A SIMULATED FLIGHT OF MALAYSIAN AIRLINES FLIGHT MH-370 Flight #2

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DRAFT
July 23, 2014

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Background.

This effort and report is a result of participation in crowdsourcing activities in an effort to find Malaysian Airlines flight MH-370 (9M-MRO) which departed from Kuala Lumpur International Airport on March 8, 2014 at 16:41 UTC bound for Beijing, China. MH-370 never made it to Beijing. This report integrates various sources of information and draws upon details of an apparent observation of MH-370 by Ms. Katherine Tee while on a yacht, the Sailing Vessel (S/V) Aaza Dana, sailing in the Indian Ocean on the day MH-370 went down on March 8, 2014. [1]

Purpose.

The purpose of this report is to document the second of three simulated flights of MH-370 performed by the author based on a flight profile that includes an engine fire and failure. The first flight is documented in “A Simulated Flight of Malaysian Airlines Flight MH-370 Flight #1.”[2] The profile attempts to tie the flight to Ms. Tee’s observation, facts known about the flight, and the timely crossing of the Inmarsat BTO rings. [3]

Objective

The objective of this technical effort is to attempt to substantiate the possibility and feasibility of Ms. Tee’s observation of flight MH-370 based on a reasonable flight profile, timing, and geometry.

Approach.

The approach was to first to develop a flight profile then fly the profile on a high fidelity PC/Mac based simulator of the Boeing 777-200ER. The simulator chosen was the X-Plane Boeing 777-200ER. A known difference between the MH-370 aircraft configuration and the simulator configuration are the engines. MH-370 had two Rolls Royce RB211 Trent 892B17 engines while the simulator uses two Pratt and Whitney PW 4090 engines. Details of the simulation are in the Appendix A, while details of the flight profile are discussed in Appendix B.

Development of the Flight Profile.

Several fundamental assumptions were made in order to develop a flight profile to be flown on the simulator. These eight assumptions are given below.

1. Initial conditions for the flight simulation could be obtained from public released documentation.
2. The MH-370 aircraft was flown at all times by a person or persons familiar with the Boeing 777-200ER until it apparently crashed into the southern Indian Ocean.
3. The sighting of MH-370 by Ms. Katherine Tee from the yacht S/V Aaza Dana was valid.

4. The Inmarsat arc concept is valid and the aircraft must crossover these rings/arcs "on time."
5. The air route was flown through a series of established waypoints available in the Boeing-200ER 777 Flight Management Computer (FMC).
6. Takeoff from Kuala Lumpur International Airport (YMKK) Runway 32R and climb out to the IGARI waypoint appeared normal until communications apparently started to come off line starting with ACARS at 1706 UTC, followed by the transponder at 1722 UTC. Voice communications were lost or not used after 1719 UTC. [3], [4], [5]
7. The initial part of the flight followed the flight path shown in the ATSB radar-based graphic until the last primary radar observation at 1822 UTC shown here as Figure 1. This graphic came from the ATSB report “MH370 – Definition of Underwater Search Areas,” dated June 26, 2014. [3]
8. MH-370 experienced an engine fire in the #1 left engine just prior to reaching the SAMAK waypoint. The crew performed the engine fire procedures followed by an emergency descent to 10,000 feet. By approximately 15 minutes after reaching 10,000 feet, the fire was out. The crew then climbed to a more optimum single-engine cruise speed and continued south.

Critical to addressing the Tee observation was to integrate an observation scenario into an overall flight profile. The resulting profile is shown in Figures 2 through 5. Figure 6 is a detailed look at the timing and geometry of the Tee observation window based on Ms. Tee’s description of the observation [1] and the GPS track file of the S/V Aaza Dana provided by the ship’s captain, Mr. Marc Horn. [6] The Inmarsat ring data for use in the graphics and analysis were from Duncan Steel of the Independent MH-370 Investigation Team. [7], [8]

As mentioned above, details of the flight profile are given in Appendix B.

Procedure.

The procedure was to fly the defined flight profile on the simulator as closely as possible to gain experience on the profile and do provide a set of lessons learned for planning of the next flight. The FMC and autopilot was used extensively, with LNAV being the autopilot mode of choice. The engine fire and engine fire procedures were simulated just prior to the turn at SAMAK.

Observations.

The following observations are made from this second simulation flight and Table 1, Flight Test Log. Table 2 provides a summary timing comparison between first and second flights.

1. The simulated flight was completed in 8 hours and 14 minutes after a takeoff from Kuala Lumpur International Airport (WMKK) on Runway 32R at 16:41 UTC. (All simulation times were lined up to the actual MH-370 flight times in UTC)

2. Level off at FL350 was 7 minutes late based on the timeline contained in the ATC to cockpit transcription. [9] Flight #1 was also 7 minutes late.
3. The waypoint IGARI was passed at 1731 UTC, 6 minutes late, likewise the turn at approximately 30 nm beyond IGARI was 5 minutes late. This was a 3-minute improvement to IGARI and a 3-minute improvement for the turn, respectively, from flight #1.
4. The crossing of the first Inmarsat arc at 18:28 UTC was 19 minutes late compared to 17 minutes late for flight #1.
5. Getting established single engine at 10,000 feet at 200 KIAS was on time this flight. The simulated engine failure needs to be started approximately 2 minutes prior to the turn at SAMAK. After the engine fire procedures are performed, a high rate, high speed, descent needs to be initiated at a descent rate of 4500 fpm and an indicated airspeed of 300 KIAS during the letdown from 36,000 feet. Speed brakes should be used to control airspeed while leaving the left engine at MCT when able.
6. The crossing of the second Inmarsat arc at 19:40 UTC was 5 minutes early. During flight #1, the crossing was 16 minutes early.
7. The crossing of the third Inmarsat arc at 20:40 UTC was 7 minutes late as compared to 5 minutes late during flight #1.
8. A MCT single-engine climb was initiated at 19:44 UTC after passing the end of the Tee observation window. The climb was aborted at 13,000 feet because of marginal thrust available and low winds aloft at 13,000 feet. The remainder of the flight was flown at 13,000 feet and MCT. At 19:54 UTC, HH was selected due to decreased directional stability.
9. The fourth Inmarsat arc of 21:40 UTC was crossed at 21:42 UTC, 2 minutes late. The flight #1 crossing was at 21:54 UTC, 14 minutes late.
10. At 22:22 UTC, LNAV was reselected due to an apparent increase in directional stability.
11. The fifth Inmarsat arc of 22:40 UTC was crossed at 22:59 UTC, 19 minutes late. The crossing time for flight #1 was 23:38 UTC, 62 minutes late.
12. The sixth and final Inmarsat arc at 00:11 UTC was passed at 00:29 UTC, 18 minutes late. This compared to a 01:20 UTC flight #1 crossing which was 69 minutes late.
13. The winds aloft were significantly lower for flight #2 versus #1 and contributed to the better timing, as did the power selection of MCT.
14. At 00:49 UTC, the fuel state was 100 kg and flameout of the left engine was expected in about 2-3 minutes. This was about 76 nm short of MALBI.
15. The fuel state went to 100 kg and never reached zero nor was a flameout initiated by the simulation (an apparent flaw in the simulation). Instead of terminating the flight, the flight was continued with the fuel state remaining at 100 kg for an additional 3 minutes.
16. At 00:52 UTC a simulated right engine flameout was initiated by shutting down the left engine. Despite having the APU on and the RAT unlocked and deployed, the author lost immediate control of the aircraft (no yoke inputs accepted by the system).

17. Soon after loss of control, the aircraft (simulation) went into a right hand spiral and impacted the water at 00:56 UTC at an estimated location of 14.317S, 107.397E.

Conclusions.

The following conclusions are made.

1. This flight of the flight #2 profile was, like the first flight, a learning experience and practice for flight #3, as well as to provide data and input for the flight #3. The Tee observation window will be flown at 13,000 feet at 200 KIAS (242 KTAS) to adjust the astern elevation angle to approximately 35 degrees. As a result, a proposed third flight profile is provided as Appendix C to this report.
2. The X-Plane simulation of the Boeing 777-200ER is an excellent tool for evaluating a flight profile but may be deficient on how it simulates the transition to engine-out control and performance. It is important to note the X-Plane simulation is not advertised as an engineering simulation. It also may not precisely match the performance of MH-370 because of the differences in engines.
3. Manual entry of wind data cannot be made in the simulation although it is possible in the real airplane. Weather and winds aloft for the simulation day were downloaded before the flight and used as "typical."
4. The flight profile may not be feasible due to the conflicting timing requirements of crossing the Inmarsat arcs on time versus being along observation track at the required flight conditions on time.

Recommendations.

The following recommendations are made.

1. The proposed third flight profile in Appendix C should be flown making appropriate adjustments to speed where the capability exists to better meet the timeline based on known times, especially the Inmarsat arc crossings.
2. The author should make an inquiry to the X-Plane Boeing 777-200ER simulation developer about the lack of proper simulation of engine flameout, all engine-out transition to a controllable gliding configuration. Manual entry of wind data should also be addressed.
3. The author should request from the X-Plane Boeing 777-200ER simulation developer, a Rolls Royce engine version of the simulation.

Figure 1. Radar-Derived Northeastern Portion of MH-370 Flight Path. [3]`

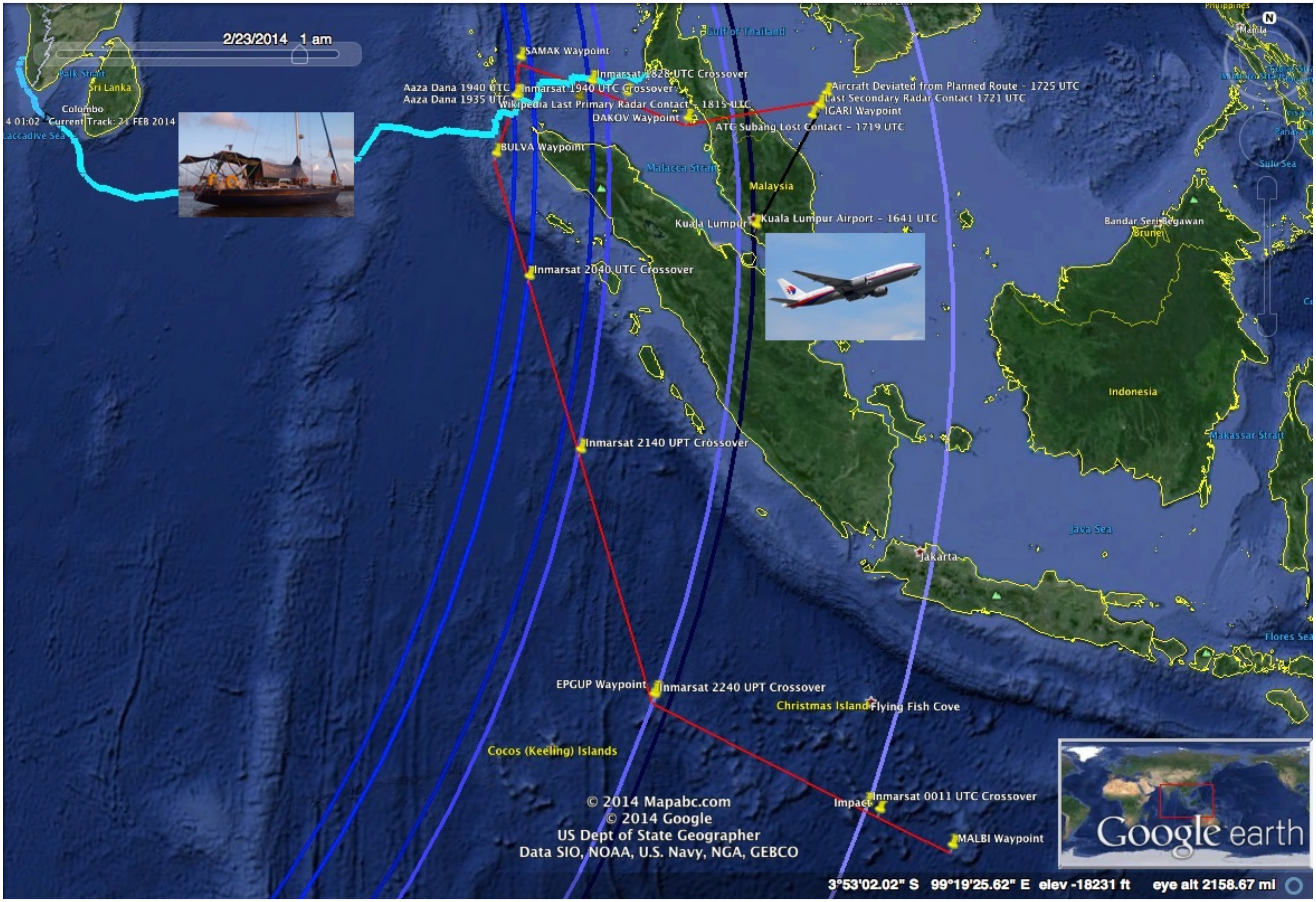

Figure 2. Overview of MH-370 Flight Profile.

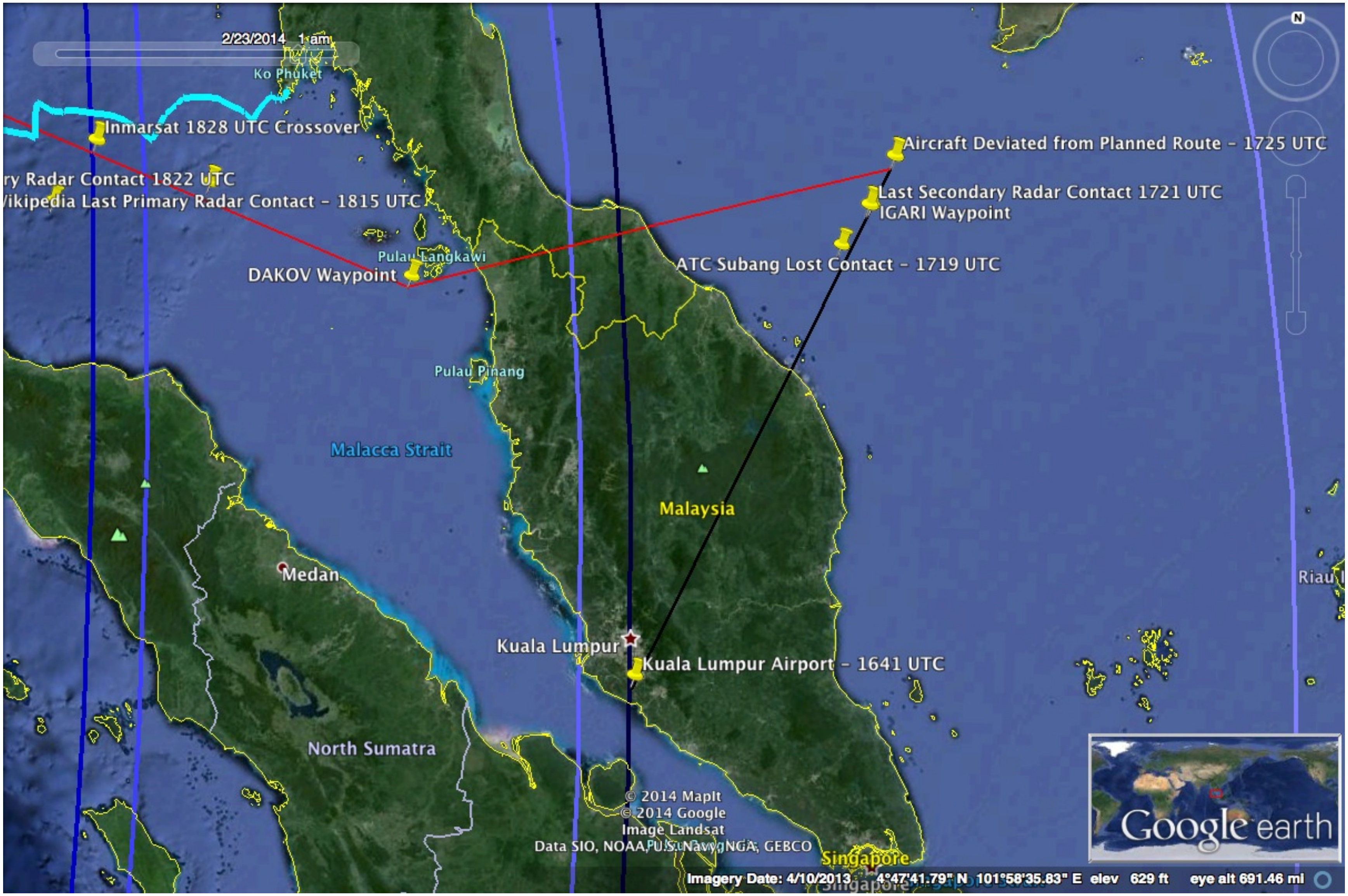

Figure 3. Northeastern Portion of Flight Profile.

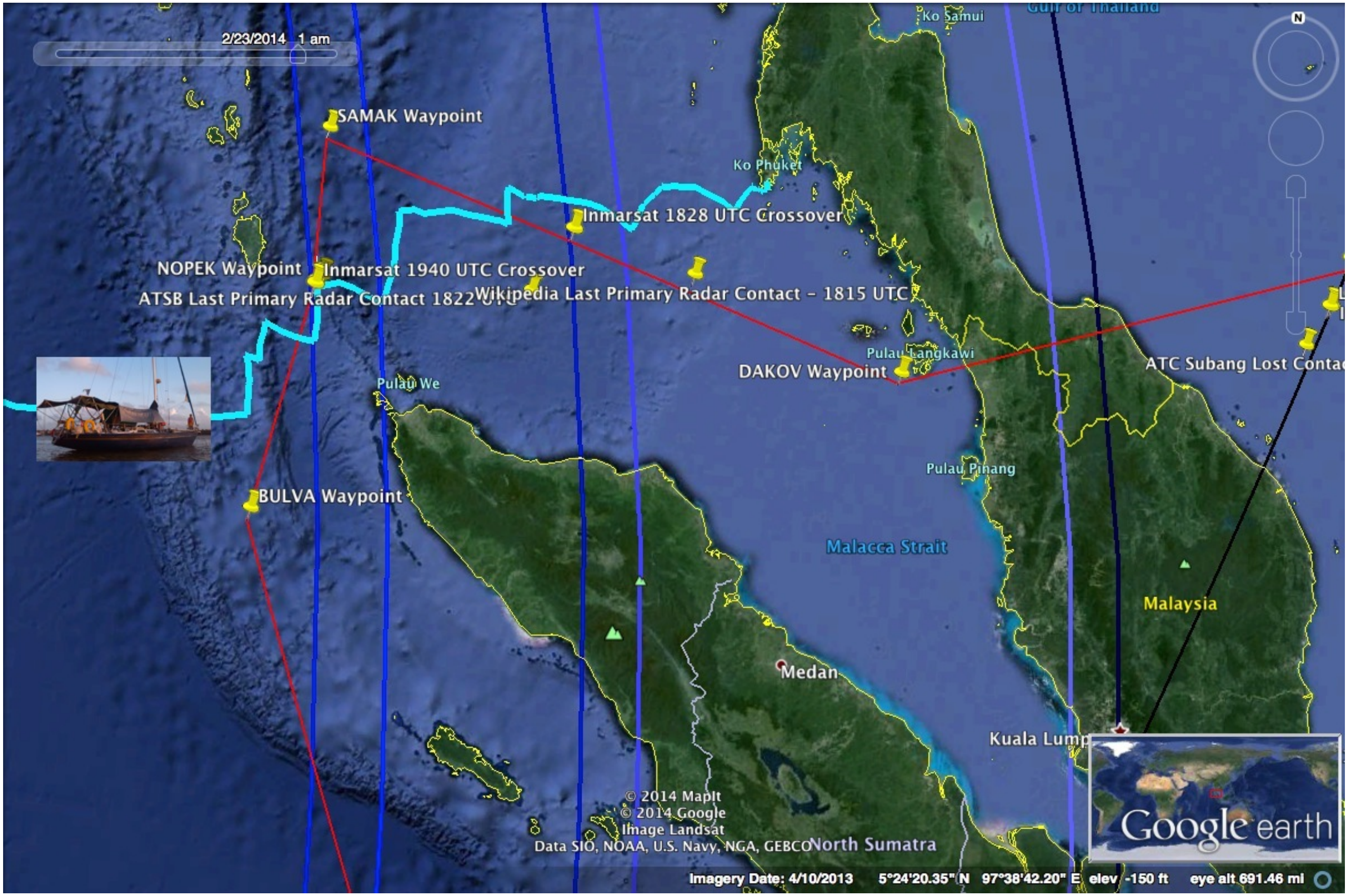

Figure 4. Northwestern Portion of Flight Profile.

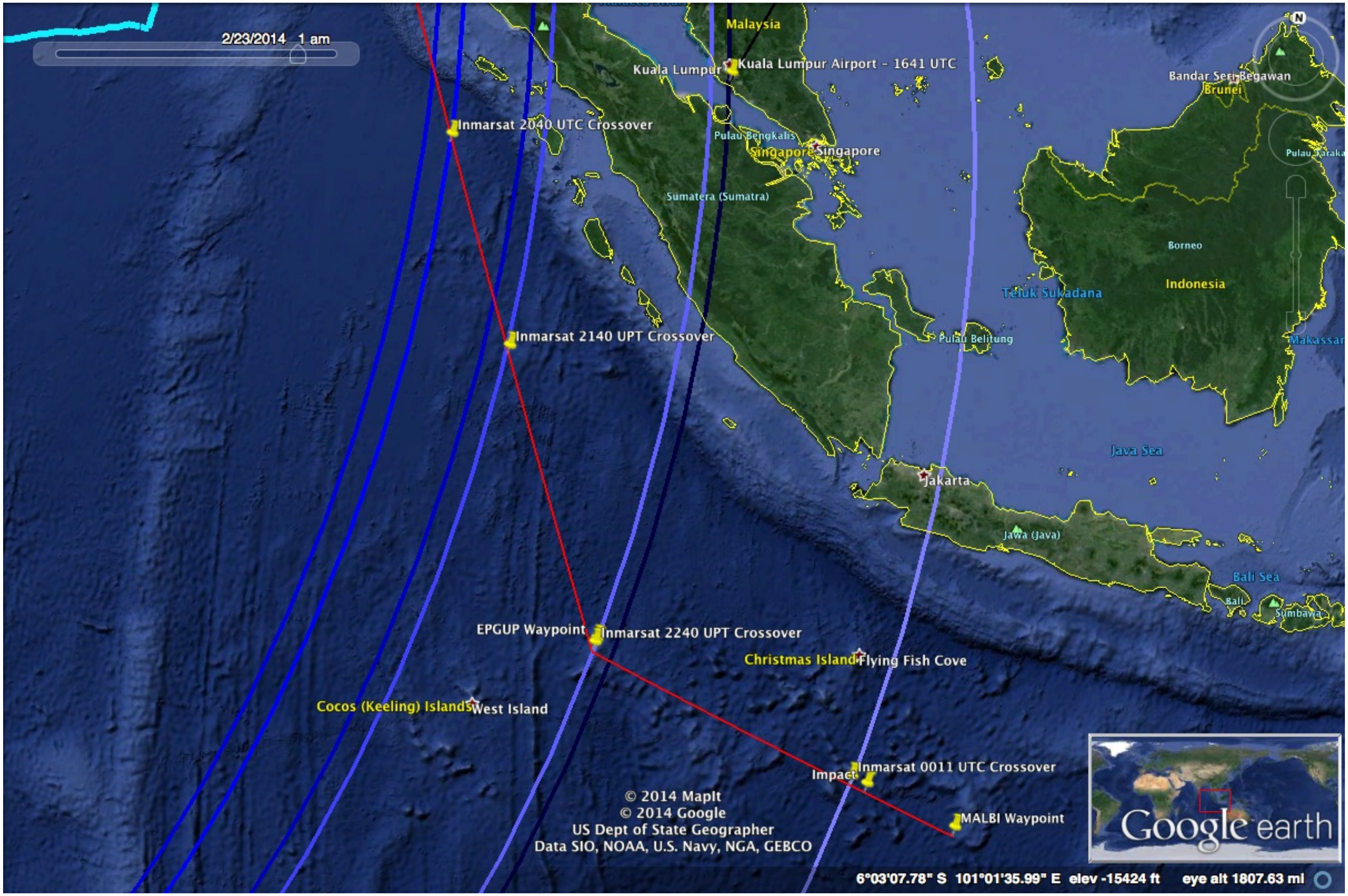

Figure 5. Southern Portion of Flight Profile.

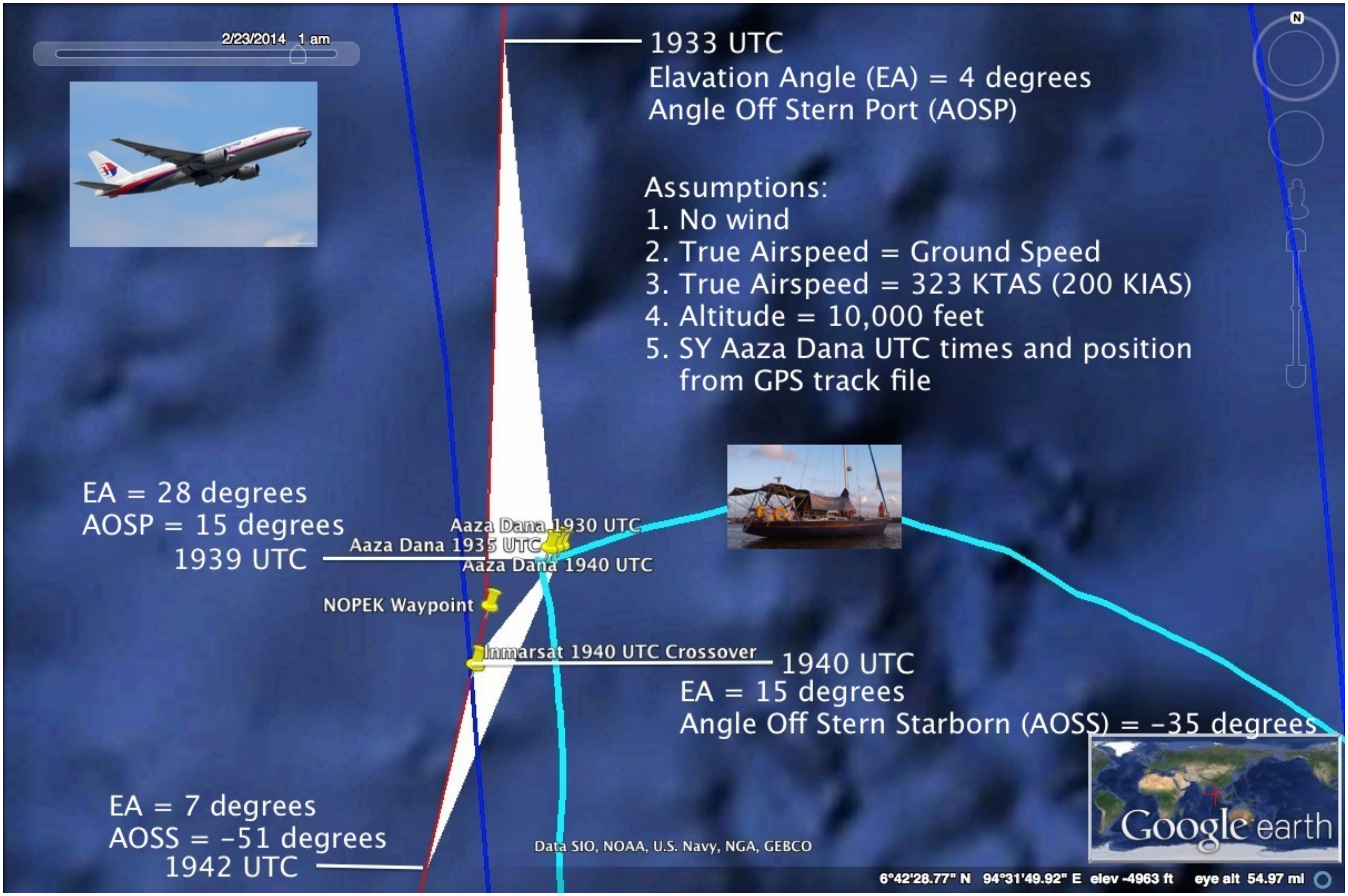

Figure 6. Overview of Tee Observation Opportunity.

Flight Test Log for 7/17/14											
Sim Time	**Flt UTC Time**	**Description**	**Altitude (feet)**	**GS (knots)**	**KTAS**	**KIAS**	**Mach**	**Wind**	**Fuel Weight**	**Gross Weight**	**Notes**
1641	1641	Takeoff Runway 32R WMKK							49.4	275.6	ZFW=226.2; IGAARI024 + WX + LNAV
1705	1705	Climbing to FL350 at MCT 160 nm from IGARI	33,000	489	493	295	0.833	291/07			
1708	1708	**Level @ FL350**	35,000	503	497	291	0.849	208/06	45.2	271.4	**7 mins late**
1728	1728	**Passing IGARI**	35,000	515	511	298		191/04	42.6	268.8	**6 mins late**
1730	1730	**Turn @ IGARI + 30 nm**	35,000	515	511	298		204/04	42.4	268.6	**5 mins late**
1741	1741	Turn complete	35,000	509	511	297	0.865	182/04	41.1	267.3	
1816	1816	Turn @ DAKOV	35,000	514	514	299	0.867		37.6	263.8	
1834	1834	SAMAK-230 nm level @ FL350	35,000	496	514	299	0.867	230/20	35.5	261.7	
1847	1847	**Passing 1828 arc (SAMAK-142 nm)**	35,000					271/20	34.1	260.3	**19 mins late**
1902	1902	Simulated fire in right engine (#2) @ SAMAK-43 nm	35,000					249/20	32.5	258.7	
1909	1909	Turn @ SAMAK in gentle descent	Deacending						32.3	258.5	
1922	1922	Level @ 10K'	10,000			200		219/15	30.0	256.2	
1932	1932	Turn complete @ 10 nm from NOPEX	10,000						32.0	258.2	
1935	1935	Turn @ NOPEK	10,000	233	239	200		251/15	29.9	256.1	
1935	1935	**Passing 1940 arc 0.88 nm past NOPEK**	10,000								**5 mins early**
1939	1939	Level accel to 250 KIAS @ 10K' from 114 nm before BULVA	10,000								250 KIAS was not at MCT
1944	1944	Start MCT climb to FL190 @ 300 fpm	Climbing			250					
1948	1948	Increase climb rate to 500 fpm losing airspeed	Climbing			250					
1949	1949	Decrease climb rate to 300 fpm	Climbing			250					
1951	1951	Climbing thru 12K' 71 nm from BULVA	Climbing	297	306	251		250/16	28.2	254.4	
1954	1954	Losing airspeed; will level a 13K' and increase airspeed	Climbing					339/03			
1954	1954	Select HH due to low directional stability	Climbing								
2005	2005	Turn @ BULVA	Climbing								
		Increase airspeed @ MCT	13,000						28.6	254.8	
2017	2017	Level @ 13K' @ MCT	13,000	402	398	326	0.618	355/03	25.2	251.4	
2047	2047	**Passing 2040 arc (EPGUP-733 nm)**	13,000	400	399	326	0.618		22.4	248.6	**7 mins late**
2142	2142	**Passing 2140 arc (EPGUP-419 nm)**	13,000	392	397	326	0.618	172/05	17.1	243.3	**2 mins late**
2205	2205	EPGUP-300 nm	13,000	367	391	319	0.607	123/29	14.7	240.9	
2222	2222	Select LNAV due to increased directional stability	13,000								
2225	2225	EPGUP-200 nm	13,000	370	398	325	0.618	131/31	12.7	238.9	
2242	2242	EPGUP-100 nm	13,000	369	394	322	0.612	121/31	10.6	236.8	
2259	2259	Turn @ EPGUP	13,000	363	390	320		113/31	8.6	234.8	
2259	2259	**Passing 2240 arc**									**19 mins late**
2311	2311	MALBI-500 nm	13,000	358	390	318	0.606	123/31	7.2	233.4	
2331	2331	MALBI-400 nm	13,000	374	390	319	0.606	126/15	5.4	231.6	
2354	2354	MALBI-300 nm	13,000	374	390	318	0.606	113/15	3.7	229.9	Noticed caution light for fuel quantity low
0023	0023	MALBI-200 nm	13,000	372	389	318	0.606	124/17	2.0	228.2	
0029	0029	**Passing 0011 arc (MALBI-174 nm)**	13,000	373	390	318	0.606	129/17	1.5	227.7	**18 mins late**
0046	0046	MALBI-100 nm	13,000	372	390	319	0.606	122/17	0.3	226.5	
0049	0049	MALBI-89 nm	13,000						0.1	226.3	**Fuel quantity did not go to zero**
0052	0052	**Simulated flame-out on left engine (#1) @ MALBI-76 nm**									
		Right spiral out-of-control									
0056	0056	**Estimated Impact @ MALBI-61.3 nm**									**Estimated impact: 14.317S; 107.937E**

Table 1. Flight Test Log.

Timing Comparision in UTC					
Profile Timing Location	**Reference Time**	**Flight #1 Time**	**Flight #2 Time**	**Flight #1 Delta**	**Flight #2 Delta**
Takeoff from Kaula Lumpur	16:41	16:41	16:41	0 mins	0 mins
Level at FL 350	17:01	17:08	17:08	7 mins late	7 mins late
Passing IGARI	17:22	17:31	17:28	9 mins late	6 mins late
Turn at IGARI + 30 nm	17:25	17:33	17:30	8 mins late	5 mins late
Turn at DAKOV		18:16	18:16		
Passing 1828 arc	18:28	18;45	18:47	17 mins late	19 mins late
Simulated engine fire		19:04	19:02		
Turn at SAMAK		19:06	19:09		
Level at 10K' at 200 KIAS		19:25	19:22		
Turn at NOPEK		19:24	19:35		
Passing 1940 arc	19:40	19:24	19:35	16 mins early	5 mins early
Turn at BULVA		19:55	20:05		
Level at 13K'		19:57	20:17		
Passing 2040 arc	20:40	20:45	20:47	5 mins late	7 mins late
Passing 2140 arc	21:40	21:54	21:42	14 mins late	2 mins late
Passing EPGUP and 2240 arc	22:40	23:38	22:59	62 mins late	19 mins late
Passing 0011 arc	00:11	01:20	00:29	69 mins late	18 mins late
Simulated flameout		01:20	00:52		
Impact time		01:24	00:56		

Table 2. Timing Comparison In UTC.

List of Abbreviations

10K’	10,000 feet
12K’	12,000 feet
13K’	13,000 feet
15K’	15,000 feet
17K’	17,000 feet
32R	Runway 32 Right
ACARS	Aircraft Communications and Reporting System
APU	Auxiliary Power Unit
ATSB	Australian Transport Safety Bureau
BTO	Burst Timing Offset
C.G.	Center of Gravity
DDR3	double data rate type three
E	East
fpm	feet per minute
FL180	Flight Level of 18,000 feet
FL190	Flight Level of 19,000 feet
FL250	Flight Level of 25,000 feet
FL350	Flight Level of 35,000 feet
FMC	Flight Management Computer
GB	gigabyte
GHz	gigahertz
GPS	Global Positioning System
GS	Ground Speed
HD	high definition
HH	Heading Hold
HHD	hybrid hard drive
IFR	instrument flight rules
kg	kilogram
KIAS	Knots Indicated Airspeed
KTAS	Knots True Airspeed
lb	pound
LNAV	Lateral Navigation
MCT	maximum continuous thrust
MHz	megahertz
mins	minutes
nm	nautical mile
PC	Personal Computer
RAT	Ram Air Turbine
S	South
SDRAM	synchronous dynamic random access memory
SID	Standard Instrument Departure
S/V	Sailing Vessel
TB	terabyte
URL	Uniform Resource Locator

USAF	United States Air Force
USB	Universal Serial Bus
UTC	Coordinated Universal Time
YMKK	ICAO designation for Kuala Lumpur International Airport

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12. Boeing 777-200LR Pilot’s Handbook (manual provided with simulation software).
13. Boeing 777-200LR Performance Charts (charts provided with simulation software).

Appendix A – Details of Simulation

Hardware.

MacBook Pro Laptop	Processor: 2.8 GHz Intel Core 2 Duo with 8 GB of 1067 MHz DDR3 SDRAM; 1 TB HHD
Apple 27" HD Display	
Apple Bluetooth Keyboard	
Logitech Bluetooth Travel Mouse	
Eclipse CH USB Yoke with paddles for yaw control	

Software

Operating System	Mac OS 10.9.4
X-Plane 10 Global Edition Extended	10.25 (64-bit)
Boeing 777-200ER (Pratt and Whitney PW 4090 engines)	1.6.1

Simulation Initial Conditions

Takeoff Location: Kuala Lumpur International Airport (YMKK) Runway 32R

Menu Inputs

Main Menu [4], [10]

No. of passengers	227 (number should not include crewmembers)
Cargo weight	55,792 kg
APU time	20 min
Taxi time	20 min
Takeoff fuel	46,410 kg
Total fuel	49,650 kg
Total weight	275,867 kg

Slider Weight and Balance Menu [4], [10]
Payload weight = 123,528 lb
Fuel total = 110,017 lb

Weather Menu (Simulation does not have capability to manually enter winds.)[11]
Select: grab real-weather from the net
Select: DOWNLOAD Real-Weather file "METAR.RWX" from the net
Select: Download right now

FMC Weight and Balance Inputs [4], [10]
ZFW = 226,217 kg
TOGW = 272,627 kg
C.G. = 26%

Appendix B – Details of Flight #2 Profile

Clearance [9]
WMKK IFR departure from runway 32R
Cleared to Beijing via PIBOS A departure to 6,000 ft
Immediately cleared to FL180 and told to cancel SID and to turn right direct to IGARI
Climb to FL250
Level at FL250
Climb to FL350
Level at FL350 40 minutes after takeoff direct to IGARI

Notes:

1. Procedures should be IAW the Boeing flight manual and procedures. [11], [12], [13]
2. Simulated climbout from WMKK was to fly 2 minutes on the runway heading of 327^{O} and then turn right and go direct to the IGARI waypoint.
3. Maintain maximum speed when possible.

Leg 1 **WMKK to IGARI** **024^{O}** **275 nm** Climb enroute to IGARI. Should be level at FL350 at 1701 UTC. Maintain flight at MCT at FL350. Cross IGARI and proceed until ~30 nm past IGARI. Initiate left turn at ~30 nm past IGARI.

Leg 2 **IGARI Turn to DAKOV** **253^{O}** **264 nm** Maintain flight at MCT at FL350.

Leg 3 **DAKOV to SAMAK** **291^{O}** **133 nm** Maintain flight at MCT at FL 350. Approximately 5 minutes before turn initiation at SAMAK, simulate fire in the right (#2) engine. Allow airspeed to bleed to 250 KIAS and when needed initiate a descent at 4500 fpm. Maintain MCT on the left engine (#1). Allow airspeed to increase to 300 KIAS and use speed brakes to maintain the 4500 fpm descent rate at 300 KIAS.

Leg 4 **SAMAK to NOPEK** **181^{O}** **82 nm** Continue descent at 4500 fpm at 300 KIAS until transition is required to arrive at a stable condition at 10,000 feet and 200 KIAS. Stable condition must be obtained approximately 8 minutes prior to the NOPEK turn to BULVA.

Leg 5 **NOPEK to BULVA** **193^{O}** **124 nm** Approximately 7 minutes after passing NOPEK accelerate to 250 KIAS, and then climb to FL190 at 300 fpm and 250 KIAS. Once level at FL190, accelerate to airspeed for MCT.

Leg 6 **BULVA to EPGUP** **161^{O}** **968 nm** Maintain single-engine flight at MCT at FL190.

Leg 7 **EPGUP to MALBI** **116^{O}** **326 nm** Maintain single-engine flight at MCT at FL190. When the left engine (#1) flames out, perform appropriate procedures. (Simulate if required).

NOTE: ***Splash could take place ~159 nm short of MALBI or ~15 nm beyond the 00:11 UTC Inmarsat arc***.

1. If engines flame out, maintain control and hold 270 KIAS at a minimum.
2. Manually deploy RAT with switch on hydraulic panel as backup to automatic system.

3. .

Appendix C – Details of Proposed Flight #3 Profile

Clearance [9]
WMKK IFR departure from runway 32R
Cleared to Beijing via PIBOS A departure to 6,000 ft
Immediately cleared to FL180 and told to cancel SID and to turn right direct to IGARI
Climb to FL250
Level at FL250
Climb to FL350
Level at FL350 40 minutes after takeoff direct to IGARI

Notes:
1. Procedures should be IAW the Boeing flight manual and procedures. [11], [12], [13]
2. Simulated climbout from WMKK was to fly 2 minutes on the runway heading of 327 ^{O} and then turn right and go direct to the IGARI waypoint.
3. Maintain maximum speed when possible.

Leg 1 **WMKK to IGARI** **024^{O}** **275 nm** Climb enroute to IGARI. Should be level at FL350 at 1701 UTC. Maintain flight at MCT at FL350. Cross IGARI and proceed until ~30 nm past IGARI. Initiate left turn at ~30 nm past IGARI. During turn, climb to FL360.

Leg 2 **IGARI Turn to DAKOV** **253 ^{O}** **264 nm** Maintain flight at MCT at FL360.

Leg 3 **DAKOV to SAMAK** **291 ^{O}** **133 nm** Maintain flight at MCT at FL 360. Approximately 2 minutes (~17 nm) before turn initiation at SAMAK, simulate fire in the left (#1) engine. Allow airspeed to bleed to 250 KIAS and when needed initiate a descent at 4500 fpm. Maintain MCT on the right engine (#2). Allow airspeed to increase to 300 KIAS and use speed brakes to maintain the 4500 fpm descent rate at 300 KIAS.

Leg 4 **SAMAK to NOPEK** **181 ^{O}** **82 nm** Continue descent at 4500 fpm at 300 KIAS until transition is required to arrive at a stable condition at 13,000 feet and 200 KIAS. Stable condition must be obtained approximately 10 minutes prior to the NOPEK turn to BULVA.

Leg 5 **NOPEK to BULVA** **193 ^{O}** **124 nm** Approximately 7 minutes after passing NOPEK, accelerate to airspeed for MCT.

Leg 6 **BULVA to EPGUP** **161 ^{O}** **968 nm** Maintain single-engine flight at MCT at 13,000 feet.

Leg 7 **EPGUP to MALBI** **116 ^{O}** **326 nm** Maintain single-engine flight at MCT at 13,000 feet. When the right engine (#2) flames out, perform appropriate procedures. (Simulate if required).

NOTE: ***Splash could take place ~61 nm short of MALBI or ~113 nm beyond the 00:11 UTC Inmarsat arc***.

4. If engines flame out, maintain control and hold 270 KIAS at a minimum.
5. Manually deploy RAT with switch on hydraulic panel as backup to automatic system.