Assignment 5: Flight Planning, ETOPS, and BADA Calculations

Due: March 17, 2023 Instructor: Trani

Problem 1

A pilots files a flight plan with the following route information.

LAX DINTY DUETS DADIE DIALO DUSAC DENNS OGG
Cruise speed 440 knots
Cruise altitude FL 360

a) State the origin and the destination airports (by name).
b) Use Skyvector to plot the route in a map and tell me the route (or airway) flown. Make a screen capture of the route and include in your solution

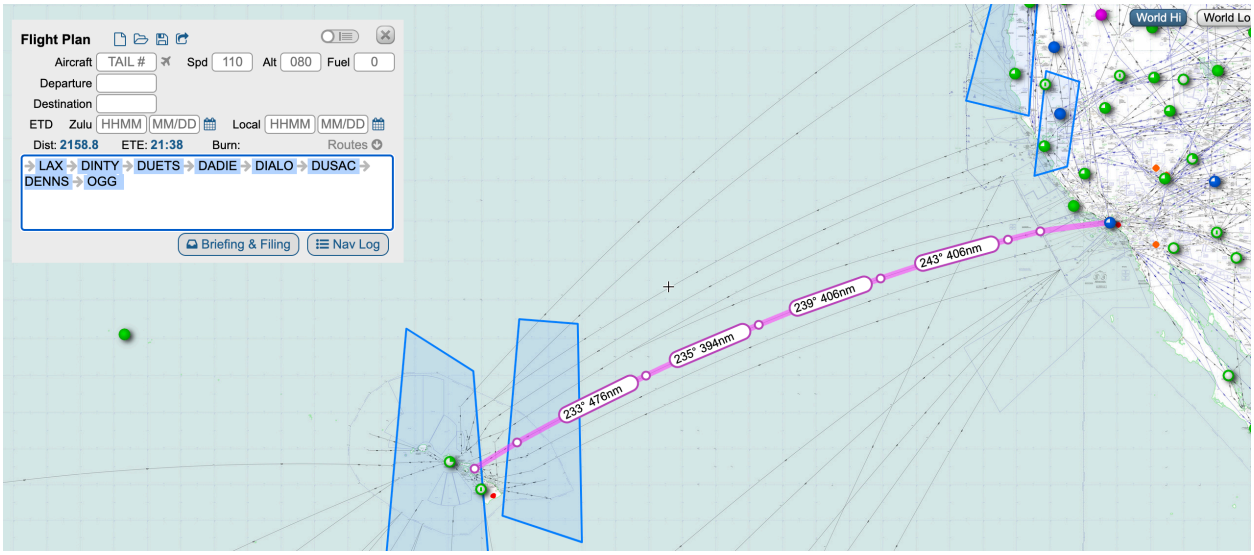

Figure 1. Flight Plan from LAX to OGG in Skyvector.

c) Use the Skyvector route and distance information to estimate if a twin-engine aircraft certified for ETOPS 138 minutes can fly the route legally. Assume no wind conditions and the single-engine aircraft speed is 385 knots.

The aircraft cannot fly the route with a 138-minute ETOP certification. Figure 2 shows the 138-minute envelope.

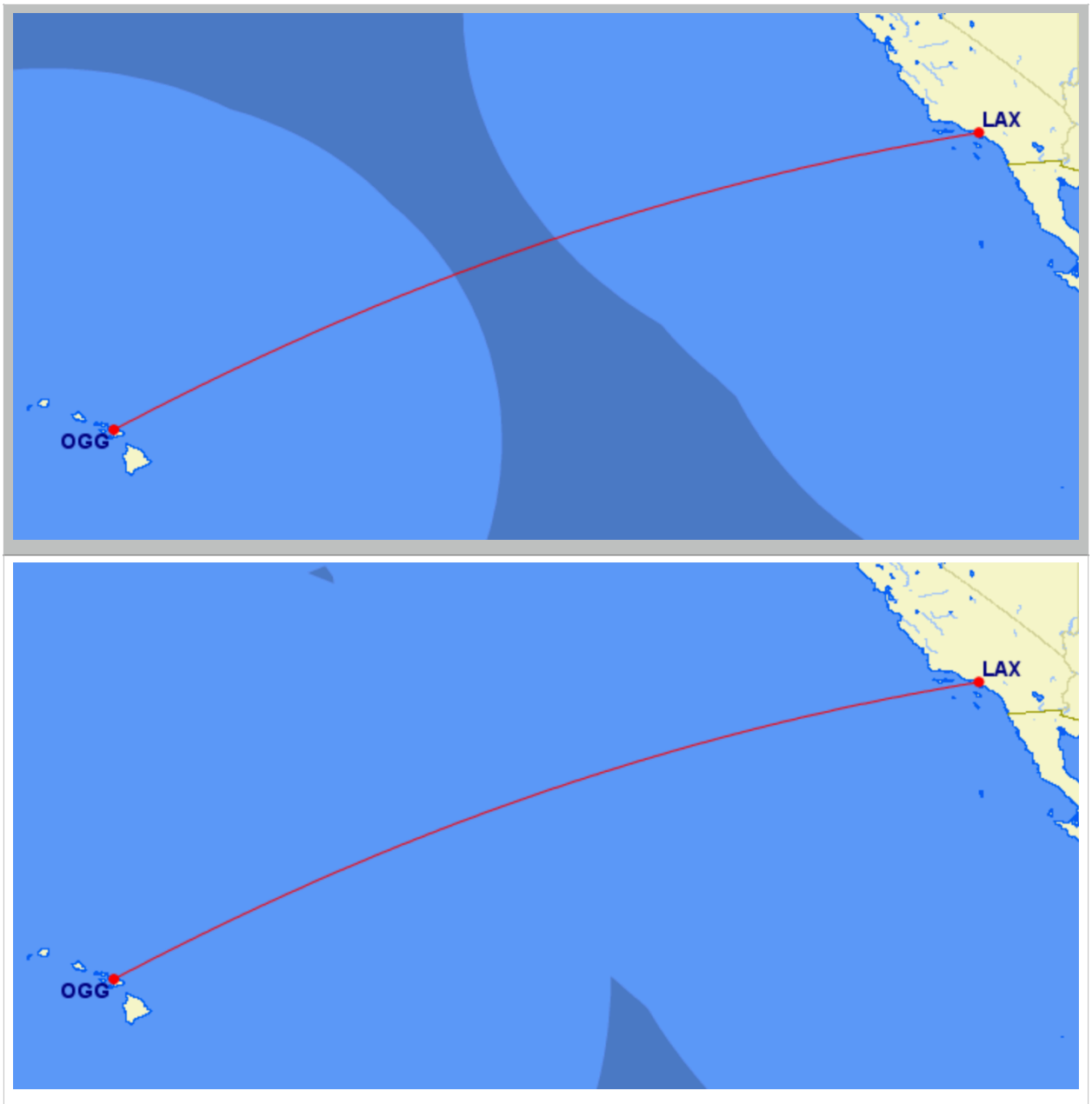

Figure 2. 138 and 180 Minute ETOPS Contours with 385 knot Single Engine Speed.

d) What is the minimum ETOPS certification (in minutes) criteria to fly the route.
The aircraft needs an ETOPS certification of 180 minutes in order to fly this route.

Problem 2

Refer to pages 160-163 in the Aircraft Performance Notes 2 (section describing the BADA Model) to answer the questions.

a) Find the fuel burn (in kilograms per minute) for the Boeing 747-8 according to the BADA model while the aircraft enters a holding pattern (a racetrack to hold at a fix) at FL 310 and flying at a true airspeed of 493 knots. The aircraft has a mass of 366,330 kilograms. The aircraft is in the cruise configuration.

Use the procedure described in class with the following BADA coefficients.

```
CC====== Actype ============================================================/
CD   B748__          4 engines    Jet                          H            /
CC  B747-8F with GENX-2B67 engines                           wake           /
CC                                                                          /
CC====== Mass (t) ==========================================================/
CC    reference      minimum      maximum     max payload  mass grad  /
CD     .36633E+03   .19105E+03   .44225E+03   .13390E+03   .62663E-01 /
CC====== Flight envelope ===================================================/
CC     VMO(KCAS)       MMO        Max.Alt       Hmax       temp grad  /
CD     .36500E+03   .90000E+00   .42100E+05   .32973E+05   -.1492E+03 /
CC====== Aerodynamics ======================================================/
CC Wing Area and Buffet coefficients (SIM)                                  /
CCndrst Surf(m2)     Clbo(M=0)       k          CM16                        /
CD 5   .51097E+03   .10815E+01   .30373E+00   .00000E+00                    /
CC   Configuration characteristics                                          /
CC n Phase  Name    Vstall(KCAS)    CD0          CD2         unused     /
CD 1 CR   CLEAN     .18400E+03   .25669E-01   .39082E-01   .00000E+00 /
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```
CC====== Engine Thrust =====================================================,
CC         Max climb thrust coefficients (SIM)                              ,
CD     .75979E+06   .52423E+05   .40968E-10   .10356E+02   .77315E-02 ,
CC     Desc(low)    Desc(high)   Desc level   Desc(app)     Desc(ld)  ,
CD     .11581E+00   -.2525E-01   .38370E+05   .24054E+00   .39605E+00 ,
CC     Desc CAS     Desc Mach     unused       unused       unused    ,
CD     .33500E+03   .86000E+00   .00000E+00   .00000E+00   .00000E+00 ,
CC====== Fuel Consumption ==================================================,
CC   Thrust Specific Fuel Consumption Coefficients                          ,
CD     .58259E+00   .12839E+04                                              ,
CC   Descent Fuel Flow Coefficients                                         ,
CD     .45380E+02   .72929E+05                                              ,
CC   Cruise Corr.    unused       unused       unused       unused    ,
CD     .89625E+00   .00000E+00   .00000E+00   .00000E+00   .00000E+00 ,
CC====== Ground ============================================================,
CC         TOL          LDL         span         length       unused    ,
CD     .32300E+04   .23770E+04   .68400E+02   .76250E+02   .00000E+00 ,
CC=========================================================================,
```

Figure 3. Coefficients for Boeing 747-8. Source: Eurocontrol.

184.8 kilograms/minute

b) Verify your answer against the value reported in table on page 163 for the Boeing 747-8.

184.8 kilograms/minute

c) Find the indicated airspeed when the aircraft holds at 493 knots at FL 310.

The indicated airspeed is 352 knots. TAS is 493 and the Mach number is 0.84.

Problem 3

Use the new generation Transonic Truss-Braced Wing (TTBA) aircraft provided in class (http://128.173.204.63/courses/cee5614/cee5614_pub/SUGAR_class.m) to answer the questions.

The TTBA flies the same route as in Problem 1. At waypoint DIALO the aircraft has a pressurization failure (cabin pressure is lost) and the pilot starts an emergency descent from FL 360 to FL100 (the highest flight level for passengers to breathe normally). At DIALO, the TTBA has a mass of 64,000 kilograms and 8000 kilograms of fuel left.

a) Find the fuel used to the destination airport from the point of pressurization failure. The speed at FL100 to the destination airport is 275 knots indicated. Include the fuel used in descent from FL360 to FL 100 and from FL100 to the destination airport.

Descent from FL 360 to FL 100
Distance to reach 10,000 feet = 113.4 nautical miles
Time reach 10,000 feet = 1338.37 seconds
Fuel to reach 10,000 feet = 138.6 kg

Descent from FL 100 to sea level
Distance to reach sea level = 58.5 nautical miles
Time to reach sea level = 913.9 seconds
Fuel to reach sea level = 190.0 kg

Total distance traveled in the two descent profiles is 171.9 NM. The distance from DIALO and OGG is 1037 nm (uncorrected). That leaves 865.1 nm for the cruise segment (917 nm corrected). The descent phases from FL360 to FL 100 and then to sea level take 0.63 hours.

The fuel burn for the flight at 10,000 feet is:

Cruise Mach Number (dim) 0.48
Cruise Distance (nm) 865.1
Cruise Fuel (kg) 5,837.8
Cruise Time (minutes) 169.4
Cruise Time (hrs) 2.8
Initial Mass (kg) 63,861
Final Mass (kg) 58,023

Considering the 6% detour factor. The following results are obtained.

Cruise Mach Number (dim) 0.48

Cruise Distance (nm) 917

Cruise Fuel (kg) 6185.6

Cruise Time (minutes) 179.5553

Cruise Time (hrs) 2.99

Initial Mass (kg) 63,861

Final Mass (kg) 57,675.4

Phase	Time (hrs)	Distance (nm)	Fuel (kgs)
Descent FL 360 to FL 100	0.372	113.7	138.6
Cruise at FL 100	2.99	917	6185.6
Descent from FL 100 to sea level	0.254	58.5	190
Total	**3.616**	1089.2	**6514.2**

Figure 4. Flight Parameters from Pressurization to OGG Cruising at Mach 0.480.

Phase	Time (hrs)	Distance (nm)	Fuel (kgs)
Descent FL 360 to FL 100	0.372	113.7	138.6
Cruise at FL 100	2.74	917	6612
Descent from FL 100 to sea level	0.254	58.5	190
Total	**3.366**	1089.2	6940.6

Figure 5. Flight Parameters from Pressurization Failure OGG Cruising at Mach 0.524 (330 Knots Indicated) .

Phase	Time (hrs)	Distance (nm)	Fuel (kgs)
Descent FL 360 to FL 100	0.372	113.7	138.6
Cruise at FL 100	2.32	917	7630
Descent from FL 100 to sea level	0.254	58.5	190
Total	**2.946**	1089.2	7958.6

Figure 6. Flight Parameters from Pressurization Failure to OGG Cruising at Mach 0.60.

Conclusions:

1. At an indicated airspeed of 275 knots, the aircraft cannot fly to OGG within the 180 minute ETOPS rule. The aircraft takes 3.62 hours.
2. The aircraft has enough fuel to do the trip to OGG at 275 knots indicated. However, the certification criteria needs to be increased to 210 or 220 minutes at single engine speed.
3. At Mach 0.6, the aircraft makes it to OGG airport.However, The fuel used is 7,958 kilograms. Too close to the maximum of 8,000 kilograms.

b) Does the aircraft has enough fuel to reach the destination airport?

Yes it does. However, at Mach 0.6, the fuel left is not enough to make the flight to an alternate. The flight would be illegal. Most likely two possible solutions are required in this problem: 1) Certify the aircraft under ETOPS 210 minutes allowing the pressurization flown at Mach 0.524 or 2) increase the fuel carried with costly modifications to the original design (at the expense of payload carried).

Problem 4

Use the new generation Transonic Truss-Braced Wing (TTBA) aircraft provided in class (http://128.173.204.63/courses/cee5614/cee5614_pub/SUGAR_class.m) to answer the questions.

The TTBA flies the same route as in Problem 1. At waypoint DIALO the aircraft has an engine failure. At DIALO, the TTBA has a mass of 64,000 kilograms and 8000 kilograms of fuel left.

a) Estimate the best true airspeed and Mach number to reach the destination at the best single-engine speed. Explain your speed and single-engine selection procedure. Avoid speeds that are on the back side of the drag curve.

Figures 7-10 show the drag and thrust characteristics the TTBA after the engine failure. Since the diversion is over water, the selection of cruise altitudes is not constrained by a minimum altitude to clear obstacles or terrain.

Cruise altitudes of FL220 and FL 200 are practical as they offer better margins between thrust and drag at Mach numbers ranging from 0.5 to 0.53. I would use FL 220 in the next steps of the solution.

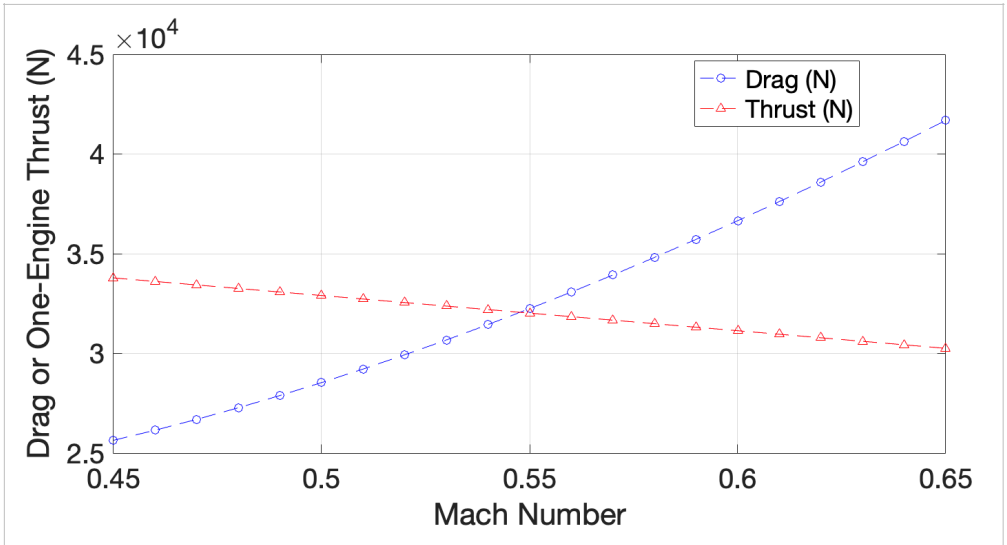

Figure 7. TTBA Aircraft Performance at FL 260.

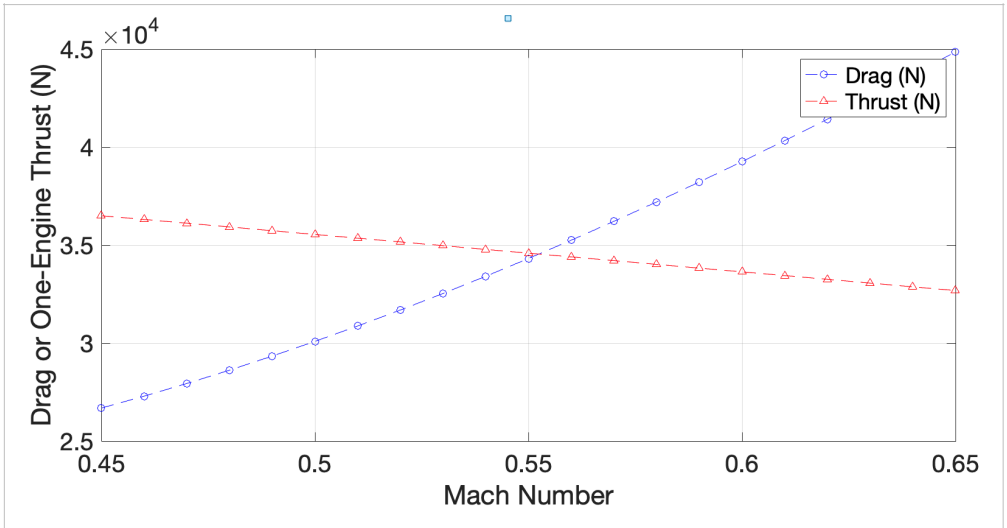

Figure 8. TTBA Aircraft Performance at FL 240.

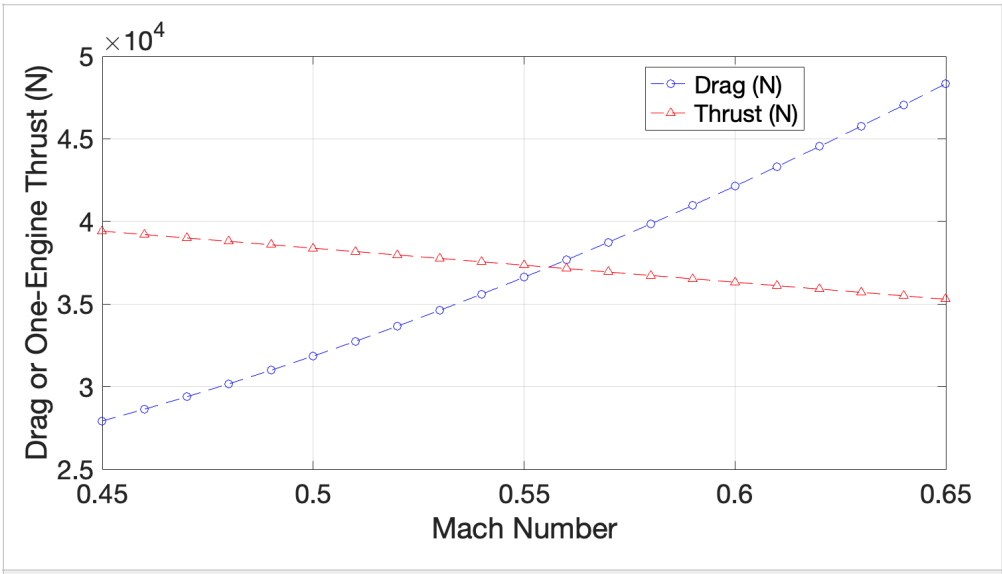

Figure 9. TTBA Aircraft Performance at FL 220.

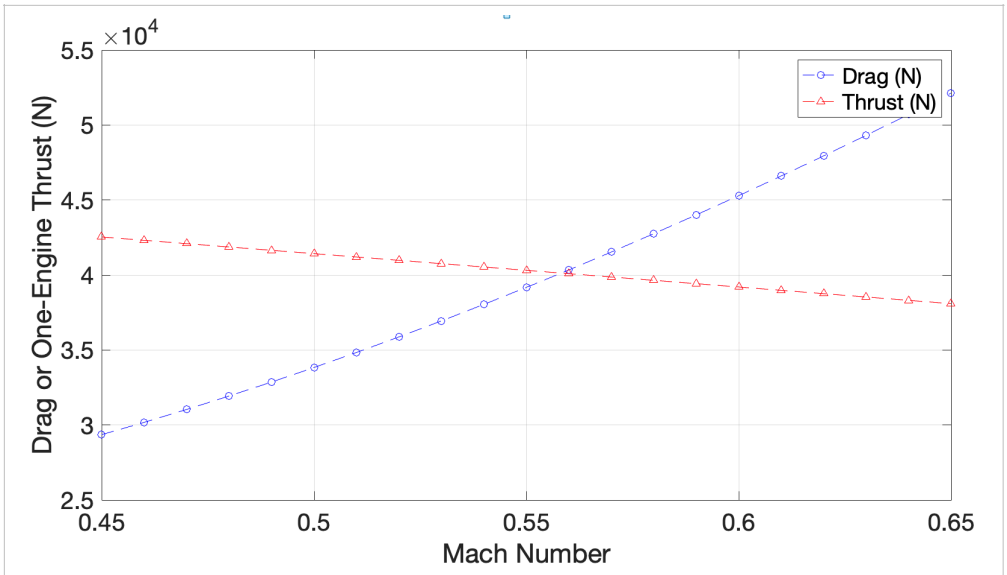

Figure 10. TTBA Aircraft Performance at FL 200.

b) Find the fuel used to the destination airport from the point of engine failure.

Phase	Time (hrs)	Distance (nm)	Fuel (kgs)
Descent FL 360 to FL 220	0.19	62	53
Cruise at FL 220	2.90	920	4619
Descent from FL 220 to sea level	0.43	108	272
Total	**3.52**	1090	4944

Figure 11. Flight Parameters from Point of Engine Failure to OGG Cruising at Mach 0.52.

c) If the TTBA aircraft is certified for ETOPS 180 minutes, can the route be flown legally. Explain.

The aircraft will take 3.52 hours to get to OGG. The aircraft cannot legally complete the diversion under ETOPS 180. Possible remedial actions: 1) increase the cruise speed or 2) test the aircraft and certify for ETOPS 210 minutes. Note that increasing the cruise speed to Mach 0.53 and improving the certification to ETOPS 210, the aircraft could fly the route legally.

d) If another TTBA aircraft flies over high terrain near the Cho Oyu (see article in https://en.wikipedia.org/wiki/Cho_Oyu) as the engine fails, what actions would the pilot have to take to avoid an accident?

Figure 12 shows the terrain around Cho You (8,190 meters above sea level - 26,860 feet). Careful flight planning will require that any twin-engine aircraft operations fly to the North of Cho You because there are more “escape” routes on the North (to Tibet) than to the South. Figure 12 illustrate one escape route towards Tang Gaxia at 4,200 meters (13,800 feet). Pilot flying such routes need to be aware of the retain at all times and have emergency descent plans for any portion of the flight.

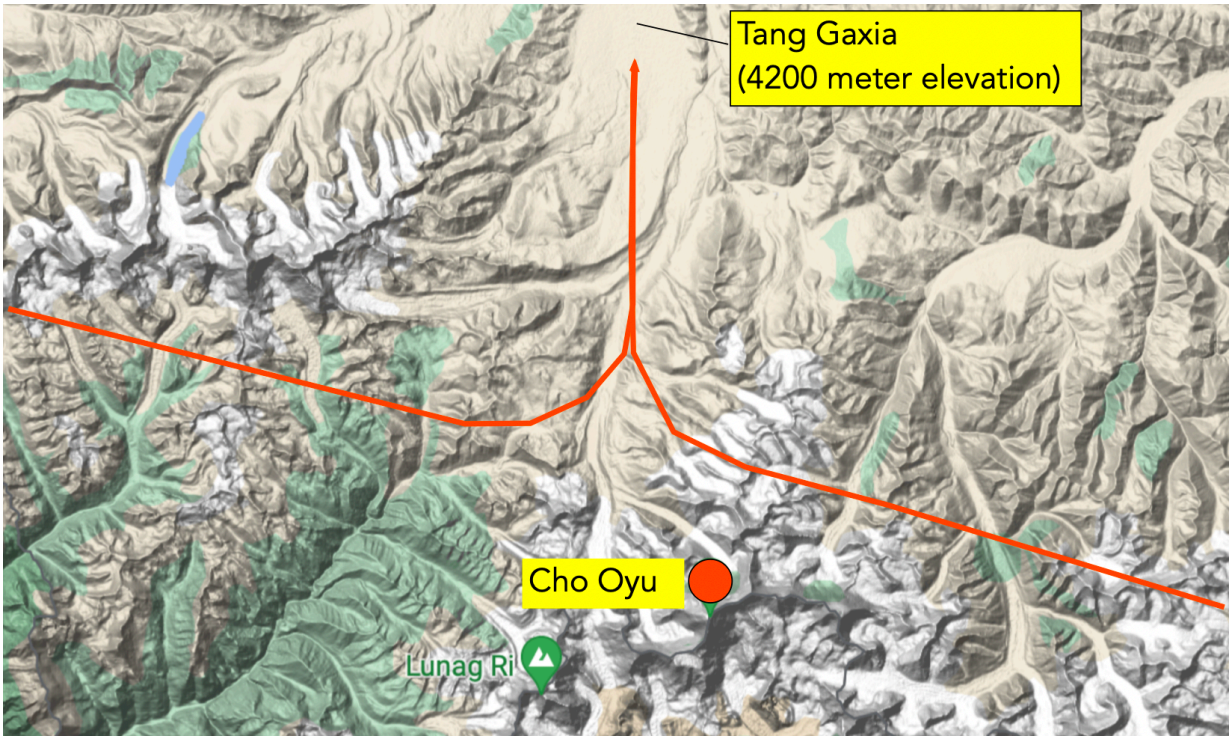

Figure 12. Notional Flights Over Cho Oyu.