Vertical Profile Design and Flight Test Results from 2004 CDA Flight Trials

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Vertical Profile Design

- **25 Simulation runs conducted at LaRC.**
  - Runs piggy-backed during development sessions for QAT project.
  - Selected runs processed for noise levels using experimental INM.
  - Candidate arrival chart and procedures developed.
- **Over 40 hours of simulation testing at UPS.**
  - Full motion 757 and fixed-base 767 training simulators.
  - Refined chart and procedures to fit UPS operations.
- **3 beta-test flights conducted by UPS prior to full flight trials.**
  - Validate procedures in flight.
- **Aircraft in-trail separation analysis conducted at MIT.**
  - Fast-time monte-carlo simulation of 757 and 767 aircraft.
  - Defined aircraft separation requirements for conducting CDAs.

LaRC Test Facility

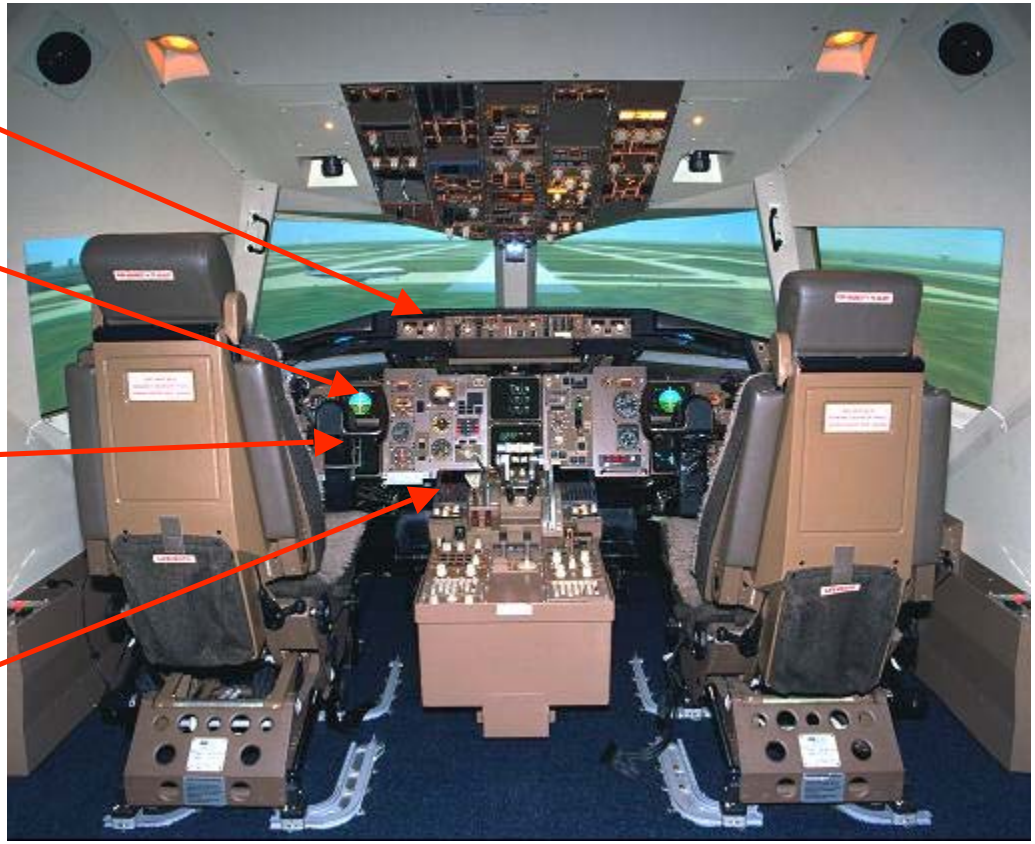
B757 Integration Flight Deck (IFD) Simulator

Mode Control Panel (MCP)

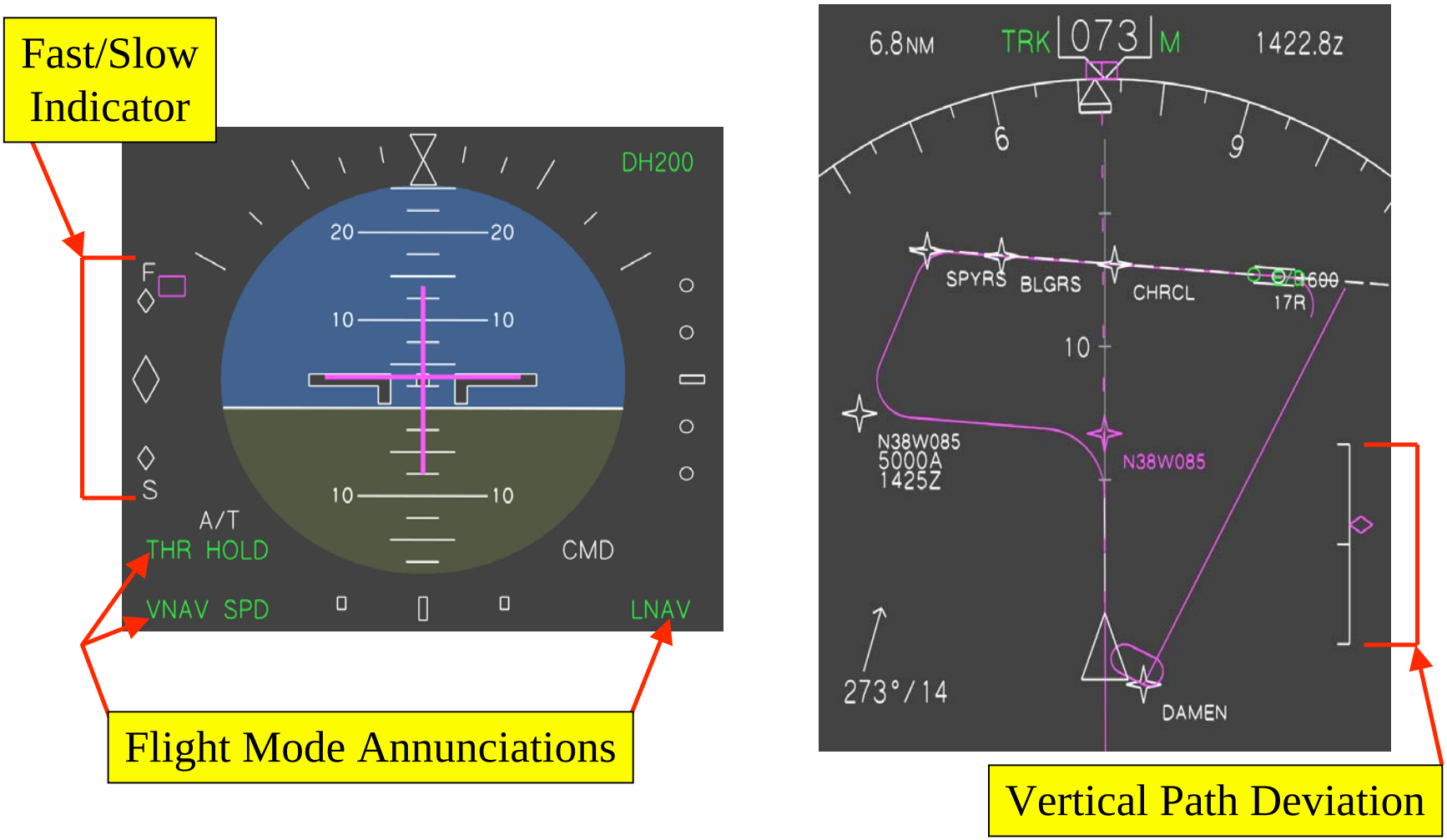
Electronic Attitude Director-Indicator (EADI)

Navigation Display (ND)

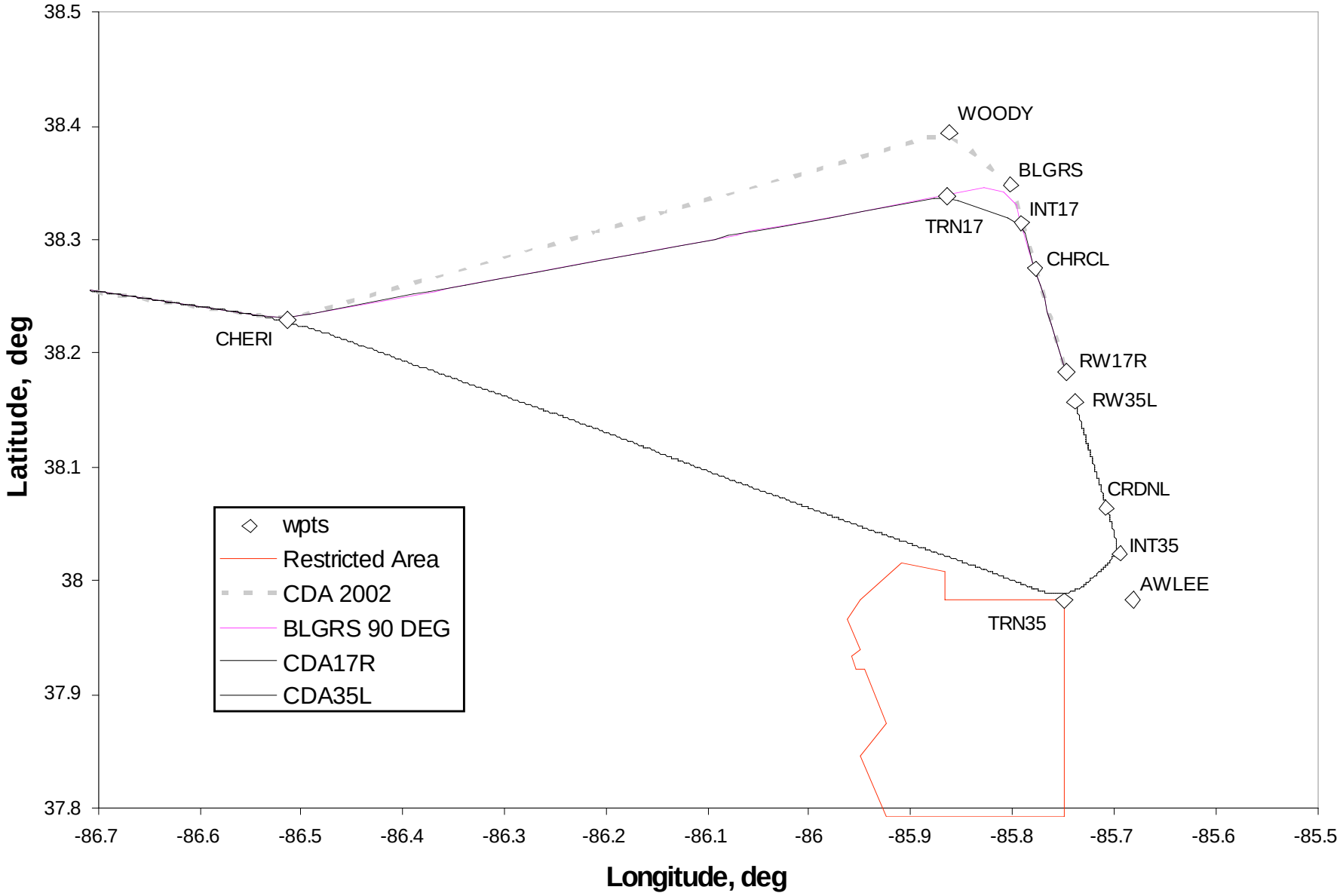
Flight Management Computer Control-Display Unit (FMC-CDU)



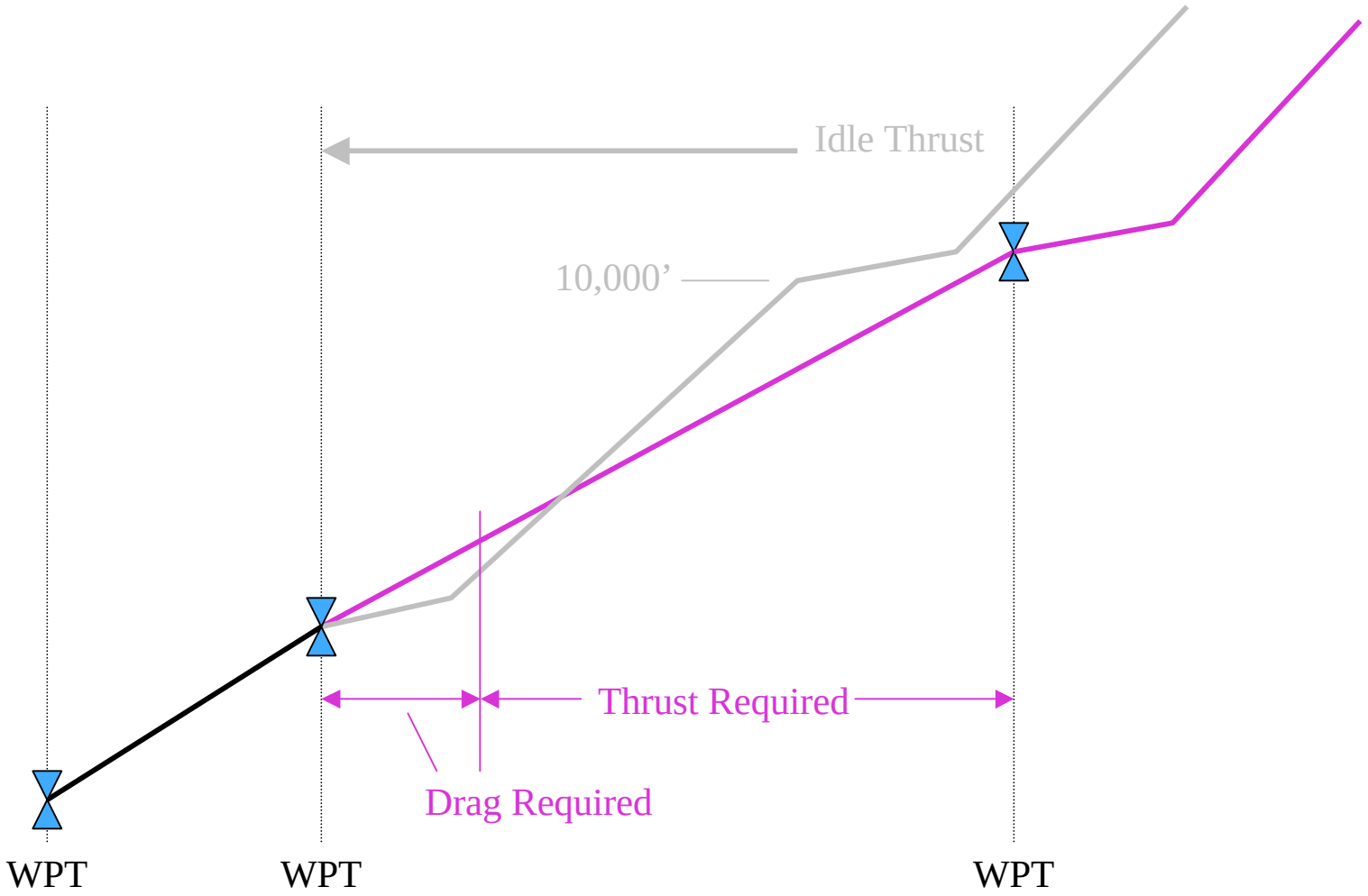
757 Standard Flight Displays



Routing Options



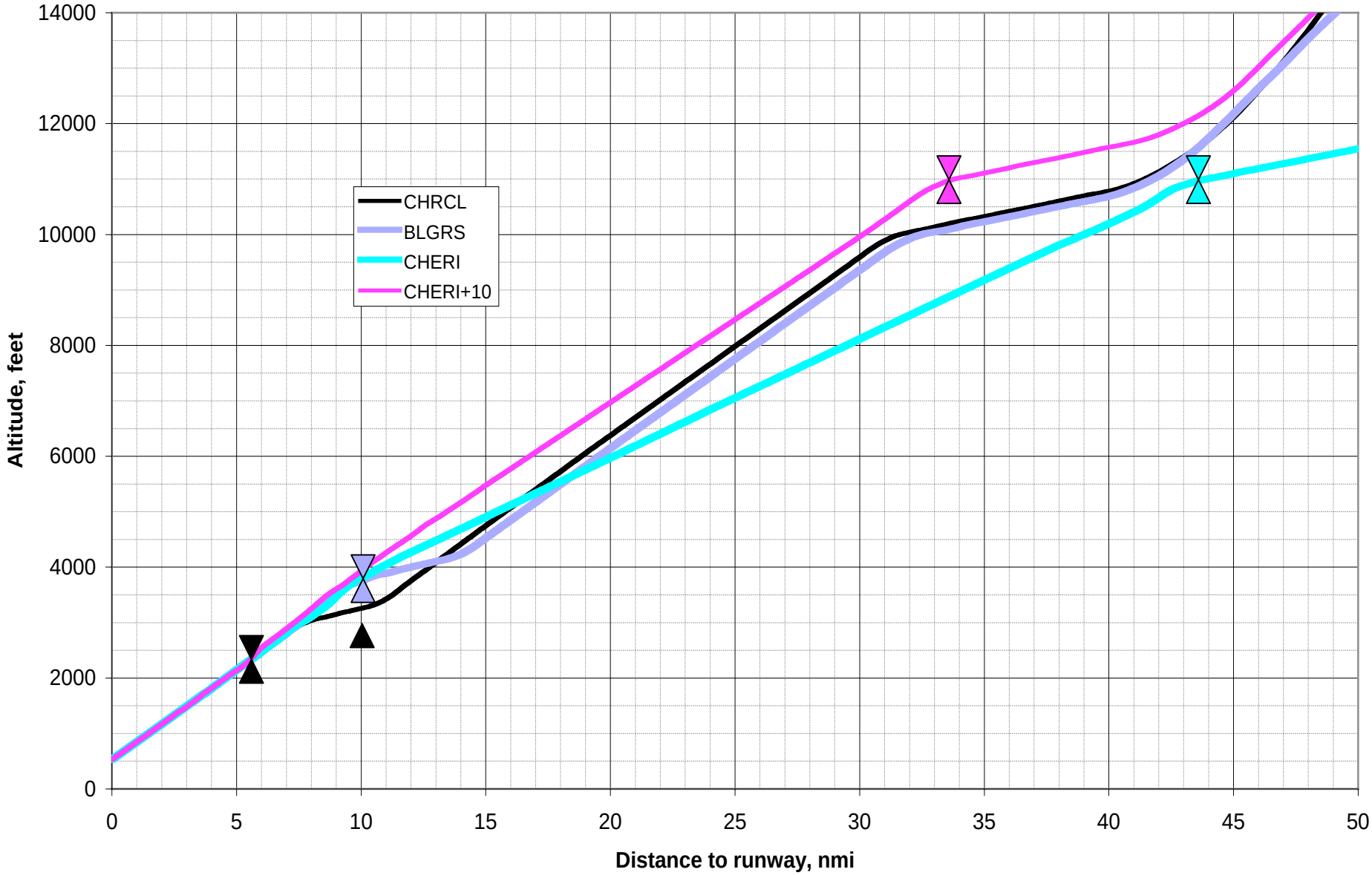
Waypoint Crossing Constraints



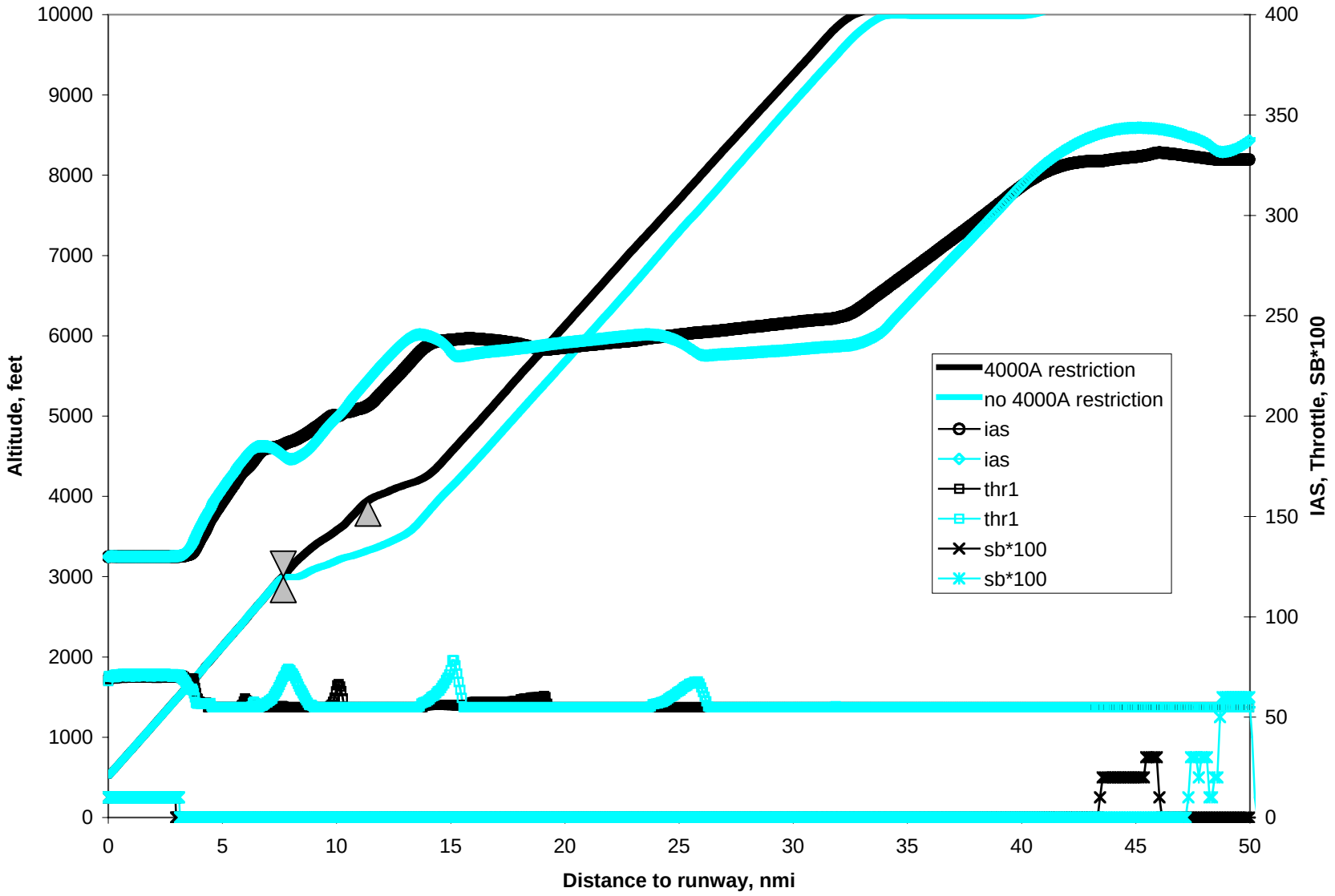
Candidate Crossing Constraints

Name	Waypoints		Comments
CHRCL	CHERI	---/-----	Default conditions for FMS
	BLGRS	---/3000A	FMS slows to 240 at 10000’
	CHRCL	170/2350	Idle thrust to CHRCL
BLGRS	CHERI	---/-----	Glide slope intercept at BLGRS
	BLGRS	190/3750	FMS slows to 240 at 10000’
	CHRCL	170/2350	Idle thrust to BLGRS
CHERI	CHERI	240/11000	2 deg descent from CHERI to BLGRS
	BLGRS	190/3750	Provides consistent slow down to 240
	CHRCL	170/2350	Thrust needed after CHERI
CHERI+10	CHERI	---/-----	3 deg descent from CHERI+10 to BLGRS
	CHERI+10	240/11000	Provides consistent slow down to 240
	BLGRS	190/3750	Near-idle thrust to BLGRS
	CHRCL	170/2350	

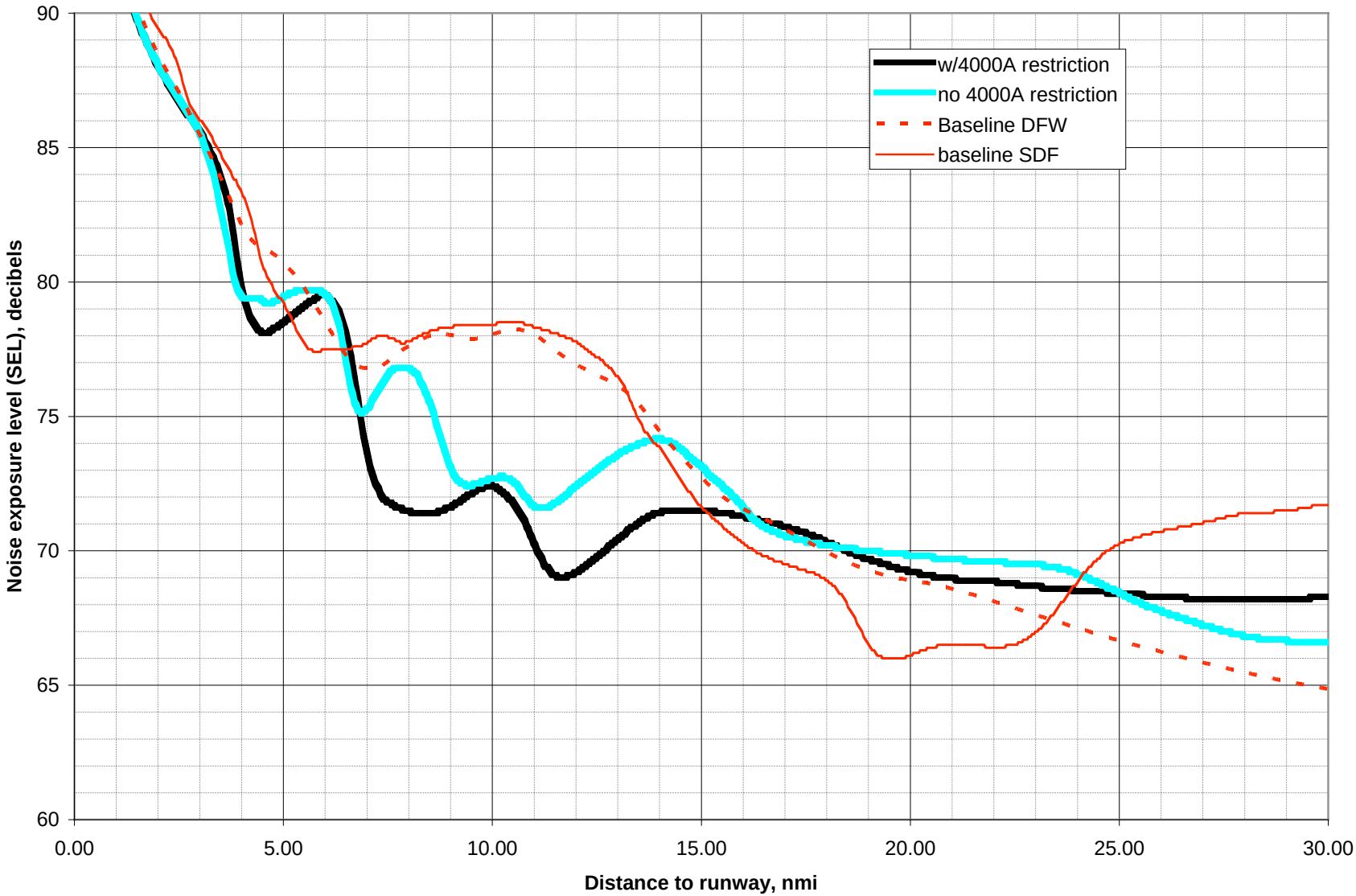
Comparison of Altitude Profiles



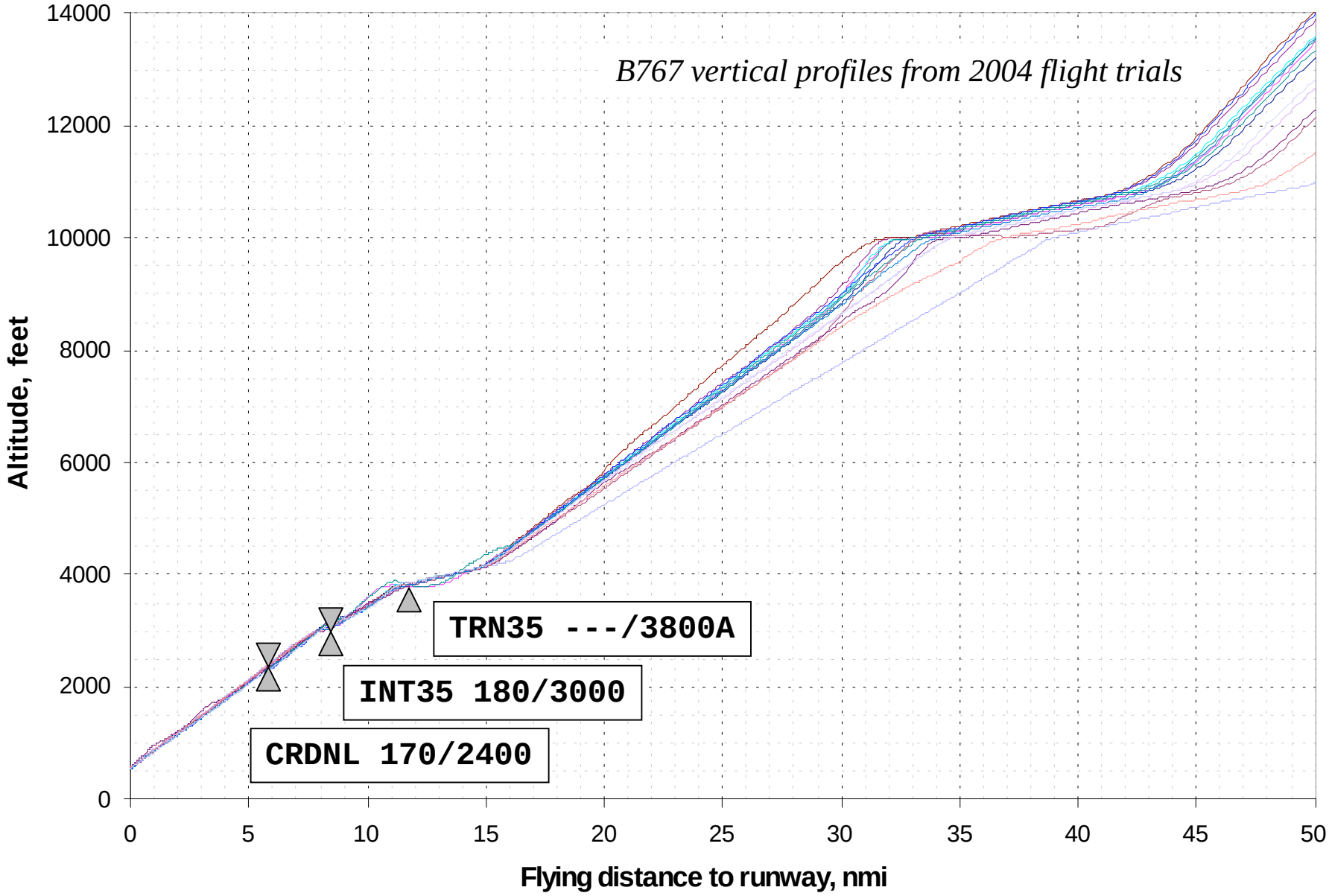
At or Above Altitude Constraint



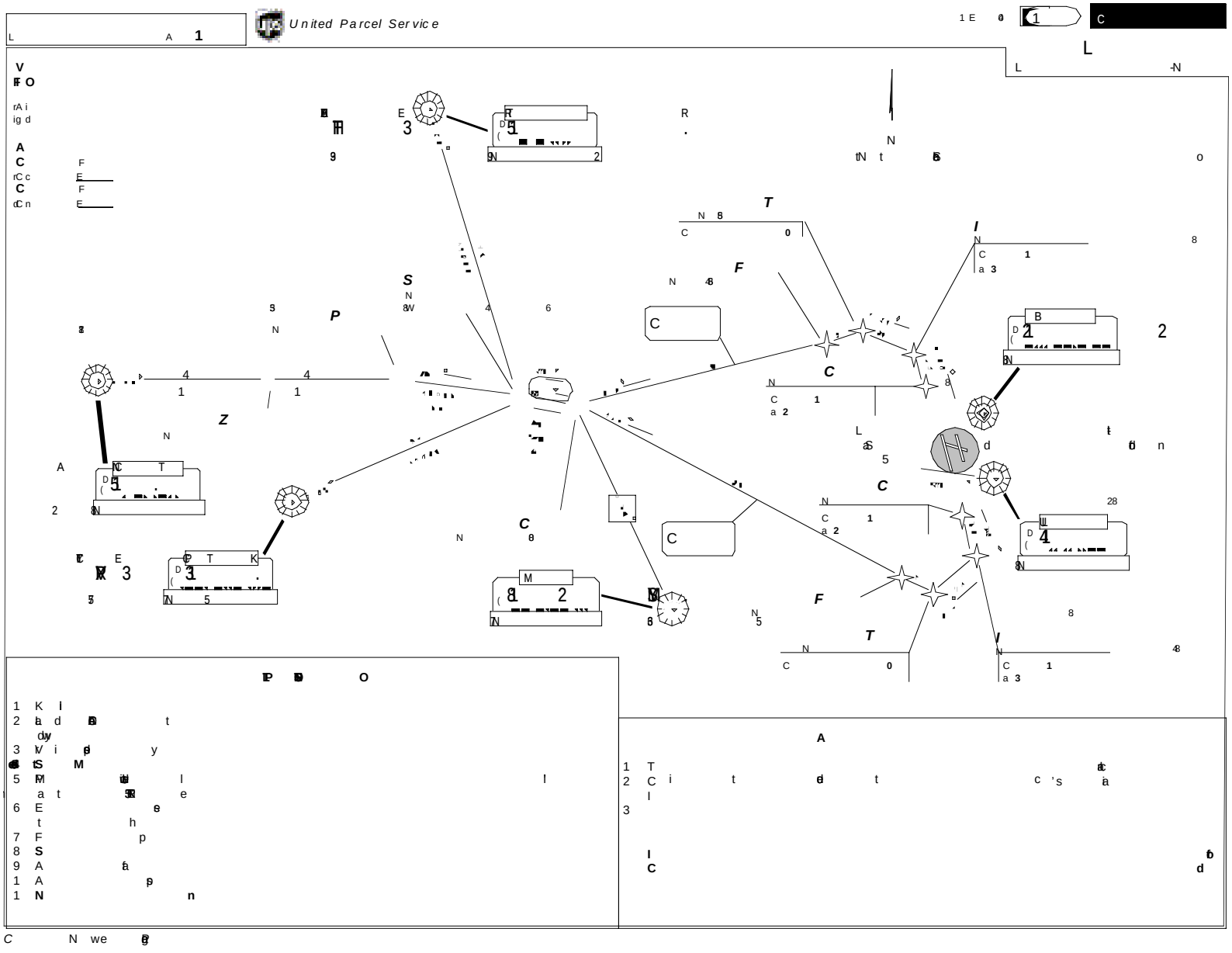
Effect of Altitude on Noise Levels



Final SDF CDA35L Vertical Profile



Final SDF CDA Arrival Chart



Some Key FMS Issues for CDA Design

- **Waypoint crossing constraints.**
  - Deceleration segments may not be inserted between constrained altitudes.
  - Speed constraints cannot be added without an altitude constraint.
  - Lowest altitude on CDA Arrival procedure must be at or above highest altitude of Approach procedure.
- **Aircraft performance, flap deployment and crew procedures must be considered in the design of vertical trajectory.**
- **Crew procedures should emphasize VNAV mode awareness.**
  - VNAV SPEED requires monitoring vertical deviation.
  - VNAV PATH requires vigilance on speed.

2004 Flight Trials

Analysis of FMS Performance

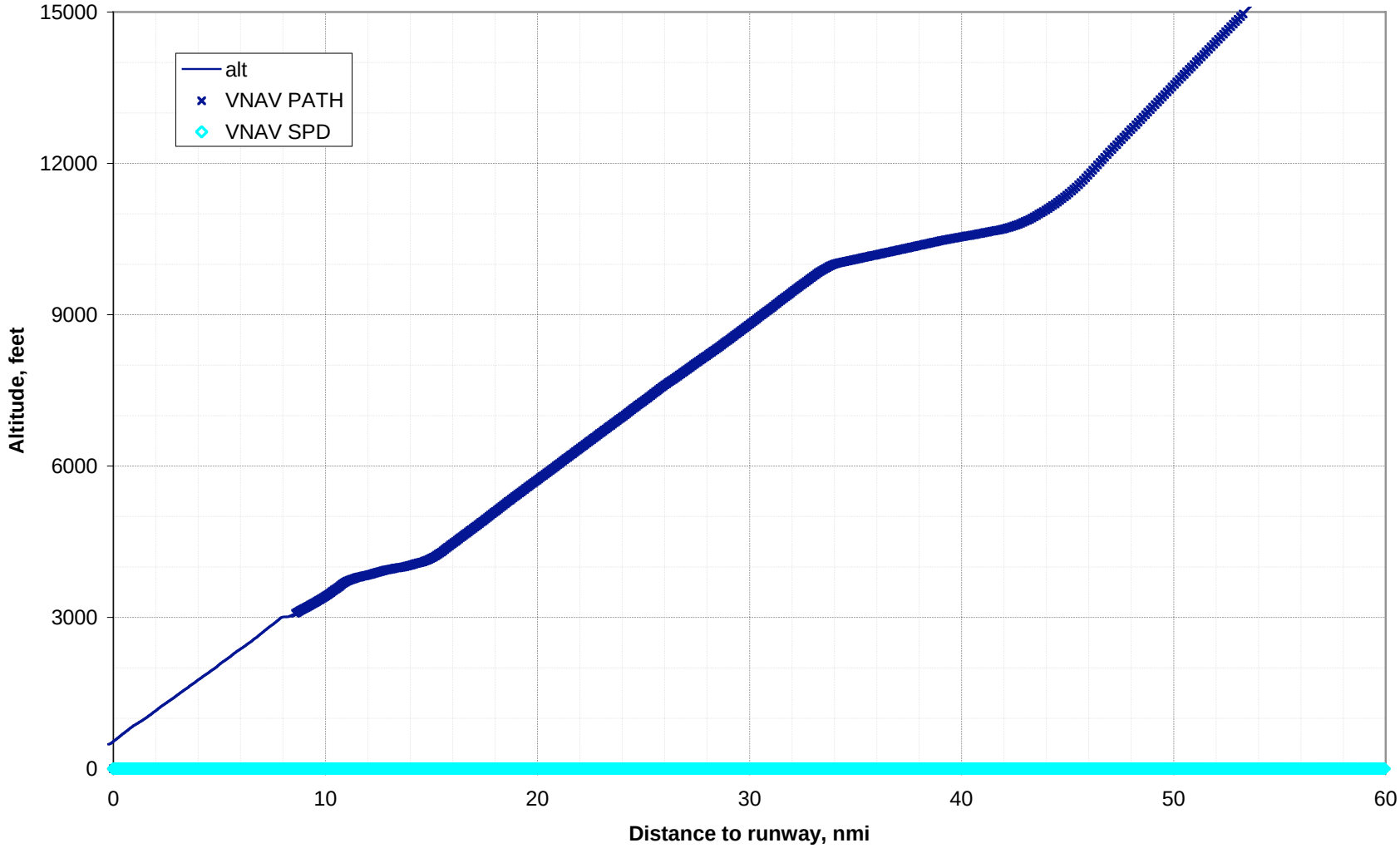
FDR Flights for FMS Analysis

	B-757		B-767		All
	R-17	R-35	R-17	R-35	
Non-CDA	0	2	1	1	4
Invalid data channels	1	4	0	0	5
Improper constraints	0	5	0	4	9
Suitable for Analysis	1	18	5	19	43
Total	2	29	6	24	61

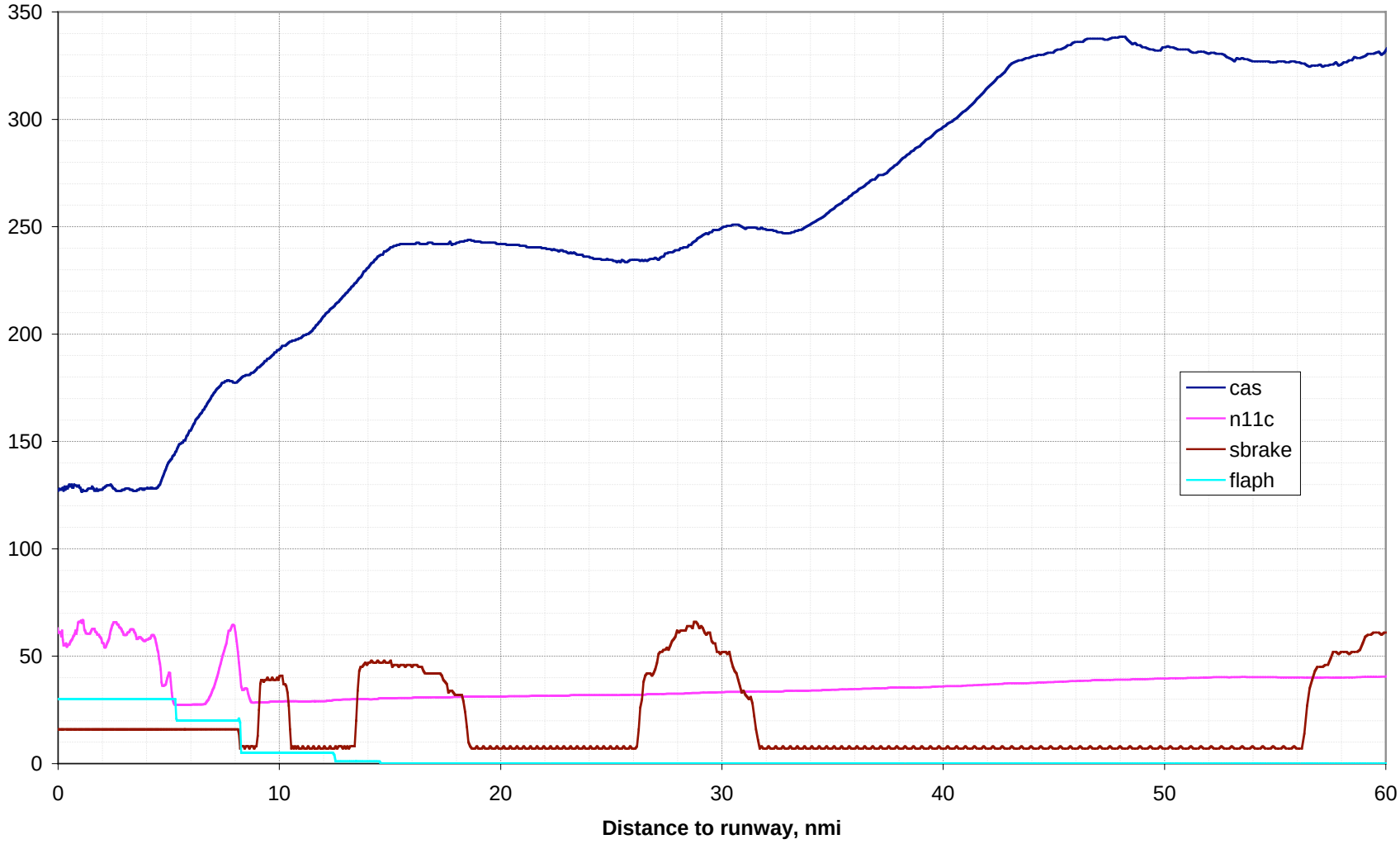
VNAV Summary

	B-757		B-767		All
	R-17	R-35	R-17	R-35	
VNAV Percent	100	96.9	95.7	95.7	96.4
VPATH Percent	100	87.2	94.9	84.3	87.4
Average N1	29.4	32.3	33.8	35.1	33.6
Average Speedbrake	16	21.6	9.6	18.3	17.7
Max Ave CHERI Altitude Min	10872 10872 10872	16683 14299 10872	10715 10621 10398	14280 13082 10719	16683 13271 10398
Ave TURN Altitude	3835	3917	3815	3839	3867
Ave INT Altitude	3039	3069	3018	3106	3078

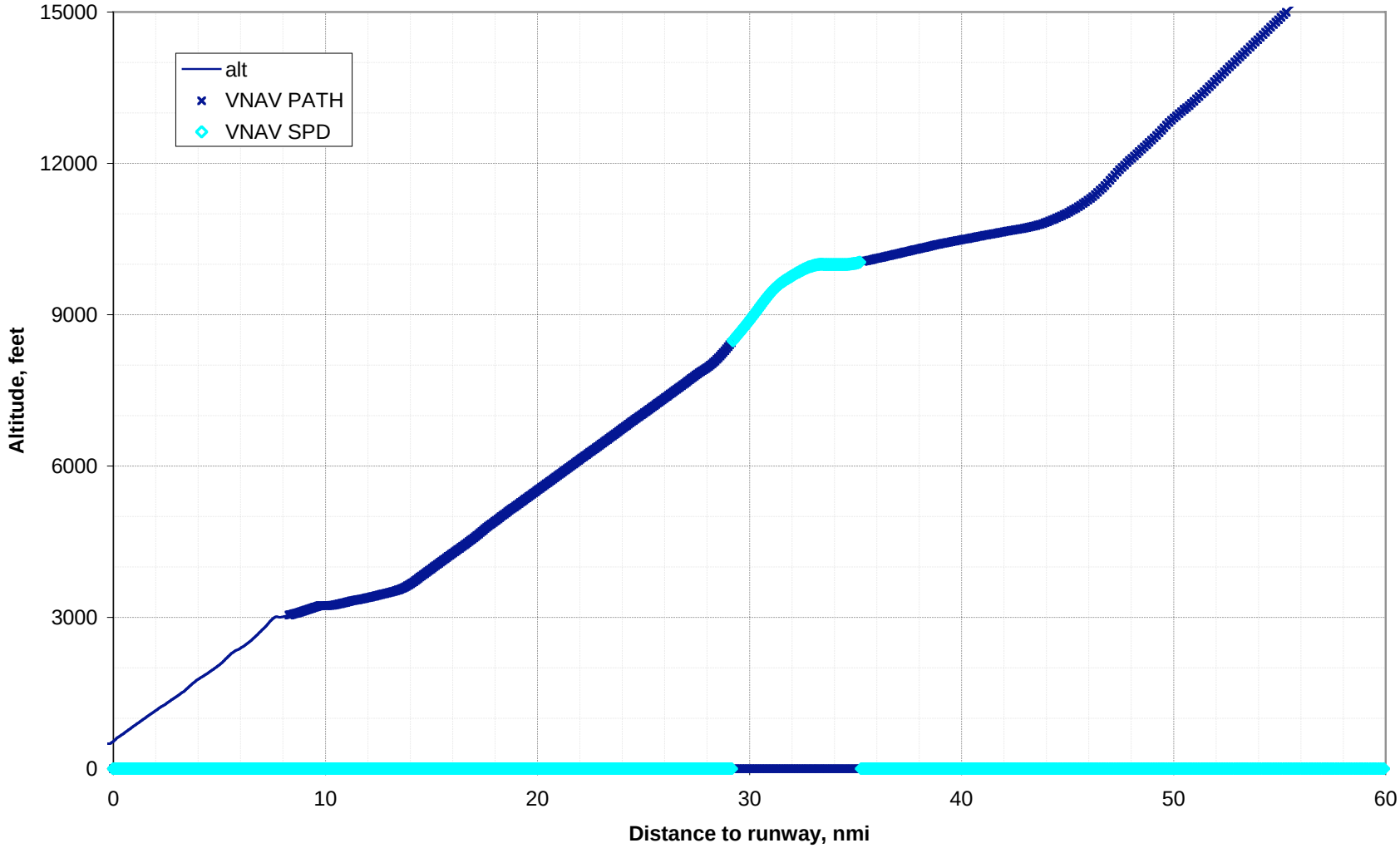
Typical VNAV PATH Vertical Profile



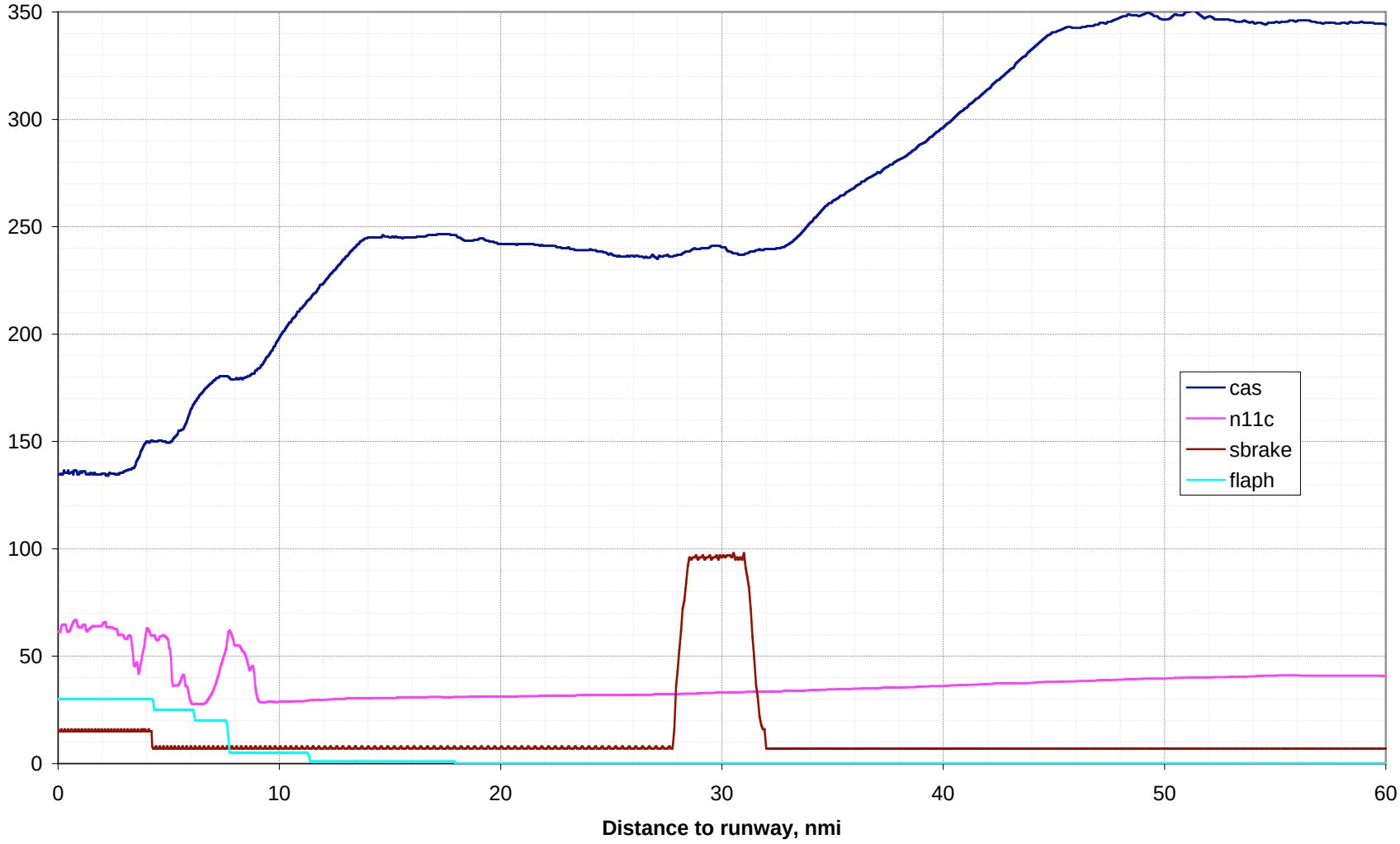
Typical VNAV (cont)



Vertical Profile with VNAV SPEED



VNAV SPEED (cont)



FMS Analysis Summary

- **FDR data obtained for about 35% of CDA test flights.**
- **VNAV usage was greater than 95% from TRACON entry to glideslope intercept.**
- **Vertical trajectories as expected.**
- **Unexpected issue of waypoint crossing constraints being cleared after loading approach.**
  - Altitude constraint for the initial approach fix of ILS 35L (AWLEE) was above the CDA TRN35 and INT35 constraints.
  - Pilots able to manually enter constraints in most cases.
- **Excessive speed brake required.**
  - Adjustment to placement of FLAP waypoint and crossing altitudes/speeds may be necessary.