This file was initially used just to store and organize information when and as it became available. When the information indicated the disappearance of MH370 could have been a deliberate act, operational expertise was added. What would/could an aviation professional do to make that happen? What would be a plausible scenario and could such a scenario assist the search for MH 370? And above all: what would falsify or confirm that scenario? For a scenario tells us only what might have happened. Not necessarily what did happen.

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What do we know

What plausible and falsifiable assumptions can we make

MH 370

File started: March 20, 2014. First published: May 3, 2014. Last revision: January 10, 2015

Revision Log

Date	Changes
January 10, 2015	In tentative flight plan changed speed along escape track to $V_{MO}/M_{MO.}$ Some editorial changes.
January 6, 2015	ATSB report *MH370 – Flight Path Analysis Update* (October 8, 2014) states that at 18:40 UTC the aircraft was travelling south, according to further analysis of the satellite data. As this correlates with position ANOKO this position was used as the starting point for the southerly track in stead of MEMAK. Consequently a potential track is proposed as true track 180° or as a great circle track to position S40°E95°. These tracks are almost the same and cross the 7th arc at about S34°E94°25'.
January 4, 2015	Most times changed from local to UTC and adjusted to the times mentioned in ATSB report *Definition of Underwater Search Areas* (June 26, 2014). Plotted a direct track from Penang to ANOKO, which then lines up with the radar track published in that report. Added last known radar position to maps. Changed potential target position from S25°E105° to S35°E100°. Direct track from MEMAK then passes through the center of the most likely search area (as defined by the satellite data analysis). Added true track and great circle segment considerations. The latter were not included in previous versions to simplify the narrative.
June 12, 2014	The ATSB* report *Considerations on Defining the Search Area* (May 26, 2014) presented radar plots. These were used to adjust the turn back in Vietnam airspace to slightly north of IGARI instead of overhead IGARI and to change the GIVAL position to Abeam GIVAL, on a direct track from N05°30'E99° to LEKIR. Minor adjustment of distances, times and fuel in the tentative flight plan to incorporate that change. Some minor editorial changes.
May 2, 2014	From the Malaysian *Preliminary Report* (April 30, 2014): ground tot air telephone calls mentioned in that report explain the gaps in the handshakes. Incorporated in the scenario.

*ATSB: Australian Transport Safety Bureau

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1. The Facts
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    - Missing radar images
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    - A lucky break?
3. A Simple and Falsifiable Scenario
    - The most simple scenario
    - The proposed events
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    - Altitudes and waypoints
    - Tracking around Indonesia
    - Possible tracks
    - Priority Search Areas versus a Tentative Final Track
    - Maximum Range Cruise Boundary
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4. Some Technical Background
    - Disabling ACARS en ADS
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    - The RAT
5. A Few Final Words

And the questions they beg

The Facts

The Facts (ET = Elapsed Time, UTC = Universal Time Coordinated, Comm = voice communication. Local time = UTC + 8)

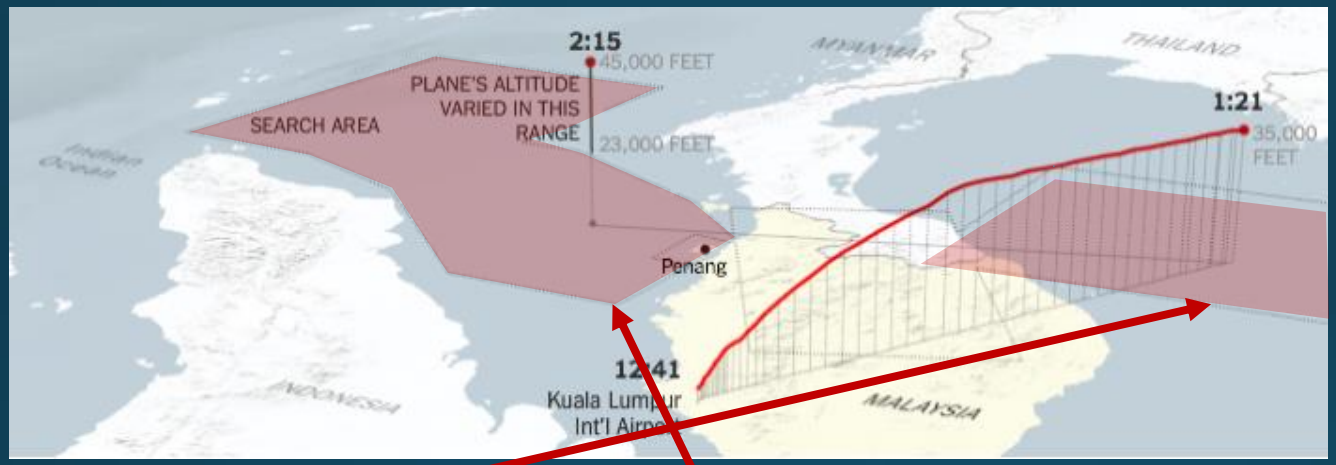
ET	UTC	Event	Remarks
0:00	16:41	Take-off	
0:20	17:01	Comm to ATC: maintaining FL 350	ATC (Lumpur Radar) standard reply.
0:26	17:08	Again comm to ATC: FL 350	ATC (Lumpur Radar) standard reply. Question: same person calling?
0:26	17:08	ACARS routine message by satcom	Second and last one transmitted.
0:38	17:19	Comm from Lumpur Radar ATC	To contact Ho Chi Ming. MH370 acknowledges, but does not comply.
0:39	17:20	ADS-B altitude to zero feet	ACARS disabled? Pilot action?
0:40	17:21	ADS-B off	Pilot action?
0:41	17:22	Transponder off	Pilot action?
0:47	17:28	Blip on Thai military radar	Going west. Also seen on Malaysian military radar tapes later that day.
1:26	18:08	No satcom handshake	Timer restarted due MAS call to MH370 at 18:03, with no answer.
1:34	18:15	Lost by Malaysian military radar	Last altitude FL 230?
1:41	18:22	Lost by Thai military radar	Flying at 4000' or lower?
1:44	18:25	Handshake 1 initiated by aircraft	Lost contact due to attitude? High bank angle? Change in Doppler shift, due turn?
1:59	18:40	Unanswered MAS ground to air call	Caused restart of timer.
3:00	19:41	Normal satcom, handshake 2	*Normal handshakes are initiated by satellite after one hour no contact,*
4:00	20:41	Normal satcom, handshake 3	*to see if aircraft is still logged on or can be dismissed. The aircraft system*
5:00	21:41	Normal satcom, handshake 4	*tries to maintain contact despite heading and attitude changes. When*
6:00	22:41	Normal satcom, handshake 5	*contact is lost, due to e.g. rapid heading change, aircraft initiates reconnection.*
7:00	23:41	No satcom handshake	Timer probably restarted when MAS tried to call MH370 at 23:14, with no answer.
7:30	00:11	Normal satcom handshake 6	Later than previous interval because of MAS call to MH370 at 23:14.
7:38	00:19	Handshake 7 by aircraft, incomplete	Elec. power lost? Flame out? Restored by deployed RAT? Then lost due water contact?

Sources: MH 370 Preliminary Report, April 30, 2014; ATSB report June 26, 2014

Wasted time, smart moves, and a misleading lucky break

The Search

Missing Radar Data

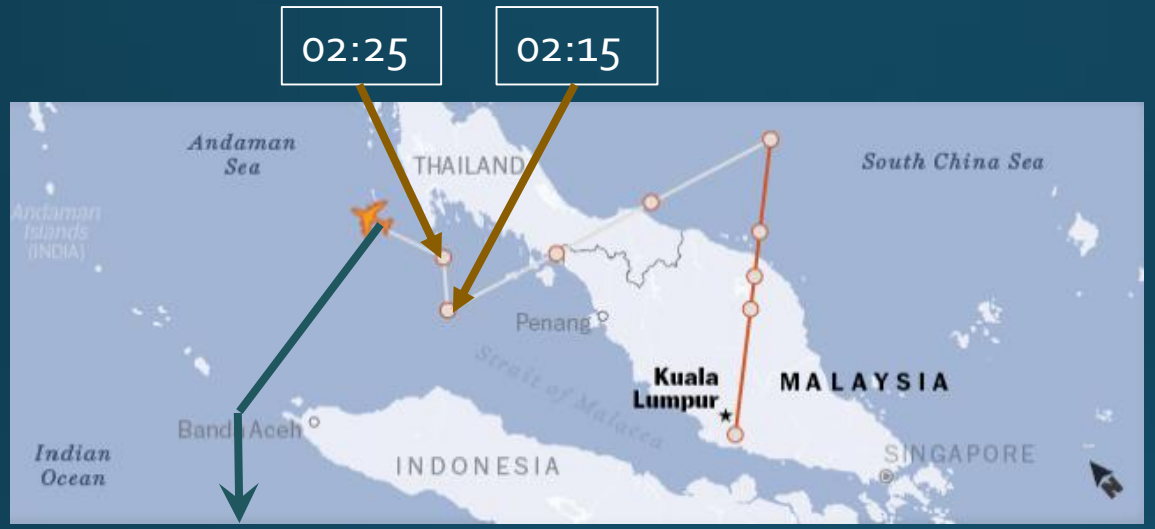


The initial search area was centered on the last known position at 01:21 LT. For lack of primary radar imagery most experts felt disintegration was the most likely scenario, caused either by a technical problem or by an explosive device.

A few days later a search area west of Malaysia was added. Another few days later the reason why became clear: there were primary radar images, with a last position at 02:15 LT. Top level officials knew about this from day one.

Source: *Series of Errors by Malaysia Mounts, Complicating the Task of Finding Flight 370*, New York Times, Asia Pacific, March 15, 2014

More Radar Data



On March 23 the Washington Post published this map with an indication of a position at 02:25 LT, seen by Thai military radar.

If we assume that both altitude and route were selected to avoid detection by radar, a route after the position at 02:25 LT would also try to avoid Indonesian radar. That would explain why no radar traces of MH370 were seen after 02:25 LT.

Note: All tracks after IGARI in this picture were later proven to be incorrect. The important and valid point however is the fact that the last radar contact by Thai military was at 02:25, ten minutes after the last contact by Malaysian military.

Initial Analysis by Inmarsat

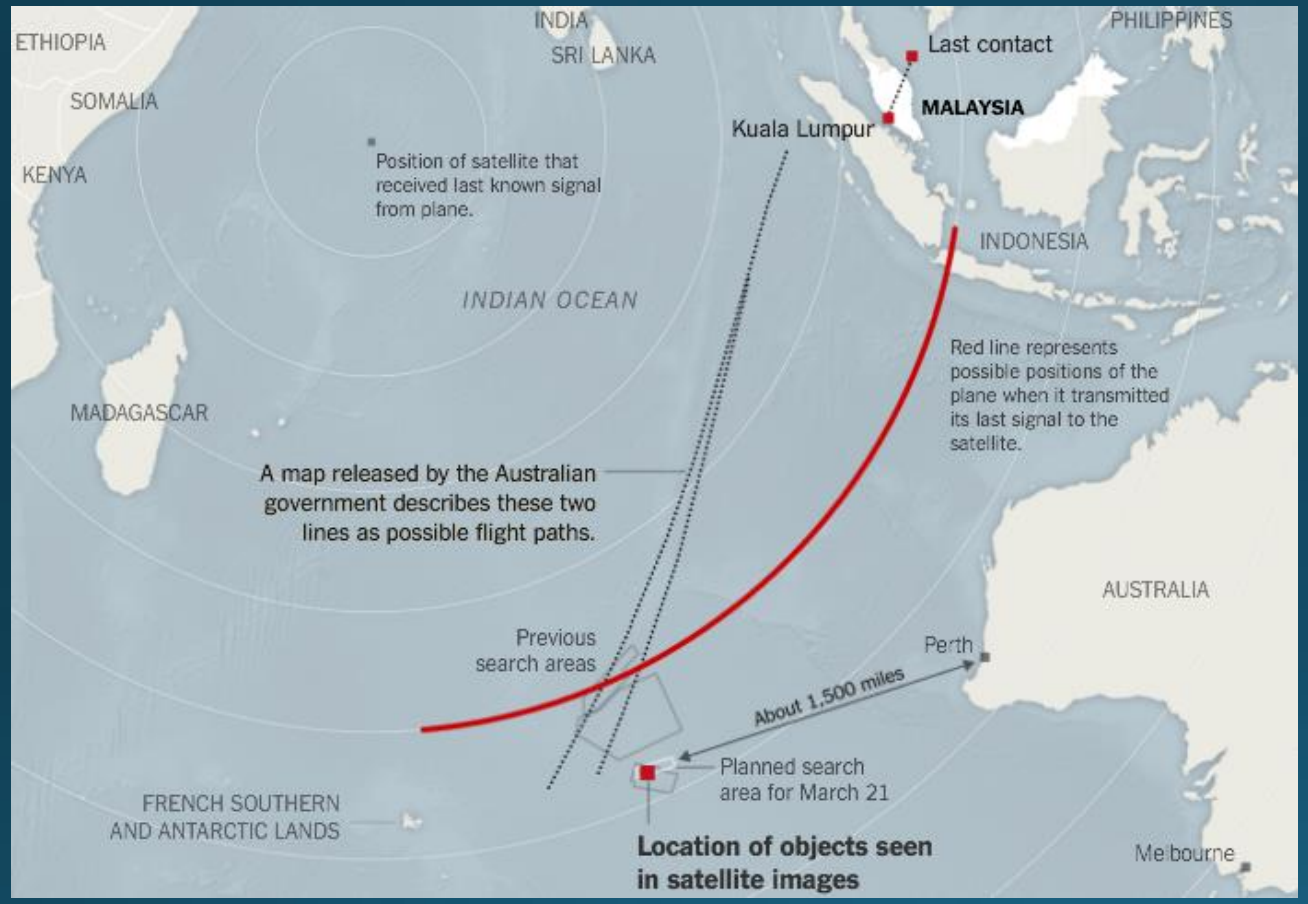
The available range at the last contact was initially estimated to be about 4000 km: the golden circle above.

Initial satellite data analysis by Inmarsat provided a second clue: the red circle segments on the right-hand map above.

The circles intersect on two points. The southern one gives the more likely position: off the coast of Australia.

However, based on further analysis, explained in the ATSB report from June 26, 2014 the first actual search areas, chosen some ten days later, were located far more tot he southwest of that position.

First Search Areas



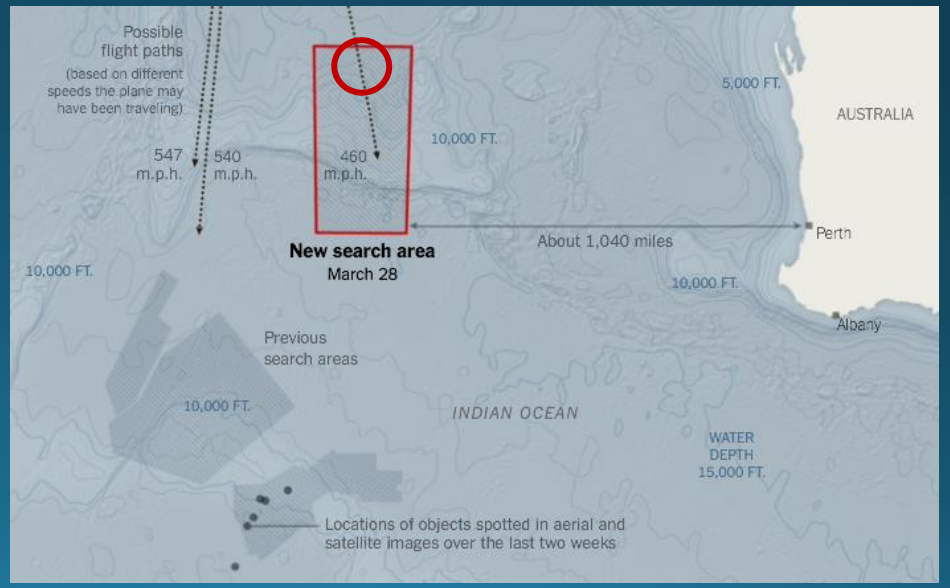
Map source: New York Times

Satellite imagery showing floating debris seemed to support the choice of the search areas. However, no debris was found that could be connected to an aircraft in general, let alone MH 370 in particular.

Second Search Area

In the mean time another piece of information surfaced: MH 370 was last seen at 02:25 LT south of Phuket. Using that position and assuming a lower speed, consistent with a lower cruise altitude than initially assumed, for March 28 a new search area was chosen in a more northwesterly location.

But a different approach is possible: an analysis that would not take a speed but a track as a starting point. That approach will, at a minimum, yield more conclusive results. See the next slides.



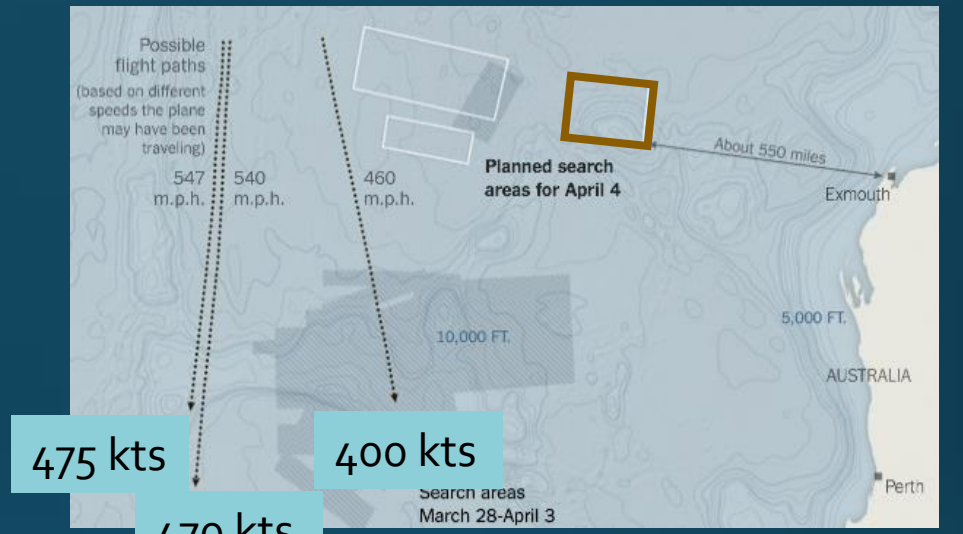
Map source: New York Times

Assuming a Speed to Find a Track

The first search areas were chosen based on an assumed **constant speed.** But the options for picking a speed are manifold. Thus many tracks will result, as is illustrated on the map, with many final positions.

Assuming a **constant track** however would simplify matters and would thus be more effective: a constant track combined with the satellite range plots will automatically yield just one final position. Plus a speed. Which can then be tested for plausibility.

Assuming deliberate action, this would better fit operational reality as well. For a pilot, wanting to fly to a specific area, will quite likely define a track and will then follow that track. And when a constant true track is plotted on an Mercator chart, the result will be a straight line. Thus a speed, at which the satellite plots yield a straight line, will be a speed that should be tested for plausibility.

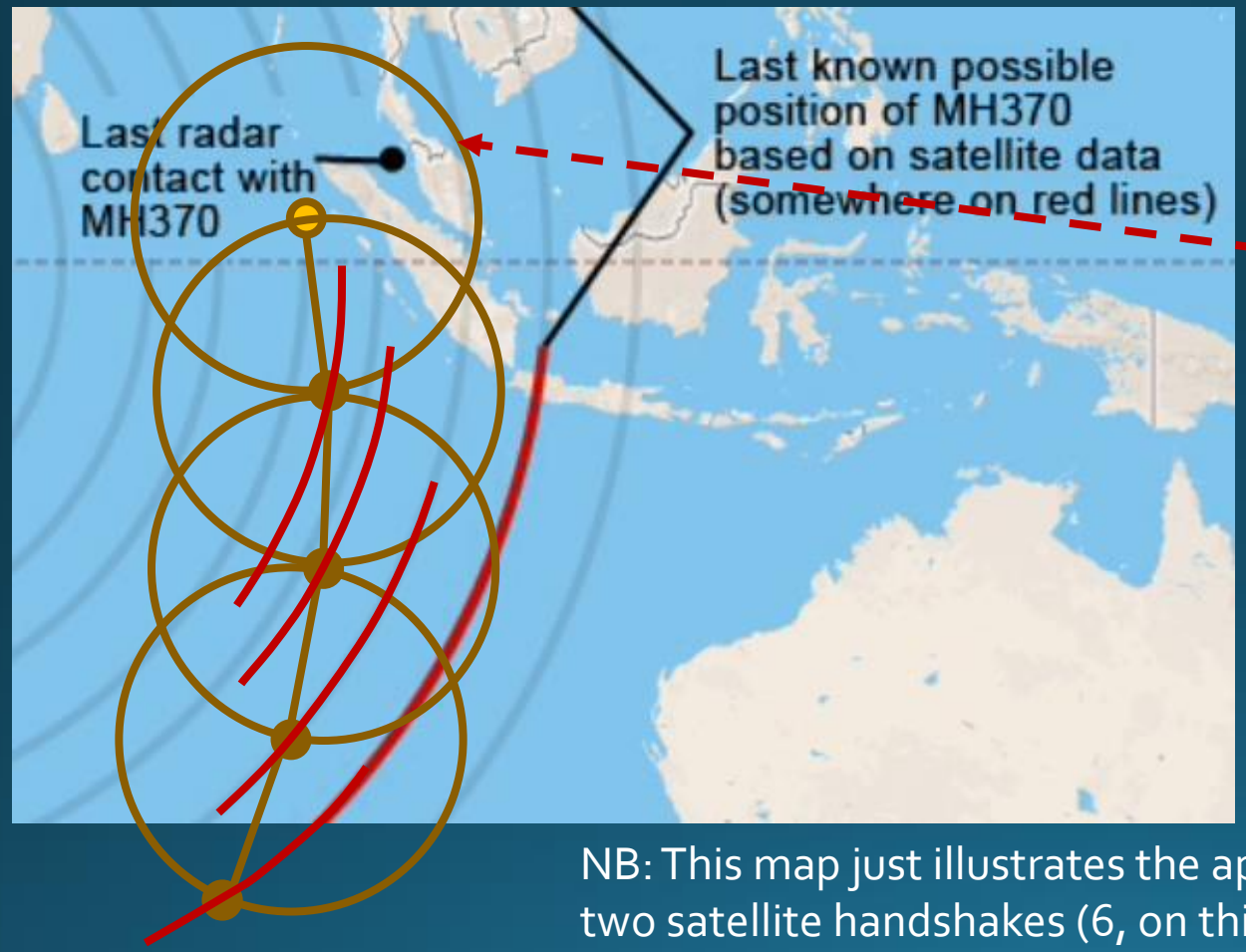


Map source: New York Times

Another navigational option is to define a distant manual waypoint in the direction the pilot wants to go. The Flight Management System (FMS) will then follow a Great Circle Segment (GCS) connecting the present position with that waypoint, as a GCS is the shortest connection between two points on a globe.

For north-south tracks true tracks and GCSs are identical, as these are always on a meridian and every meridian is itself a great circle. For East-West tracks the difference is only zero on the equator, as this is also a great circle. Away from the equator the difference increases with increasing latitudes.

Assuming a Track to Find a Speed



Most speeds do not yield a straight line or a GCS.

This one e.g. doesn't.

NB: This map just illustrates the approach. So far only the last two satellite handshakes (6, on this map, and 7, the incomplete one) were actually published.

Assuming a Track to Find a Speed

Most speeds do not yield a straight line or a GCS.

Nor does this one, a somewhat lower speed.

NB: This map just illustrates the approach. So far only the last two satellite handshakes (6, on this map, and 7, the incomplete one) were actually published.

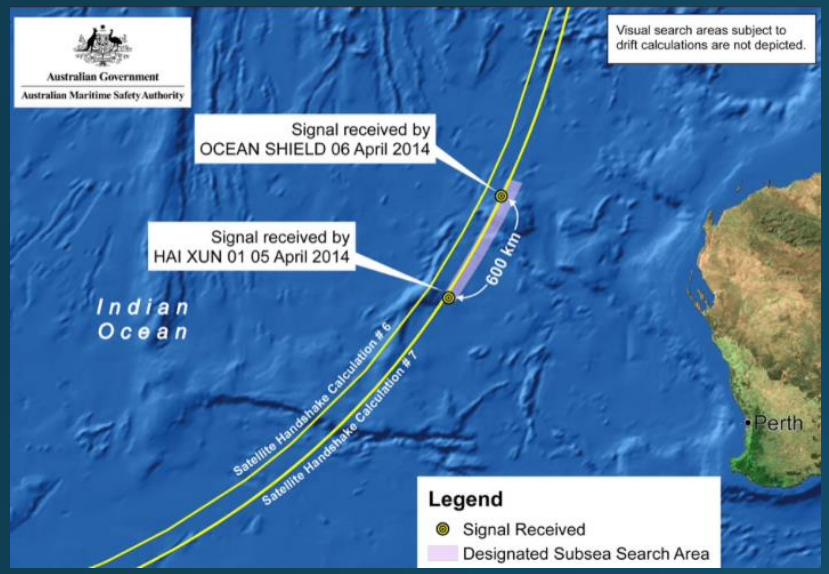
Assuming a Track to Find a Speed

Most speeds do not yield a straight line or a GCS.

But this speed does and should thus be tested for plausibility.

NB: This map just illustrates the approach. So far only the last two satellite handshakes (6, on this map, and 7, the incomplete one) were actually published.

A Lucky Break?



The specified pinger battery life time was almost over.

In a somewhat desperate attempt the limited-range pinger locator was deployed, near the most likely location the satellite data yielded, even though the area of uncertainty was still quite large.

And initially signals were detected. However, no more signals were heard after April 8 .

Furthermore, signal analysis indicated that all signals were most probably false. All that remains now is a time-consuming sonar search, starting with the mapping of a large area of the seabed, at locations based on further sophisticated and truly ground-breaking satellite data analysis.

A story that fits the facts and can be falsified

A Simple Scenario

The Most Simple Scenario

The complexity of the events appears to fit a plan. The most simple, but not necessary correct, scenario presumes a deliberate act, with one of the crewmembers*, most likely the Captain, as actor and the creation of a mystery as the intention. This is of course just a hypothesis. But it is a falsifiable one. The hypothesis can be supported or dismissed by already available or potentially available data. The next set of questions e.g. can already be answered now, even though so far that has not yet been done. At least not publicly:

- What was the actual take-off weight and how much fuel was carried?
- Who made the first report to ATC that FL 350 was reached?
- Who did that the second time, six minutes later?
- Who spoke last with Air Traffic Control?
- What times and altitudes are available from the plot of the military radar sightings?
- What are the exact plots of the not-yet-published satellite handshake circles?

More data to support or dismiss the hypothesis has to come from the flight data recorder. Some of the questions are:

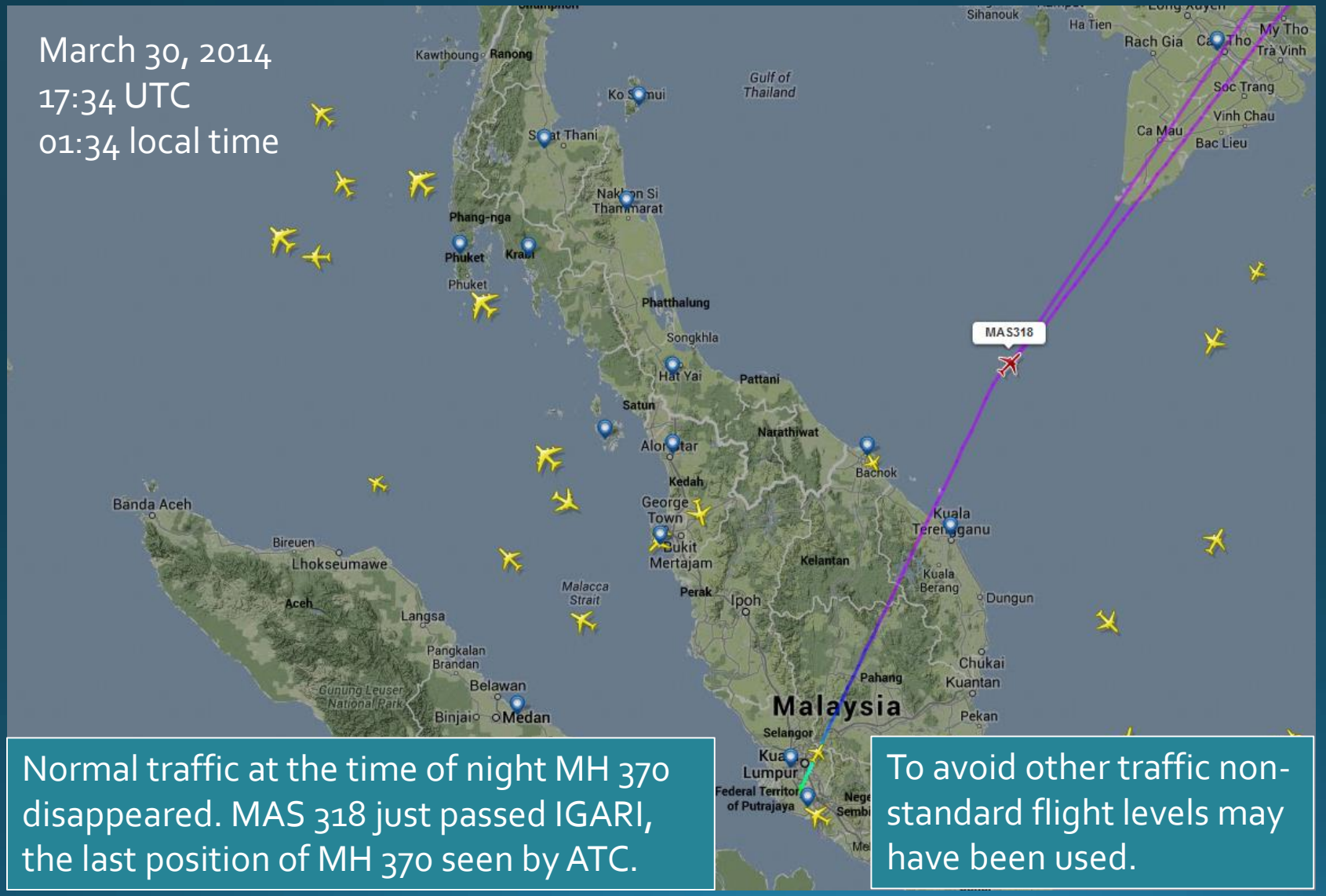
- How were the track and altitude changes initiated?
- Has the pressure cabin system been manipulated?
- Has the passenger oxygen system been manipulated?
- Did the engines flame-out due to fuel starvation?
- Where the fuel cross-feed valves opened?
- Did the APU perform the designed auto-start?
- If it did, how long did it remain running?
- Did the Ram Air Turbine (RAT) activate?
- Was a controlled ditching attempted?
- If so, was that attempt successful, or did the aircraft crash?

** A hijack is also a possibility of course , but would yield a much more complex scenario.*

The Proposed Events

	Event	Remarks
1	Capt. sends F/O away	The other way around is unlikely / a hijack is more complicated
2	The actor locks the cockpit door	Since 9/11 designed to keep people out
3	Switches off all communication	In four stages: Radio, ACARS, ADS-B, Transponder
4	Leaves airway in Vietnam airspace	A mid-air collision would prevent the mystery
5	Turns back and climbs to max unused level	E.g. FL 395 or FL 400, close to maximum for estimated weight
6	Disables pax oxygen, opens outflow valves	Or pax oxygen deploys: supply lasts only about 10 minutes
7	Crosses Malaysia via airways to Penang	To reduce suspicion by military radar operators
8	Leaves airway, descents to 4000'	Direct to ANOKO, passes N0530E99 (near Perak Island)
9	Hooks around Indonesia out of radar range	4000' or lower limits radar detection range to less then 80 NM
10	Sets track for South of Indian Ocean	True Track 180° or manual waypoint S40E95
11	Climbs to FL 300	To extend range, and normally unused, higher is possible
12	Sunrise at ± 07:00 LT, 19:00 UTC	Ditching in the dark is more likely to fail
13	Opens fuel cross-feed valves	To ensure engines stop at the same time
14	Starts descent, engines flame-out	Loss of electrical power and thus satellite connection
15	Ram Air Turbine (RAT) deploys	Restores some elec. power, explains start of partial handshake
14	Ditches aircraft, RAT stops, handshake stops	If successful prevents floating debris and ELT activation
15	Ditching successful, aircraft sinks	Mystery would be complete, save for satellite data

Avoiding Other Traffic

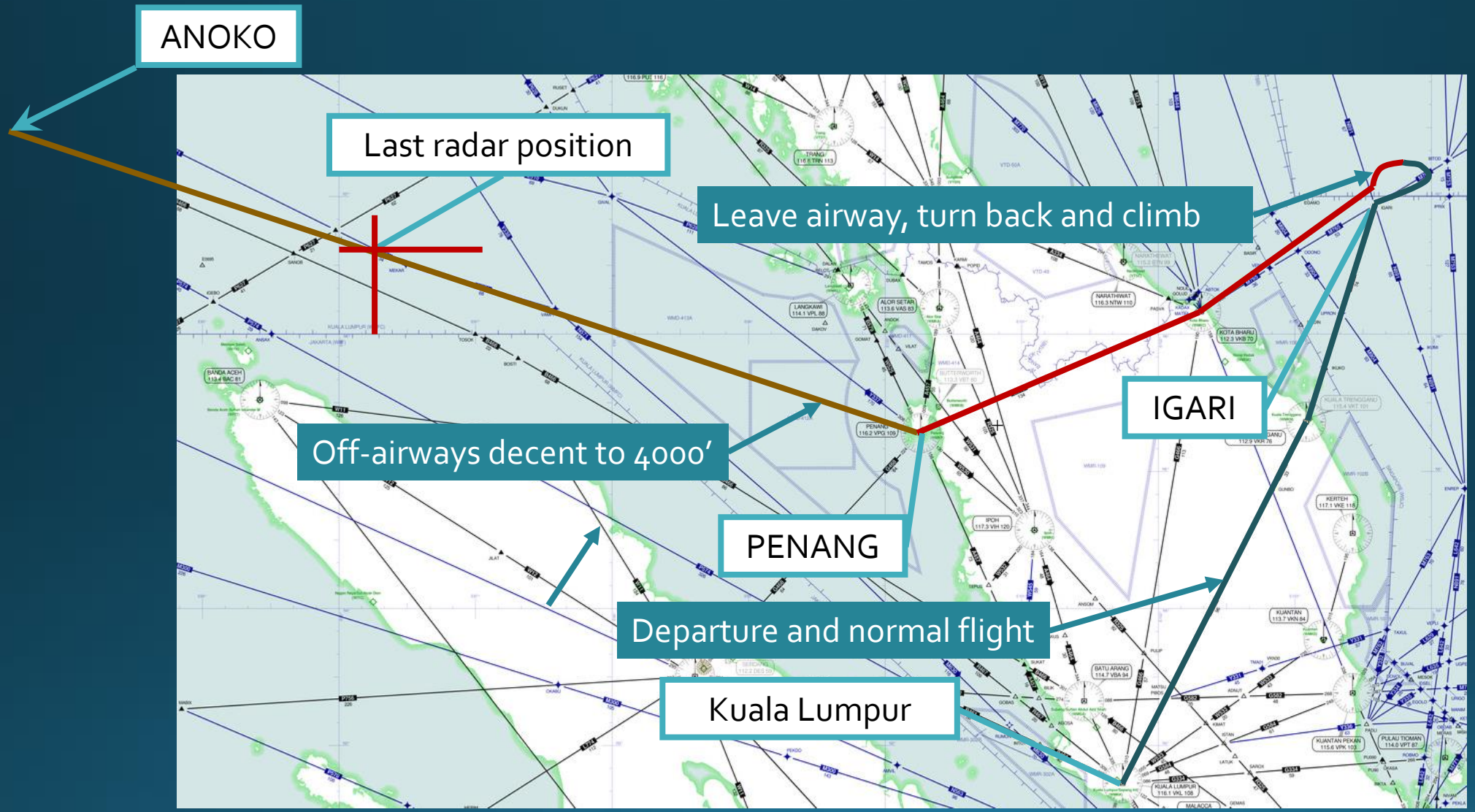


Normal traffic at the time of night MH 370 disappeared. MAS 318 just passed IGARI, the last position of MH 370 seen by ATC.

To avoid other traffic non-standard flight levels may have been used.

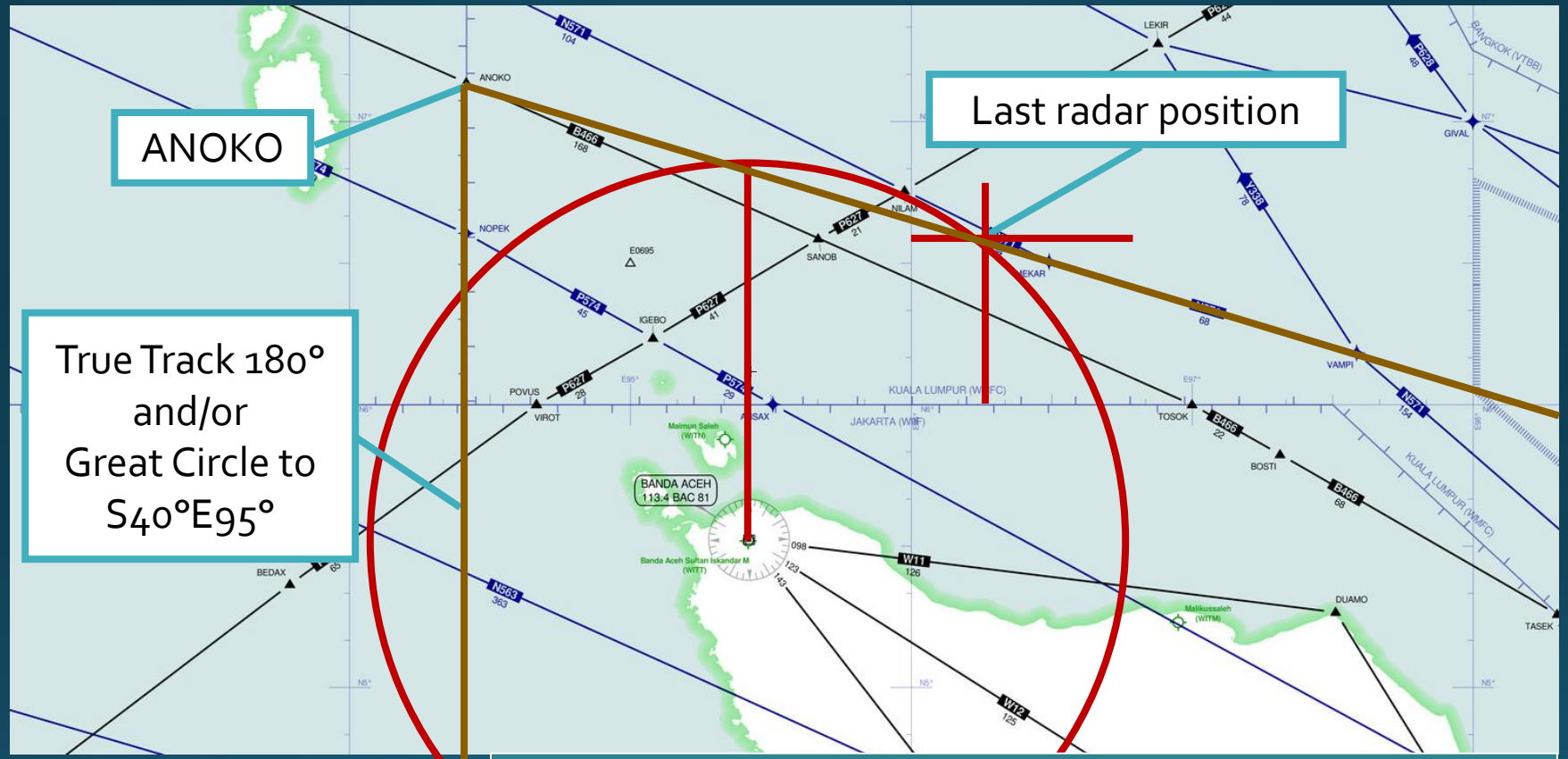
Map source: Flightradar24.com

Altitudes and Waypoints Possibly Used



Map source: SkyVector.com

Around Indonesia (range radar: ± 80 NM, the red circle, for 4000', ± 60 NM for 2000')



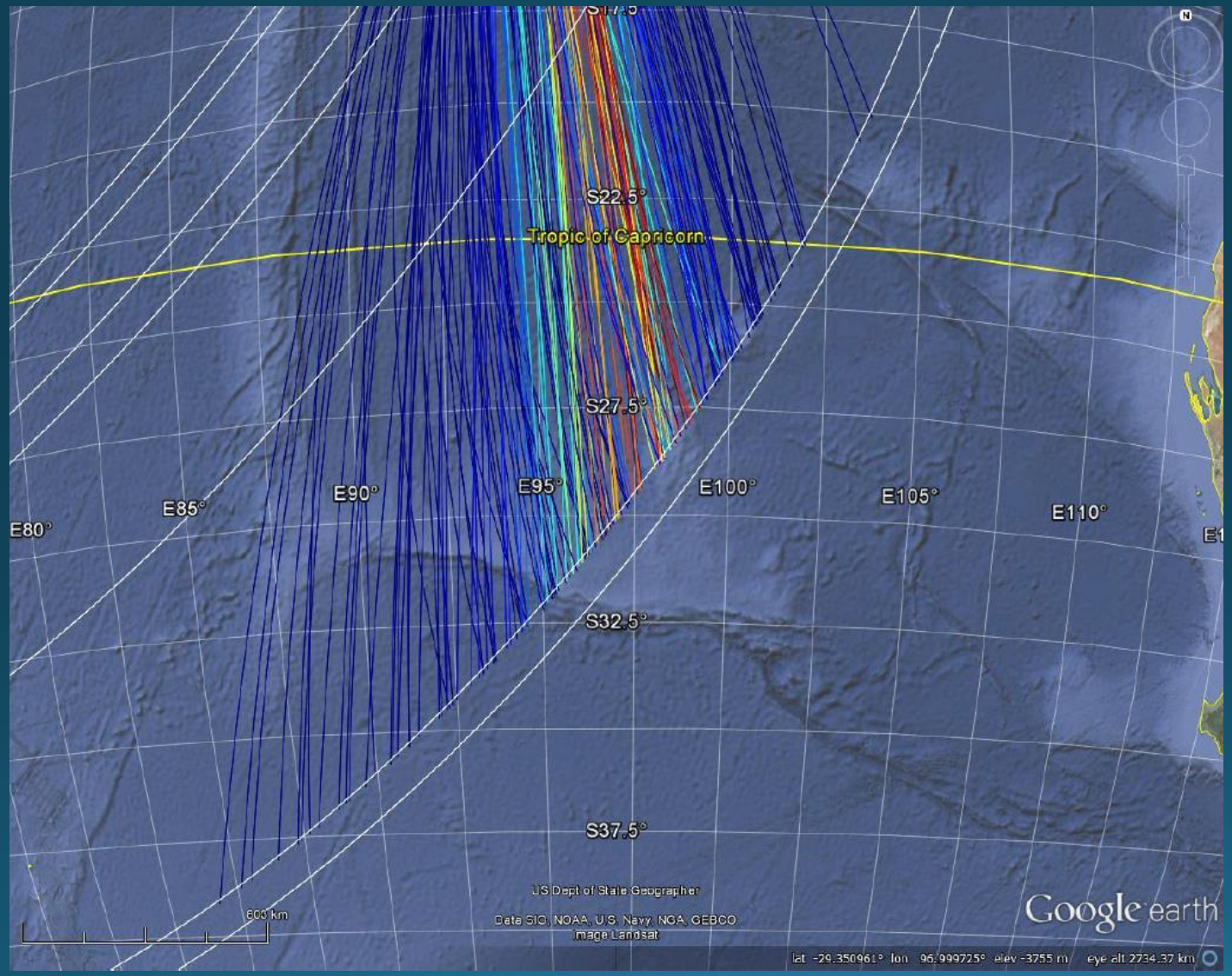
Map source: SkyVector.com

Note: actual presence, location or nominal range of radar stations unknown at this time.

To get a track on the navigation display from ANOKO to the possible final position a true track of 180° could be selected or a simple manual waypoint could be entered into the FMS (Flight Management System), likeS40°E95°. The resulting tracks would be almost the same in this case because of the North-South orientation.

Possible tracks

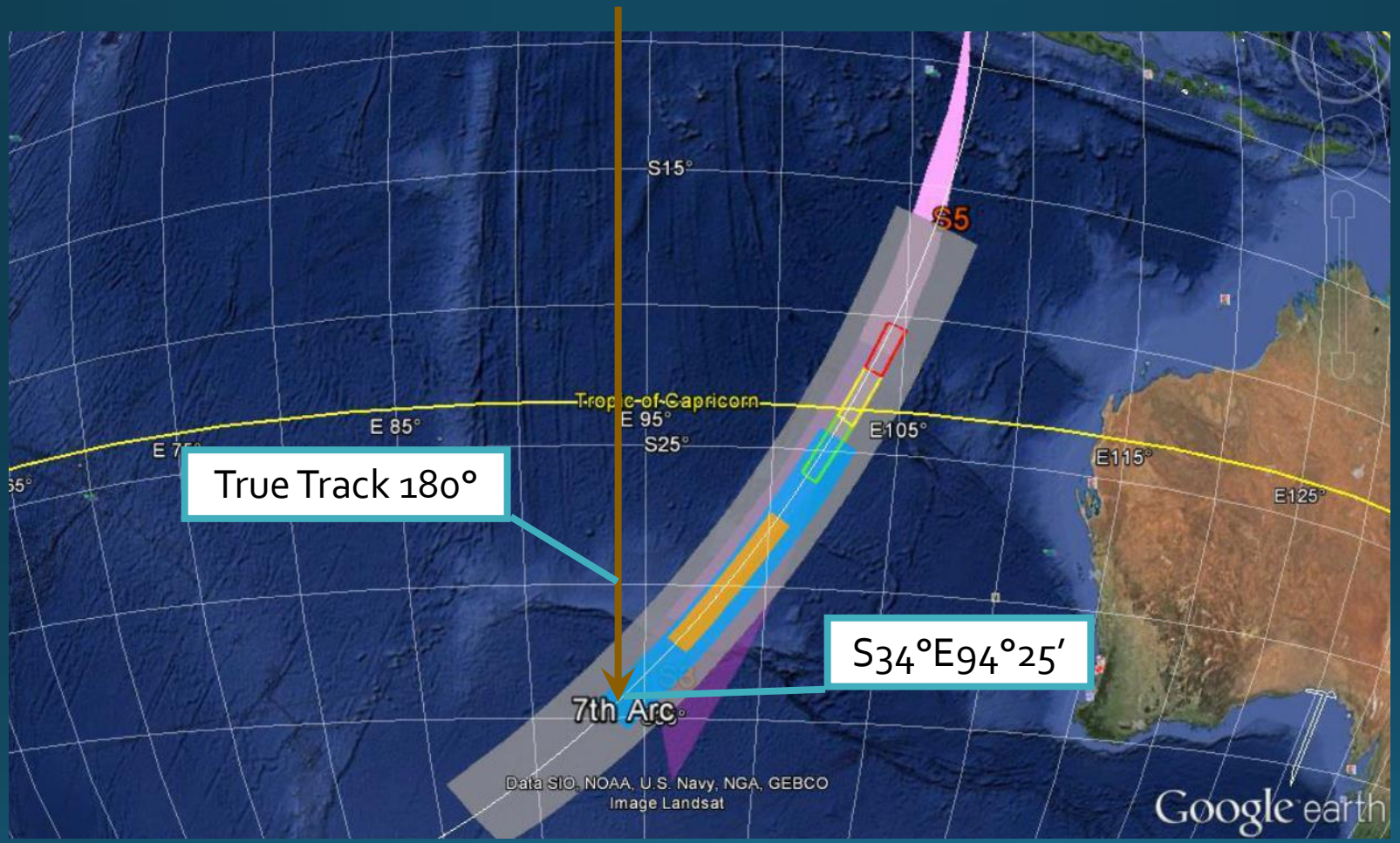
(based on sophisticated satellite data analysis and different auto pilot modes)



Source: ATSB

Priority Search Areas versus a Tentative Final Track

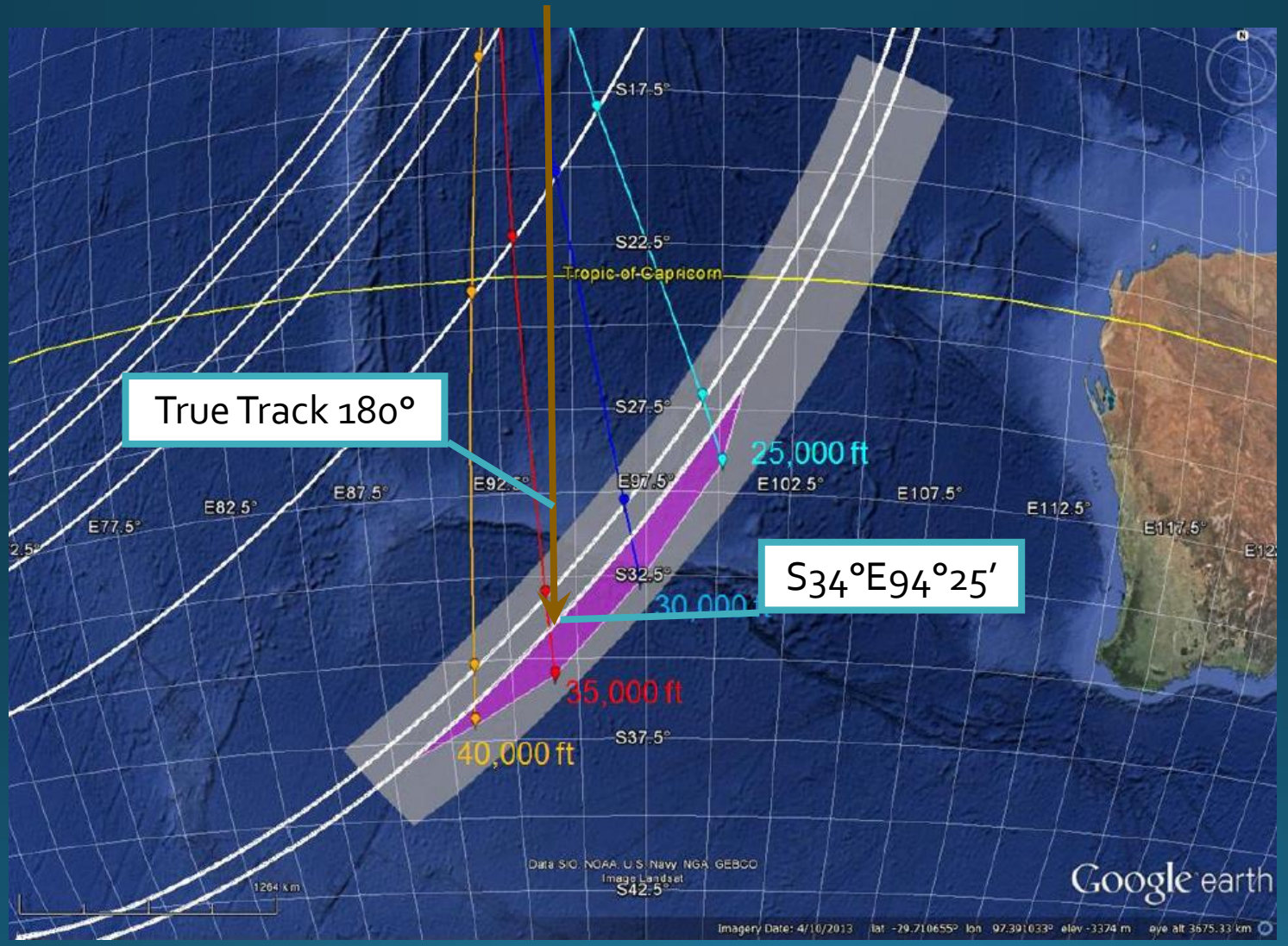
A track straight south from ANOKO has the benefit of simplicity and might fit the data



Underwater search area from June report. Orange area has the highest priority. True track 180° from ANOKO crosses the 7th arc at S34°E94°25′, thus more to the south, at the edge of the blue lower priority area. A later report from the ATSB, *MH370 – Flight Path Analysis Update* (October 8, 2014), states that a more southerly location is more likely, based on further analysis of the satellite data.

Maximum Range Cruise Boundary

A track straight south from ANOKO would also end within the magenta are, the maximum possible range as established by the ATSB



Source: ATSB - Flight path reconstruction group

Crash or controlled ditching?

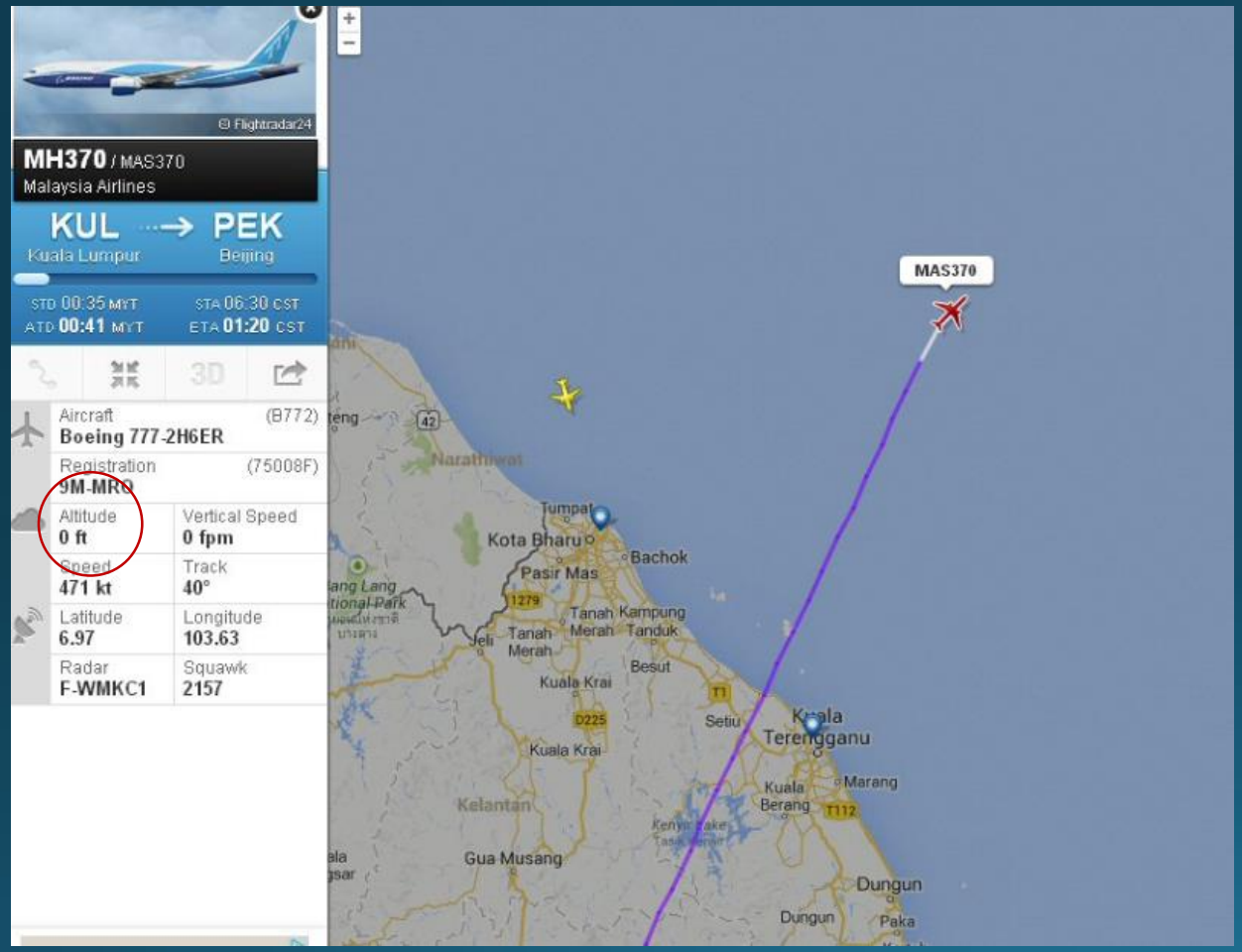
- Crash:
  - Flight completion on auto pilot without human control
  - Not likely that engines will flame out at the same time
  - Thus not likely that APU will start and Ram Air Turbine (RAT) will deploy
  - Emergency locator beacons (ELT) might activate
- Controlled ditching:
  - With cross feed valves open engines will flame out at the same time
  - Electrical power will be lost
  - Thus APU tries auto start and RAT will deploy for limited electrical and hydraulic power
  - APU might start on residual fuel in lines but will stop quickly as fuel is exhausted
  - Limited electrical power will be available till contact with water stops RAT
  - ELTs will probably not activate
- The last satellite handshake, off-schedule and incomplete, supports the controlled ditching sequence

Note: At this time it is not known to us whether or not the RAT also feeds the SATCOM Classic Aero terminal. If it does not, the APU must have been able to run for a few minutes and the actual ditching area could be quite far beyond the 7th arc, because the connection would then stop due to fuel starvation of the APU. Thus the 7th arc would be less indicative of the actual ditching position. This would complicate the search effort even more.

how to do what

Technical background

ACARS disabled at 01:19 LT?

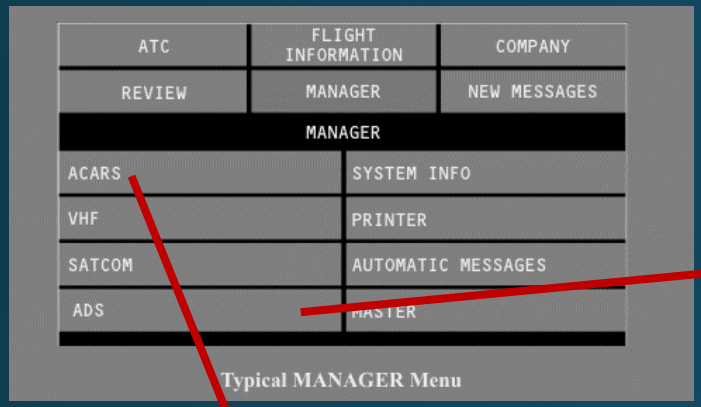


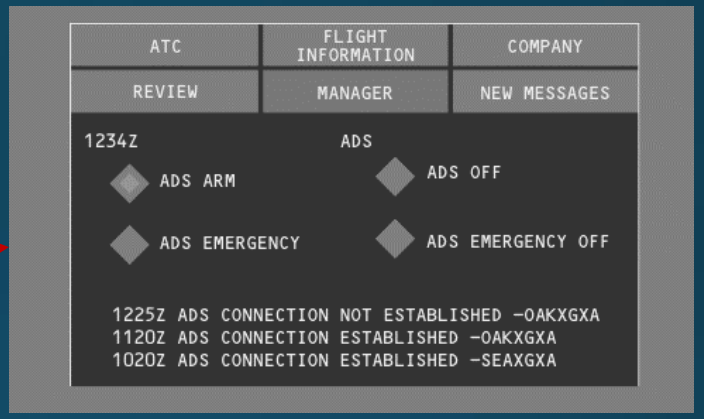
The last ADS-B picture of flight MH 370, just past waypoint IGARI. From this point on ADS-B information was not transmitted anymore.

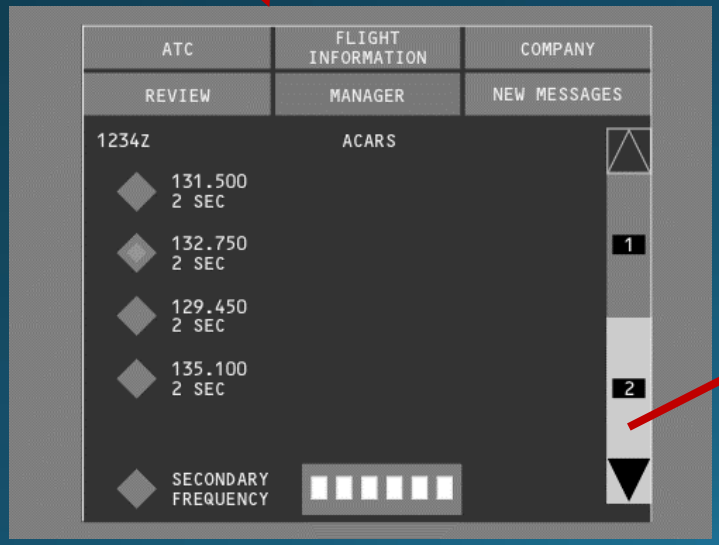
However, about a minute earlier the altitude information was already gone: at the position where the track line turns white the altitude indication dropped to zero. This could indicate that at that time the ACARS system was switched off.

Map source: Flightradar24.com

Disabling ACARS and ADS







Can be done via the COM page on an MFD (Multi Function Display). Not complicated, but requires extensive system knowledge.

Time of Useful Consciousness (TUC)

Time of Useful Consciousness	
Altitude (feet)	Consciousness
15,000	30 minutes or more
18,000	20-30 minutes
22,000	5-10 minutes
25,000	3-5 minutes
28,000	2.5-3 minutes
30,000	1-3 minutes
35,000	30-60 seconds
40,000	15-20 seconds
45,000	9-15 seconds
50,000	6-9 seconds

De TUC indicates how long sensible actions remain possible when the aircraft depressurizes at the altitude given.

After the TUC, actions become random and the individual will become euphoric, until consciousness is lost and the individual deceases.

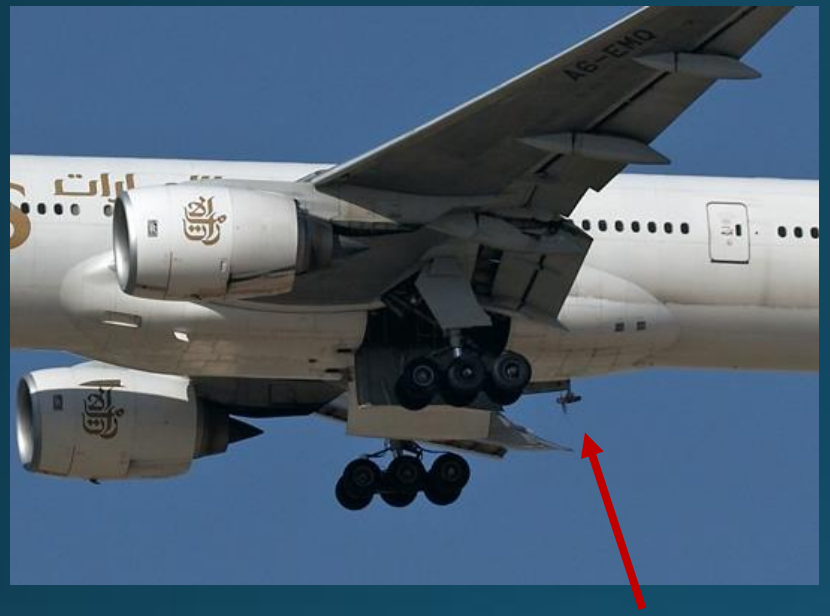
Source: Skybrary.aero

A Tentative Flight Plan

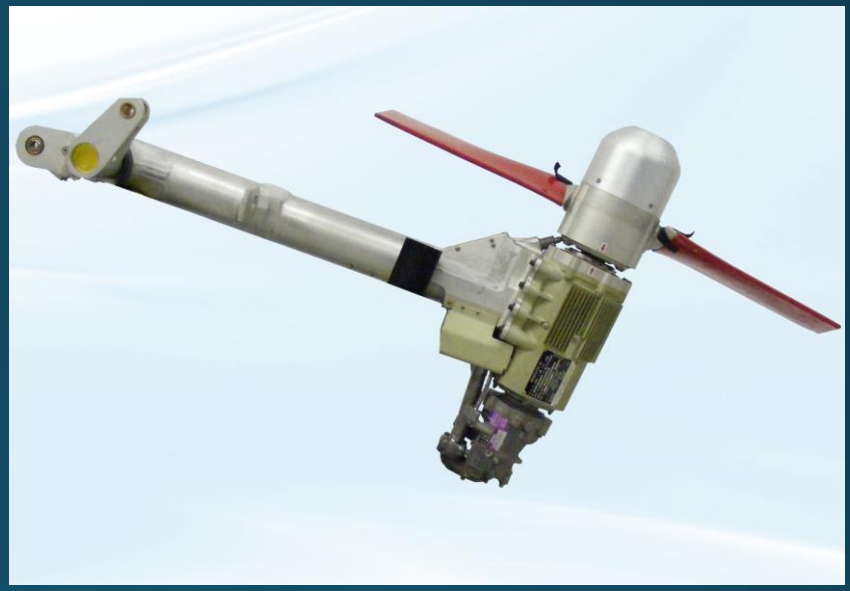
	Distance			Time			Speed			Fuel in tons			
Waypoint	Interval	Total	FL	Int.	ET	UTC	GS	TAS	Selected	Used	Rem.	FF	Remarks
KUALA LUMPUR	0	0	T/O		0:00	16:41				0.0	49.0		Fuel on departure is estimated
MATOU	60	60	climb										
TOC	60	120	climb	0:20	0:20	17:01							
GUNBO	36	156	350	0:06	0:26	17:07			CRZ ECO	5.2	43.8		Last ACARS message
VKR	33	189	350						CRZ ECO				
IKUNO	23	212	350						CRZ ECO				
IGARI (outbound)	74	286	350	0:13	0:39	17:20			CRZ ECO				Transponder off.
IGARI (inbound)	80	366	390						V_{MO}/M_{MO}				In Vietnam Airspace.
VENLI	53	419	390						V_{MO}/M_{MO}				
VKB	36	455	390						V_{MO}/M_{MO}				
PENANG	134	589	390						V_{MO}/M_{MO}				
N05°30'E99°	75	664	descent	0:33	1:12	17:53			V_{MO}/M_{MO}	4.3	39.5	6.1	
Last radar position	176	840	40	0:29	1:41	18:22	363	358	V_{MO}/M_{MO}				Last seen by Thai radar.
ANOKO	114	954	40	0:19	2:00	18:41	363	358	V_{MO}/M_{MO}				
South of ANOKO	200	1154	climb	0:33	2:33	19:14	363	358	V_{MO}/M_{MO}	11.0	28.5	8.1	
S34°E94°25' ???	2268	3422	300	5:05	7:38	00:19	454	465	LRC	28.5	0.0	6.0	With 20 minutes power off descent
Note: N05°30'E99° is near Perak Island													

IAS = Indicated Air Speed, TAS = True Air Speed, GS = Ground Speed, all in knots. LRS = Long Range Cruise. Distance is in Nautical Mile (NM)
After IGARI maximum speed, V_{MO}/M_{MO}, is chosen to limit the exposure time after the missing of MH370 is noticed.
The only fuel figure publicized to date is the fuel from the last ACARS message at 17:07 UTC.
All fuel figures are plausible best estimates.

The Ram Air Turbine (RAT)



B777-200ER in flight with deployed RAT



When all electrical power is lost the RAT will deploy automatically and will supply limited electrical and hydraulic power for some flight instruments, some flight controls and some communication.

Closure delayed is closure denied

A Few Final Words

As stated earlier, this presentation does not state was has happened to MH 370, but just formulates the most simple scenario possible that would fit the available information. The next scenario, complexity-wise, is a deliberate act by the First Officer, the next by a hijacker. These three scenarios should be analyzed and supported or dismissed in this order.

If all three are dismissed, the remaining scenarios will be far more complex and the likelihood of finding the wreckage of MH 370 anytime soon will rapidly decrease.

If one of the three deliberate action scenarios can be confirmed, this will at least bring closure. The relatives of the people that were on board of MH 370 will then know for certain that their family and friends are gone. And they might find some comfort in the knowledge that in these three scenarios their loved ones most likely did not suffer, but passed away, perhaps even peacefully, in a very early stage.

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May 3, 2014