparation Distance (nm)
May 19, 2005 - Second Flight

Elapsed Time (h:mm:ss)

Separation Distance

0.00 25.00 50.00 75.00 100.00 125.00 150.00
1090ES Message Reception

616 to 933
msg number vs. separation distance (nm)

933 to 616
msg number vs. separation distance (nm)
<table>
<thead>
<tr>
<th>Date</th>
<th>Direction</th>
<th>Sent</th>
<th>Received</th>
<th>% Received</th>
<th>Sent</th>
<th>Received</th>
<th>% Received</th>
<th>Sent</th>
<th>Received</th>
<th>% Received</th>
</tr>
</thead>
<tbody>
<tr>
<td>May 17</td>
<td>616 to 933</td>
<td>6</td>
<td>9</td>
<td>66.7%</td>
<td>11</td>
<td>5</td>
<td>44.5%</td>
<td>15</td>
<td>6</td>
<td>27.8%</td>
</tr>
<tr>
<td>May 17</td>
<td>933 to 616</td>
<td>11</td>
<td>5</td>
<td>30.2%</td>
<td>54</td>
<td>16</td>
<td>27.6%</td>
<td>98</td>
<td>27</td>
<td>30.2%</td>
</tr>
<tr>
<td>May 19 – 1</td>
<td>616 to 933</td>
<td>54</td>
<td>16</td>
<td>26.7%</td>
<td>53</td>
<td>16</td>
<td>26.7%</td>
<td>98</td>
<td>28</td>
<td>30.2%</td>
</tr>
<tr>
<td>May 19 – 1</td>
<td>933 to 616</td>
<td>53</td>
<td>16</td>
<td>0.0%</td>
<td>98</td>
<td>27</td>
<td>30.2%</td>
<td>98</td>
<td>28</td>
<td>30.2%</td>
</tr>
<tr>
<td>May 19 – 2</td>
<td>616 to 933</td>
<td>98</td>
<td>28</td>
<td>0.0%</td>
<td>105</td>
<td>28</td>
<td>0.0%</td>
<td>105</td>
<td>26</td>
<td>15.2%</td>
</tr>
<tr>
<td>June 15</td>
<td>616 to 933</td>
<td>105</td>
<td>28</td>
<td>0.0%</td>
<td>171</td>
<td>26</td>
<td>15.2%</td>
<td>171</td>
<td>501</td>
<td>24.6% (average)</td>
</tr>
</tbody>
</table>

**TOTAL**

<table>
<thead>
<tr>
<th>Message Rate</th>
<th>60sec</th>
<th>30sec</th>
<th>20sec</th>
</tr>
</thead>
<tbody>
<tr>
<td>May 17</td>
<td>6</td>
<td>11</td>
<td>15</td>
</tr>
<tr>
<td>May 19 – 1</td>
<td>54</td>
<td>53</td>
<td>98</td>
</tr>
<tr>
<td>May 19 – 2</td>
<td>105</td>
<td>98</td>
<td>105</td>
</tr>
<tr>
<td>June 15</td>
<td>171</td>
<td>171</td>
<td>171</td>
</tr>
<tr>
<td>TOTAL</td>
<td>501</td>
<td>501</td>
<td>501</td>
</tr>
</tbody>
</table>
Bi-Directional Air-Ground link

VDL - 3
• Reliable Air-ground turbulence messages
• Reliable Air-ground message for requesting additional graphical weather products
• Broadcast Ground-Air FIS-B weather products
• The turbulence message consisted of the following parameters:
  1. Time
  2. Latitude
  3. Longitude
  4. Altitude
  5. Aircraft Weight
  6. Airspeed
  7. Mach Number
  8. Processed Normal Load
  9. Processed Aircraft Constant

• Additional parameters are required beyond those in the turbulence alert message, to allow ground processing of the downlinked messages to be assimilated into weather prediction models and a future national turbulence weather product.
• In order to allow pilots to request graphical weather products which may not be part of the standard weather product set, a request message will be transmitted to schedule the uplink of the desired product. This requested product will be transmitted as the channel is available.
For the purposes of the WINCOMM project, the broadcast FIS-B messages consist of the adjacent weather products. These products conform to DO-267 (FIS-B MASPS).

In addition to the standard products, the pilot requested messages will be transmitted as requested and as the channel is available.
VDL Mode 3

Weather Product in UDP Datagram

IP Fragments

DLS Frame

VDLMES Data Burst

490 bytes per second (3.92 kbps)

1. Values are based on IP MTU = 922 bytes = (54 + 14’62).
2. PID = 0x40 and IPI = 0xCC indicates an IP4 Datagram.
VDL Mode 3 Lab Testing

• Lab testing was conducted at both NASA GRC and at the FAA Technical Center. These tests were conducted in both cabled and RF environments, under varying attenuation schemes.
Five flights (11hrs total) were conducted between April 10-13, 2005, using the FAA Technical Center VDL-3 ground station.
Standard Weather Product Reception

<table>
<thead>
<tr>
<th></th>
<th>#1</th>
<th>#2</th>
<th>#3</th>
<th>#4</th>
<th>#5</th>
<th>#6</th>
<th>#7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bytes</td>
<td>4,293</td>
<td>2,977</td>
<td>2,544</td>
<td>2,220</td>
<td>2,005</td>
<td>1,527</td>
<td>889</td>
</tr>
<tr>
<td>Desc.</td>
<td>METAR</td>
<td>Term. Wx</td>
<td>SIGMETS</td>
<td>Wx CONUS</td>
<td>PIREPS</td>
<td>NEXRAD</td>
<td>NEXRAD</td>
</tr>
</tbody>
</table>
Turbulence Message Reception

<table>
<thead>
<tr>
<th></th>
<th>Flt. #2</th>
<th>Flt. #3</th>
<th>Flt. #4</th>
<th>Flt. #5</th>
</tr>
</thead>
<tbody>
<tr>
<td>TTM Sent</td>
<td>136</td>
<td>122</td>
<td>217</td>
<td>444</td>
</tr>
<tr>
<td>TTM Rec’d.</td>
<td>136</td>
<td>122</td>
<td>217</td>
<td>444</td>
</tr>
<tr>
<td>TTM Lost</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Retransmissions:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>at the TCP layer</td>
<td>5</td>
<td>6</td>
<td>20</td>
<td>34</td>
</tr>
<tr>
<td>at the DLS layer</td>
<td>55</td>
<td>32</td>
<td>49</td>
<td>93</td>
</tr>
</tbody>
</table>
Request Message Reception

<table>
<thead>
<tr>
<th>Flight</th>
<th>Flt. #2</th>
<th>Flt. #3</th>
<th>Flt. #4</th>
<th>Flt. #5</th>
</tr>
</thead>
<tbody>
<tr>
<td>REQs Sent</td>
<td>16</td>
<td>43</td>
<td>43</td>
<td>102</td>
</tr>
<tr>
<td>REQs Rec’d.</td>
<td>16</td>
<td>43</td>
<td>43</td>
<td>102</td>
</tr>
<tr>
<td>REQs Lost</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Retransmissions:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>at TCP layer</td>
<td>5</td>
<td>11</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>at DLS layer</td>
<td>4</td>
<td>20</td>
<td>8</td>
<td>30</td>
</tr>
</tbody>
</table>
Requested Weather Products

Winds/Temps, FL34, 00Z (2,211 bytes)

Winds/Temps, FL30, 00Z (2,218 bytes)

Winds/Temps, FL33, 00Z (2,177 bytes)

Turbulence, FL34, 00Z (983 bytes)

Turbulence, FL30, 00Z (1,256 bytes)

Turbulence, FL33, 00Z (1,074 bytes)

Icing, FL24, 00Z (1,021 bytes)

Icing, FL24, 00Z (983 bytes)

Icing, FL30, 00Z (723 bytes)

Icing, FL33, 00Z (723 bytes)
Requested Weather Products

NEXRAD, Northwest (401 bytes)
NEXRAD, Northcentral (508 bytes)
NEXRAD, Northeast (1,495 bytes)
NEXRAD, Southcentral (526 bytes)
NEXRAD, Southeast (592 bytes)
UAT Messages

- AIRMET
- SIGMET
- Convective SIGMET
- TFR

Additional Ground-to-Air Textual Products

- Temperature
- Wind Speed
- Wind Direction
- Turbulence
- Humidity
- Arctic
- Airspeed

Additional messages transmitted using unreserved bits with no Type 2 ADS-B message, Type 2 ADS-B (TAMDAR) data Air-to-Air & Air-to-Ground Weather Sensor.
• All equipment modifications were software based in order to allow the reception and transmission of these additional messages.

• All modifications were made within the accepted standards or in a manner consistent with the standards.

• These changes were worked closely with industry partners with a path toward certification.