Operations in Mountainous Areas

Terrain Clearance and Oxygen Requirements

Performance Engineer - Operations

Flight Operations Engineering

November 2002

Agenda:

- Descent Modes
- Terrain Clearance
  - Regulations
  - Analysis Methods
  - Operational Issues
- Oxygen Requirements (Passengers and Crew)
  - Oxygen Systems Overview
  - Regulations
  - Analysis Methods
  - Operational Issues

Issues

Terrain Clearance

- What are the legal requirements that I need to consider to plan a flight over mountainous areas?
- Where do I get terrain elevation information along a route? How much detail do I need?
- How do I conduct a terrain clearance analysis? Where do I find performance data?
- Are there any operational issues that might change how I do an analysis? What are they?

Issues

Oxygen Requirements (Passenger and Crew)

❖ What do the oxygen systems look like on Boeing airplanes for the flight crew? For passengers?

❖ What are the legal requirements that I need to consider to plan for flight over mountainous areas?

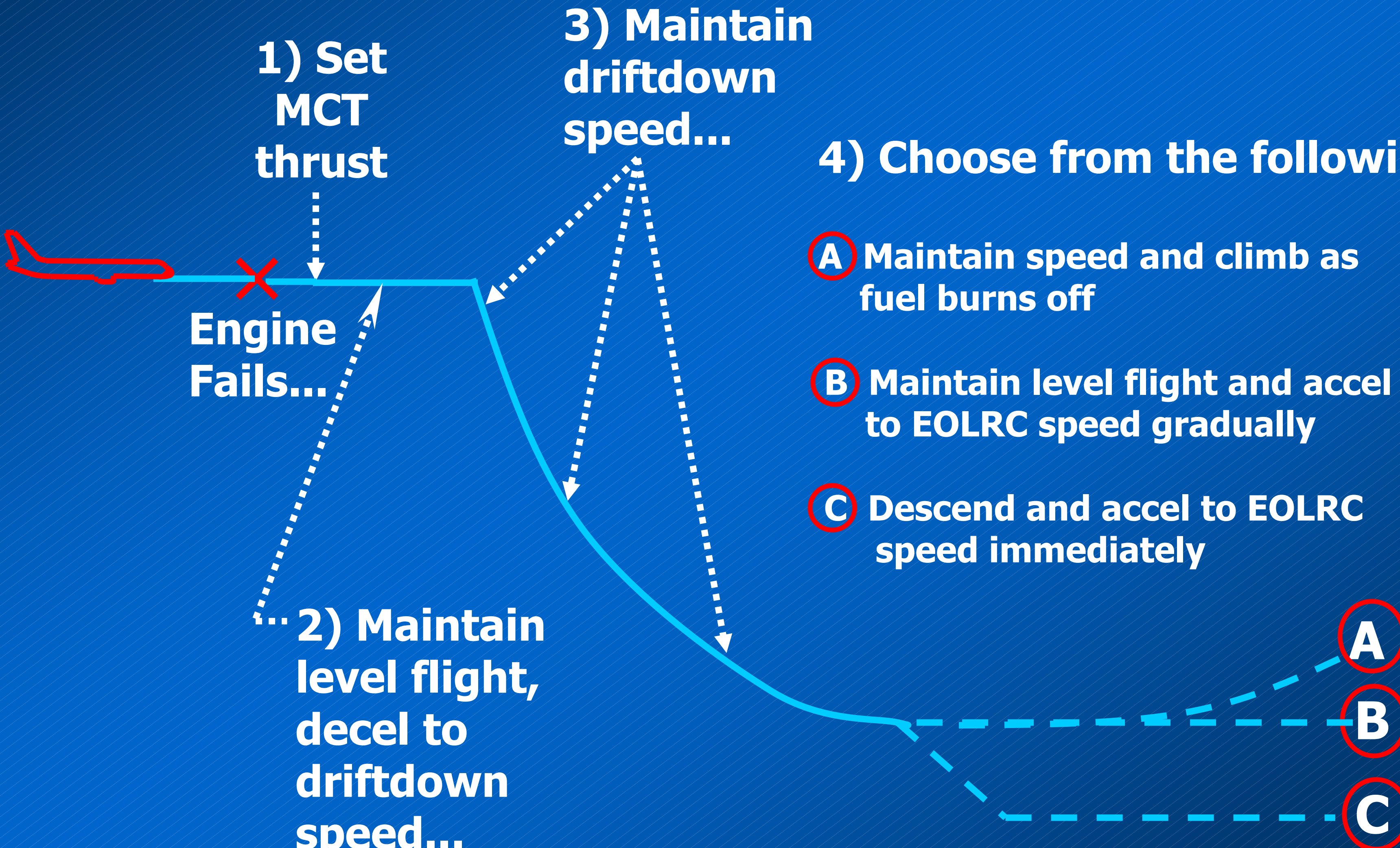
❖ How do I calculate oxygen requirements?

❖ Are there any operational or practical issues that I should consider in addition to the legal requirements?

Enroute Descent Modes

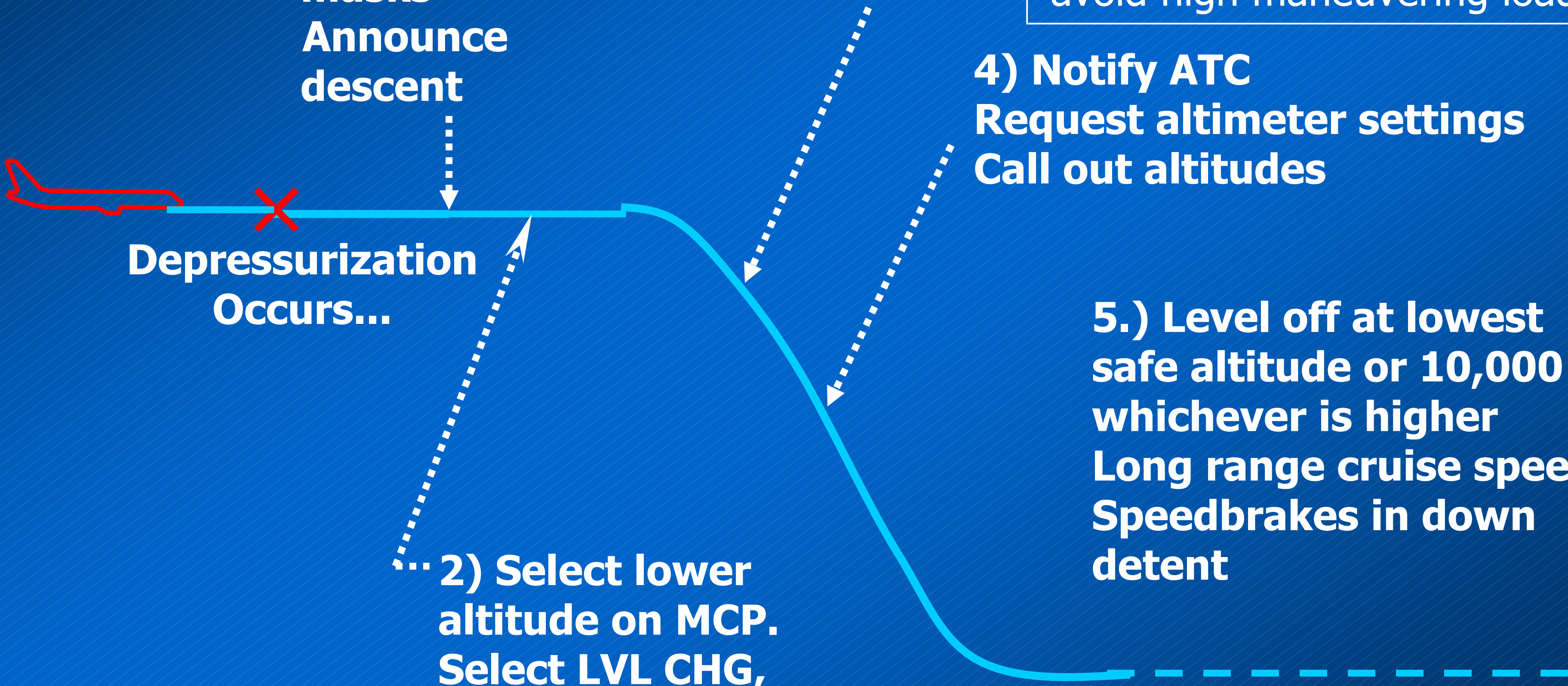
Mode	Constraint	Speed
Normal Enroute Descent Modes		
• *Min Fuel*	*Minimize descent fuel*	*CI = 0*
• *Min Time*	*Minimize trip time*	*CI = max*
• *Min Cost*	*Minimize descent cost*	*CI = K*
Non-normal Descent Modes		
• *Engine Inoperative Driftdown*	*Minimize R/D*	*Best L/D*
• *Emergency*	*Maximize R/D*	V_{MO}/M_{MO}

Driftdown Profile

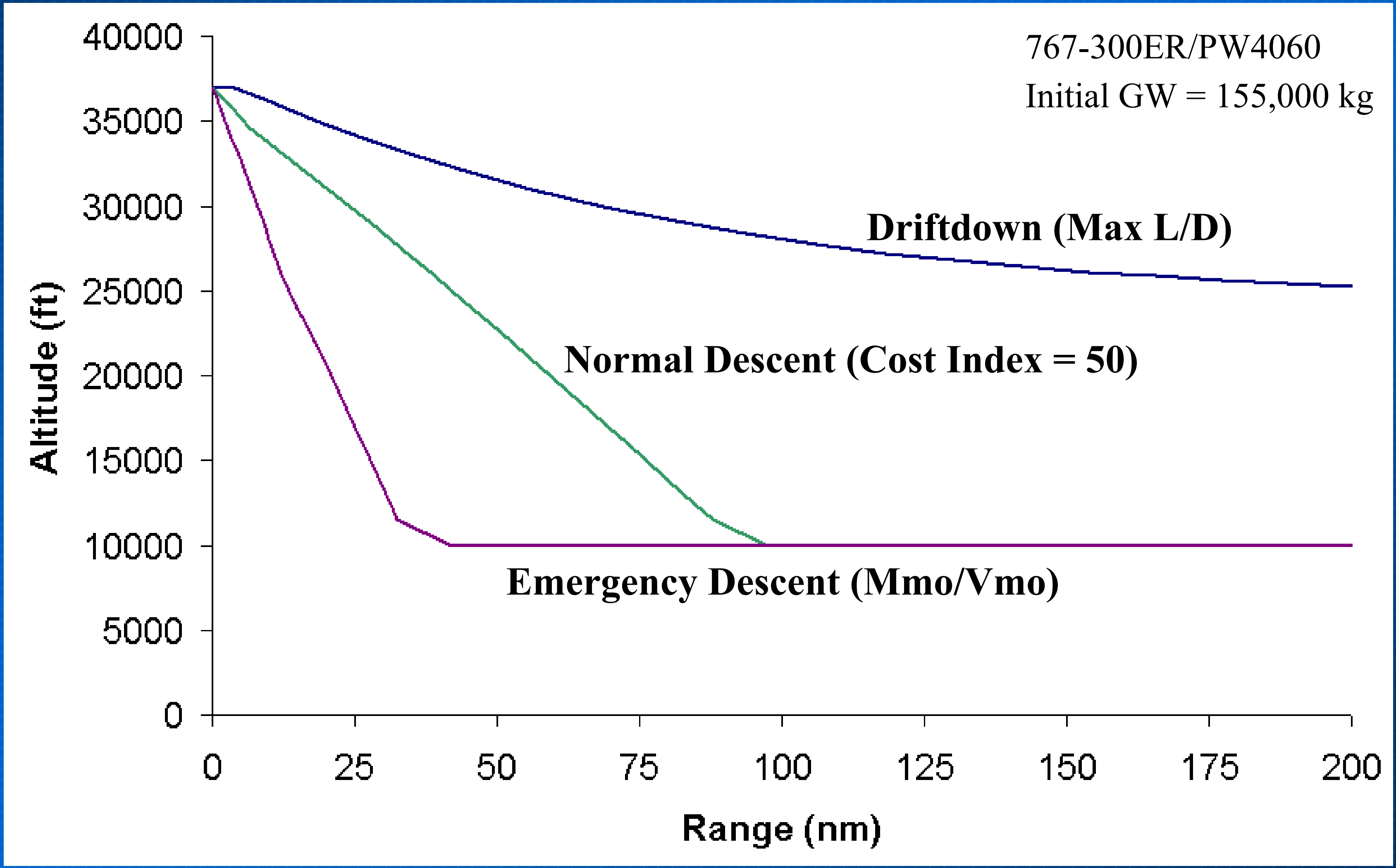


Generic Emergency Descent Profile

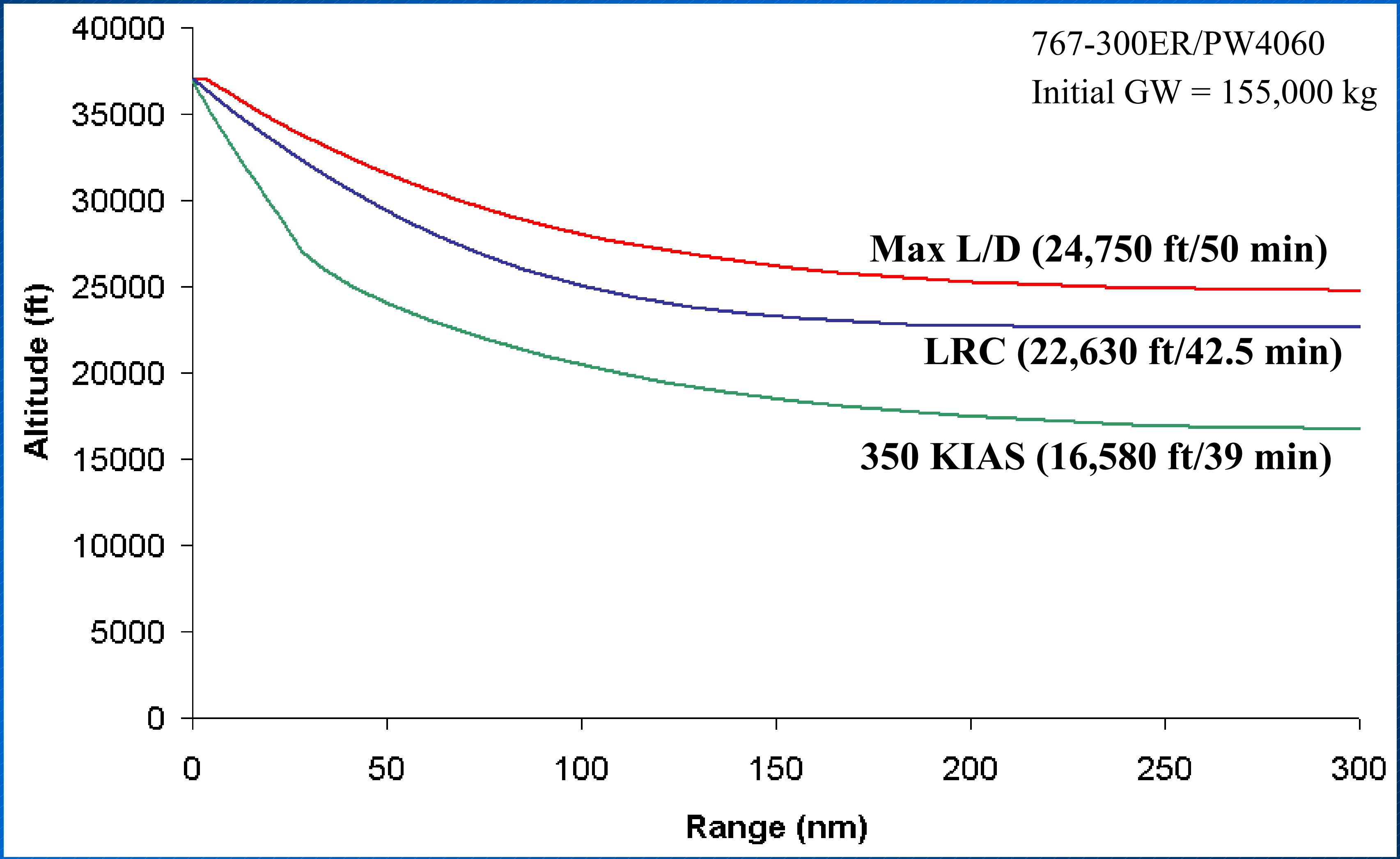
NOTE: If structural damage is suspected, limit airspeed and avoid high maneuvering loads.



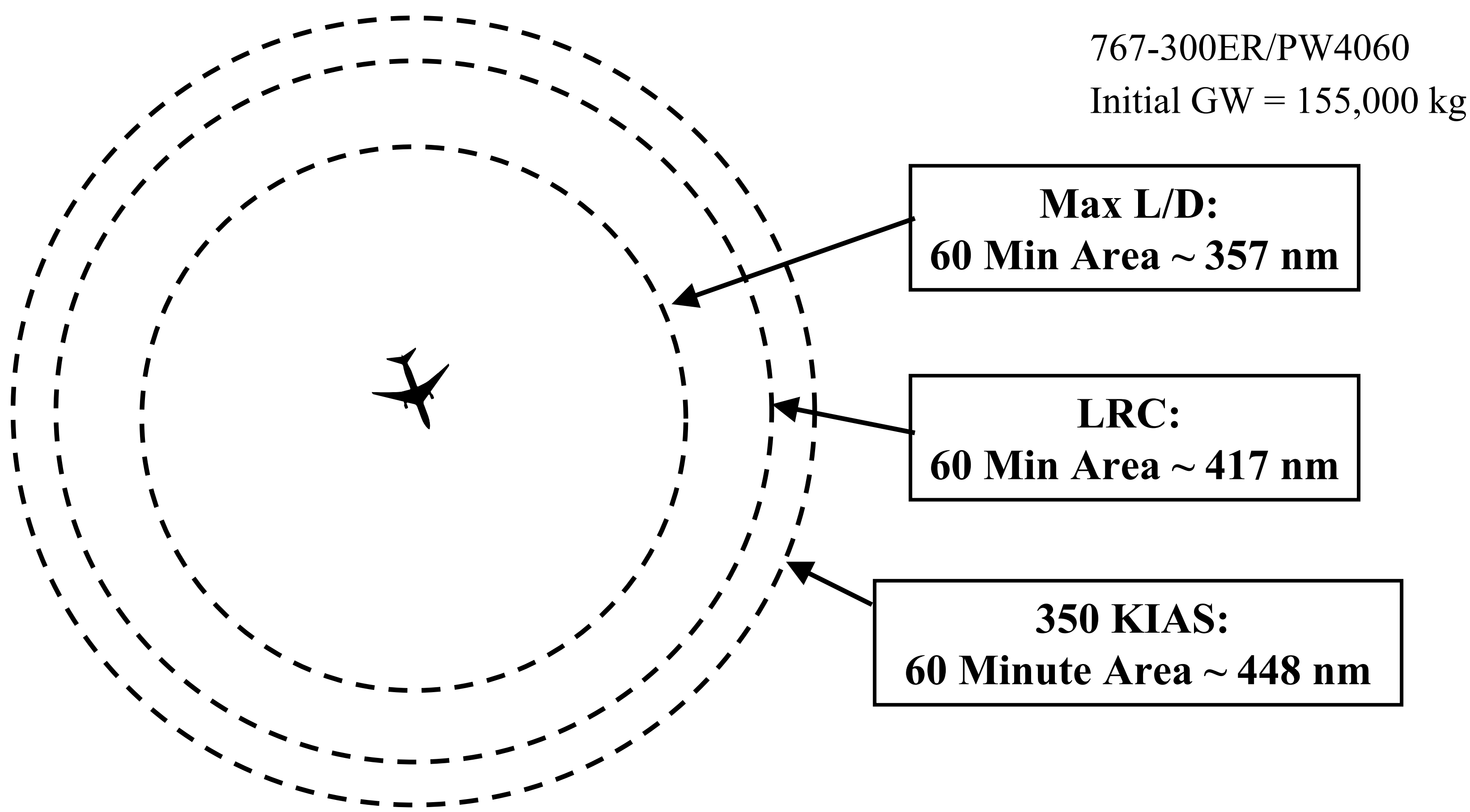
Descent Profile for Various Descent Modes



Altitude Capability after Engine Failure for Various Descent Speeds



ETOPs Area Capability after Engine Failure for Various Descent Speeds



Requirement to calculate terrain clearance

FAR (CFR), JAR OPS, CAA, CAAC, CASA, ???

↓

Obtain terrain information

Data Sources

↓

Determine terrain clearance

Escape Route
Special Procedure
Reroute
Reduce payload

↓

Consider oxygen requirements

Escape Route
Special Procedure
Change O2 System
Reroute

Terrain Clearance Analysis

FAR / JAR Requirements for Terrain Clearance

- **FAR 121.191 / JAR OPS 1.500**
  - Turbine Engine Powered: En Route Limitations: One Engine Inoperative.
- **FAR 121.193 / JAR OPS 1.505**
  - Turbine Engine Powered: En Route Limitations: Two Engines Inoperative.

But first, consider FAR 25.123 . . .

Net Flight Path [Enroute] – FAR 25.123

FAR Part 25.123 requires that the actual enroute airplane climb performance be calculated in the most conservative airplane configuration and then further decreased by the following gradient conservatisms:

One-engine inoperative net flight path requirement

1.1% for two engine airplanes

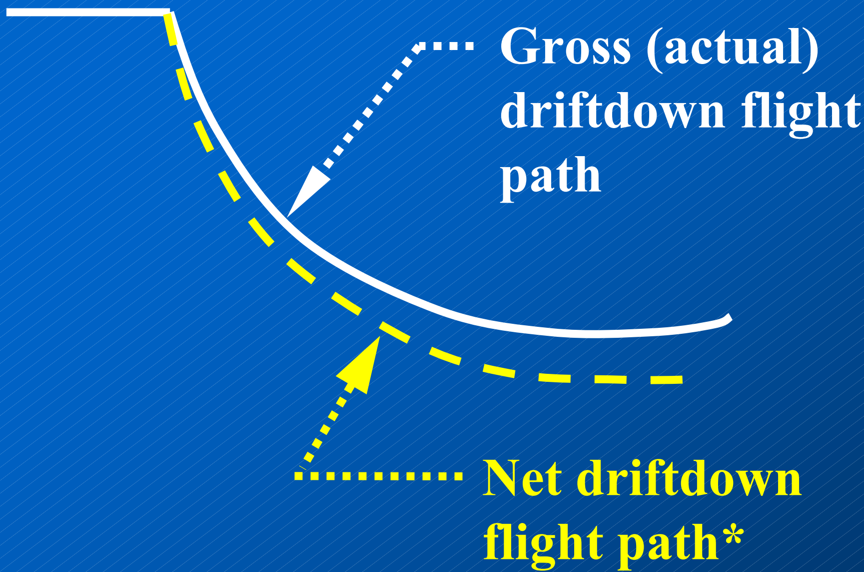
1.4% for three-engine airplanes

1.6% for four-engine airplanes

Two-engine inoperative net flight path requirement

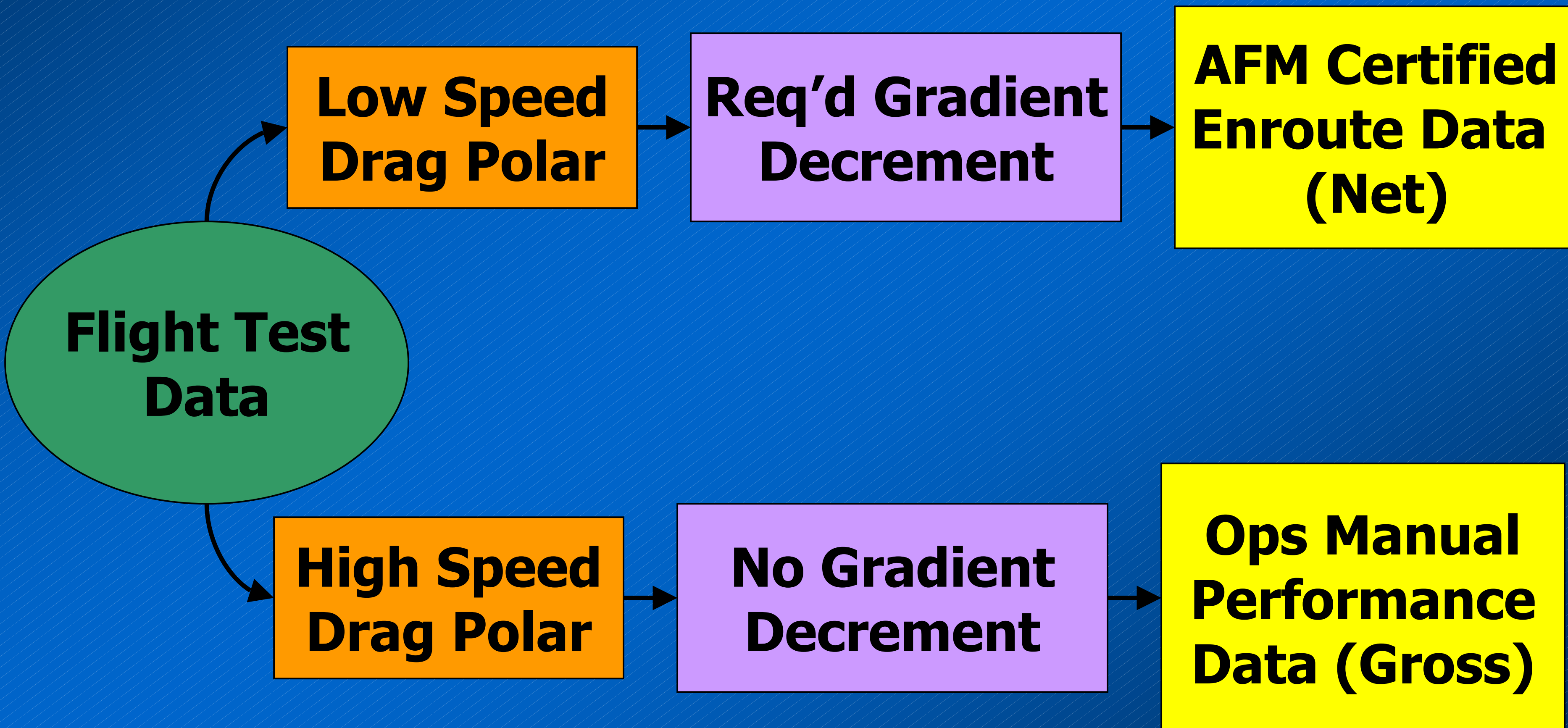
0.3% for three-engine airplanes

0.5% for four-engine airplanes

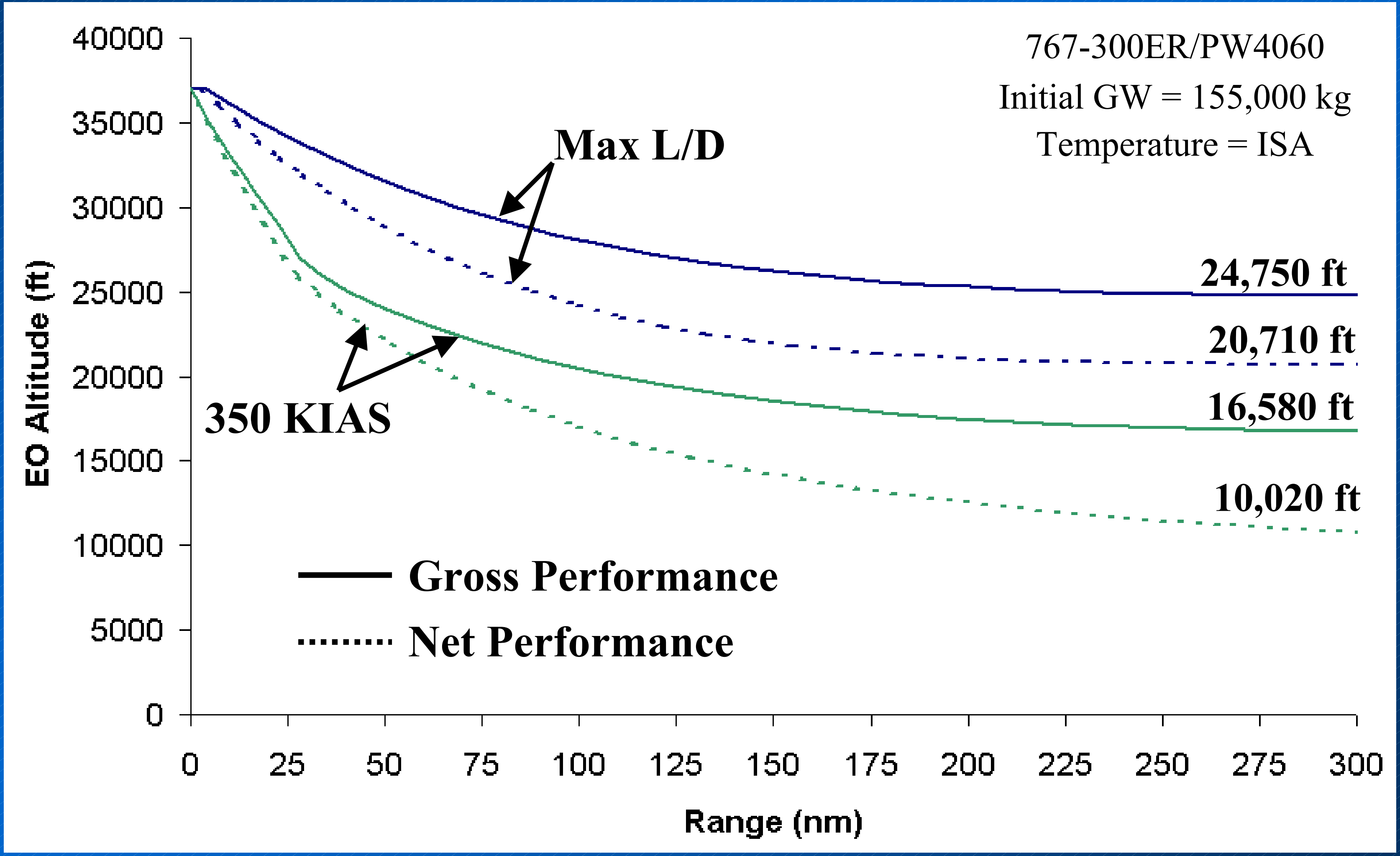


** The enroute net flight path is used to ensure enroute terrain clearance*

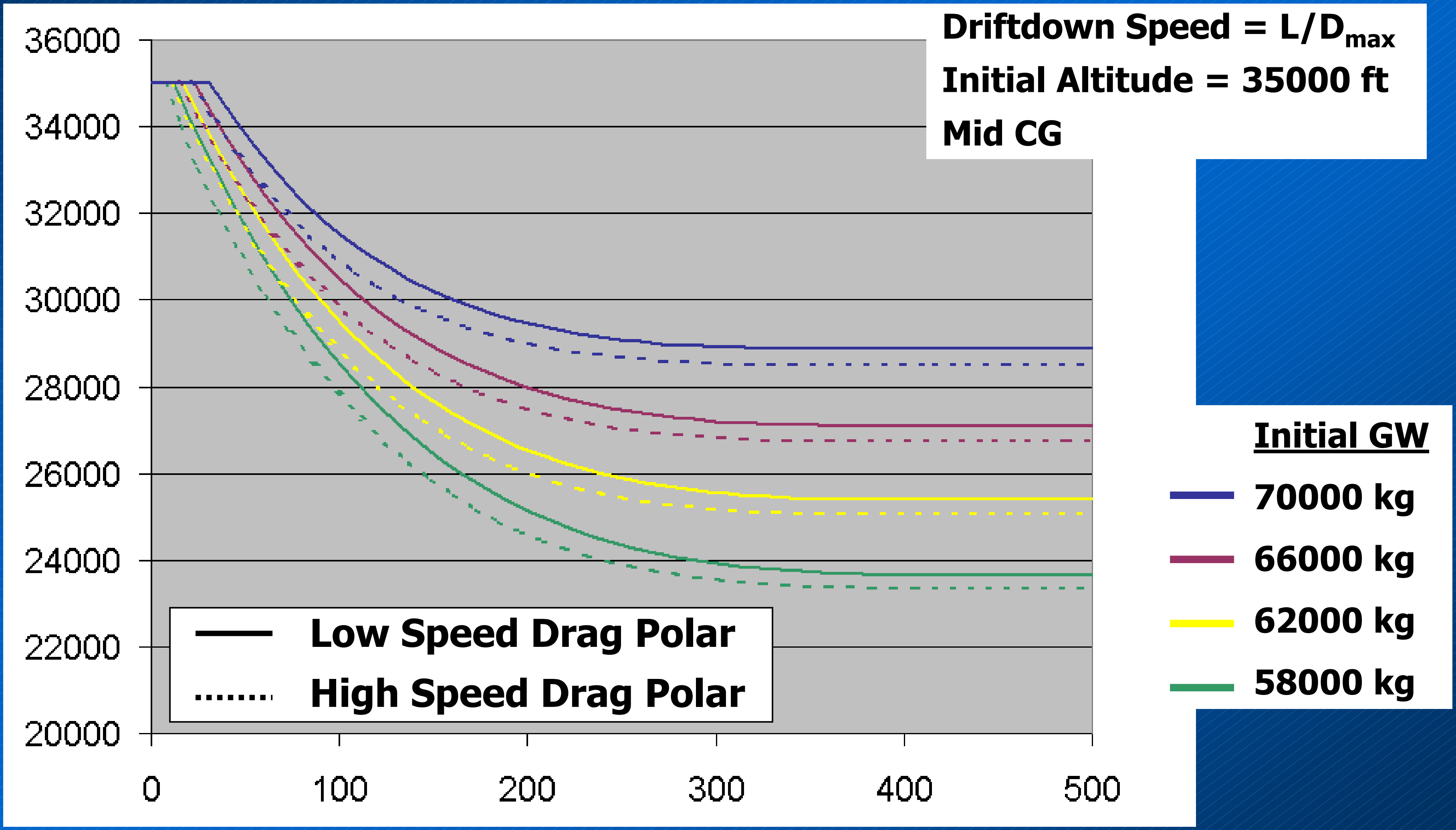
AFM Engine-Out Data Uses Low Speed Drag Polar



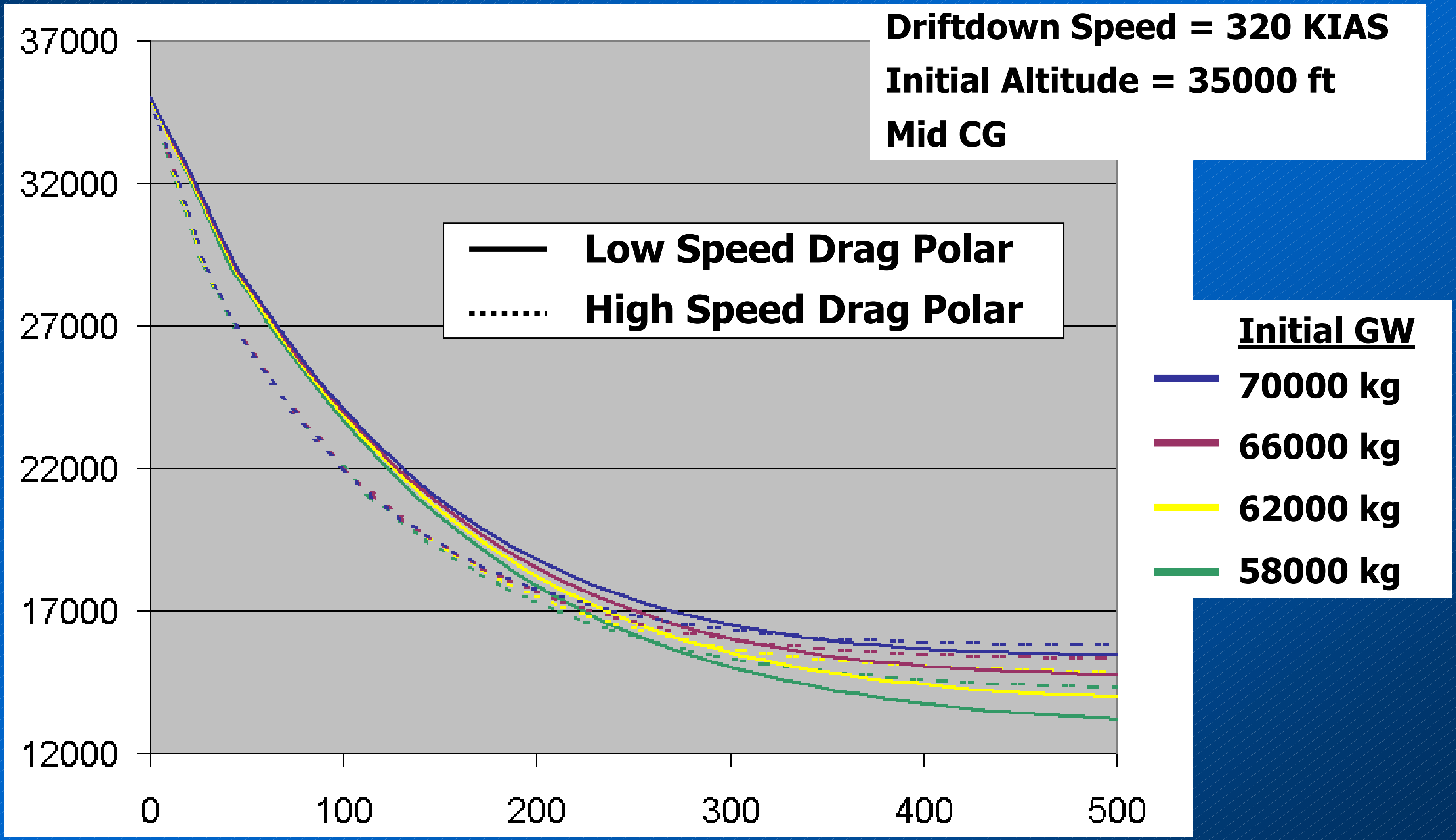
Gross and Net Performance Comparison During Driftdown



737-700 Driftdown from 35000 ft

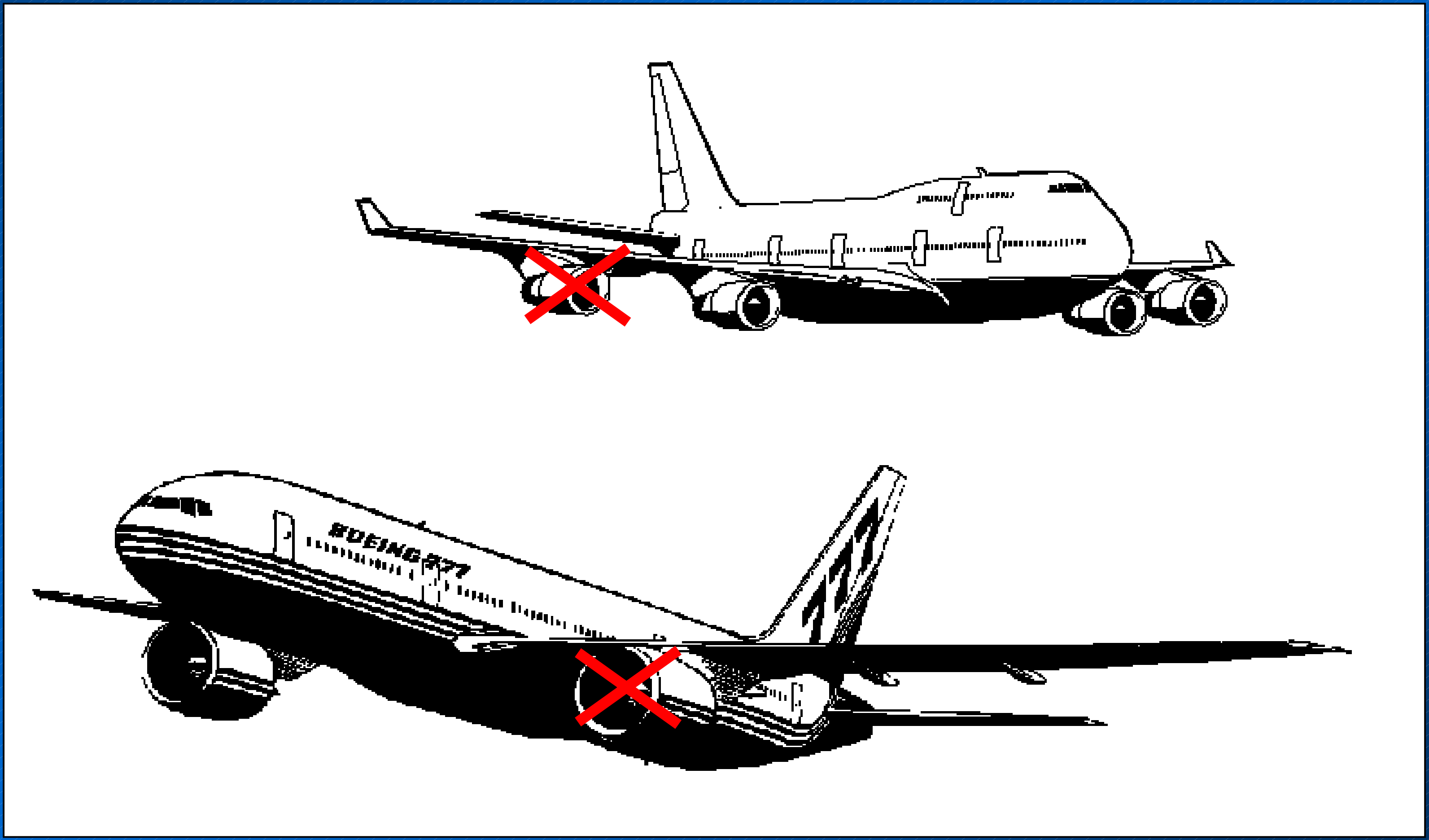


737-700 Driftdown from 35000 ft



FAR 121.191 / JAR OPS 1.500

Turbine Engine Powered: En Route Limitations:
One Engine Inoperative.



FAR 121.191 *(paraphrased)*

No person shall takeoff in an airplane at a weight that is greater than that which allows for compliance with the requirements of paragraph (a) (1) *OR* (a) (2), assuming the following conditions:

- **En route net flight path data from the AFM is used**
- **Expected ambient en route temperatures are used**
- **Normal fuel and oil consumption is assumed**

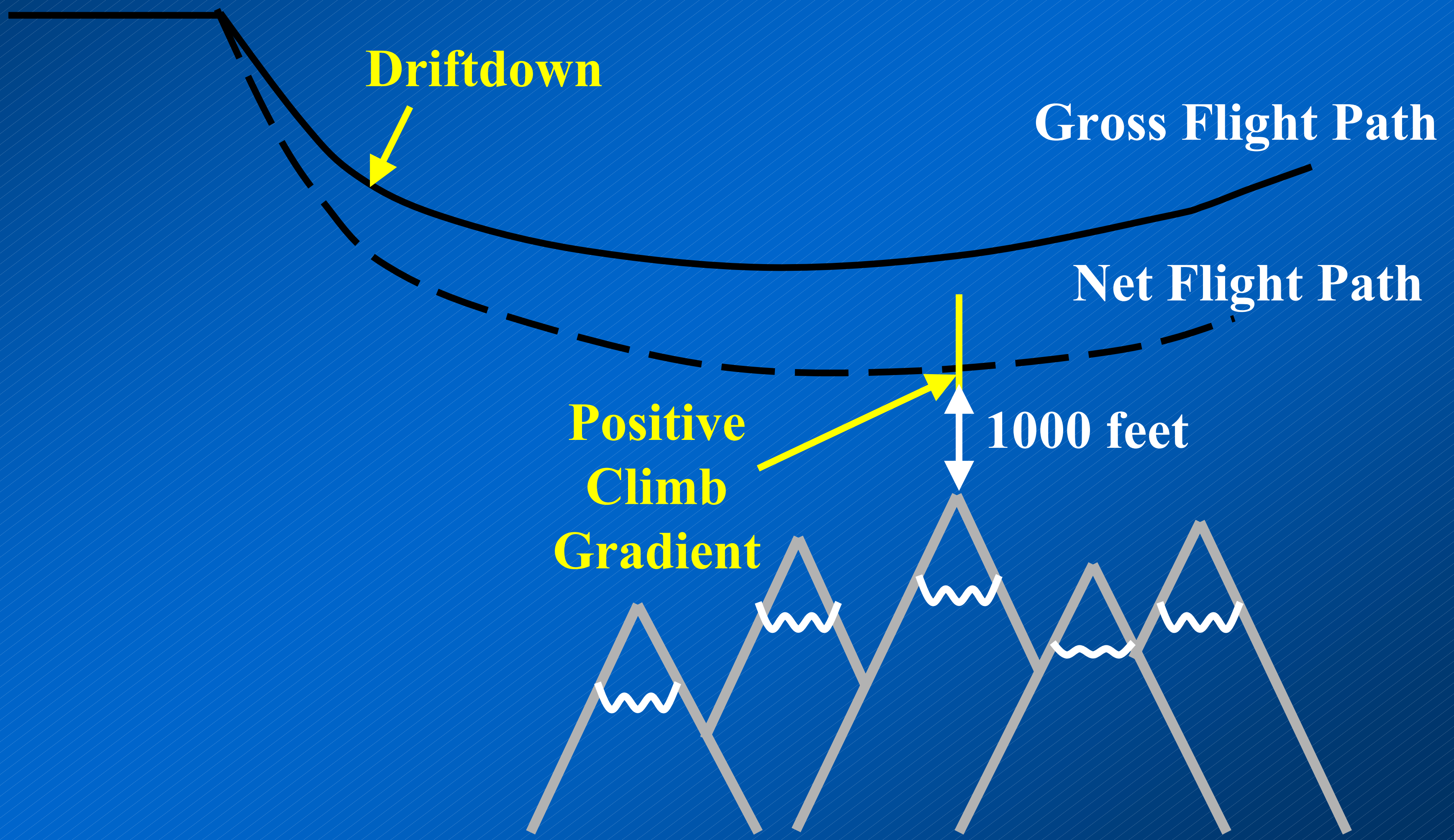
FAR 121.191(a) (1) *(paraphrased)*

- There is a positive slope (climb gradient) at an altitude of at least 1,000 feet above all terrain and obstructions within five statute miles on each side of the intended track

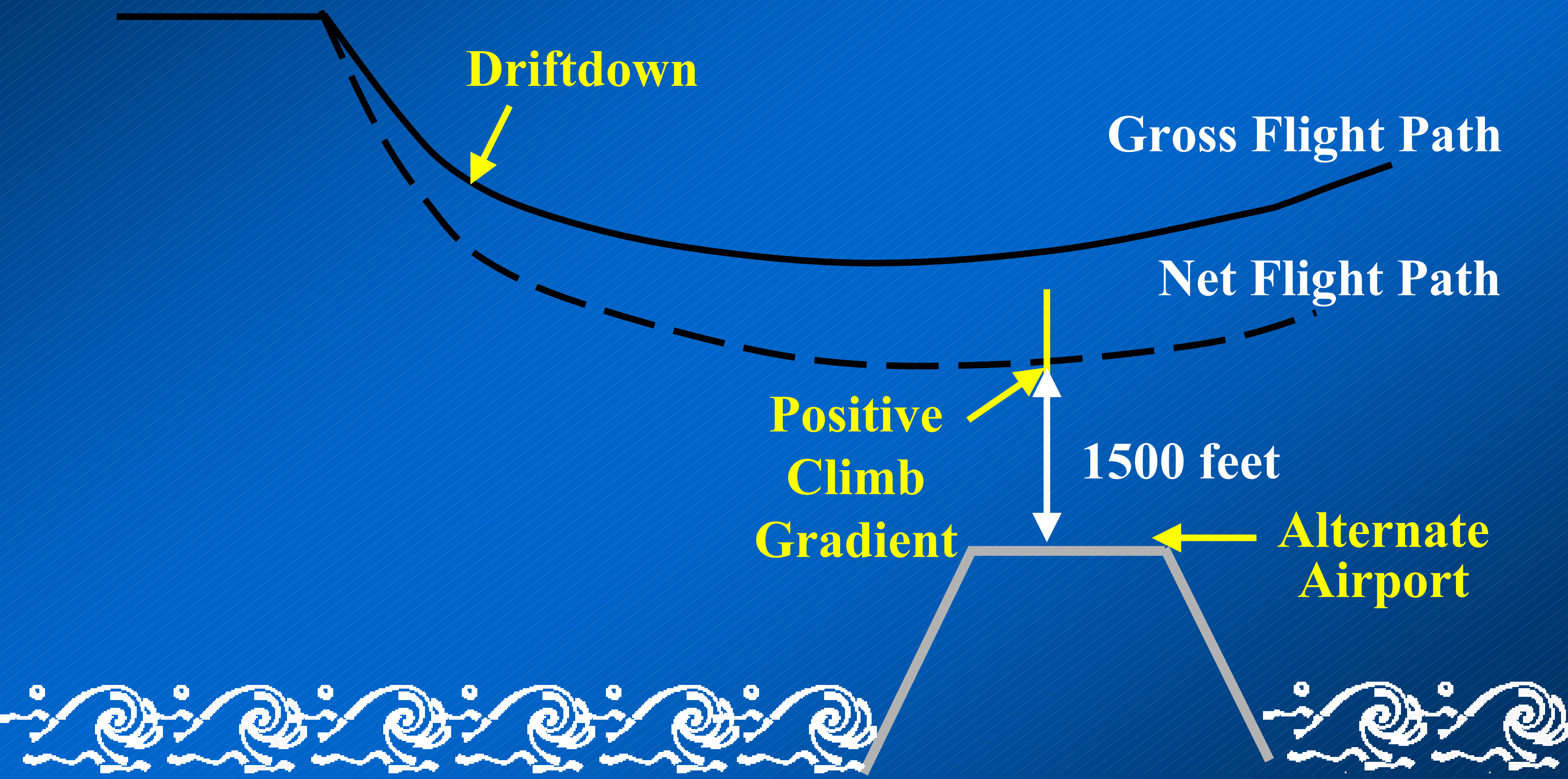
and

- There is a positive slope (climb gradient) at 1,500 feet above the airport where the airplane is assumed to land after an engine fails.

FAR 121.191(a) (1) (pictorial)



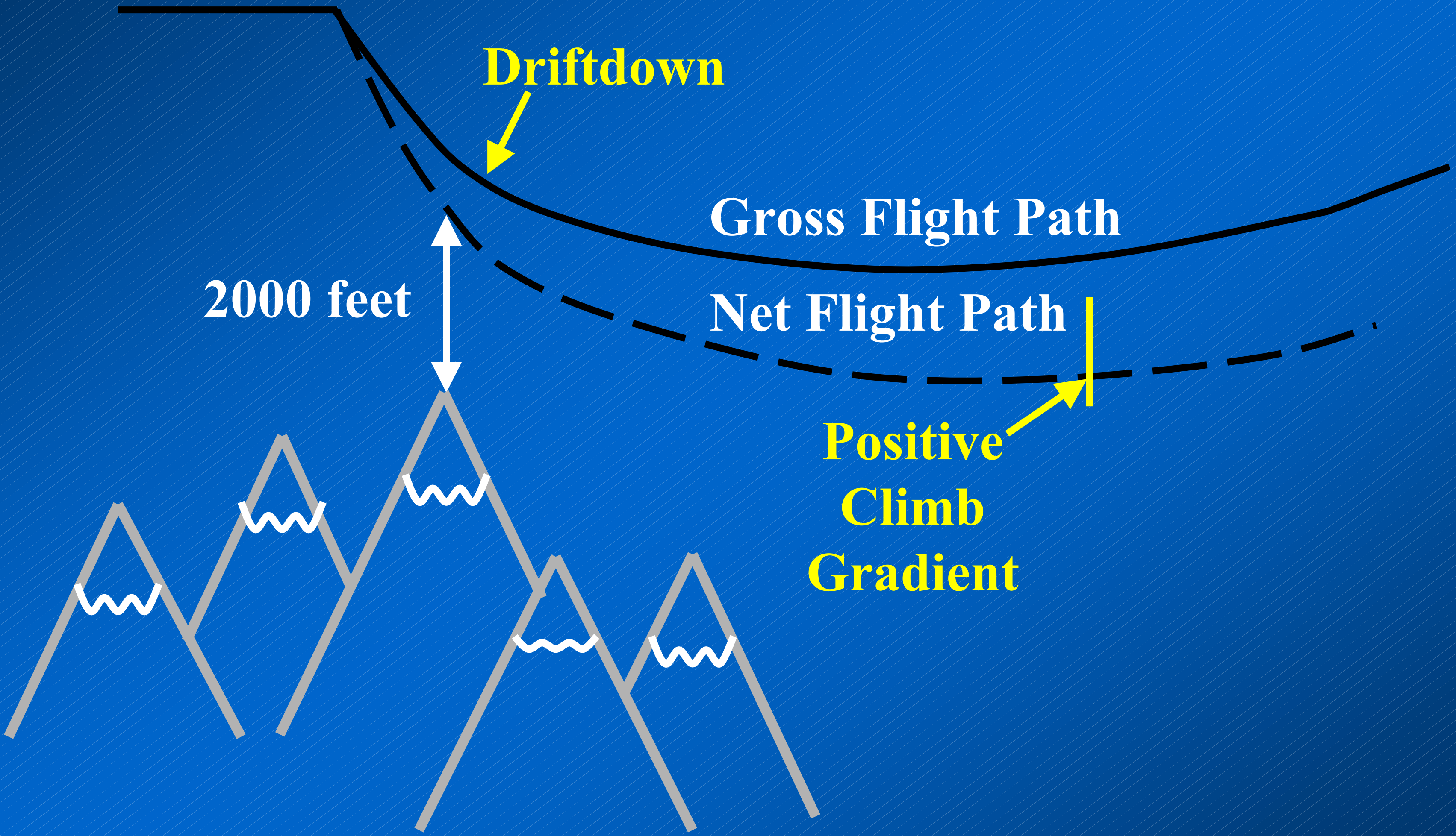
FAR 121.191(a) (1) (pictorial)



FAR 121.191(a) (2) *(paraphrased)*

The net flight path allows the airplane to continue flight from the cruising altitude to an airport where a landing can be made, clearing all terrain and obstructions within five statute miles of the intended track by at least 2,000 feet vertically

FAR 121.191(a) (2) (pictorial)



FAR 121.191 Performance Assumptions

For the purposes of paragraph (a) (2), it is assumed that:

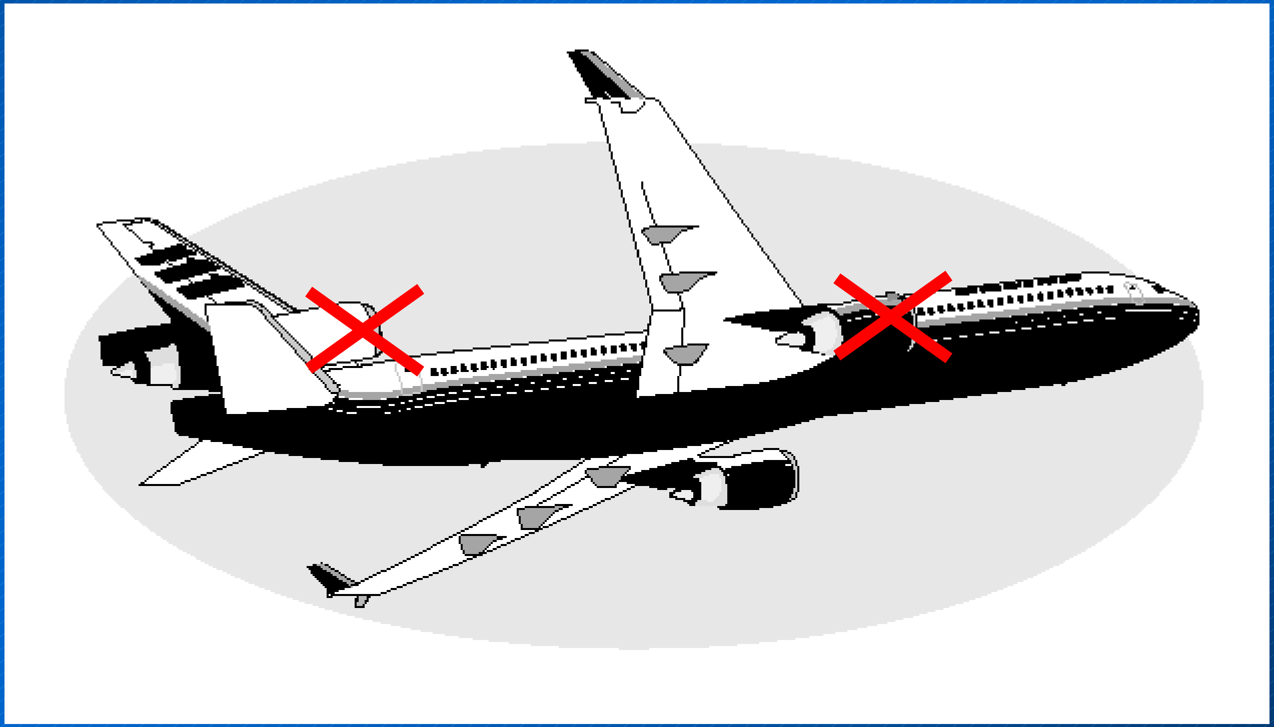
- The engine fails at the most critical point en route
- Navigational accuracy is considered
- Adverse winds are considered
- Fuel jettison is allowed
- Alternate airport is in dispatch release and meets weather minima (adequate and suitable)
- Take into account normal fuel and oil consumption

JAR OPS 1.500

- Essentially the same as FAR 121.191 with the following exception
  - Must consider terrain and obstructions within 5 nautical miles not 5 statute miles (4.34 nautical miles)

FAR 121.193 / JAR OPS 1.505

Turbine Engine Powered: En Route Limitations: Two Engines Inoperative.



FAR 121.193(c)* *(paraphrased)*
Enroute Limitations - Two Engines Inoperative

No person may operate a turbine engine powered airplane along an intended route unless he complies with either of the following:

(1) There is no place along the intended track that is more than 90 minutes (with all engines operating at cruising power) from a suitable alternate airport.

OR

(2) The airplane can fly from the point where two engines are assumed to fail simultaneously to a suitable alternate airport, with the net flight path clearing vertically by at least 2,000 feet all terrain and obstructions within five statute miles (4.34 nautical miles) on each side of the intended track.

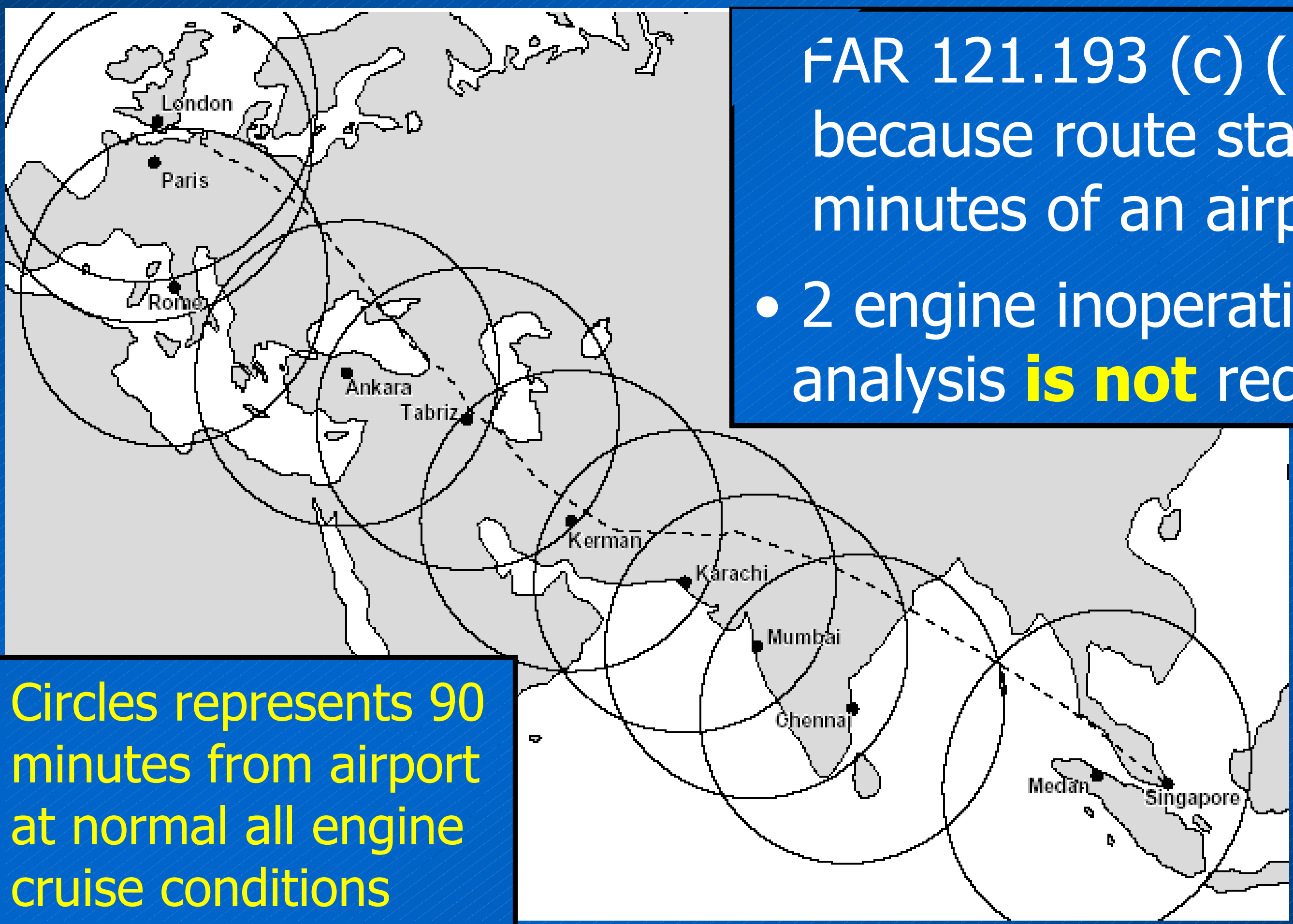
AND

The net flight path has a positive slope at 1,500 feet above the airport where the landing is assumed to be made after the engines fail;

* For aircraft certificated after August 29, 1959.

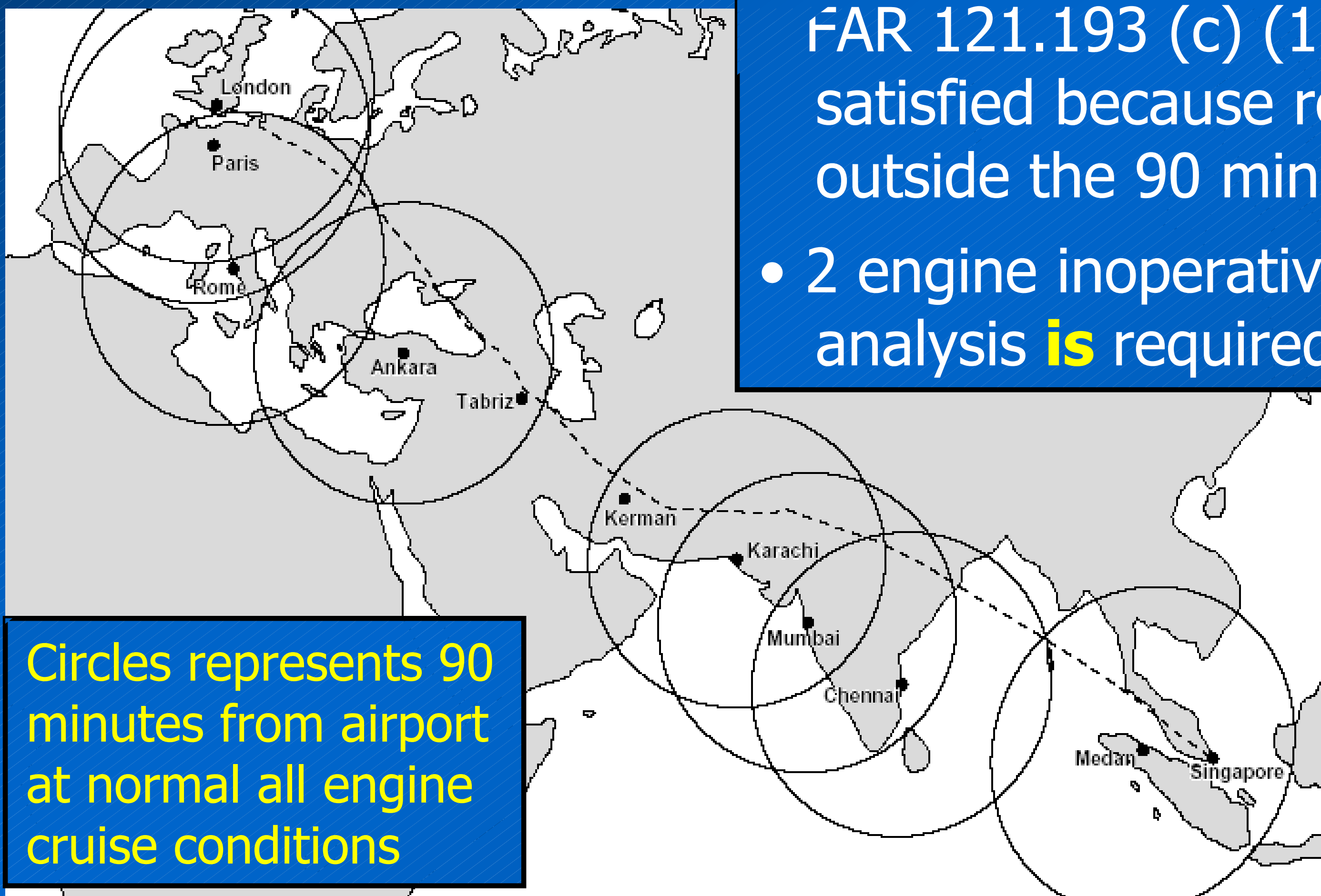
Example 747-400 Route and Alternates

- FAR 121.193 (c) (1) is satisfied because route stays within 90 minutes of an airport
- 2 engine inoperative driftdown analysis **is not** required



Circles represents 90 minutes from airport at normal all engine cruise conditions

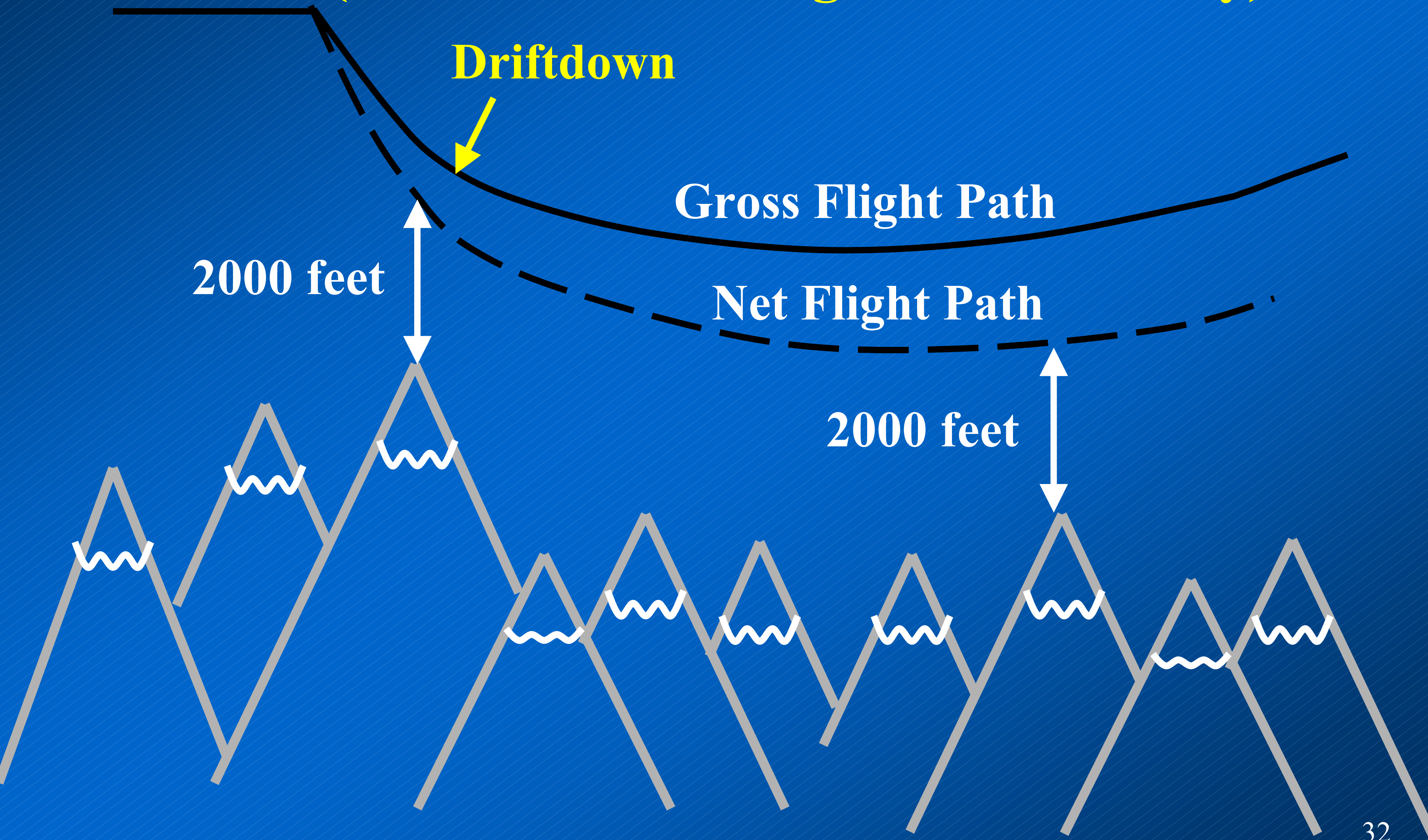
Example 747-400 Route and Alternates



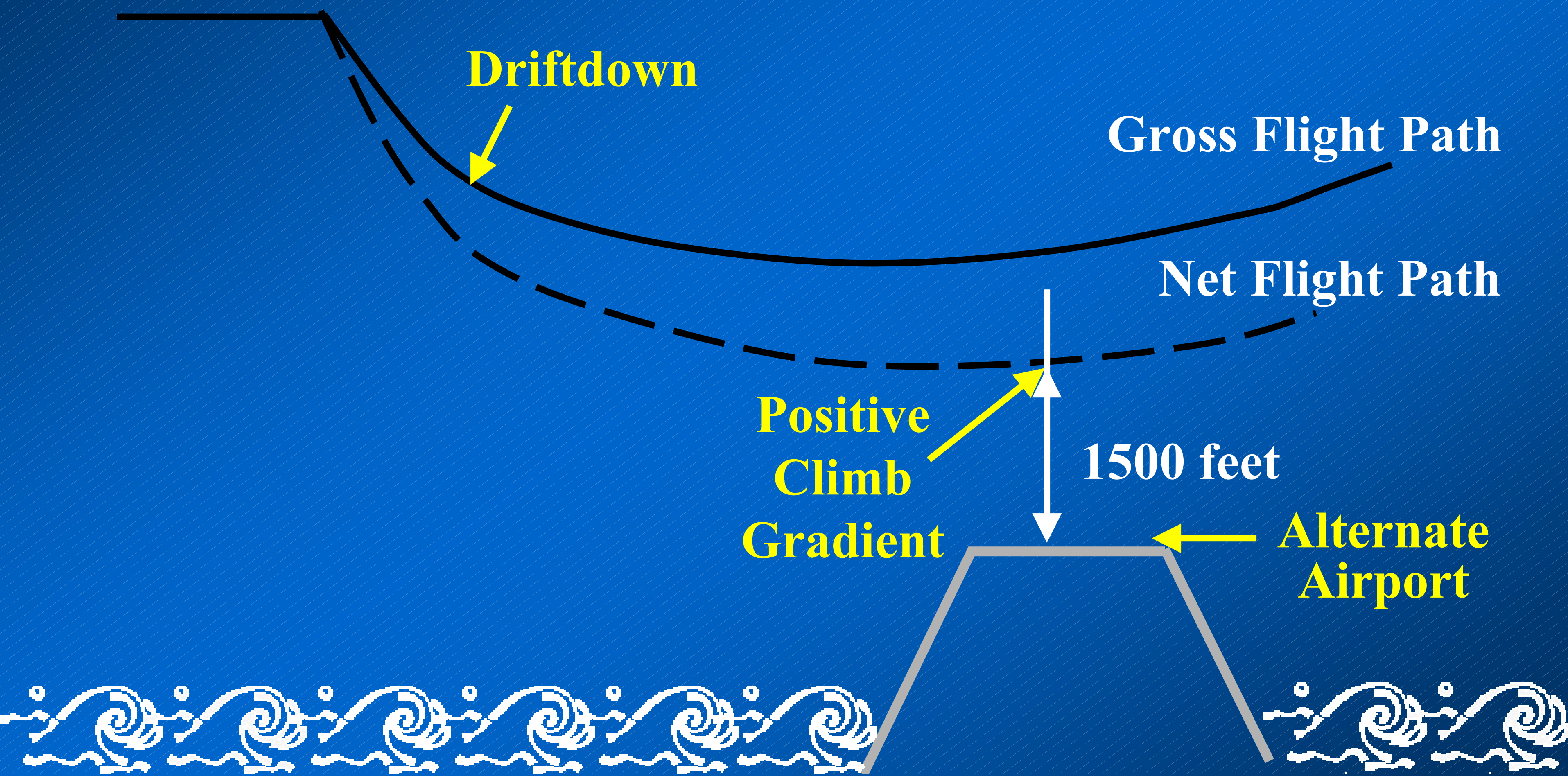
- FAR 121.193 (c) (1) is not satisfied because route is outside the 90 minute circles
- 2 engine inoperative driftdown analysis **is** required

Circles represents 90 minutes from airport at normal all engine cruise conditions

FAR 121.193 (c) (2) (pictorial)
(three- and four-engine aircraft only)



FAR 121.193(c) (2) (ii) (pictorial)

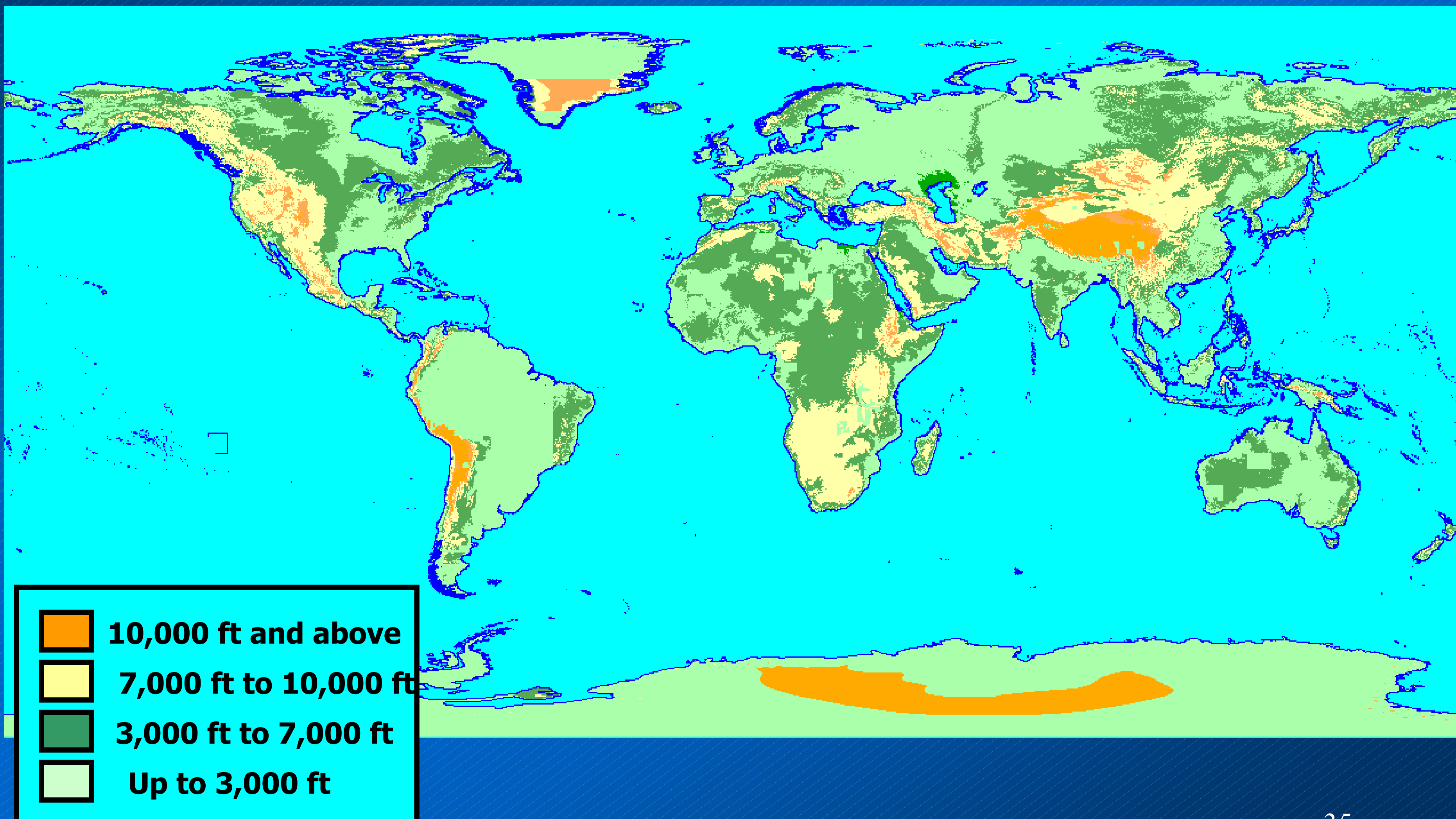


FAR 121.193 (c)(2) Continued

For the purposes of this subparagraph, it is assumed that:

- The two engines fail at the most critical point en route
- Ambient temperatures anticipated along the route are considered
- Fuel jettison is allowed
- The airplane's weight at the point where the two engines are assumed to fail provides enough fuel to continue to the airport and to fly for 15 minutes at cruise power or thrust, or both
- Analysis takes into account normal fuel and oil consumption

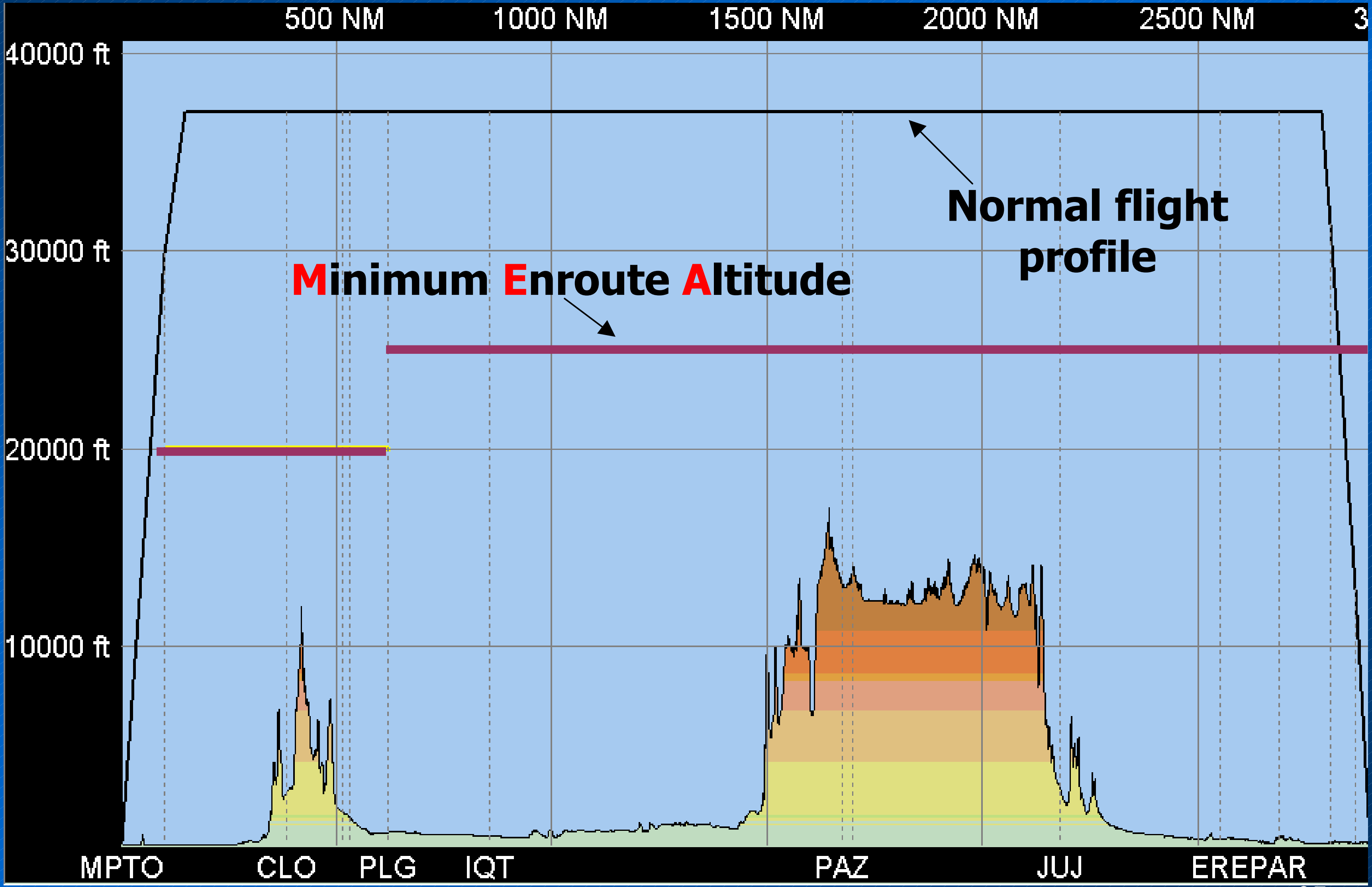
Terrain Information



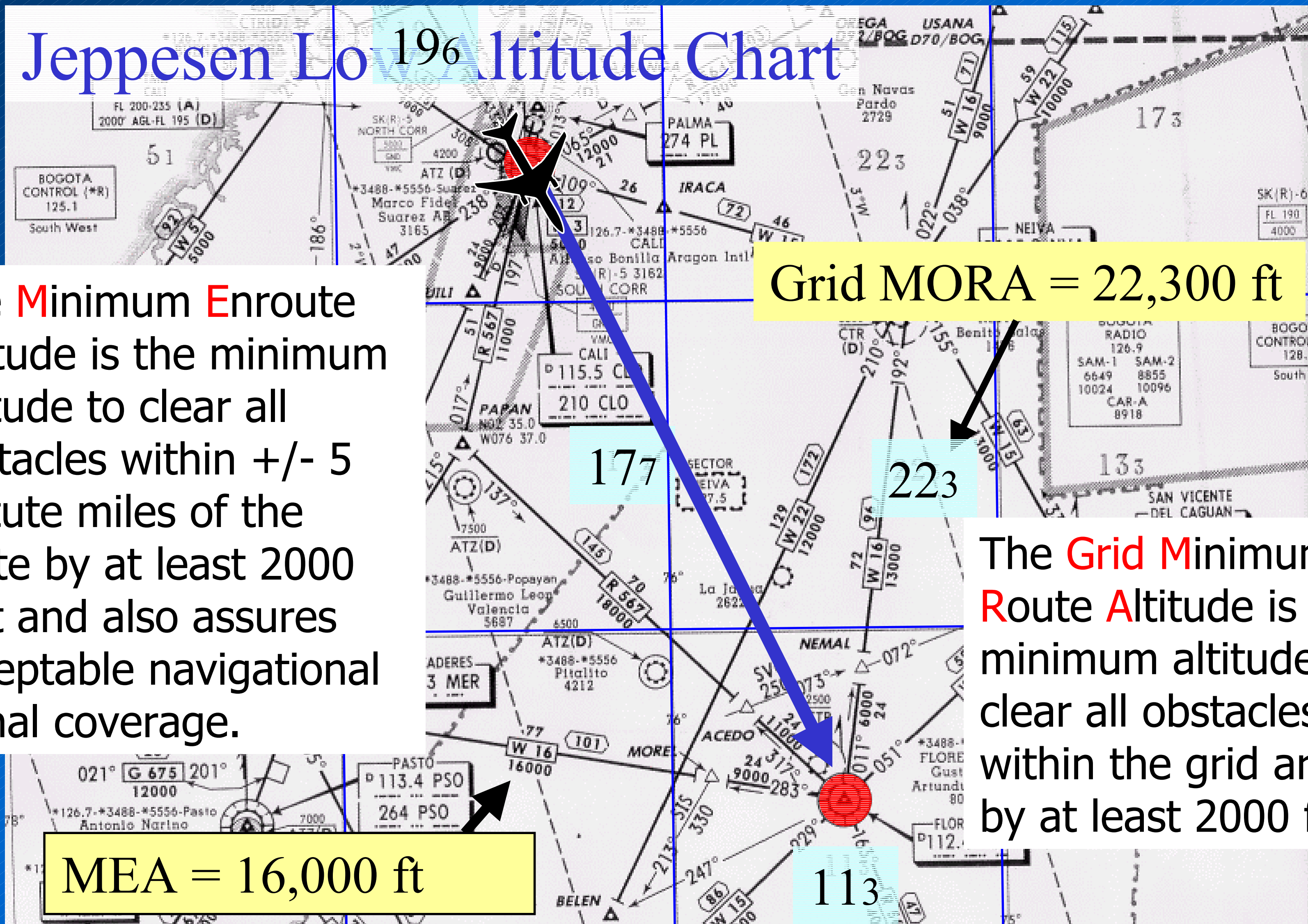
Terrain Clearance Information Sources

- Flight Planning Service route profile
- Jeppesen High Altitude Charts
- Jeppesen Low Altitude Charts
- Governmental Terrain Charts
- Operational Navigational Charts (ONC)
- Tactical Pilotage charts (TPC)
- Other Sources ? ? ?

Terrain Profile Provided in Jeppesen FliteStar

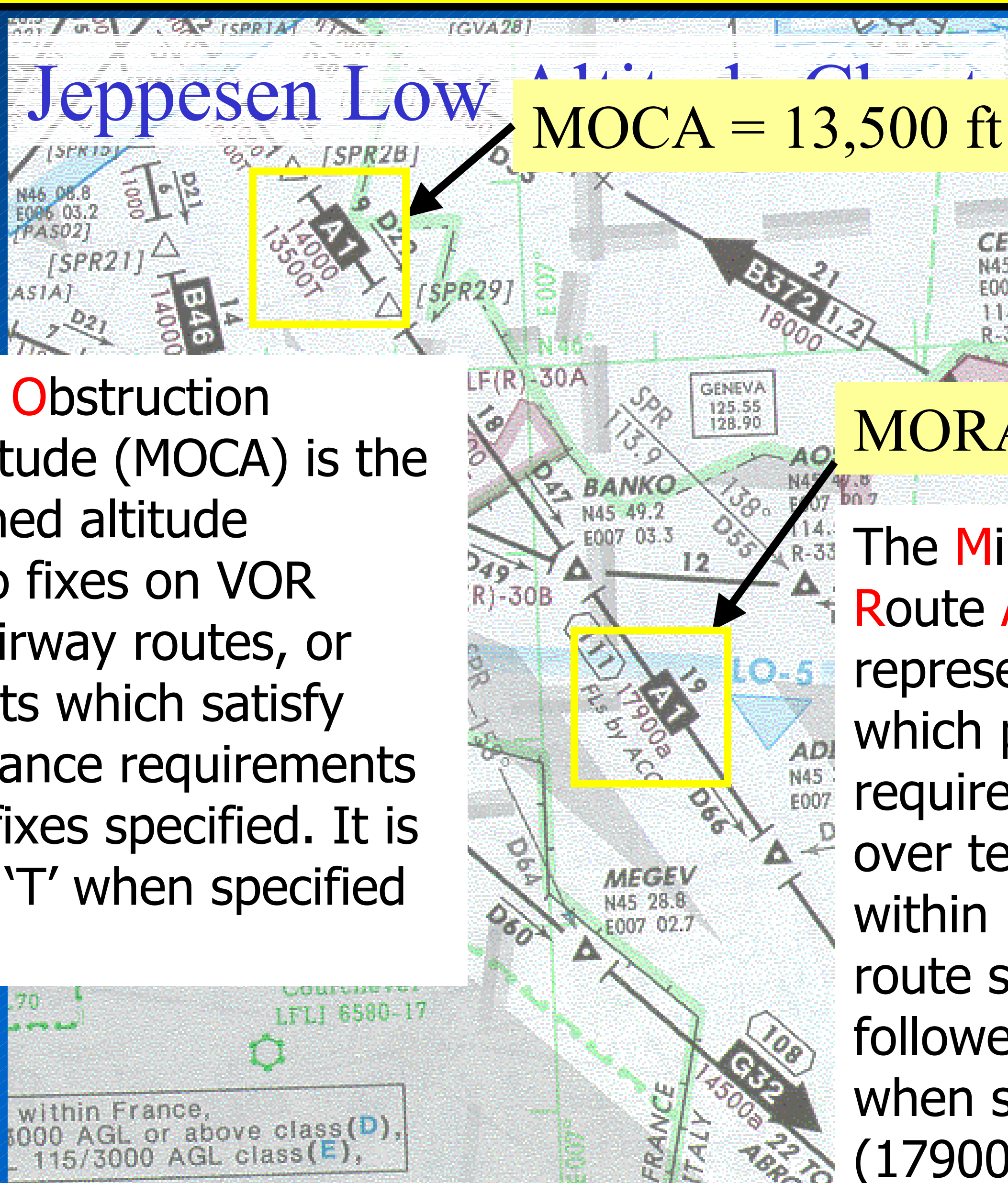


Jeppesen Low Altitude Chart



The Minimum Enroute Altitude is the minimum altitude to clear all obstacles within +/- 5 statute miles of the route by at least 2000 feet and also assures acceptable navigational signal coverage.

The Grid Minimum Off Route Altitude is the minimum altitude to clear all obstacles within the grid area by at least 2000 feet.

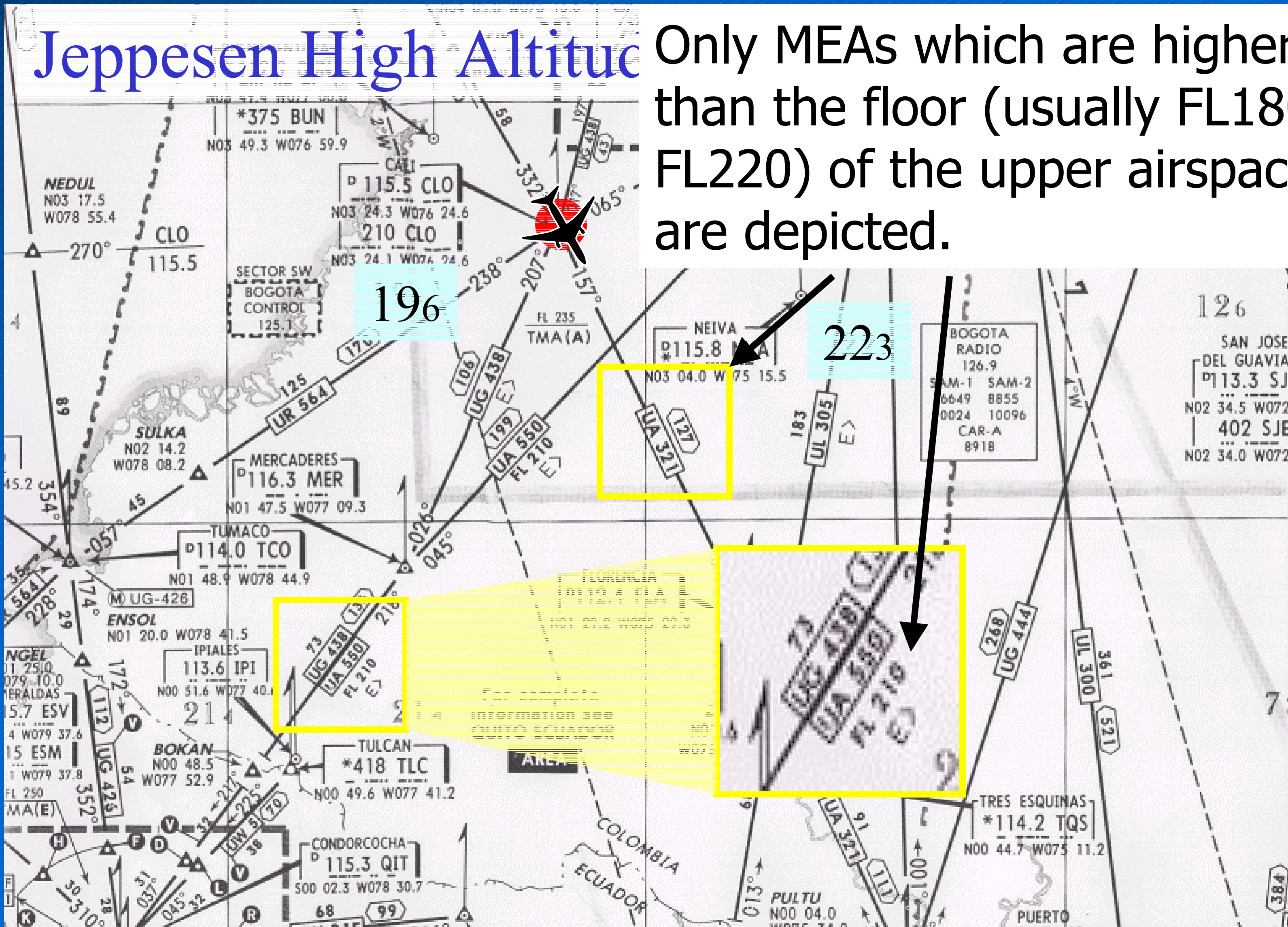


The **M**inimum **O**bstruction **C**learance **A**ltitude (MOCA) is the lowest published altitude between radio fixes on VOR airways, off-airway routes, or route segments which satisfy obstacle clearance requirements between the fixes specified. It is followed by a 'T' when specified (13500T).

The **M**inimum **O**ff **R**oute **A**ltitude (MORA) represents altitudes which provide the required clearance over terrain located within 10 nm of the route segment. It is followed by an 'a' when specified (17900a)

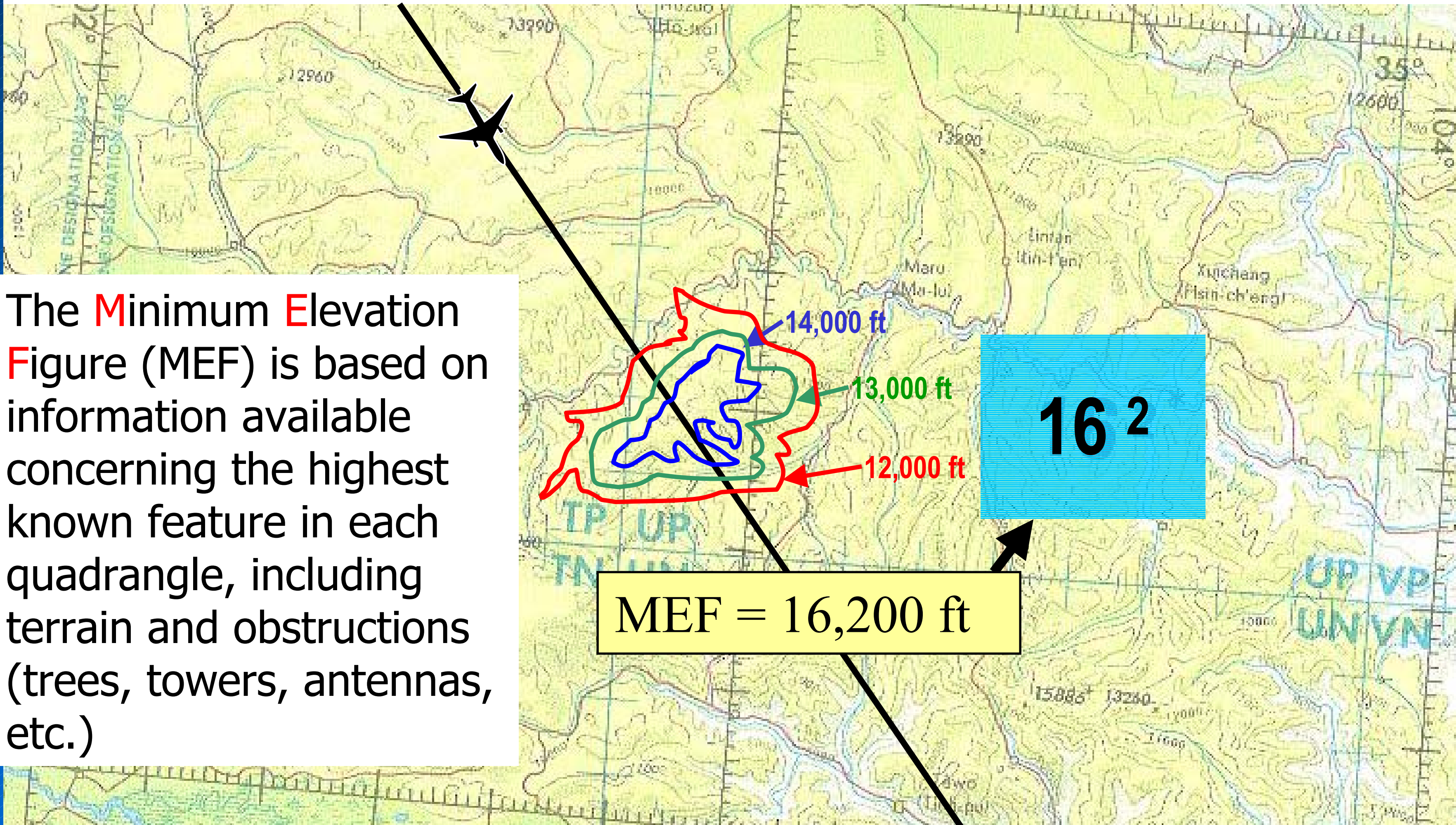
Terrain Clearance Information Sources

Only MEAs which are higher than the floor (usually FL180 – FL220) of the upper airspace are depicted.



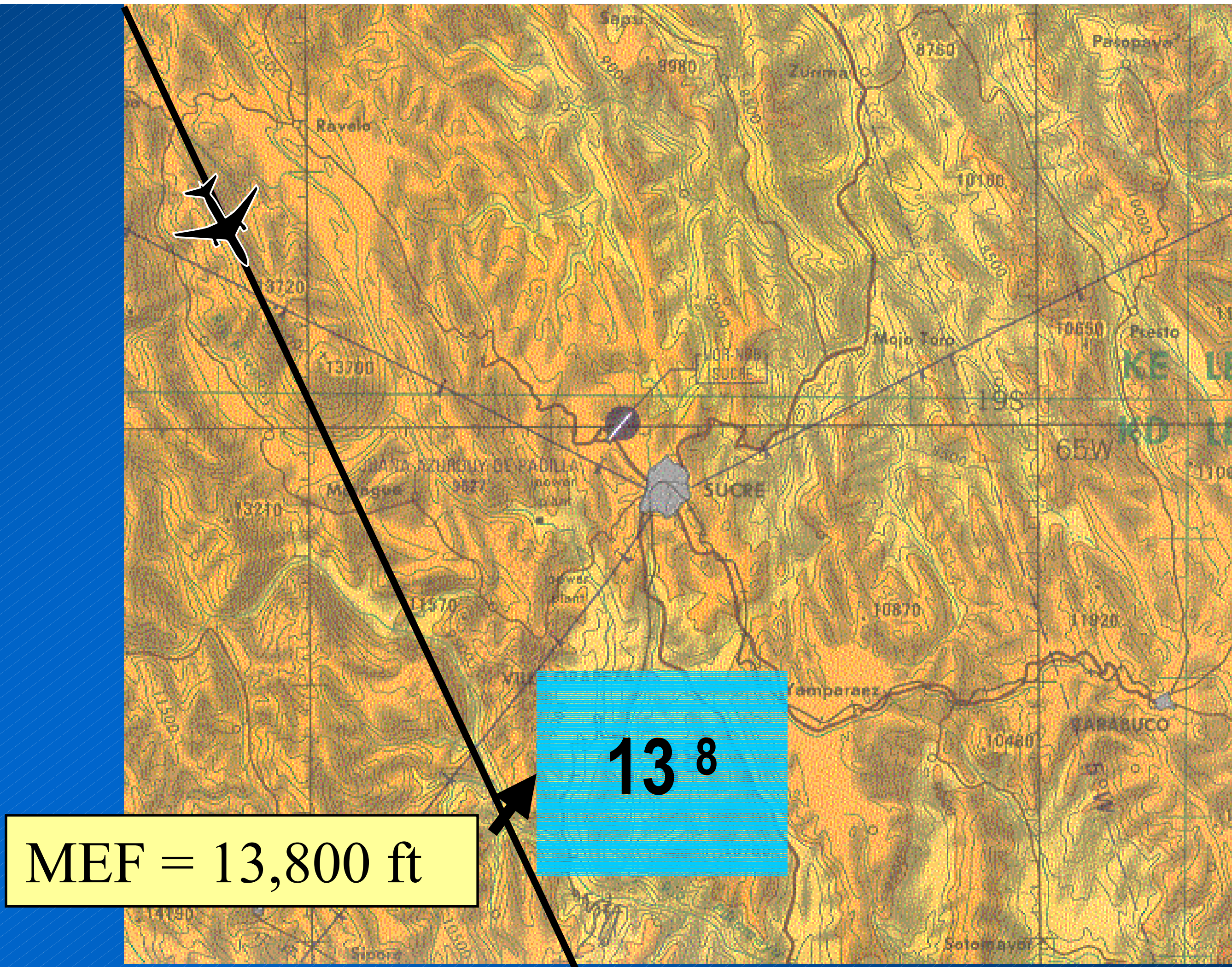
Operational Navigation Chart (ONC) Area Map

(For Use in Determining Off-track Escape Routes)



The Minimum Elevation Figure (MEF) is based on information available concerning the highest known feature in each quadrangle, including terrain and obstructions (trees, towers, antennas, etc.)

Tactical Pilotage Chart (TPC) Area Map
(For Use in Determining Off-track Escape Routes)

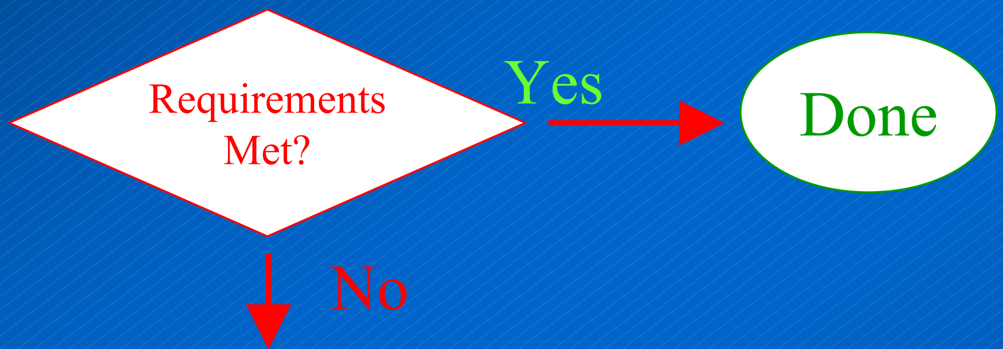


Other Sources of Terrain Information???

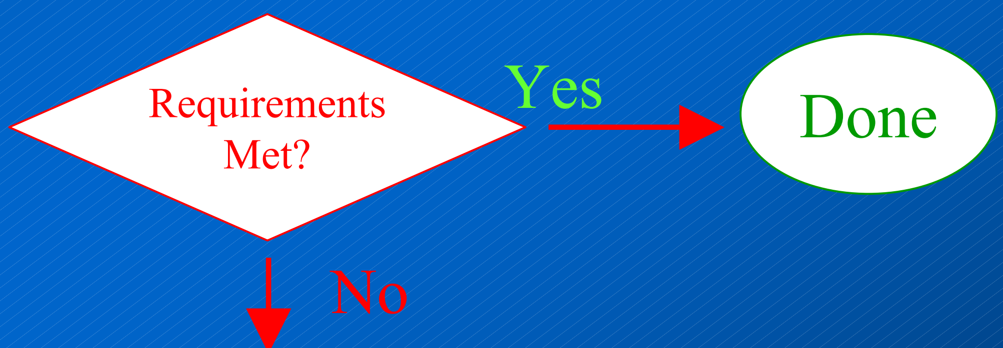
Example Route for Flight Planning Terrain Clearance Analysis

Engine-out Terrain Clearance Analysis Procedure

1) check engine-out net level-off height at takeoff gross weight.



2) check engine-out net level-off height at actual enroute weight upon entering mountainous area.



3) check engine-out driftdown profile at actual enroute weight for critical terrain. If not sufficient, look at re-routing options, escape paths or reduce payload.

Driftdown Data in Documents

Airplane Flight Manual

Enroute climb speeds - 1 and 2 engines inoperative
Enroute climb gradient - 1 and 2 engines inoperative
Enroute climb weights - 1 and 2 engines inoperative

Operations Manual/FPPM

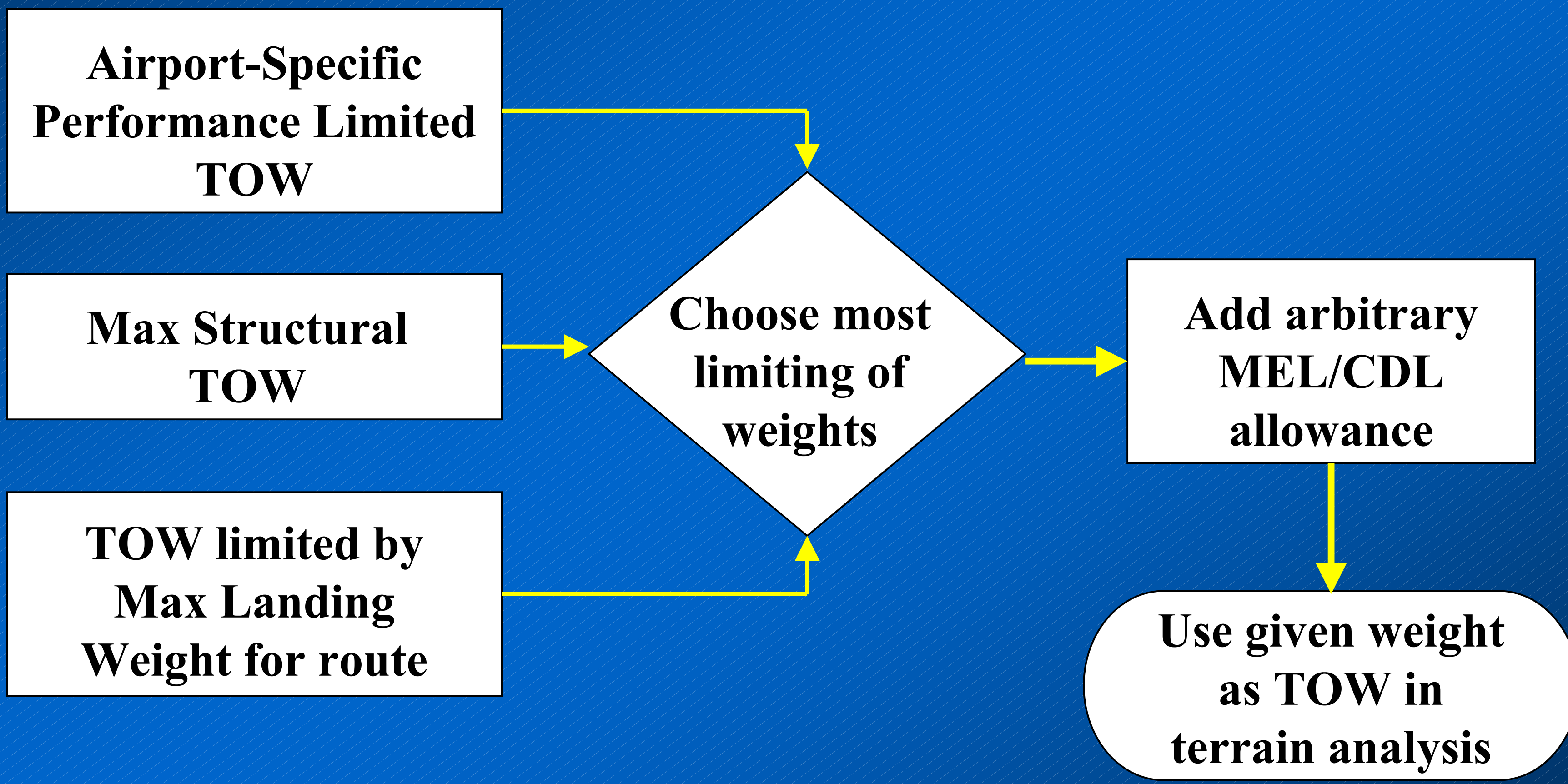
QRH - Speeds and gross level-off altitude
Dispatch data in OM/FPPM:

- Net driftdown profiles
- Net level off height/weight (optimum)
- Net level off height/weight (ETOPS)
- Driftdown/LRC cruise range capability

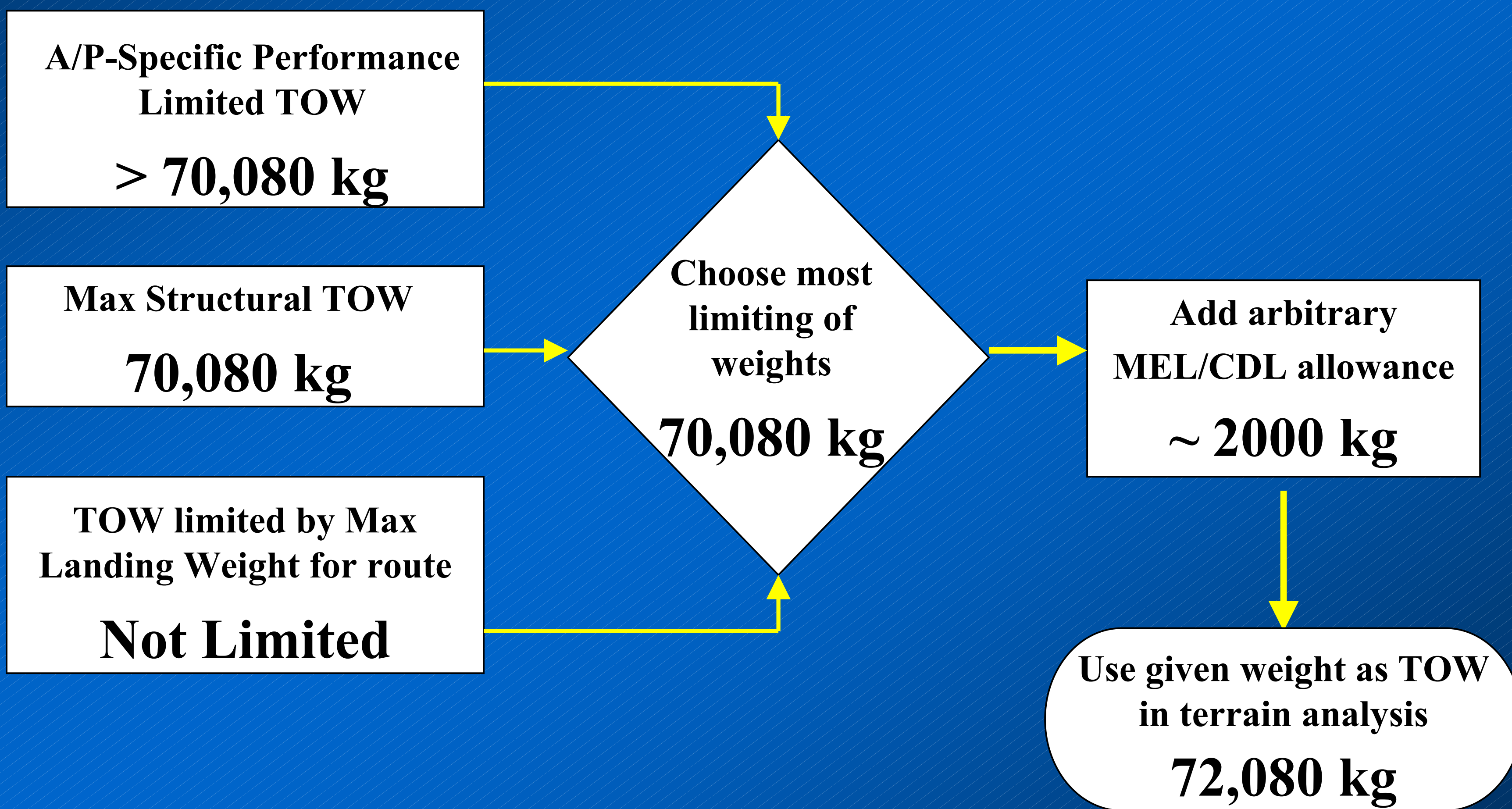
INFLT Software

Driftdown profiles can be calculated at any speed...

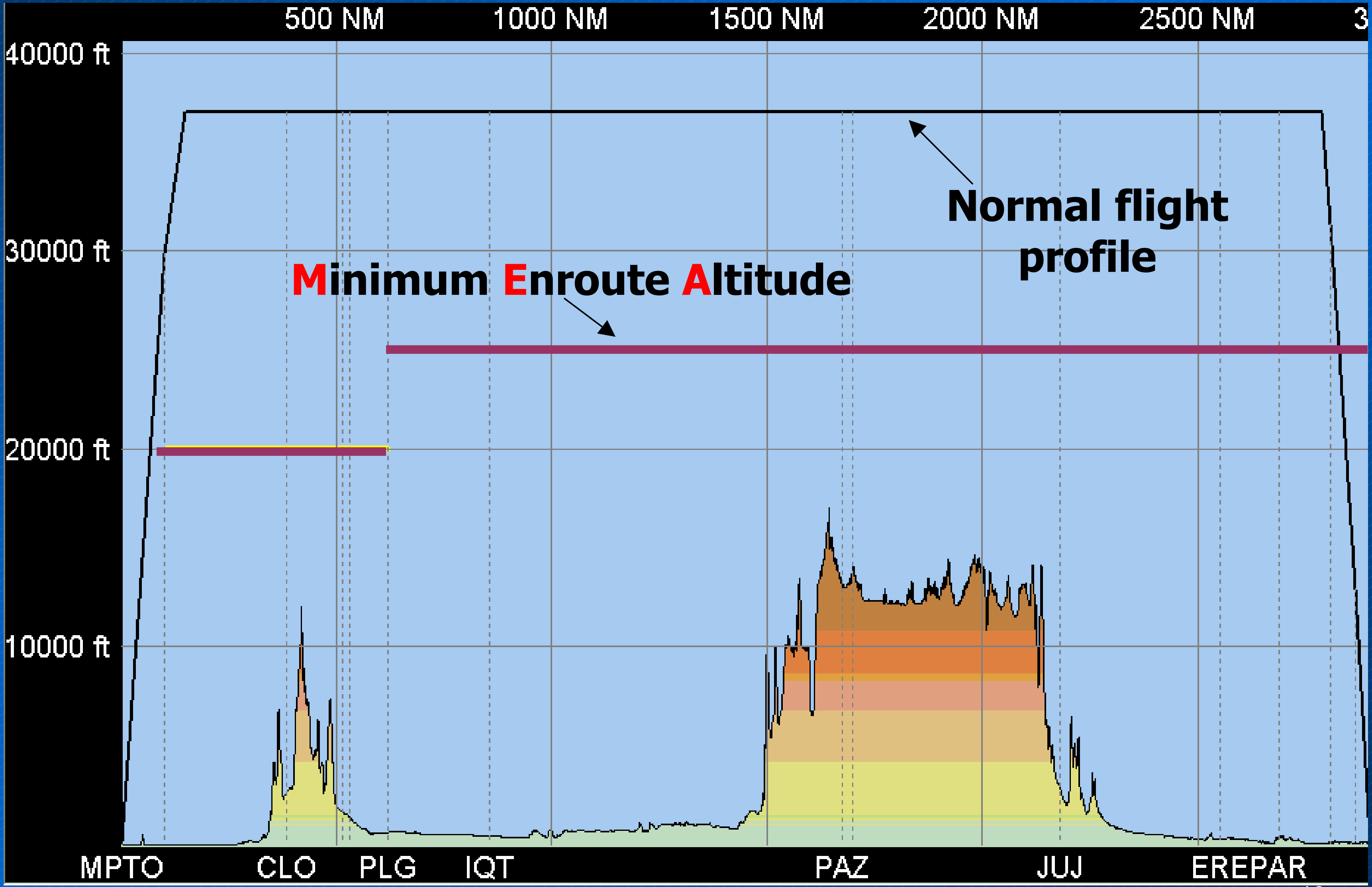
Calculate Takeoff Gross Weight



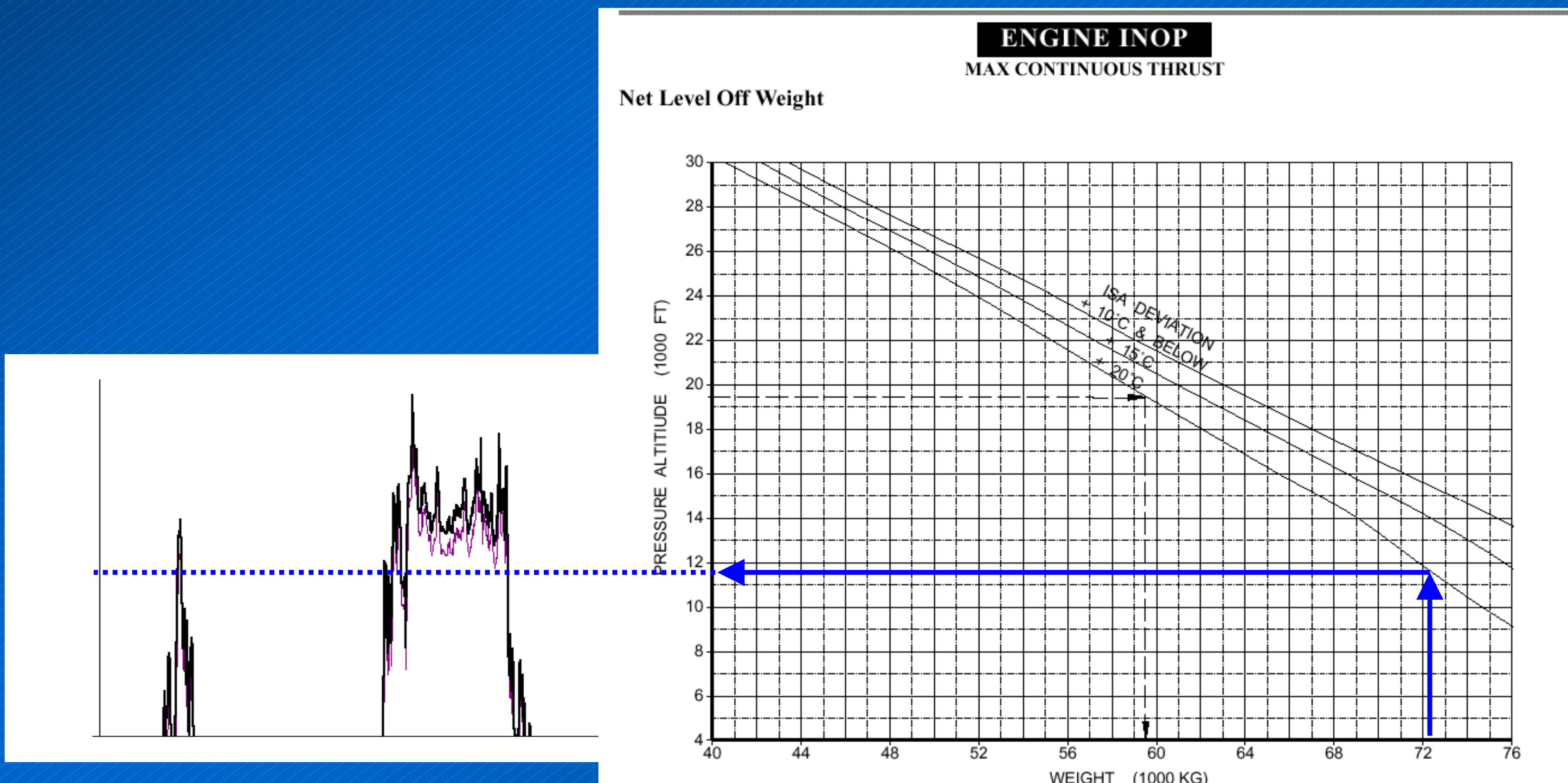
Calculate Takeoff Gross Weight for example analysis



Terrain Profile Provided in Jeppesen FliteStar



Check whether TOGW clears terrain by at least 1000 feet



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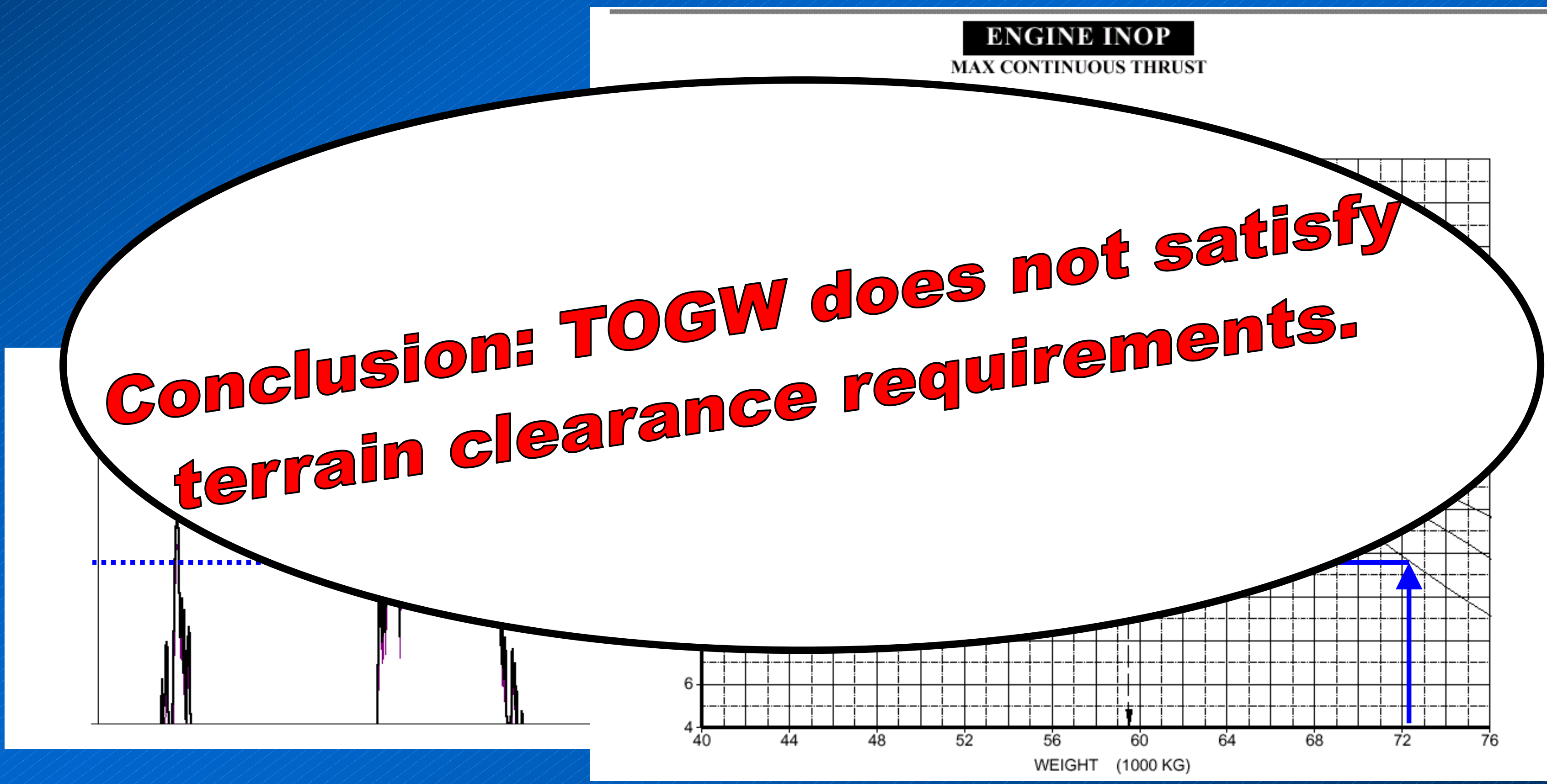
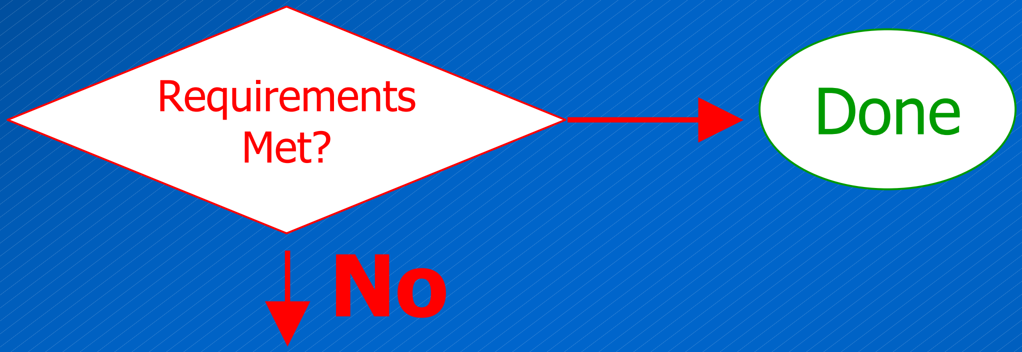


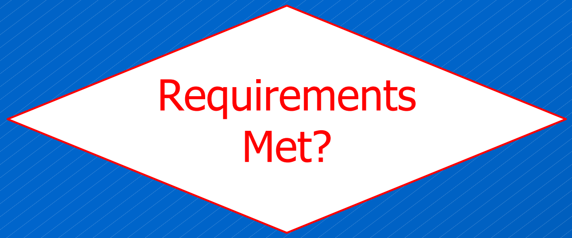
Conclusion: TOGW does not satisfy terrain clearance requirements.

Engine-out Terrain Clearance Analysis Procedure

1) check engine-out net level-off height at takeoff gross weight.



2) check engine-out net level-off height at actual enroute weight upon entering mountainous area.



Calculate Actual Enroute Weight

- Weight @ 1st Mtns = TOGW - Fuel Burned
  (1st Mtns are 800 nm along the route)

- Fuel Burned = Climb fuel + Cruise fuel

280/.78 Enroute Climb
ISA & Below

PRESSURE ALTITUDE (FT)	UNITS MIN/KG NM/KTAS	BRAKE RELEASE WEIGHT (1000 KG)										
		80	75	70	65	60	55	50	45	40	35	30
41000	TIME/FUEL					23/1750	19/1500	16/1300	14/1150	12/1000	10/850	9/700
	DIST/SPD					143/408	117/405	99/403	85/401	73/399	62/398	53/397
40000	TIME/FUEL				25/1950	21/1650	18/1400	15/1250	13/1100	12/950	10/850	8/700
	DIST/SPD				158/409	126/404	107/401	92/400	80/398	69/397	59/396	50/394
39000	TIME/FUEL			28/2200	22/1800	19/1550	17/1350	14/1200	13/1050	11/950	10/800	8/700
	DIST/SPD			180/410	137/403	115/400	99/398	86/397	75/395	65/394	56/393	47/391
38000	TIME/FUEL			24/1950	20/1700	18/1500	16/1350	14/1200	12/1050	11/900	9/800	8/650
	DIST/SPD			148/402	123/399	106/397	92/395	81/394	71/392	61/391	53/390	44/389
37000	TIME/FUEL		26/2150	22/1850	19/1650	17/1450	15/1300	13/1150	12/1000	10/900	9/750	7/650
	DIST/SPD		160/402	132/398	113/395	99/393	87/392	76/391	67/390	58/389	50/387	42/386
36000	TIME/FUEL	28/2350	24/2000	20/1750	18/1550	16/1400	14/1250	13/1100	11/1000	10/850	8/750	7/650
	DIST/SPD	175/402	141/396	121/394	105/392	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	40/383
35000	TIME/FUEL	25/2200	22/1900	19/1700	17/1500	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	7/600
	DIST/SPD	152/396	129/392	112/390	99/388	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	38/380
34000	TIME/FUEL	24/2050	21/1850	18/1650	16/1500	15/1300	13/1200	12/1050	10/950	9/800	8/700	7/600
	DIST/SPD	138/391	119/388	105/386	93/385	82/384	73/383	64/382	57/381	49/380	43/379	36/377
33000	TIME/FUEL	22/2000	20/1750	17/1600	16/1450	14/1300	12/1150	11/1050	10/900	9/800	7/700	6/600
	DIST/SPD	127/386	111/384	98/383	87/381	78/380	69/379	61/378	54/378	47/377	40/376	34/374
32000	TIME/FUEL	21/1900	18/1700	17/1550	15/1400	13/1250	12/1100	11/1000	9/900	8/800	7/650	6/600
	DIST/SPD	117/381	103/379	91/378	81/377	72/376	64/375	57/374	50/374	44/373	38/372	32/370
31000	TIME/FUEL	19/1800	17/1600	16/1450	14/1350	13/1200	11/1050	10/950	9/850	8/750	7/650	6/550
	DIST/SPD	106/375	94/374	84/373	75/372	67/371	60/370	53/370	47/369	41/368	35/367	30/365
30000	TIME/FUEL	18/1700	16/1550	15/1400	13/1300	12/1150	11/1050	10/900	8/800	7/700	6/650	6/550
	DIST/SPD	97/370	87/369	77/368	69/367	62/367	55/366	49/365	44/364	38/364	33/362	28/361
29000	TIME/FUEL	17/1650	15/1500	14/1350	13/1250	11/1100	10/1000	9/900	8/800	7/700	6/600	5/500
	DIST/SPD	89/366	80/365	71/364	64/363	58/362	51/362	46/361	41/360	35/359	31/358	26/356
28000	TIME/FUEL	16/1550	14/1450	13/1300	12/1200	11/1050	10/950	9/850	8/750	7/650	6/600	5/500
	DIST/SPD	82/361	74/360	66/359	59/359	53/358	48/357	43/357	38/356	33/355	28/354	24/352
27000	TIME/FUEL	15/1500	14/1350	12/1250	11/1150	10/1050	9/900	8/850	7/750	6/650	6/550	5/500
	DIST/SPD	76/357	68/356	61/355	55/355	50/354	44/353	40/353	35/352	31/351	26/350	22/348
26000	TIME/FUEL	14/1450	13/1300	12/1200	11/1100	10/1000	9/900	8/800	7/700	6/650	5/550	5/450
	DIST/SPD	70/352	63/352	57/351	51/351	46/350	41/350	37/349	33/348	29/347	25/346	21/344
25000	TIME/FUEL	13/1350	12/1250	11/1150	10/1050	9/950	8/850	7/750	7/700	6/600	5/550	4/450
	DIST/SPD	64/348	58/348	52/347	47/347	43/346	38/346	34/345	30/344	27/343	23/342	19/340
24000	TIME/FUEL	13/1300	11/1200	11/1100	10/1000	9/900	8/800	7/750	6/650	6/600	5/500	4/450

Climb Fuel = 1800 kg

Long Range Cruise Table

35000 FT to 30000 FT

PRESS ALT (1000 FT) (STD TAT)		WEIGHT (1000 KG) 80	75	70	65	60	55	50	45	40	35	30
35 (-31)	%N1	94.3	90.8	88.5	86.6	85.0	83.3	81.4	79.2	76.6	73.9	70.8
	MAX TAT	-17	-8	-1								
	KIAS	267	268	267	263	259	254	247	236	223	211	197
	MACH	.787	.791	.787	.777	.765	.752	.732	.702	.667	.634	.595
	FF/ENG	1560	1410	1291	1190	1105	1029	948	859	777	693	612
	KTAS	454	456	453	448	441	434	422	404	384	365	343
34 (-29)	%N1	91.8	89.4	87.5	85.9	84.3	82.7	80.7	78.3	75.9	73.3	70.0
	MAX TAT	-9	-2	4								
	KIAS	274	274	271	267	262	257	248	235	224	212	197
	MACH	.790	.789	.781	.770	.758	.744	.719	.686	.655	.622	.582
	FF/ENG	1514	1390	1282	1193	1113	1038	951	857	780	698	615
	KTAS	458	457	452	446	439	431	417	397	379	360	337
33 (-28)	%N1	90.3	88.4	86.8	85.3	83.7	82.0	80.0	77.6	75.2	72.6	69.3
	MAX TAT	-3	4	9								
	KIAS	280	278	274	270	265	258	248	236	224	213	197
	MACH	.790	.784	.774	.763	.751	.733	.705	.673	.643	.611	.569
	FF/ENG	1492	1378	1283	1200	1124	1042	952	859	783	703	618
	KTAS	459	456	450	444	437	426	410	391	374	356	331

Cruise Fuel = Fuel Flow/hr X Hours

= FF/hr X Distance / Speed   Distance = 800 – 120 nm = 680 nm

= 1291 kg/eng/hr X 2 engines X 680 nm / 453 nm per hour

= 3875 kg

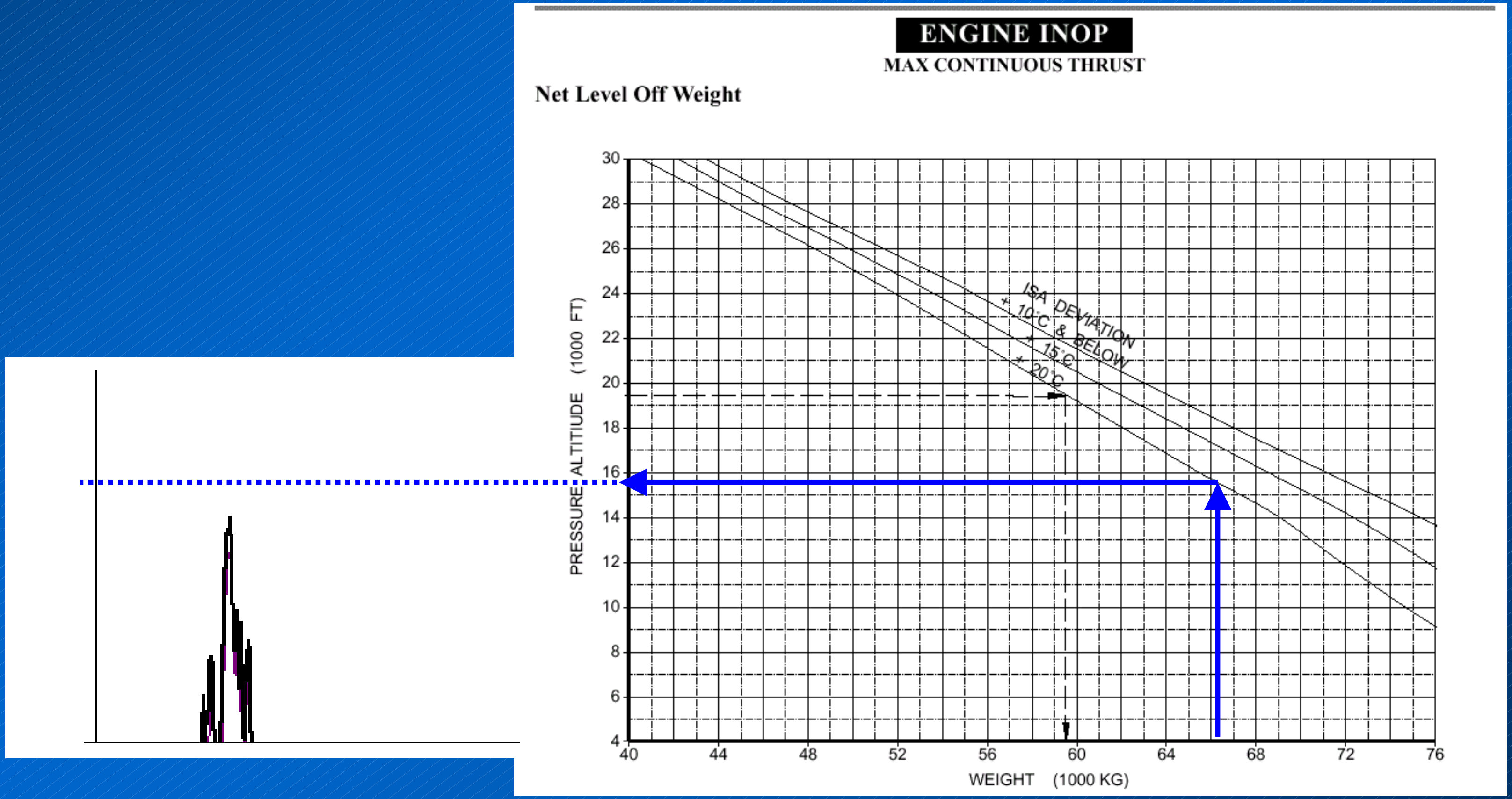
Enroute Weight @ 1st Mountains

- Weight@Mtns = TOGW - Fuel Burned

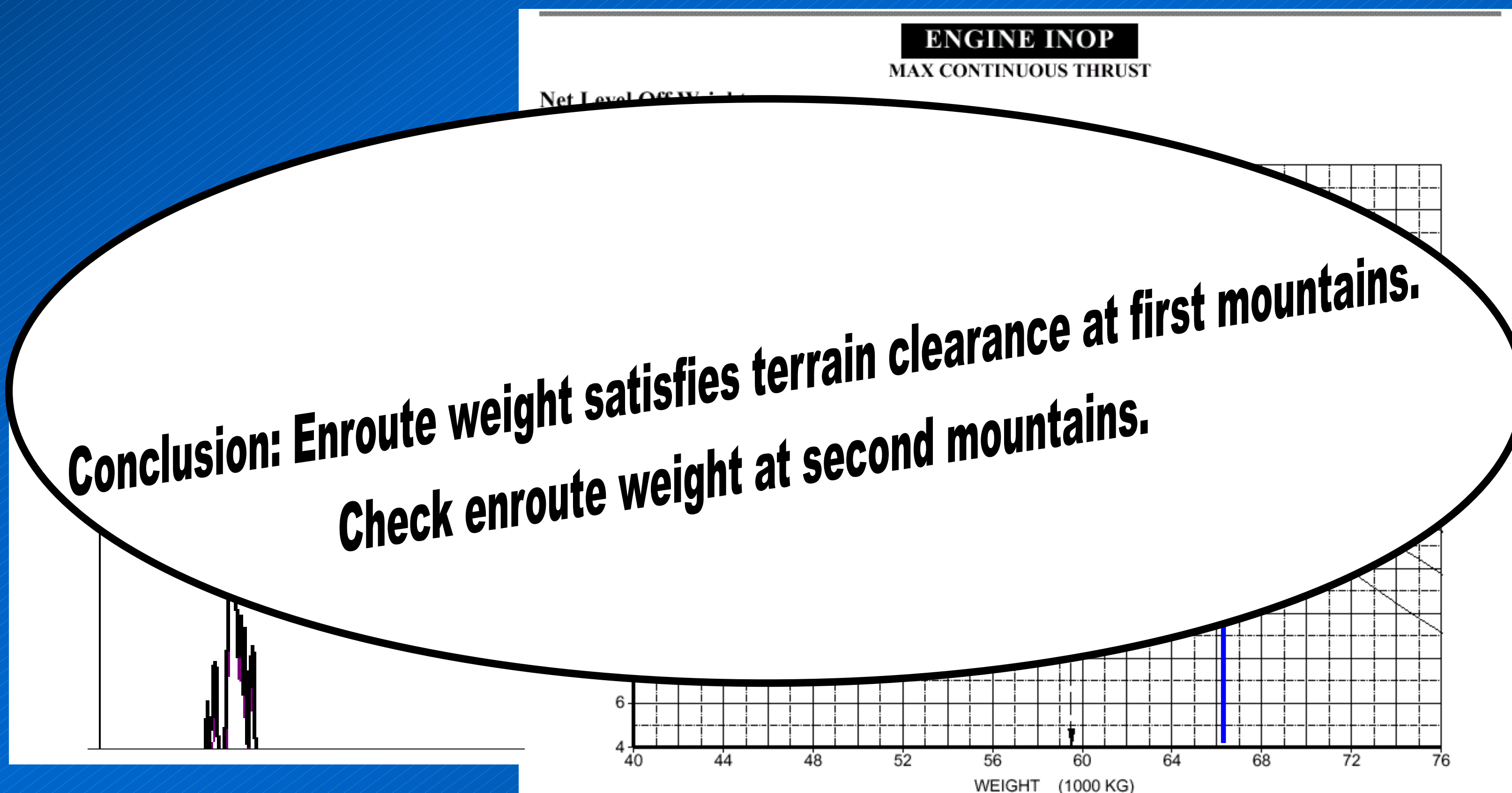
- Fuel Burned = Climb + Cruise
  = 1800 kg + 3875 kg
  = 5675 kg

- Weight@Mtns = 72,080 kg - 5675 kg
  = 66405 kg

Check whether enroute weight clears terrain by at least 1000 feet



Check whether enroute weight clears terrain by at least 1000 feet



Calculate Actual Enroute Weight

- Weight @ 2nd Mtns = TOGW - Fuel Burned
  (2nd Mtns are 1400 nm along route)

- Fuel Burned = Climb + Cruise

Long Range Cruise Table

35000 FT to 30000 FT

PRESS ALT (1000 FT) (STD TAT)		WEIGHT (1000 KG) 80	75	70	65	60	55	50	45	40	35	30
35 (-31)	%N1	94.3	90.8	88.5	86.6	85.0	83.3	81.4	79.2	76.6	73.9	70.8
	MAX TAT	-17	-8	-1								
	KIAS	267	268	267	263	259	254	247	236	223	211	197
	MACH	.787	.791	.787	.777	.765	.752	.732	.702	.667	.634	.595
	FF/ENG	1560	1410	1291	1190	1105	1029	948	859	777	693	612
	KTAS	454	456	453	448	441	434	422	404	384	365	343
34 (-29)	%N1	91.8	89.4	87.5	85.9	84.3	82.7	80.7	78.3	75.9	73.3	70.0
	MAX TAT	-9	-2	4								
	KIAS	274	274	271	267	262	257	248	235	224	212	197
	MACH	.790	.789	.781	.770	.758	.744	.719	.686	.655	.622	.582
	FF/ENG	1514	1390	1282	1193	1113	1038	951	857	780	698	615
	KTAS	458	457	452	446	439	431	417	397	379	360	337
33 (-28)	%N1	90.3	88.4	86.8	85.3	83.7	82.0	80.0	77.6	75.2	72.6	69.3
	MAX TAT	-3	4	9								
	KIAS	280	278	274	270	265	258	248	236	224	213	197
	MACH	.790	.784	.774	.763	.751	.733	.705	.673	.643	.611	.569
	FF/ENG	1492	1378	1283	1200	1124	1042	952	859	783	703	618
	KTAS	459	456	450	444	437	426	410	391	374	356	331
32 (-26)	%N1	89.2	87.6	86.1	84.6	83.1	81.3	79.2	76.9	74.6	71.8	68.4
	MAX TAT	2	8									
	KIAS	285	282	278	273	268	259	248	236	225	213	197
	MACH	.786	.778	.767	.756	.742	.720	.690	.661	.632	.599	.556
	FF/ENG	1475	1375	1288	1209	1132	1045	951	861	787	707	620

Cruise Fuel = Fuel Flow/hr X Hours

= FF/hr X Distance / Speed   Distance = 1400 nm – 120 nm = 1280 nm

= 1190 kg/eng/hr X 2 engines X 1280 nm / 448 nm per hour

= 6800 kg

Enroute Weight @ 2nd Mtns

- Weight@Mtns = TOGW - Fuel Burned

- Fuel Burned = Climb + Cruise

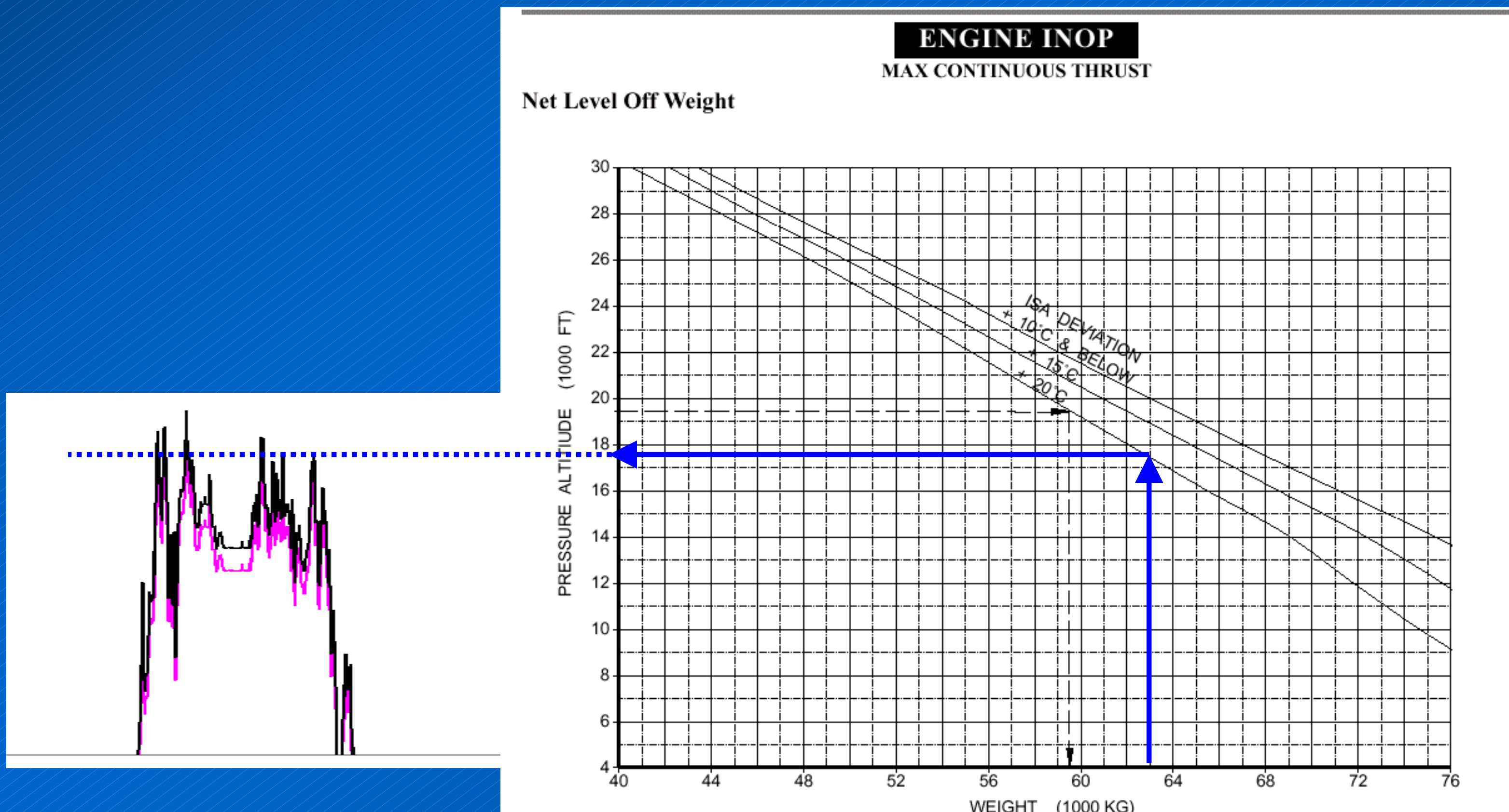
  = 1800 kg + 6800 kg

  = 8,600 kg

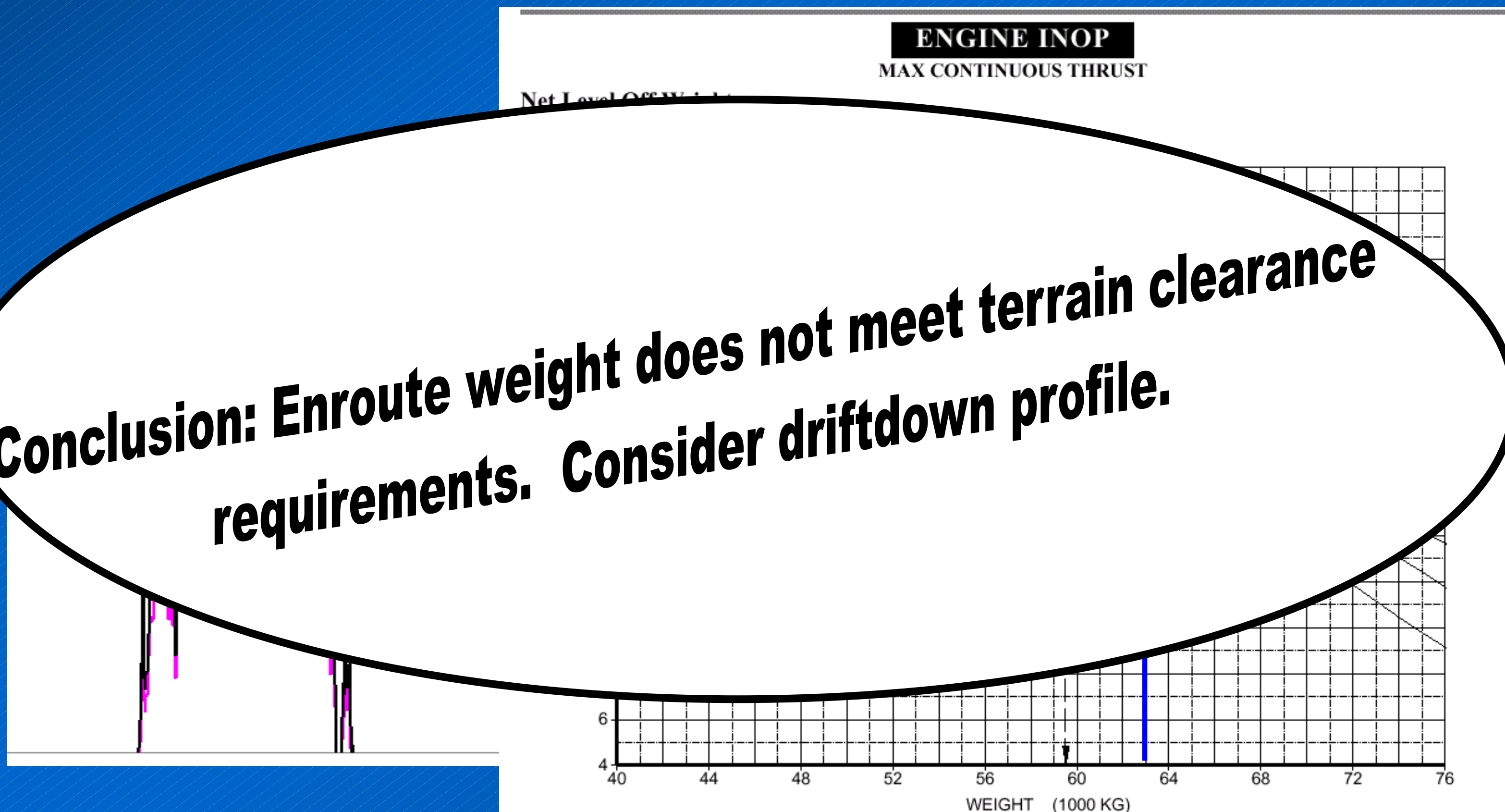
- Weight@Mtns = 72,080 kg – 8,600 kg

  = 63,480 kg

Check whether enroute weight clears terrain by at least 1000 feet



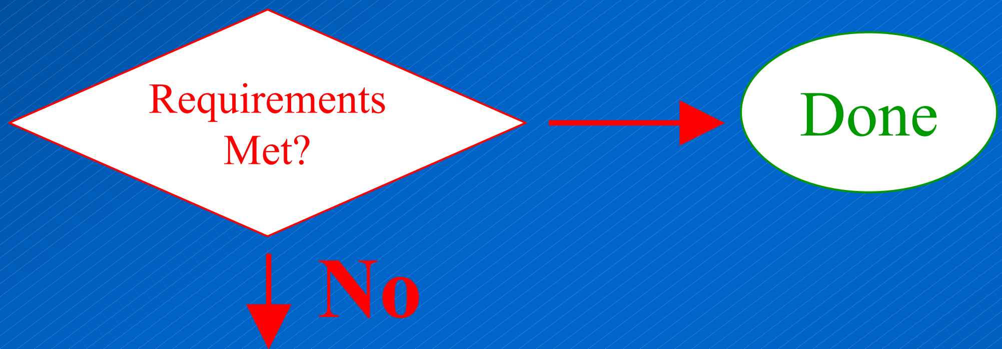
Check whether enroute weight clears terrain by at least 1000 feet



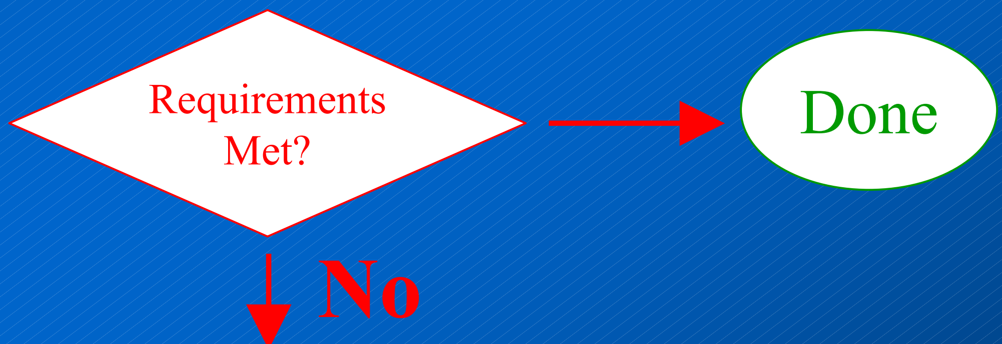
Conclusion: Enroute weight does not meet terrain clearance requirements. Consider driftdown profile.

Engine-out Terrain Clearance Analysis Procedure

1) check engine-out net level-off height at takeoff gross weight.



2) check engine-out net level-off height at actual enroute weight upon entering mountainous area.



3) check engine-out driftdown profile at actual enroute weight for critical terrain. If not sufficient, look at re-routing options, escape paths or reduce payload.

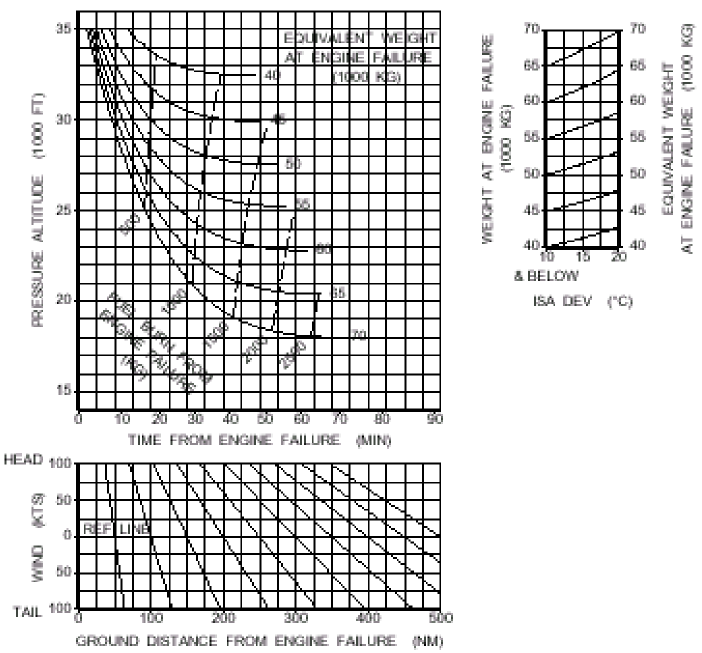
Operations in Mountainous Areas

ENGINE INOP

MAX CONTINUOUS THRUST

Driftdown Profiles Net Flight Path

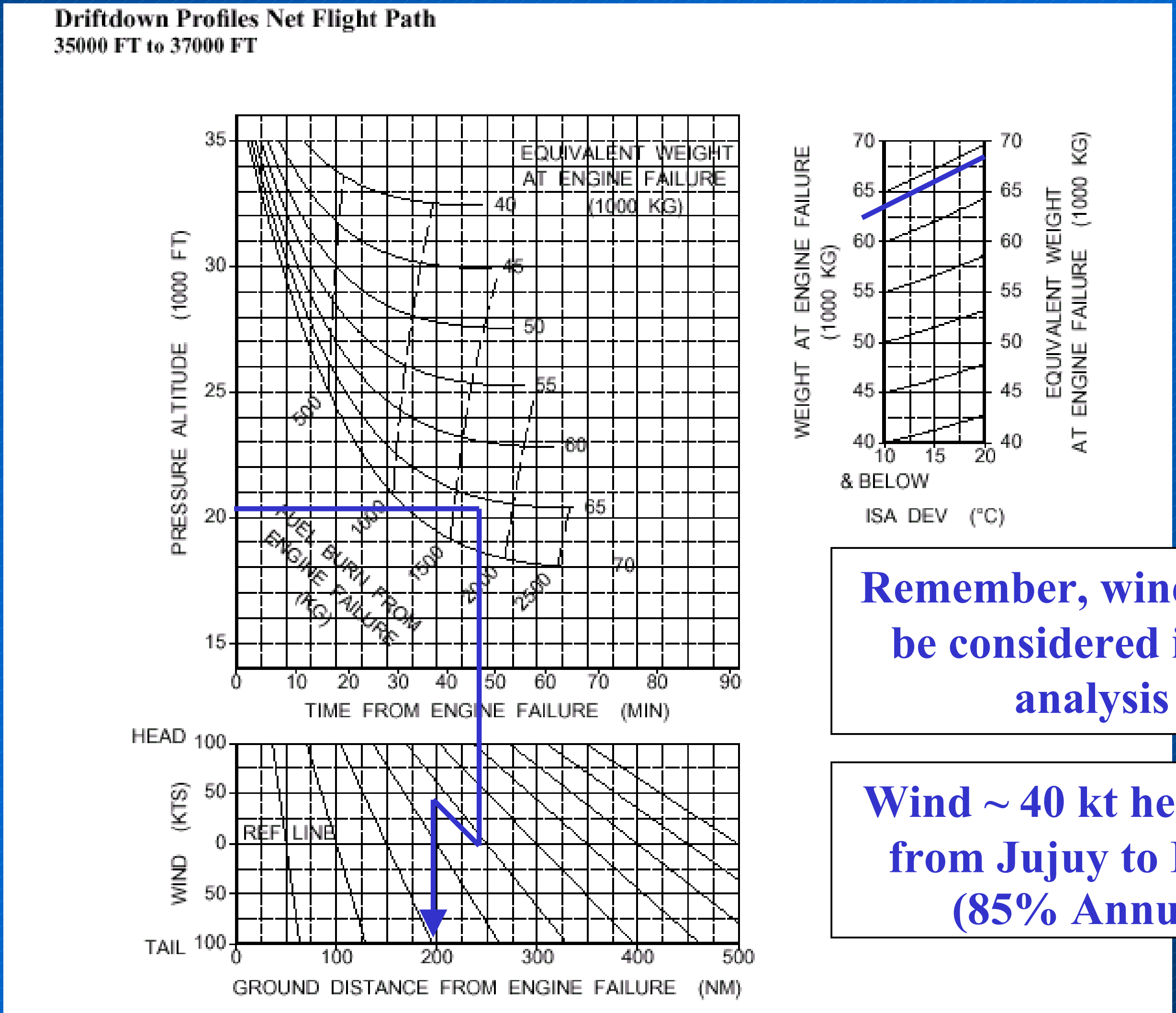
35000 FT to 37000 FT



Anti-Ice Adjustments

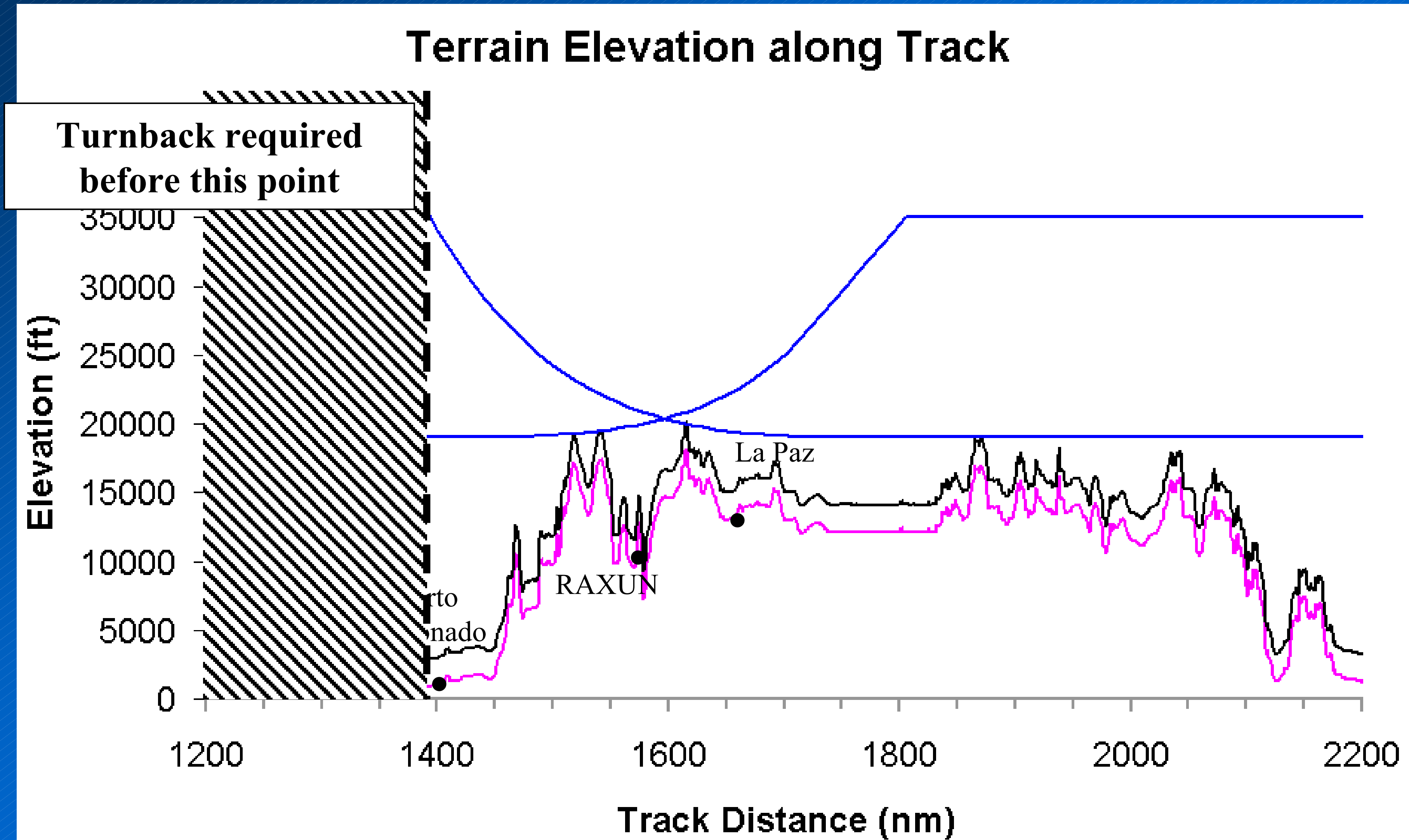
ANTI-ICE CONFIGURATION	EQUIVALENT WEIGHT ADJUSTMENT (1000 KG) PRESSURE ALTITUDE (1000 FT)								
	12	14	16	18	20	22	24	26	28
ENGINE ONLY	2.5	2.5	2.1	1.9	1.6	1.4	1.3	1.2	1.1
ENGINE AND WING	8.5	7.5	7.2	7.1	6.5	5.6	4.8	4.6	4.3

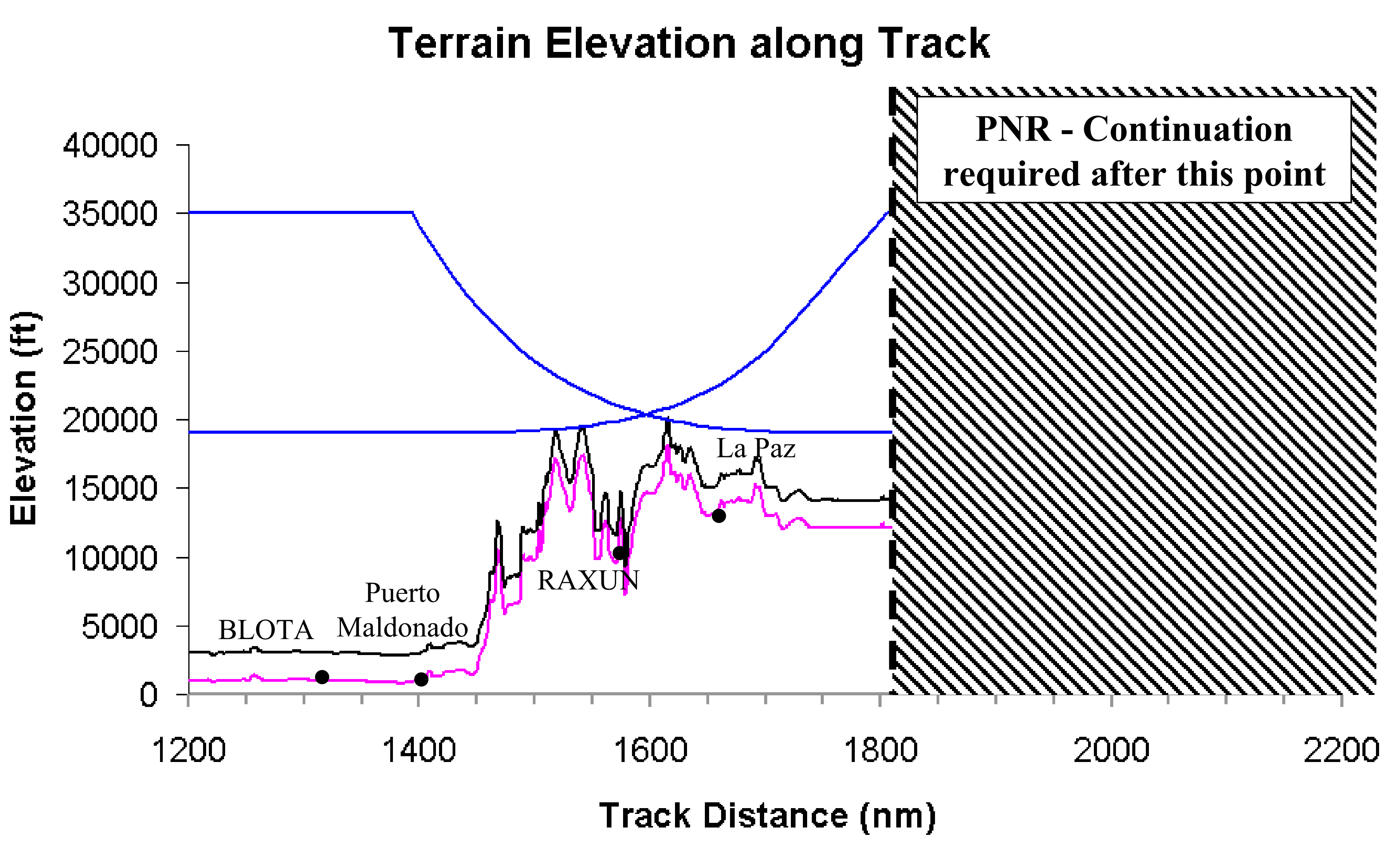
Determine the driftdown distance to 20,200 ft (terrain + 2000 ft) at the actual enroute weight (63,500 kg)

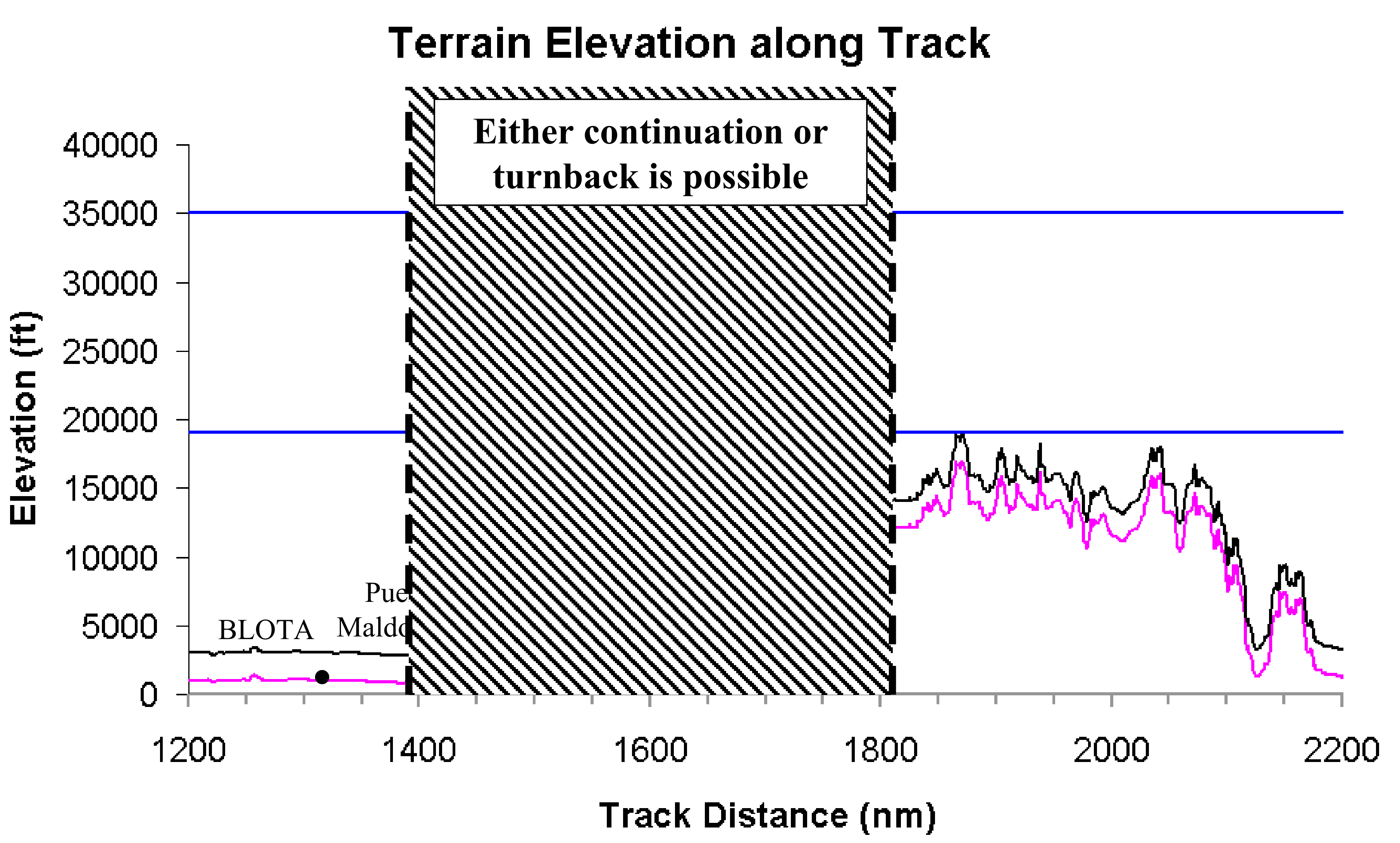


Remember, winds must be considered in this analysis

Wind ~ 40 kt headwind from Jujuy to LaPaz (85% Annual)


Terrain Elevation along Track
Turnback required before this point
35000
30000
25000
20000
15000
10000
5000
0
Elevation (ft)
La Paz
RAXUN
rto
nado
1200
1400
1600
1800
2000
2200
Track Distance (nm)

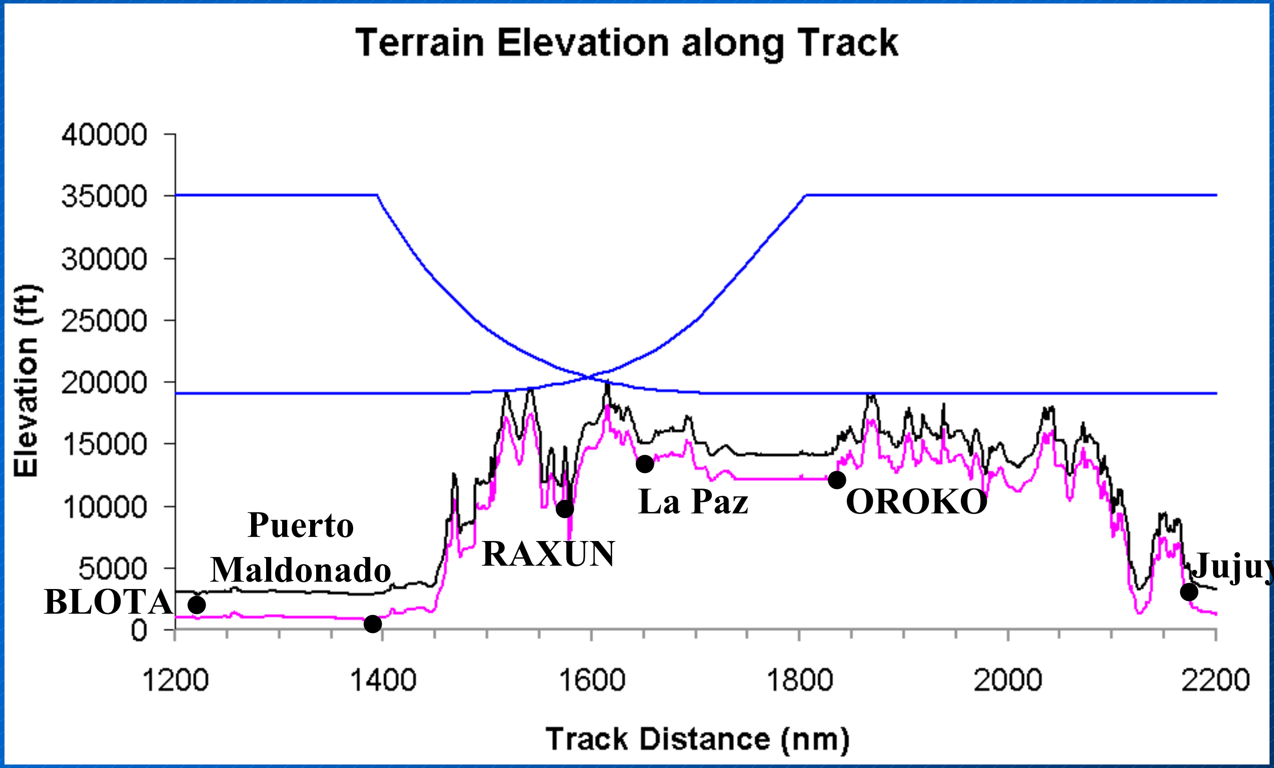

Terrain Elevation along Track
PNR - Continuation
required after this point
40000
35000
30000
25000
20000
15000
10000
5000
0
Elevation (ft)
La Paz
RAXUN
Puerto
Maldonado
BLOTA
1200
1400
1600
1800
2000
2200
Track Distance (nm)



Terrain Elevation along Track
Either continuation or turnback is possible
40000
35000
30000
25000
20000
15000
10000
5000
0
Elevation (ft)
BLOTA
Pue
Maldo
1200
1400
1600
1800
2000
2200
Track Distance (nm)

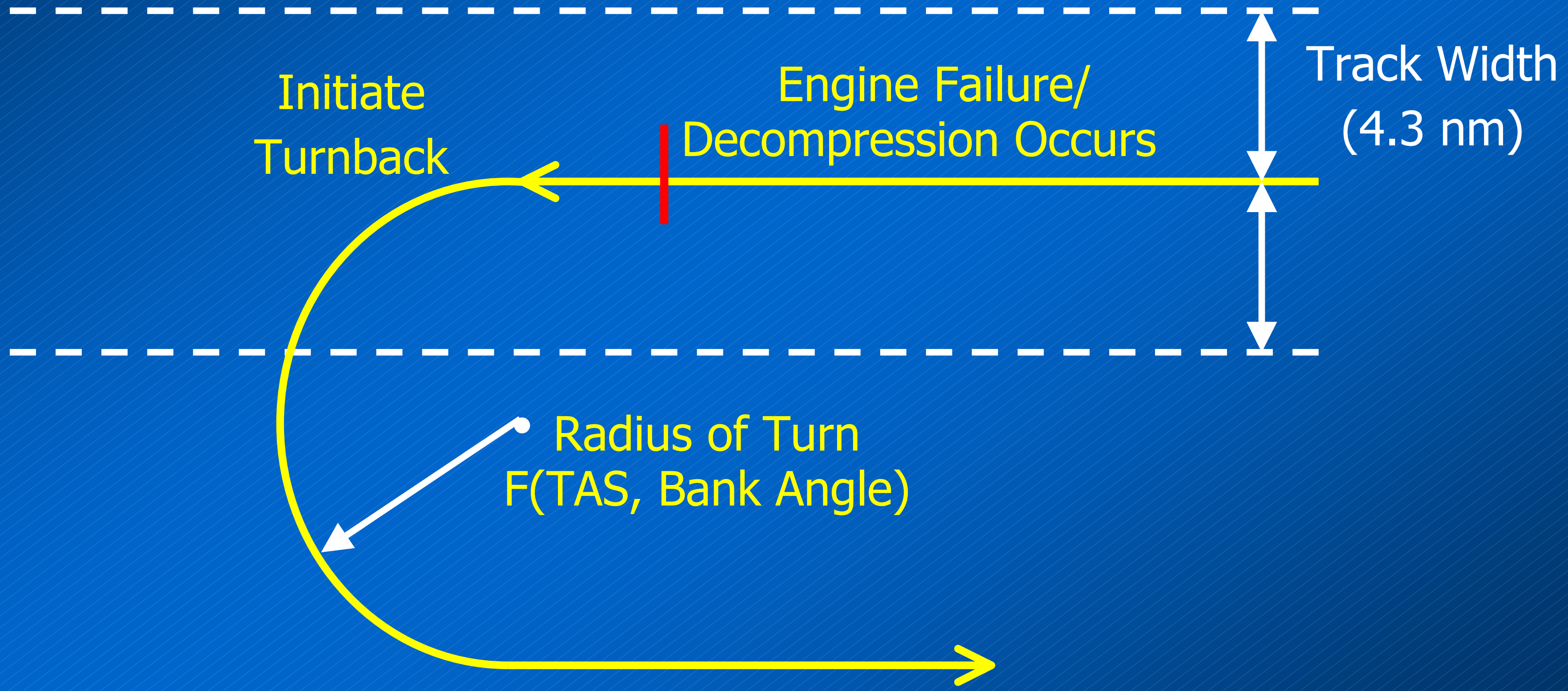
Example text of dispatch pilot procedures

- Between BLOTA (S08 08.9 W071 16.2) and RAXUN (S14 26.9 W069 28.8), divert on-track to Puerto Maldonado.
- Between RAXUN (S14 26.9 W069 28.8) and OROKO (S21 52.0, W066 08.0), divert on-track to La Paz.
- After OROKO (S21 52.0, W066 08.0), divert on-track to Jujuy.



Operational Considerations for Terrain Clearance Analysis???

Possible Turnback Scenario at High Speeds/Small Bank Angles



Radius of Turn Requirements at Cruise Speeds

Initial Cruise Speed (.78 Mach, FL370) ~ 240 IAS (430 KTAS)

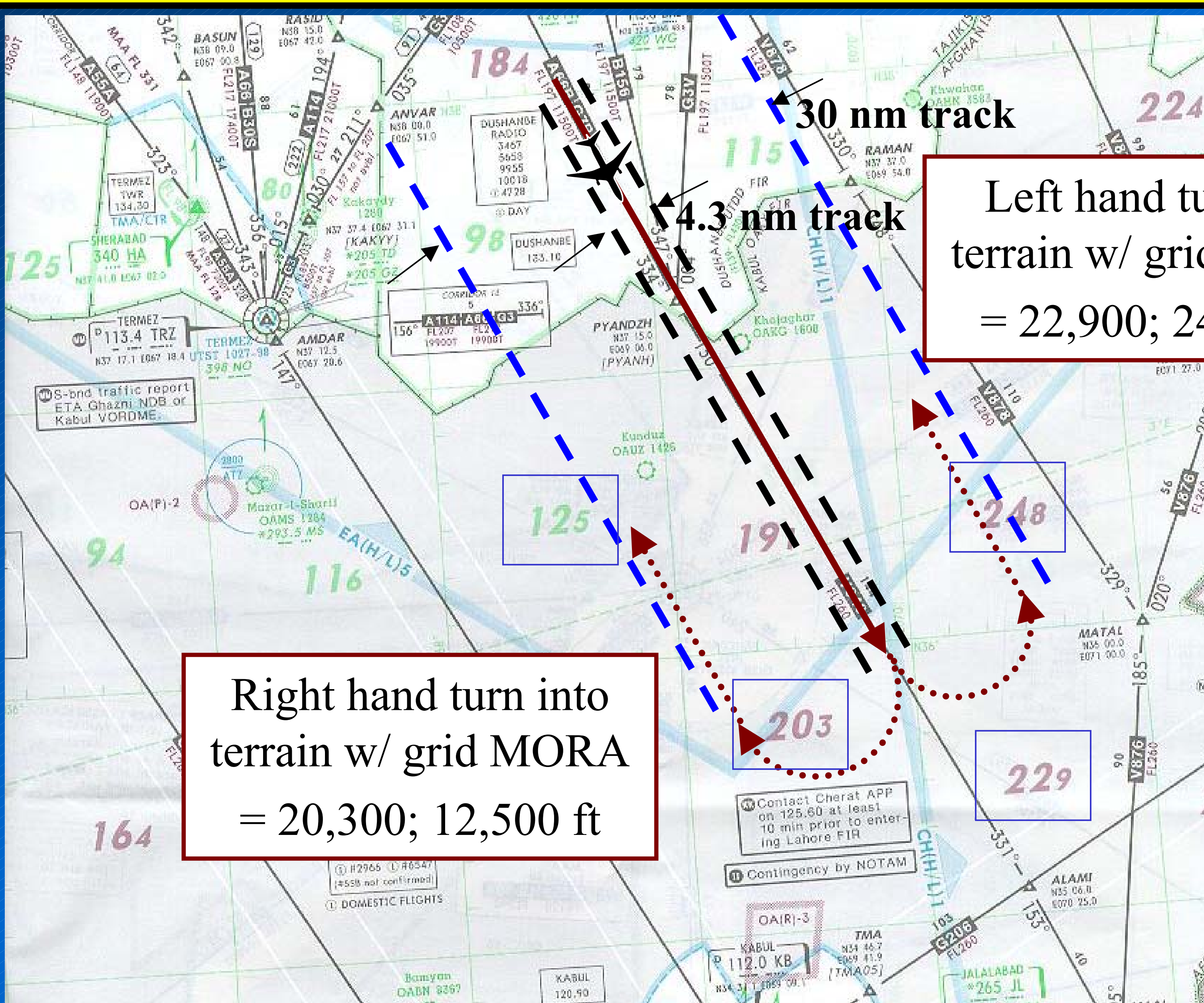
Bank Angle	Radius of Turn	Req'd Track Width (2*R)
15°	67,500 ft	22.2 nm
25°	38,000 ft	12.6 nm
35°	26,000 ft	8.6 nm

Approximate Final Driftdown Speed ~ 220 IAS (320 KTAS)

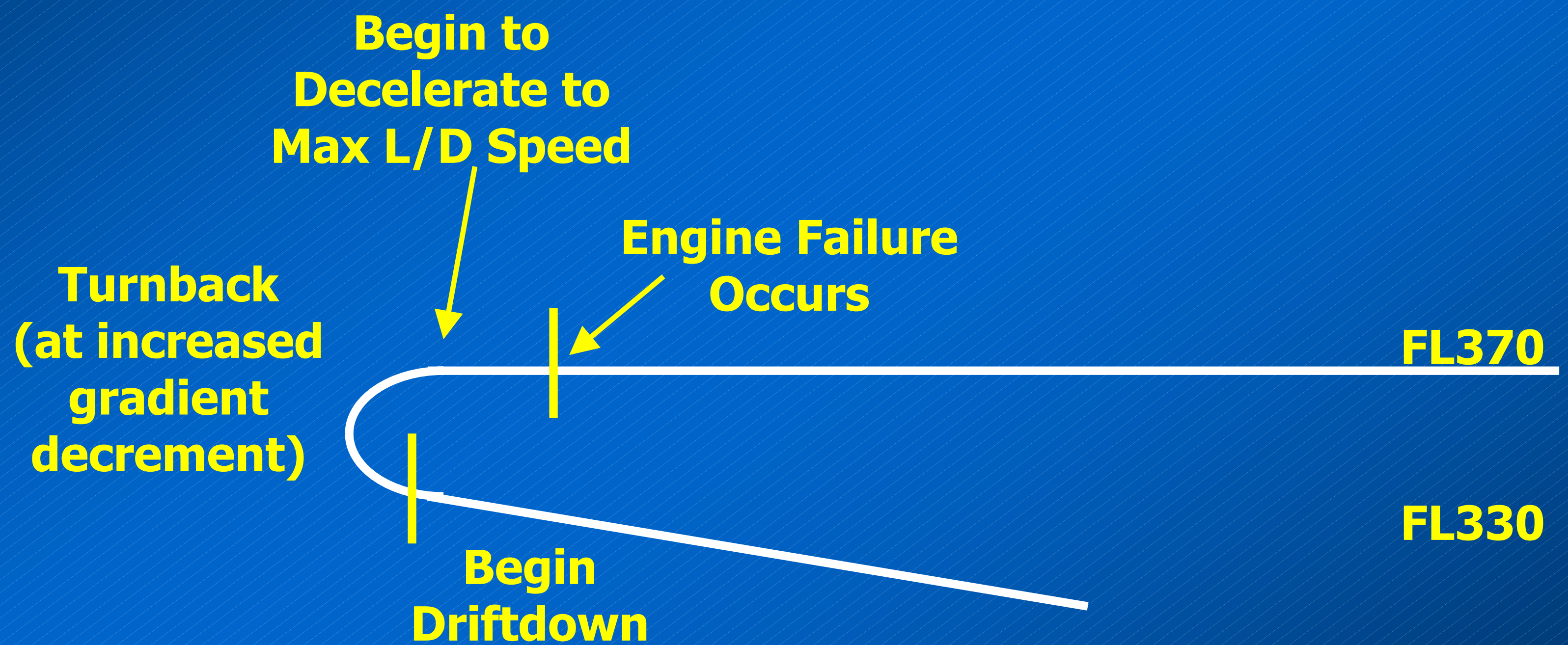
Bank Angle	Radius of Turn	Req'd Track Width (2*R)
15°	35,000 ft	11.6 nm
25°	20,000 ft	6.6 nm
35°	13,000 ft	4.2 nm

Considerations for Turn Radius

- Terrain outside of 5 statute mile track width?
- Difficult terrain on one side of track, but not on the other
- Flight path after turnback: go back to track or continue parallel to track (offset by XX nm)
- Can you meet engine out requirements for a 23 nm track width on both sides of the flight path? On one side of the flight path?


30 nm track
4.3 nm track
Left hand turn into terrain w/ grid MORA = 22,900; 24,800 ft
Right hand turn into terrain w/ grid MORA = 20,300; 12,500 ft
184
224
115
98
125
80
191
248
94
116
203
229
164
TERMEZ
113.4 TRZ
AMDAR
ANVAR
BASUN
RAMAN
PYANDZH
MATAL
ALAMI
KABUL
112.0 KB
S-bnd traffic report ETA Ghazni NDB or Kabul VORDME.
Contact Cherat APP on 125.60 at least 10 min prior to entering Lahore FIR
Contingency by NOTAM
DOMESTIC FLIGHTS

Gradient Decrement Profile in a Turn with One Engine Inoperative



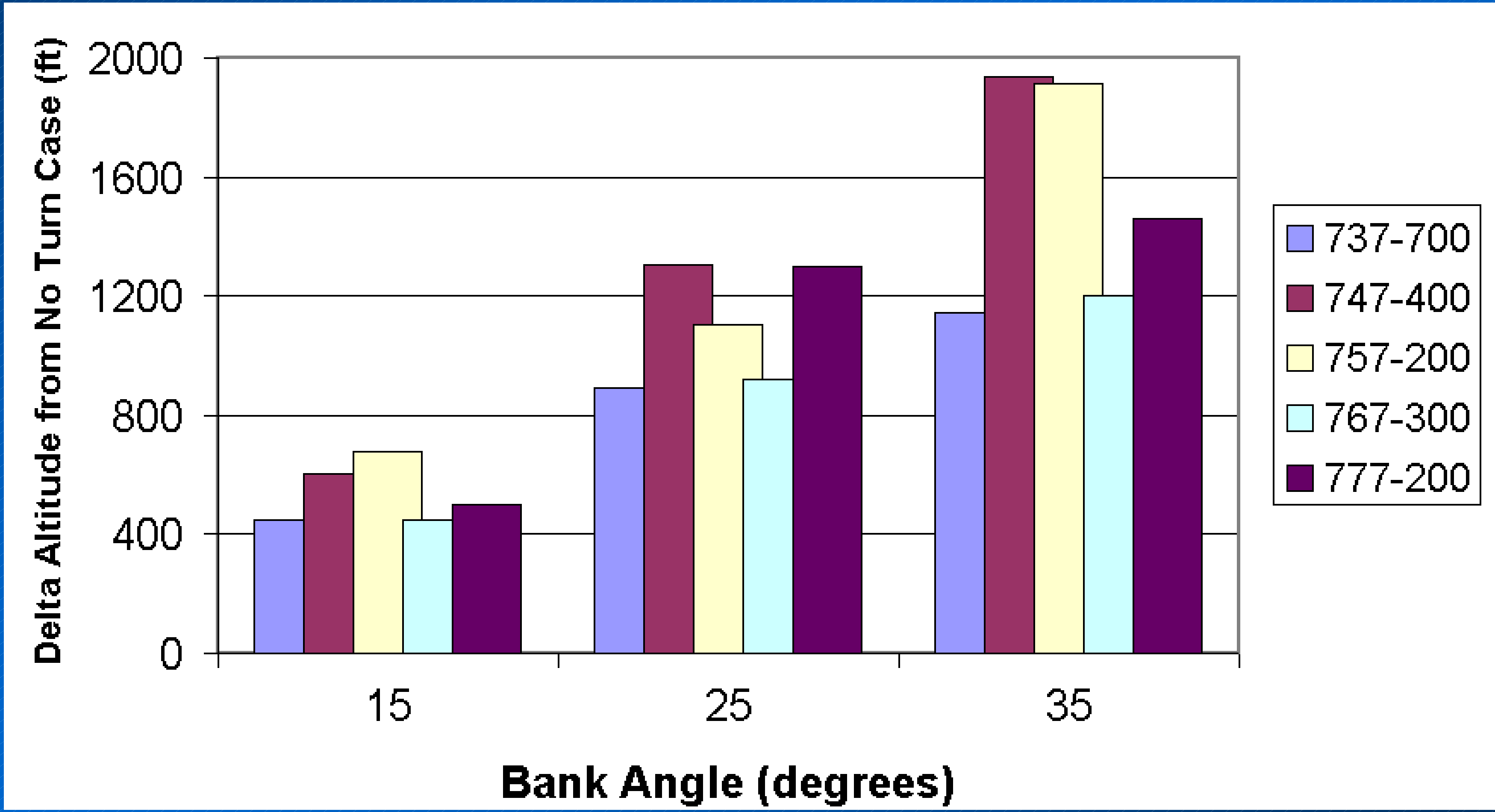
Procedure Assumed for Altitude Decrement Calculation Due to Turnback

-All Aircraft-

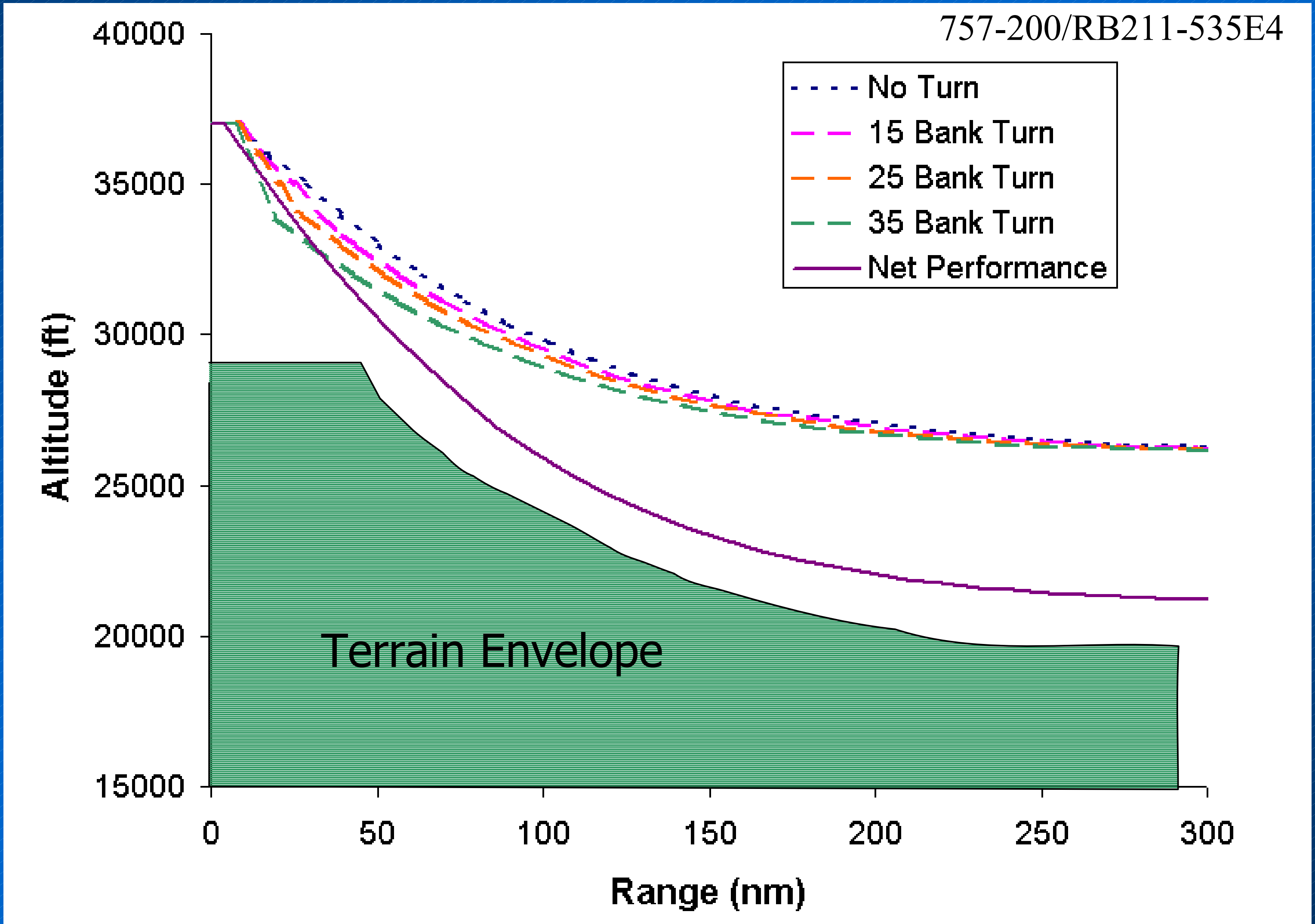
- Initiate turnback 1 minute after engine failure.
- Speed: LRC before loss of engine
  Max L/D after loss of engine
- Weight: Generally middle to light weight
  ~ MLW + 5000 kg
- Assume gross driftdown performance;
- Assume A/C maintains constant gradient decrement in turn (initial gradient);
- Turn radius calculated based on TAS entering turn.

Effect of Turning on Altitude

Maximum Altitude Decrease Due to Turnback



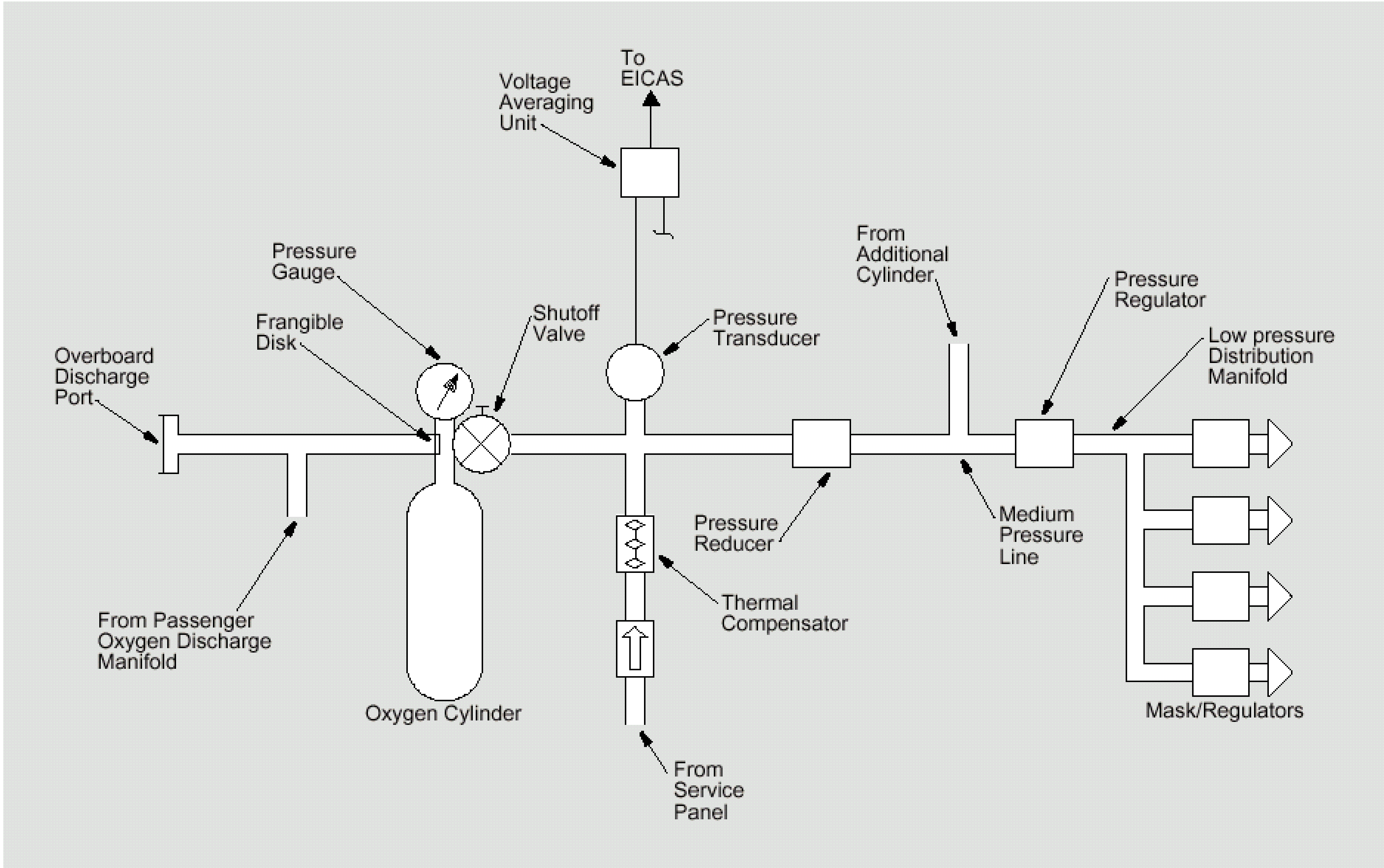
Effect of Turning on Altitude
Gross vs. Net Performance



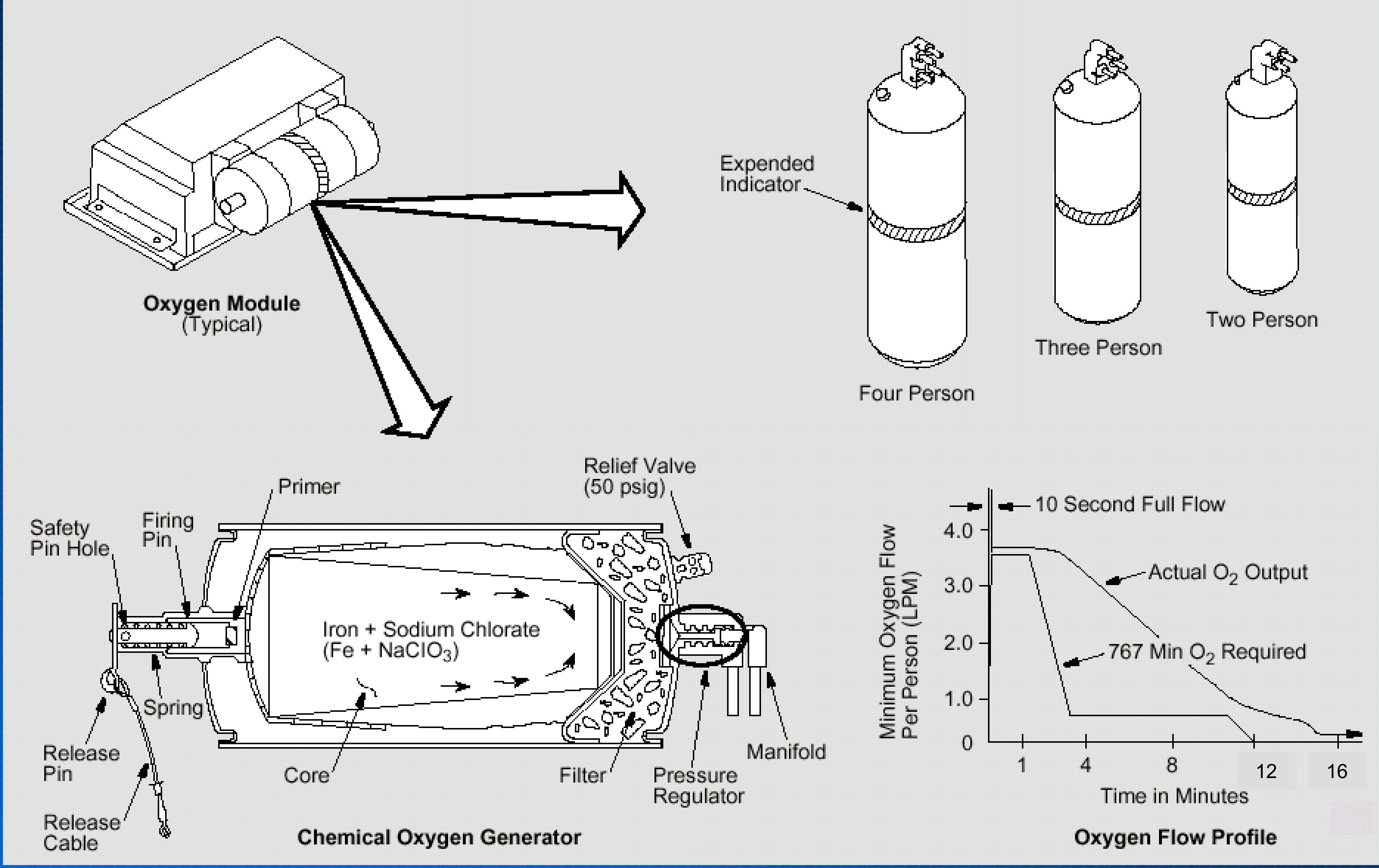
Oxygen Systems, Requirements & Analysis

Oxygen Systems

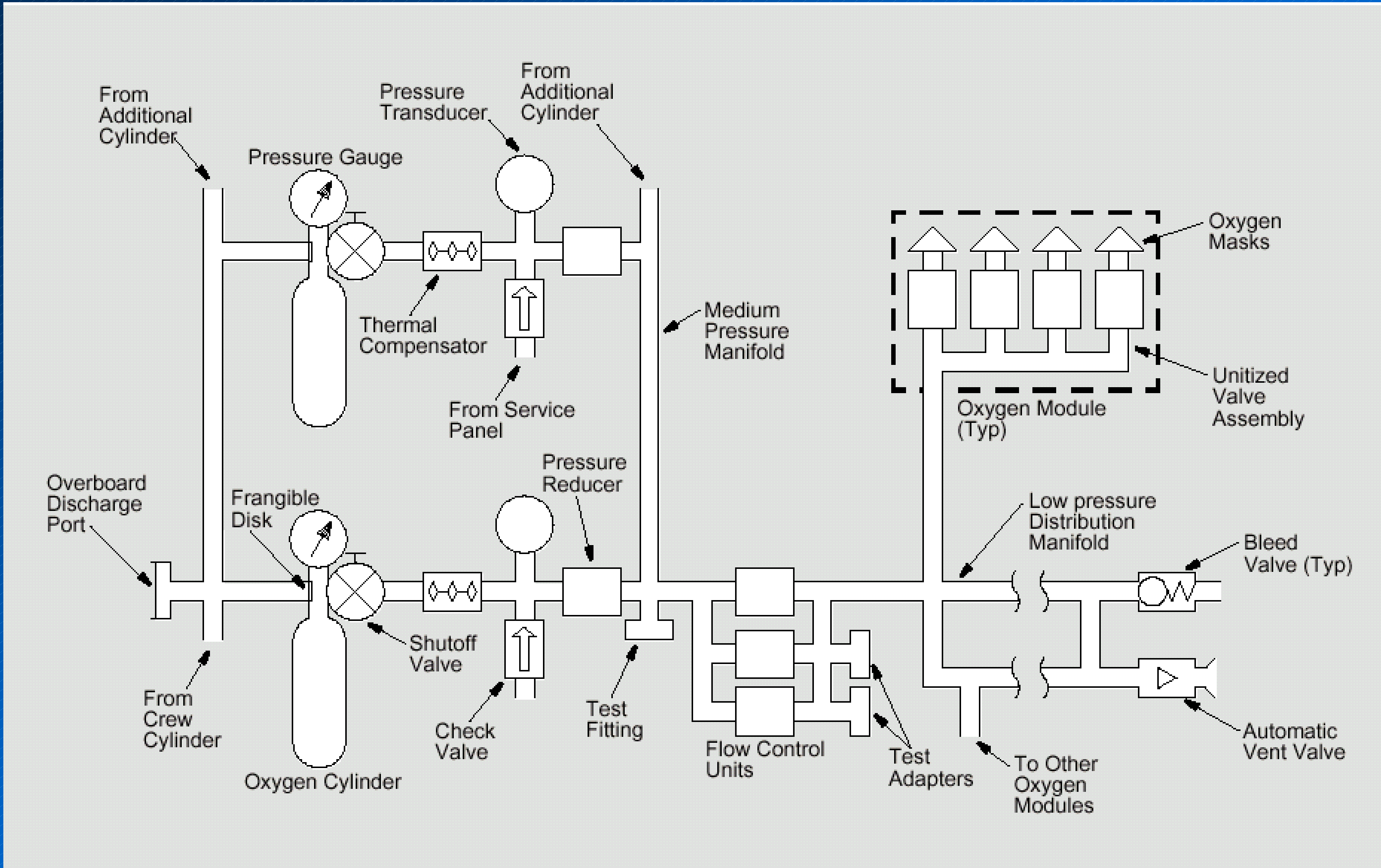
- Flight Crew
  - Gaseous System (fixed bottles)
- Passenger Cabin
  - Chemical System (fixed canisters)
  - Gaseous System (fixed bottles)



Flight Crew Oxygen System



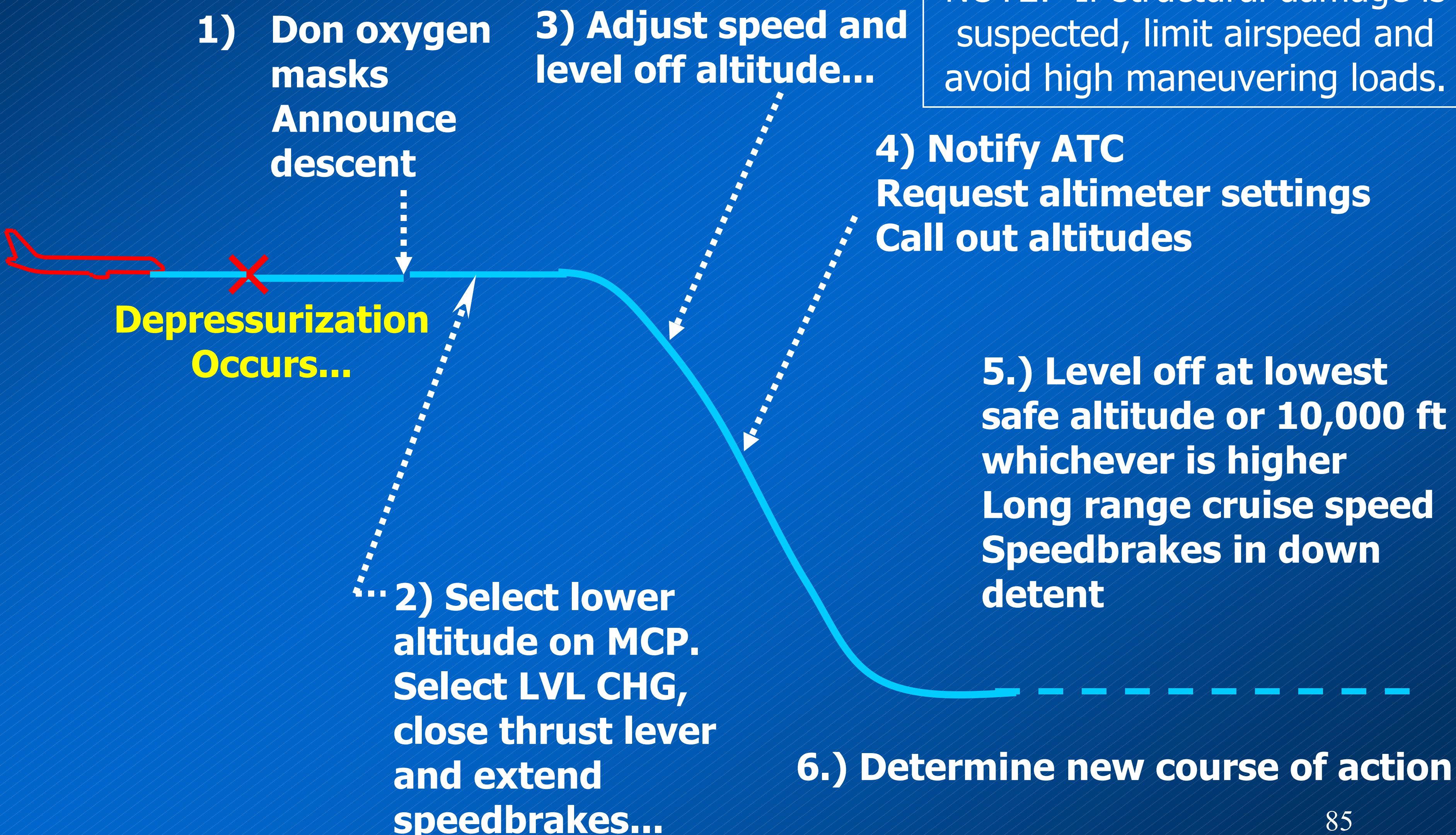
Passenger Chemical Oxygen System



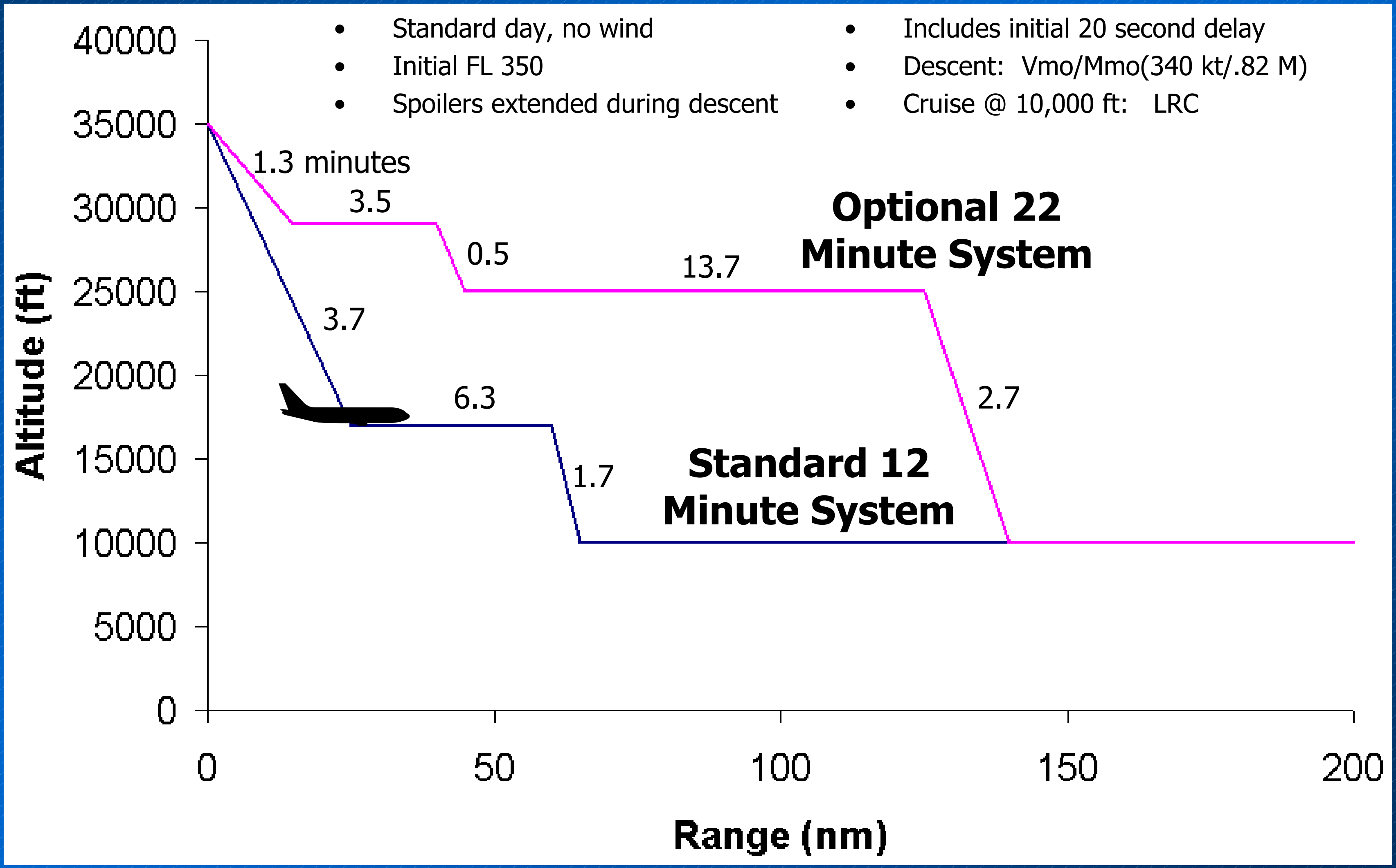
Passenger Gaseous Oxygen System

Generic Emergency Descent Profile

NOTE: If structural damage is suspected, limit airspeed and avoid high maneuvering loads.



737-700 CFM56-7 Emergency Descent Profiles for Chemical Oxygen System



FARs Governing Crew and Passenger Oxygen Systems

Crew	Passenger	Federal Air Regulation (FAR)	
X		25.1439	Protective Breathing Equipment
X	X	25.1443	Minimum Mass Flow of Supplemental Oxygen
X	X	25.1447	Equipment Standards for Oxygen Dispensing Units
X	X	121.329	Supplemental Oxygen for Sustenance: Turbine Engine Powered Airplanes
X	X	121.333	Supplemental Oxygen for Emergency Descent and for First Aid: Turbine Engine Powered Airplanes with Pressurized Cabins
X		121.337	Operators Protective Breathing Requirements

Oxygen Requirements

There are two types of requirements for oxygen:

Supplemental Oxygen

- Protects against hypoxia in the case of decompression or loss of cabin altitude

- Oxygen required is altitude dependent (higher oxygen flow rate is required at higher altitudes)

Protective Oxygen

Protects against smoke and harmful gas inhalation in the case of a fire etc. (required for flight crews only; not required for passengers)

Flight Crew Oxygen Requirements

The flight crew oxygen system must supply sufficient oxygen to each flight deck occupant for each of the following conditions:

FAR Sec. 121.329 (b)(1),(b)(2) – Supplemental Oxygen

- **The airplane's actual emergency descent profile from maximum certified cruise altitude to 10,000 feet following the loss of cabin pressurization.**

FAR Sec. 121.333(b) – Supplemental Oxygen

- **The FAA theoretical constant rate of descent from the airplane's maximum certified cruise altitude to 10,000 feet in 10 minutes, followed by 110 minutes at 10,000-foot cabin altitude.**

FAR Sec. 121.337(b)(7)(i) – Protective Oxygen

- **15 minutes of protective breathing for each crew member at a normal cabin pressure altitude of 8,000 ft (no decompression).**

Flight Crew mask Usage

3 settings:

EMERG	**Used for Protective Breathing**
100%	**Used for Supplemental/Descent**
NORMAL	**Used after Descent (level off)**

Flight Crew Oxygen Requirements (Protective Breathing)

FLIGHT PLANNING
Simplified Flight Planning

BOEING
Flight Planning and Performance Manual

737-700
CFM56-7B24

Crew Oxygen Requirements

Required Pressure (PSI) for 76 FT3 Cylinder

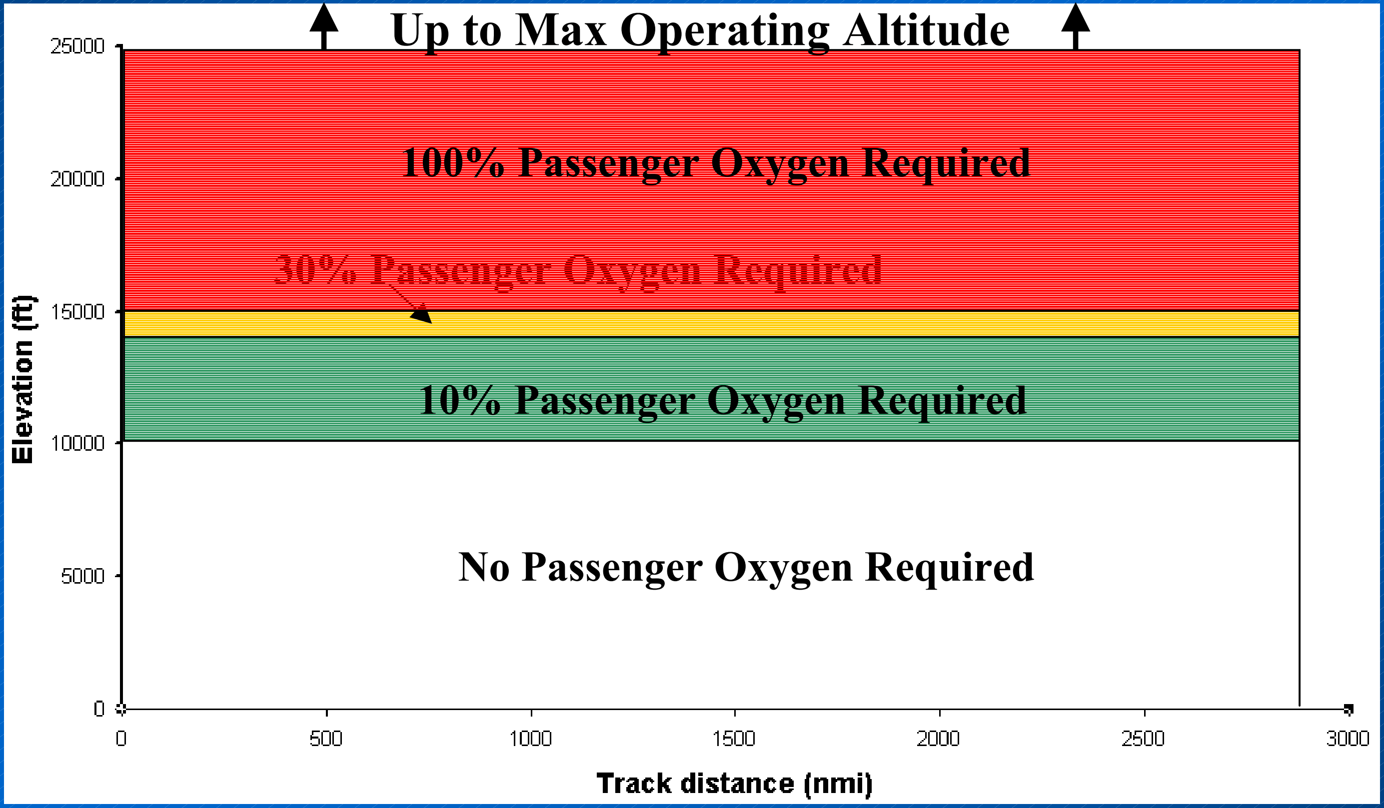
BOTTLE TEMPERATURE		NUMBER OF CREW USING OXYGEN		
°C	°F	2	3	4
50	122	735	1055	1360
45	113	725	1040	1340
40	104	715	1020	1320
35	95	700	1005	1300
30	86	690	990	1280
25	77	680	975	1255
20	68	670	960	1240
15	59	655	940	1215
10	50	645	925	1195
5	41	635	910	1175
0	32	620	890	1150
-5	23	610	875	1130
-10	14	600	860	1110

Required Pressure (PSI) for 114/115 FT3 Cylinder

BOTTLE TEMPERATURE		NUMBER OF CREW USING OXYGEN		
°C	°F	2	3	4
50	122	530	735	945
45	113	520	725	930
40	104	510	715	915
35	95	505	700	900
30	86	495	690	885
25	77	485	680	870
20	68	480	670	860
15	59	470	655	840
10	50	460	645	830
5	41	455	635	815
0	32	445	620	800
-5	23	440	610	785
-10	14	430	600	770

FAR 121 .329(c) /JAR 1.770 **Passenger Cabin Oxygen Requirements**

Each certificate holder shall provide a supply of oxygen for passengers in accordance with the following:



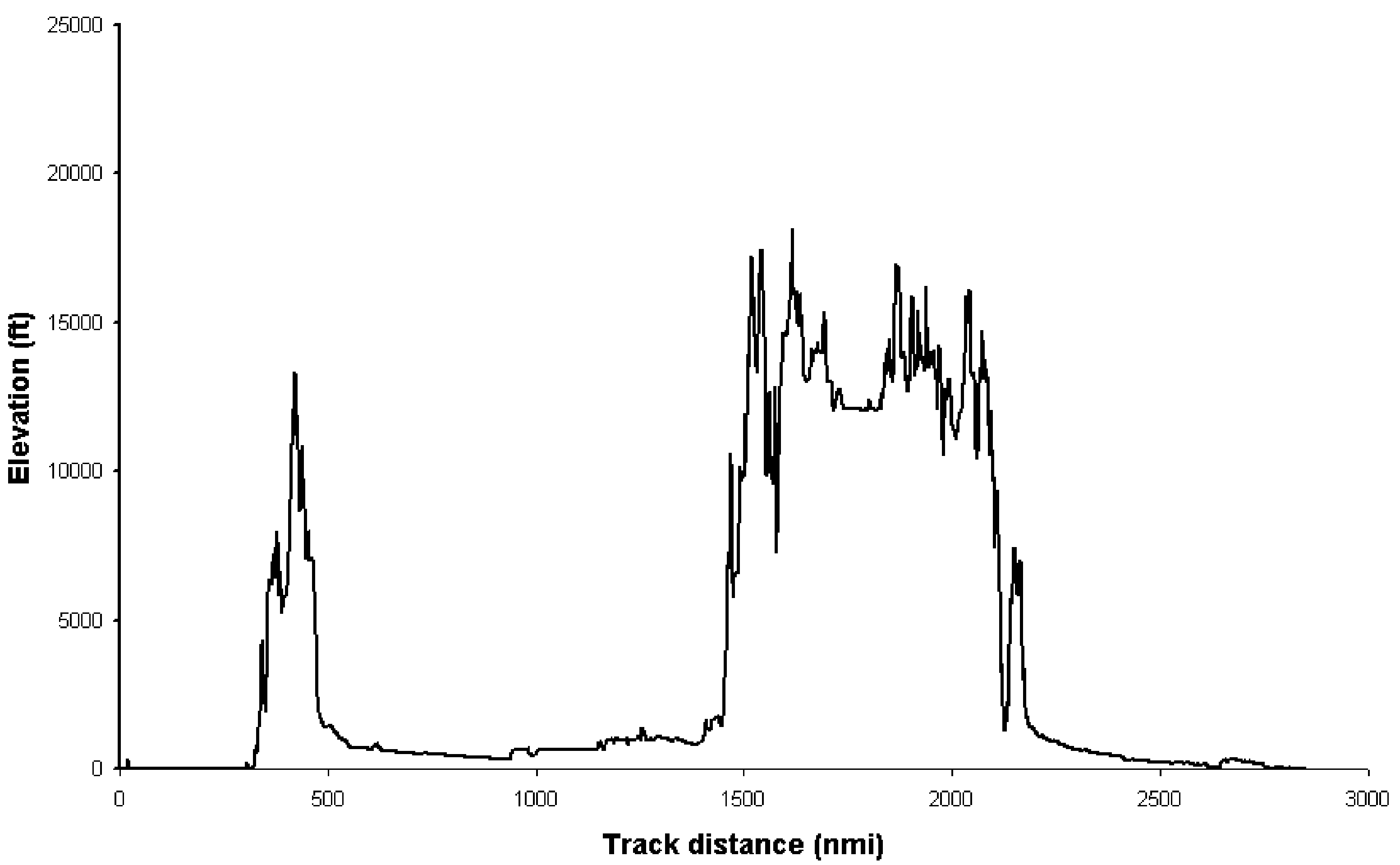
FAR 121.333(e) **There must be not less than a 10-minute supply of oxygen for passenger cabin occupants.**

Oxygen Requirements Analysis

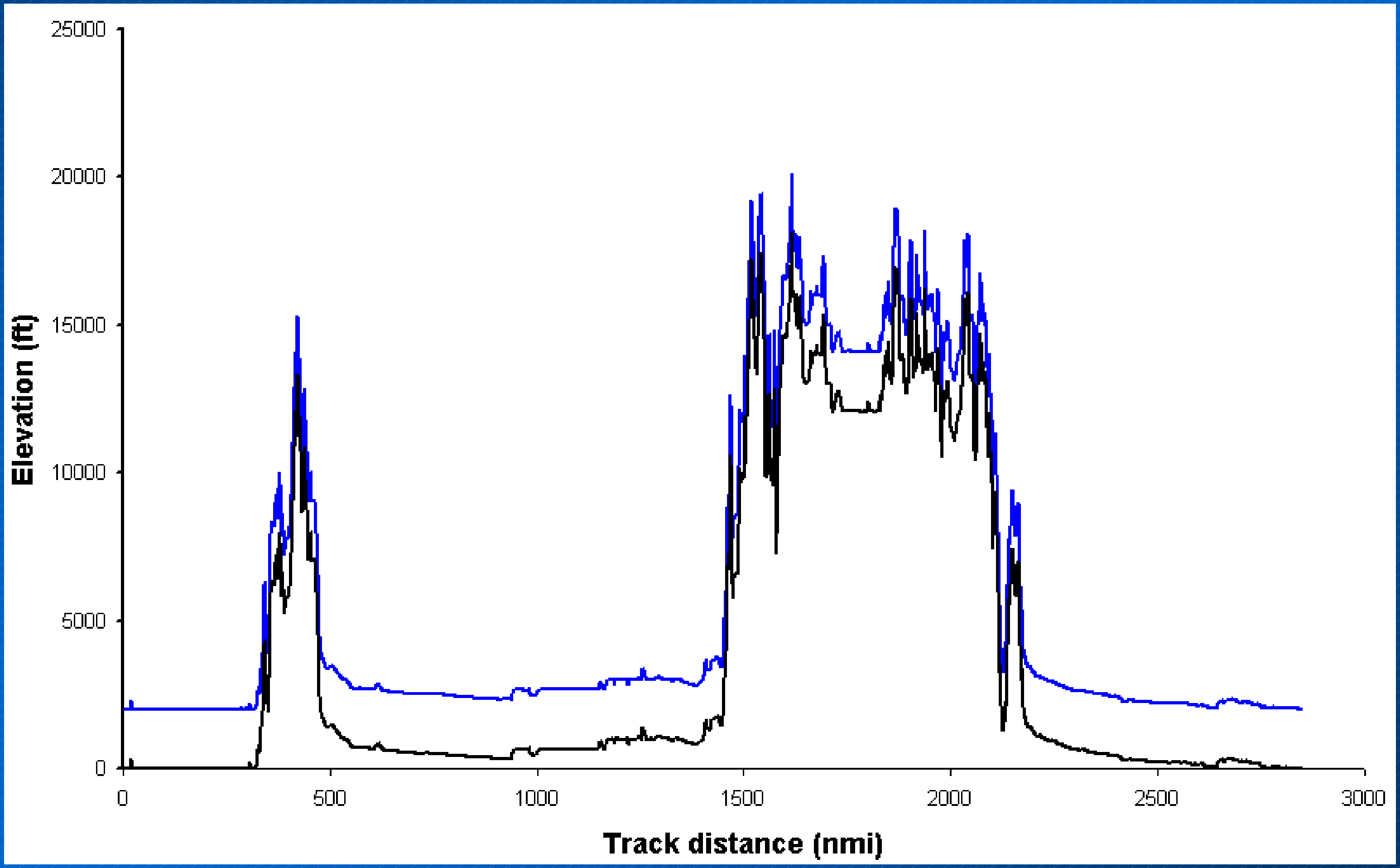
FAR 121.657 (c)
All-engine Terrain Clearance

- **No person may operate an aircraft under IFR including over-the-top or at night under VFR at an altitude less than 1,000 feet above the highest obstacle within a horizontal distance of five miles from the center of the intended course, or, *in designated mountainous areas*, less than 2,000 feet above the highest obstacle within a horizontal distance of five miles from the center of the intended course.**

All-engine Mountainous Terrain Clearance Requirement

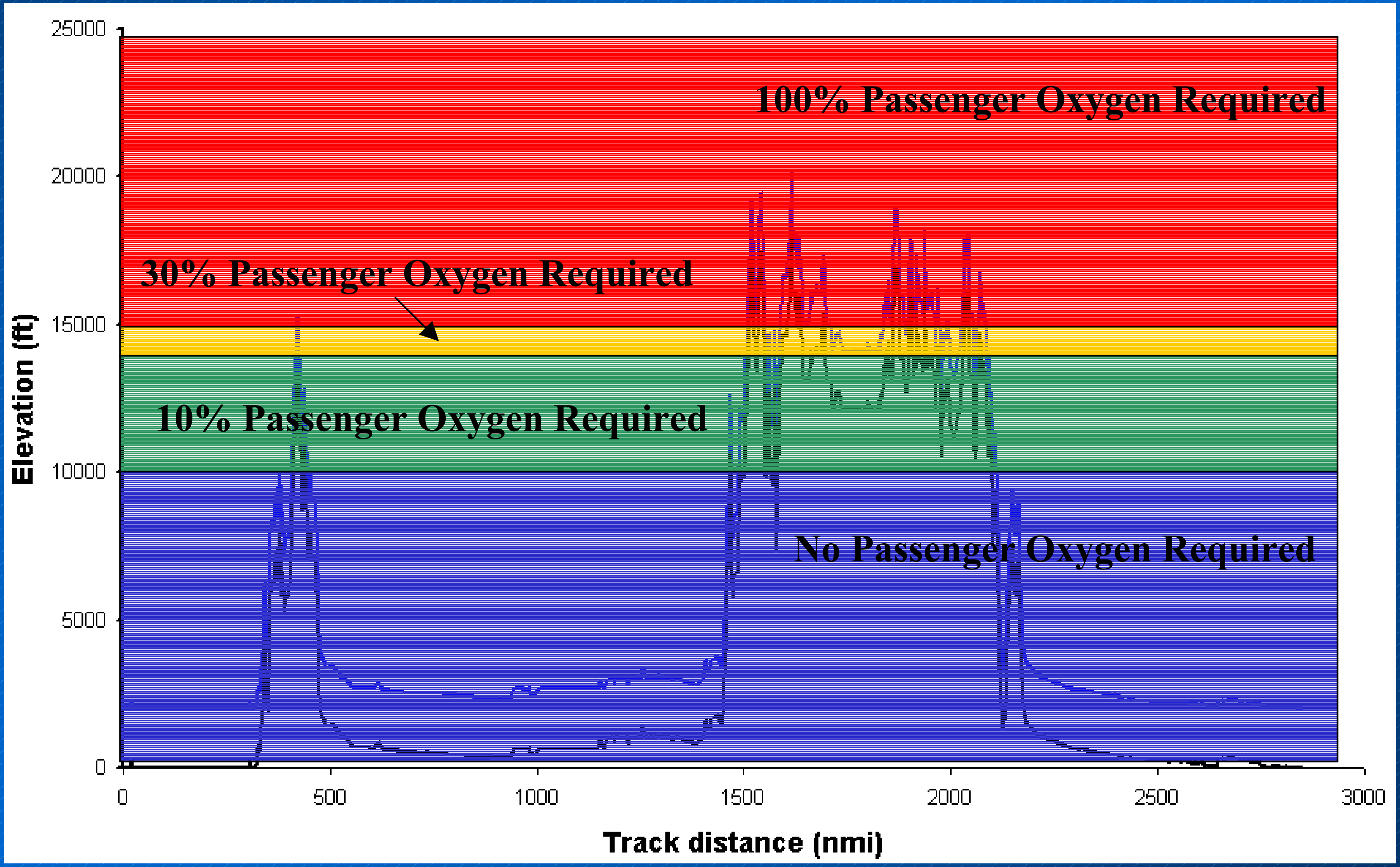


All-engine Mountainous Terrain Clearance Requirement

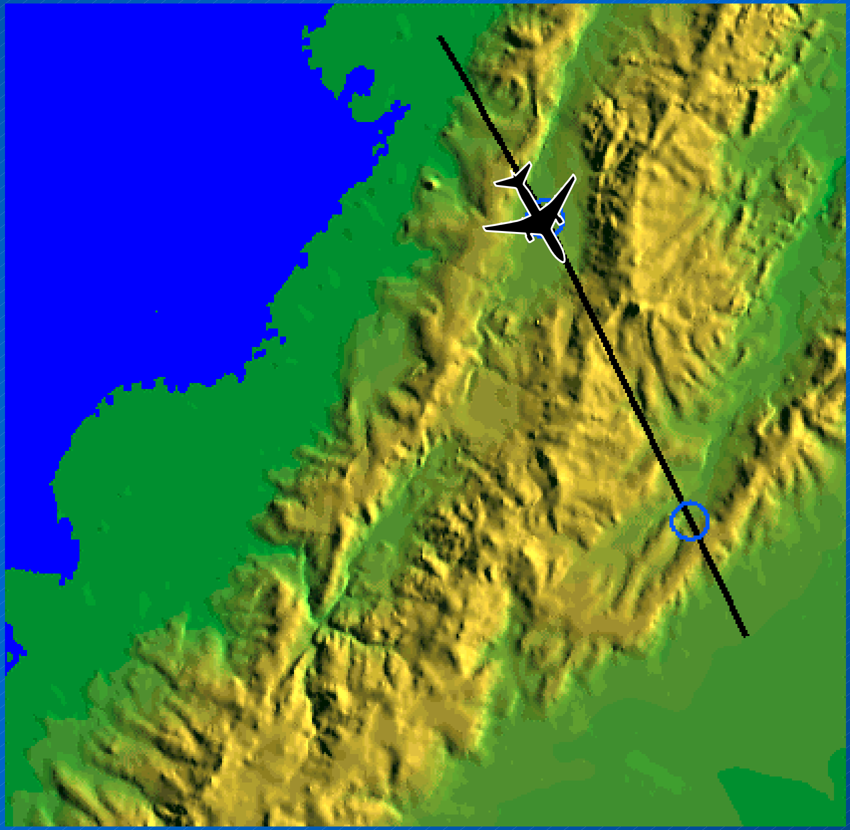


FAR 121 .329(c) /JAR 1.770 **Passenger Cabin Oxygen Requirements**

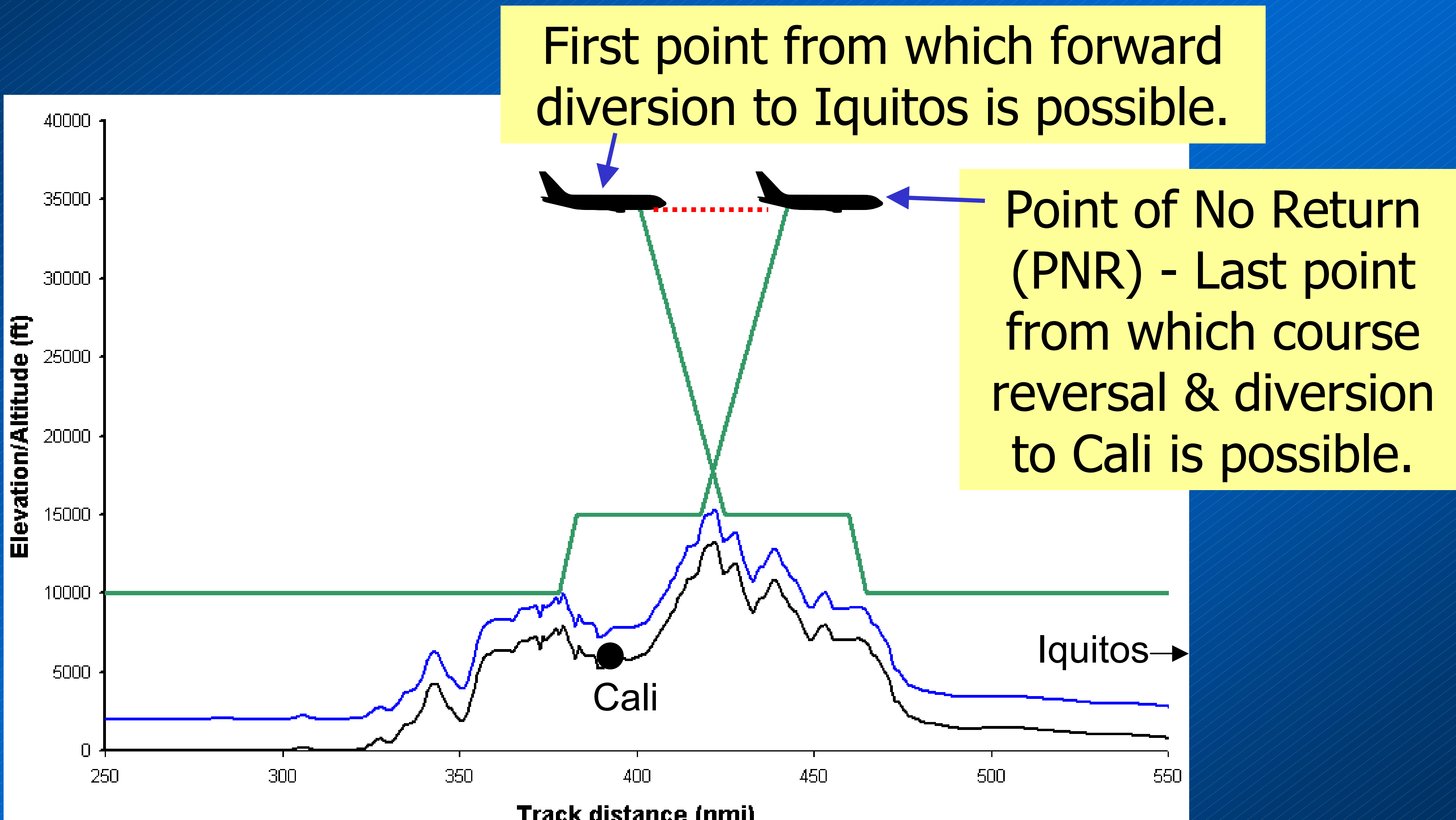
Each certificate holder shall provide a supply of oxygen for passengers in accordance with the following:



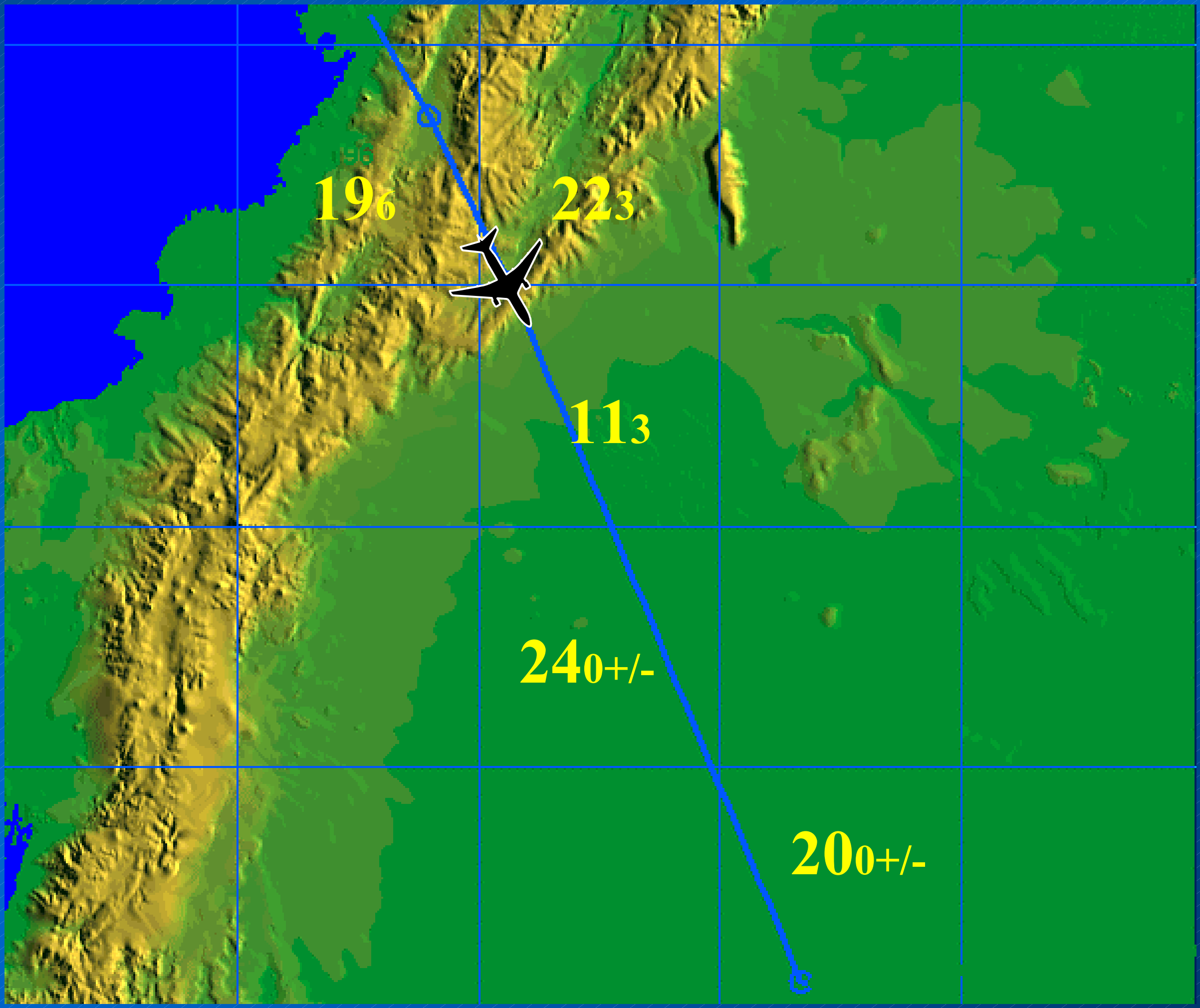
Operations in Mountainous Areas



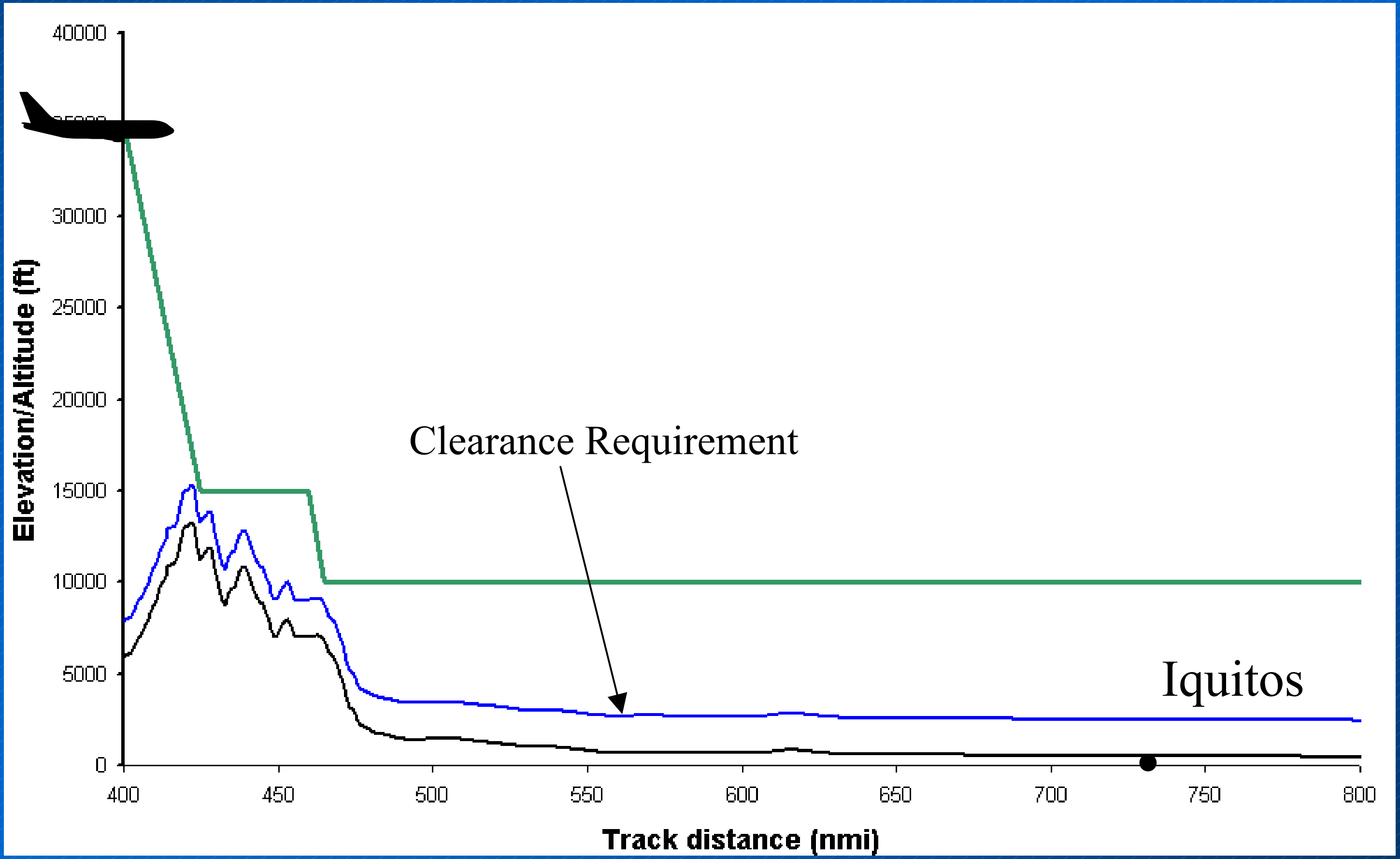
Range of Decision Points



Route beyond critical point

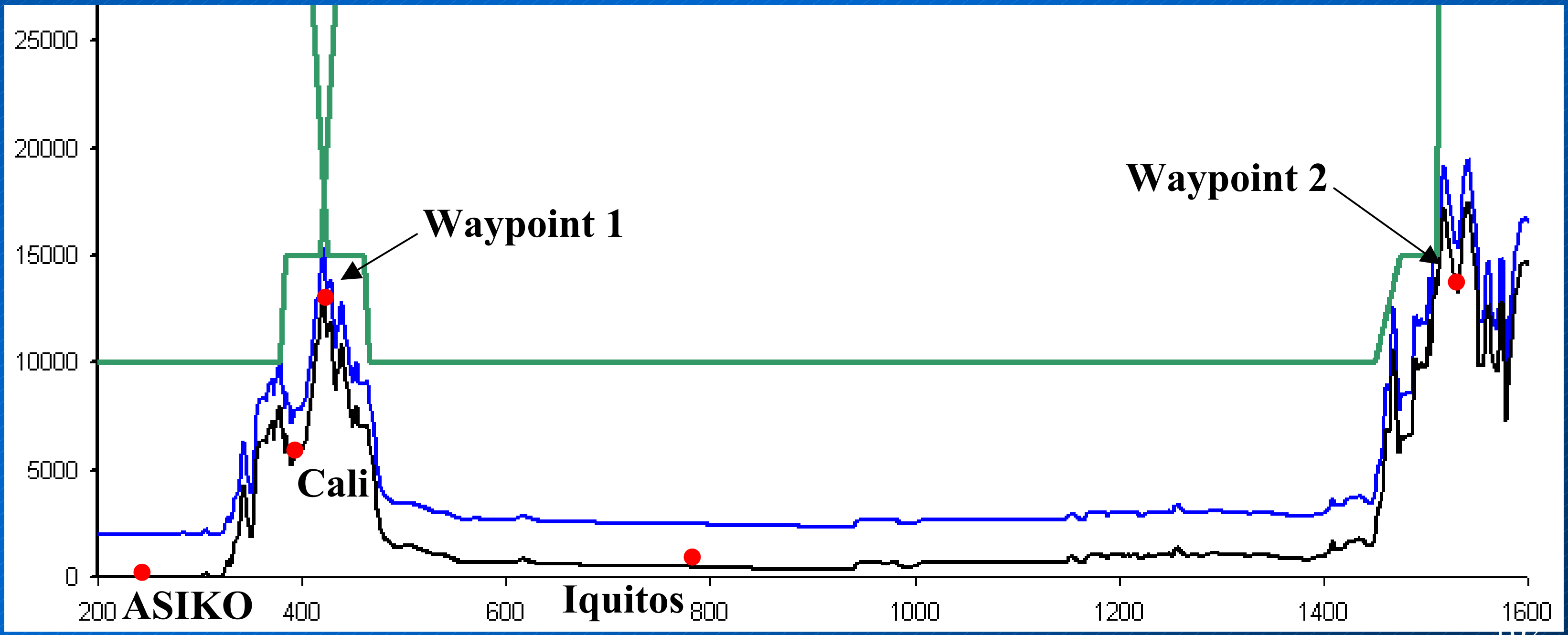


Oxygen Profile from Critical Point to Iquitos



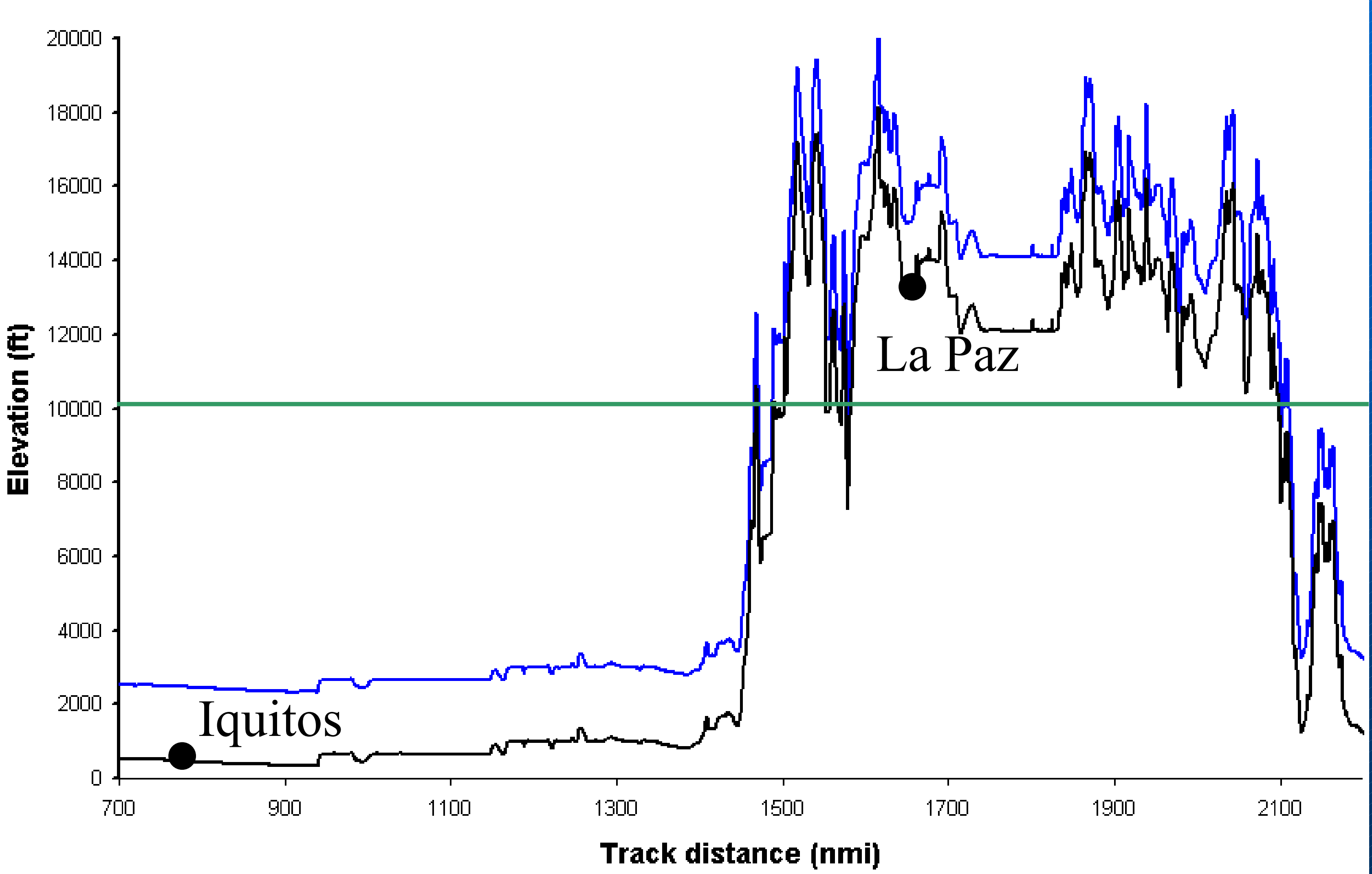
Procedures as part of the dispatch package

- Example text of dispatch pilot procedures
  - Between ASIKO (N04 14.8 W076 53.9) and Waypoint #1 (N01 59.4 W075 43.8), divert on-track to Cali.
  - Between Waypoint #1 and Waypoint #2 (S14 28.64 W069 03.81), divert on-track to Iquitos.

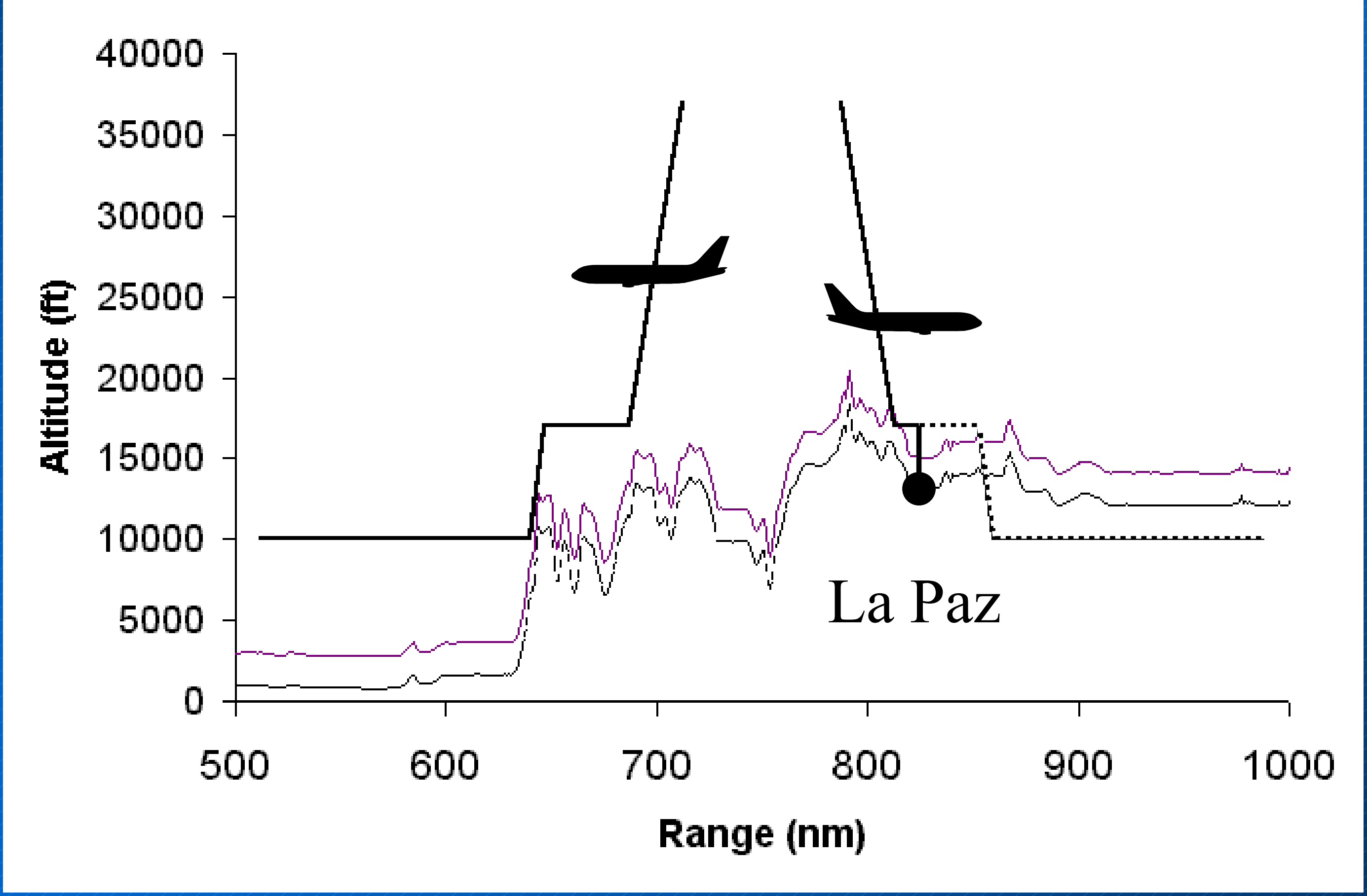


Operations in Mountainous Areas

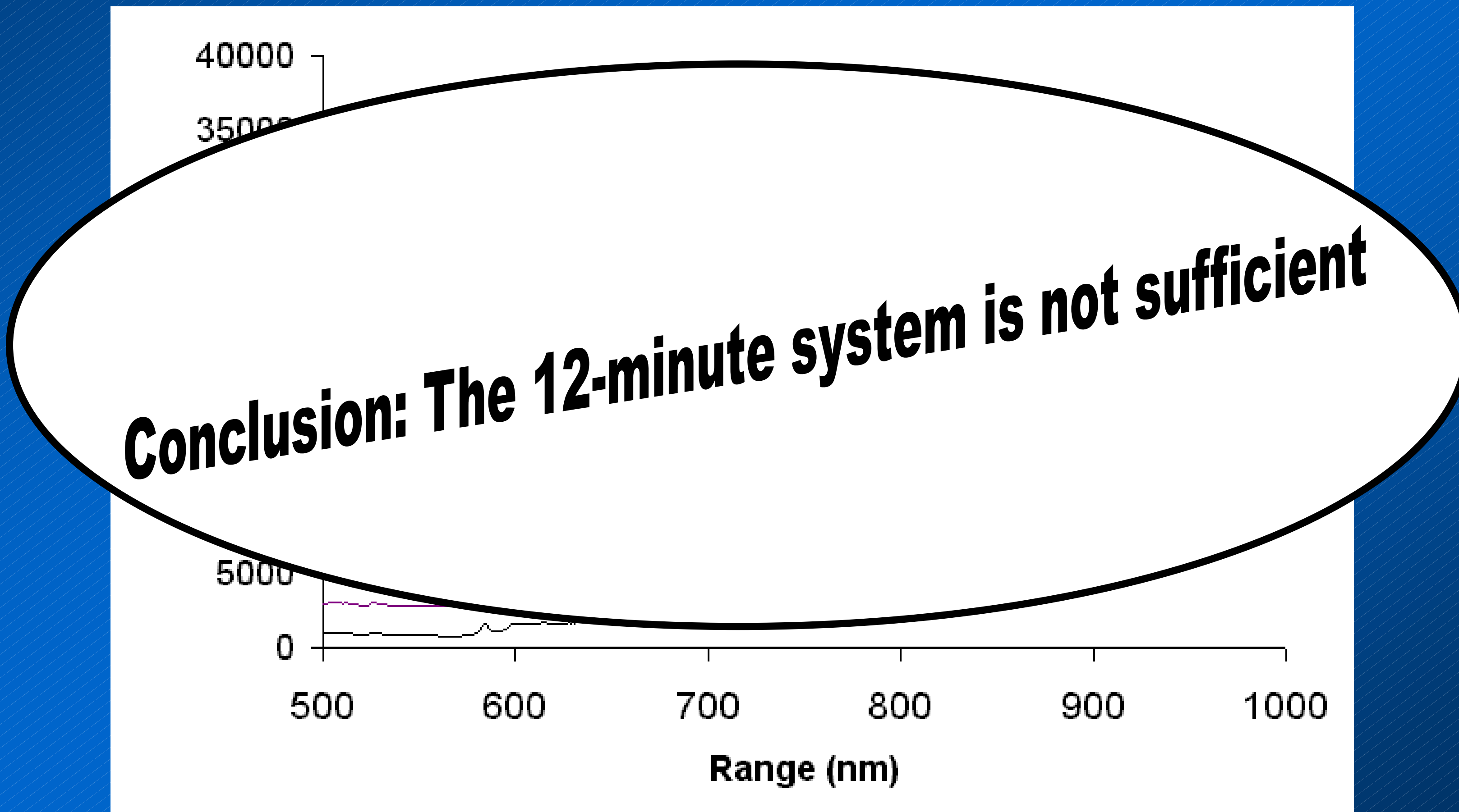
Terrain for Second Half of Route



12-minute oxygen system into La Paz



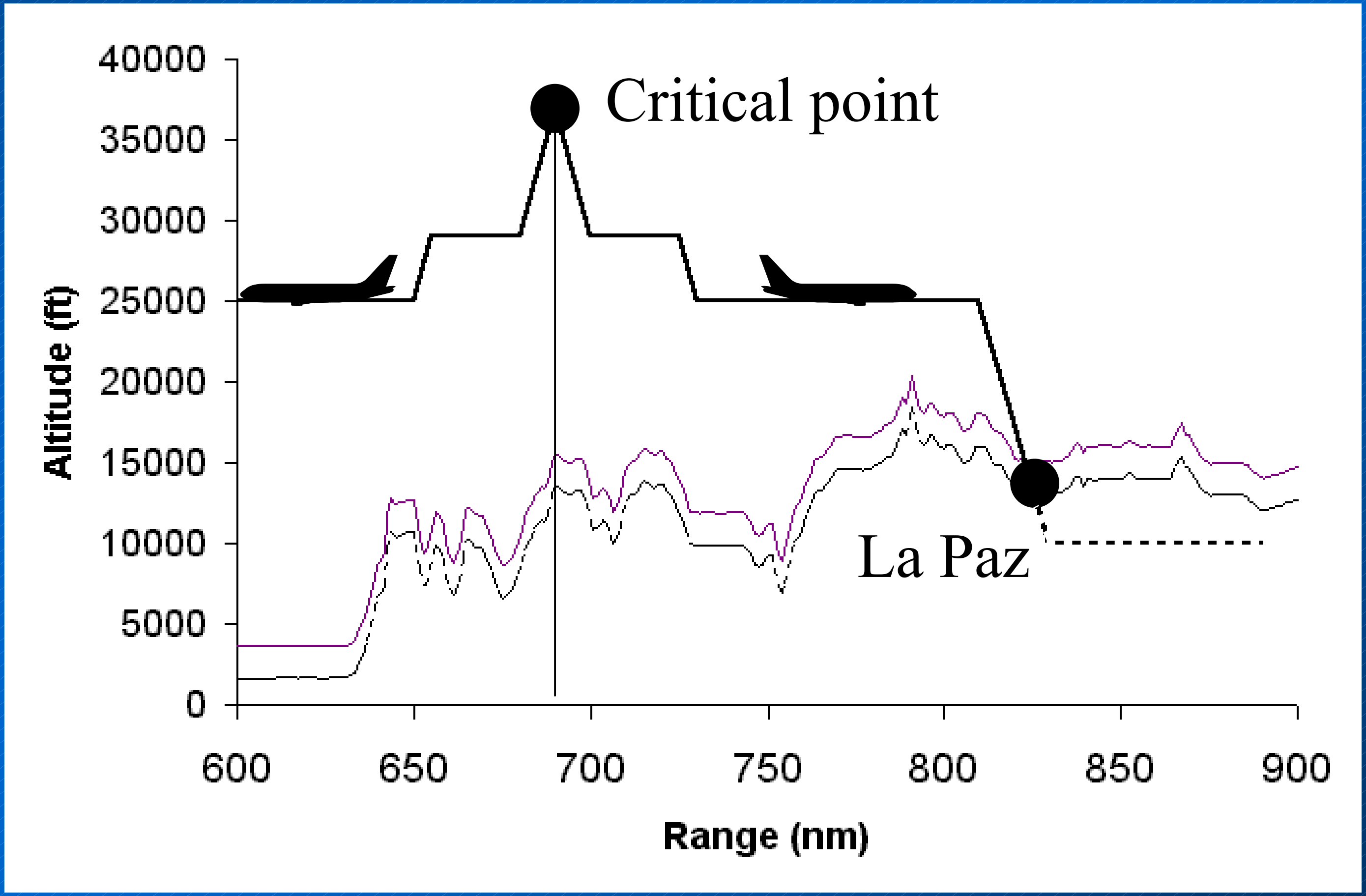
12-minute oxygen system into La Paz



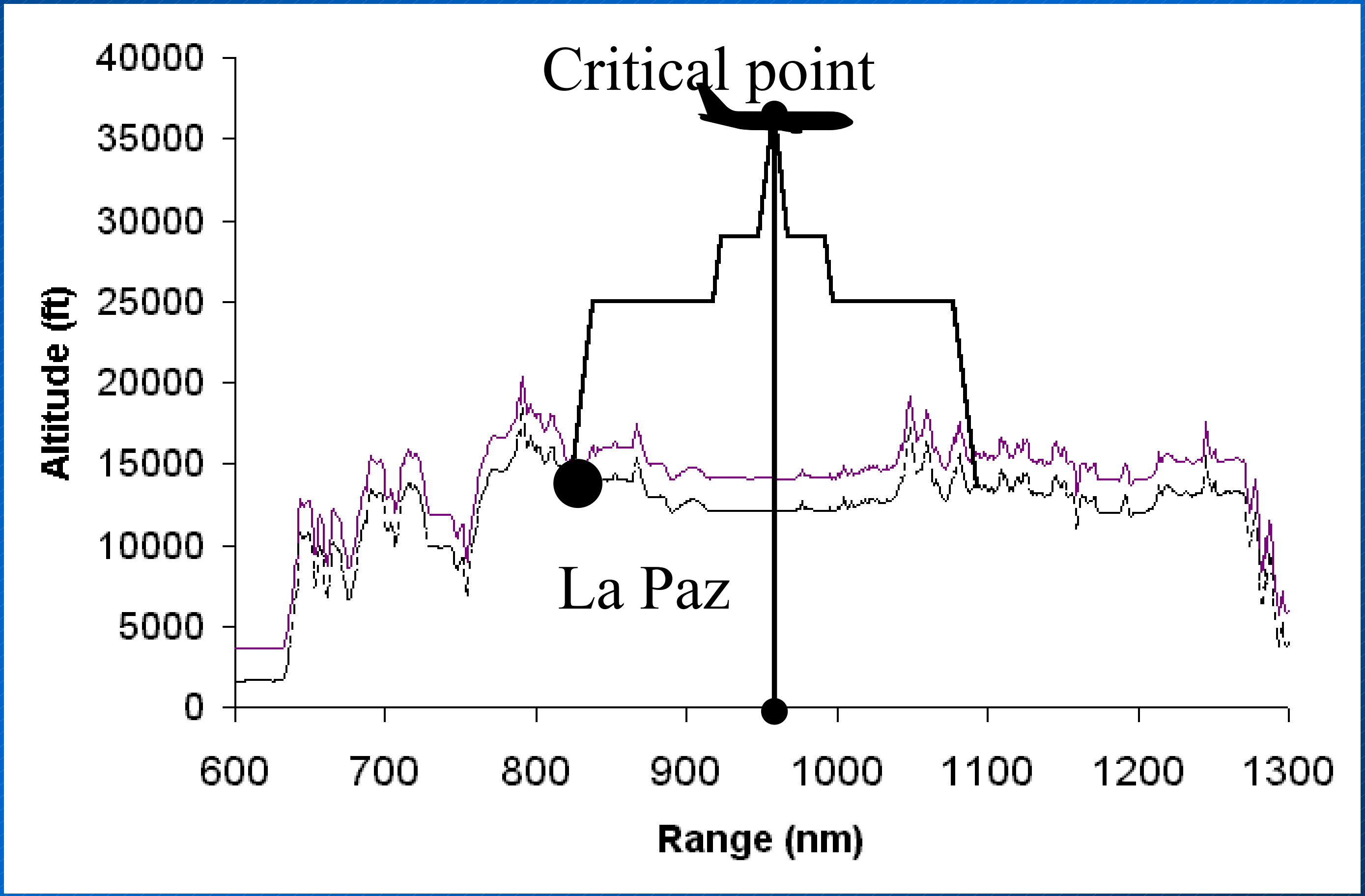
Options if 12 Minute System does not meet Requirements

- Determine the details of limiting terrain to see if descent to 10,000 ft is possible while avoiding terrain.
- Consider off-track diversions to alternates.
- Establish a different flight plan to avoid the limiting terrain
- Consider a 22 minute oxygen system instead of a 12 minute system.
- Add portable supplemental oxygen bottles to increase the time that the airplane can fly over limiting terrain and still meet the oxygen requirements.

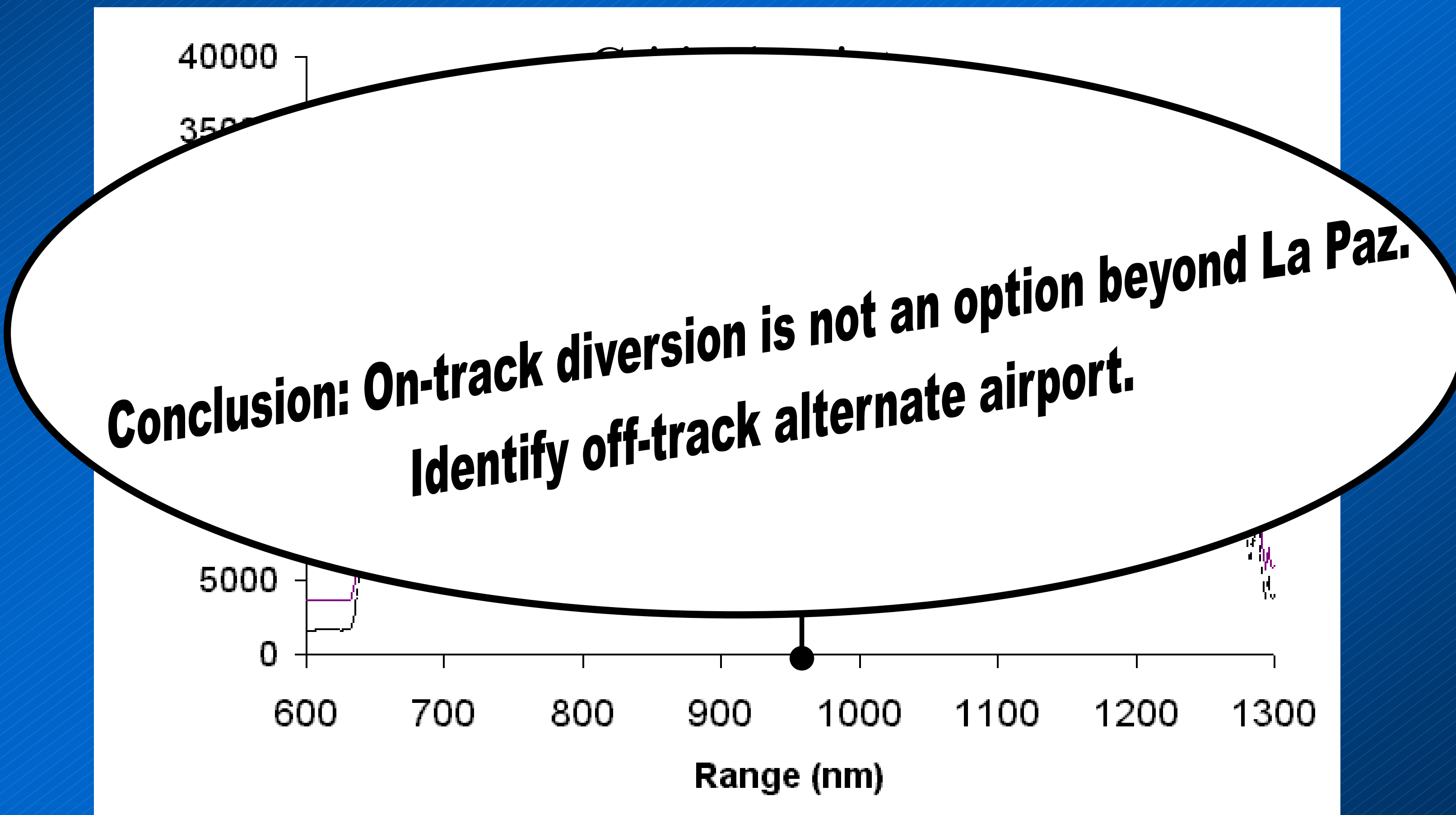
Diversion to La Paz with 22-minute system



Diversion along track beyond critical point

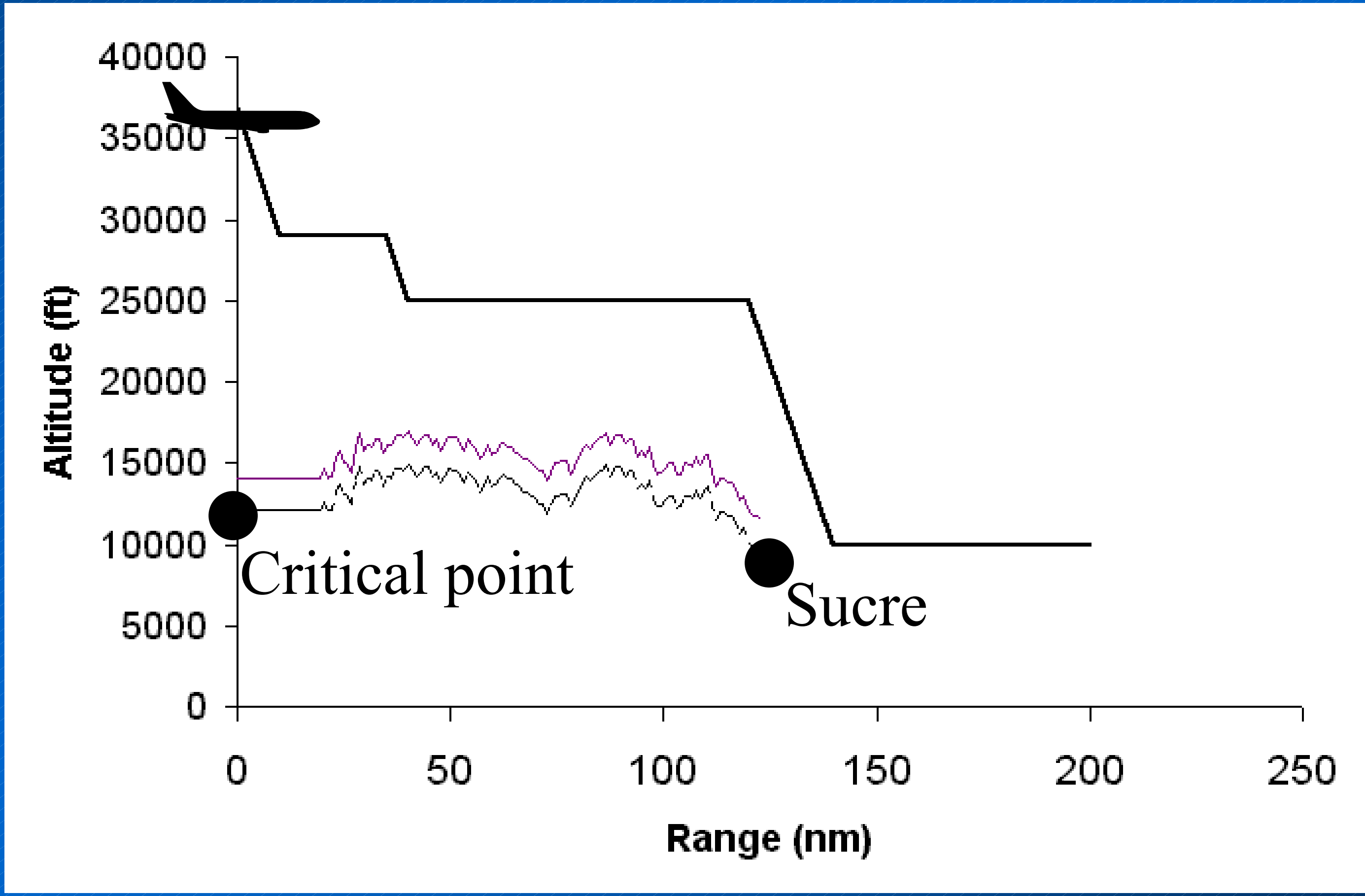


Diversion along track beyond critical point

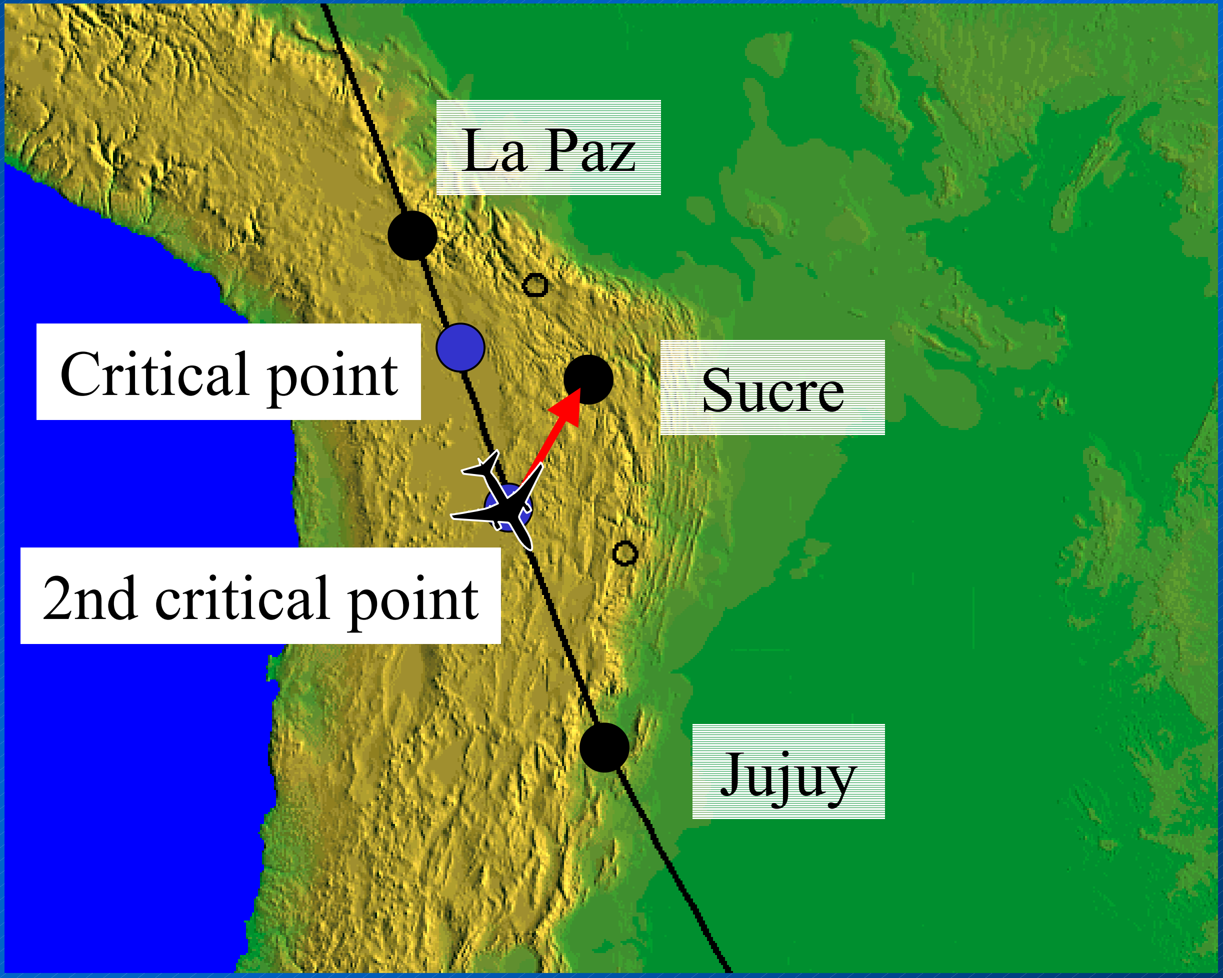


Off-route Alternates

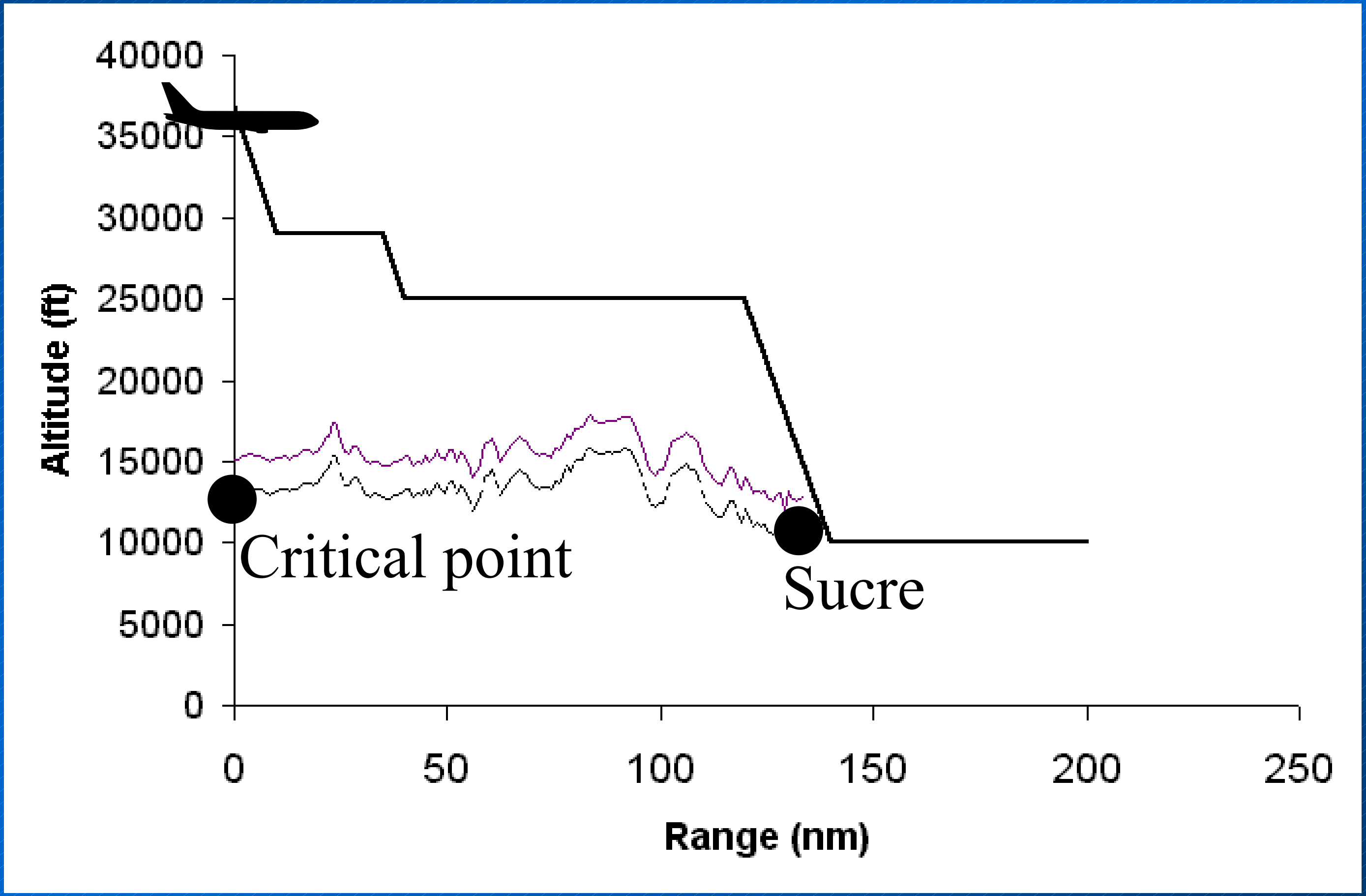
Off-route diversion from critical point to Sucre



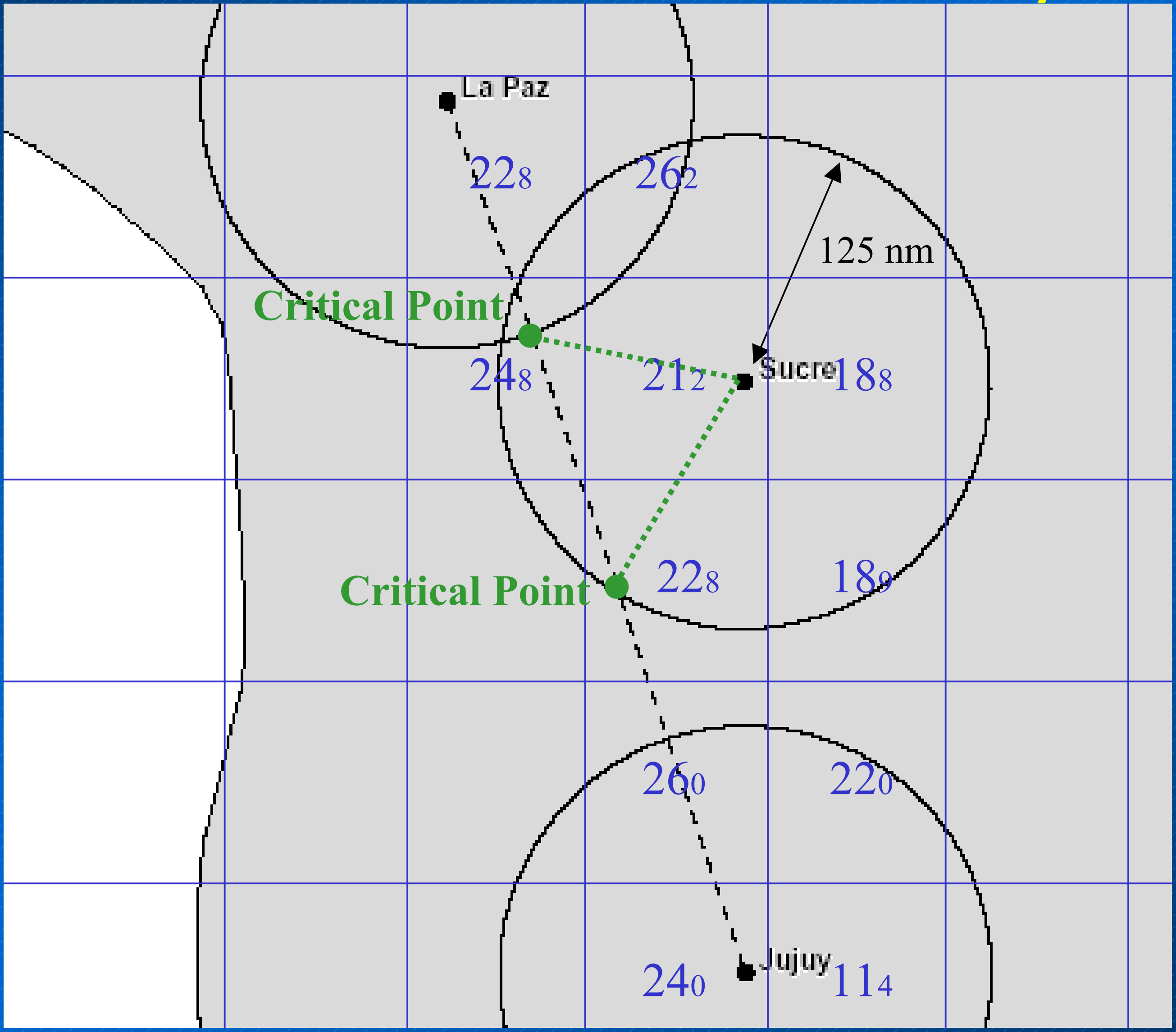
Off-route Alternates



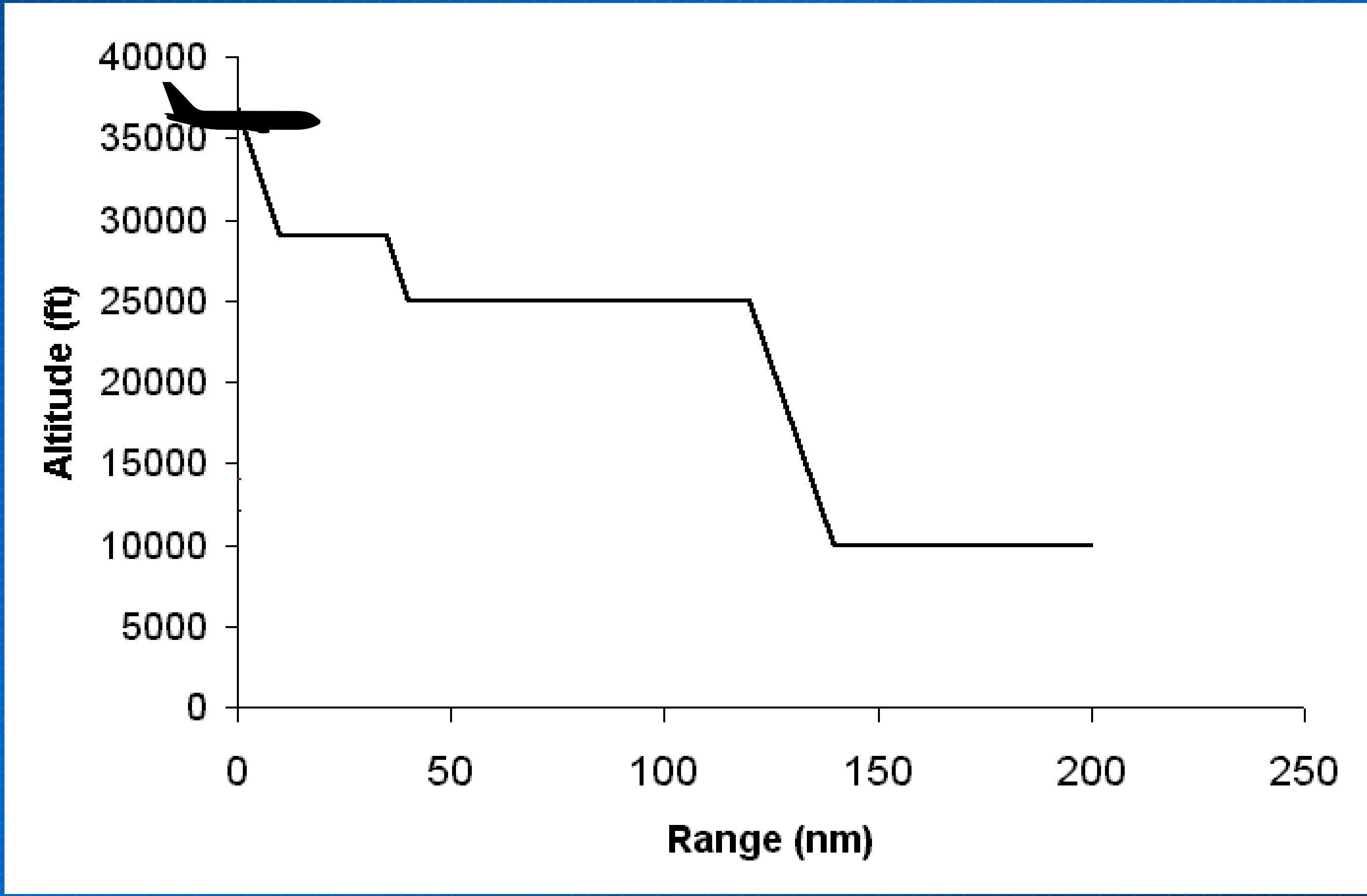
Off-route diversion from second critical point to Sucre



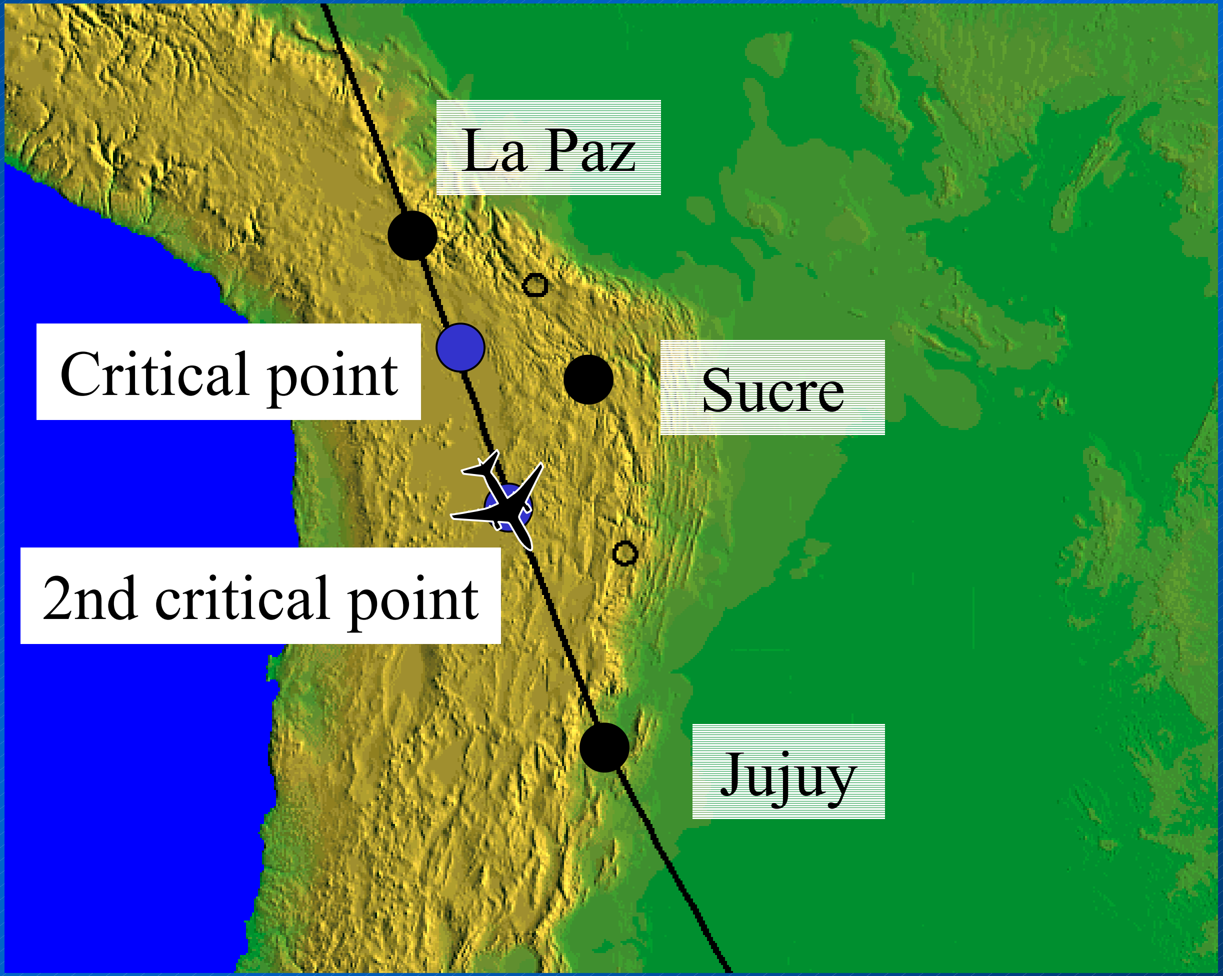
Off-track Alternate Availability Areas



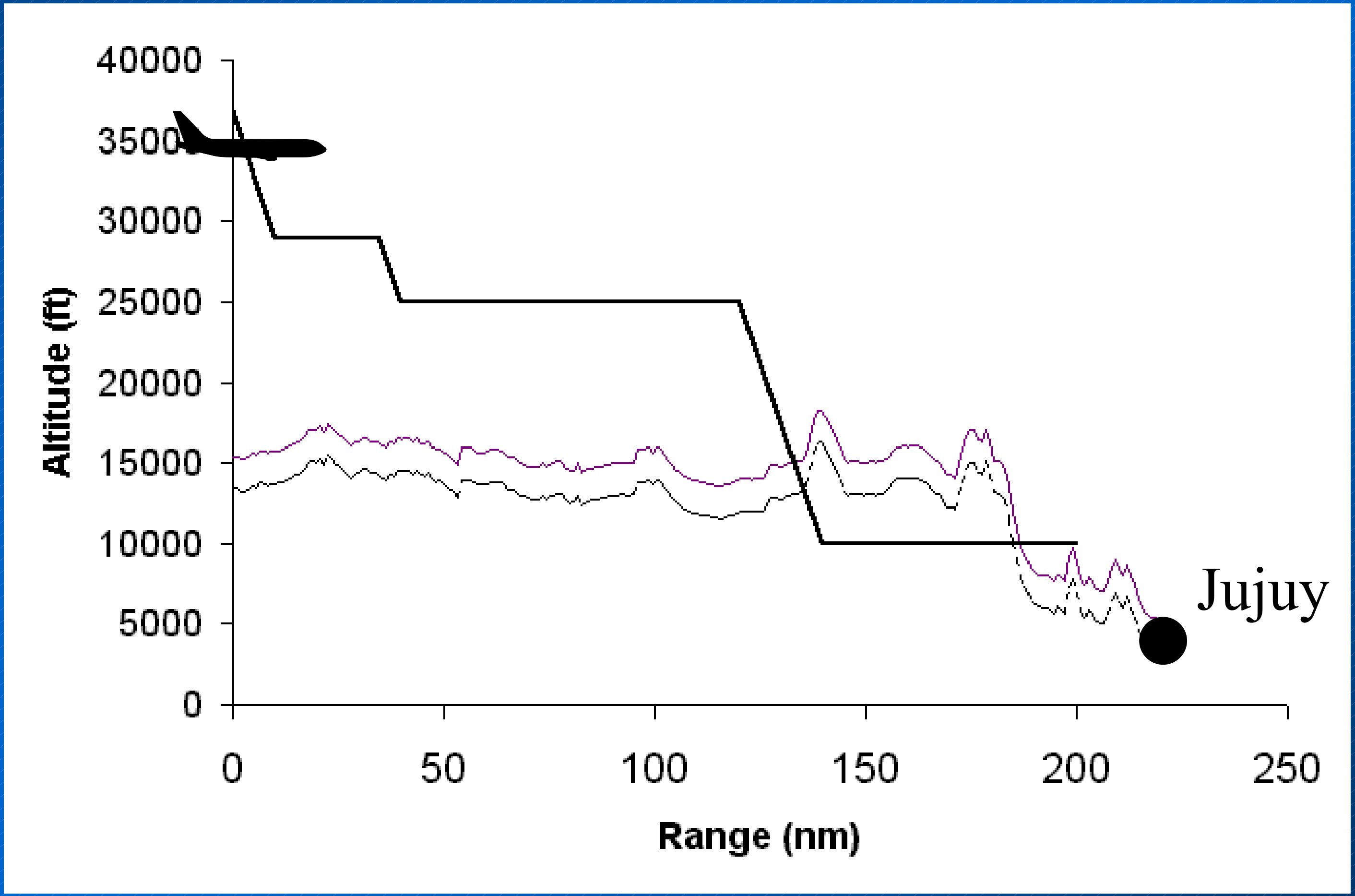
Generic Descent Profile for 22-minute System



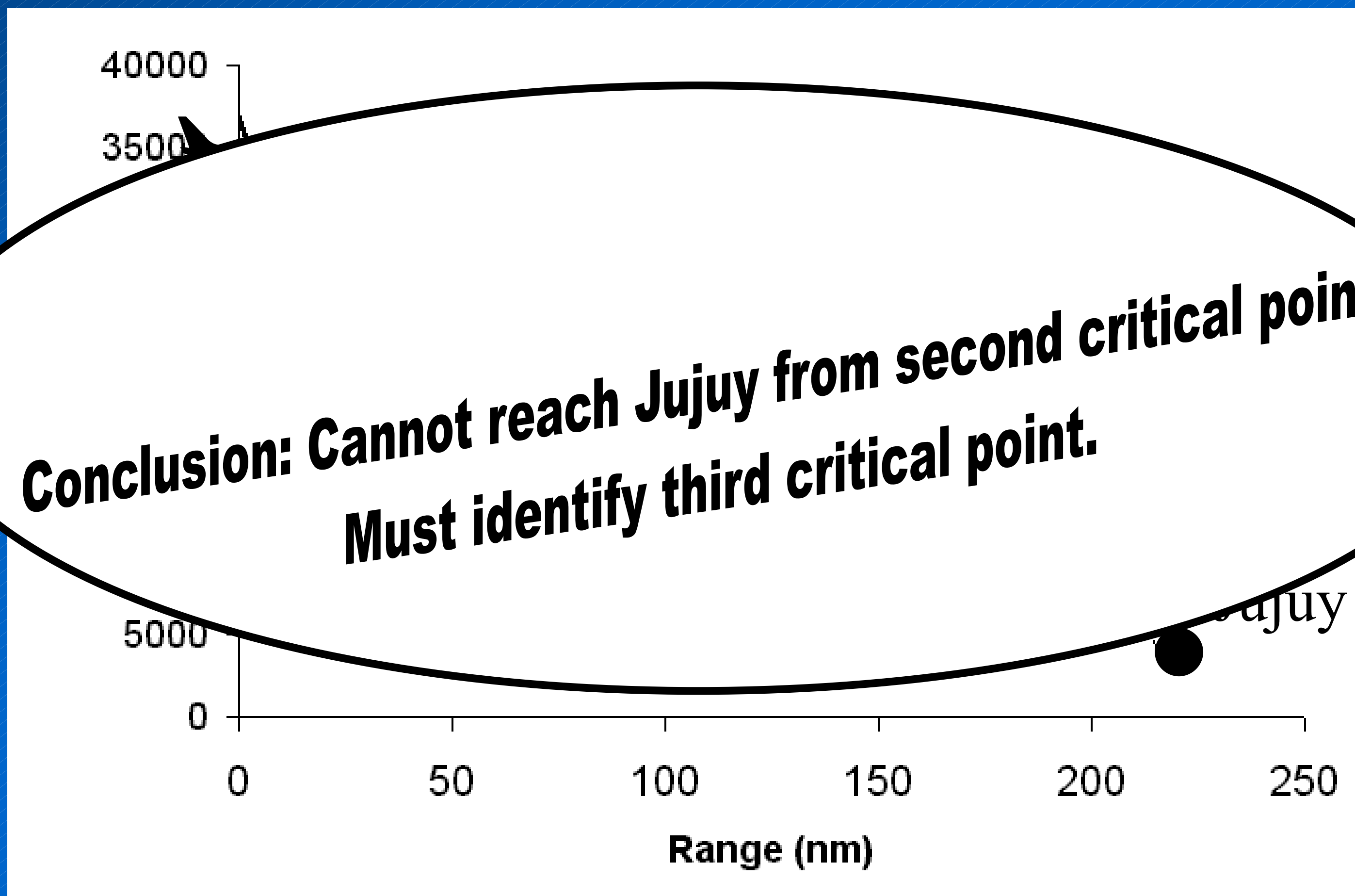
Off-route Alternates



On-track diversion from 2nd critical point to Jujuy

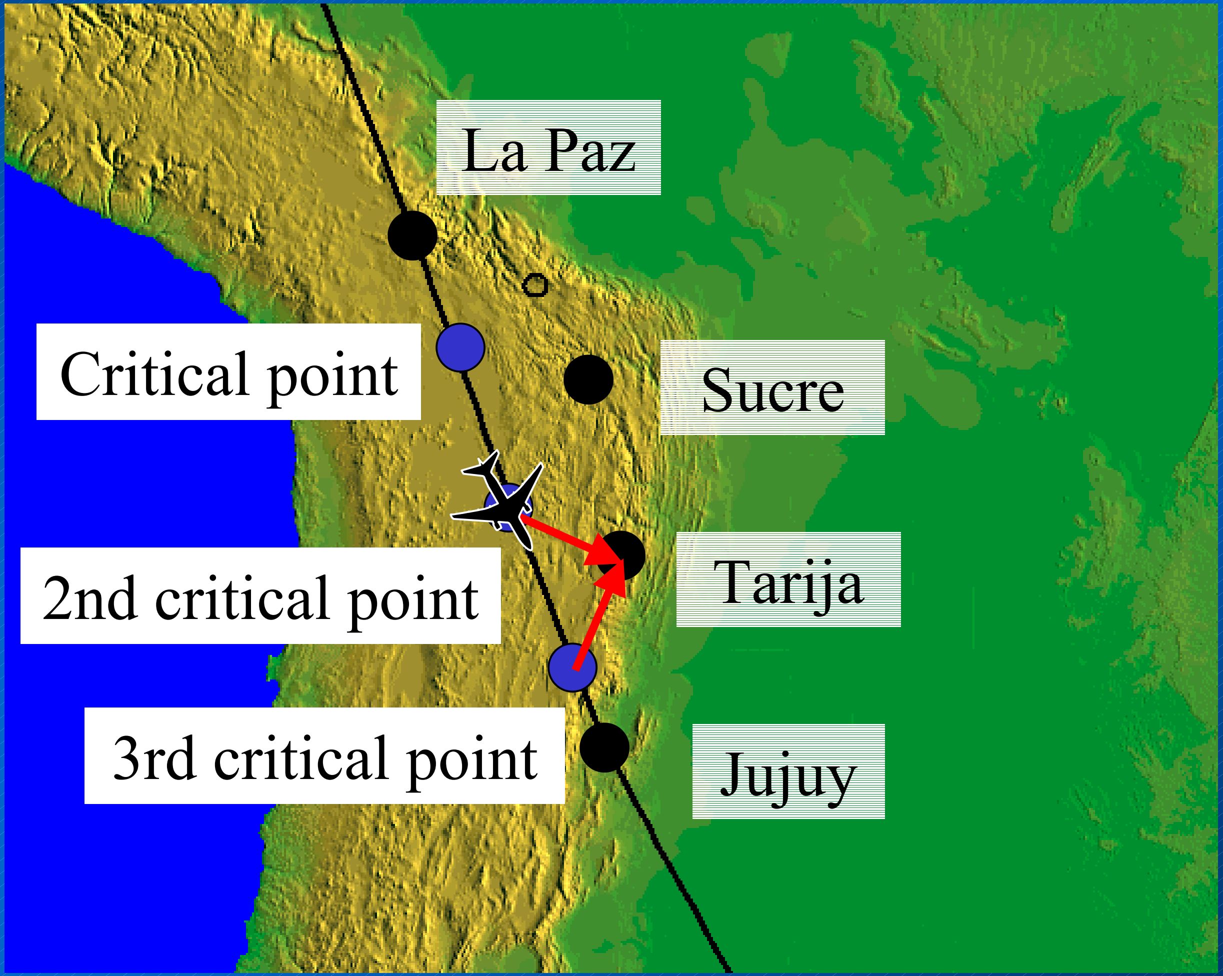


On-track diversion from 2nd critical point to Jujuy

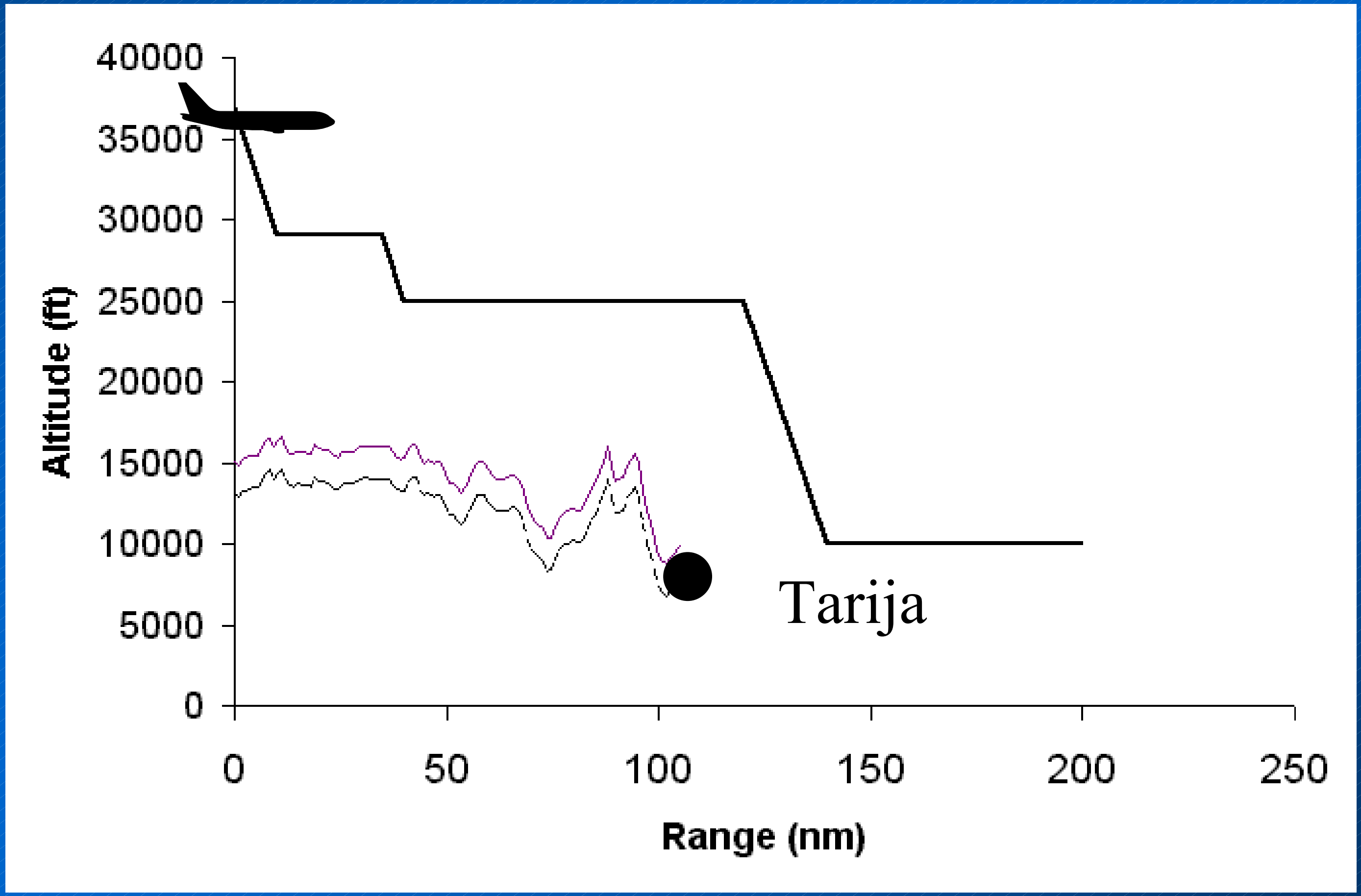


Conclusion: Cannot reach Jujuy from second critical point.
Must identify third critical point.

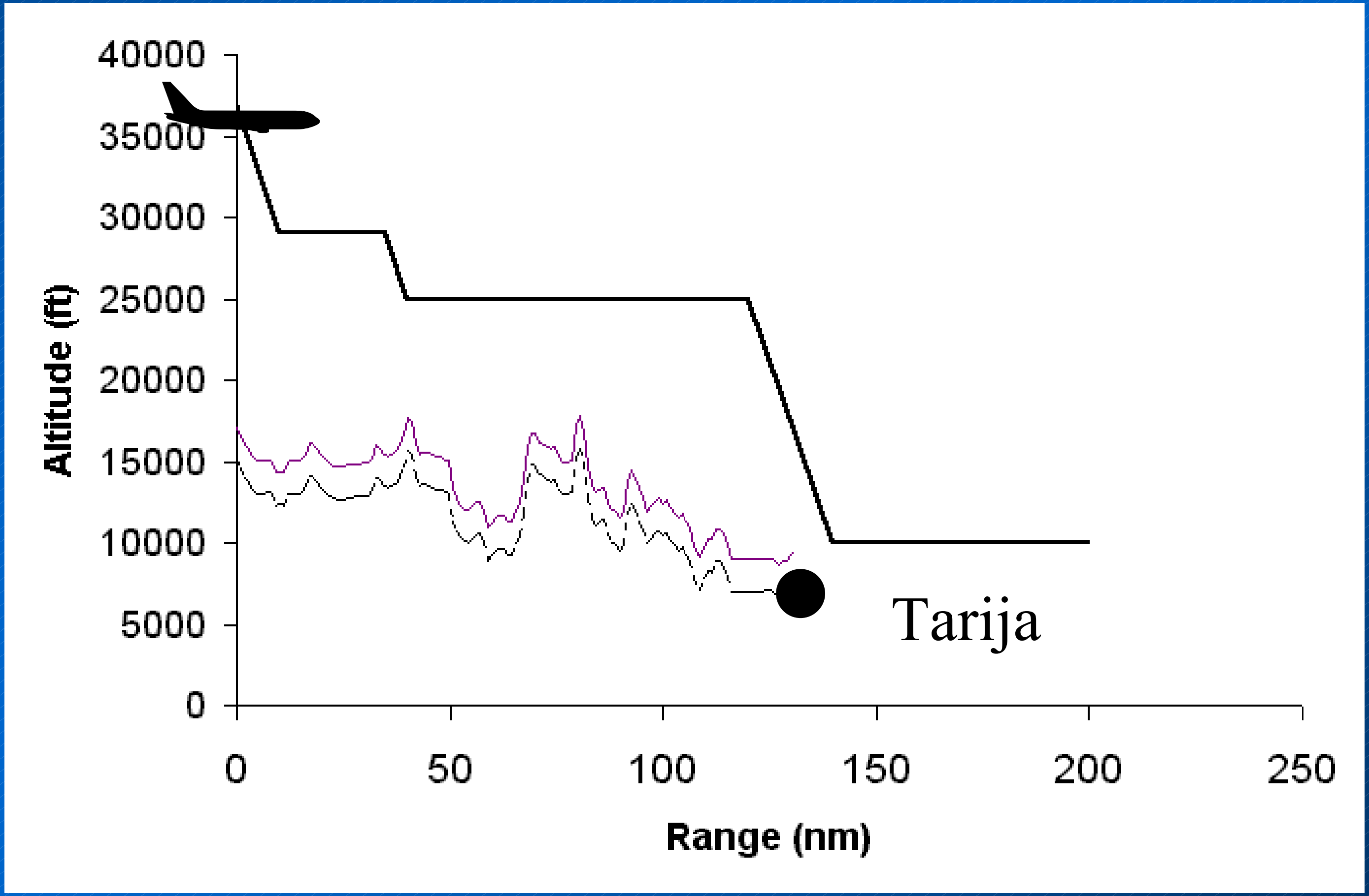
Off-route Alternates



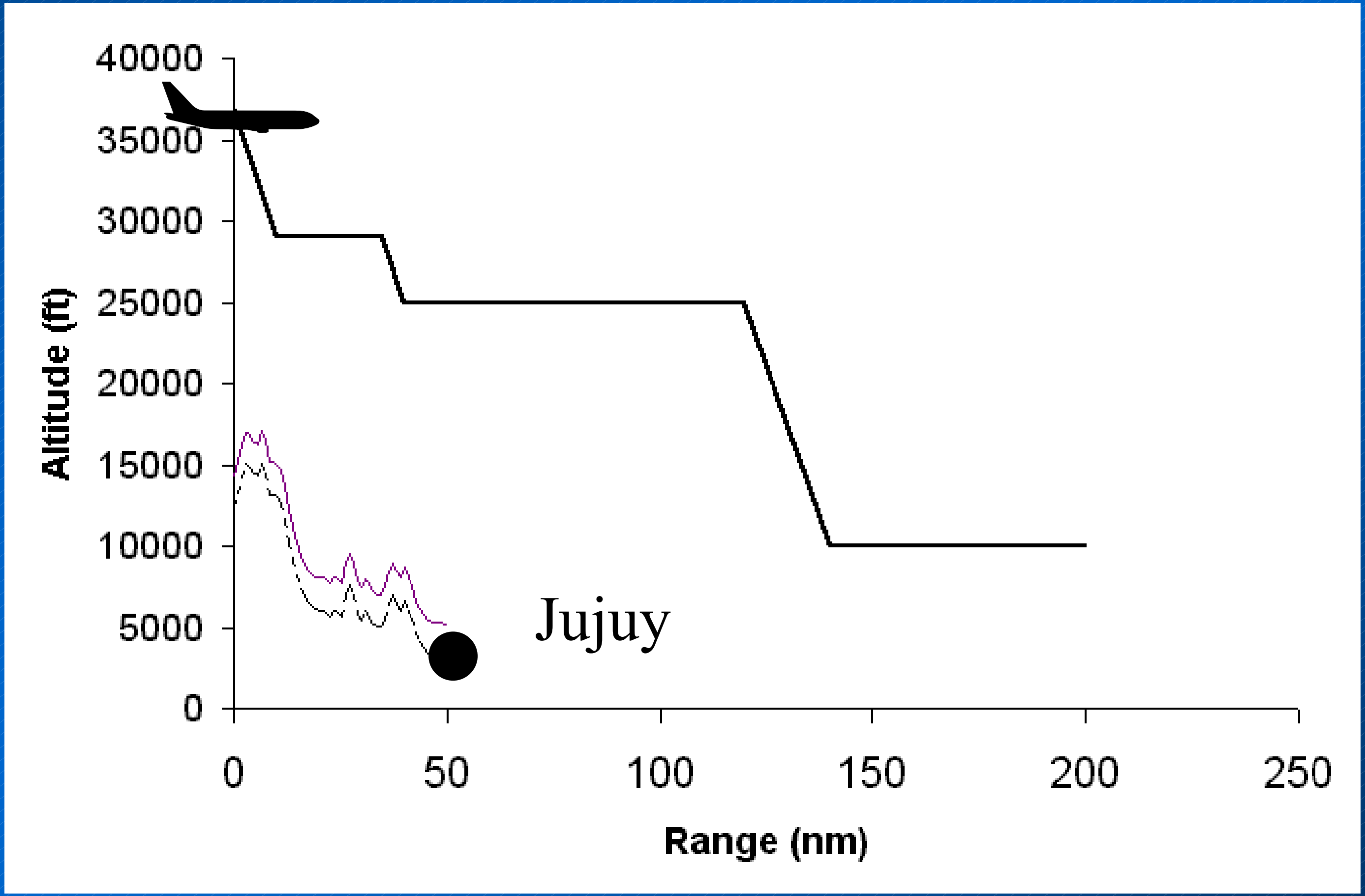
Off-route diversion from second critical point to Tarija



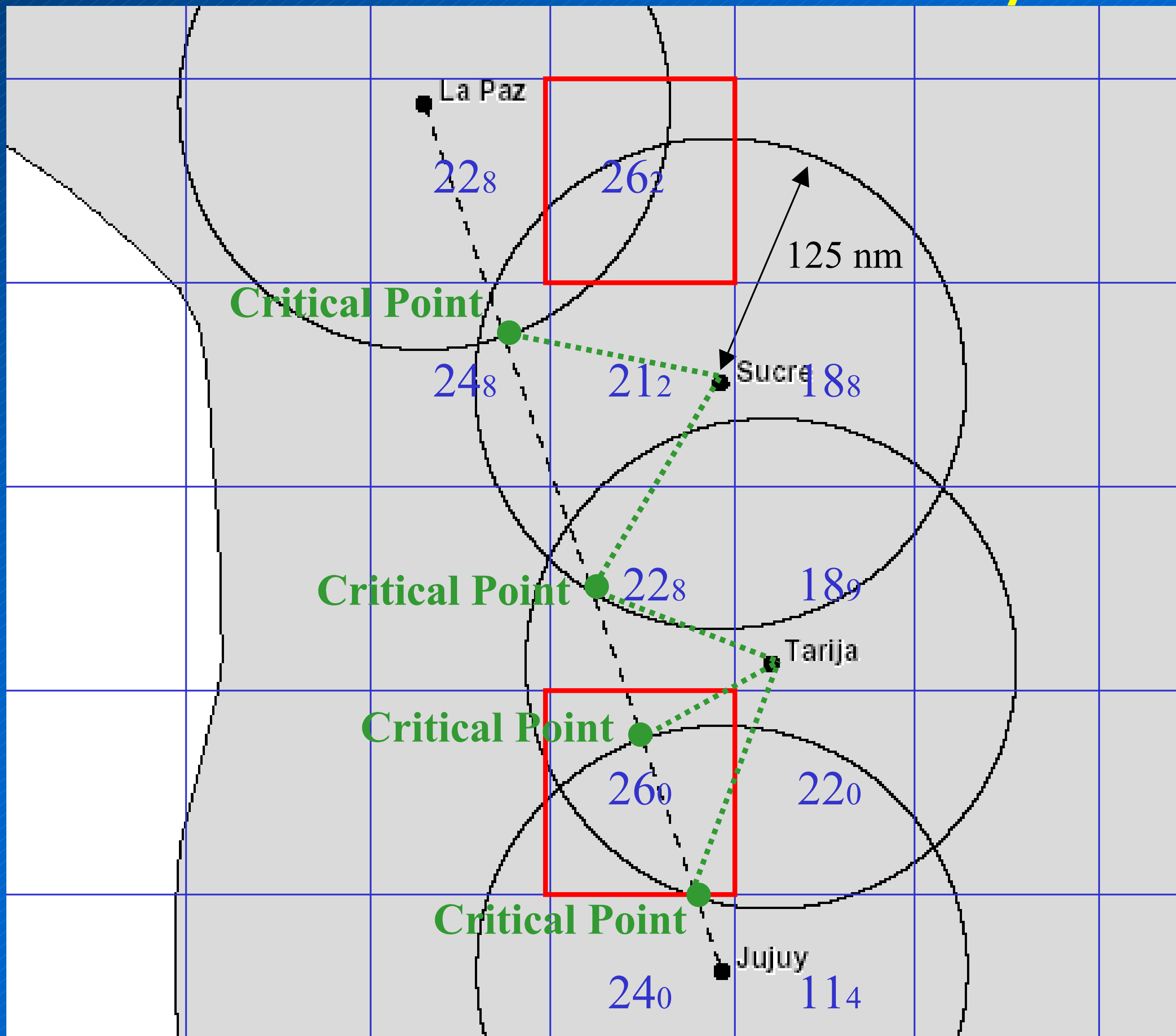
Off-route diversion from 3rd critical point to Tarija



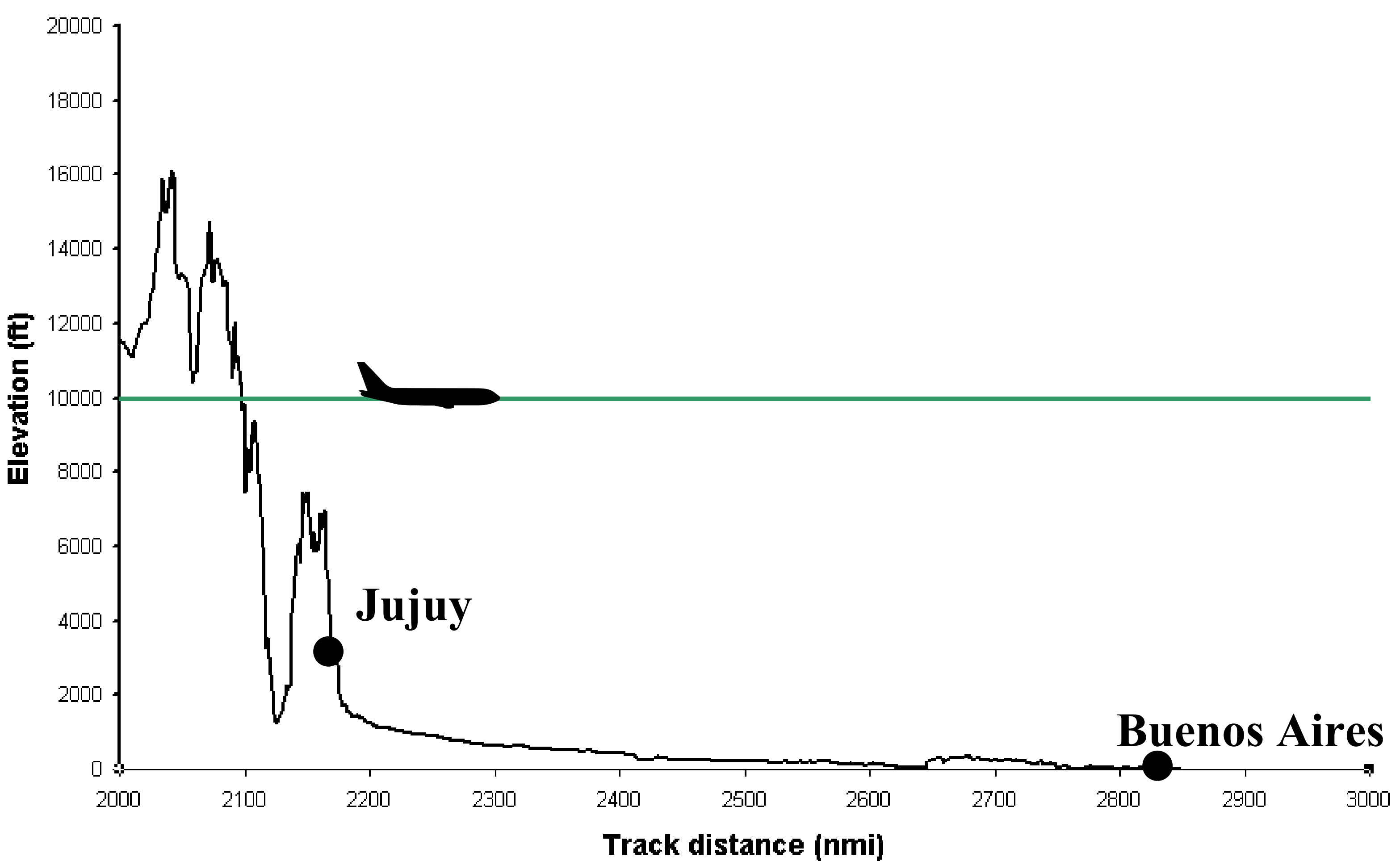
On-track diversion from 3rd critical point to Jujuy



Off-track Alternate Availability Areas



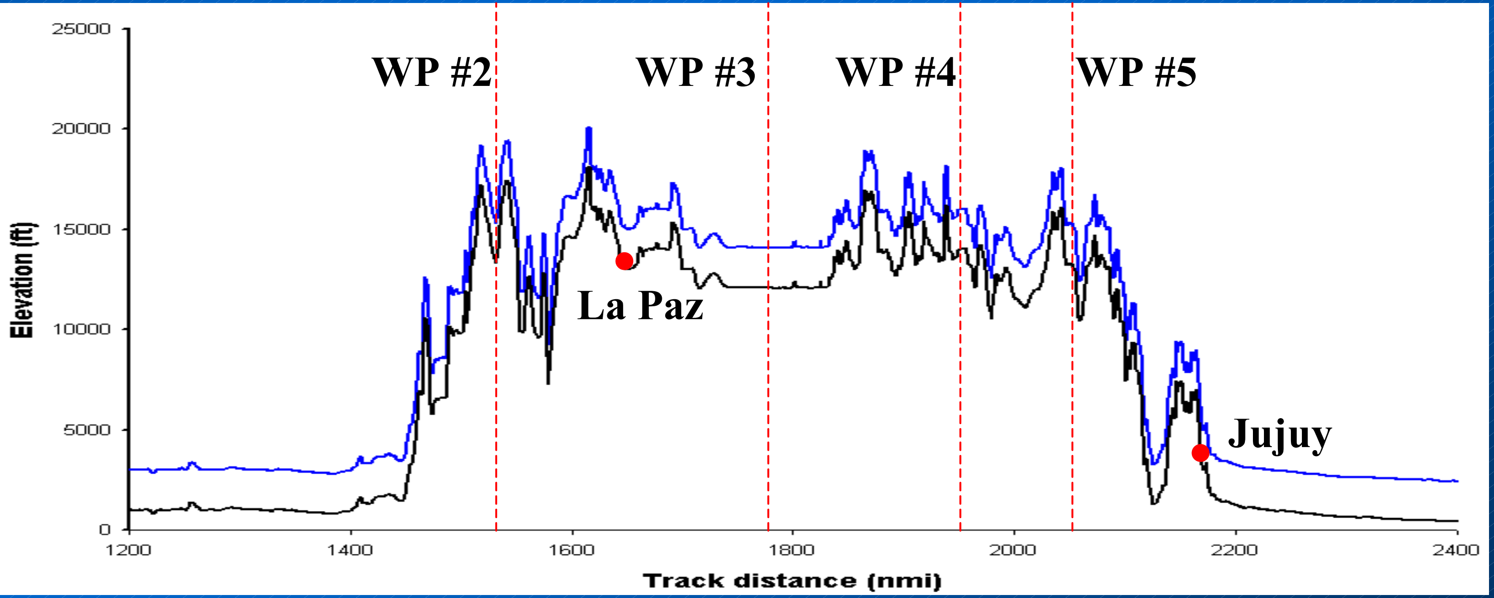
Terrain Height between Jujuy and Buenos Aires is not critical for oxygen analysis.



Procedures as part of the dispatch package

Example text of dispatch pilot procedures

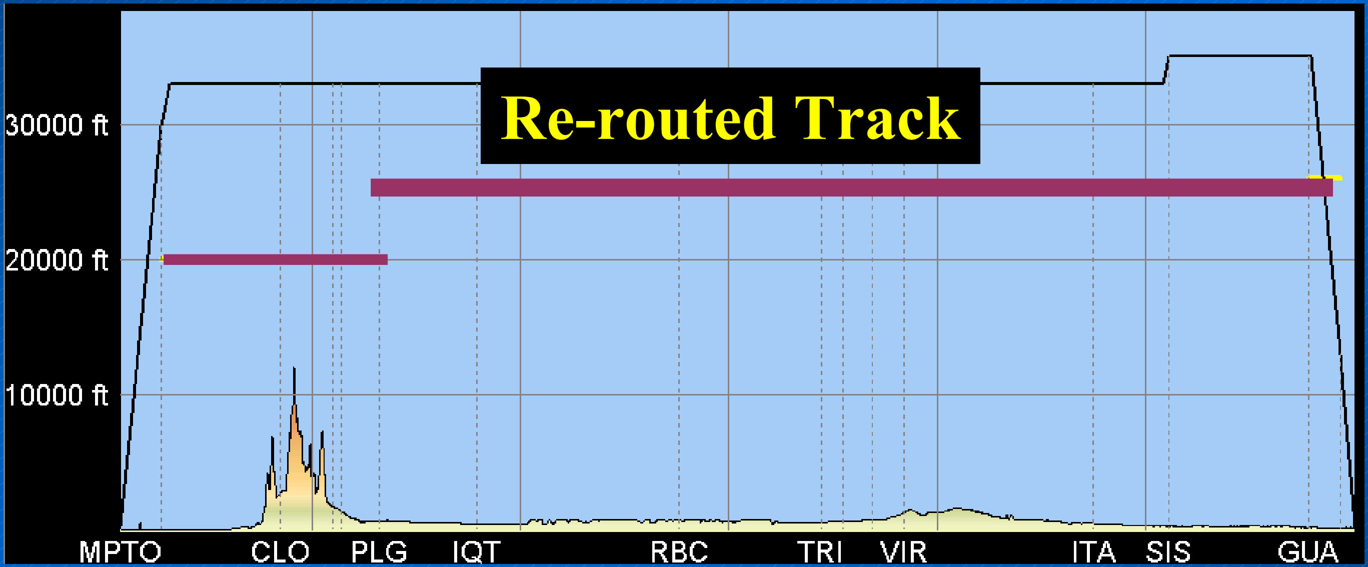
- Between Waypoint #2 (S14 28.64 W069 03.81) and Waypoint #3 (S18.30 W067 30.00), divert on-track to La Paz.
- Between Waypoint #3 (S18 30.00 W067 30.00) and Waypoint #4 (S20 30.00 W066 50.00), divert off-track to Sucre.
- Between Waypoint #4 (S20 30.00 W066 50.00) and Waypoint #5 (S22 30.00 W066 00.00), divert off-track to Tarija
- After Waypoint #5 (S22 30.00 W066 00.00), divert on-track to Jujuy



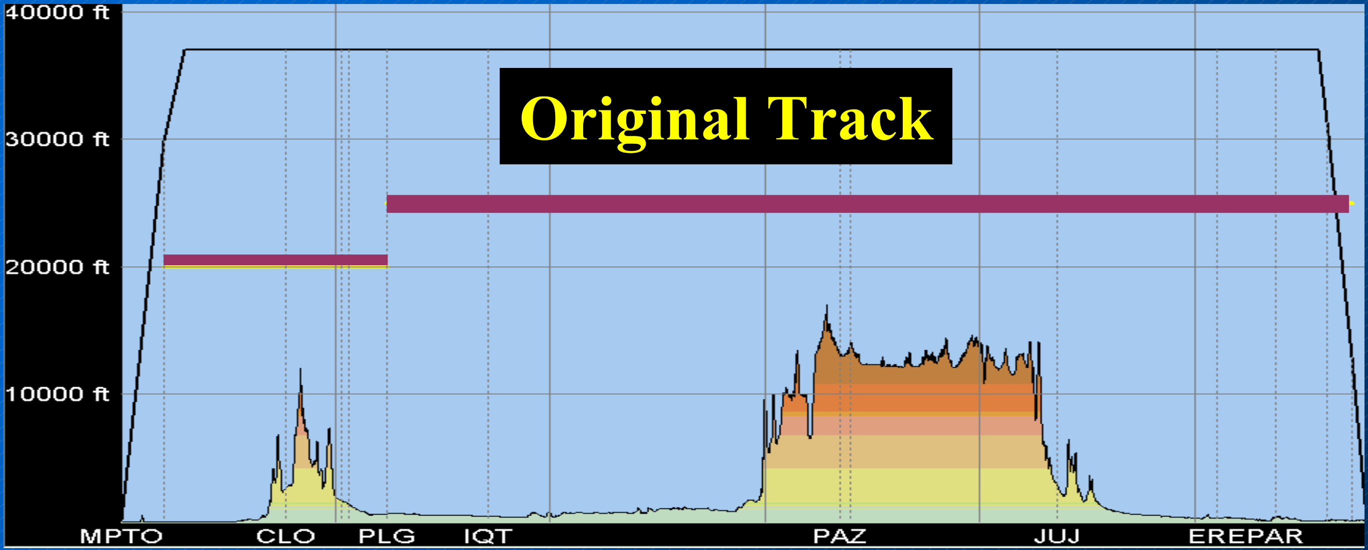
Modifying a Route to Avoid High Terrain

Operations in Mountainous Areas

Route distance = 2960 nm



Route distance = 2900 nm



Pros and Cons to Rerouting to Avoid Terrain

- \- Increased track distance (2%)
  - Increased Fuel (Potential loss of P/L?)
  - Crew duty time ?
  - Flight time
- \+ Requirement to verify suitable alternate airports at dispatch over high terrain with escape plans
- \+ Decreased complexity of crew work load in normal flight plan
- \+ If event occurs, less complicated diversion workload for flight crew
- +/- Weather ?

Operational Considerations for Oxygen Analysis???

Operation in Mountainous Areas

- Terrain clearance requirements satisfied ✓
- Oxygen requirements satisfied ✓
- Dispatch package includes special procedures or information ✓