FAA EDR Performance Standards

Project Summary and Recommendations

Presented To:

Turbulence Workshop - 2

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Outline

- Background
- Project Team / Key Stakeholders
- Final Report
- Process
  - Winds
  - Statistical Analysis
- Variability Analysis
- Performance Recommendations
- Follow-on Recommendations

Background

- EDR is a calculated. There are multiple computational algorithms employing a variety of parametric data from diverse aircraft avionics.

Airline	Type	Method	Count
American and others	B737-800, B757-200 B767-300, A320, A321, A330-300	Vertical Acceleration	500+
Delta	B737NG, B767	Vertical Wind	167
Southwest	B737-700, B737NG	Vertical Wind	156
United	B757 (EDR equipped B737 no longer in fleet)	Vertical Acceleration	54 (reducing to 15 by Dec 31, 2015)
Regional Airlines via TAMDAR	SAAB 340, ERJ-145, ERJ-190, ERJ-195, Beech 1900C, Dash 8 (Q-100, Q-300, Q-400)	Longitudinal Wind (via TAS)	256
		Total:	***1133***

- Aviation Rulemaking Committee and RTCA have recommended that EDR performance standards be established.

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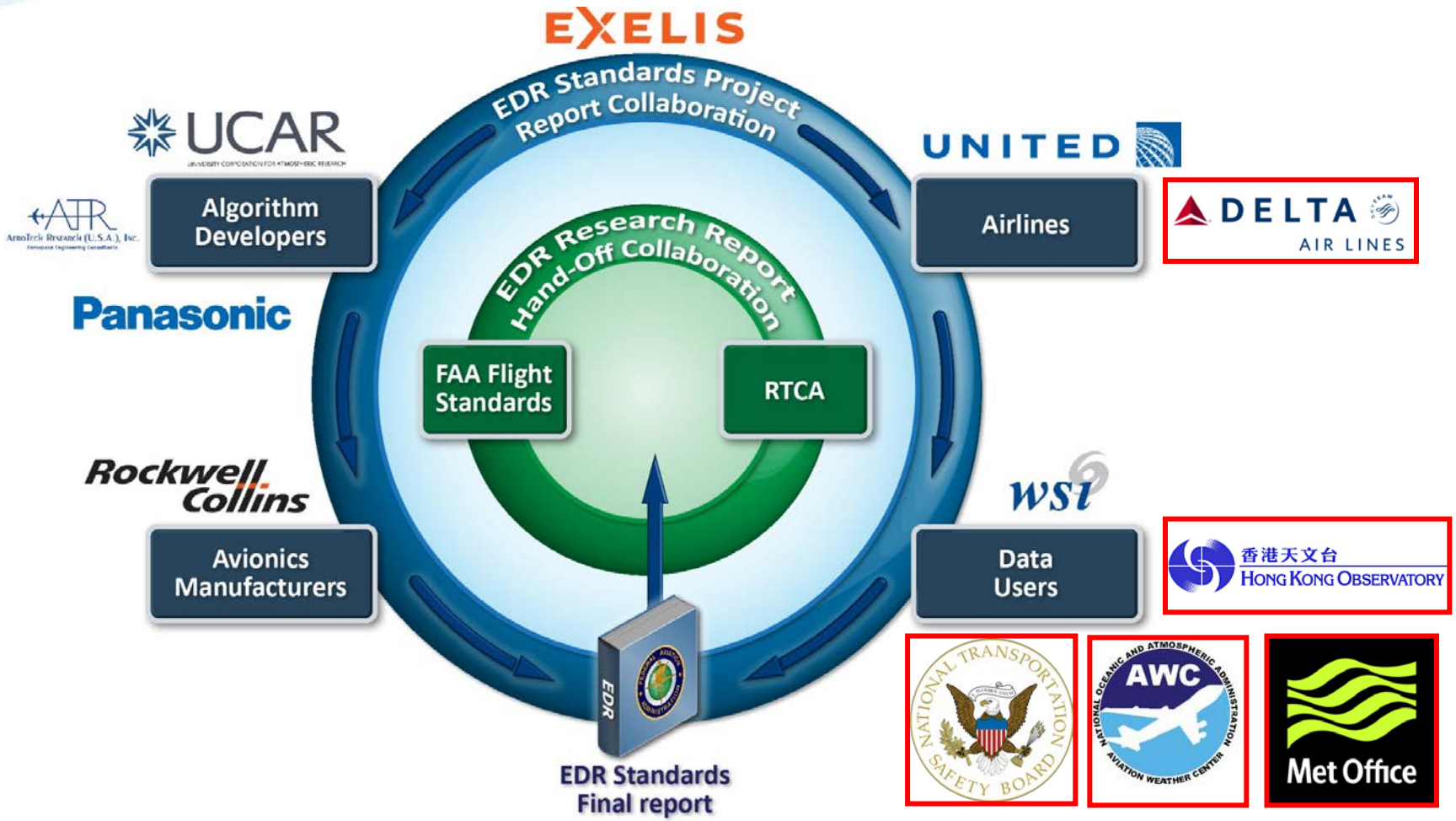
Project Team and Key Stakeholders



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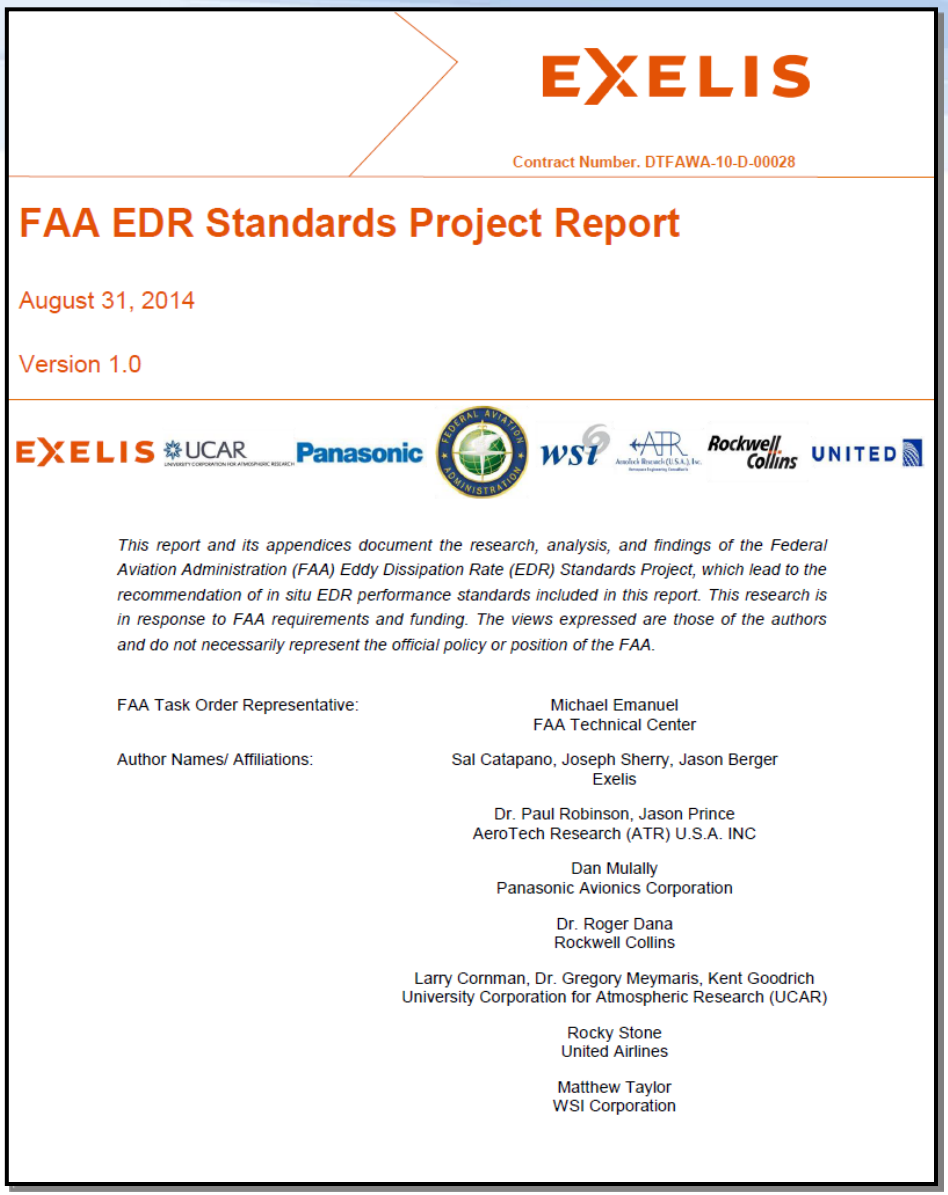
Final Report

- Delivered to FAA August 31, 2014
- To be briefed in detail to RTCA SC-206
- Distribution method is still TBD
- DOES NOT score implementation approaches



EXELIS

Contract Number. DTFAWA-10-D-00028

FAA EDR Standards Project Report

August 31, 2014

Version 1.0

EXELIS UCAR Panasonic wsi Rockwell Collins UNITED

This report and its appendices document the research, analysis, and findings of the Federal Aviation Administration (FAA) Eddy Dissipation Rate (EDR) Standards Project, which lead to the recommendation of in situ EDR performance standards included in this report. This research is in response to FAA requirements and funding. The views expressed are those of the authors and do not necessarily represent the official policy or position of the FAA.

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Standards Research Process

Wind Datasets
Create Wind Datasets to Drive Process

Algorithm Inputs
Generate *In Situ* Algorithm Inputs in Simulated Pseudo Operational Environment

EDR Expected Values
Determine/Estimate EDR Expected Values

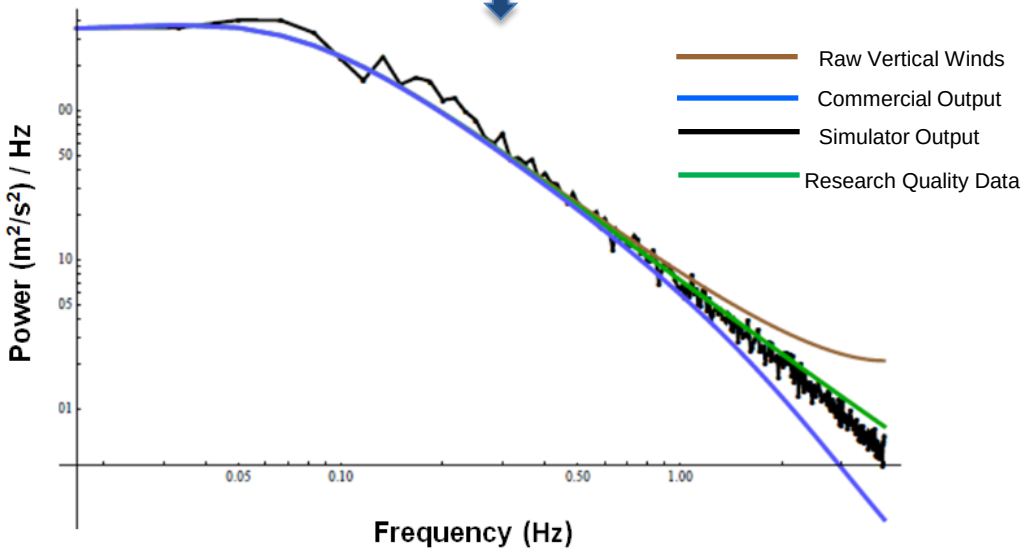
Pseudo Operational Runs
Perform Pseudo Operational Runs to Calculate *In Situ* EDR

Statistical Analyses
Perform Statistical Analyses to Determine Today's *In Situ* EDR Performance

Performance Objectives
Identify User Performance Objectives for *In Situ* EDR

Performance Thresholds
Recommend *In Situ* EDR Performance Thresholds

Input Winds → Flight Simulation → Sensor Noise Characteristics → Filtering → Quantization → Resampling → EDR Algorithms



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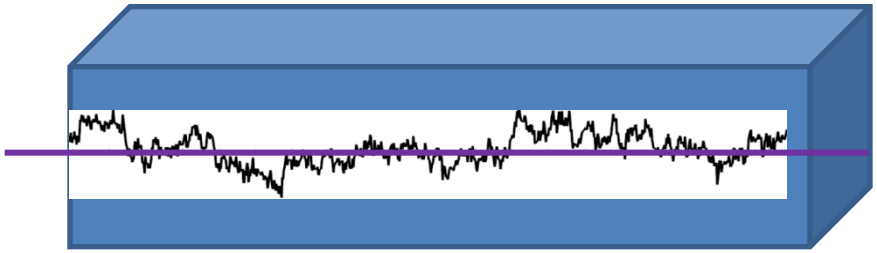
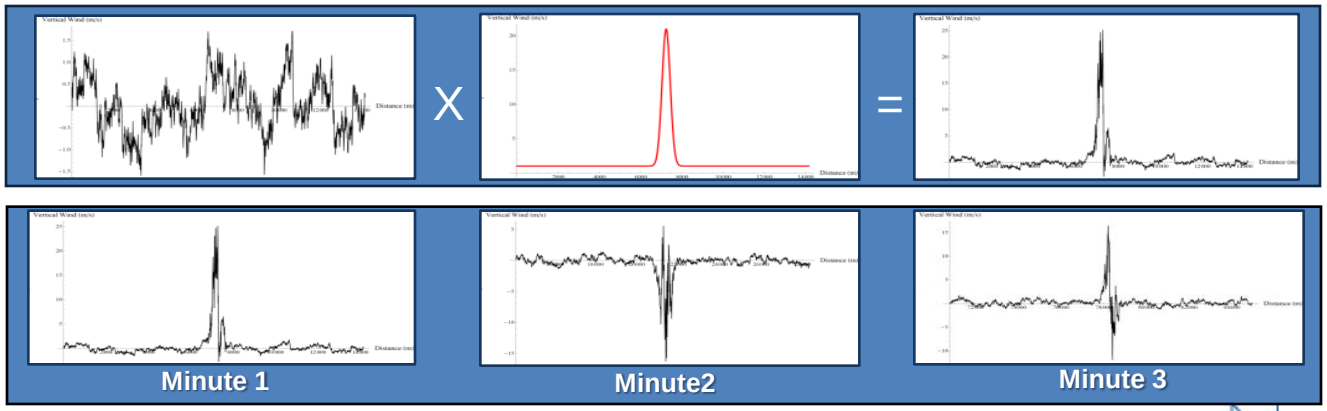
Input Winds

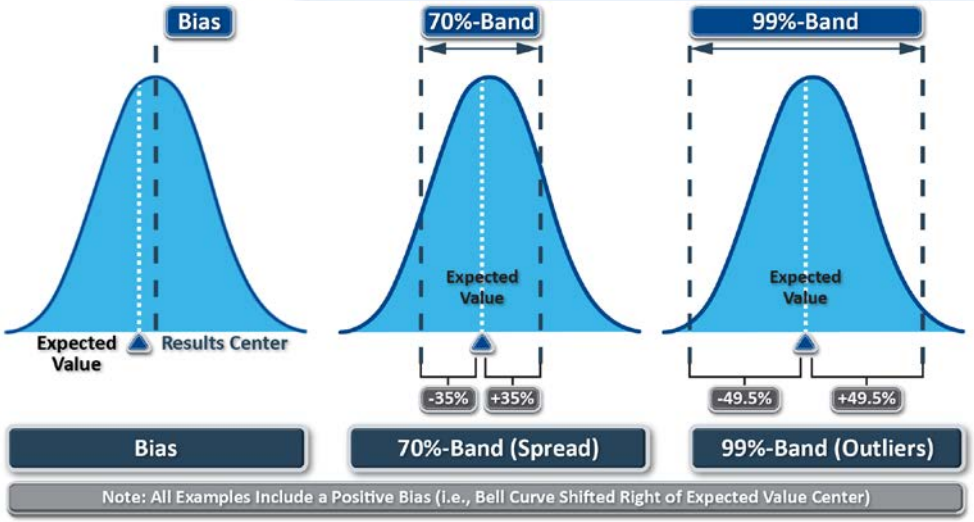
- Homogenous – *exercise <u>mean</u> EDR*
  - Maintains single EDR on average throughout wind dataset (e.g. 0.5 EDR)

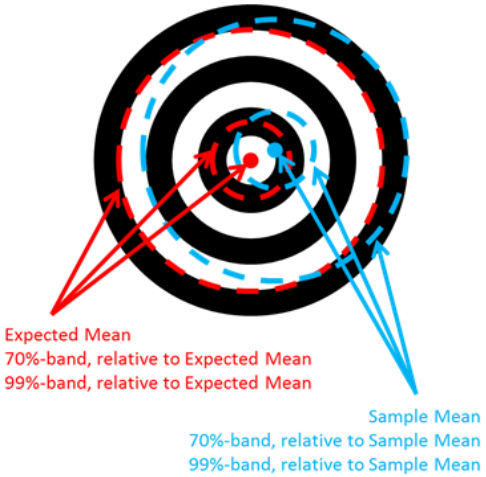


- Non-Homogenous – *exercise <u>peak</u> EDR*
  - Simulate “burst” of turbulence embedded in background field of ambient turbulence

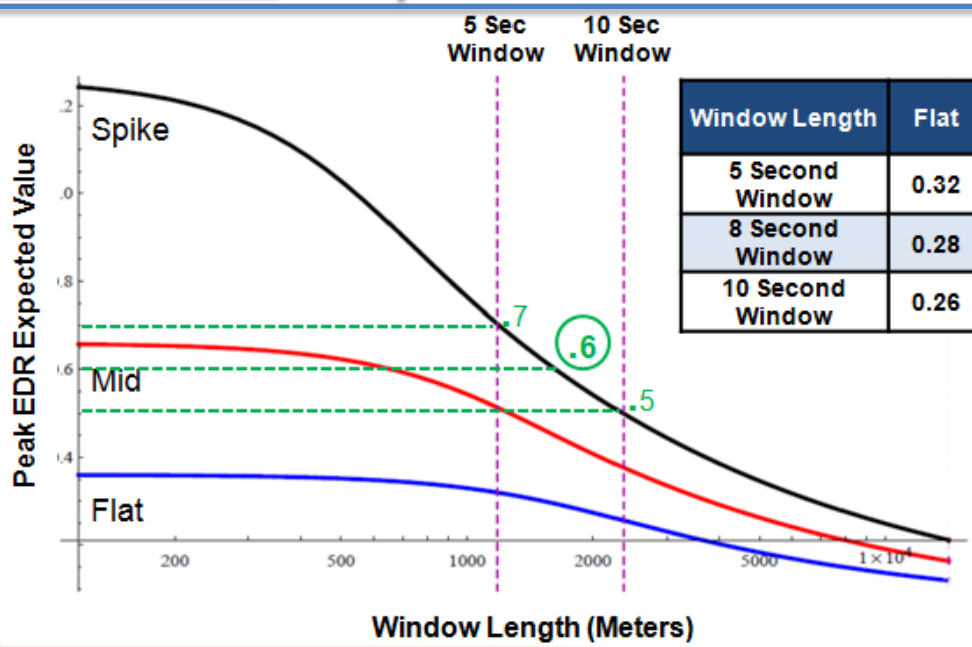


Performance Standard Framework





- Framework centers, tightens, and bounds performance
- Mean EDR
  - Bias normalized to expected mean; tolerance bands normalized to sample mean
- Peak EDR
  - Bias normalized to "Representative" Expected mean; Tolerance bands normalized to sample mean



Window Length	Flat	Mid	Spike
5 Second Window	0.32	0.51	0.70
8 Second Window	0.28	0.42	0.56
10 Second Window	0.26	0.38	0.50

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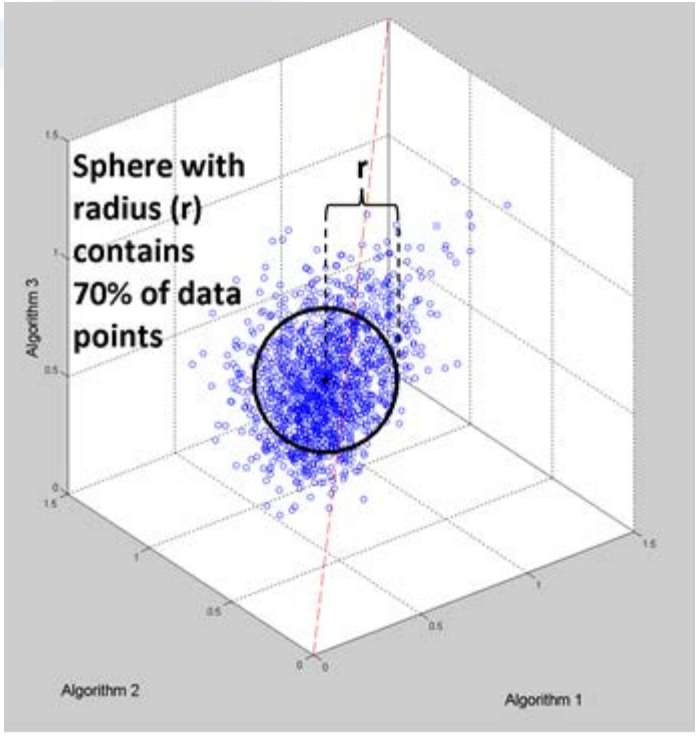
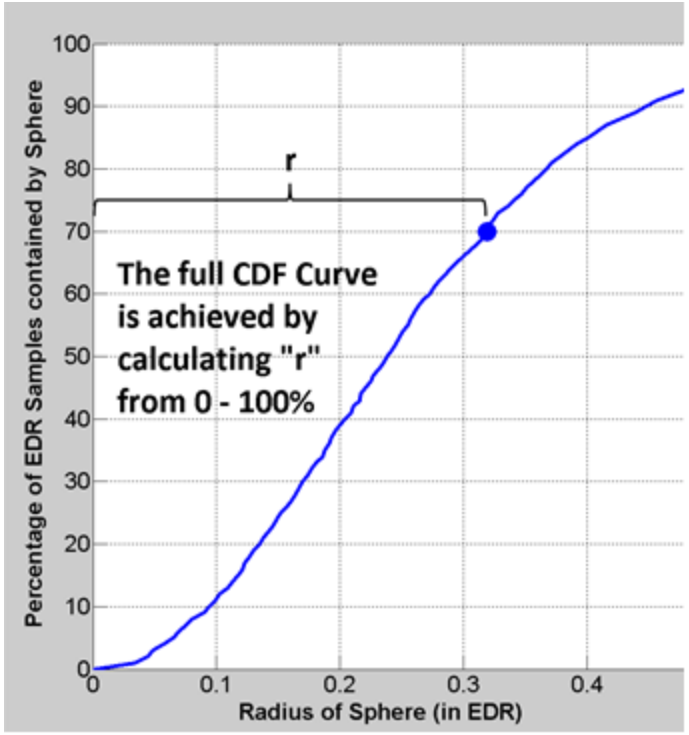
Variability Analysis



Scatter Plot of Results

Parameters
Input Type
Window Length
Window Function
Window Overlap
Lower Cutoff Wavenumber
Upper Cutoff Wavenumber

Algorithm Components



Consistency Performance Curve

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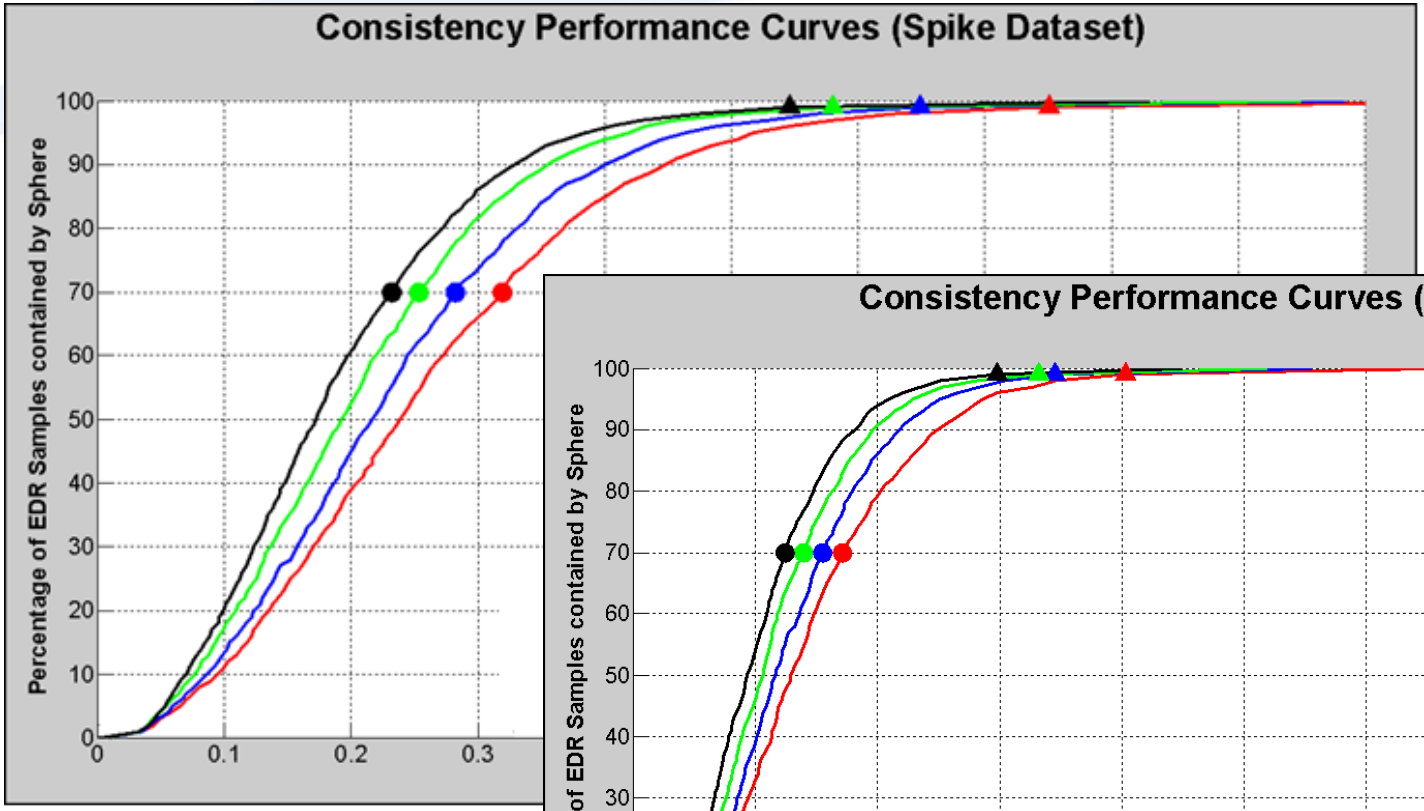
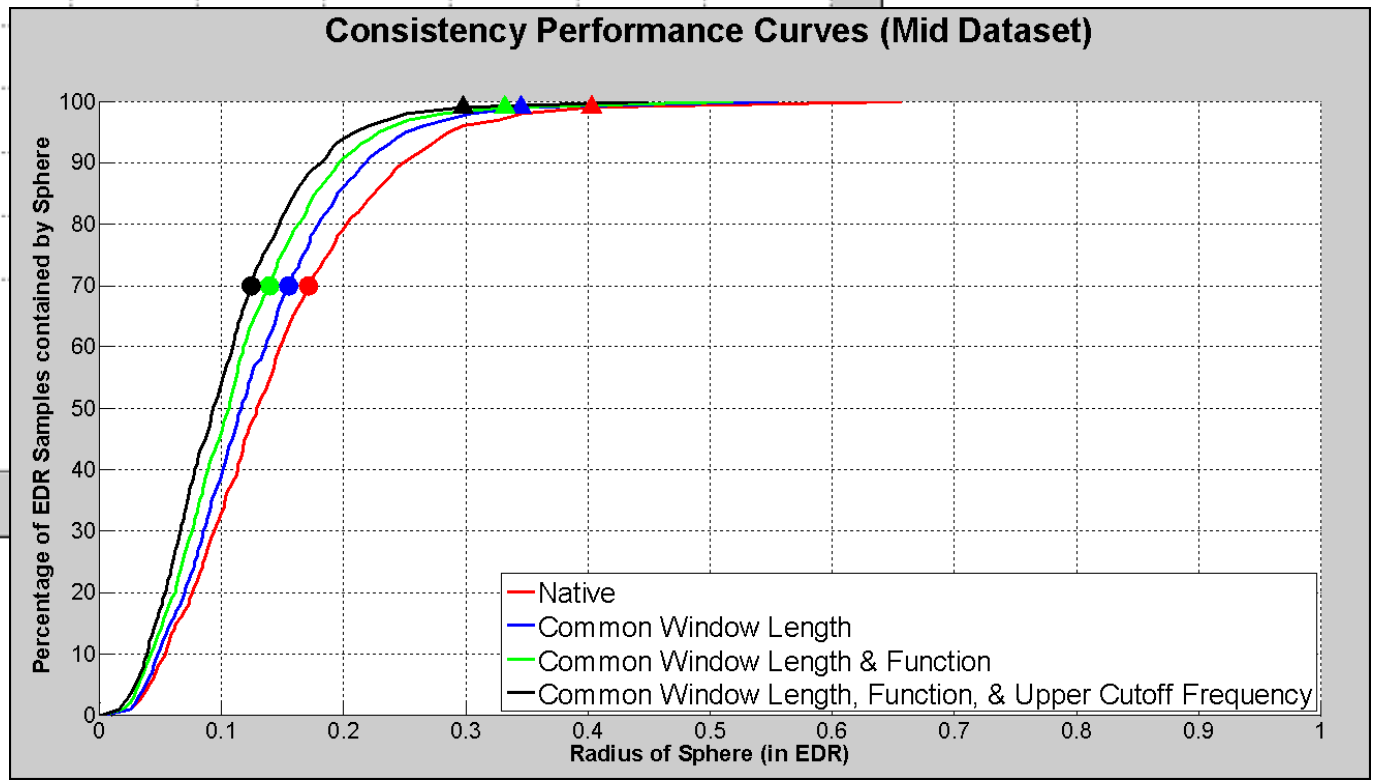
Consistency Improvement Potential





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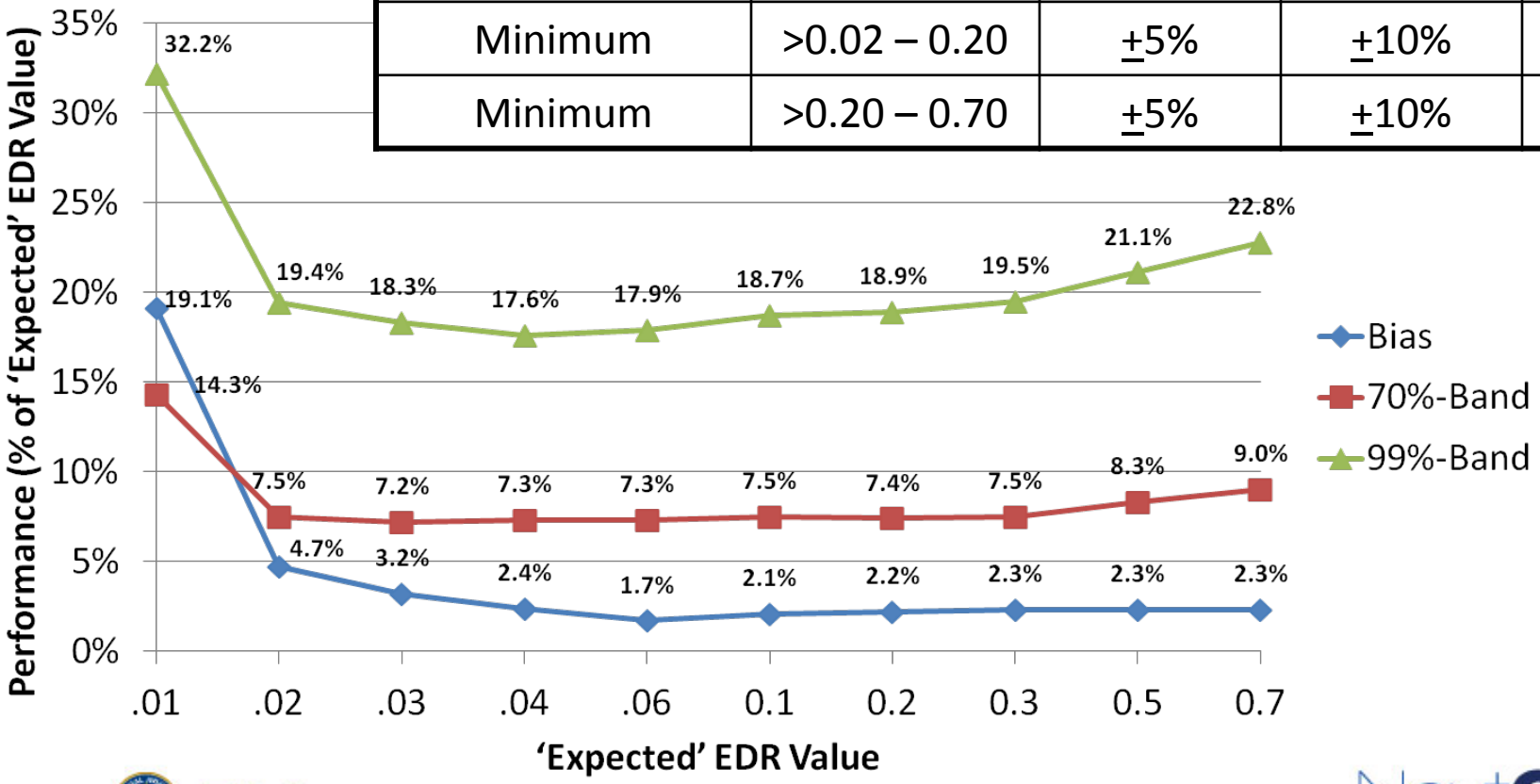
Mean EDR Recommendations

Performance Category	EDR Range	Bias	70%-band	99%-band
Supplemental	0.01 - 0.02	±5%	±10%	±20%
Minimum	>0.02 – 0.20	±5%	±10%	±20%
Minimum	>0.20 – 0.70	±5%	±10%	±25%



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Peak EDR Recommendations

Metric	Current Performance (FLT)	Current Performance (MID)	Current Performance (SPIKE)
[1]Bias	±15.6%	±18.3%	±23.2%
[2]70%-band	±23.8%	±26.9%	±35.7%
[2]99%-band	±65.6%	±69.2%	±82.9%

Metric	Recommended Standard (FLT)	Recommended Standard (MID)	Recommended Standard (SPIKE)
[1]Bias	±20%	±20%	±25%
[2]70%-band	±25%	±30%	±40%
[2]99%-band	±70%	±70%	±85%

[1]Bias is normalized to the "representative" expected value

[2] 70% and 99% bands are normalized to the "window length specific" expected value

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Follow-on Recommendations

- Performance standard adoption
  - Validate *in situ* recommendations
  - Determine how compliance will be enforced
- Define operational requirements
  - Pursue broad ConOps for EDR
  - Perform application specific sensitivity analyses
- Continue variability analyses
  - Research additional algorithm components
  - Define parameter values for all components
- Pursue additional research into the science of EDR
  - Analyze impact of distorting assumptions
  - Define an approach to develop vertical EDR profiles
- Consider non-*in situ* EDR performance standards

Leverage momentum of Project Team's Success

Follow-on activities MUST have operational significance and benefit

Questions?

Back-up Slides

Turbulence Intensity Thresholds

Org	Year	Aircraft Category	Flight Level	*In Situ* EDR Thresholds			
				Null	Light	Moderate	Severe
ICAO	2001	Medium Transport	En Route	0.0 to <0.1	0.1 to 0.3	>0.3 to 0.5	>0.5
ICAO	2007	Medium Transport	En Route	0.0 to 0.1	>0.1 to 0.4	>0.4 to 0.7	>0.7
UCAR (EDR)	2011	Medium Transport	En Route	0.05	0.15	0.25	0.45
UCAR (GTG 2.0)	2011	Medium Transport	En Route	0.0	0.3	0.475	0.8
UCAR (GTG 2.5)	2011	Medium Transport	En Route	0.0	0.15	0.31	0.54
HKO	2010	Heavy Transport	Low-Level	----	<0.3	0.3 to <0.5	≥0.5

In situ EDR Algorithms

NCAR Vertical Acceleration-Based

Input: TAS, Altitude, Vertical Acceleration, Weight, Frequency Response, Mach, Flap Angle, Autopilot Status, QC Parameters

Users: United Airlines

Windowing: 10 sec window every 5 sec

Average Calc: Arithmetic mean over 1 min

Peak Calc: 95th percentile over 1 Minute

Accelerometer-Based

Input: TAS, Altitude, Vertical Acceleration, Weight, Frequency Response

Users: American Airlines, others

Windowing: 5 sec running window

Average Calc: N/A

Peak Calc: Largest EDR in 30 seconds

NCAR Vertical Wind-Based

Input: TAS, Altitude, Inertial Vertical Velocity, Body Axis AoA, Pitch Rate, Pitch, Roll Angle, QC, Filter Parameters

Users: Delta and Southwest Airlines

Windowing: 10 sec running

Average Calc: Median over 1 min

Peak Calc: Largest EDR over 1 minute

Panasonic Longitudinal Wind-Based

Input: TAS, Roll Angle for QC, TAMDAR Icing for QC (if using TAMDAR Sensor)

Users: TAMDAR - Regional Airlines

Windowing: 9 sec window

Average Calc: 1, 3, 7min; 300, 1500ft

Peak Calc: Largest EDR in 1, 3, 7min; 300, 1500ft

Implementation Details

Algorithm	Required Inputs				
ATR Algorithm Accelerometer-based	TAS	Altitude	Vertical Acceleration	Weight	Freq. Response
NCAR Algorithm Vertical acceleration-based	TAS	Altitude	Vertical Acceleration	Weight	Freq. Response
	Mach	Flap Angle	Autopilot Status	Parameters for Quality Control Algorithms	
NCAR Algorithm Vertical wind-based	TAS	Altitude	Inertial Vertical Velocity	Body Axis AoA	Pitch Rate
	Pitch	Roll Angle	Quality Control	Filter Parameters	
TAMDAR Algorithm Longitudinal wind-based using TAMDAR Sensor	TAMDAR TAS		Roll Angle for quality control (TAMDAR calculated)	TAMDAR Icing for quality control	
TAMDAR Algorithm Longitudinal wind-based using aircraft bus data	Bus TAS		Roll Angle for quality control (TAMDAR calculated)		

Algorithm	Required Sensors					
ATR Algorithm Accelerometer-based	Body-Axis Vertical Accelerometer					
NCAR Algorithm Vertical acceleration-based	Body-Axis Vertical Accelerometer	Static Pressure	Dynamic Pressure	Outside Temperature	Flap Position	
NCAR Algorithm Vertical wind-based	Attitude and Attitude Rate	Static Pressure	Dynamic Pressure	Outside Temperature	Accelerometer	AoA Vanes
TAMDAR Algorithm Longitudinal wind-based using TAMDAR sensor	TAMDAR dynamic pressure (10.67 Hz)		TAMDAR Static Pressure or bus data	TAMDAR outside air temperature or bus temperature	TAMDAR roll calculated from GPS track, TAS and ext. bus heading	
TAMDAR Algorithm Longitudinal wind-based using aircraft bus data	Bus TAS (based on aircraft static and dynamic pressure, and temperature		TAMDAR roll calculated from GPS track, TAS and ext. bus heading.			