

Flight Test Results of VDL-3, 1090ES, and UAT Datalinks for Weather Information Communications

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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

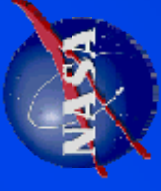
(216) 433-5787

jgriner@nasa.gov

Outline

WINCOMM
at
glennresearchcenter

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Commercial Transport

- 1090ES
- VDL-3

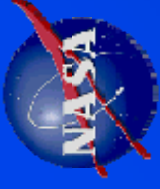
General Aviation

- UAT

Commercial Transport

WINCOMM
a weather project

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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.

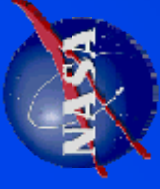
VDL-3

Air-to-Air

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at www.gcrp.nasa.gov

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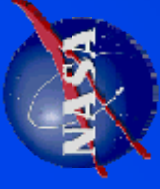


1090ES

Turbulence Alert Message

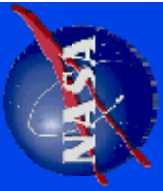
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- The turbulence alert message consisted of the following parameters:
 1. Time
 2. Latitude
 3. Longitude
 4. Altitude
 5. Processed Normal Load
 6. Processed Aircraft Constant
- Standard ADS-B messages already contain the first four parameters, it 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

Turbulence Alert Message



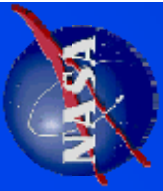
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- In compliance with DO-260, with a downlink format (DF) of 17 (standard for ADS-B messages over 1090ES).
- Uses the test type code (23), and BDS codes 4 & 5 (already designated in ICAO Annex 10, Volume II, as Meteorological Hazard Report).
- The messages are sent as encountered turbulence exceeds one of three thresholds, but is never transmitted at a rate greater than once per 60 seconds. (For testing purposes a message is sent every 60 seconds.)

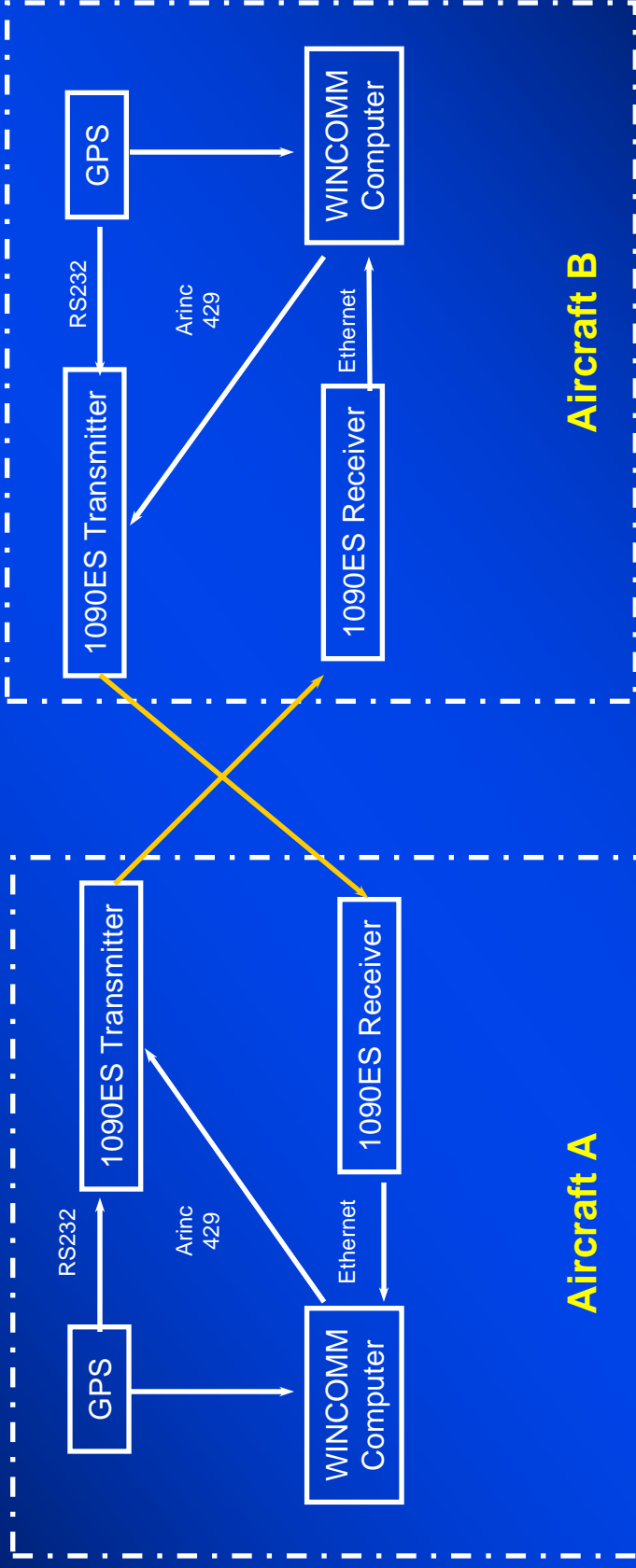
1	MSB	1
2		0
3	FORMAT TYPE CODE = 23 (TEST)	1
4		1
5	LSB	1
6		1
7	SUBTYPE CODE = 6	1
8		0
9	MSB	
10		
11	Load-Based Parameter	
12		
13	LSB	
14		
15	MSB	
16	Aircraft Constant	
17		
18	LSB	
19		
20		
21	Pad with Zeros	
22		
23		
24		

1090ES Data Flow



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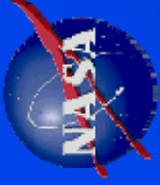
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Aircraft A

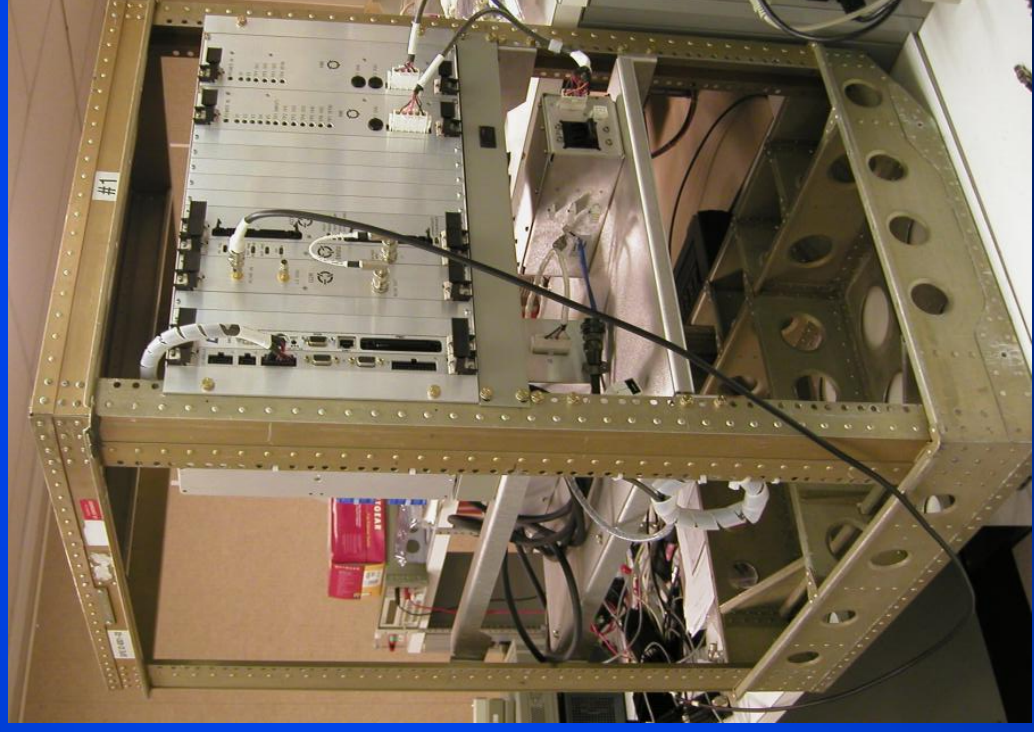
Aircraft B

1090ES Equipment



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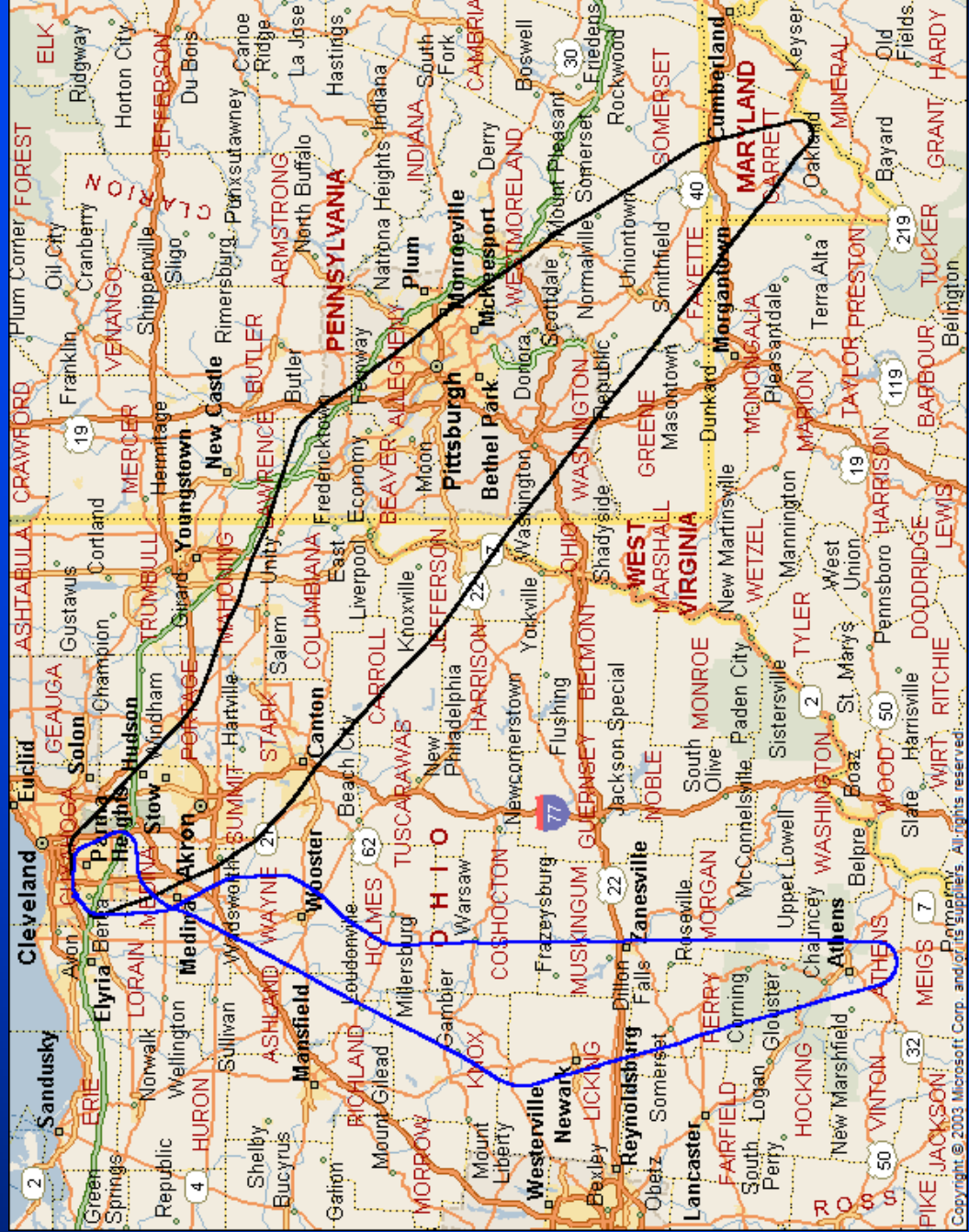
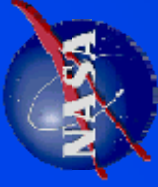
WINCOMM



1090ES Flight #3

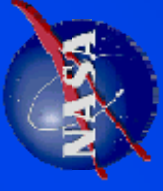
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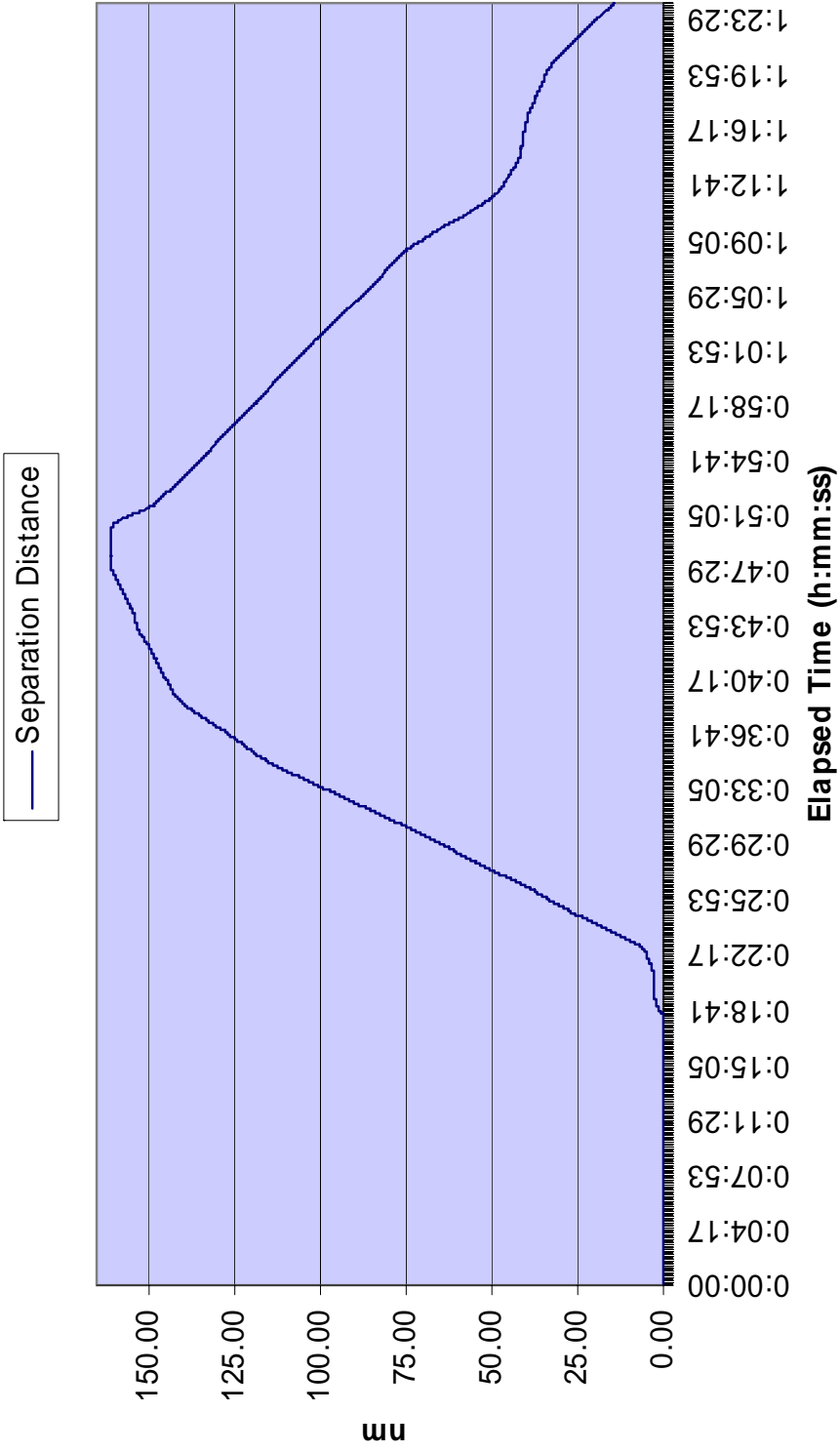
1090ES Flight #3



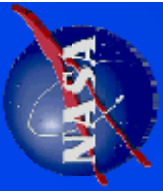
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N616NA and N933NASeparation Distance (nm)
May 19, 2005 - Second Flight

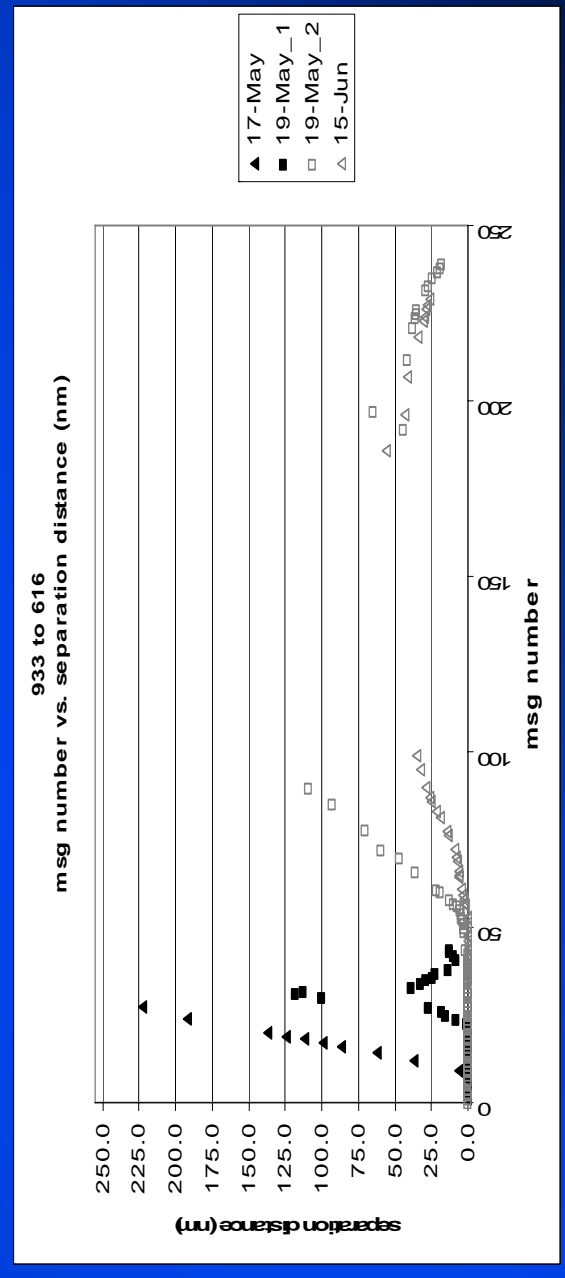
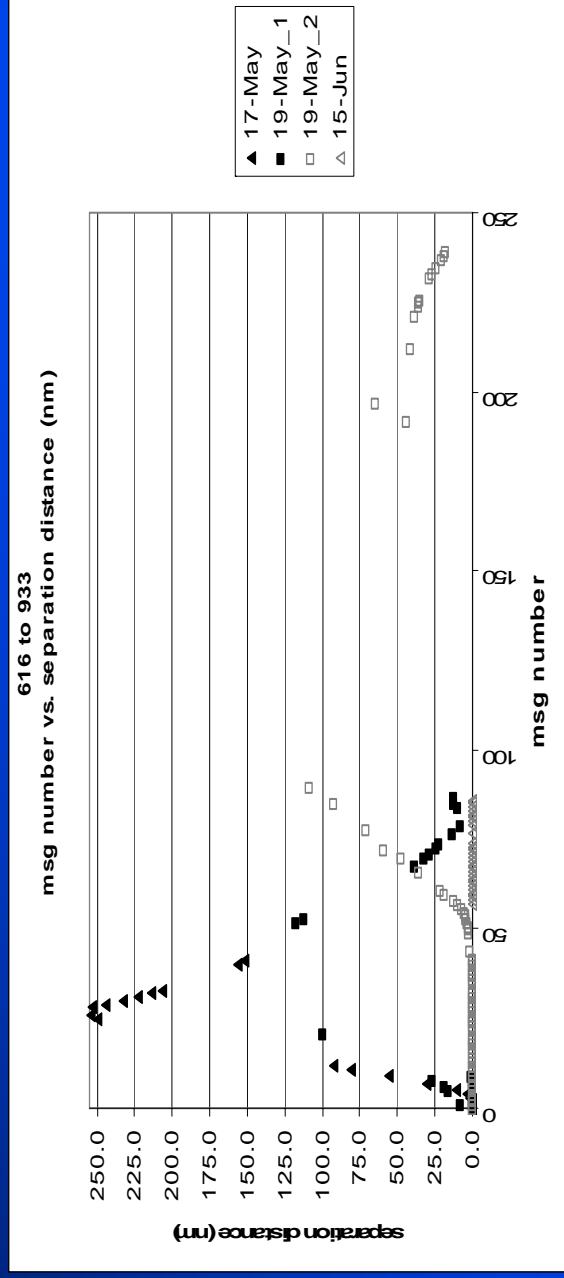


1090ES Message Reception

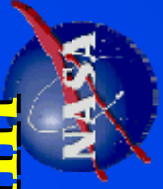


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1090ES Message Reception 3nm-100nm



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Message
Rate

60sec

30sec

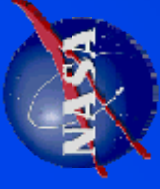
20sec

Date	Direction	Sent	Received	% Received
May 17	616 to 933	9	6	66.7%
May 17	933 to 616	11	5	44.5%
May 19 – 1	616 to 933	54	15	27.8%
May 19 – 1	933 to 616	53	16	30.2%
May 19 – 2	616 to 933	98	27	27.6%
May 19 – 2	933 to 616	105	28	26.7%
June 15	616 to 933	0	0	0.0%
June 15	933 to 616	171	26	15.2%
TOTAL		501	123	24.6% (average)

Bi-Directional Air-Ground link

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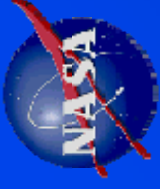


VDL - 3

VDL Mode 3 Messages

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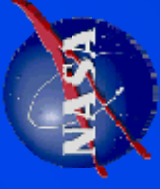


- Reliable Air-ground turbulence messages
- Reliable Air-ground message for requesting additional graphical weather products
- Broadcast Ground-Air FIS-B weather products

Air-Ground Turbulence Message

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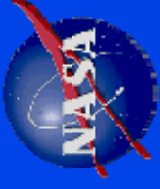


- The turbulence message consisted of the following parameters:
 1. Time
 2. Latitude
 3. Longitude
 4. Altitude
 5. Aircraft Weight
 6. Airspeed
 7. Mach Number
 8. Processed Normal Load
 9. Processed Aircraft Constant
- Additional parameters are required beyond those in the turbulence alert message, to allow ground processing of the downlinked messages to be assimilated into weather prediction models and a future national turbulence weather product.

Air-Ground Request Message

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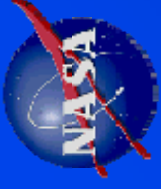
- In order to allow pilots to request graphical weather products which may not be part of the standard weather product set, a request message will be transmitted to schedule the uplink of the desired product. This requested product will be transmitted as the channel is available.

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Ground-Air Weather Products

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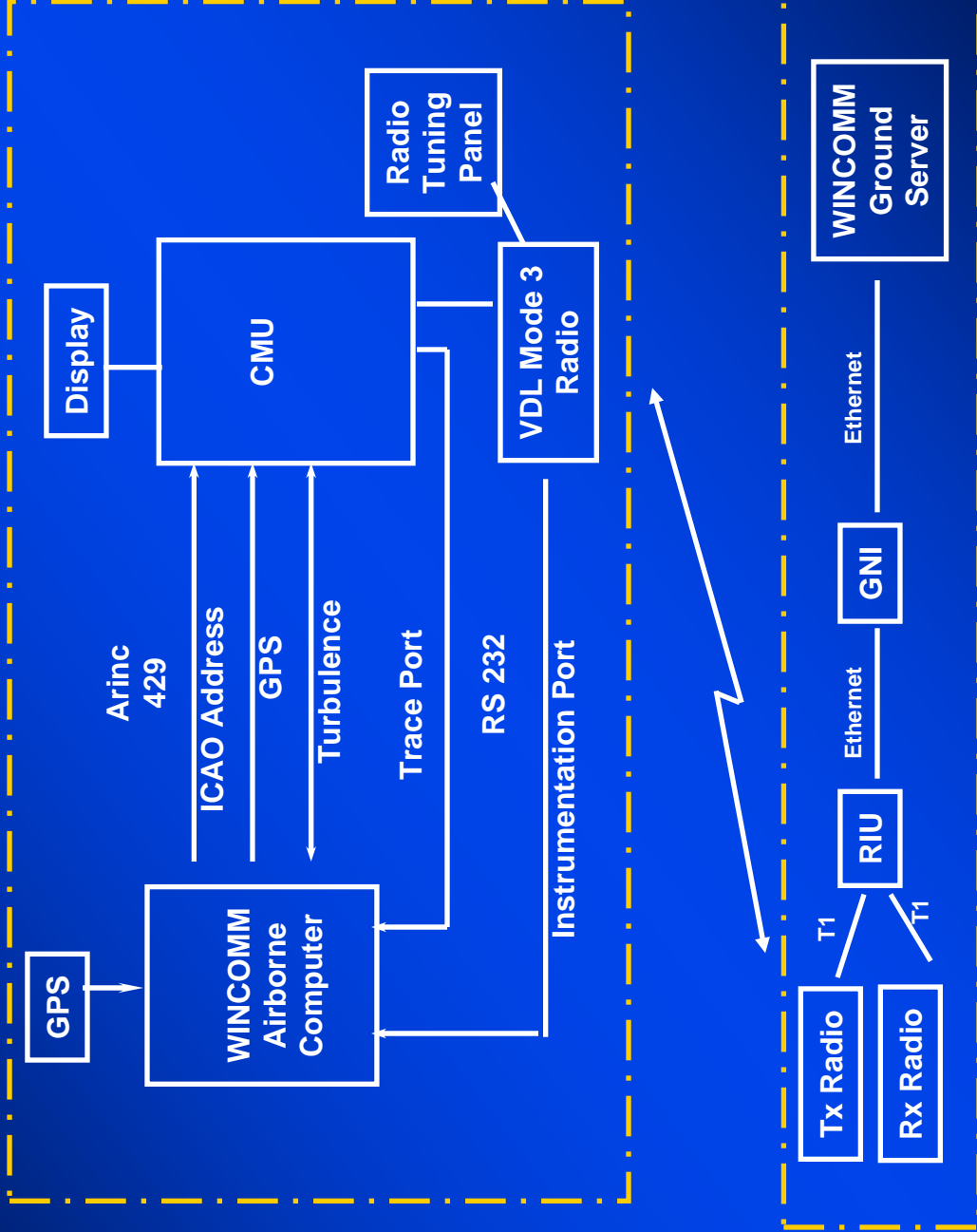
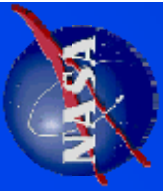
- For the purposes of the WINCOMM project, the broadcast FIS-B messages consist of the adjacent weather products. These products conform to DO-267 (FIS-B MASPS).
- In addition to the standard products, the pilot requested messages will be transmitted as requested and as the channel is available

Standard Products	Size (Bytes)
METARs, SPECIs	4,293
SIGMETs, Convective SIGMETs,	
AIRMETs, Severe Weather Forecast Alerts	2,544
TAFs	2,977
PIREPs	2,005
Graphical NexRad	899
Graphical Tops/Movement	1,527
Graphical Weather Depiction	2,220
Requested Products	Size (Bytes)
Graphical Winds/Temps, FL24	2,177
Graphical Winds/Temps, FL30	2,238
Graphical Winds/Temps, FL34	2,311
Graphical Turbulence, FL05	923
Graphical Turbulence, FL24	1,074
Graphical Turbulence, FL30	1,256
Graphical Turbulence, FL34	983
Graphical Icing, FL24	1,021
Graphical Icing, FL30	723
Graphical NexRad, Region: Northwest	401
Graphical NexRad, Region: Northcentral	508
Graphical NexRad, Region: Northeast	1,495
Graphical NexRad, Region: Southcentral	526
Graphical NexRad, Region: Southeast	592

VDL Mode 3 Data Flow

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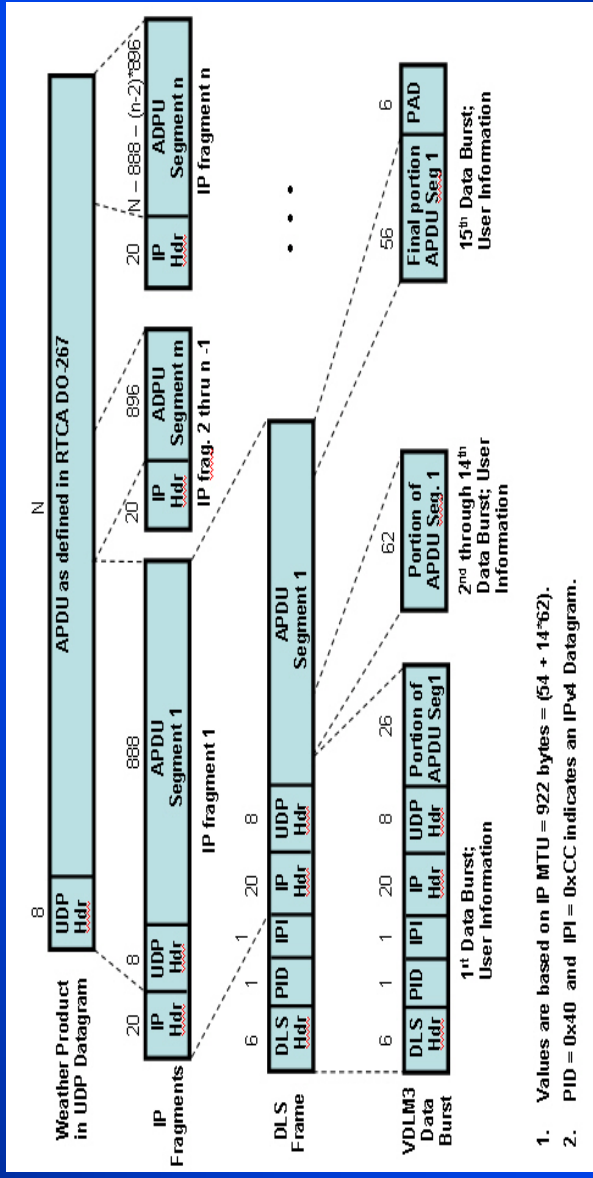
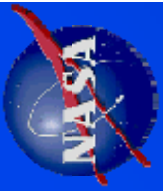
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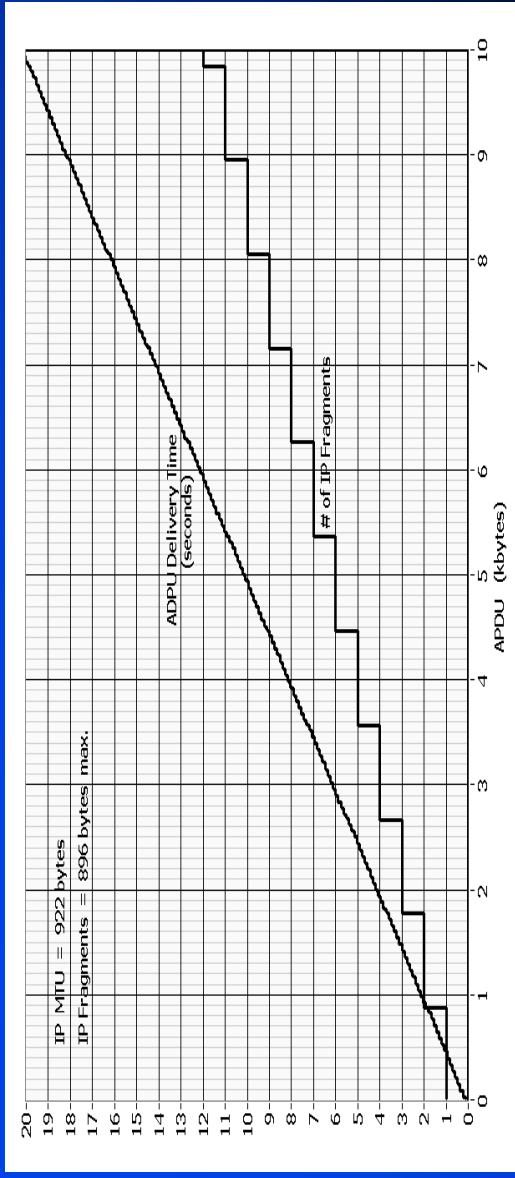
VDL Mode 3

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1. Values are based on IP MTU = 922 bytes = (54 + 14*62).
2. PID = 0x40 and IPI = 0xCC indicates an IPv4 Datagram.

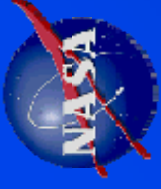


490 bytes per second
(3.92 kbps)

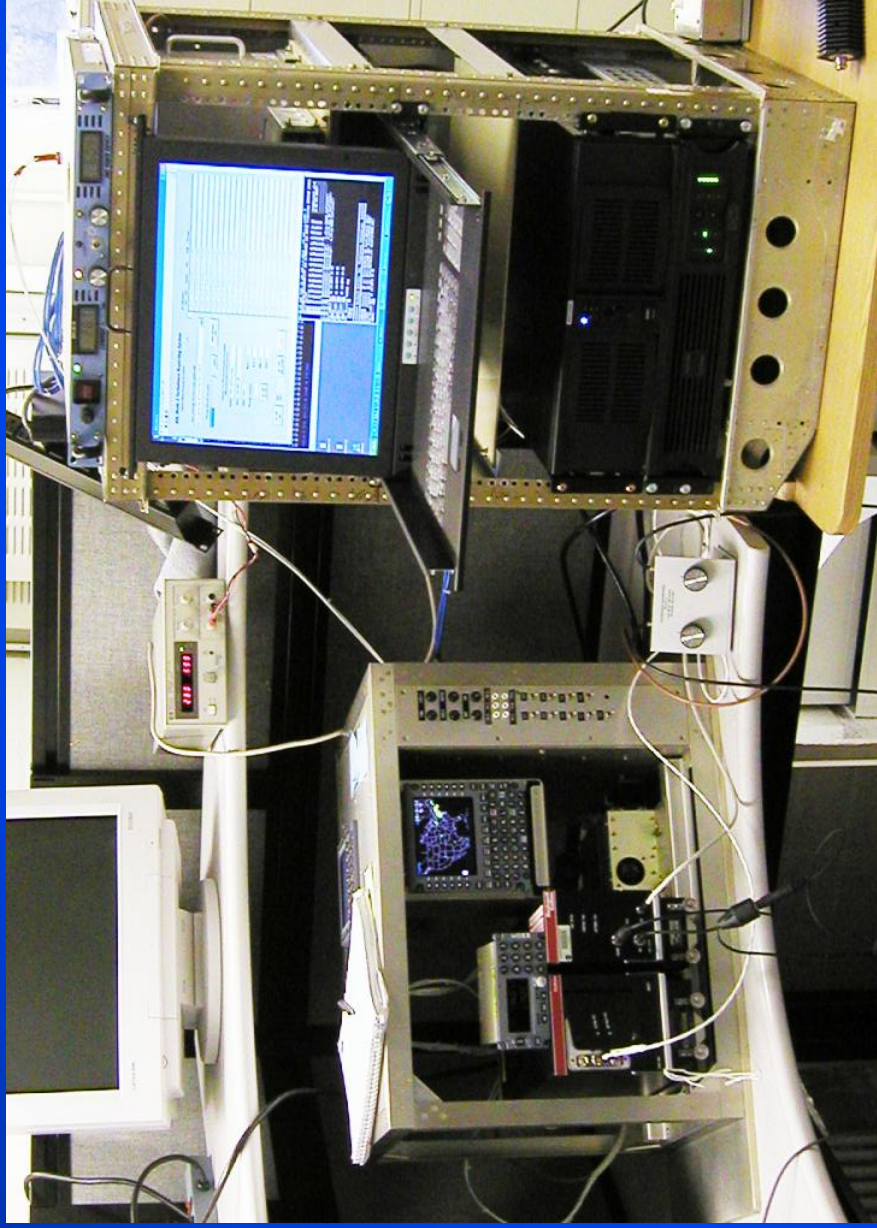
VDL Mode 3 Lab Testing

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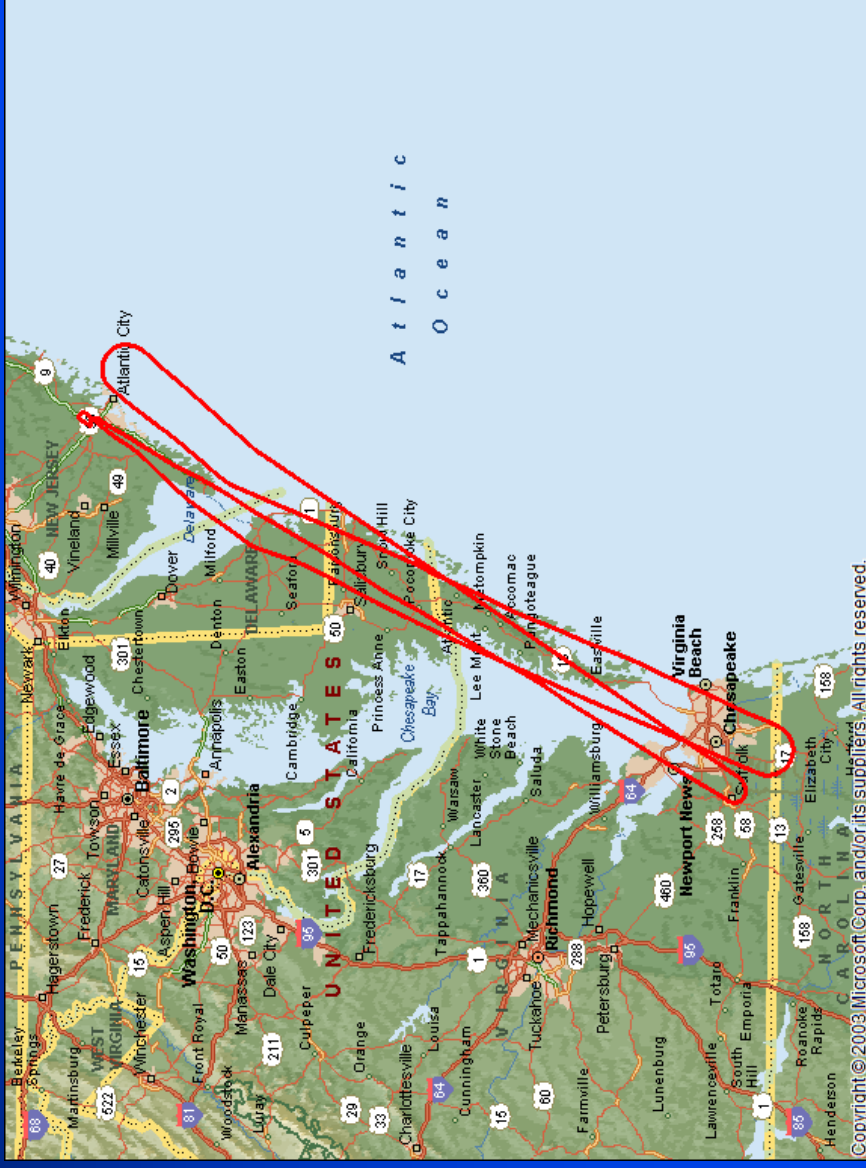
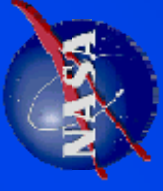
- Lab testing was conducted at both NASA GRC and at the FAA Technical Center. These tests were conducted in both cabled and RF environments, under varying attenuation schemes.



VDL Mode 3 Flight Testing

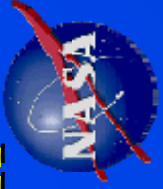
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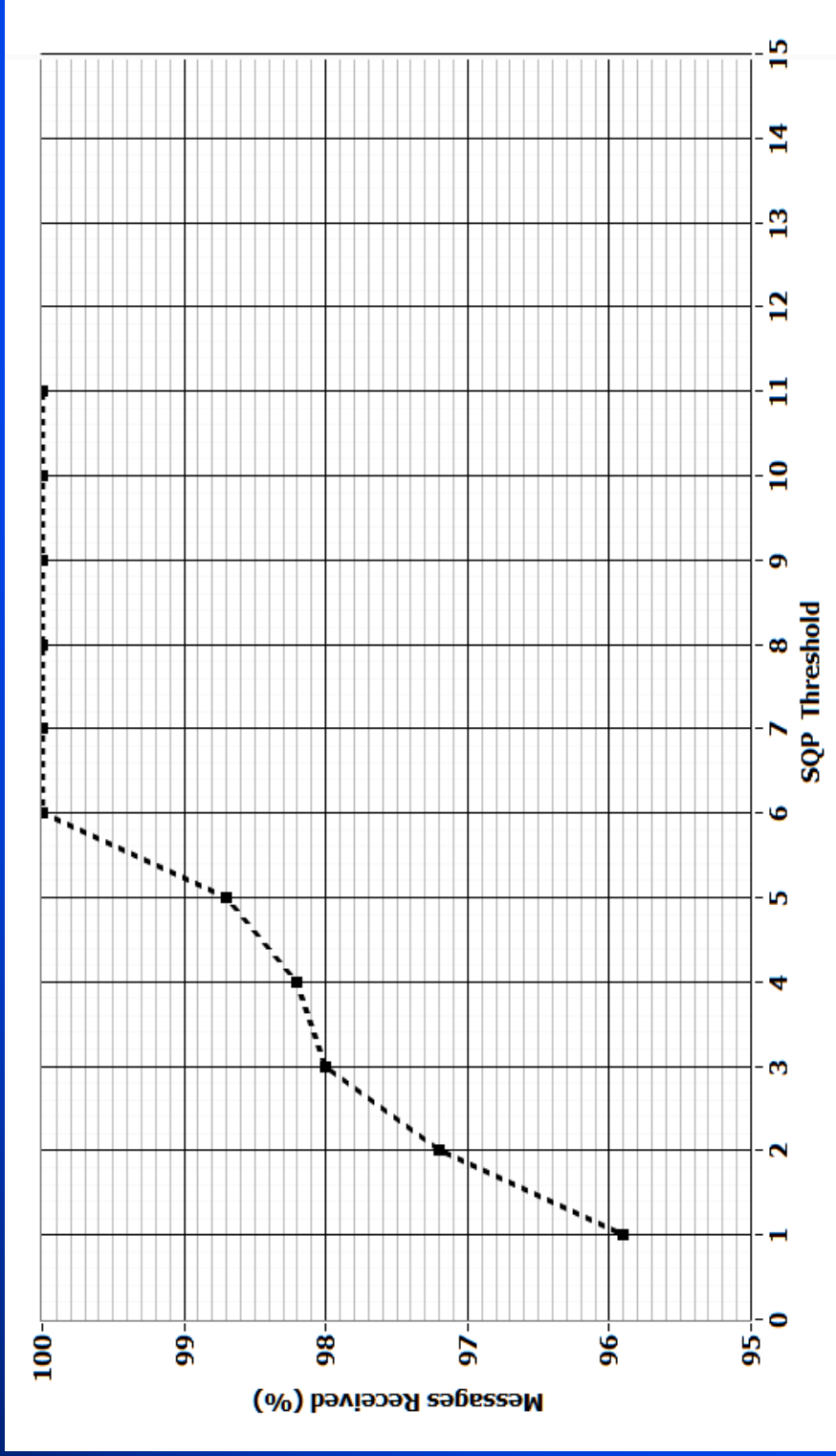
Five flights (11 hrs total) were conducted between April 10-13, 2005, using the FAA Technical Center VDL-3 ground station.

Standard Weather Product Reception

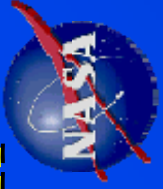


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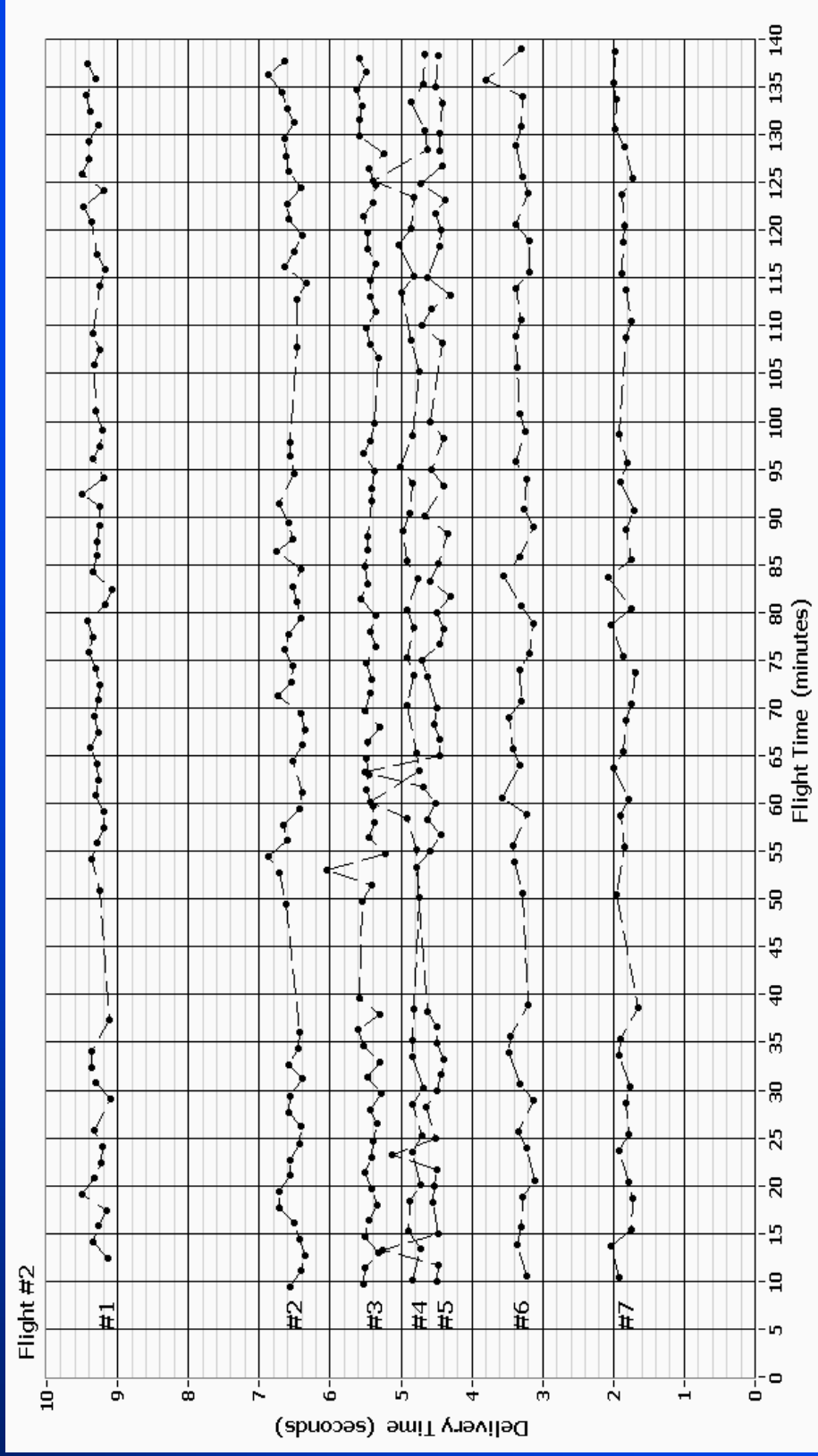


Standard Weather Product Reception



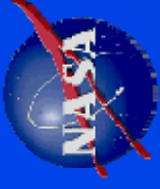
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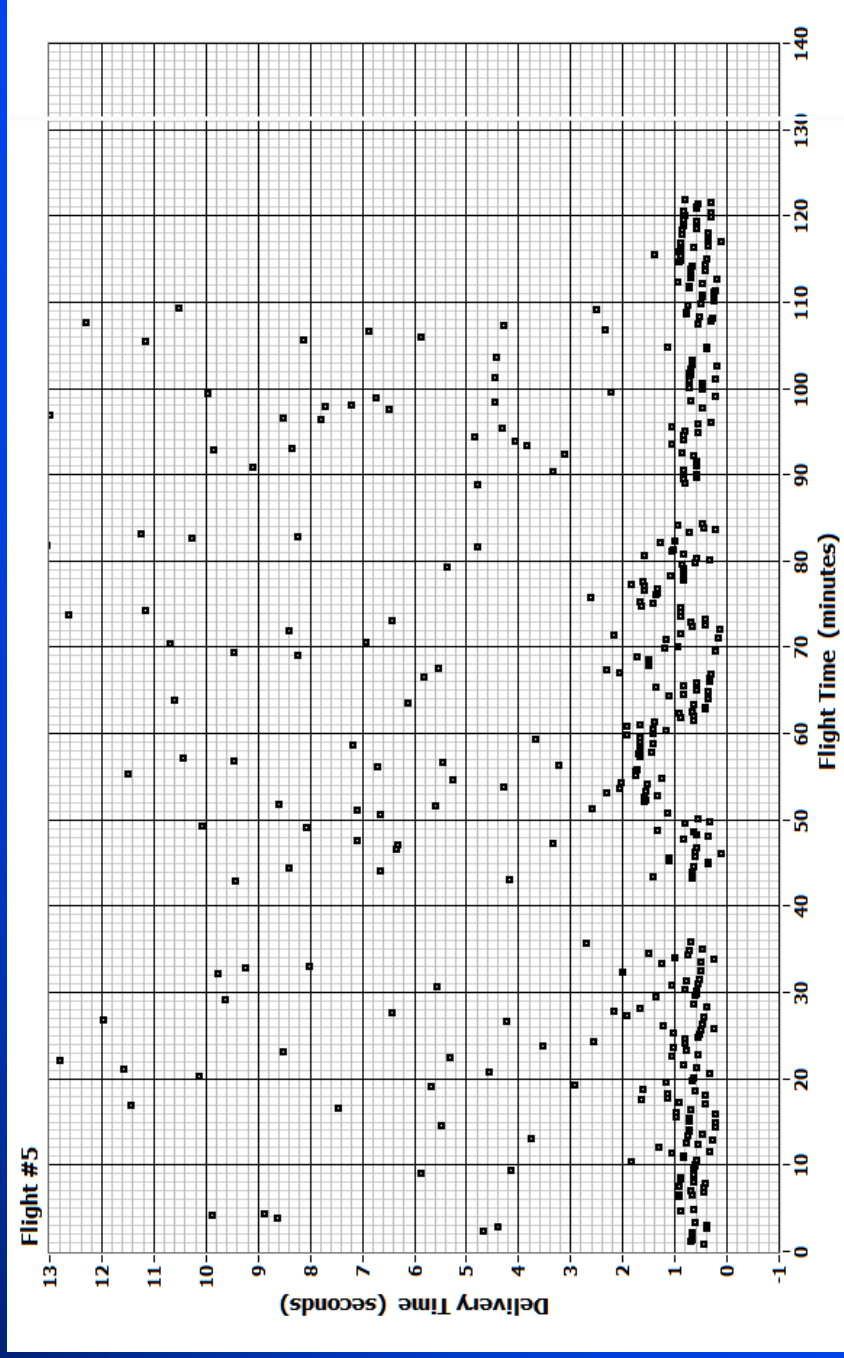
WTP	#1	#2	#3	#4	#5	#6	#7
Bytes	4,293	2,977	2,544	2,220	2,005	1,527	889
Desc.	METAR	Term. Wx	SIGMETS	Wx CONUS	PIREPS	NEXRAD	NEXRAD

Turbulence Message Reception



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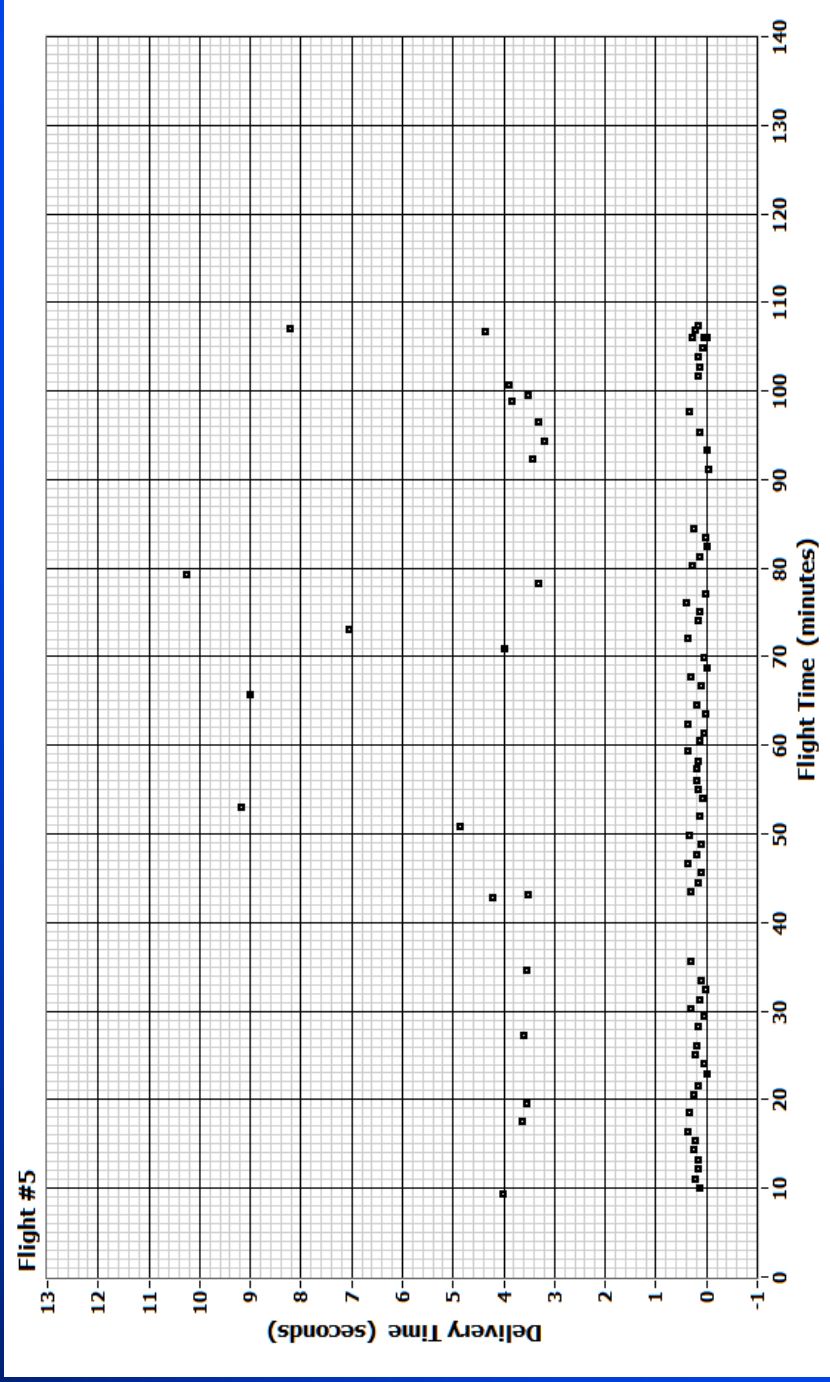
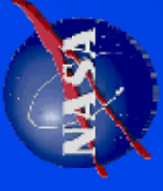


	Flt. #2	Flt. #3	Flt. #4	Flt. #5
TTMs Sent	136	122	217	444
TTMs Rec'd.	136	122	217	444
TTMs Lost	0	0	0	0
Retransmissions: at the TCP layer	5	6	20	34
at the DLS layer	55	32	49	93

Request Message Reception

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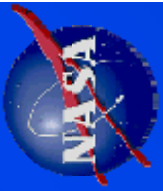
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Flt. #2 Flt. #3 Flt. #4 Flt. #5

REQs Sent	16	43	43	102
REQs Rec'd.	16	43	43	102
REQs Lost	0	0	0	0
Retransmissions: at TCP layer	5	11	6	6
at DLS layer	4	20	8	30

Standard Weather Products



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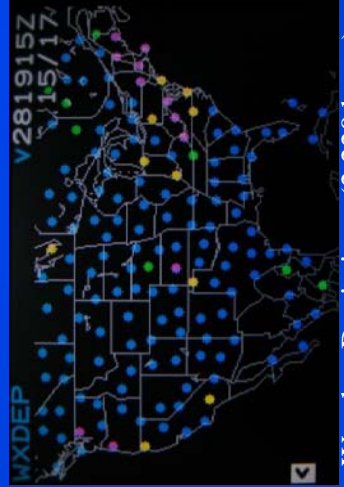
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```
DLNK -METAR/SPECI 2 / 24
METAR KCLE 151751Z
21013KT 10SM FEW150
SCT200 BKN250 14/06
A2996
RMK AO2 SLP147
8/075 T01440061 I0144
20044 58025
METAR KLPR 151753Z AUTO
23016G21KT 10SM CLR
PRN INOP
VOICE MODE
<RETURN 18:49 SIGMETS*
```

METAR, SPECI (4,293 bytes)

```
DLNK -SIGMETS 4 / 17
AIRMET IFR...WI IL LM IN
MI
FROM 20E MBS TO 10SSE
DXO TO FWA TO 10SSE BDF
TO 30ESE DBQ TO
10SSE BAE TO 20E MBS
OCNL CIG BLW 010/VIS BLW
3SM PCPN/BR/FG. CONDS
ENDG WI IL LM IN
PRN INOP
VOICE MODE
<RETURN 18:49 PIREPS*
```

SIGMETS, AIRMETS (2,544 bytes)



Weather Depiction (2,220 bytes)

```
DLNK -PIREPS 1 / 13
LPR UJA /OV MFD020025/TM
1733/FL060/TP CYP/TB
SEV 030-045/RM DURGC
HLC UA /OV HLC/TM
1815/FL100/TP C10/TA
M4/IC LGT RIME/RM FM ZDV
GCN UA /OV GCN/TM
PRN INOP
VOICE MODE
<RETURN 18:50
```

PIREPS (2,005 bytes)



NEXRAD, CONUS (889 bytes)

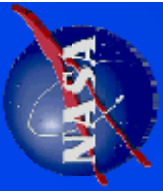
```
DLNK -TERM WX 1 / 17
TAF KCLE 151727Z 151818
22012KT P6SM BKN120
OVC250
FM2300 20006KT P6SM
OVC100 TEMPO 0405 5SM
-RA BR OVC050
FM0500 32008KT 4SM
-RA BR OVC025 TEMPO 0708
2SM -RASN BR
PRN INOP
VOICE MODE
<RETURN 18:49 SIGMETS*
```

Terminal Weather (2,977 bytes)



NEXRAD, w/tops (1,527 bytes)

Requested Weather Products



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Winds/Temps, FL24, 00Z (2,177 bytes)



Winds/Temps, FL30, 00Z (2,238 bytes)



Winds/Temps, FL34, 00Z (2,311 bytes)



Turbulence, FL05, 00Z (923 bytes)



Turbulence, FL24, 00Z (1,074 bytes)



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



Turbulence, FL34, 00Z (983 bytes)

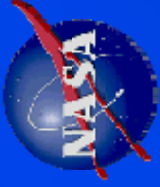


Icing, FL24, 00Z (1,021 bytes)



Icing, FL30, 00Z (723 bytes)

Requested Weather Products



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NEXRAD, Northwest (401 bytes)



NEXRAD, Northcentral (508 bytes)



NEXRAD, Northeast (1,495 bytes)

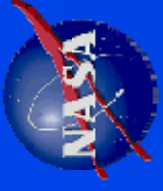


NEXRAD, Southcentral (526 bytes)



NEXRAD, Southeast (592 bytes)

VDL-3 Team Members



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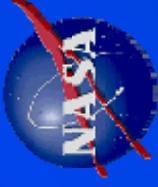
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General Aviation

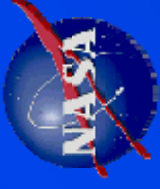
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UAT

UAT Messages

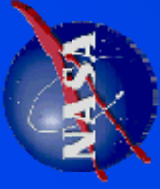


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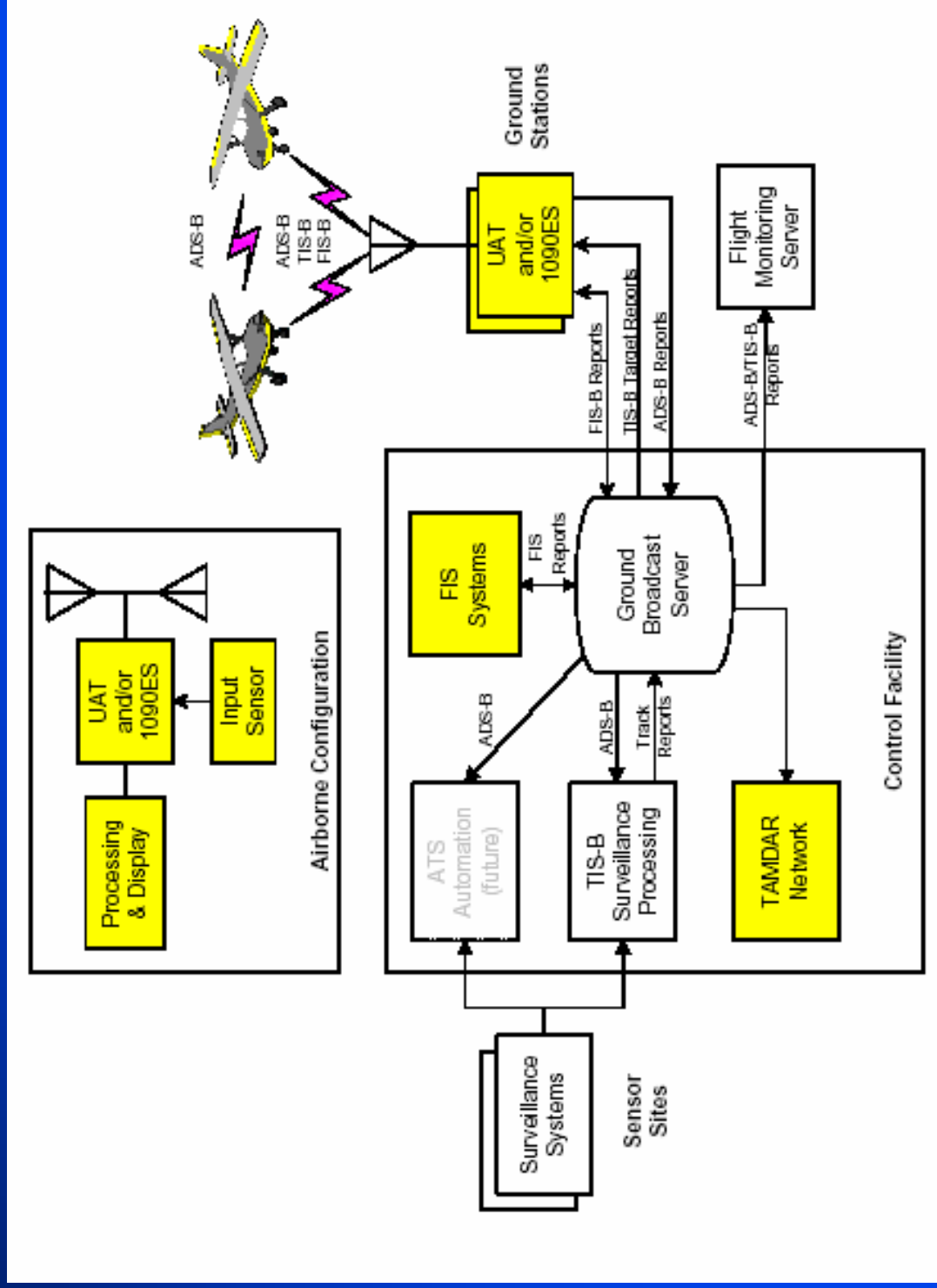
- Additional Ground-to-Air Textual Products
 - AIRMET
 - SIGMET
 - Convective SIGMET
 - TFR
- Weather Sensor (TAMDAR) data Air-to-Air & Air-to-Ground
 - Type 2 ADS-B message, using unreserved bits with no additional messages transmitted
 - Temperature
 - Wind Direction
 - Turbulence
 - Wind Speed
 - Humidity
 - Airspeed
 - Icing

UAT Architecture



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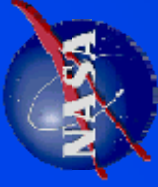
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UAT Flights

WINCOMM

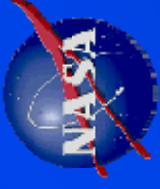
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Summary

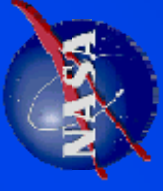
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- All equipment modifications were software based in order to allow the reception and transmission of these additional messages.
- All modifications were made within the accepted standards or in a manner consistent with the standards.
- These changes were worked closely with industry partners with a path toward certification.

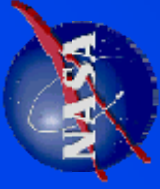




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Raw Message Display

UAT Airborne Msg Display - Msg Valid

Header

Payload Type 2
Address Qualifier 0
Address 2

State Vector

Latitude 39.44568
Longitude -74.56374
Altitude Type 1
Altitude .75
Nav Integrity 8
Air-Ground State Ground
UTC Coupled True
TIS-B Site 0

Auxiliary State Vector

Secondary Alt -1

On Ground

Ground Speed 1
Trk Area/Head Fmt 0
Trk Area/Head 0
A/M Len & Width 0
POA False

TAMDAR Msg Display -

Temperature 7.9
Wind Speed 9
Wind Direction 8
Humidity 7
Icina 1
Normalized Turb 112
AC Constant 22
Data Quality False