Impact of Flight Operation Uncertainties on the the Design of Advanced Noise Abatement Procedures

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Noise Abatement Procedures

- **Noise is an important factor in the siting and operation of airports**
  - **Lengthy environmental studies and community agreement required required for approval of airport expansion or airspace changes and and federal mitigation funding**
- **Problem is global**
  - **Large international airports make significant contributions to national economies**
- **Engine technology has provided significant noise reductions**
  - **Higher bypass-ratio engines (designed for increased fuel consumption) generate lower noise levels for same thrust**
  - **Now in period of diminishing returns**

Noise Abatement Procedures (2)

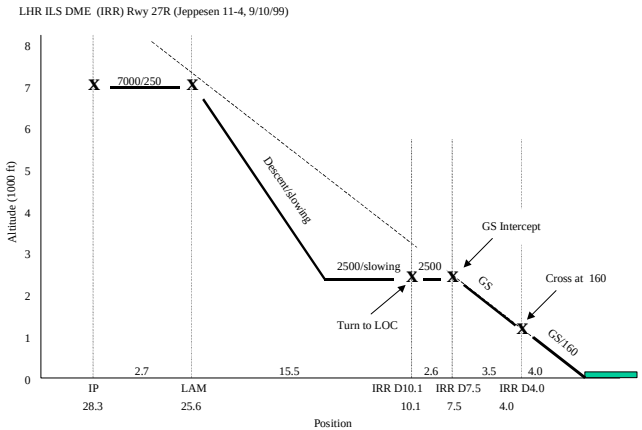
- **Advanced flight guidance technologies enable operational procedures that provide significant additional noise reductions**
  - **Thrust management strategies redistribute noise impact during departure and reduce impact during approach**
  - **Lateral deviations direct aircraft away from populated areas during during departure and approach**
  - **Area Navigation (RNAV) using position information from the Global Global Positioning System (GPS) enables trajectories that can be adjusted for noise considerations**

Experimental Study : pilot-in-the-loop simulation

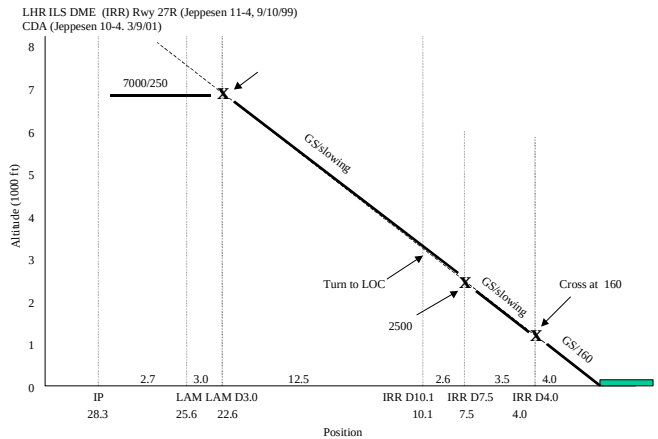
- **Objectives**
  - Investigate the operational acceptability and human factors issues of advanced noise abatement procedures (ANAP)
  - Examine the noise impact of each procedure
- **Method**
  - NASA Ames Research CVSRF (Crew-Vehicle Research Simulation Facility) Facility) B747-400 simulator
  - Eight B747-400 airline captains and eight first officers
  - Equipage: PFD, NAV Display, FMS, MCP, AFDS, MCDU
- **Experiment Design**
  - Noise sensitive Airport : London Heathrow (LHR)
  - Arrival NAPs : Standard, CDA(Continuous Descent Approach), Two-Segment Segment Approach(TSA), Low Power/Low Drag(LPLD), LHR Runways 27L/R 27L/R
  - Departure NAPs : ICAO-A, ICAO-1000, MCG (Maximum Climb Gradient), LHR LHR Runways 9L/R

Four Arrival NAPs

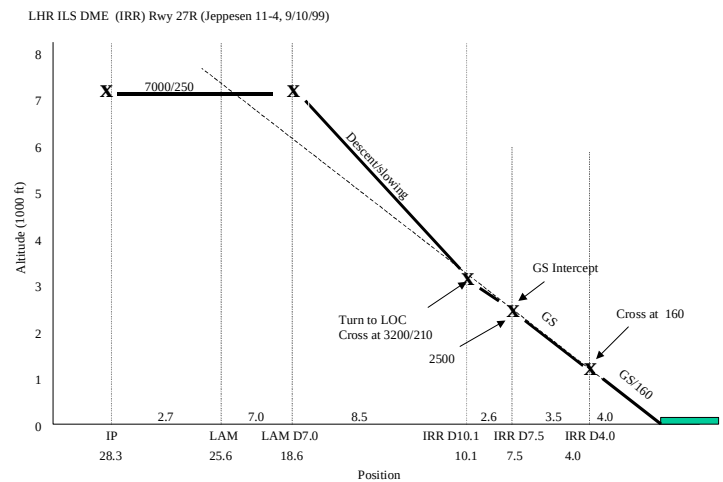
LHR ILS DME 27R Arrival Profile - Standard



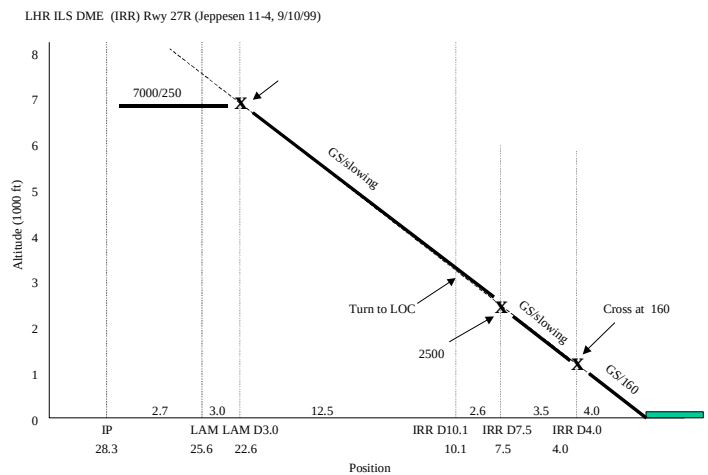
LHR ILS DME 27R Arrival Profile - CDA



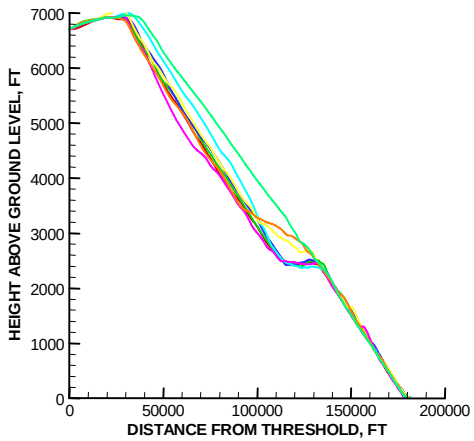
LHR ILS DME 27R Arrival Profile - TSA

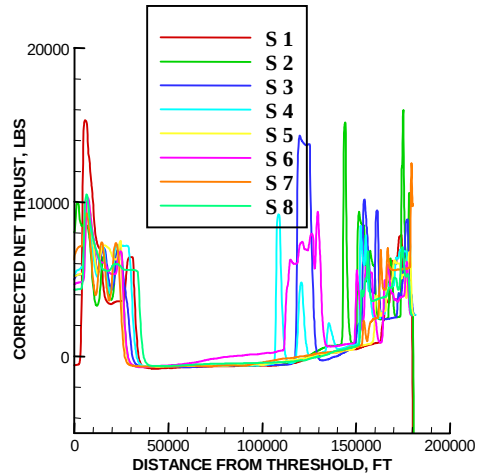


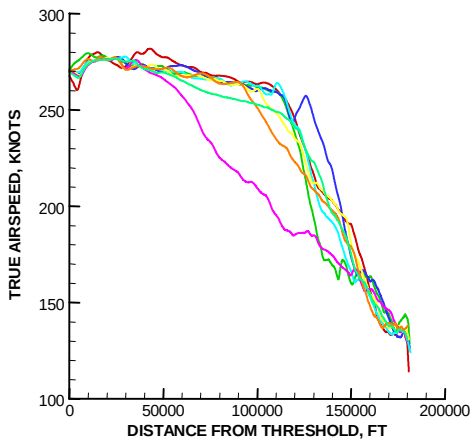
LHR ILS DME 27R Arrival Profile - LPLD

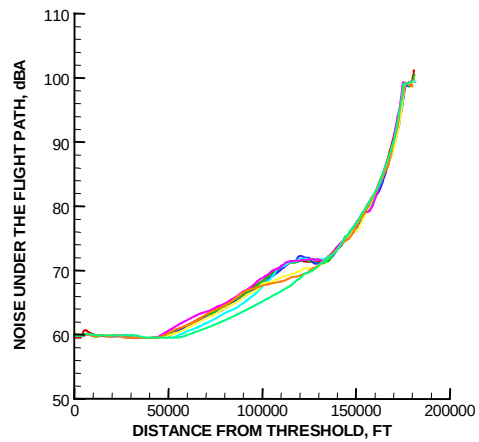


Standard Approach in Manual Mode

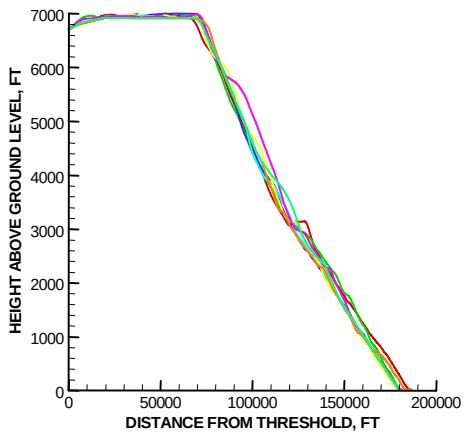


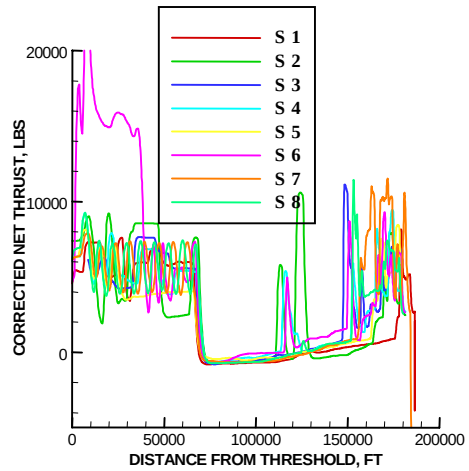


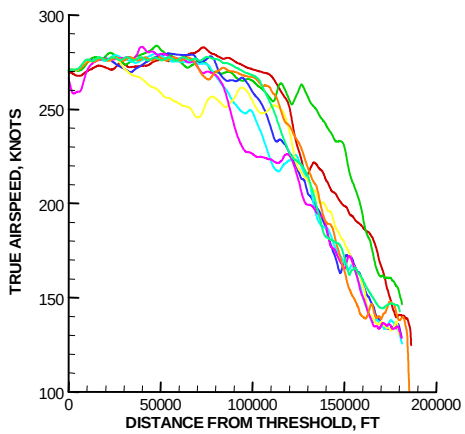


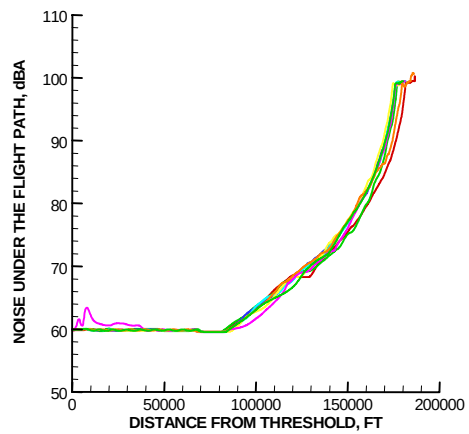


Two Segment Approach in Manual Mode

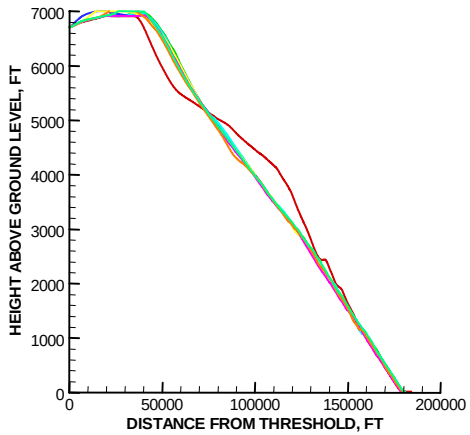


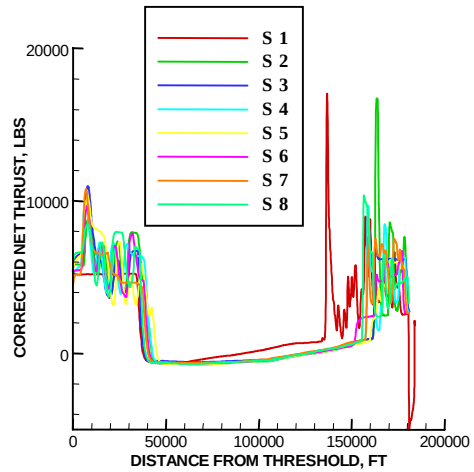


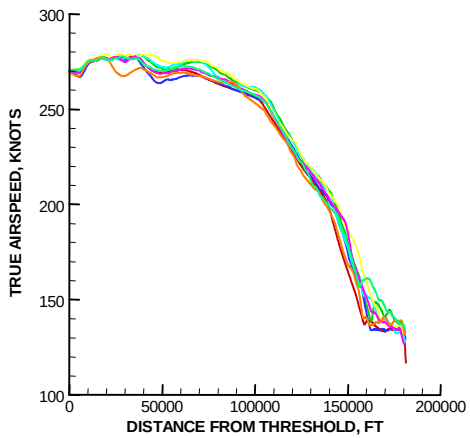


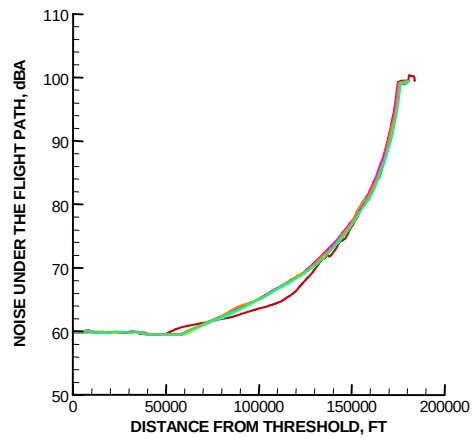


Continuous Descent Approach in Manual Mode

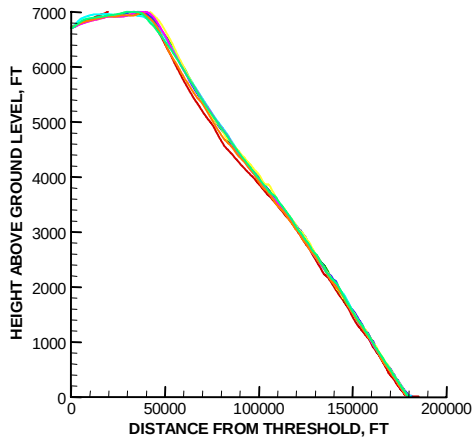


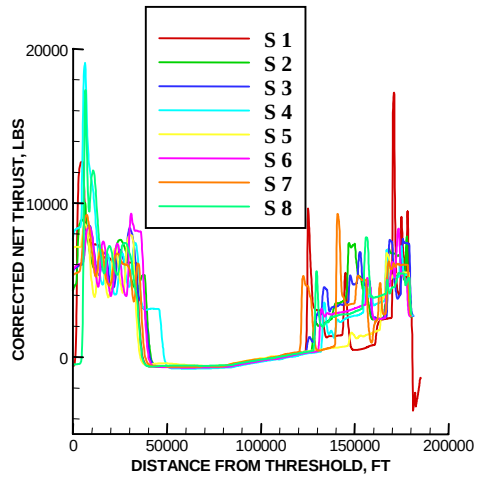


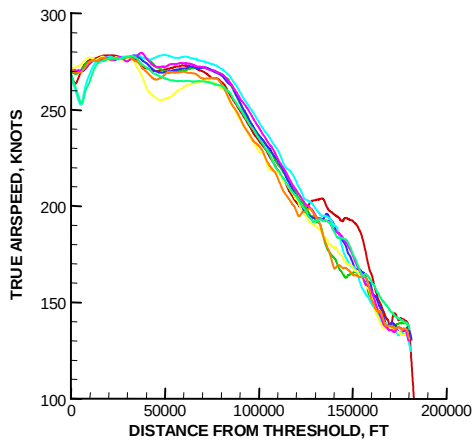


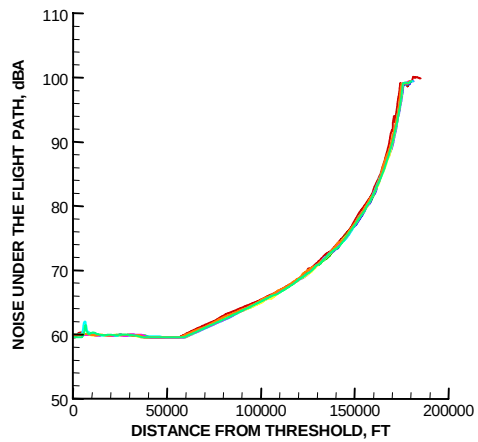


LPLD Approach in Manual Mode









Implementation of NAPs

- **Benefits of advanced approach noise abatement procedures (CDA, ACDA, LPLD,TSA) have been recognized and documented documented (ex: Clarke,CVSRF experiments).**
- **Implementation of procedures limited by air traffic control considerations**
  - **Difficult to predict future position of aircraft not flying at constant speed, especially in ill-defined wind field or severe weather**
  - **High controller workload to mix traffic while maintaining appropriate separation and sequencing**
  - **Procedures only implemented in low traffic environments (tested in Europe) Europe)**

Need to add automation and structure to ATC process to complement human monitoring and decision making

- **Automation decision aids and/or**
- **Additional rules/structure**

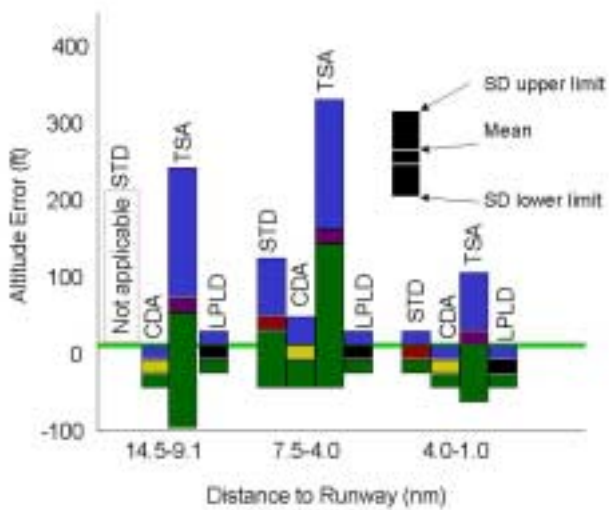
Quantification of Operation Uncertainty (CVSRF Experimental Study)

- **Pilot judgments and operational acceptability**

Rating	Definition
1	Excellent; no pilot effort required
2	Good; negligible deficiencies; pilot effort not a factor
3	Fair; mild deficiencies; minimal pilot effort required for desired performance
4	Minor deficiencies; moderate pilot effort required for desired performance
10	Impossible; unacceptable; pilot cannot complete task

Independent Variable	Questionnaire Score (Mean/SD)			
NAP	STD	CDA	TSA	LPLD
	1.85/ 0.35	2.35/ 0.72	3.41/ 0.74	2.07/ 0.34
Control Mode	AUTO	MAN		
	2.05/ 0.39	2.78/ 0.53		

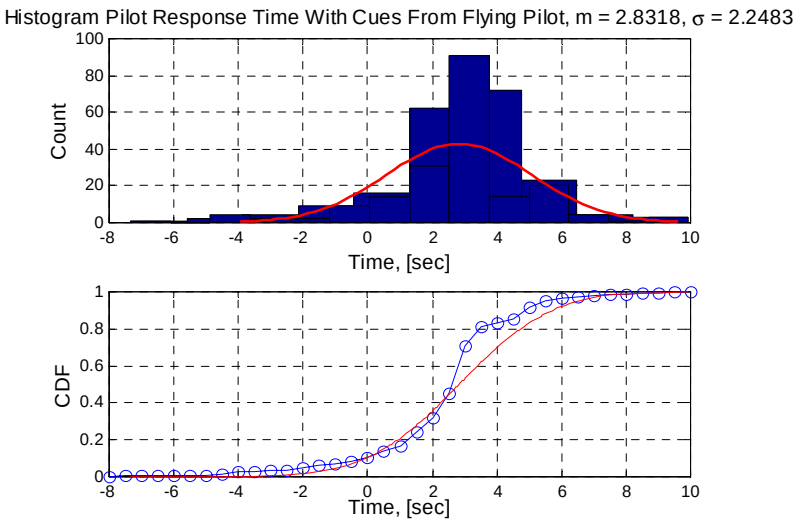
- **Pilot performance (auto & manual), flying accuracy**

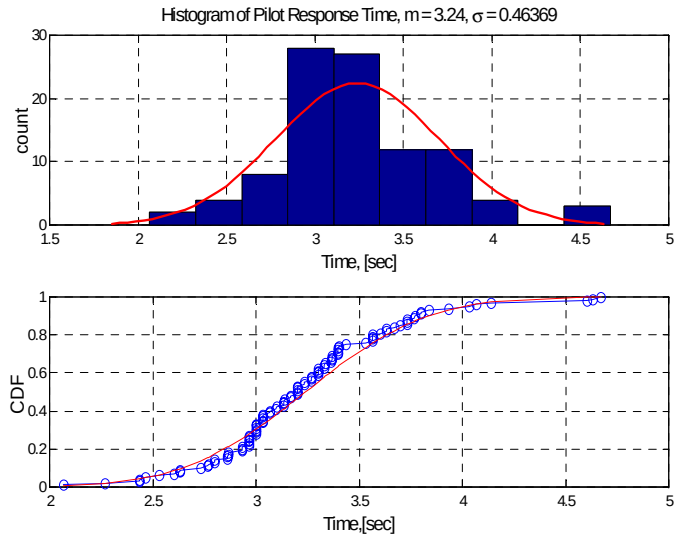


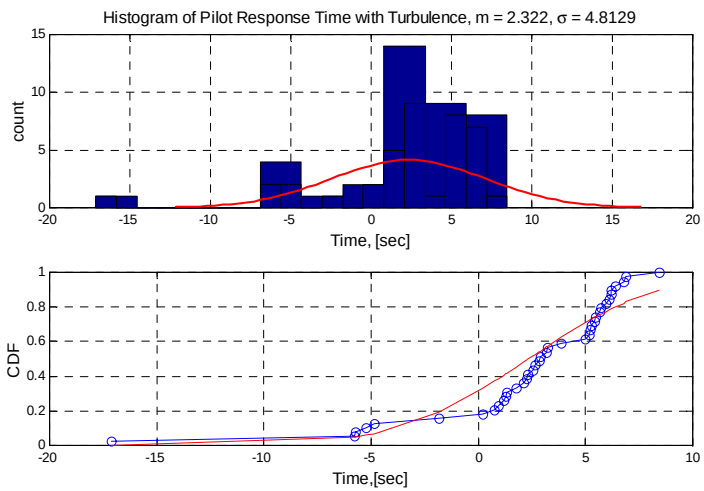
NAP	Vertical Path Deviation		Lateral Path Deviation	
	Mean Error	SD	Mean Error	SD
STD	27.0	70.3	-3.3	59.5
CDA	-14.8	5.1	-6.7	14.7
TSA	131.4	168.4	-196.8	430.9
LPLD	-7.1	10.7	19.3	19.7

Quantification of Operation Uncertainty

- **Pilot response time (gear,flap)**

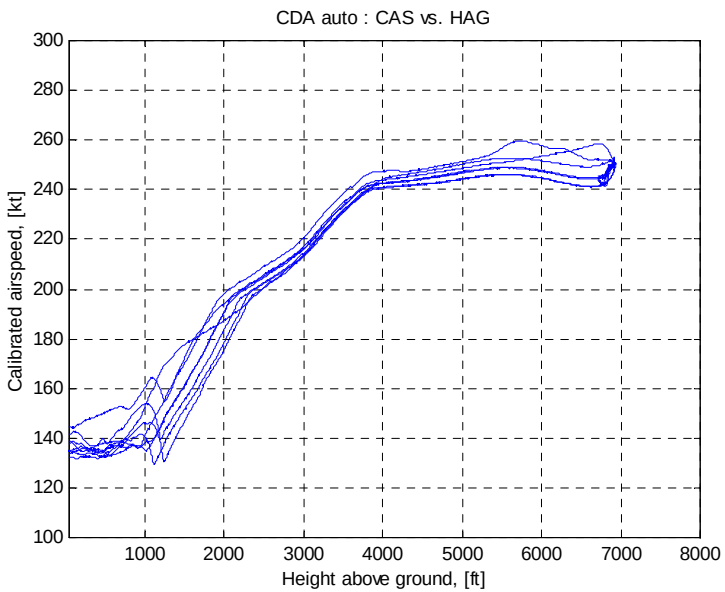


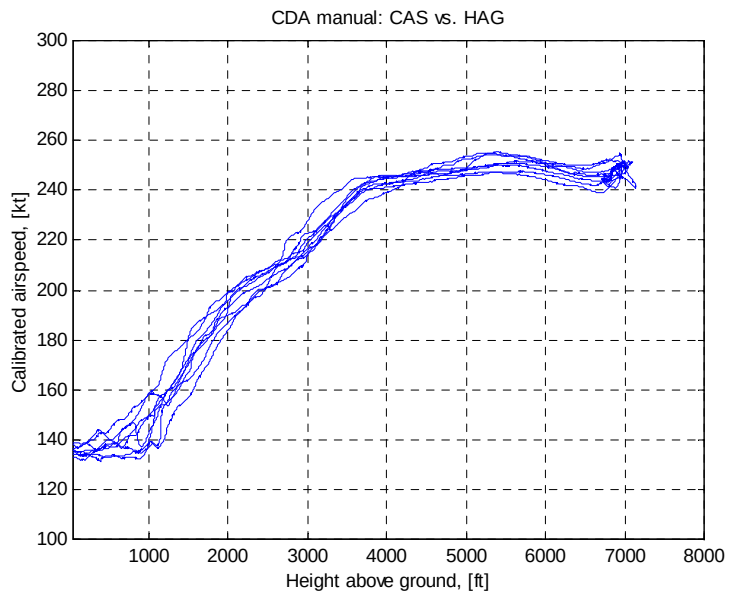




Quantification of Operation Uncertainty

- **Uncertainty in aircraft's**
  - **Position : limited by ASRs radar resolution ~ 150-300m**
  - **Velocity : influenced by order of pitching and cutting back thrust at GS intercept**



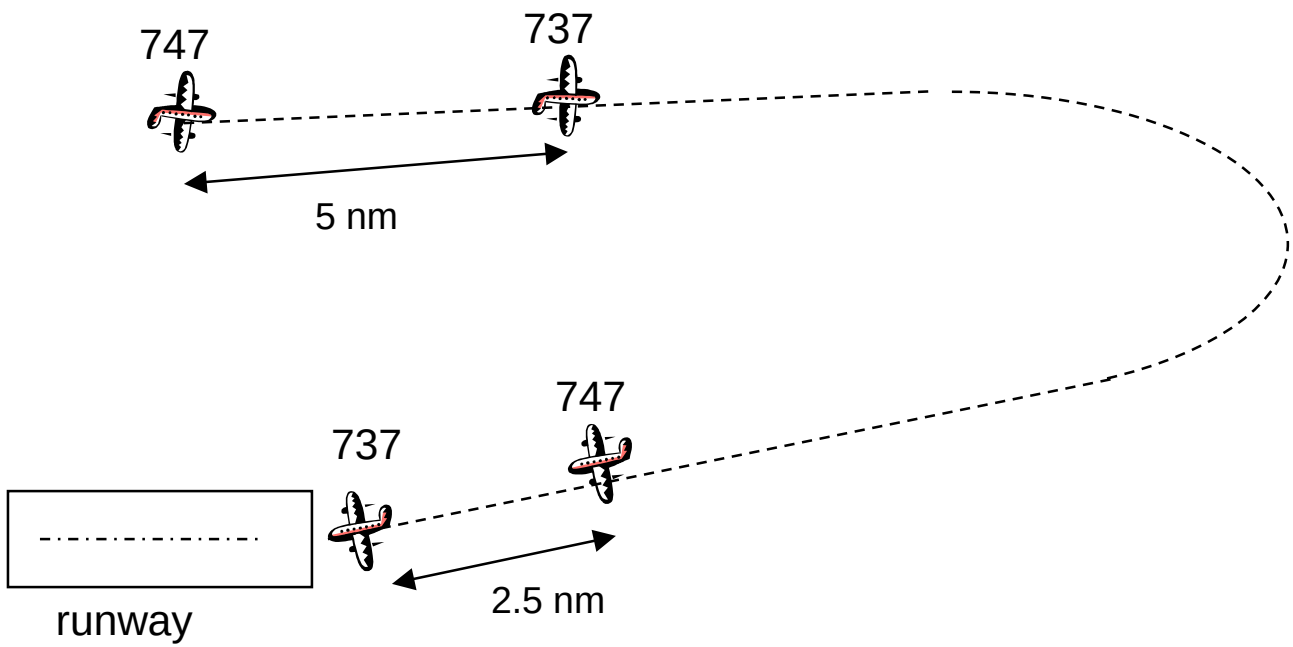


Quantification of Operation Uncertainty

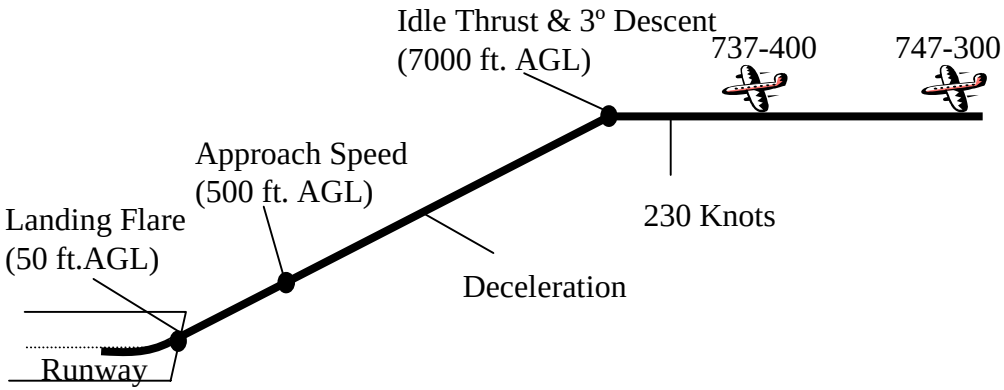
- **Others :**
  - **Aircraft characteristics:Heavy vs. Large vs. Medium vs. Small**
  - **Aircraft Navigation System: FMS types (geometric vs. aircraft performance database) and capability(VNAV,FPA)**

Performance and Limitation of Automation Tools

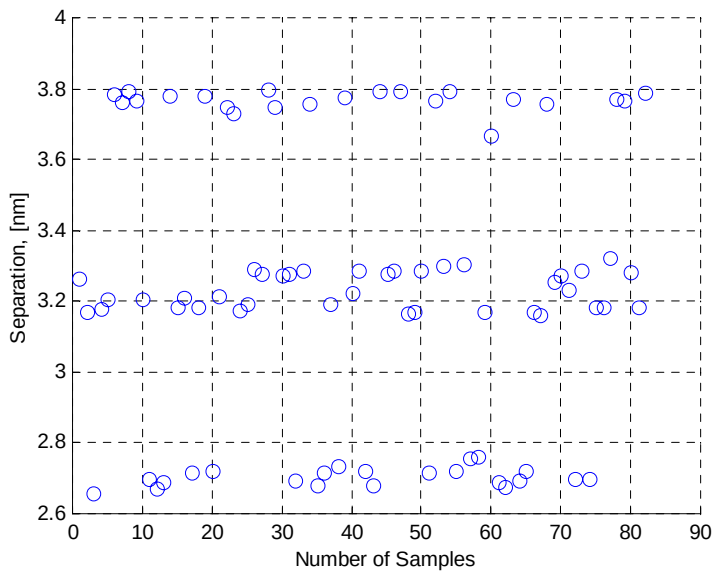
- **Governed by quality and quantify of information available i.e. quality of sensors,GPS signals …**
- **Established through Monte-Carlo simulations results results**

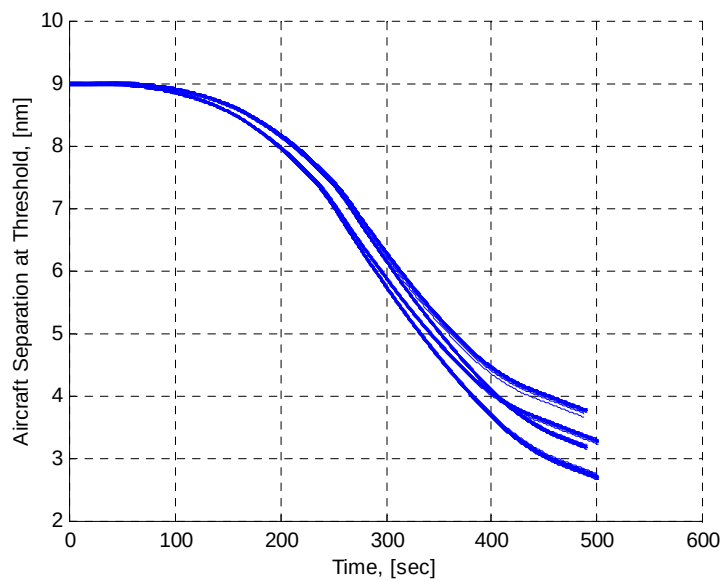


Two aircraft simulation example (1)



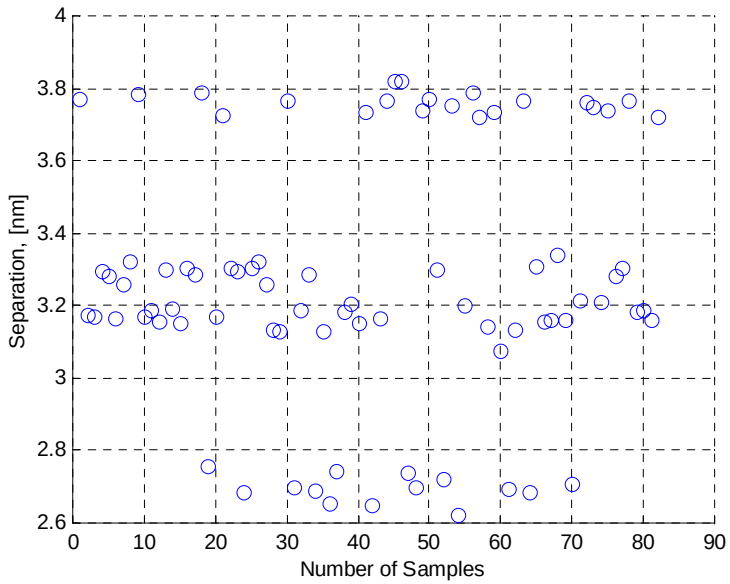
- Normal pilot response time :

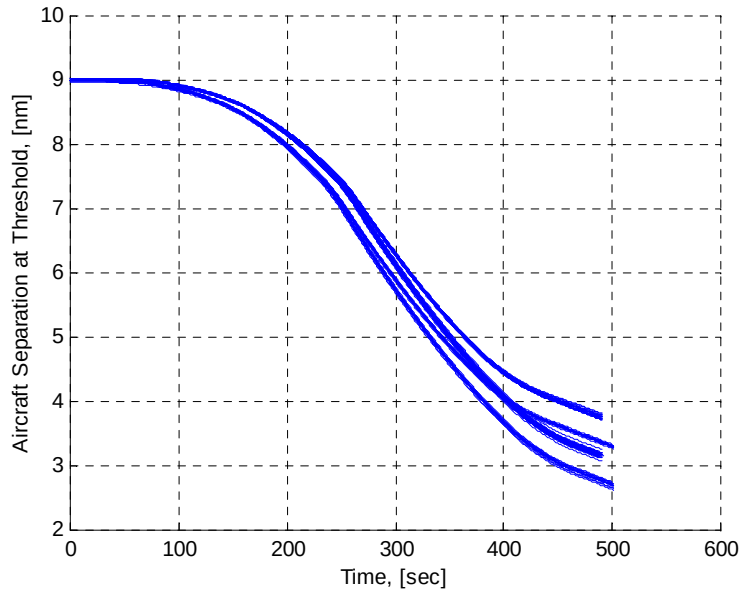




Two aircraft simulation example (2)

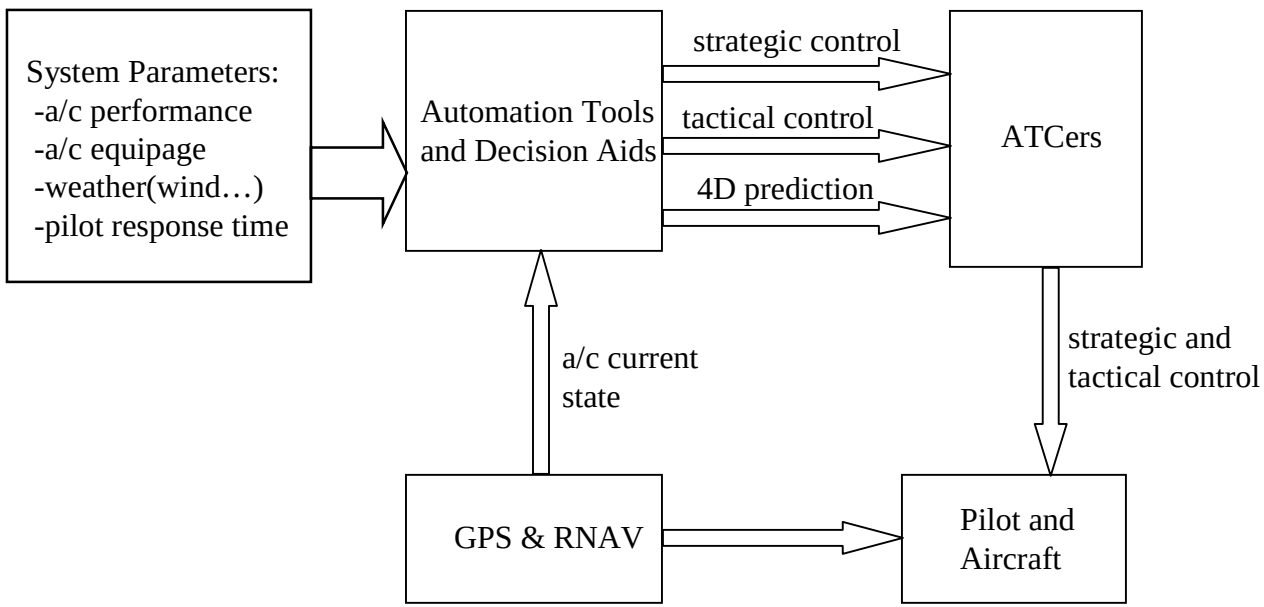
- Pilot response time with turbulence





Framework to Integrate NAPs into the ATC System

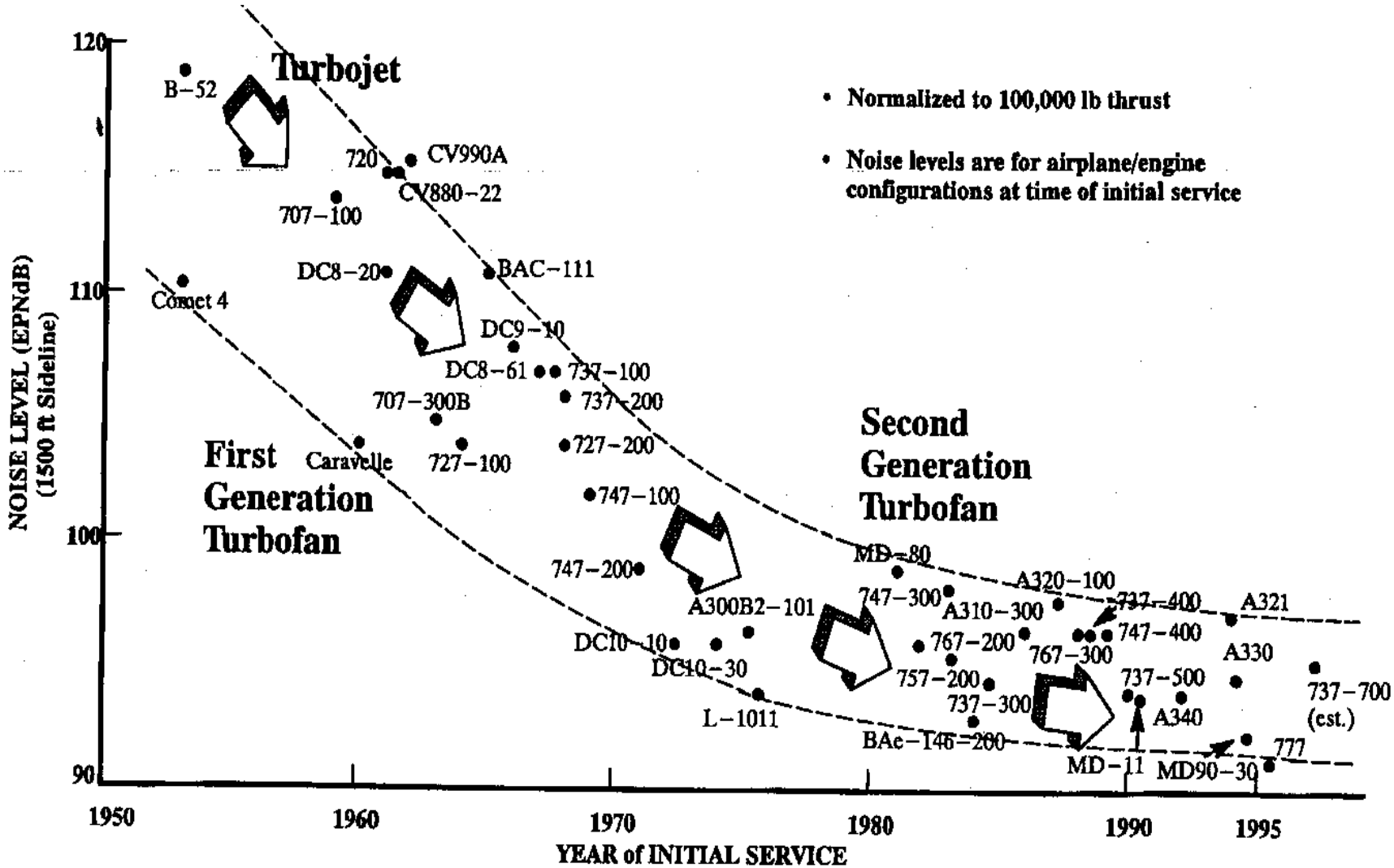
- **Identify appropriate task-allocation architectures (strategic vs. vs. tactical control, air vs. ground responsibility) required to manage system complexity.**
- **Example of a proposed framework:**



Ongoing Research…

- **Evaluate developed NAP through simulator experiments with pilots and air traffic controllers in the loop:**
  - **Incorporate system constraints, automation limitations, and and proposed frameworks. Include realistic traffic, wind, VNAV FMS,….**
  - **Conduct experiments in an aFAST-like environment i.e. fly with aFAST advisories to optimize system's capacity, so meeting a speed target may not be required**
  - **Obtain air traffic controller's performance and response, and and other ATC operation issues**

Aircraft Noise

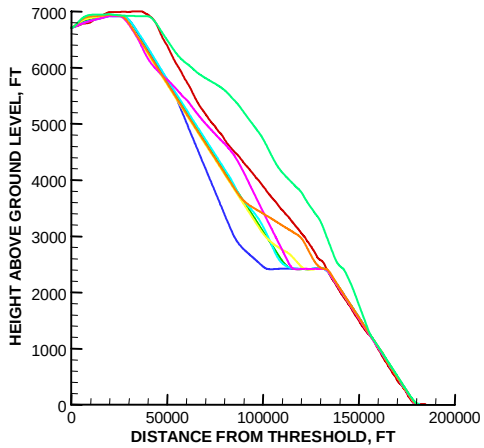


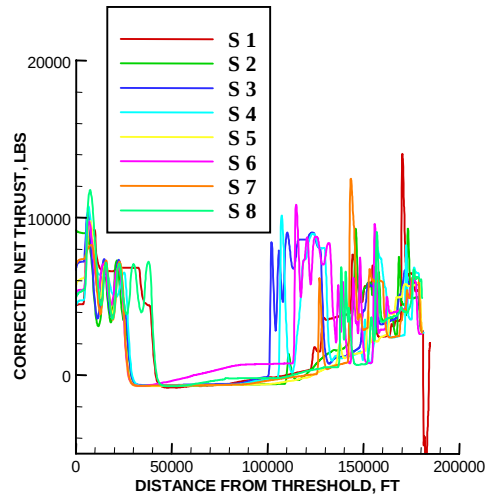
* Courtesy of Kenneth W. Orth, The Boeing Company

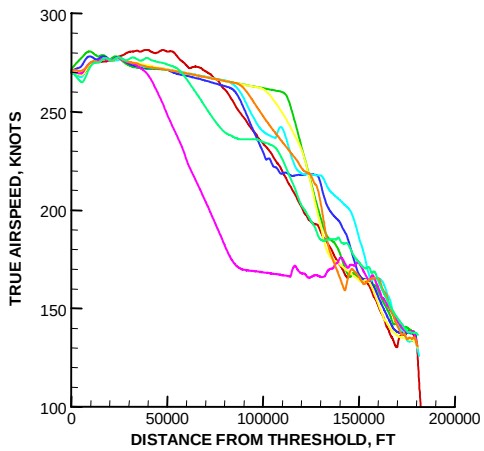
Problems with “Europe” CDAs

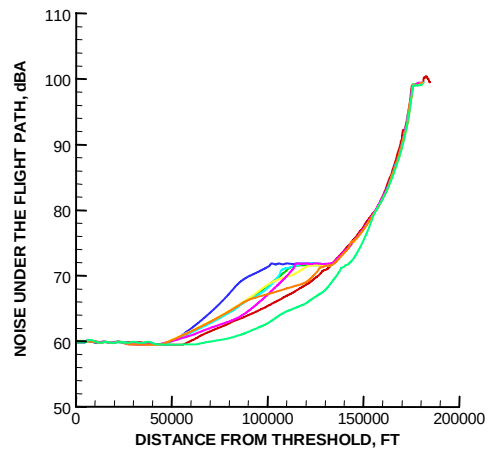
- **Adopted in 6 nations**
- **ATC can’t intervene once CDA procedures started**
- **Arrival time highly unpredictable:**
  - **Pilot do not respond uniformly to ATC instructions : banking early early or causing delay because of clarification request .**
  - **Wind changes in direction and speed with altitude : as a/c descend descend (at diff. rates), effect of wind on ground track varies.**
  - **Aircraft turn at different rates.**
  - **Wind shear cause aircraft to experience rapid change in its ground ground track or speed as descending through wind shear level.**

Standard Approach in Auto Mode

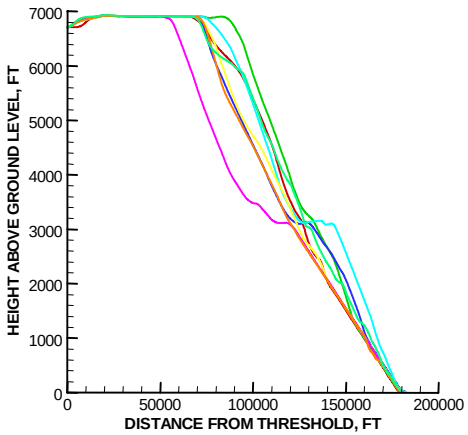


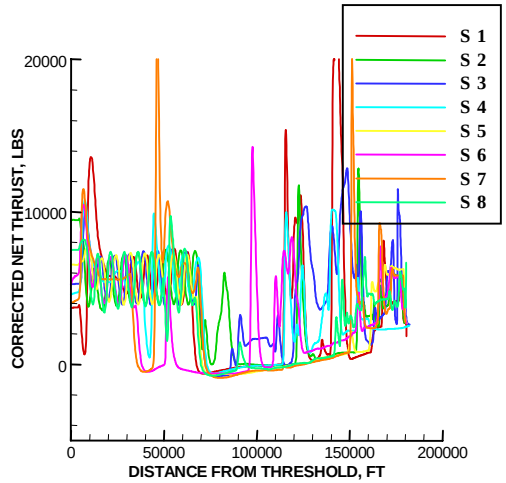


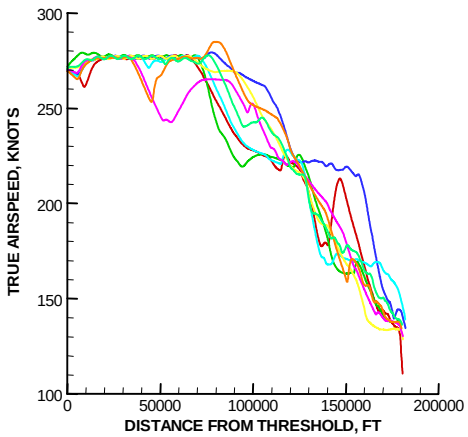


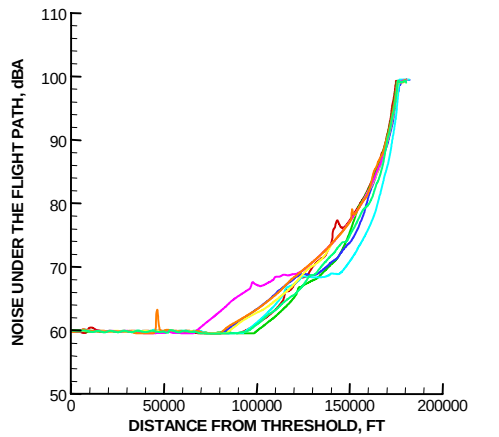


Two Segment Approach in Auto Mode

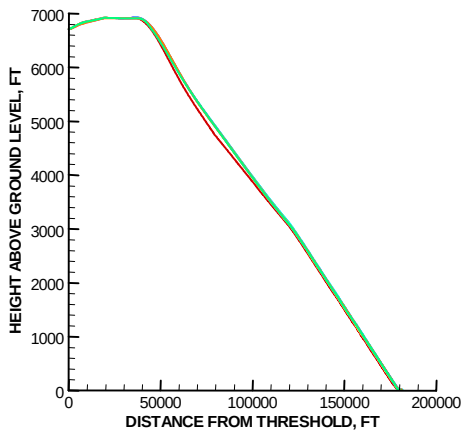


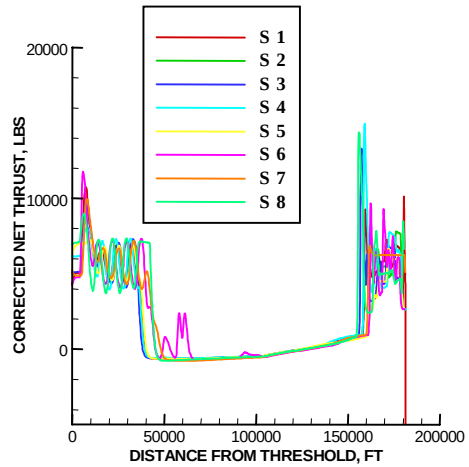


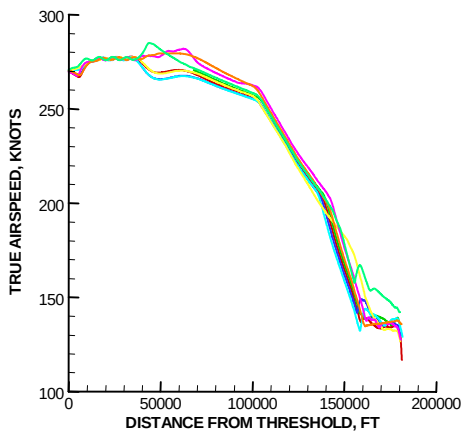


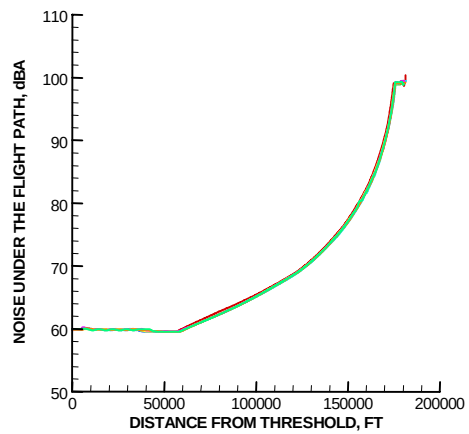


Continuous Descent Approach in Auto Mode









LPLD Approach in Auto Mode