

International Flight Inspection Symposium

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Glide Slope Considerations to Provide Support for Aircraft Certification for Steep Angle Approaches

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ILS Signal Requirements

- Localizer Signal:
 - Aligned with runway centerline
 - Meet Category I course roughness tolerances
- Glide Slope Signal
 - 5.5 to 8.65 degree path angle
 - Meet Category I path roughness down to an altitude of 344 feet

Location

- Previous Facility: Blythe removed when cooling tower built under approach
 - Aircraft decoupling due to updraft
- TMB: 09L
 - Known site performance
 - National FAA ILS test facility
 - Equipment and infrastructure [power, foundations, buildings] already exists
 - Established working relations with ATC

Summary of Aircraft Using Facility

Aircraft Type	Avionics	Path Angles Flown (Degrees)	Engineering Flight Dates
E-175	Honeywell	5.5	5/08-6/1/08
Cessna Mustang	Garmin	5.5	2/20-2/21/07
Gulfstream G-550	Honeywell	5.5	1/09/07
Gulfstream G -150	Honeywell	5.5	1/09/07
Cessna Encore+	Rockwell Collins	5.5	3/14/07
Cessna Excel	Rockwell Collins	5.5	3/31-4/01/08
Falcon 900	Honeywell	5.5, 6.65, 8.65	8/10-8/12/08;10/24-26/07

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TMB Layout



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Summary of Ground Equipment

Parameter	Equipment	
	Localizer	Glide Slope
Frequency (MHz)	109.7	333.2
Antenna Type	Log Periodic Dipole	FAA 8971
Array Type	8-Element Single-Frequency	Null Reference
Transmitter	Mark 20	Mark 1F
CSB Power (W)	15.0	4.0
Standby Power	Batteries (6 hours minimum)	Batteries (6 hours minimum)

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Glide Slope Mast All-Angles



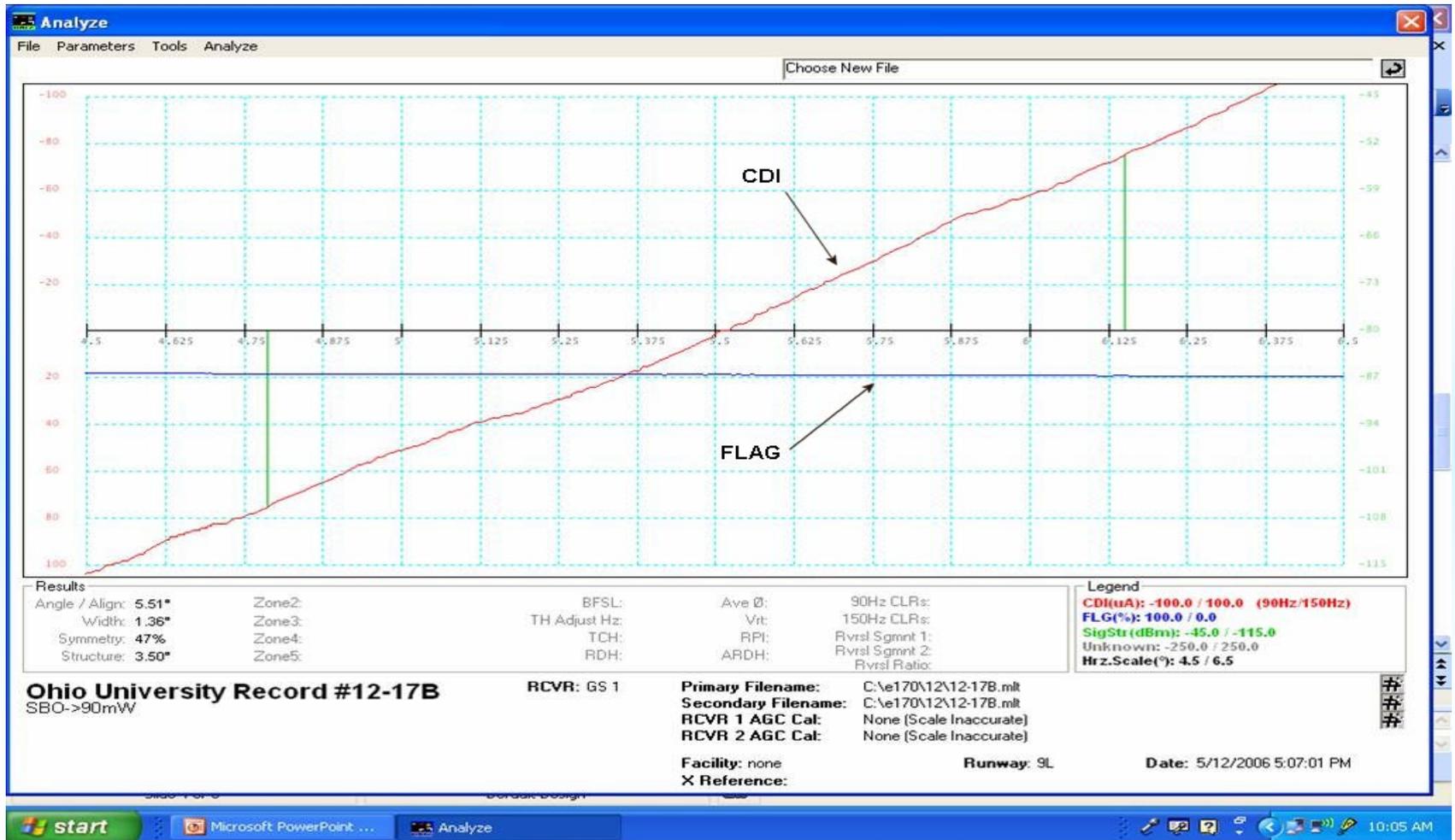
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Flight Results Summary

Parameter	Flight Measurement Results	Flight Inspection Tolerance
Path Angle 5.5 Degrees 5/12/06 - 8/27/07		
Width (degrees)	1.36[1.41]	1.22 -1.42
Symmetry (%)	47[47]	33 - 67
Structure Angle (degrees)	3.50[3.41]	1.65 (minimum)
Path Angle (degrees)	5.49[5.46]	5.4 - 5.6
Path Angle 6.65 Degrees 8/27/07		
Width (degrees)	1.61	1.5-1.7
Symmetry (%)	46	33 - 67
Structure Angle (degrees)	4.3	2.0 (minimum)
Path Angle (degrees)	6.61	6.6 - 6.7
Path Angle 8.65 Degrees 8/27/07		
Width (degrees)	3.0	3.0-3.2
Symmetry (%)	47	33 - 67
Structure Angle (degrees)	4.8	2.6 (minimum)
Path Angle (degrees)	8.51	8.5- 8.8

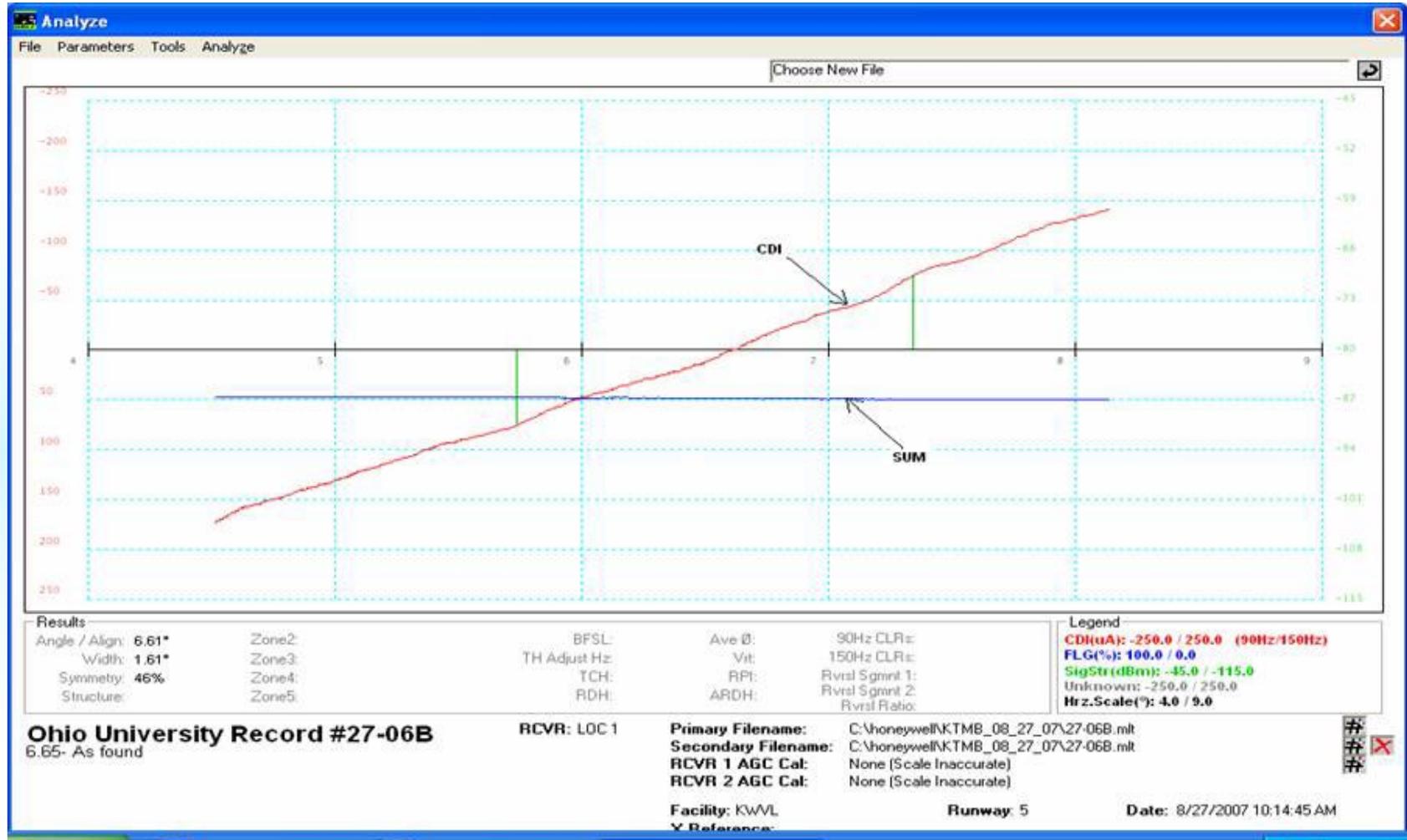
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Proportional Guidance Sector 5.5 Degrees



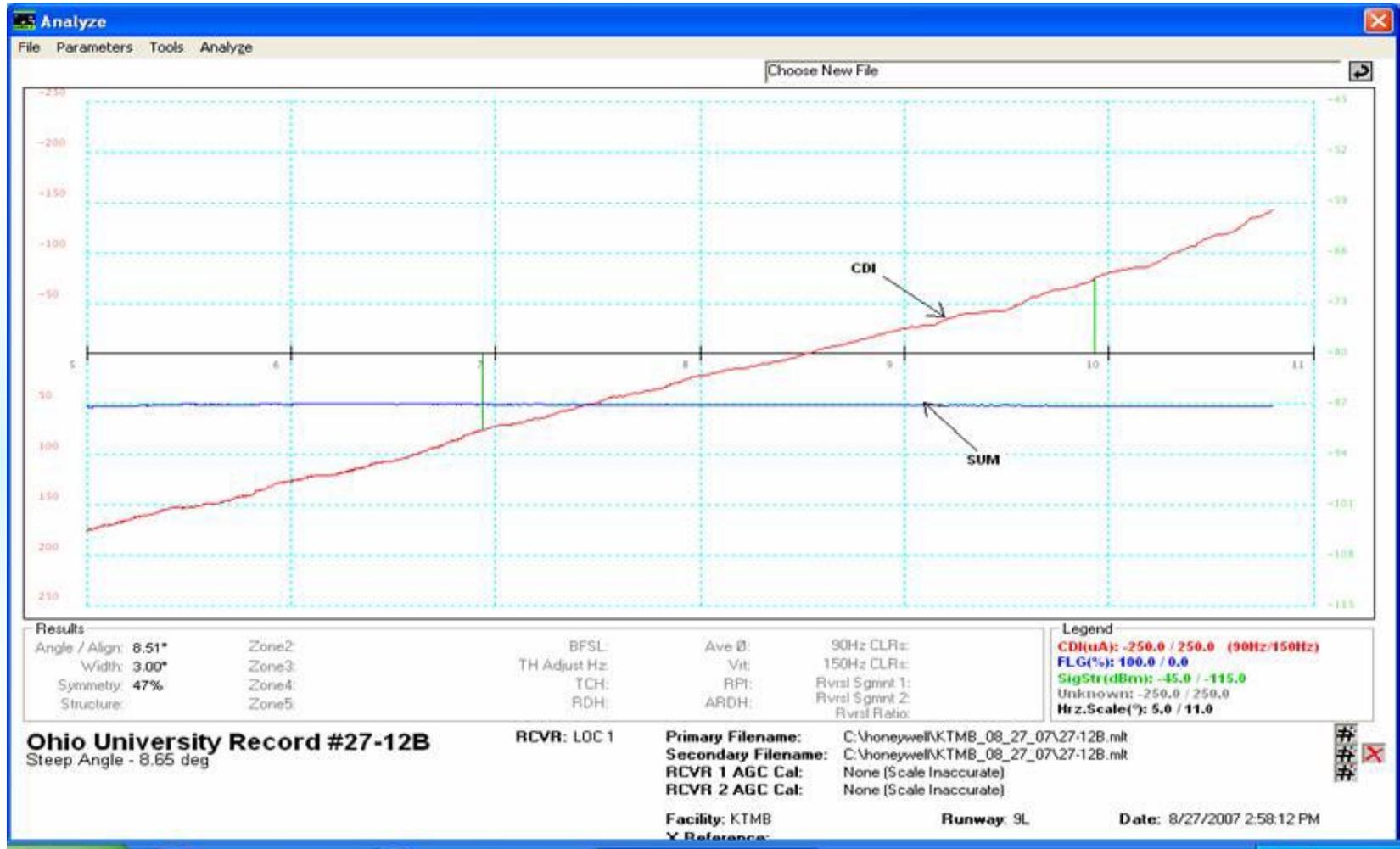
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Proportional Guidance Sector 6.65 Degrees



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Proportional Guidance Sector 8.65 Degrees



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Path Quality Summary

Category	Structure Roughness (μA / % Tolerance / nmi)	
	ILS Zone 2	ILS Zone 3
Path Angle 5.5 Degrees 5/12/07		
	18.2/66.5/2.96	4.5/14.8/0.23
III	16.8/82.5	11.1/59.4/0.20
Path Angle 5.5 Degrees 8/27/07		
I	23.3 / 77.5 / 4.0	5.8 / 15.9 / 0.18
III	19.7 / 96.6 / 0.72	4.8 / 23.9 / 0.18
Path Angle 6.65 Degrees 8/27/07		
I	9.9 / 33 / 0.73	3.8 / 12.7 / 0.09
III	9.9 / 48.5 / 0.73	3.8 / 19.1 / 0.09
Path Angle 8.65 degrees 8/27/07		
I	9.0 / 30.1 / 1.78	8.4 / 27.8 / 0.13
III	8.5 / 42.4 / 0.59	8.4 / 41.7 / 0.13

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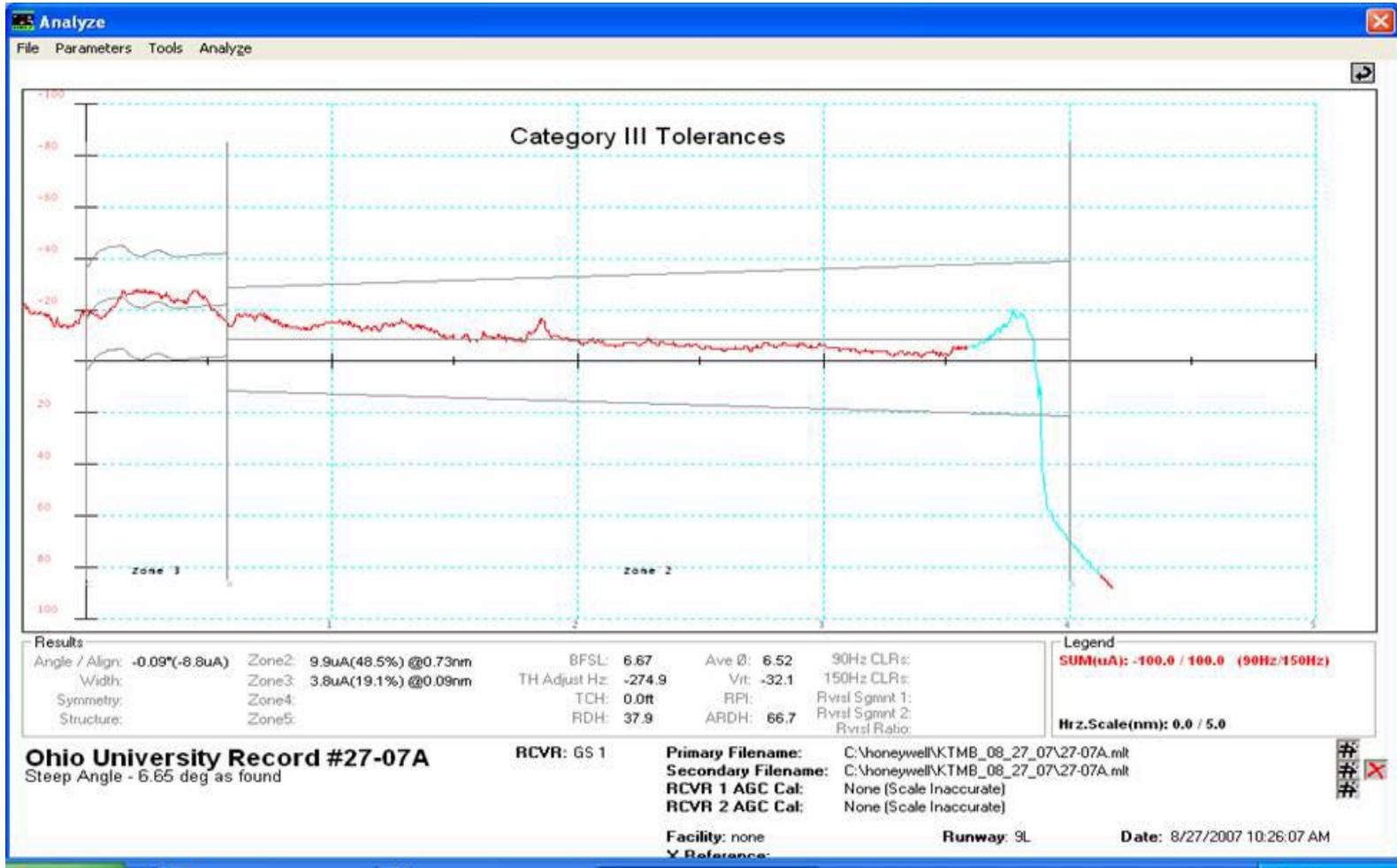
Structure Roughness

5.5 Degrees



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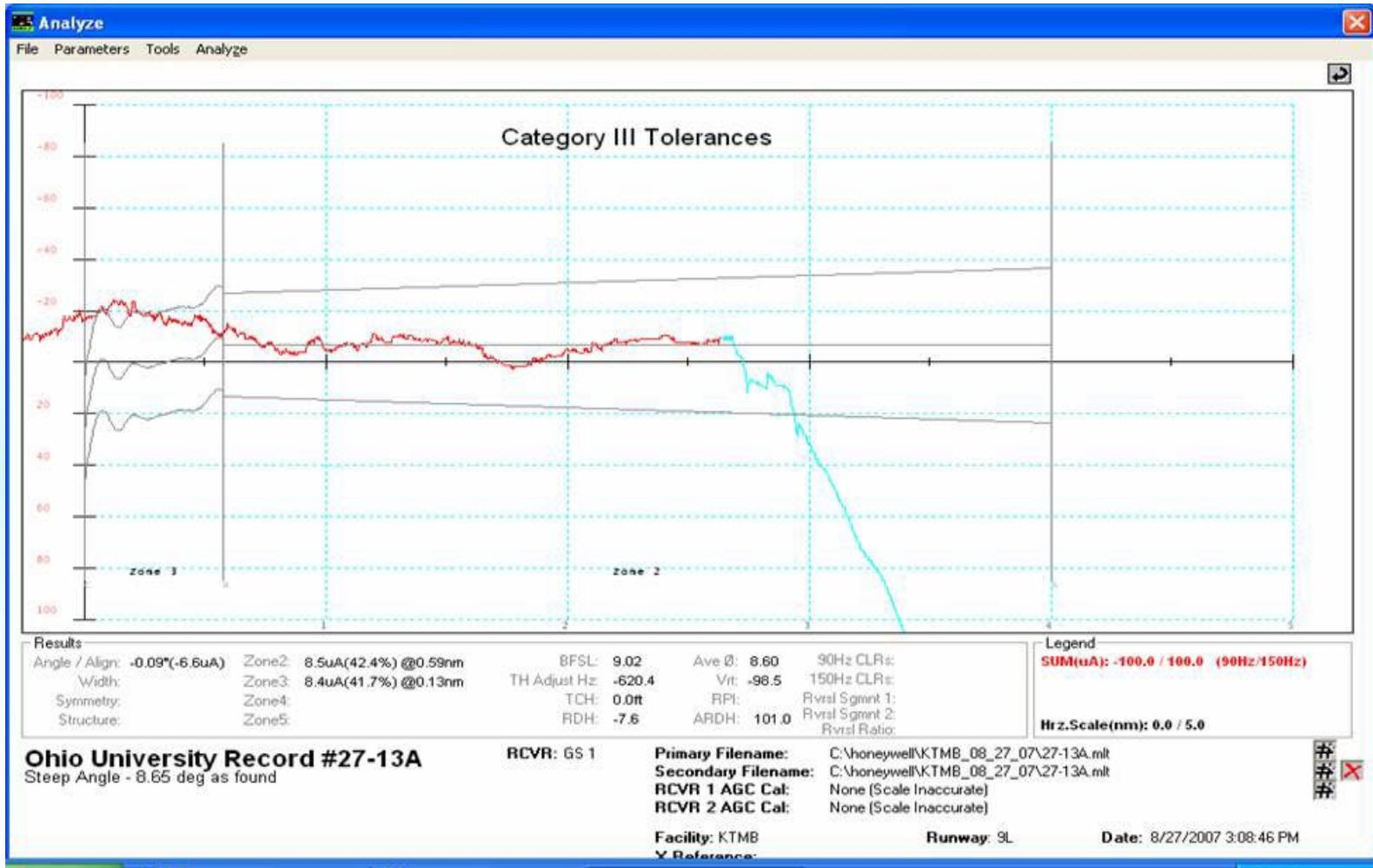
Structure Roughness 6.65 Degrees



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Structure Roughness

8.65 Degrees



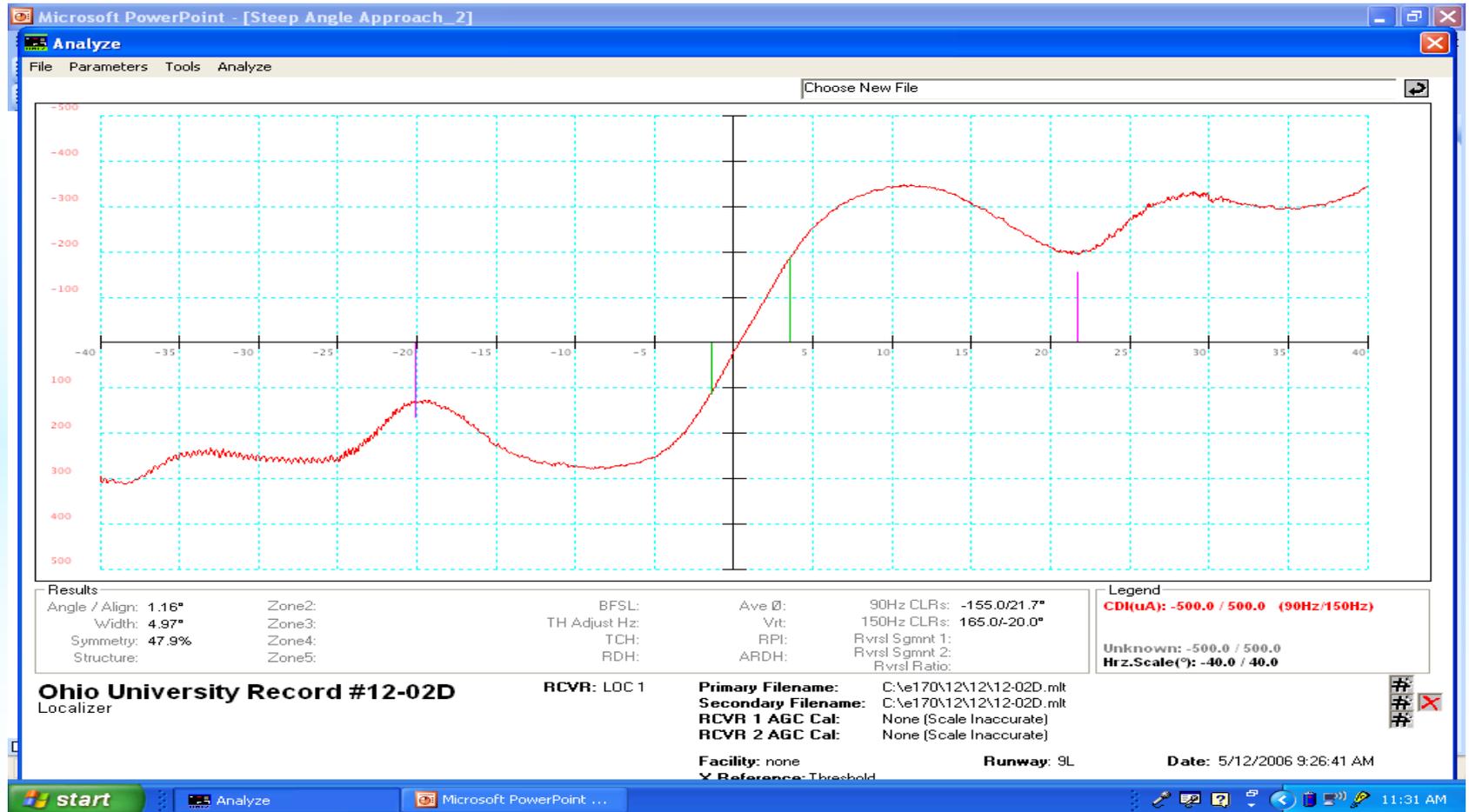
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Summary Localizer Performance

Parameter	Flight Measurement Results	Flight Inspection Tolerance
Width (degrees)	4.97	4.5 - 5.5
Symmetry (%)	48	45 - 55
Minimum Clearance 90 Hz (μ A)	155	150 (minimum)
Minimum Clearance 150 Hz (μ A)	165	150 (minimum)

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Horizontal Sector



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Localizer Performance

ILS Zone	Structure Roughness (μA / % / nmi)	
	Category I	Category III
2	2.6 / 13.6 / 1.46	1.9 / 36.3 / 0.62
3	2.1 / 13.8 / 0.76	3.9 / 52.3 / 0.02
4	N/A	5.4 / 108.3 / 0.42
5	N/A	2.9 / 36.9 / 0.59

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Course Quality



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Equipment Consideration

– Path Angle Change

- CEGS/M-Array:
 - » Antenna heights
 - » UA- amplitude/phase change
 - » LA-amplitude/phase change
 - » Snow accumulation
- SBR:
 - » Antenna heights
 - » UA-amplitude change
 - » LA-amplitude change
 - » Snow accumulation
- EFGS:
 - » Pedestal displacement
 - » Phase change [F-R]

Null Reference

– Path Angle Change

- Upper Antenna Height [0.01° per 1"]
 - Verified height with tape measure
- Snow Accumulation

Path Roughness

- Aircraft on Taxiways
 - No taxiways near mast
- Terrain Modification
 - Visual inspection
- SBO CSB Power Ratio
 - Test equipment

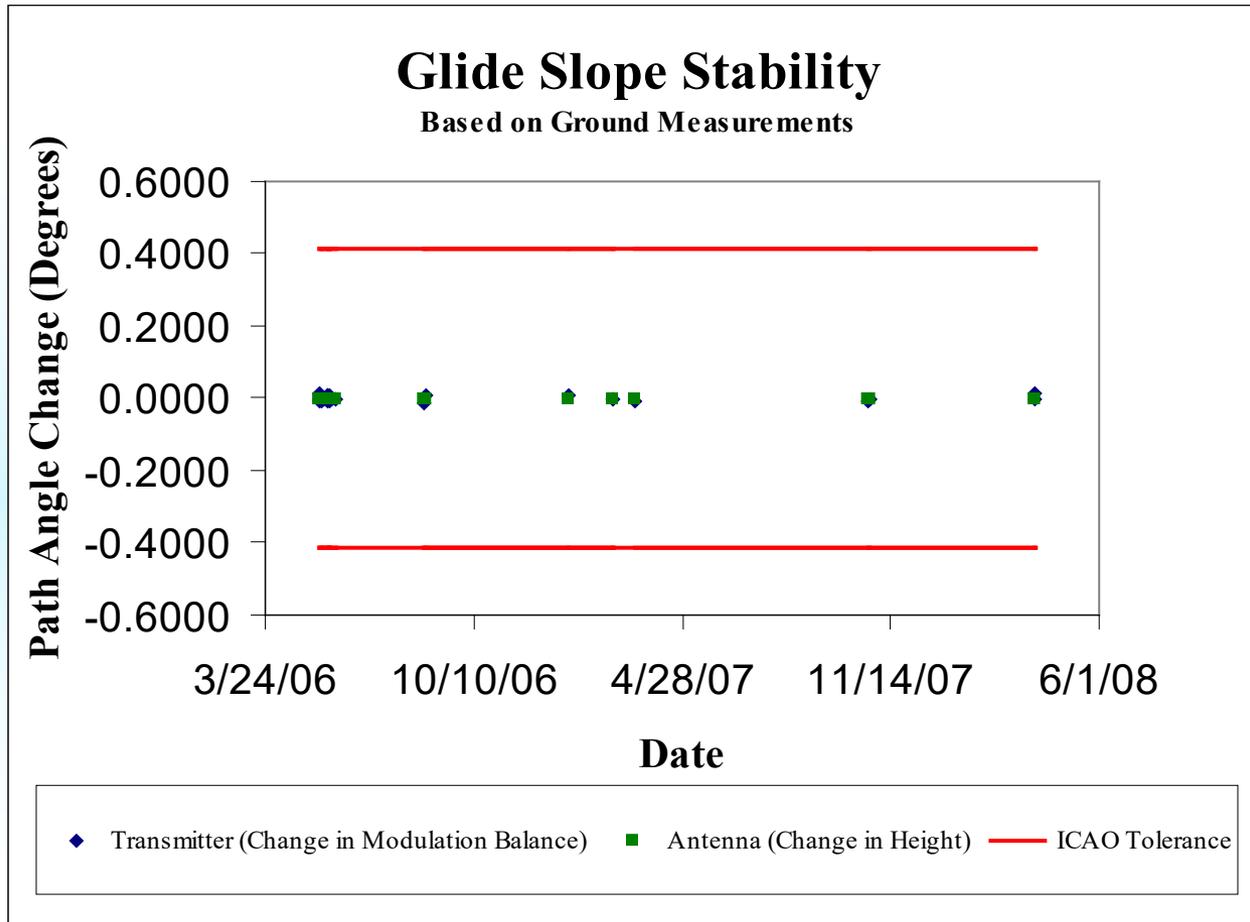
8-Element Array

- Course Alignment Change
 - Phase change in antenna cable or DU
 - Verified with ground checks
 - Modulation Balance [0.001 DDM=> 2.3' at threshold]
 - Verified using calibrated external equipment
- Structure Roughness
 - Constant
 - No change to environment [buildings/parked aircraft] in front of array
 - » Visual inspection
 - No change in CSB/SBO power ratio
 - » Verified using thru-line elements

Signal Verification

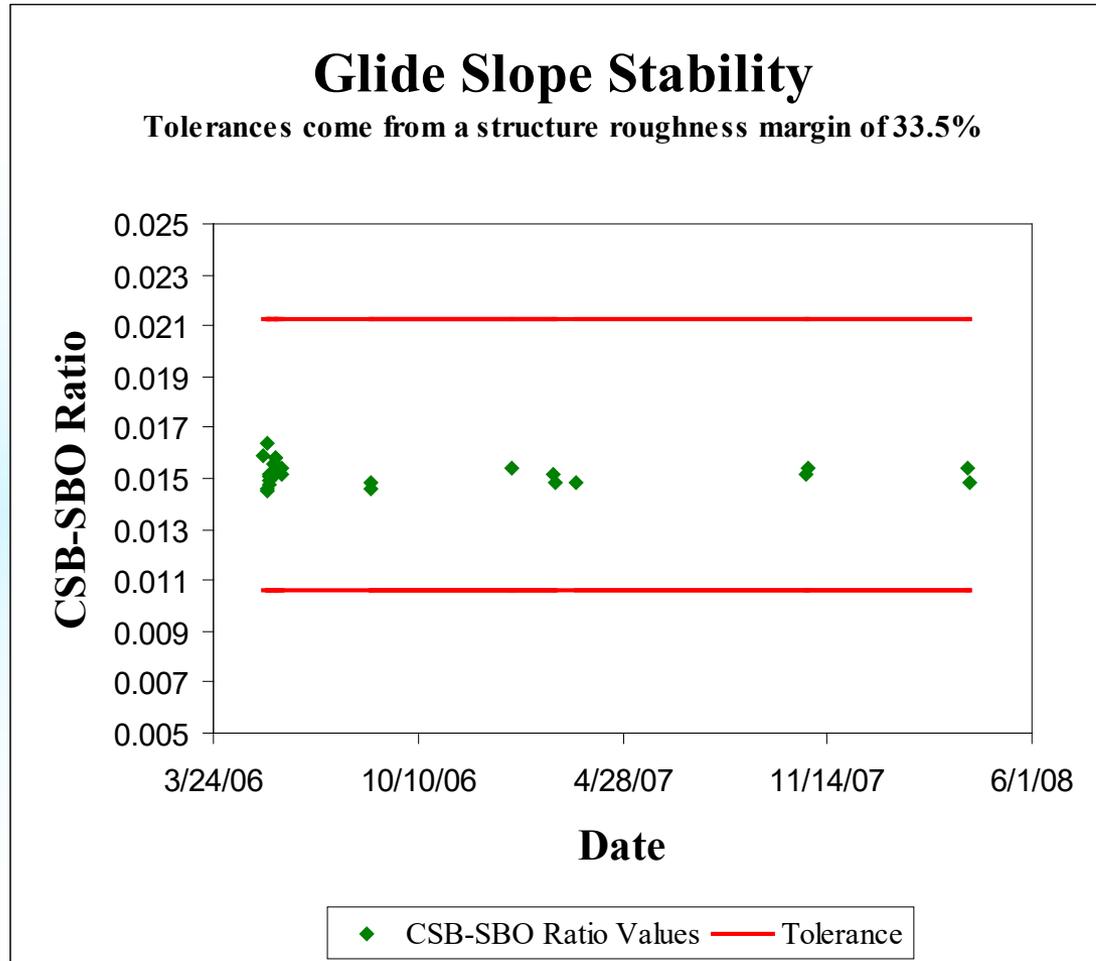
- Based on ground measurements
 - Transmitter output power & modulation
 - In-line phase
 - GS antenna heights
 - Localizer ground checks (CL, width points)
 - Taken pre & post mission

Path Angle Stability



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Structure Roughness



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Conclusions

- Localizer & Glide Slope remained within tolerances during all certification flights.
- Based on reference readings (antenna height); angle remained within 0.00015-degrees.