MH370 Search Area Recommendation
The Independent Group
September 9, 2014

1 Executive Summary

Shortly after the disappearance of MH370 on March 8th, an informal group of people with diverse technical skills and backgrounds came together on-line to discuss the event and analyse the technical information that had been released. The group has since become known as the “Independent Group”, or “IG”. The IG has continued to share an extensive array of reference material and their experience with aircraft, satellite, radar, and meteorological systems. Several high fidelity flight path models have been independently developed, refined and compared. These models now incorporate state-of-the-art satellite geometry and physics. They make use of the available radar, ADS-B, BTO, BFO, magnetic declination and meteorological data, as well as the operational and practical knowledge contributed by experienced, current B777 pilots.

In a statement released June 17, 2014, the IG recommended that the search area be defined based on an estimated 6th arc location of 36.0S, 88.6E. At that time, the 00:19 “partial ping data” was not well understood, nor did the BTO and BFO models reflect the information disclosed in the ATSB Report AE-2014-054. However, with new information in hand, as well as confidence in the 7th arc data, we have revised the estimate to a likely point of impact close to 37.5 S, 89.2 E.

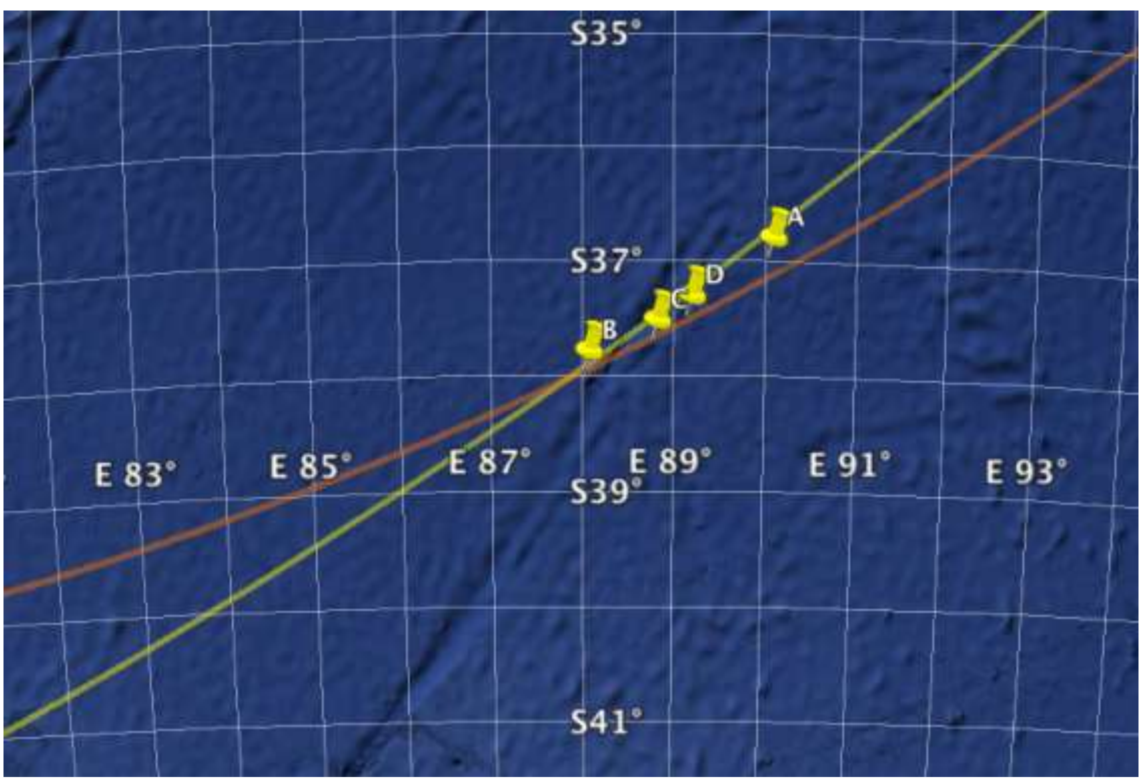

Figure 1 Results for 4 independent models assuming a nominal cruise altitude and speed. Green line is the 7th arc and the brown line is the estimated fuel exhaustion circle given in the ATSB report.

2 New Information and Developments

2.1 ATSB Report AE-2014-054

The ATSB Report AE-2014-054, first released June 26, 2014 and revised August 18, 2014, contained valuable new data and analysis. It also provided insight into the methodology used by the ATSB for the selection of the Underwater Search Areas. This document answered many questions about the crucial metadata missing from the Inmarsat Signaling Unit Log for MH370, released May 26, 2014. In particular, the revised definition of the BFO values made possible more accurate use of the BFO data. We have independently simulated the EAFC residual errors assuming the geographic location of the Perth GES is 31° North and the results match the trend of the data in Table 4. However, the match is not perfect, leaving some doubt about the accuracy of the measured values in Table 4. We therefore urge Inmarsat to disclose further details of the configuration of the Perth EAFC, firmware version and the specific details of how the values in Table 4 were measured or computed.

2.2 Turn to the south; 1840 BFO data analysis

Based on recent news reports, it appears that ATSB is now incorporating the BFO data available at 18:39/18:40, as recommended by the IG in our July 17, 2014 Update. We reiterate our opinion that MH370 was probably headed generally to the south at that time.

2.3 7th Arc BFO Data Analysis

We agree with the ATSB that MH370 impacted the water very near the 7th arc. We also agree with the assessment that the second engine reached fuel exhaustion approximately 03:40 minutes before the 00:19:29 logon. Given that the autopilot would have disengaged at approximately 00:15:49, the BFO values at 00:19:29 and 00:19:37 indicate that the aircraft was already in a spiral dive at 00:19:29. We estimate the Rate of Climb (ROC) was approximately -15,000 ft/min at 00:19:37 and accelerating at approximately 22 ft/sec^2. Thus, we believe MH370 impacted the water within seconds after the last signaling unit log record, and within 1 NM of the 7th arc. This finding suggests that the width of the impact arc could be reduced from -20/+30 NM to approximately ±10 NM.

2.4 Aircraft Performance Limitation

The ATSB Report provided an estimate of the maximum range based on available fuel as of 17:07 (reported in an ACARS message) and the PDA numbers for the 2 engines. The details were not provided, but Figure 20 on page 22 provided a graphical estimate of the range data. We now acknowledge that the performance range limit data is potentially of greater value than previously understood. We note that the southern intersection of the 7th arc and range limit coincides with the IG model results for the nominal case. If the range estimates are accurate, then the most likely impact areas would be close to the northern or southern limits, not the center of the arc.

2.5 Refined BFO Model

We have refined and updated the BFO model in our path models to use the BFO definition provided in the ATSB Report at Page 55. We believe the BFO bias is approximately 153.7 Hz based on calibration at Gate C1 and the available ADS-B data in the early part of the flight. To estimate the BFO values at times other than those listed in Table 4, we have developed a sinusoidal function that fits the values in Table 4 for those times in which the satellite was not eclipsed, and then added back the effect of the eclipse. This model produces values in close agreement with the values in Table 4.

2.6 NOAA Wind and Temperature Fields

We have incorporated data from NOAA wind and temperature fields to estimate TAS and ground speed.

2.7 B777 Pilot Interviews

We have conducted interviews with several B777 pilots and incorporated their experience, especially with respect to system configurations pilots would typically use.

3 Applying Human Factors to the Analysis

The ATSB analysis used two basic analysis techniques referred to as "Data Driven" and "Flight path/mode driven" (page 18). While we agree that these statistical methods are reasonable techniques, both tend to overlook or minimize likely human factors in favor of pure mathematical statistics. This ATSB approach appears to have resulted in a conclusion that the most likely average speed was approximately 400 kts (Appendix A). However, 400 kts is not consistent with standard operating procedure (typically 35,000 feet and 470-480 kts), nor is it consistent with the likely speed a pilot would choose in a decompression scenario (10,000 feet and 250-300 kts). A speed of 400 kts may minimize the BTO and BFO errors for a given set of assumptions, but the errors can also be shown to be very small for other speeds. Given all the tolerances and uncertainties, we believe it is important to consider human factors with more weight.

3.1 Normal Cruise Scenario

B777 pilots consistently tell us that under normal conditions, the preferred cruise attitude would be 35,000 feet and the TAS would be approximately 470-480 kts. We believe this is the most likely case for MH370, and note that the last ADS-B data available indicated that MH370 was at 35,000 feet and 471 kts at that time. Although few primary radar data details have been released, the data from 18:02 to 18:22 is believed to be more consistent with this normal speed range than an assumed 400 kts. We note that the Normal Cruise Scenario produces a path that matches the southern fuel limit at the 7th arc, making this the most likely scenario.

3.2 Decompression Scenario

If the aircraft experienced a decompression event around IGARI, B777 pilots tell us the standard operating procedure would be to turn to the nearest available airport and descend rapidly to 10,000 feet. Depending on the weight of the aircraft (mainly fuel on board), the TAS would be set to 250-300 kts. MH370 did make a turn and headed back towards land and several possible intended airports. However, the limited radar data released so far does not seem to be consistent with this lower speed range. Nevertheless, if MH370 did experience a decompression event, and did descend to 10,000 feet at some point, the speed would have been necessarily reduced to approximately 300 kts. We note that using a TAS assumption of approximately 323 kts, the path terminates on the 7th arc near the northern intersection of the fuel limit, making this another case consistent with the fuel/performance limit. The BFO errors are somewhat larger for this case compared to the Normal Cruise Scenario, but still within reason.

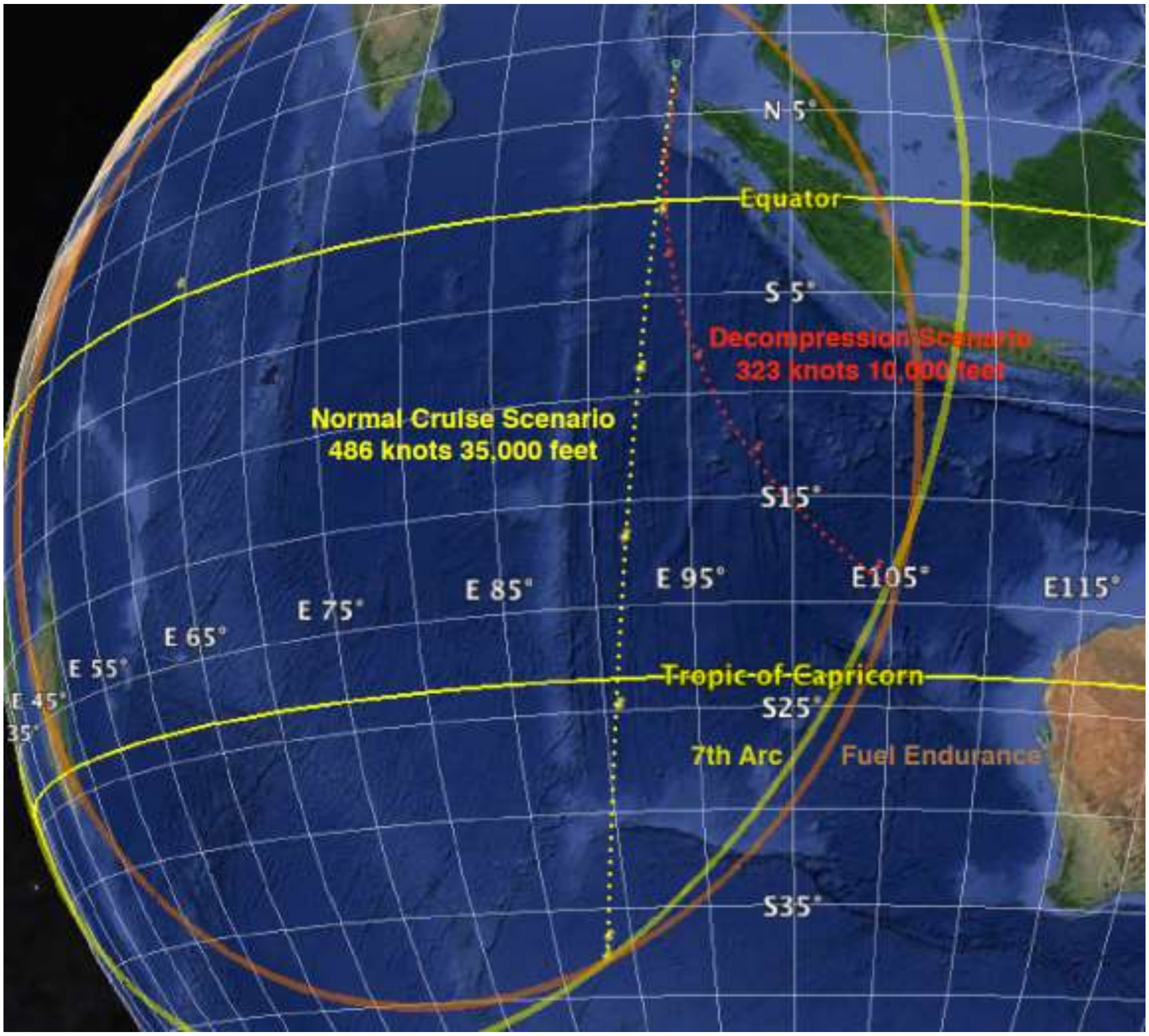

Figure 2 Paths for Normal and Decompression Scenarios. Note that both paths intersect the performance limits where the 7th arc and the fuel circle intersect.

3.3 ATSB 400 kts Scenario

ATSB considered thousands of paths, with many possible speeds tested. However, the most likely scenario chosen by ATSB (low BTO and BFO errors) had a TAS of 400 kts. But ATSB provides no rationale for a pilot to have made a deliberate selection of this speed. If the aircraft was flying under the control of the autopilot, a human must have selected the configuration. We doubt that a pilot would select 400 kts, and a lower altitude to match, regardless of the motivation. Using our path models, we have confirmed that the path would end on the 7th arc in the ATSB Priority Search Area if the speed was 400 kts, but we note that this result is the least consistent with (a) the most likely speeds a human would chose and (b) the fuel range/performance intersections with the 7th arc.

4 IG Analysis

The assumptions common to the models used by our group for the Normal Cruise Scenario are level flight at FL350 at normal cruising Mach numbers with AFDS LNAV/VNAV roll and pitch modes engaged. In most cases, we assume a small, gradual reduction in TAS as the fuel is burned off. We have constrained the path solutions so that only one major turn occurs between 18:28 and 18:39. We assume a track of about 300°T turning south to about 186°T. Candidate solution paths generate BFOs within 5 Hz, are within 50 km over the earth's surface of each ping ring from 19:41 onwards and have endpoints on the 7th ping ring clustered around 37.5 S, 89.2 E.

5 Recommendations

1. We recommend that the Priority Search Area be moved further south from the present location. The most likely point of impact is near the intersection of the 7th arc, the fuel exhaustion circle and the path model end points given in Figure 1 above, and Figure 3 below.
2. The width of the priority Search Area can be reduced to approximately ±10 NM, thereby allowing for the length of the search area arc to be increased for a fixed budget of 60,000 km^2.

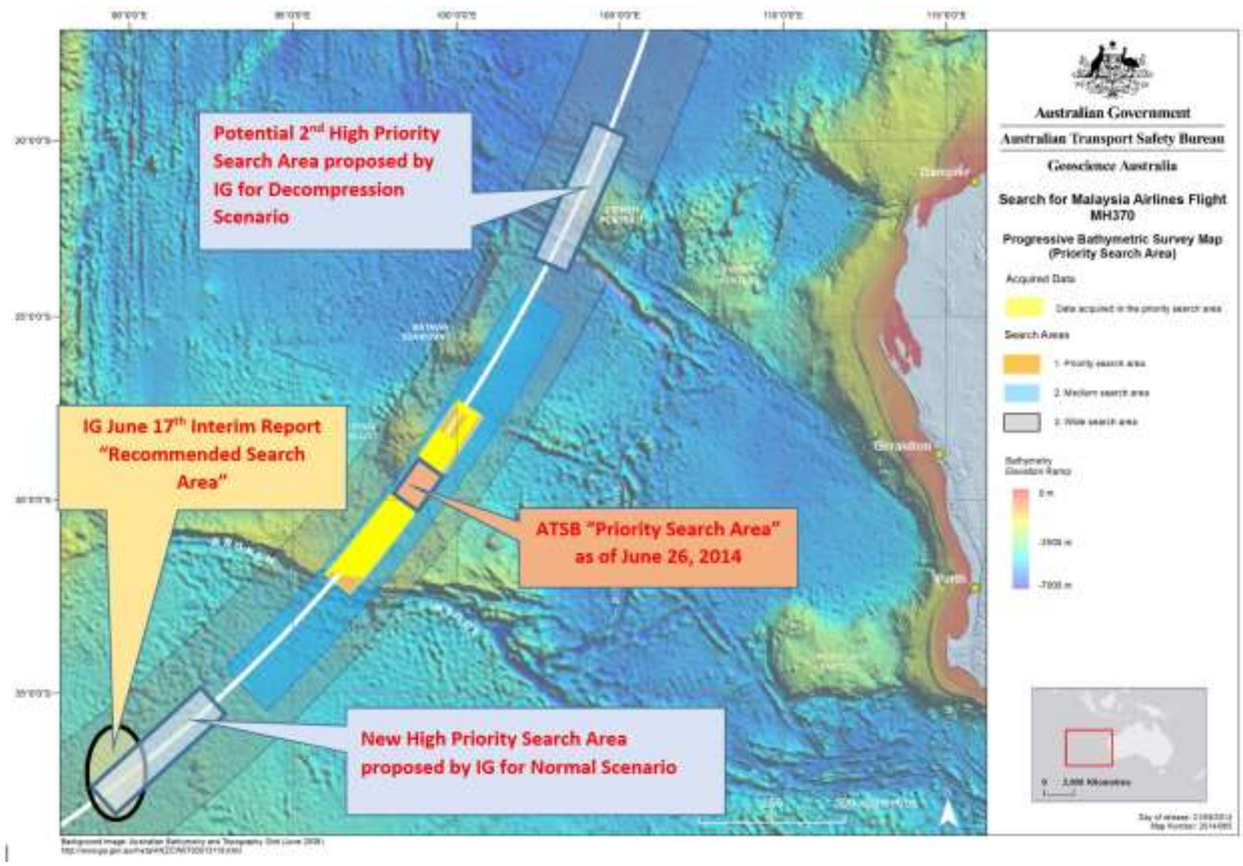

Figure 3. Illustration of Search Areas corresponding to the three scenarios described in Section 3. Search area dimensions are not to scale.

6 Independent Group

The following individuals have agreed to be publicly identified with this statement, to represent the larger collective that has contributed to this work, and to make themselves available to assist with the investigation in any constructive way. Other members prefer to remain anonymous, but their contributions are gratefully acknowledged.

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Appendix A: Links to detailed Flight Models

https://www.dropbox.com/s/nliujaly0yqnrfn/MH370%20Flight%20Path%20Model%20V11.3%20495%20knots.xlsx?dl=0

http://www.aqqa.org/MH370/models/Doppler_WGS84_v7-6-7.xlsx

https://dl.dropboxusercontent.com/u/15200211/Doppler_WGS84_v7-3-4_090614-187h.xlsx