Aerospace Testing EXPO2005

Method for Category III (a) Autoland Performance Check

Hamburg Messe, Germany
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- Objective
- Introduction
- Standard Procedures
- Methods Description
- Analysis and Results
- Conclusion

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■ Objective

Present a method for longitudinal and lateral distance determination for the Category III (a) Autoland touchdown performance evaluation.

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■ Introduction

- Difficulties for DGPS antennas installation when conducting flight test on airports outside Brazil due to EMI/EMC polices restriction;

- Runway survey in order to get runway equations for data reduction is not practical in some airports

- Time and cost savings;

- Accuracy and precision shall be enough to allow adequate correlation with Monte Carlo Simulation.

- Two Methods for touchdown performance evaluation and crosscheck (one will be backup once proved equivalence);

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Standard Procedures

- DGPS
- Glideslope/Localizer signals
- Belly Camera.
- WAAS

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Methods Description

- Two Methods were developed for the Autoland Performance Check with crosscheck/backup purposes:

  - Method I: FPA Corrected Category III (a) Autoland Peformance Check
  - Method II: Airport Aids Category III (a) Autoland Performance Check

- DGPS was (and is still being) used for method validation (only some Brazilian Airports)

- Belly Cam will be available for all flights in order to sort out doubts as necessary (in case of Certification request)

Method I

- This method is a Visual Basic based program using the Excel with DDE (Dynamic Data Exchange) feature for feeding data on the required input strings for real time calculation.

- Program Features:
  - Airport Database
  - Parameters Setting
  - Results Summary Table
  - Longitudinal and Lateral Distance Graphic
  - Touchdown Rate Graphic
  - Runway Localizer Beam Survey Plot

■ Method I

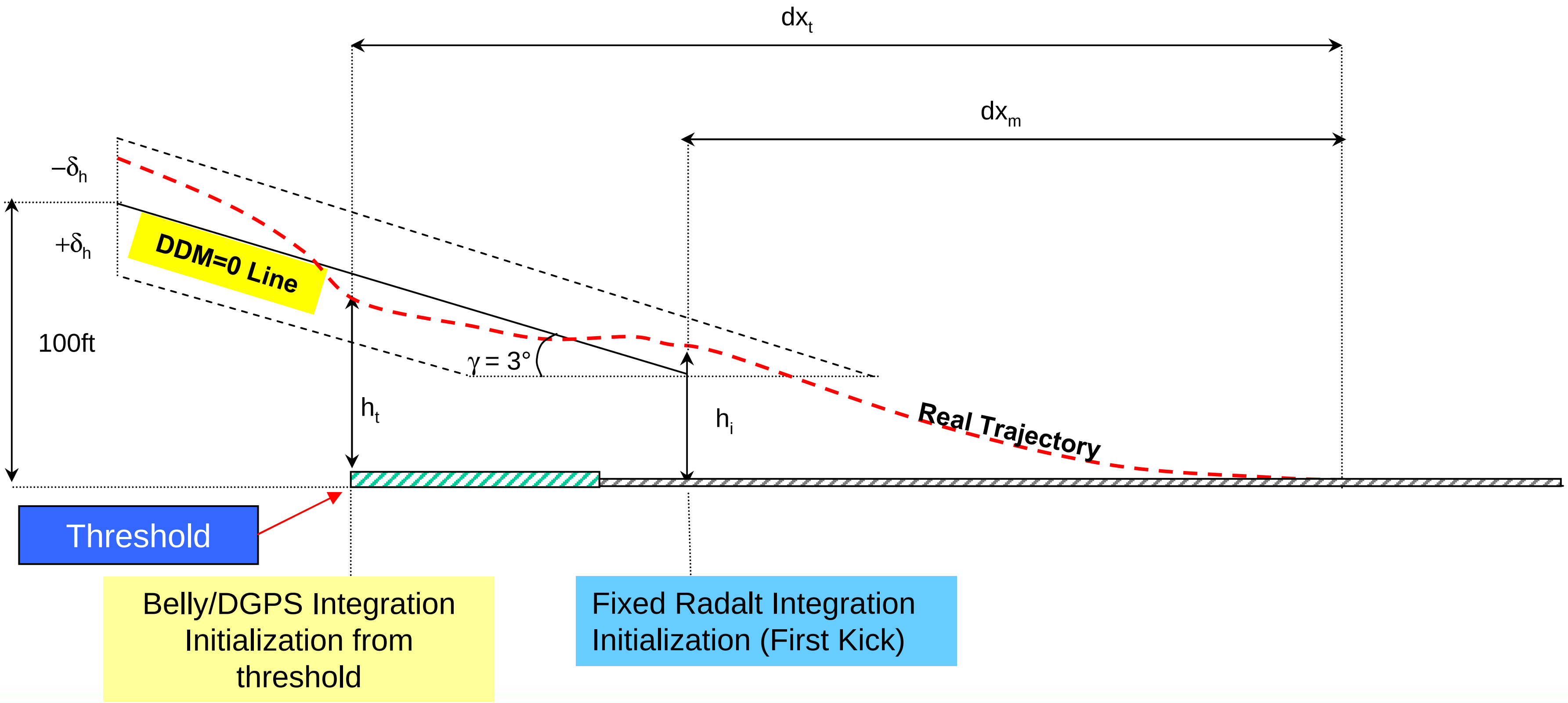
- <u>Calculation</u>: Longitudinal Distance (dx)
  - Integrates the distance from the initialization point.
  - Some main questions to be answered:
    - What should be the initialization triggering point?
    - How to determine this point?
    - How is the expected accuracy in order to have an adequate correlation to the Monte Carlo simulation?

Method I

- **Calculation: Longitudinal Distance (dx)**
  - **Fixed Radalt**

h_t : Real Threshold Height

h_i : Initial Estimated Height



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▪ Method I

- Calculation: Longitudinal Distance (dx)
  - Fixed Radalt
    - Whenever $h_t \neq h_i$ longitudinal distance error will be $dx_t - dx_m$
    - How to set h_i in order to minimize error since h_t is unknown?
  - Some boundary or relevant conditions:
    - δh (100ft) $\in$ [-12,12]ft, otherwise aircraft would get Excess Dev. (AC 120-29A)
    - Autoland Control law will shift to the 3° flight path angle command between 100ft and 50ft
    - Keeping the 3° FPA between 100ft and 50ft will keep the aircraft parallel to the glideslope DDM=0 line, i.e. within [-12,12]ft.
    - Aircraft does not necessarily fly a perfect parallel FPA trajectory from the DDM=0 Line
    - Flare Control Law initiates at 50ft

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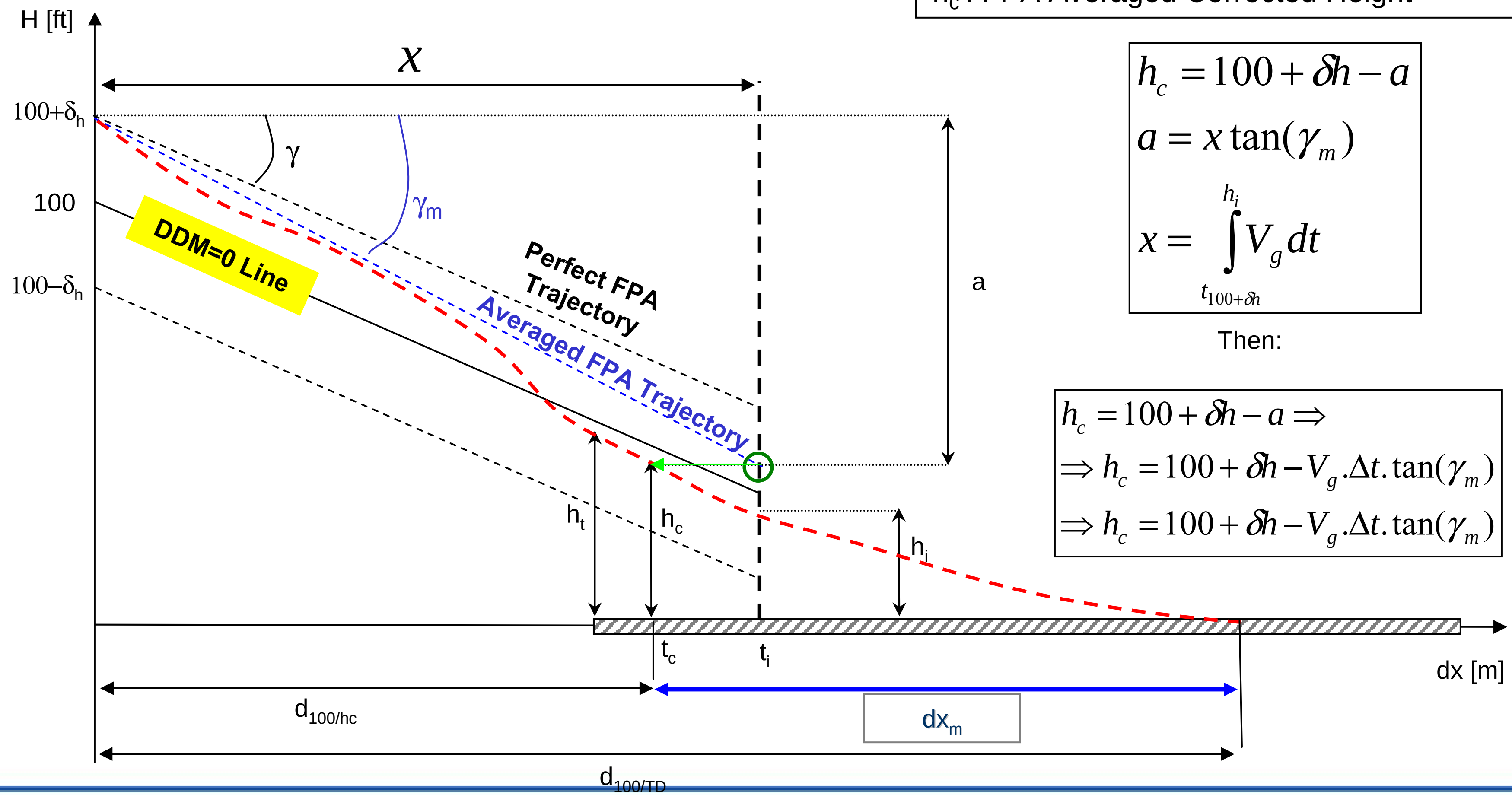
■ Method I

- Calculation: Longitudinal Distance (dx)

h_t : Real Threshold Height

h_i : Initial Estimated Height

h_c : FPA Averaged Corrected Height



$$h_c = 100 + \delta h - a$$
$$a = x\tan(\gamma_m)$$
$$x = \int_{t_{100+\delta h}}^{h_i} V_g\,dt$$

Then:

$$h_c = 100 + \delta h - a \Rightarrow$$
$$\Rightarrow h_c = 100 + \delta h - V_g.\Delta t.\tan(\gamma_m)$$
$$\Rightarrow h_c = 100 + \delta h - V_g.\Delta t.\tan(\gamma_m)$$

Method I

- <u>Calculation</u>: Longitudinal Distance (dx)

  - t_i is the moment when the aircraft reached h_i
  - h_c is calculated from averaged FPA along with the trajectory
  - The instant t_c is obtained through a routine which looks for the moment when the aircraft reached the height h_c
  - In the same way, distance $d_{100/hc}$ is calculated from the moment when the aircraft reached $100 \pm \delta_h$ to h_c.

  - <u>But</u>: still missing the calculation of δ_h.

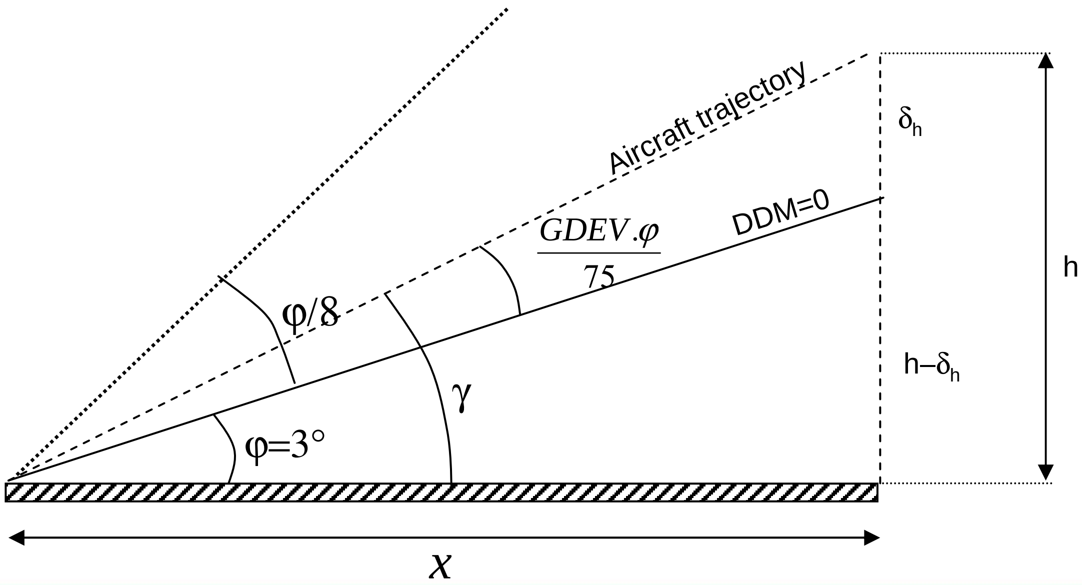
Method I

- Calculation: Longitudinal Distance (dx)
    - Consider the figure below:
    - ICAO Annex 10

$$\tan(\gamma) = \frac{h}{x}$$

$$\tan(\varphi) = \frac{h - \delta h}{x}$$

$$\frac{h}{\tan(\gamma)} = \frac{h - \delta h}{\tan(\varphi)} \Rightarrow \delta h = \left[1 - \frac{\tan\varphi}{\tan\gamma}\right] h$$



Method I

- **Calculation: Longitudinal Distance (dx)**

  - **For 75uV, we have 0.175/2 DDM which is φ/8 (ICAO)**

    But γ = φ + (GDEV/75).(φ/8) (from the drawn)

  - **Finally:**

$$\delta h = \left[1 - \frac{\tan\varphi}{\tan\left(1 + 0.125.\frac{GDEV}{75}\right).\varphi} \right] h$$

Method I

- Calculation: Longitudinal Distance (dx)
  - Propose: Fixed Radalt with FPA trajectory estimation (Cont.)
    - Calculate the longitudinal distance from (100ft + δ_h) RA point to the touchdown point;
    - Calculate the longitudinal distance as being:

$$dx_m = d_{100/TD} - d_{100/hc}$$

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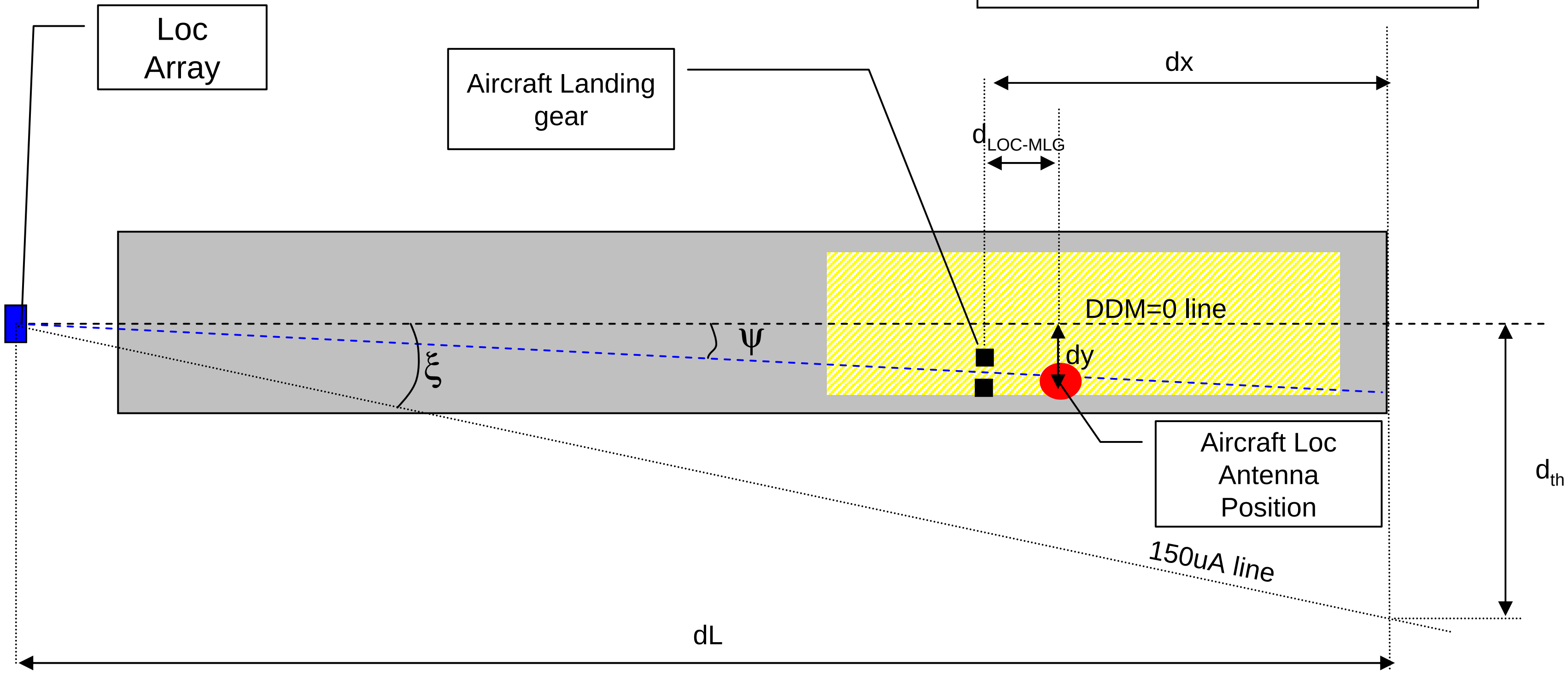
■ Method I

- Calculation: Lateral Distance (dy)

$$\psi = LOCDEV.\frac{\xi}{150}$$

$$\tan(\xi) = \frac{d_{th}}{dL} \Rightarrow \xi = \arctan\left(\frac{d_{th}}{dL}\right)$$

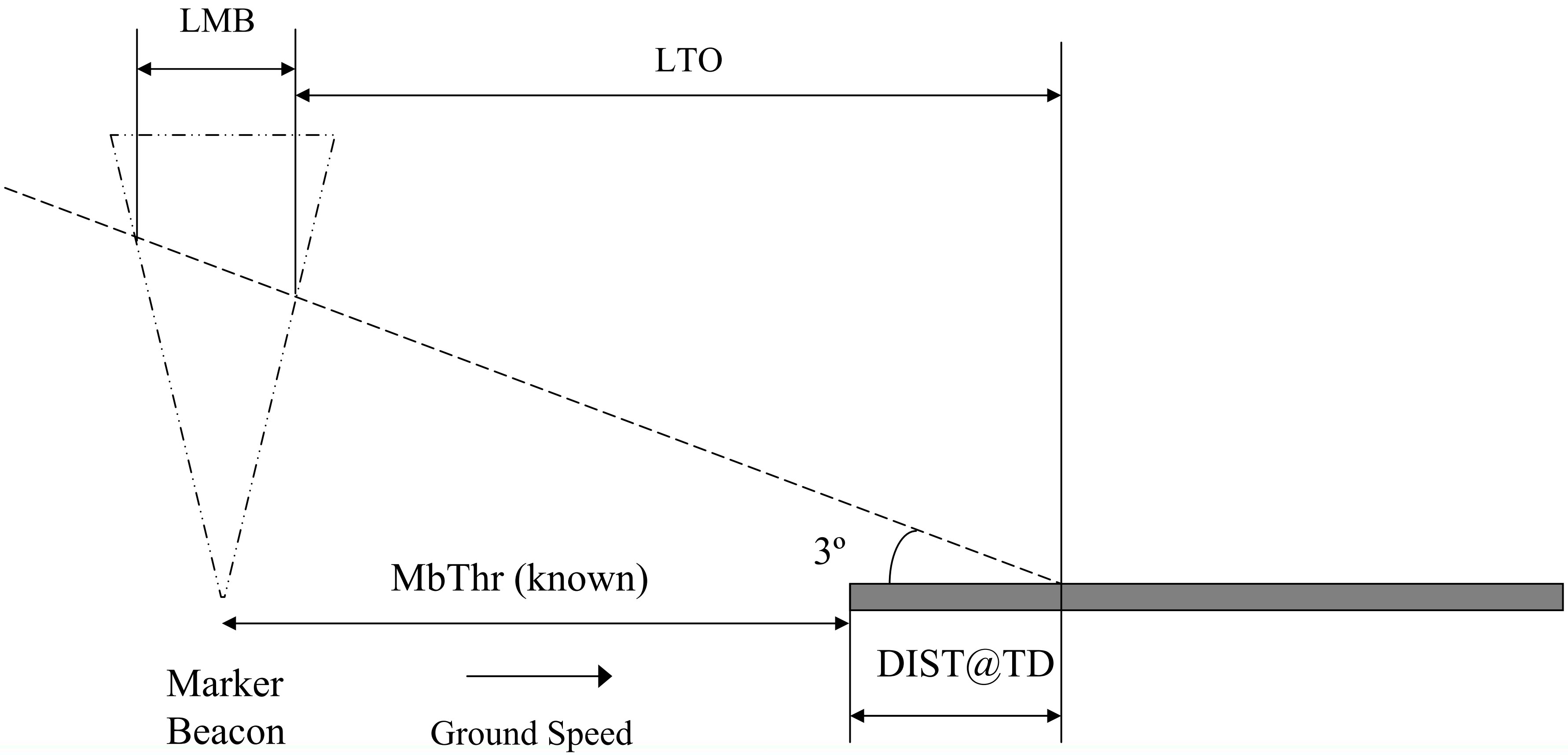


$$\tan(\psi) = \frac{dy}{(dL - dx + d_{LOC-LG})} \Rightarrow dy = (dL - dx + d_{LOC-LG}).\tan\left(\frac{LOCDEV}{150}.\arctan\left(\frac{d_{th}}{dL}\right)\right)$$

Method II

- **Calculation: Longitudinal Distance**

$$DIST@TD = LTO + 0.5(LMB) - MbThr$$



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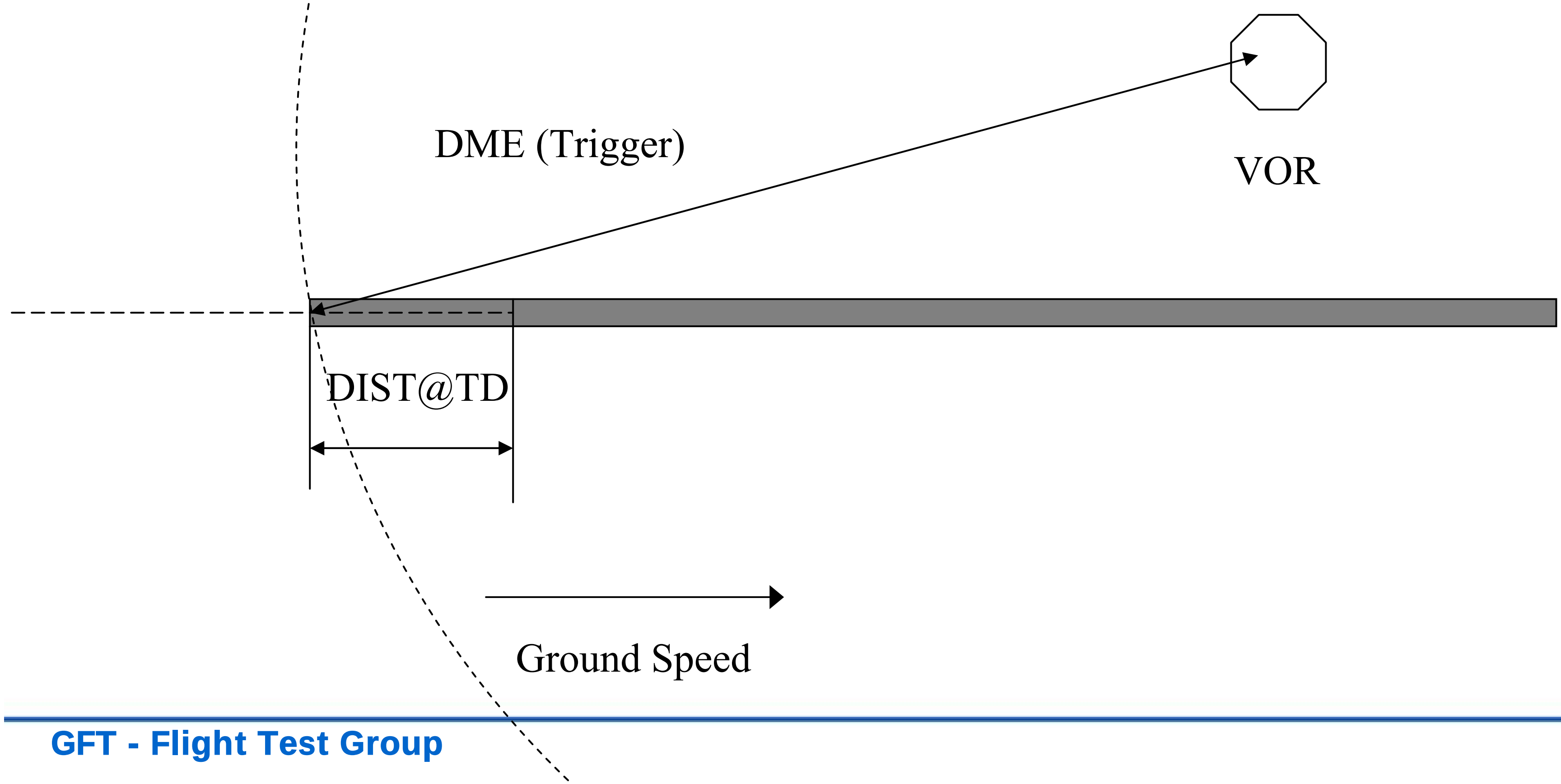
- **Method II**
  - **Calculation: Longitudinal Distance**

DIST@TD Triggered by DME



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Analysis and Results

- **Uncertainty Analysis has been conducted following the general uncertainty theory:**

Measurements	Uncertainty Method I [m]	Uncertainty Method II [m]
Longitudinal Distance (U_{dx})	10.10	10.72
Lateral Distance (U_{dy})	0.89	0.41

Analysis and Results

- 2 Sigma Confidence Interval Study
- DGPS, Belly Camera, Method 1, Method 2, Comparisons
- Comparison to 2 sigma for the tested points from the desired footprint
- Comparison to 2 sigma from Monte Carlo Dispersion from the desired footprint

■ Analysis and Results

▪ Methods x DGPS

DGPS (27 Test Points)					
	Longitudinal Distance Method 1	Longitudinal Distance Method 2	Longitudinal Distance DGPS	Lateral Distance	Lateral Distance (Belly)
	[m]	[m]	[m]	[m]	[m]
Average	514.65	494.96	490.89	0.28	0.03
Sigma	62.34	55.80	59.30	2.54	2.19

▪ Methods x Belly Camera

Belly (89 Test Points)					
	Longitudinal Distance Method 1	Longitudinal Distance Method 2	Longitudinal Distance BELLY	Lateral Distance	Lateral Distance (Belly)
	[m]	[m]	[m]	[m]	[m]
Average	434.77	419.68	426.01	1.36	0.96
Sigma	91.10	94.86	84.51	3.19	3.16

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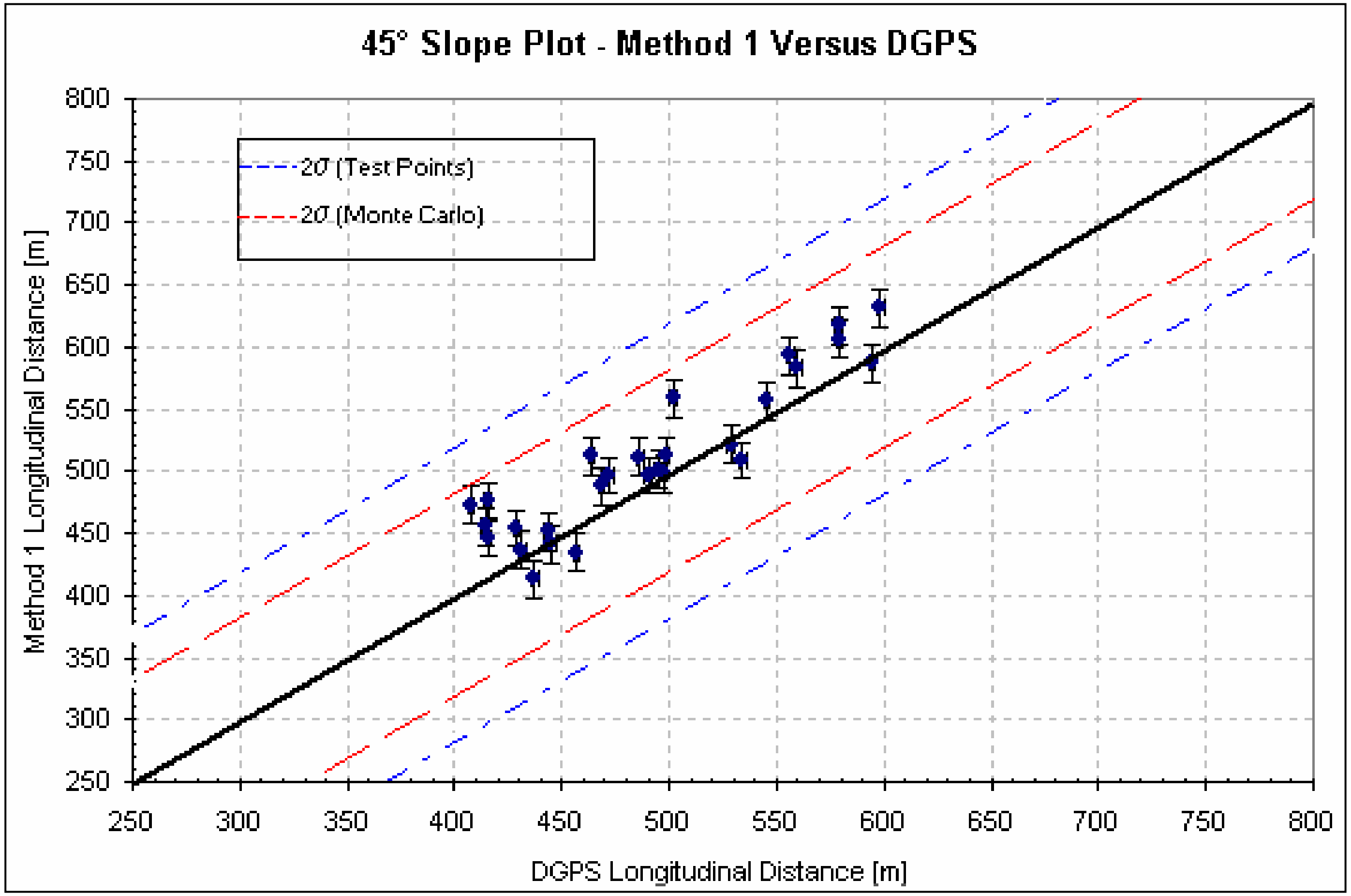
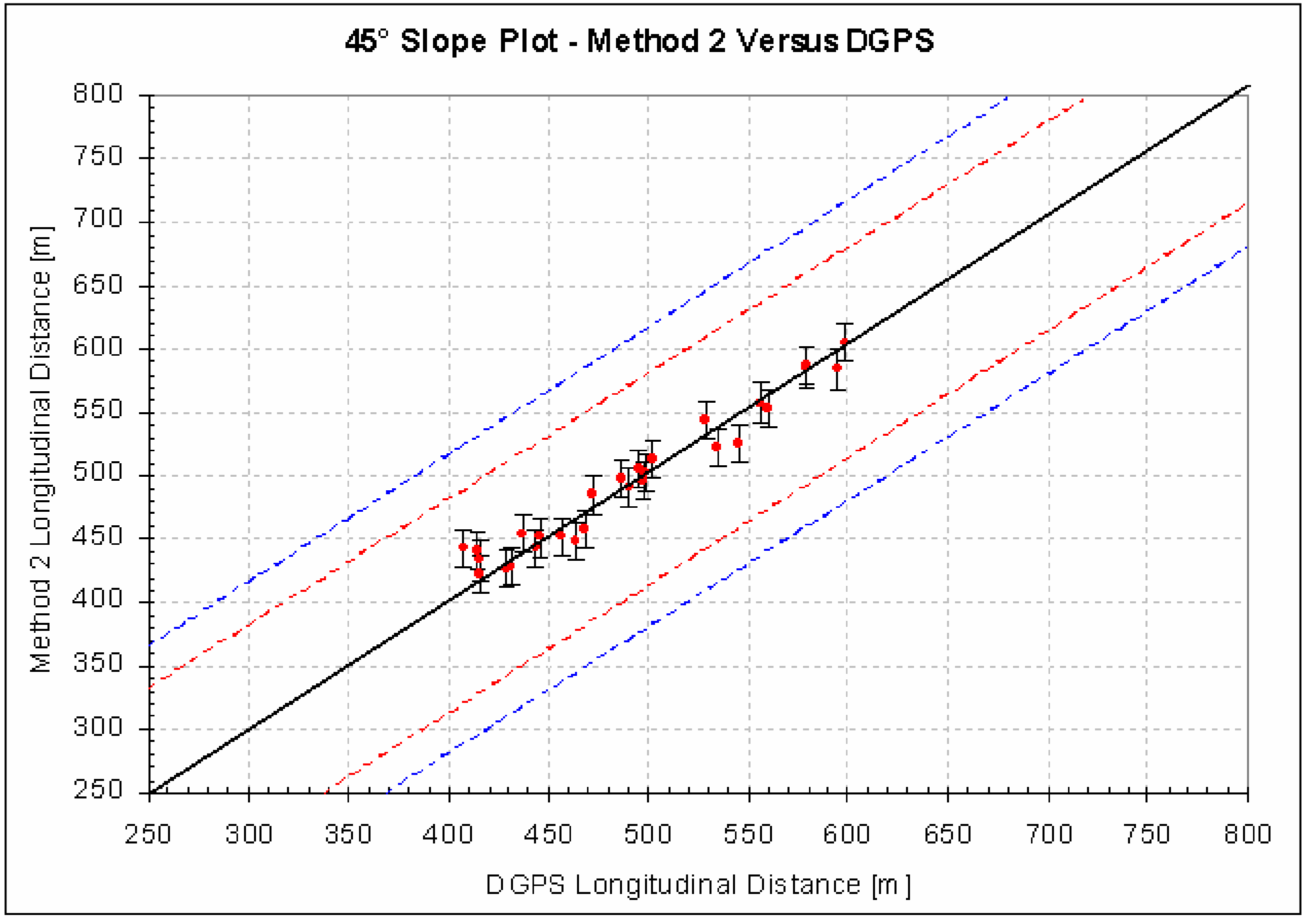
■ Analysis and Results

▪ Method I x DGPS

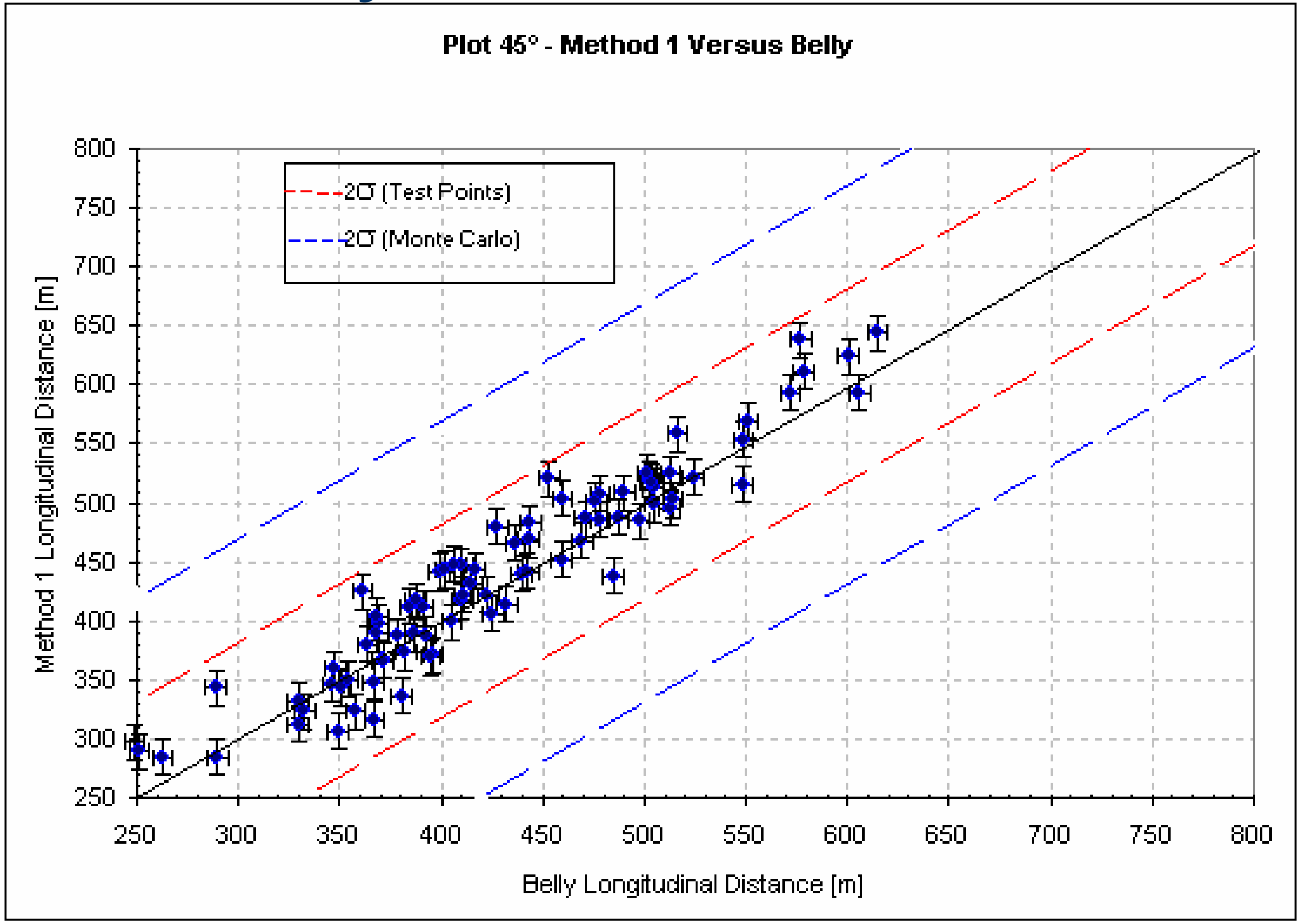


■ Analysis and Results

▪ Method II x DGPS

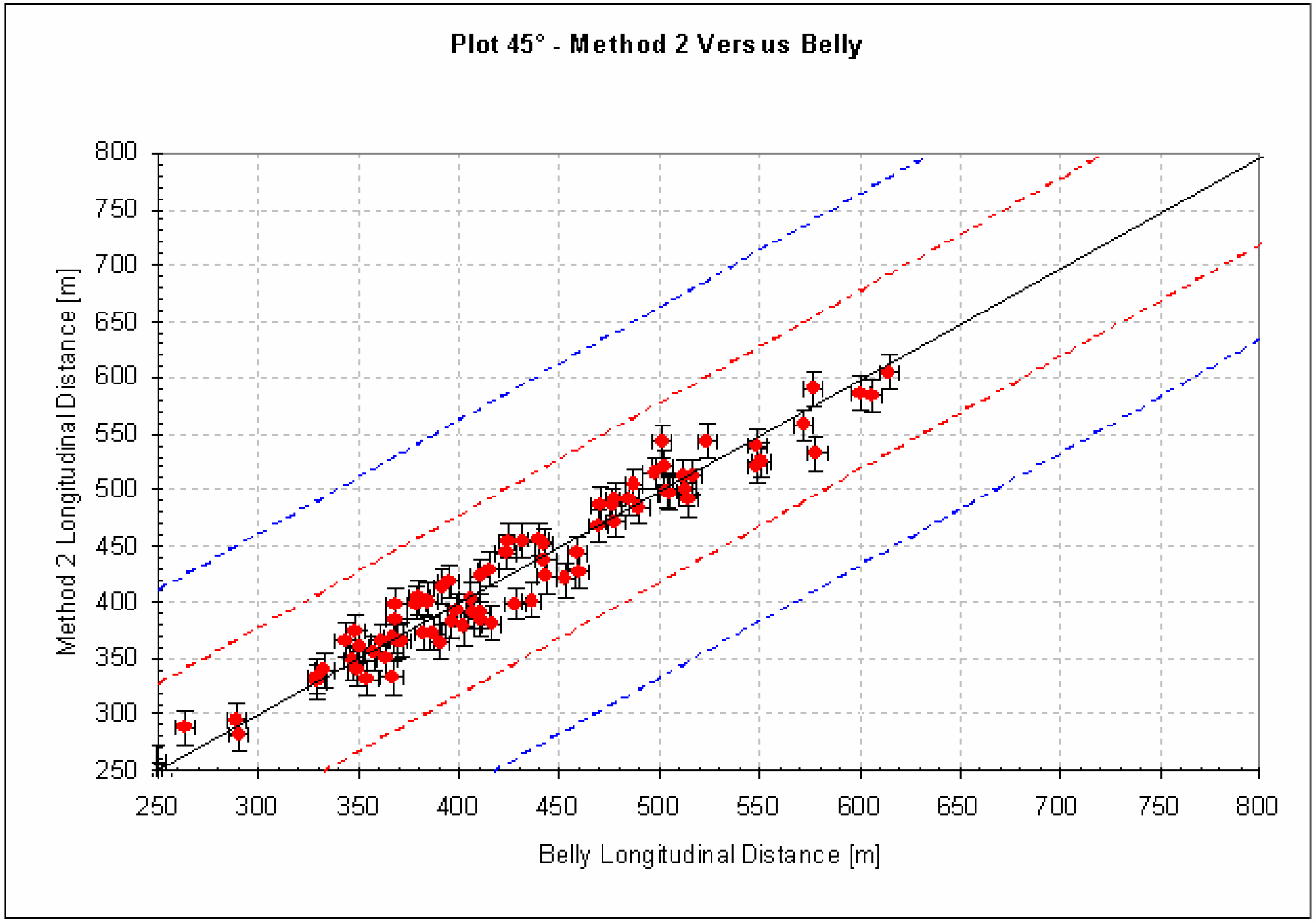


- **Analysis and Results**
  - **Method I x Belly Camera**



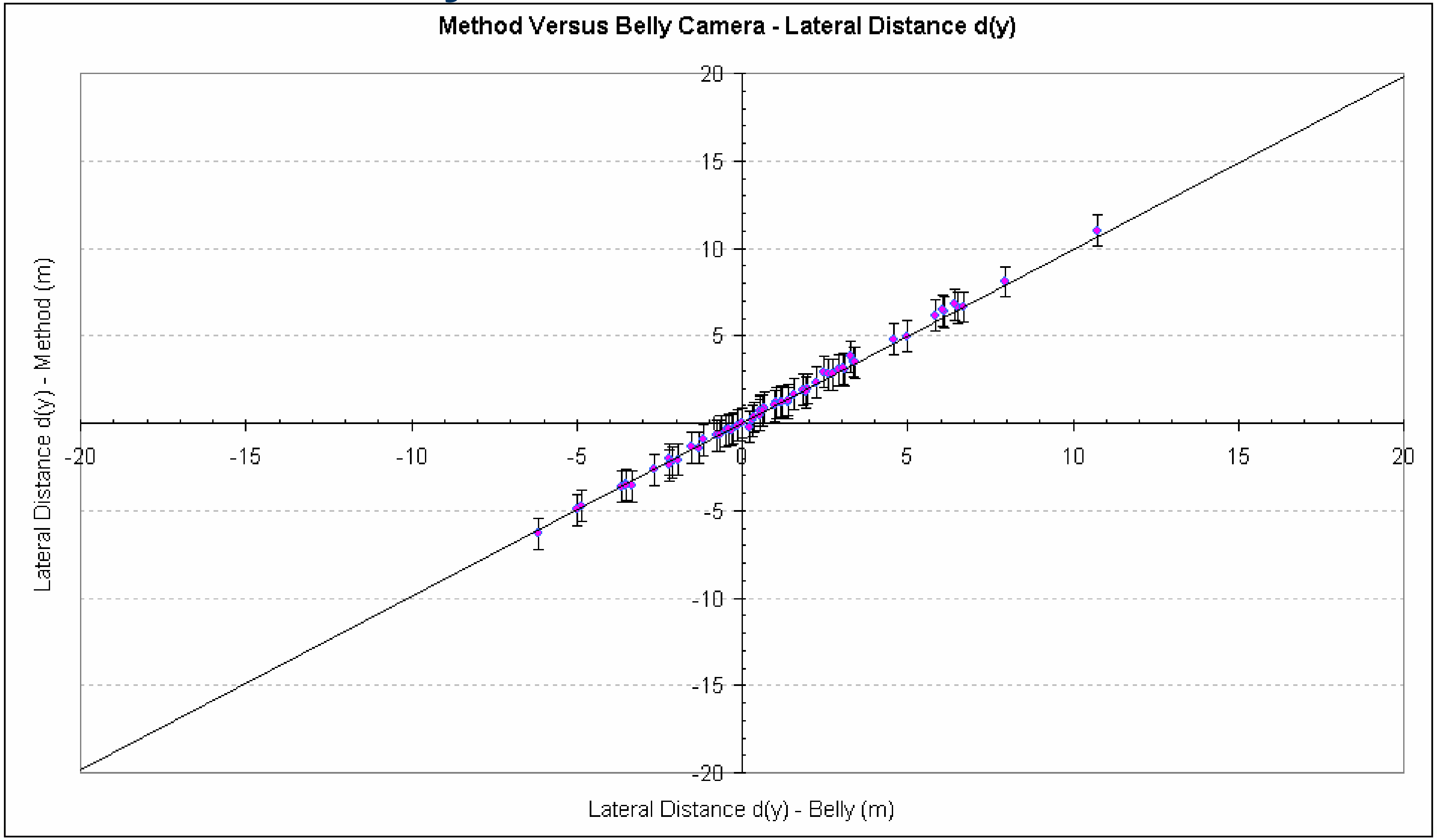
■ Analysis and Results

▪ Method II x Belly Camera



■ Analysis and Results

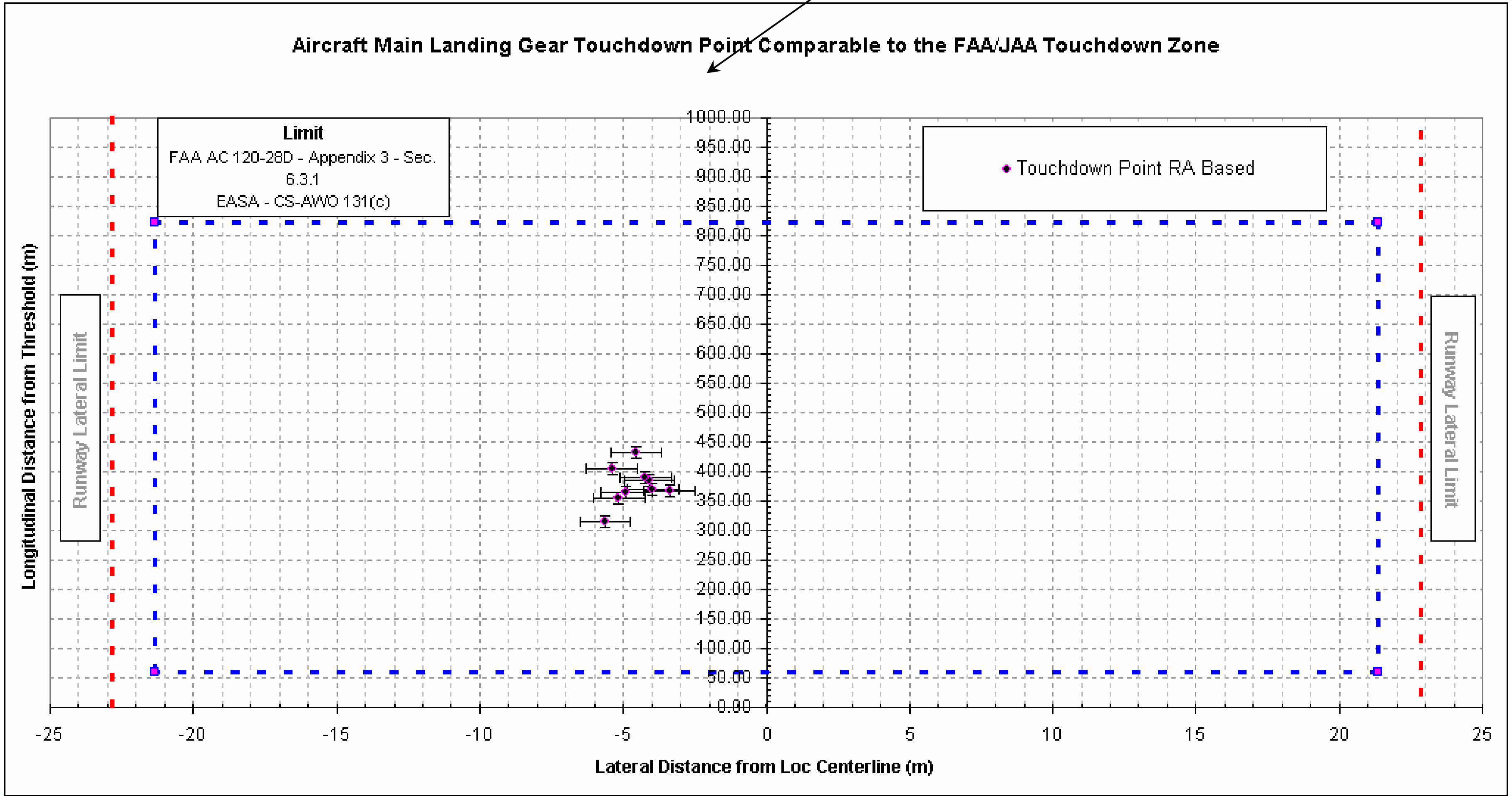
▪ Method x Belly Camera - Lateral Distance



Analysis and Results

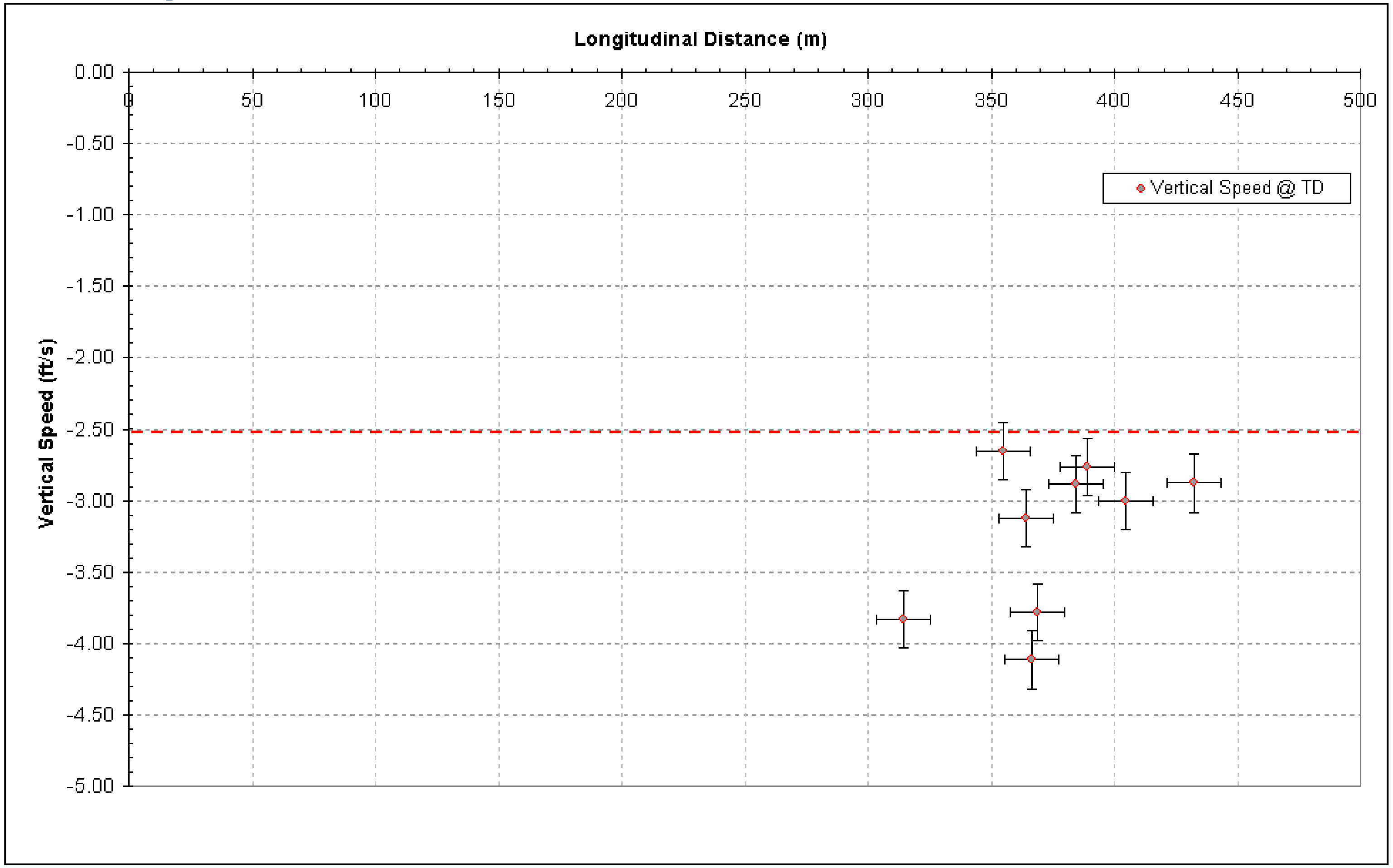
Example: Touchdown Dispersion

Real Data: Flight 170-001-0502
(Begginig of development)



Method I

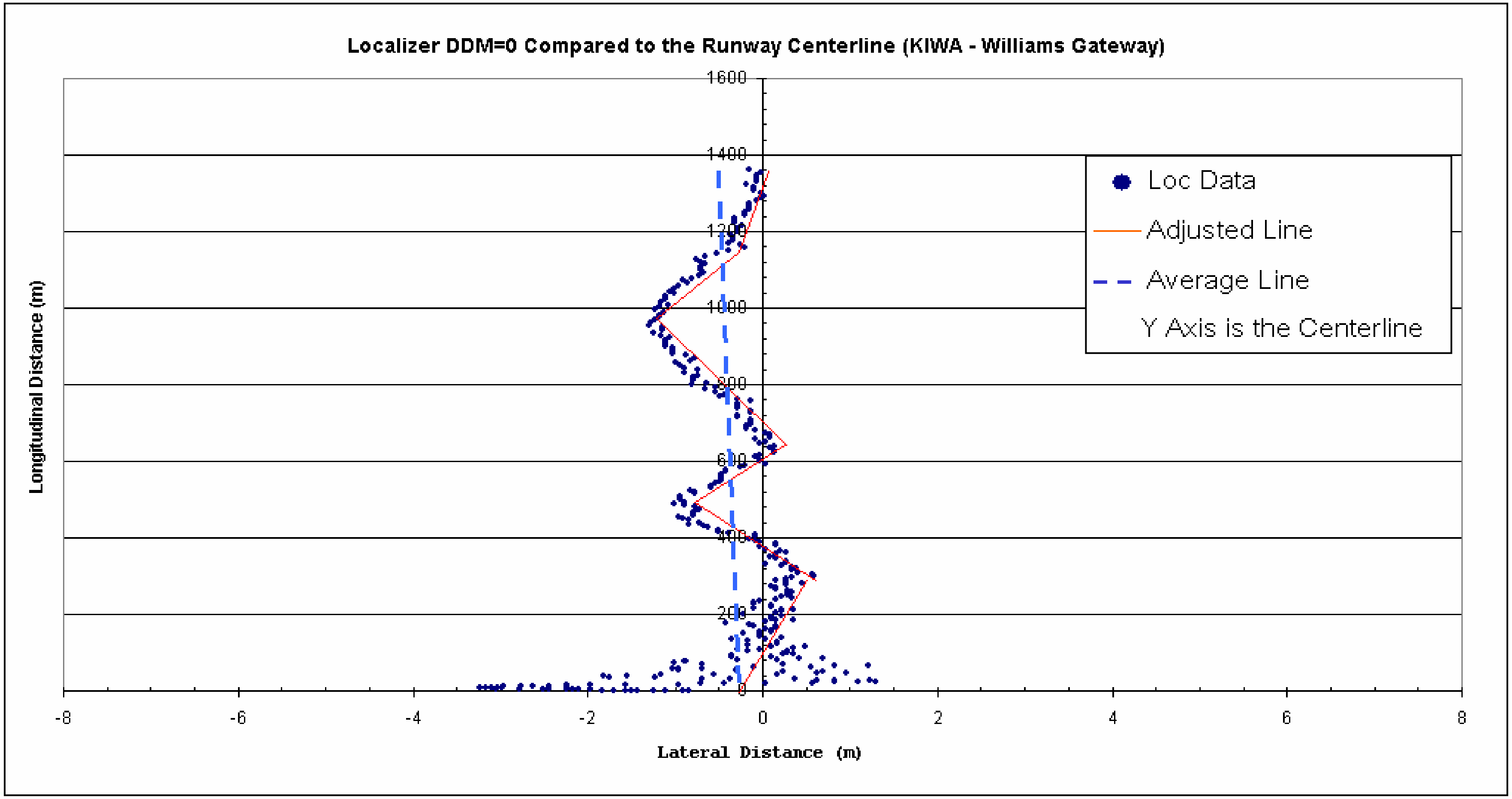
Example: Touchdown Rate



Method for Autoland Performance Check

■ Method I

▪ Output Parameters: Runway Localizer Beam Survey



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Conclusions and Final Considerations

- Method I has been defined as the main method and Method II as the backup method

- Validation process has demonstrated that Methods I and II are equivalents since it presents results within 95% confidence interval compared to the desired footprint (2 Sigma)

- Method I was chosen because:
  - **It is Equivalent to Method II**
  - **It is more conservative rather than method II**
  - **It is not depended on navy aids position and signal precision**
  - **Terrain irregularities before threshold affects the dispersion but not enough to induce points outside 95% confidence interval (10m for each 2ft)**
  - **Terrain irregularities affects just 100ft radalt height detection and FPA past history correction would reduce this effect**

▪ Conclusions and Final Considerations

- Whenever footprint description becomes an outlier, radalt x FPA trace will be provided to confirm terrain irregularity issue.
- In last case, Backup (Method II) will be executed in order to provide accurate data, since equivalence has been proven.
- Both Backup and Method I will be ran during all certification flights in order to have as much data as possible
- Belly Camera (All Airports) and DGPS (Brazilian Airports) will be the tools for method validation.

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■ Bibliography

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- EASA CS-AWO – Certification Specifications for All Weather Operations , October 2003

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