GBAS-Components, Verification, and Development

Engineering Development Services (EDS)

By: Chad Kemp, Navigation
AJP-652

Date: October 19, 2010

Federal Aviation Administration

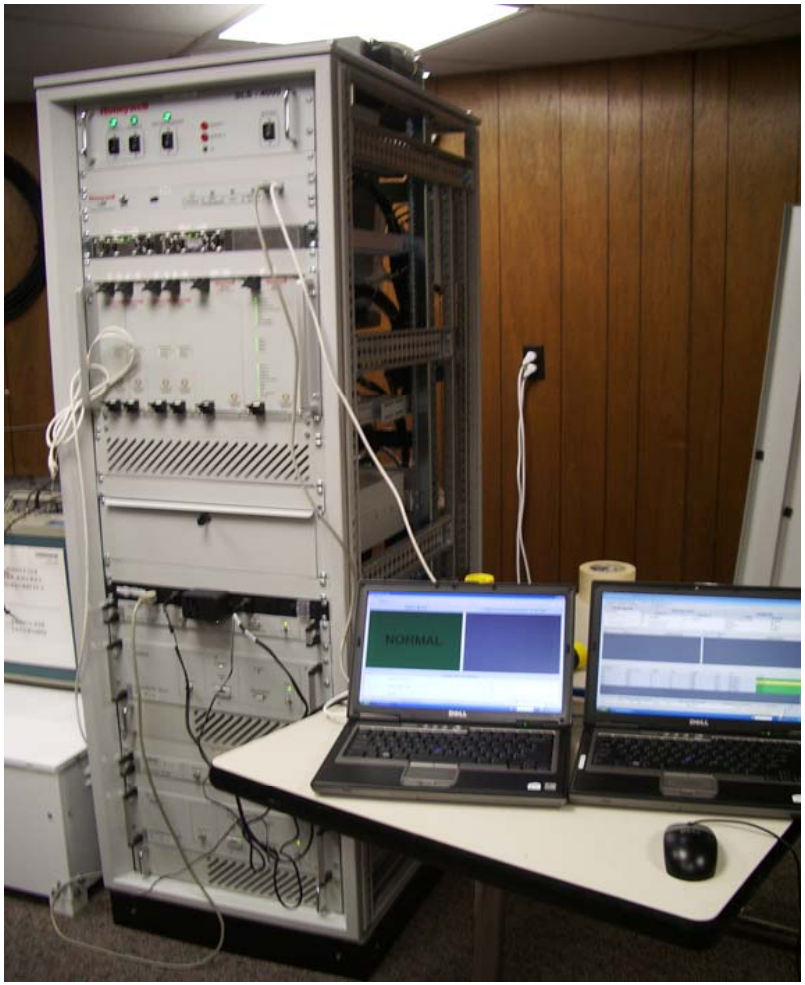
Overview

- **SLS-4000 Background**
- **Basic Equipment**
- **Data Logs**
- **Performance Analysis**

SLS-4000 System Background

- **Initial installation and broadcast of SLS-4000 in Atlantic City – September 2008**
  - Newark, NJ (EWR) – November 2009
- **Adaptation File, Measured site Data (MSD), Type 4 (FAS only)**
- **Maintenance Data Terminal (MDT) and Air Traffic Status Unit (ATSU)**

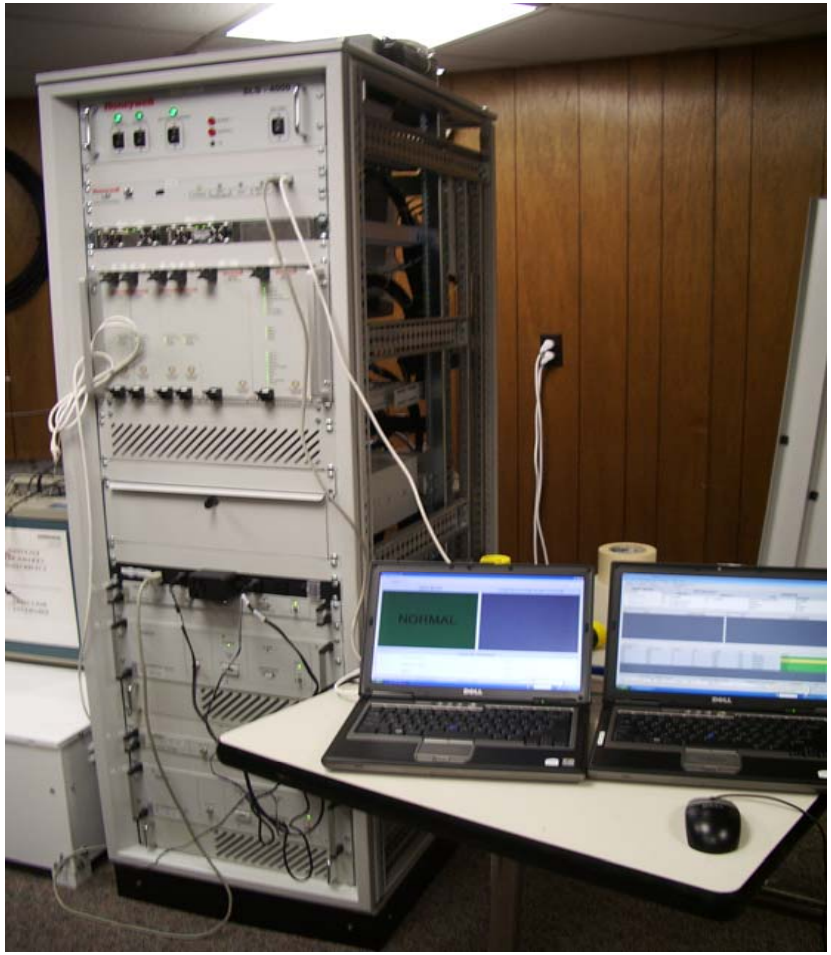
SLS-4000 Pictorial View



Basic System Equipment

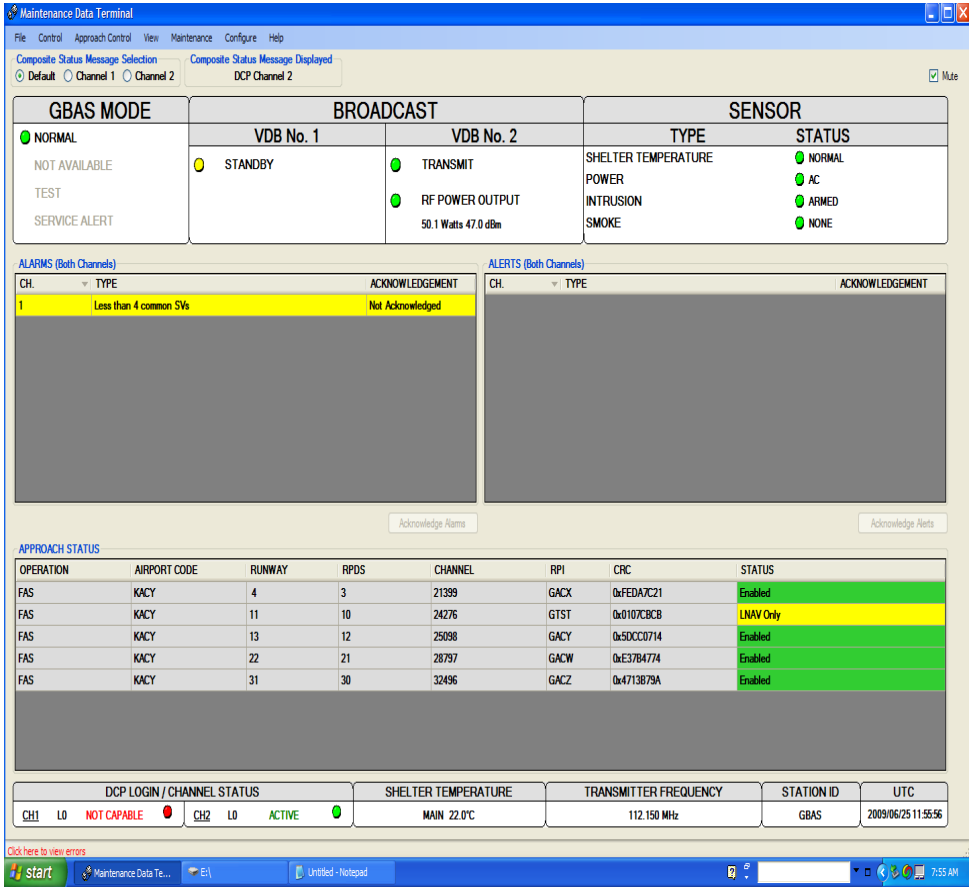
- **One (1) HPOL VDB Antenna**
- **Four (4) Remote Satellite Measurement Units (RSMU)**
- **Four (4) BAE ARL-1900 GPS Antennae**

System Equipment Continued

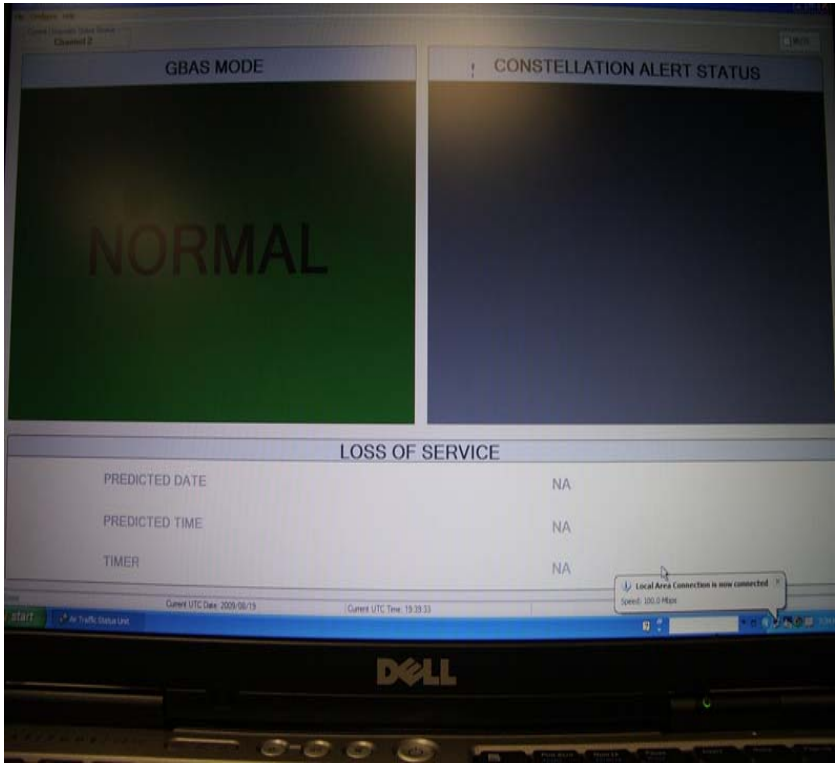


- Redundant Very-High Frequency (VHF) Data Broadcast (VDB) TX/RX Pairs
- Redundant Differential Correction Processor (DCP) Pairs
- Local Status Panel (LSP)
- Robust Power Distribution Panel (RPDP)
- Battery Rack and Batteries

System Equipment – Terminal Displays



- **Maintenance Data Terminal (MDT)**

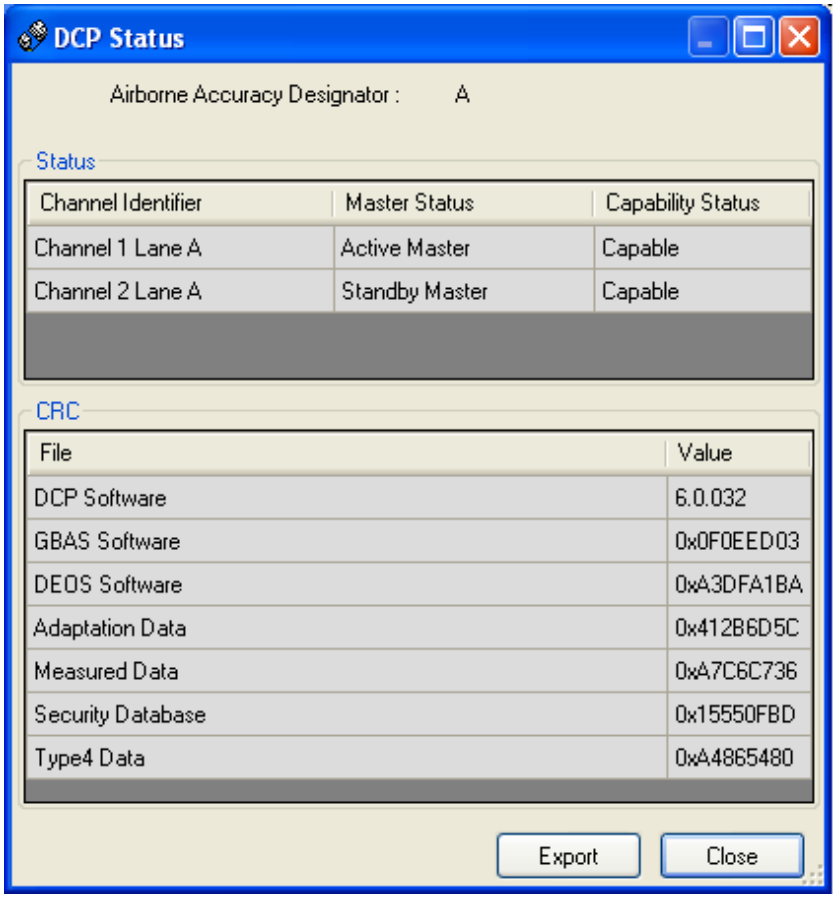


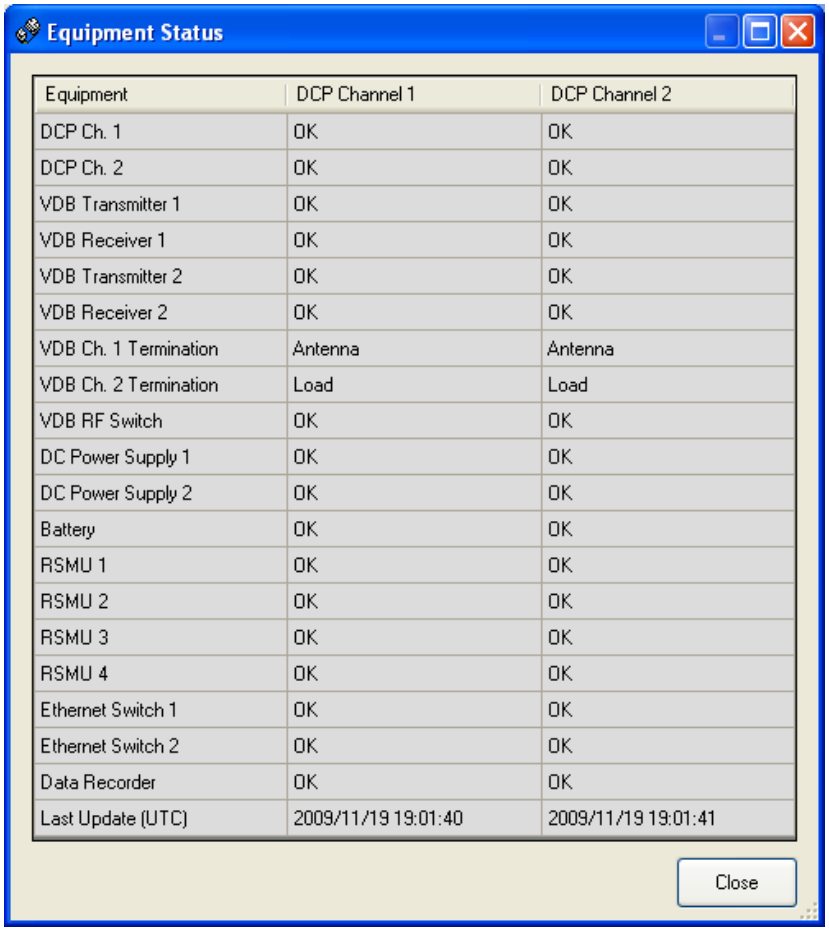
- **Air Traffic Status Unit (ATSU) – Display Optional**

MDT - Features

- **Displays information and status**
  - System Mode of Operation
  - Active DCP Channel and Transmitter
  - Power Level of VHF broadcast
  - Availability and status of equipment
  - Environment and Security Sensors
- **VHF message information**
  - Type 1 (Corrections)
  - Type 2 (Ground Station Information)
  - Type 4 (Approach Procedures)
- **Uploading/Downloading of Software and configuration files**
  - DCP SW, Measured Site Data (MSD), Type 4

MDT – Display Information





- DCP Status
- Equipment Status Information

MDT – Display Information (RSMU)

RSMU Data

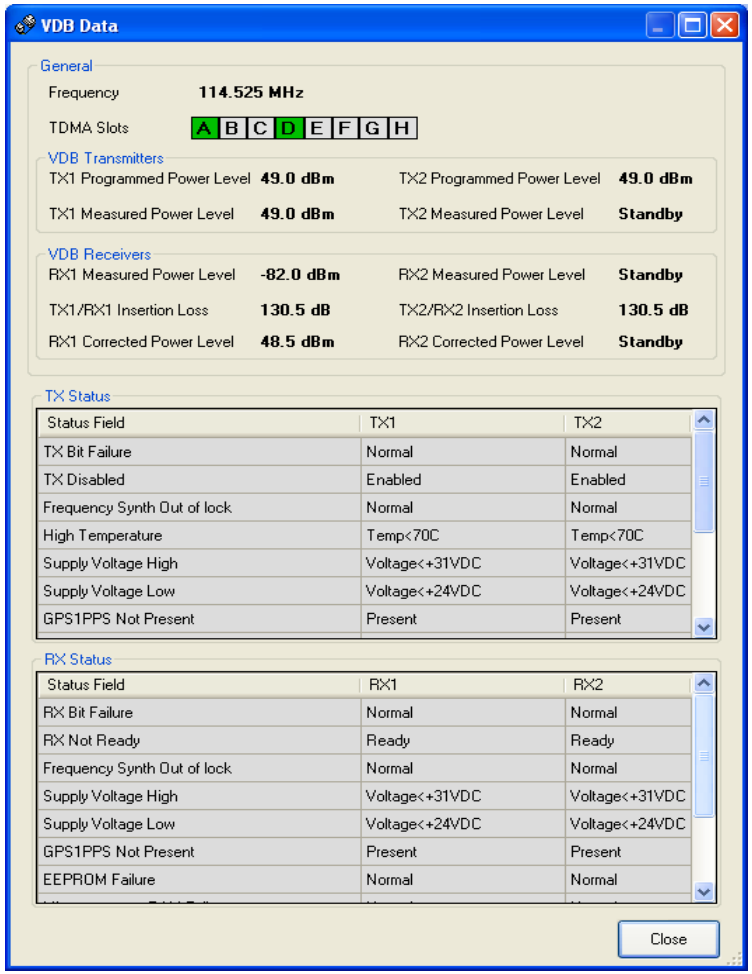
Geodetic Coordinates | Azimuth and Elevation Sector Masks

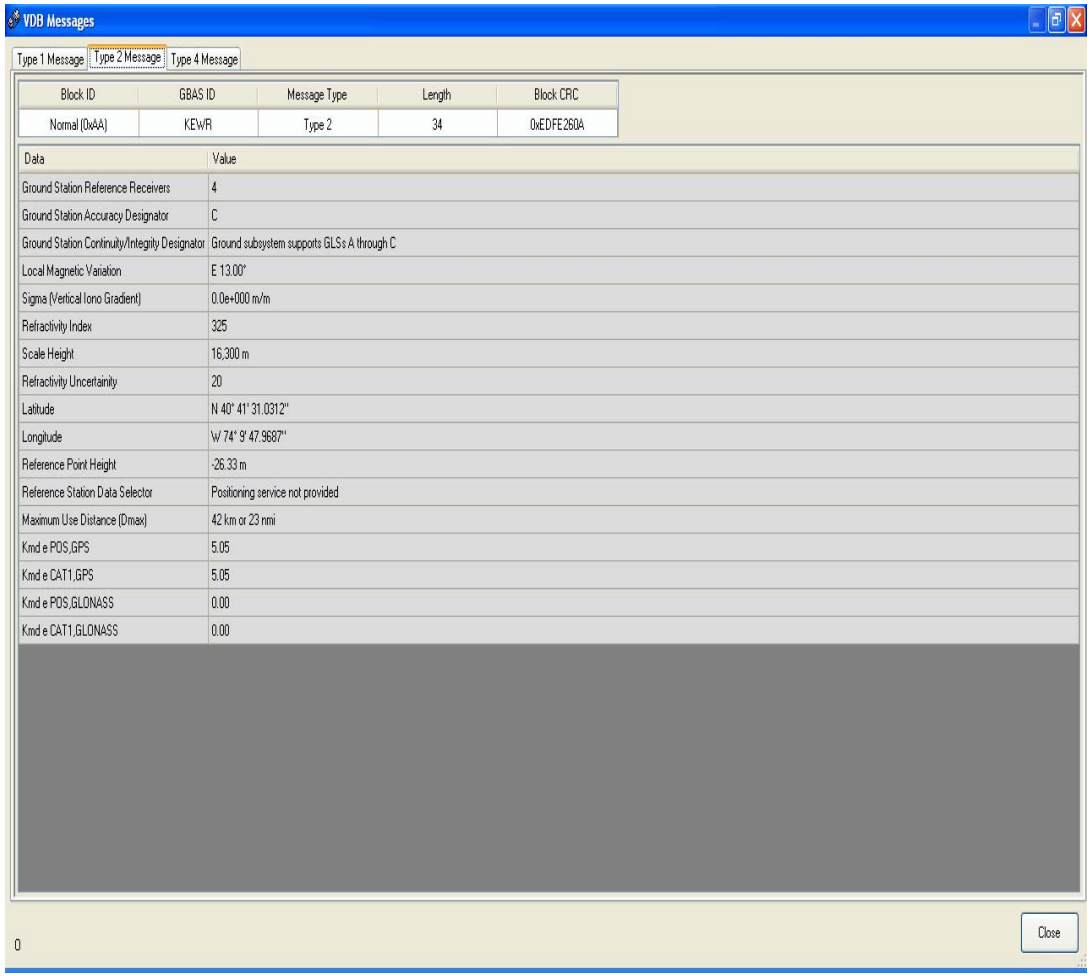
Name	Sector Mask	Azimuth Range (in deg)	Elevation Range (in deg)
RSMU No.1	SECTOR MASK1	313-330	0-8
	SECTOR MASK2	109-114	0-8
	SECTOR MASK3	150-153	0-7
	SECTOR MASK4	162-165	0-8
	SECTOR MASK5	0-0	0-0
	SECTOR MASK6	0-0	0-0
	SECTOR MASK7	0-0	0-0
	SECTOR MASK8	0-0	0-0
	SECTOR MASK9	0-0	0-0
	SECTOR MASK10	0-0	0-0
RSMU No.2	SECTOR MASK1	64-66	36-38
	SECTOR MASK2	310-326	0-8
	SECTOR MASK3	121-124	0-7
	SECTOR MASK4	192-200	0-7
	SECTOR MASK5	150-153	0-6
	SECTOR MASK6	292-294	8-11
	SECTOR MASK7	54-56	13-15
	SECTOR MASK8	282-285	0-7
	SECTOR MASK9	0-0	0-0
	SECTOR MASK10	0-0	0-0
RSMU No.3	SECTOR MASK1	310-322	0-12
	SECTOR MASK2	136-139	0-7
	SECTOR MASK3	0-0	0-0
	SECTOR MASK4	0-0	0-0
	SECTOR MASK5	0-0	0-0
	SECTOR MASK6	0-0	0-0
	SECTOR MASK7	0-0	0-0
	SECTOR MASK8	0-0	0-0
	SECTOR MASK9	0-0	0-0

Close

- RSMU Sector Masks

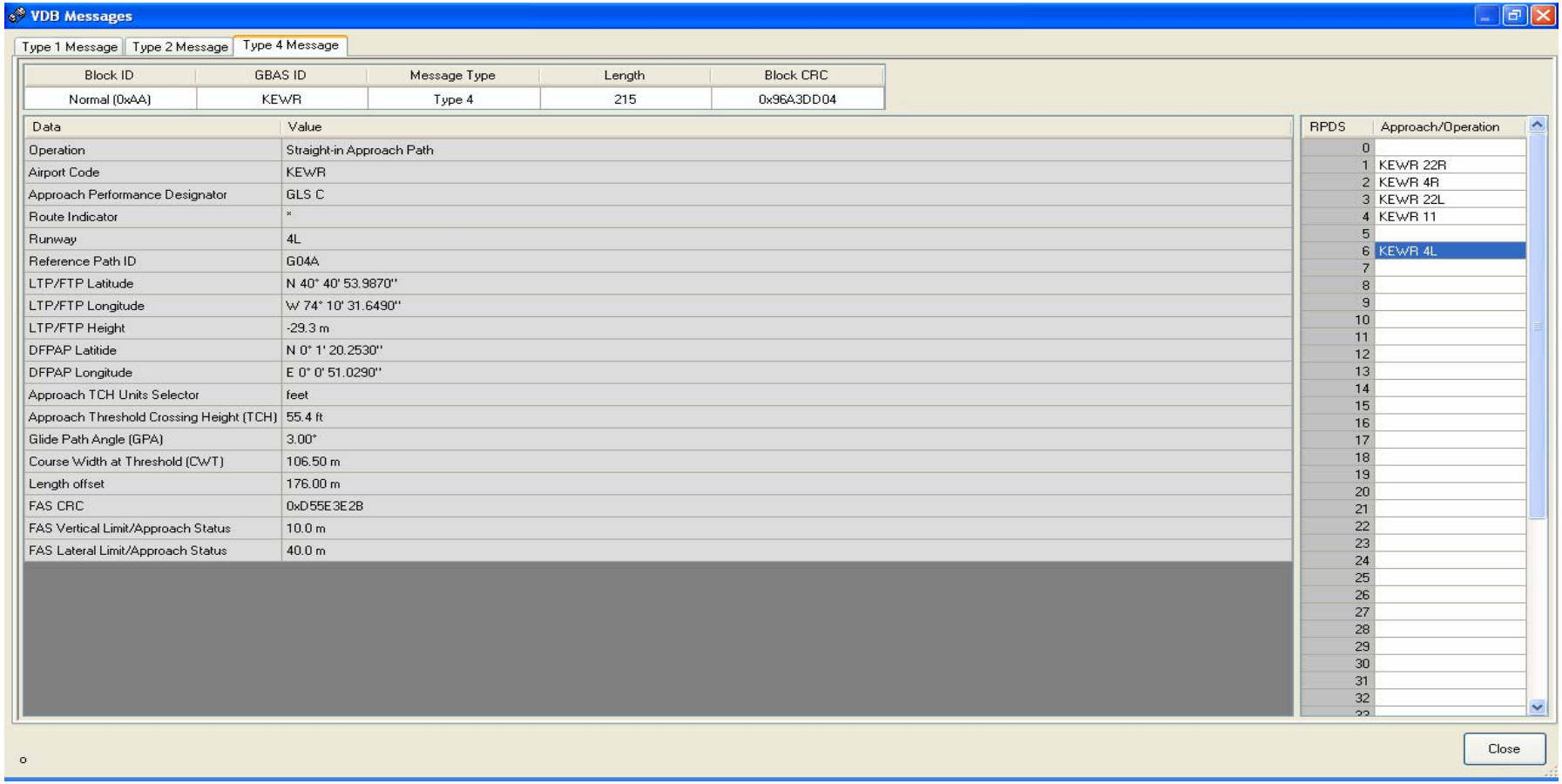
MDT – Displays (VDB Information)





- VDB Status
- Type 2 Broadcast Message

MDT – Displays (Approach Data)



Block ID	GBAS ID	Message Type	Length	Block CRC
Normal (0xAA)	KEWR	Type 4	215	0x96A3DD04

Data	Value
Operation	Straight-in Approach Path
Airport Code	KEWR
Approach Performance Designator	GLS C
Route Indicator	*
Runway	4L
Reference Path ID	G04A
LTP/FTP Latitude	N 40° 40' 53.9870"
LTP/FTP Longitude	W 74° 10' 31.6490"
LTP/FTP Height	-29.3 m
DFPAP Latitide	N 0° 1' 20.2530"
DFPAP Longitude	E 0° 0' 51.0290"
Approach TCH Units Selector	feet
Approach Threshold Crossing Height (TCH)	55.4 ft
Glide Path Angle (GPA)	3.00°
Course Width at Threshold (CWT)	106.50 m
Length offset	176.00 m
FAS CRC	0xD55E3E2B
FAS Vertical Limit/Approach Status	10.0 m
FAS Lateral Limit/Approach Status	40.0 m

RPDS	Approach/Operation
0	
1	KEWR 22R
2	KEWR 4R
3	KEWR 22L
4	KEWR 11
5	
6	KEWR 4L
7	
8	
9	
10	
11	
12	
13	
14	
15	
16	
17	
18	
19	
20	
21	
22	
23	
24	
25	
26	
27	
28	
29	
30	
31	
32	

- Type 4 Message Broadcast

MDT – Displays (Corrections Data)

VDB Messages

Type 1 Message | Type 2 Message | Type 4 Message

Block ID	GBAS ID	Message Type	Length	Block CRC
Normal (0xAA)	KEWR	Type 1	105	0x7CD42E45

Number of Measurements	Modified Z-count	Additional Message Flag	Measurement Type
8	987.0	Single Message (0)	C/A code L1 (0)

PRN	Issue of Data	Pseudorange Correction (m)	Range Rate Correction (m/s)	Sigma_pr_gnd (m)	B1 (m)	B2 (m)	B3 (m)	B4 (m)	Ephemeris Decorrelation (m/m)	Ephemeris CRC
7	20	3.41	-0.004	0.26	0.00	0.00	0.00	0.00	0.000185	0x0AFE
11	8	7.03	0.005	0.28	0.00	0.05	0.00	0.00		
17	14	6.15	-0.001	0.26	0.00	0.00	0.00	0.00		
19	31	1.11	-0.007	0.26	0.00	0.00	0.00	0.00		
20	100	-11.61	0.005	0.26	0.00	0.00	0.00	0.00	0.000185	0xA04B
25	10	-2.31	-0.007	0.26	0.00	0.00	0.00	0.00		
28	48	5.98	-0.002	0.28	0.00	0.00	0.00	-0.05		
32	91	-9.76	0.010	0.26	-0.05	0.00	0.00	0.00	0.000185	0x455D

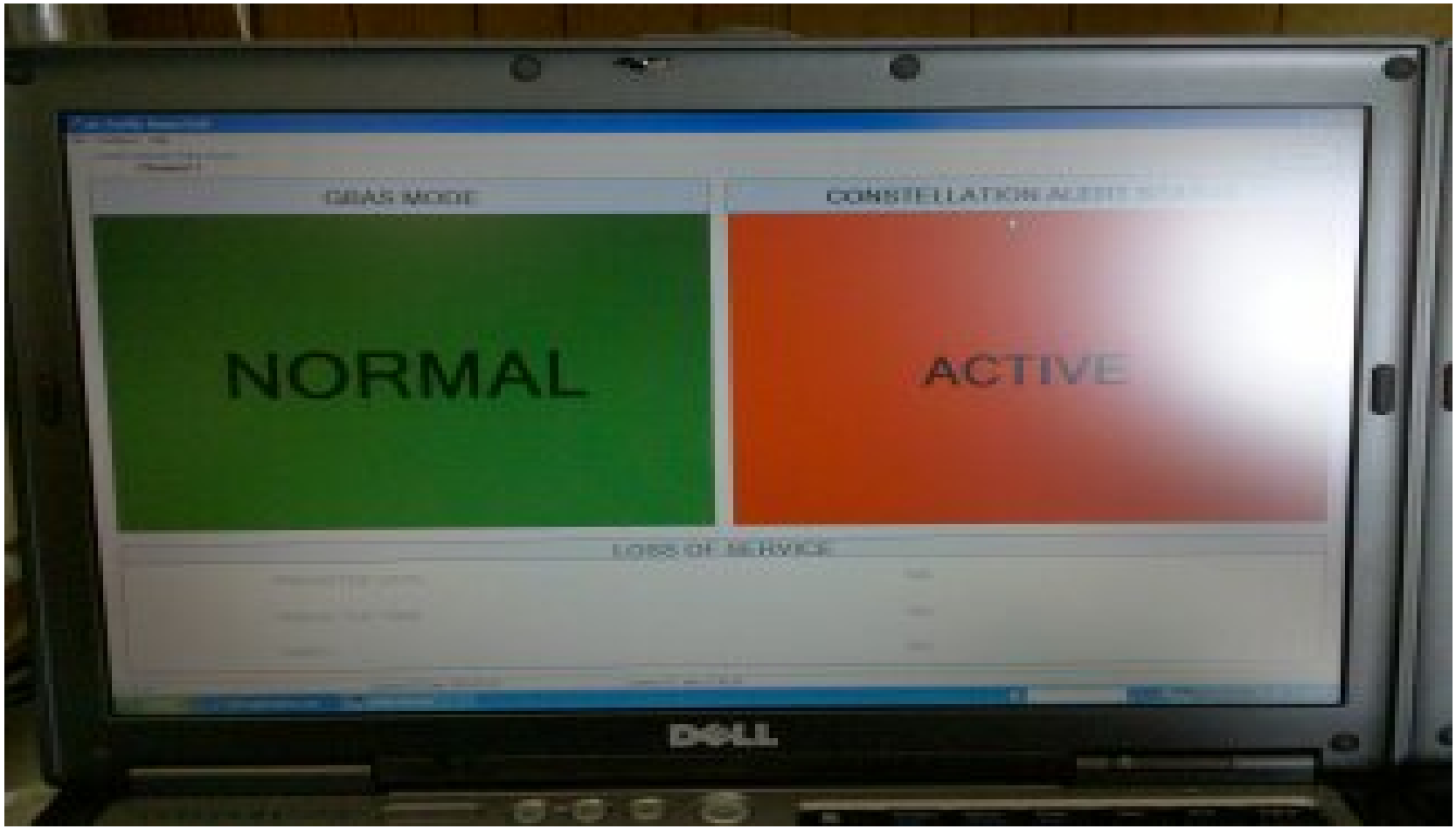
Close

- Type 1 Message Broadcast Data

ATSU - Features

- **Displays system mode of operation**
- **Indicates if Constellation Alert is present**
  - Displays time-frame for how long condition will be present

ATSU - Display



Differential Correction Processors (DCP)

- **Maintain operational SW, system information, and integrity monitor data**
- **Process RSMU data and Time Marks**
- **Redundant and "hot-swappable"**
  - Backup for failure
  - Replaceable with minimal system downtime

Event Log

- **Log of status information for irregular performance events**
  - Includes satellite events, as well as various station issues, service alerts, and alarms.
- **Event Log downloadable into a readable .csv Microsoft Excel file.**

Event Log - Example

Microsoft Excel - SystemEventLog

	C	D	E	F	G	H	I	J	K	L	M	N
1	UTC Date & Time	Cur Ch	Cur Ln	Evt Ch	Evt Ln	Status	Mode	State	Corrections	VDB	Evt ID	Event Description
2	2009/07/01 05:10:05:00	Ch. 1	A	Ch. 1	A	Active	Normal	Nominal	Yes	Ch. 2	19	[GPS - Satellite Not Healthy] A measurement has been excluded because the satellite declared its
3	2009/07/01 05:10:05:00	Ch. 1	A	Ch. 1	A	Active	Normal	Nominal	Yes	Ch. 2	19	[GPS - Satellite Not Healthy] A measurement has been excluded because the satellite declared its
4	2009/07/01 05:10:05:00	Ch. 1	A	Ch. 1	A	Active	Normal	Nominal	Yes	Ch. 2	19	[GPS - Satellite Not Healthy] A measurement has been excluded because the satellite declared its
5	2009/07/01 05:10:05:00	Ch. 1	A	Ch. 1	A	Active	Normal	Nominal	Yes	Ch. 2	19	[GPS - Satellite Not Healthy] A measurement has been excluded because the satellite declared its
6	2009/07/01 05:10:05:00	Ch. 1	B	Ch. 1	B	Active	Normal	Nominal	Yes	Ch. 2	19	[GPS - Satellite Not Healthy] A measurement has been excluded because the satellite declared its
7	2009/07/01 05:10:05:00	Ch. 1	B	Ch. 1	B	Active	Normal	Nominal	Yes	Ch. 2	19	[GPS - Satellite Not Healthy] A measurement has been excluded because the satellite declared its
8	2009/07/01 05:10:05:00	Ch. 1	B	Ch. 1	B	Active	Normal	Nominal	Yes	Ch. 2	19	[GPS - Satellite Not Healthy] A measurement has been excluded because the satellite declared its
9	2009/07/01 05:10:05:00	Ch. 1	B	Ch. 1	B	Active	Normal	Nominal	Yes	Ch. 2	19	[GPS - Satellite Not Healthy] A measurement has been excluded because the satellite declared its
10	2009/07/01 05:10:05:00	Ch. 2	A	Ch. 2	A	Standby	Normal	Nominal	Yes	Ch. 2	19	[GPS - Satellite Not Healthy] A measurement has been excluded because the satellite declared its
11	2009/07/01 05:10:05:00	Ch. 2	A	Ch. 2	A	Standby	Normal	Nominal	Yes	Ch. 2	19	[GPS - Satellite Not Healthy] A measurement has been excluded because the satellite declared its
12	2009/07/01 05:10:05:00	Ch. 2	A	Ch. 2	A	Standby	Normal	Nominal	Yes	Ch. 2	19	[GPS - Satellite Not Healthy] A measurement has been excluded because the satellite declared its
13	2009/07/01 05:10:05:00	Ch. 2	A	Ch. 2	A	Standby	Normal	Nominal	Yes	Ch. 2	19	[GPS - Satellite Not Healthy] A measurement has been excluded because the satellite declared its
14	2009/07/01 05:10:05:00	Ch. 2	B	Ch. 2	B	Standby	Normal	Nominal	Yes	Ch. 2	19	[GPS - Satellite Not Healthy] A measurement has been excluded because the satellite declared its
15	2009/07/01 05:10:05:00	Ch. 2	B	Ch. 2	B	Standby	Normal	Nominal	Yes	Ch. 2	19	[GPS - Satellite Not Healthy] A measurement has been excluded because the satellite declared its
16	2009/07/01 05:10:05:00	Ch. 2	B	Ch. 2	B	Standby	Normal	Nominal	Yes	Ch. 2	19	[GPS - Satellite Not Healthy] A measurement has been excluded because the satellite declared its
17	2009/07/01 05:10:05:00	Ch. 2	B	Ch. 2	B	Standby	Normal	Nominal	Yes	Ch. 2	19	[GPS - Satellite Not Healthy] A measurement has been excluded because the satellite declared its
18	2009/06/30 18:58:05:00	Ch. 1	A	Ch. 1	A	Standby	Normal	Nominal	Yes	Ch. 1	19	[GPS - Satellite Not Healthy] A measurement has been excluded because the satellite declared its
19	2009/06/30 18:58:05:00	Ch. 1	A	Ch. 1	A	Standby	Normal	Nominal	Yes	Ch. 1	19	[GPS - Satellite Not Healthy] A measurement has been excluded because the satellite declared its
20	2009/06/30 18:58:05:00	Ch. 1	A	Ch. 1	A	Standby	Normal	Nominal	Yes	Ch. 1	19	[GPS - Satellite Not Healthy] A measurement has been excluded because the satellite declared its
21	2009/06/30 18:58:05:00	Ch. 1	A	Ch. 1	A	Standby	Normal	Nominal	Yes	Ch. 1	19	[GPS - Satellite Not Healthy] A measurement has been excluded because the satellite declared its
22	2009/06/30 18:58:05:00	Ch. 1	B	Ch. 1	B	Standby	Normal	Nominal	Yes	Ch. 1	19	[GPS - Satellite Not Healthy] A measurement has been excluded because the satellite declared its
23	2009/06/30 18:58:05:00	Ch. 1	B	Ch. 1	B	Standby	Normal	Nominal	Yes	Ch. 1	19	[GPS - Satellite Not Healthy] A measurement has been excluded because the satellite declared its
24	2009/06/30 18:58:05:00	Ch. 1	B	Ch. 1	B	Standby	Normal	Nominal	Yes	Ch. 1	19	[GPS - Satellite Not Healthy] A measurement has been excluded because the satellite declared its
25	2009/06/30 18:58:05:00	Ch. 1	B	Ch. 1	B	Standby	Normal	Nominal	Yes	Ch. 1	19	[GPS - Satellite Not Healthy] A measurement has been excluded because the satellite declared its
26	2009/06/30 18:58:05:00	Ch. 2	A	Ch. 2	A	Active	Normal	Nominal	Yes	Ch. 1	19	[GPS - Satellite Not Healthy] A measurement has been excluded because the satellite declared its
27	2009/06/30 18:58:05:00	Ch. 2	A	Ch. 2	A	Active	Normal	Nominal	Yes	Ch. 1	19	[GPS - Satellite Not Healthy] A measurement has been excluded because the satellite declared its
28	2009/06/30 18:58:05:00	Ch. 2	A	Ch. 2	A	Active	Normal	Nominal	Yes	Ch. 1	19	[GPS - Satellite Not Healthy] A measurement has been excluded because the satellite declared its
29	2009/06/30 18:58:05:00	Ch. 2	A	Ch. 2	A	Active	Normal	Nominal	Yes	Ch. 1	19	[GPS - Satellite Not Healthy] A measurement has been excluded because the satellite declared its
30	2009/06/30 18:58:05:00	Ch. 2	B	Ch. 2	B	Active	Normal	Nominal	Yes	Ch. 1	19	[GPS - Satellite Not Healthy] A measurement has been excluded because the satellite declared its
31	2009/06/30 18:58:05:00	Ch. 2	B	Ch. 2	B	Active	Normal	Nominal	Yes	Ch. 1	19	[GPS - Satellite Not Healthy] A measurement has been excluded because the satellite declared its
32	2009/06/30 18:58:05:00	Ch. 2	B	Ch. 2	B	Active	Normal	Nominal	Yes	Ch. 1	19	[GPS - Satellite Not Healthy] A measurement has been excluded because the satellite declared its
33	2009/06/30 18:58:05:00	Ch. 2	B	Ch. 2	B	Active	Normal	Nominal	Yes	Ch. 1	19	[GPS - Satellite Not Healthy] A measurement has been excluded because the satellite declared its
34	2009/06/30 14:06:28:50	Ch. 1	A	Ch. 1	A	Active	Normal	Nominal	Yes	Ch. 1	11	[GPS - Failed Parity/Default Nav Data] A satellite has been excluded due to failed parity or sub-fram
35	2009/06/30 14:06:28:50	Ch. 1	A	Ch. 1	A	Active	Normal	Nominal	Yes	Ch. 1	11	[GPS - Failed Parity/Default Nav Data] A satellite has been excluded due to failed parity or sub-fram
36	2009/06/30 14:06:28:50	Ch. 1	A	Ch. 1	A	Active	Normal	Nominal	Yes	Ch. 1	11	[GPS - Failed Parity/Default Nav Data] A satellite has been excluded due to failed parity or sub-fram
37	2009/06/30 14:06:28:50	Ch. 1	A	Ch. 1	A	Active	Normal	Nominal	Yes	Ch. 1	11	[GPS - Failed Parity/Default Nav Data] A satellite has been excluded due to failed parity or sub-fram
38	2009/06/30 14:06:28:50	Ch. 2	A	Ch. 2	A	Standby	Normal	Nominal	Yes	Ch. 1	11	[GPS - Failed Parity/Default Nav Data] A satellite has been excluded due to failed parity or sub-fram
39	2009/06/30 14:06:28:50	Ch. 2	A	Ch. 2	A	Standby	Normal	Nominal	Yes	Ch. 1	11	[GPS - Failed Parity/Default Nav Data] A satellite has been excluded due to failed parity or sub-fram
40	2009/06/30 14:06:28:50	Ch. 2	A	Ch. 2	A	Standby	Normal	Nominal	Yes	Ch. 1	11	[GPS - Failed Parity/Default Nav Data] A satellite has been excluded due to failed parity or sub-fram
41	2009/06/30 14:06:28:50	Ch. 2	A	Ch. 2	A	Standby	Normal	Nominal	Yes	Ch. 1	11	[GPS - Failed Parity/Default Nav Data] A satellite has been excluded due to failed parity or sub-fram
42	2009/06/30 14:06:28:50	Ch. 2	B	Ch. 2	B	Standby	Normal	Nominal	Yes	Ch. 1	11	[GPS - Failed Parity/Default Nav Data] A satellite has been excluded due to failed parity or sub-fram
43	2009/06/30 14:06:28:50	Ch. 2	B	Ch. 2	B	Standby	Normal	Nominal	Yes	Ch. 1	11	[GPS - Failed Parity/Default Nav Data] A satellite has been excluded due to failed parity or sub-fram
44	2009/06/30 14:06:28:50	Ch. 2	B	Ch. 2	B	Standby	Normal	Nominal	Yes	Ch. 1	11	[GPS - Failed Parity/Default Nav Data] A satellite has been excluded due to failed parity or sub-fram
45	2009/06/30 14:06:28:50	Ch. 2	B	Ch. 2	B	Standby	Normal	Nominal	Yes	Ch. 1	11	[GPS - Failed Parity/Default Nav Data] A satellite has been excluded due to failed parity or sub-fram
46	2009/06/30 14:06:28:49	Ch. 1	B	Ch. 1	B	Active	Normal	Nominal	Yes	Ch. 1	11	[GPS - Failed Parity/Default Nav Data] A satellite has been excluded due to failed parity or sub-fram
47	2009/06/30 14:06:28:49	Ch. 1	B	Ch. 1	B	Active	Normal	Nominal	Yes	Ch. 1	11	[GPS - Failed Parity/Default Nav Data] A satellite has been excluded due to failed parity or sub-fram
48	2009/06/30 14:06:28:49	Ch. 1	B	Ch. 1	B	Active	Normal	Nominal	Yes	Ch. 1	11	[GPS - Failed Parity/Default Nav Data] A satellite has been excluded due to failed parity or sub-fram
49	2009/06/30 14:06:28:49	Ch. 1	B	Ch. 1	B	Active	Normal	Nominal	Yes	Ch. 1	11	[GPS - Failed Parity/Default Nav Data] A satellite has been excluded due to failed parity or sub-fram
50	2009/06/30 13:41:10:51	Ch. 1	A	Ch. 1	A	Active	Normal	Nominal	Yes	Ch. 1	40	[Excessive Carrier Rate] A satellite has been excluded because the Carrier Rate exceeds the thresl
51	2009/06/30 13:41:10:51	Ch. 1	B	Ch. 1	B	Active	Normal	Nominal	Yes	Ch. 1	40	[Excessive Carrier Rate] A satellite has been excluded because the Carrier Rate exceeds the thresl

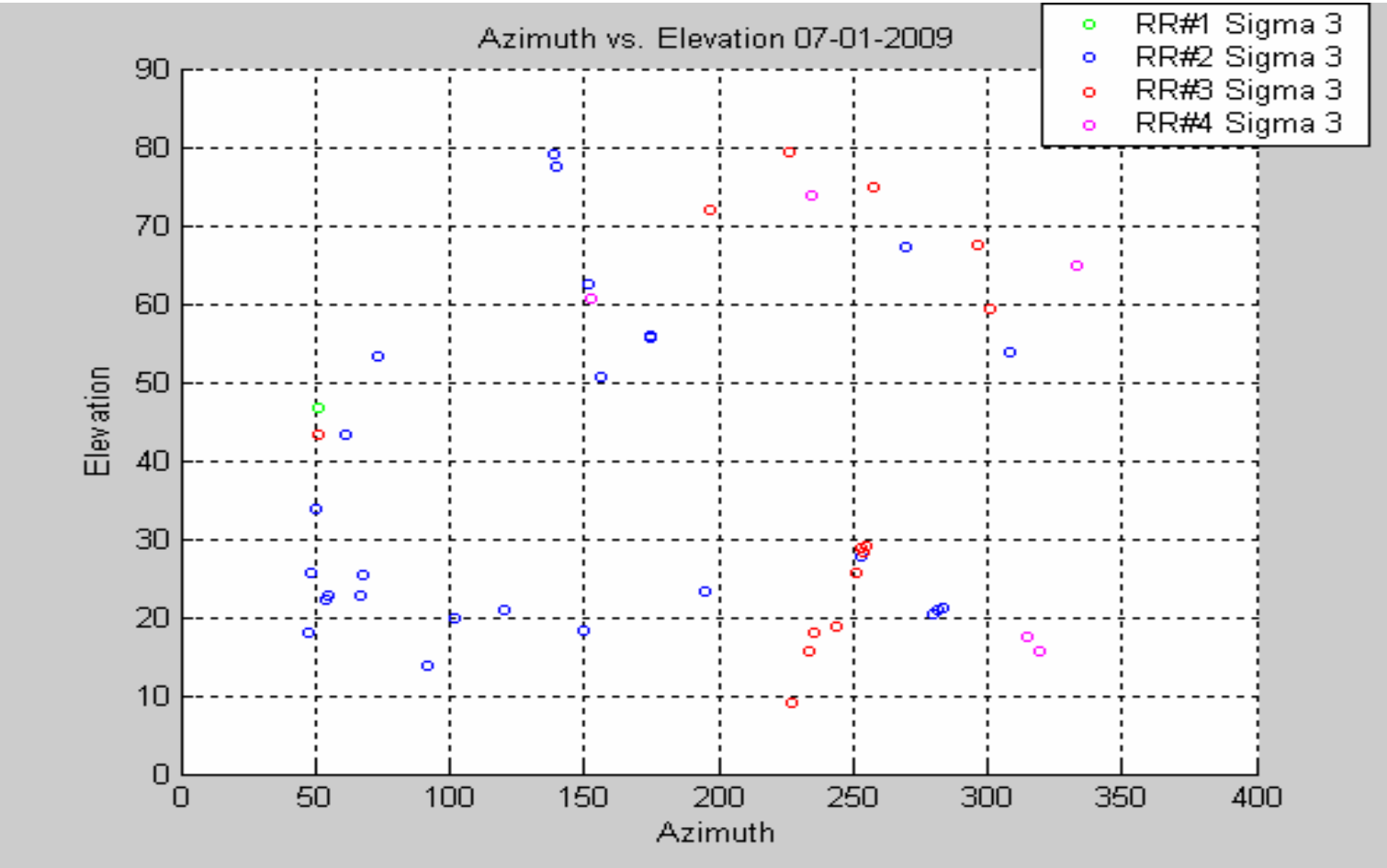
SystemEventLog

Ready

System Performance Analysis – Sigma Monitor

- **Sigma Monitor checks for abnormal events in satellite signal integrity**
  - Data stored in DCPs
- **External converter allows for analysis of all 3, 4, 4.8 and 5.5 sigma events.**
- **Large amounts of higher sigma events could be caused by a bad environment around RSMUs**
  - Updated MSD file to mask these areas would be needed

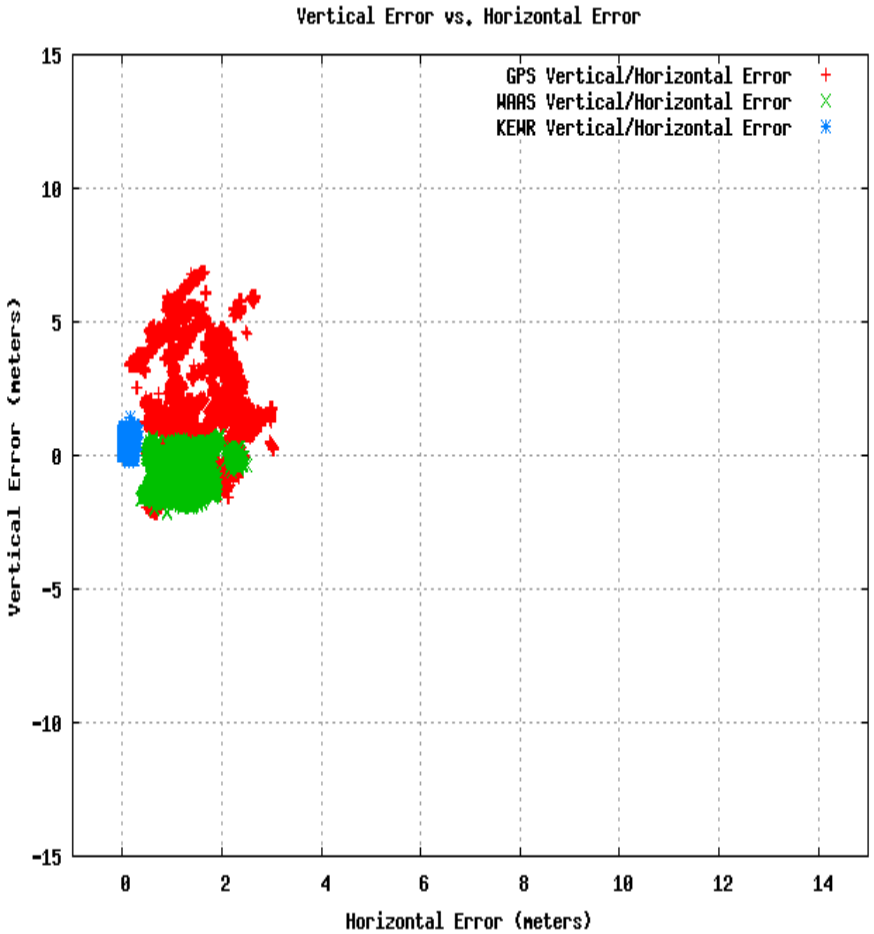
Performance Analysis – Sigma Monitor Sample Plot

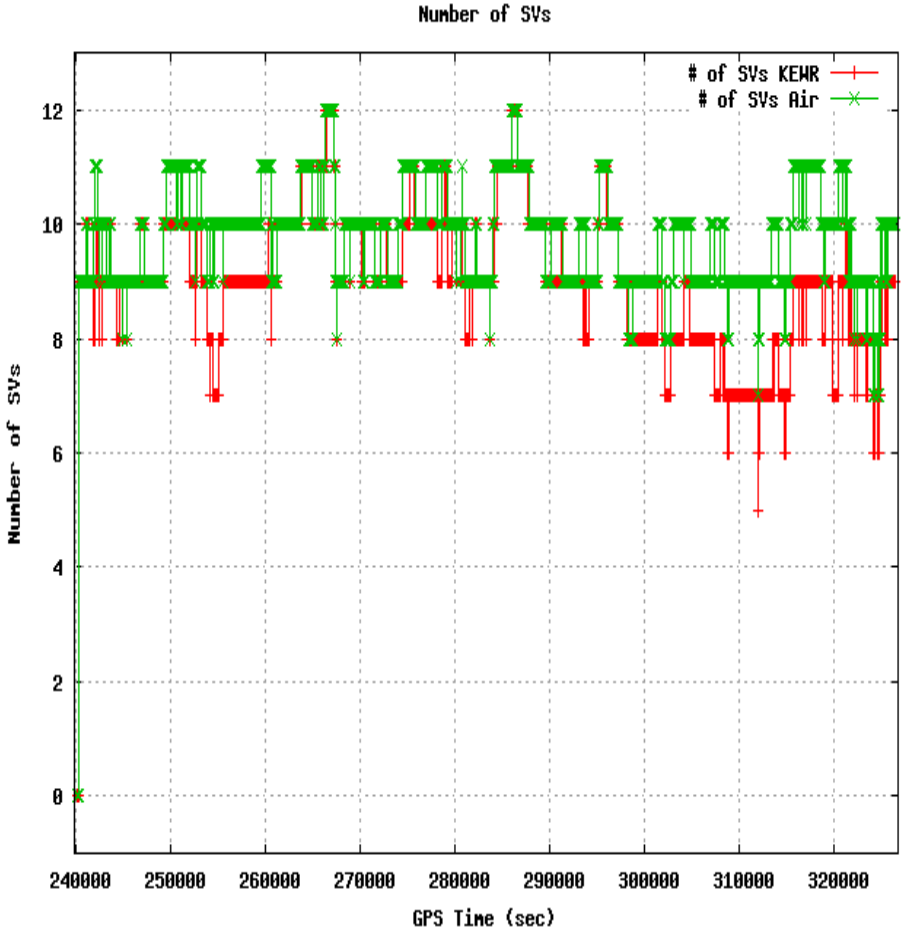


System Performance Analysis – GBPM

- Ground-based Performance Monitor (GBPM) – isolated system
- Incorporates broadcast corrections from the DGPS SLS-4000 system, along with raw data from the monitor's localized GPS receiver to compute a position
- Calculated position is compared to the surveyed GPS antenna's position to compute associated error
- Error used to determine accuracy and integrity of ground facility

Performance Analysis - GBPM





- Position Error
- Number of SVs Tracked

System Observations for future developments (CAT I Updates, CAT III)

- **Improving executive monitor functions and misleading information displayed for user**
  - Specular Multipath monitoring in SDM
  - Optimize coding by eliminating redundant or unnecessary functions
- **More detailed information regarding status and information of RSMUs**
- **Improving online/Normal operation time after system restarts, repairs**
  - Specifically, analysis for Ephemeris Monitor (can take 54 hours to accomplish under some circumstances)

GPS Anomalous Event Monitor (GAEM)

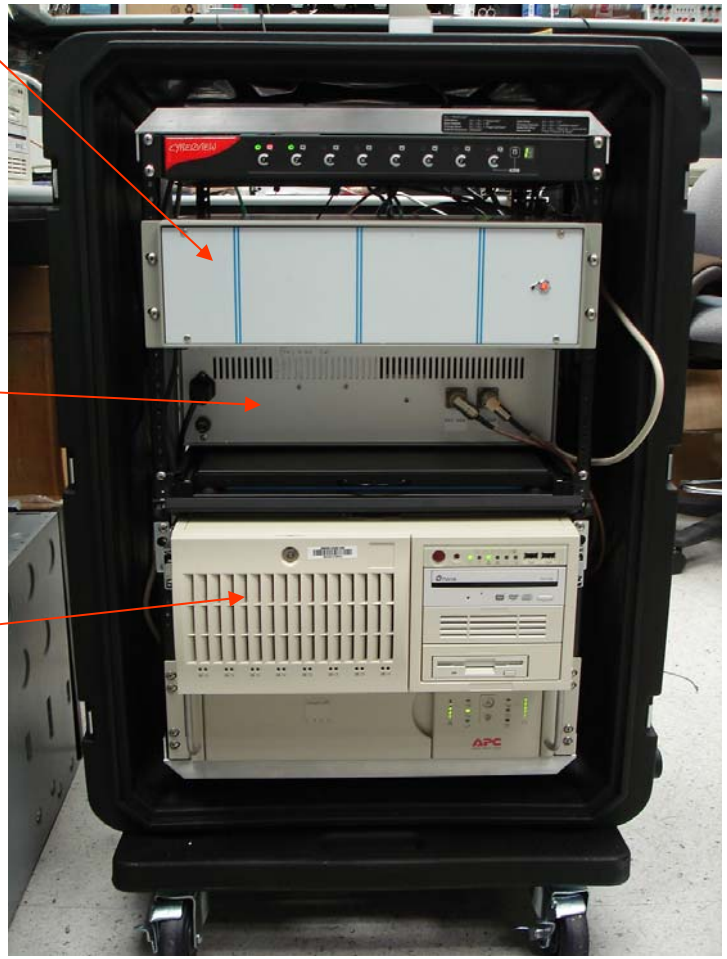
- **Converts GPS RF Spectrum into digitized form and processes using FPGA card.**
- **Ability to store raw and digitized data before and after an anomalous event occurs.**
  - 5 mega samples per second
  - Offline processing in 1-ms intervals
- **Systems installed at ACY and Ohio University**

GAEM System

Trigger

RF Front-End

GAEM Server



GAEM: Trigger Box System

- **2 GPS RF inputs to 2 NovAtel DL-4 GPS receivers**
- **Analyzing GPS data at 1 Hz time-frame for anomalous events**
- **Main triggering component to initialize data collection of GPS events in GAEM system**
- **Separate data files allow for additional analysis on possible abnormal GPS events**

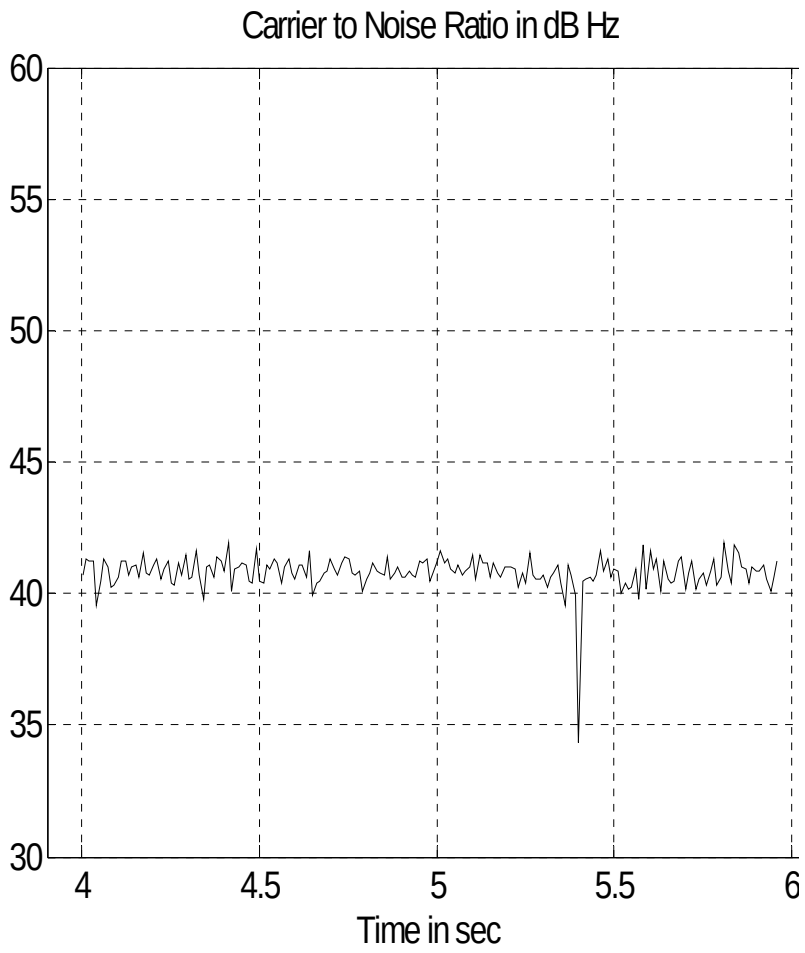
GAEM: RF Front-End

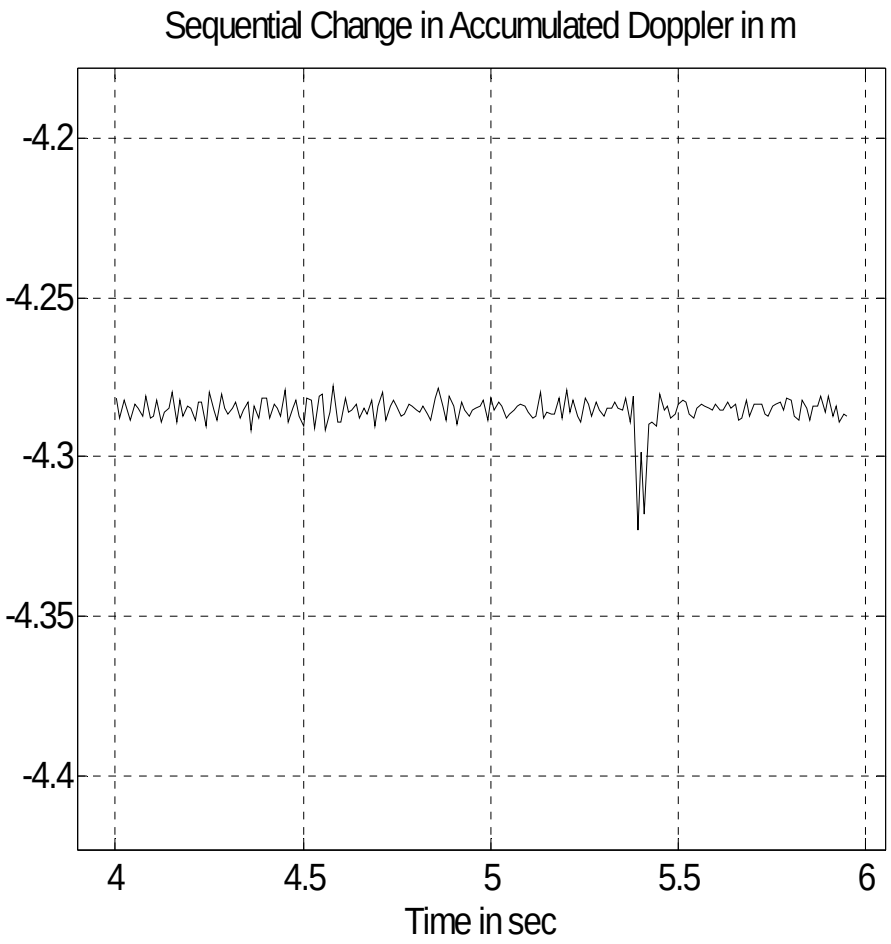
- **Converts raw GPS spectrum into format for GAEM Server**
- **2 Input/Output for redundant data**
- **RF data collected at 5 mega samples per second**
- **Multiple stages of circulation, filtering, and amplification of the spectrum allows for mitigating noise and multipath**
  - Down converts signal to correct format for GAEM server to process

GAEM: GAEM Server

- Main processor of GAEM system
- A/D converter digitizes signal from RF Front End and stores data in buffer
- Files created and labeled with Processor Time and what system initialized the triggering of the event

Example of GPS Event – SV21 on 05/01/08





Example of GPS Event – SV21 on 05/01/08

- **The C/No graph indicates the signal strength of the satellite at a given period.**
- **The Accumulated Doppler (AD) graph illustrates the incremental changes in the AD measurement, which is obtained by differencing consecutive AD measurements. It is a function of satellite Doppler frequency.**
- **For a normal GPS satellite, these measurements stay at a relatively constant level during an observation window up to 10 seconds.**

Summary

- **GBPM grants ability to analyze performance of a GBAS**
- **GAEM grants ability to analyze performance of GPS**
- **Sigma Monitor analysis one instance of ability to analyze data directly from SLS-4000**
- **Together, allow for demonstrating the integrity of the LGF and for analyzing any abnormal information or performance issues.**

Questions or Comments?

- **Contact Information:**
  - Email: chad.kemp@faa.gov
  - Office: (609) 485-6308