A Case Study In Public Data Release:
Flight Path of Malaysia Airlines MH370

On Public Data Release

May 27, 2014, Malaysia DCA and Inmarsat released satellite communication logs for flight MH370.

"The goal of publication is transparency, not verification"

Mark Dickinson, Inmarsat

"The data itself is barely understandable, very opaque and you cannot draw too much from it."

"It is definitely not something someone can pick up and run with it and generate the same numbers."

The purpose of this talk is to demonstrate otherwise.

I. Timeline

II. Satellite Communication System

III. Public data products and analysis
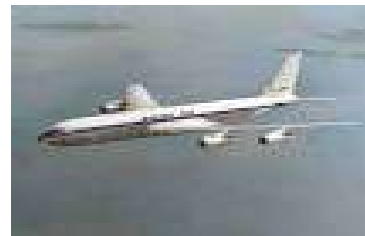
IV. Breaking News

V. Lessons learned

A seemingly ordinary air disaster –

March 8, 2014 (MT) Malaysia Airlines Flight MH370, a Boeing 777 jet on a flight from Kuala Lumpur to Beijing, has lost contact. All indications are that it has crashed in the South China Sea between Malaysia and Vietnam.

[BOAC 781 (1954); Flying Tiger 739 (1961); Varig PP-VLU (1979); Air France 447 (2009)]

07:24 (MT) – MAS issues media statement

MEDIA STATEMENT released at 7.24am/8 Mar 2014 MH370 Incident

Sepang, 8 March 2014: Malaysia Airlines **confirms that flight MH370 has lost contact with Subang Air Traffic Control at 2.40am, today (8 March 2014).**

Flight MH370, operated on the B777-200 aircraft, departed Kuala Lumpur at 12.41am on 8 March 2014. MH370 *was* expected to land in Beijing at 6.30am the same day. The flight *was* carrying a total number of 227 passengers (including 2 infants), 12 crew members.

Malaysia Airlines is currently working with the authorities who have **activated their Search and Rescue team to locate the aircraft.**

However, there is one small detail ...

Unbeknownst to anyone, the plane is

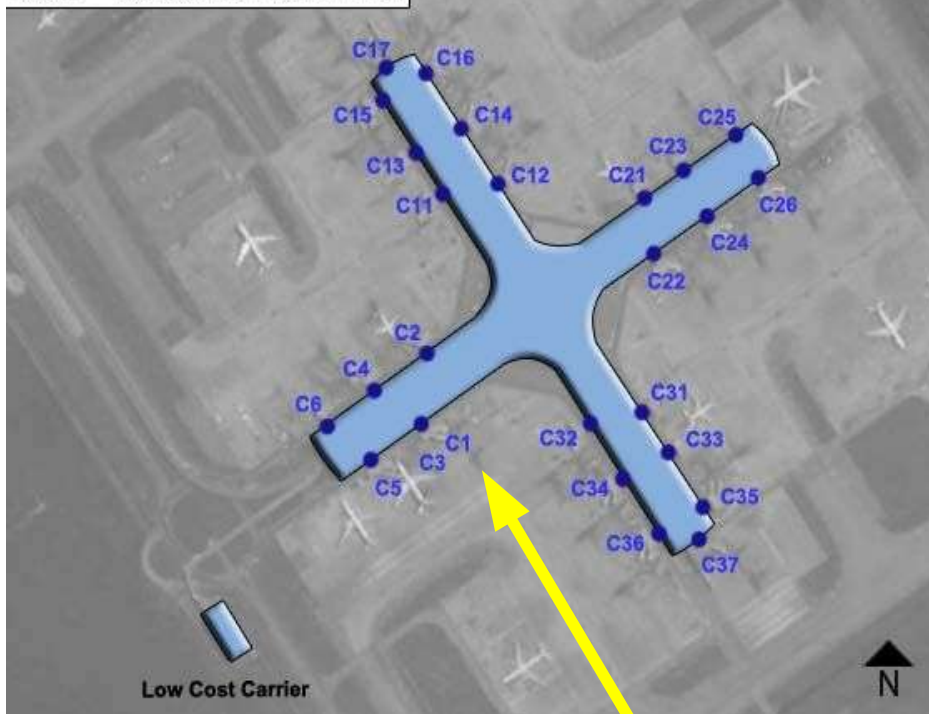*STILL IN THE AIR!*

I. Timeline of MH370

Planned Flight

- 16:00 to 24:19 UT, March 7, 2014

- Note: Malaysia and China timezone are 8 hours ahead of UT – hence March 8 MST.

16:00 UT – Passengers boarding MH370 at Kuala Lumpur airport satellite terminal, gate C1. SATCOM activated. ACARS message.

What are ACARS messages?

16:29 UT - Plane pushes back from gate. ACARS message.

16:42 UT - Takeoff for Beijing, runway 32R
6 hour flight. ACARS messages.

17:07 UT - MH370 cruising at 35,000 feet 469 knots GS, heading for waypoint IGARI. Last ACARS message.
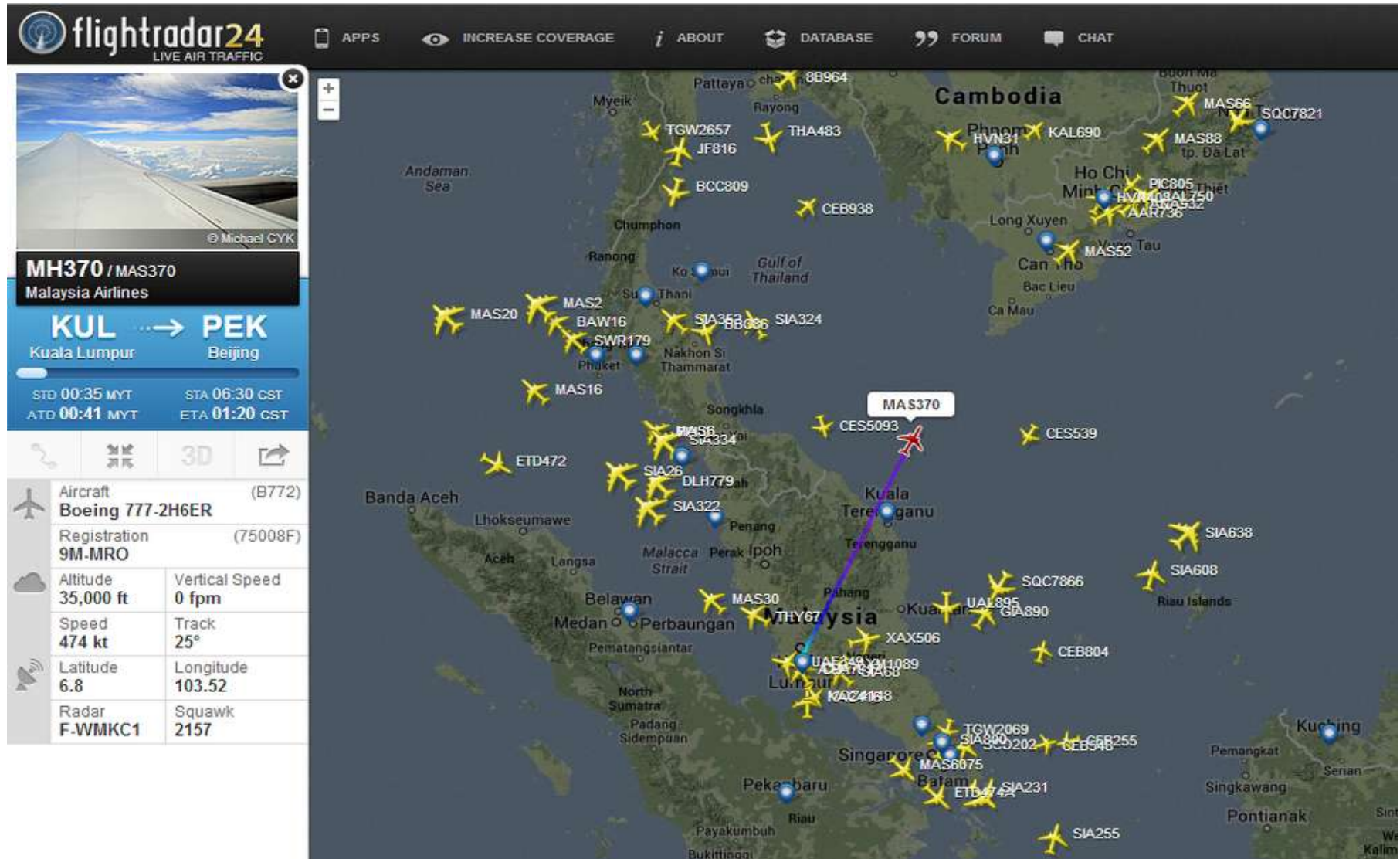
12 minutes later

17:19:29 UT – KL Radar signs off; transfer to HCM FIR. Last voice communication.

17:19:24 (ATC) "Malaysian three seven zero contact Ho Chi Minh 120 decimal nine. Good night."

17:19:29 (MAS 370) "Good night, Malaysian three seven zero."

17:20:31 UT – Arrival at waypoint IGARI ("Transfer of Control Point" - TCP)

2-42 seconds later

17:20:33 UT – Aircraft symbols start dropping off Secondary Radar at HCM, KL, and Bangkok ATCC. Plane becomes invisible to ATC.
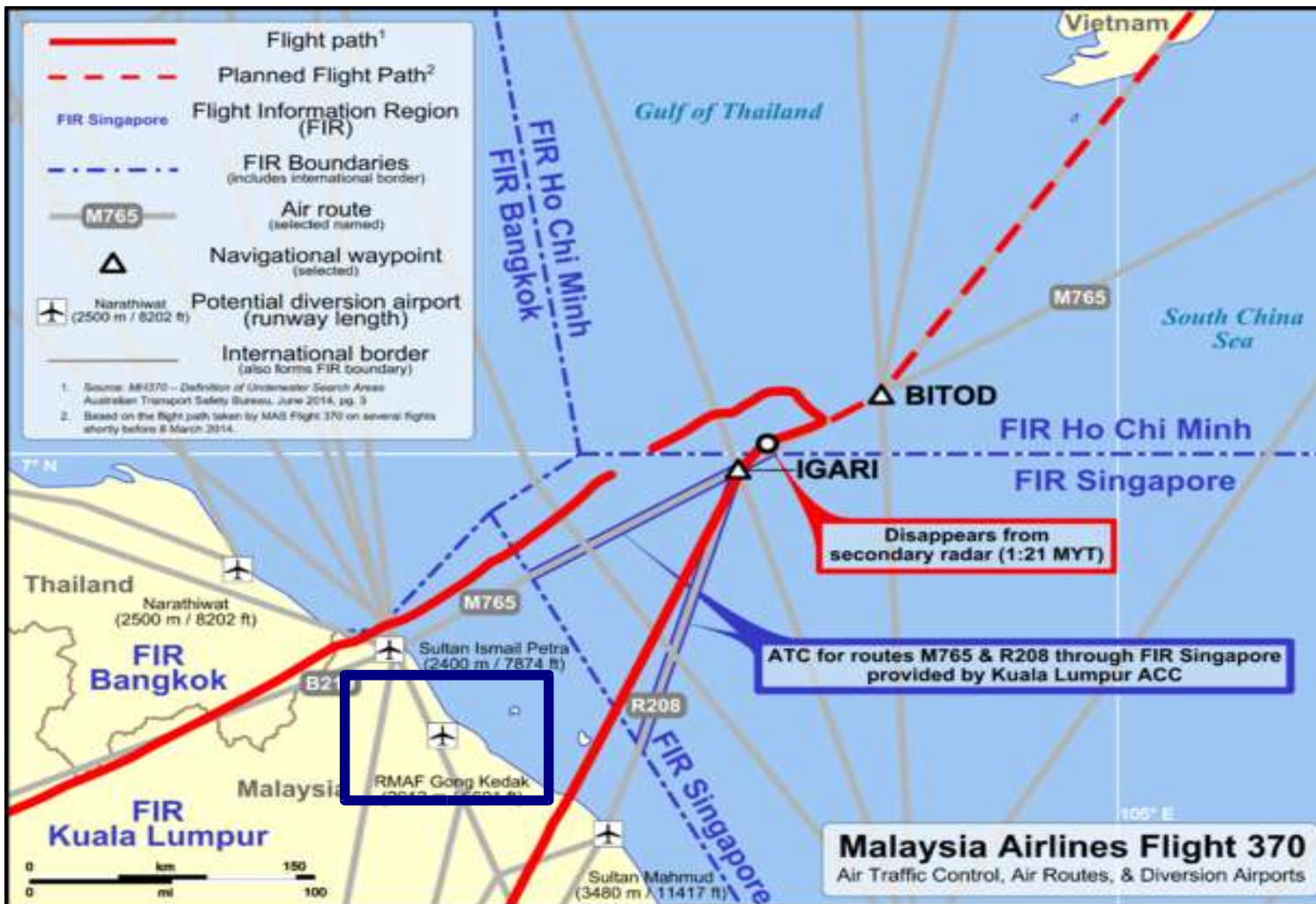

Primary Radar

Secondary Radar

17:23 UT – Plane is still tracked by military primary radar. Plane banks left; heads along Malaysia-Thailand border.

17:37 UT – Next ACARS message due from aircraft - never sent

1 minute later

17:38 UT – HCM and KL ATC begin communicating r.e. location of MH370. Four hours pass before it is fully established that the plane is missing.

Event

17:38:19 Ho Chi Minh first enquired about MH370, informed KL-ATCC that verbal contact was not established with MH370 and radar target was last seen at BITOD.

13 minutes later

17:51 UT – Plane passes S of Penang Island and turns WNW along Strait of Malacca. Now being tracked by military radar on Penang Island
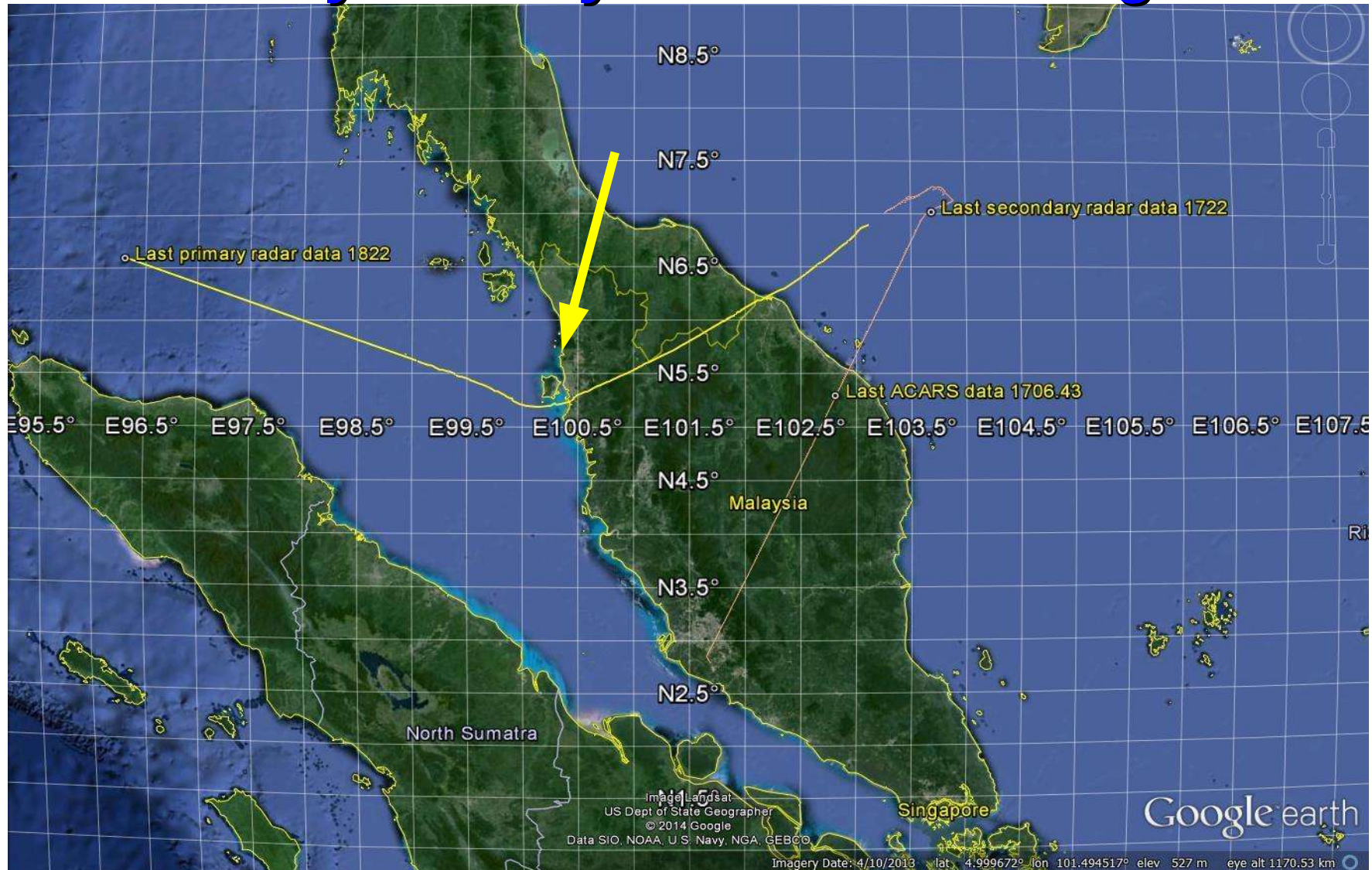
18:04 UT – ACARS message sent from ground to aircraft via satellite; no response. SATCOM inoperative.

18:03 - No Response to Ground to Air DATA-2 ACARS Data. Link lost at sometime between 17:07:48 and here.

|						
7/03/2014 18:03:41.405	IOR-P10500-0-3859	IOR	305	10	P-Channel TX	0x71 - User Data (ISU) - RLS
7/03/2014 18:03:41.405	IOR-P10500-0-3859	IOR	305	10	P-Channel TX	Subsequent Signalling Unit

"PLS CONTACT HO CHI MING ATC ASAP THEY COMPLAIN CANNOT TRACK YOU ON THEIR RADAR"
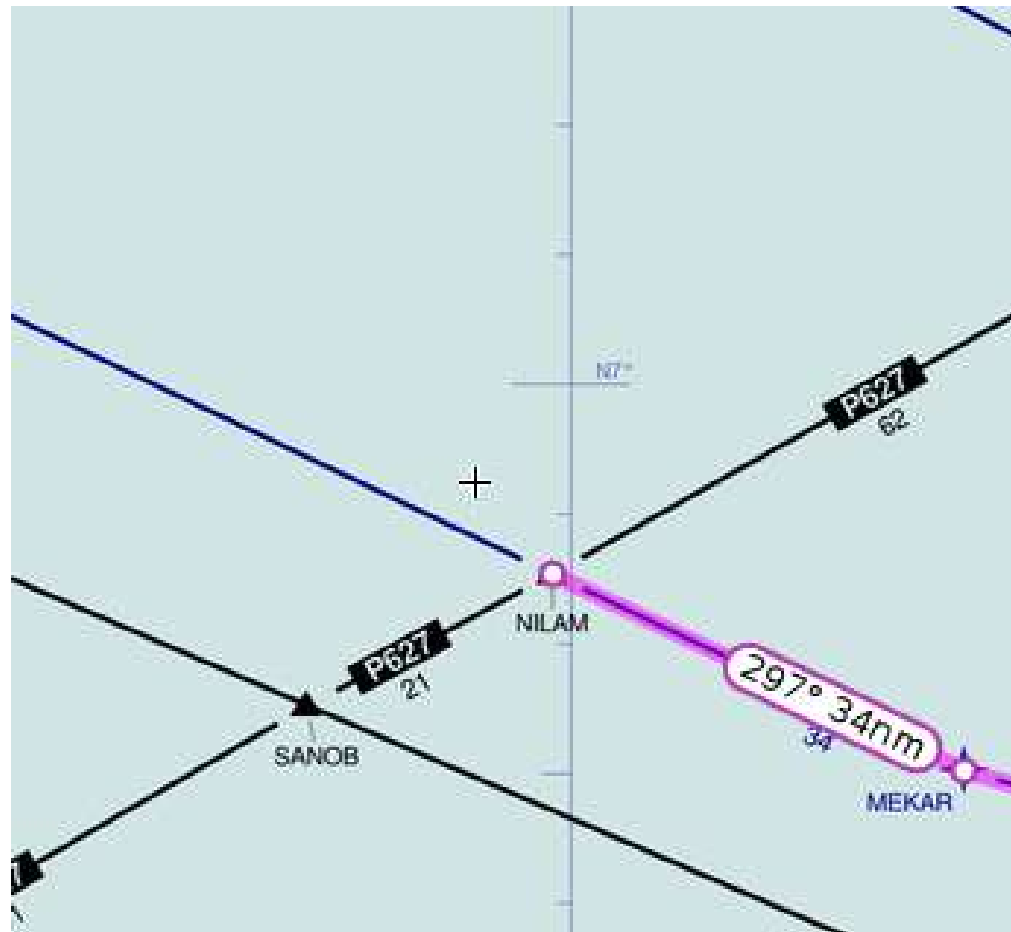
8 minutes later

18:12 UT – Plane reaches waypoint VAMPI; begins following airway N571

18:22 UT – Plane passes out of range of military primary radar. Plane invisible to all.
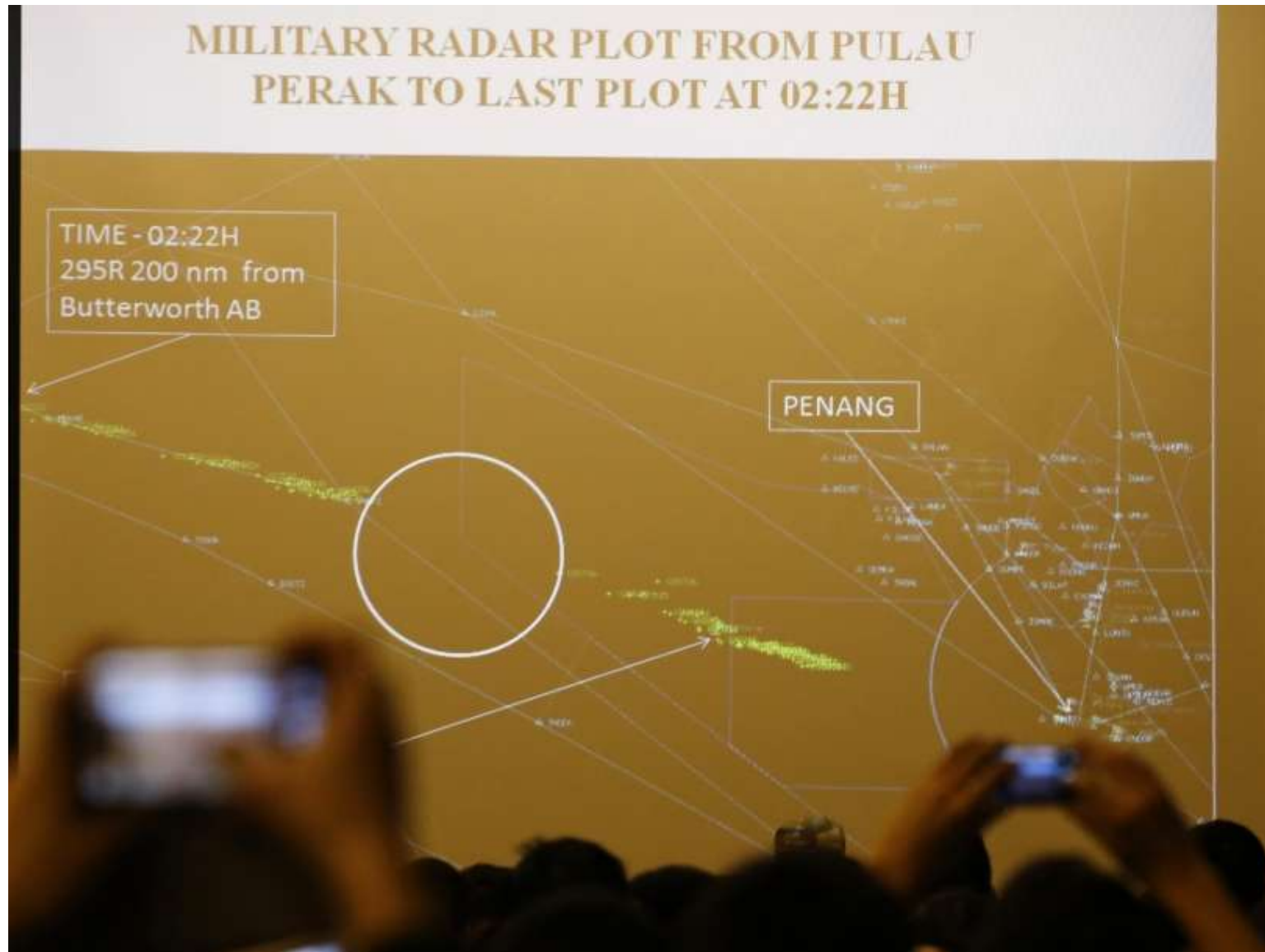
18:25 UT – SATCOM reactivated; logs on to satellite network. Plane appears to be continuing WNW track

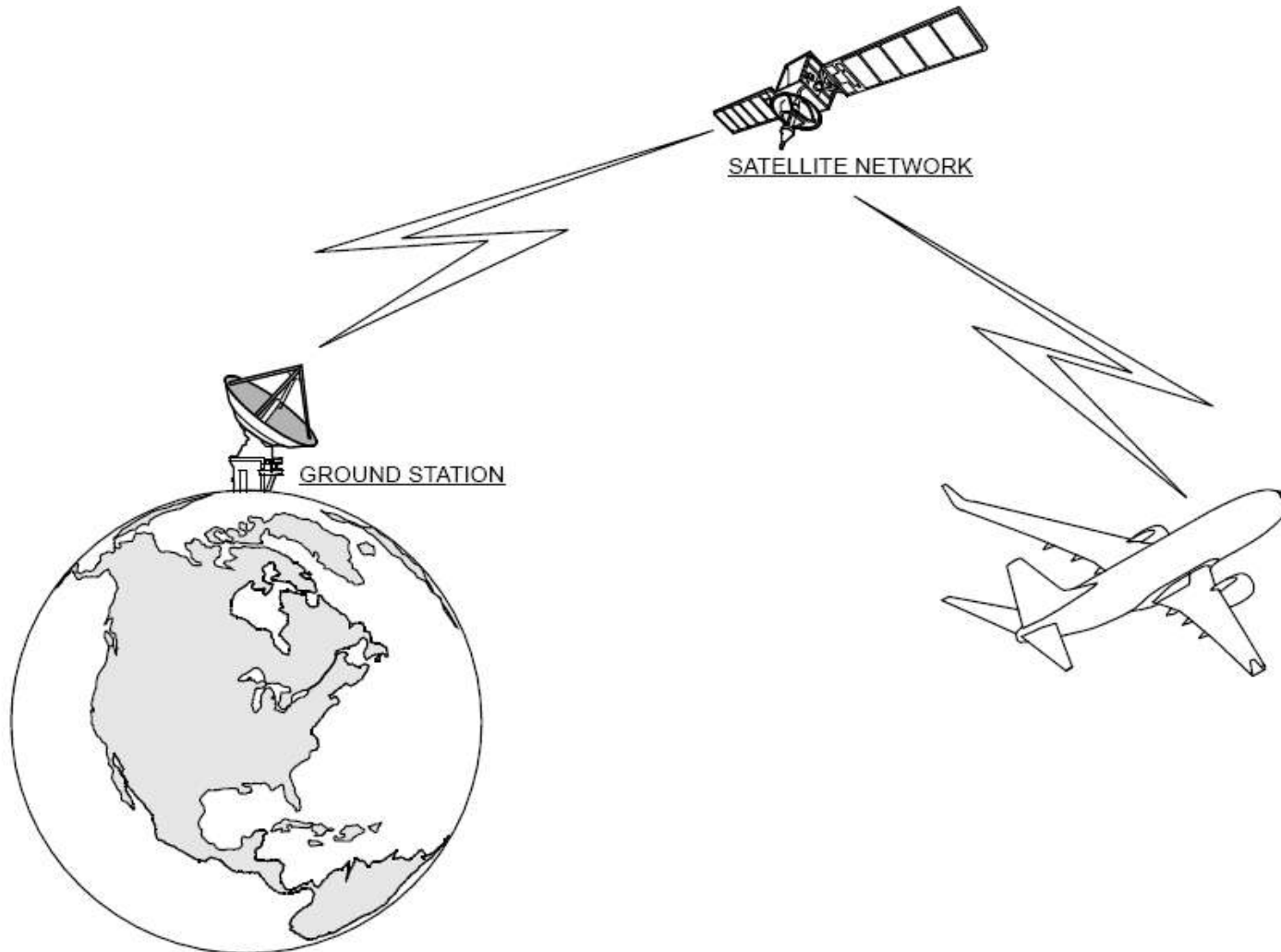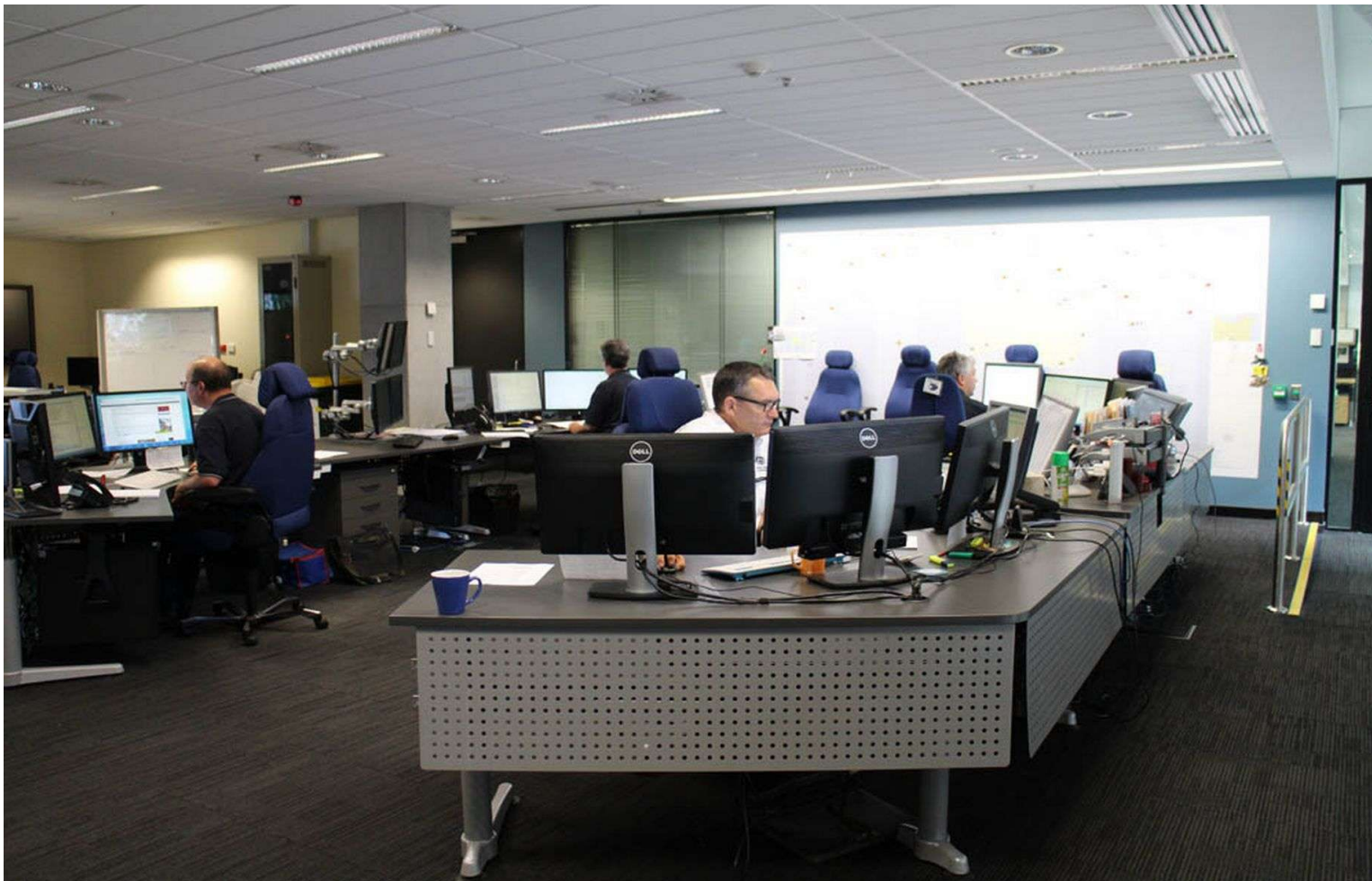# **18:28 – 18:39 UT – Sometime in here plane makes sharp turn South**

18:40 UT – Satellite call from Malaysian Airlines to MH370 attempted. SATCOM acknowledges, but call not answered.

19:41 UT and hourly thereafter – ground station send "keep-alive pings" to aircraft SATCOM; acknowledgement returned.

21:30 UT – KL Rescue Coordination Center activated

60 minutes later

22:30 UT – Plane is overdue in Beijing

23:10 UT – Malaysia Airlines makes second attempted phone call; same result

23:24 UT – MAS issues media statement

MEDIA STATEMENT released at 7.24am/8 Mar 2014 MH370 Incident

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Flight MH370, operated on the B777-200 aircraft, departed Kuala Lumpur at 12.41am on 8 March 2014. MH370 *was* expected to land in Beijing at 6.30am the same day. The flight *was* carrying a total number of 227 passengers (including 2 infants), 12 crew members.

Malaysia Airlines is currently working with the authorities who have **activated their Search and Rescue team to locate the aircraft.**

24:11 UT – Last ground-initiated "ping" exchange with aircraft (6th handshake)
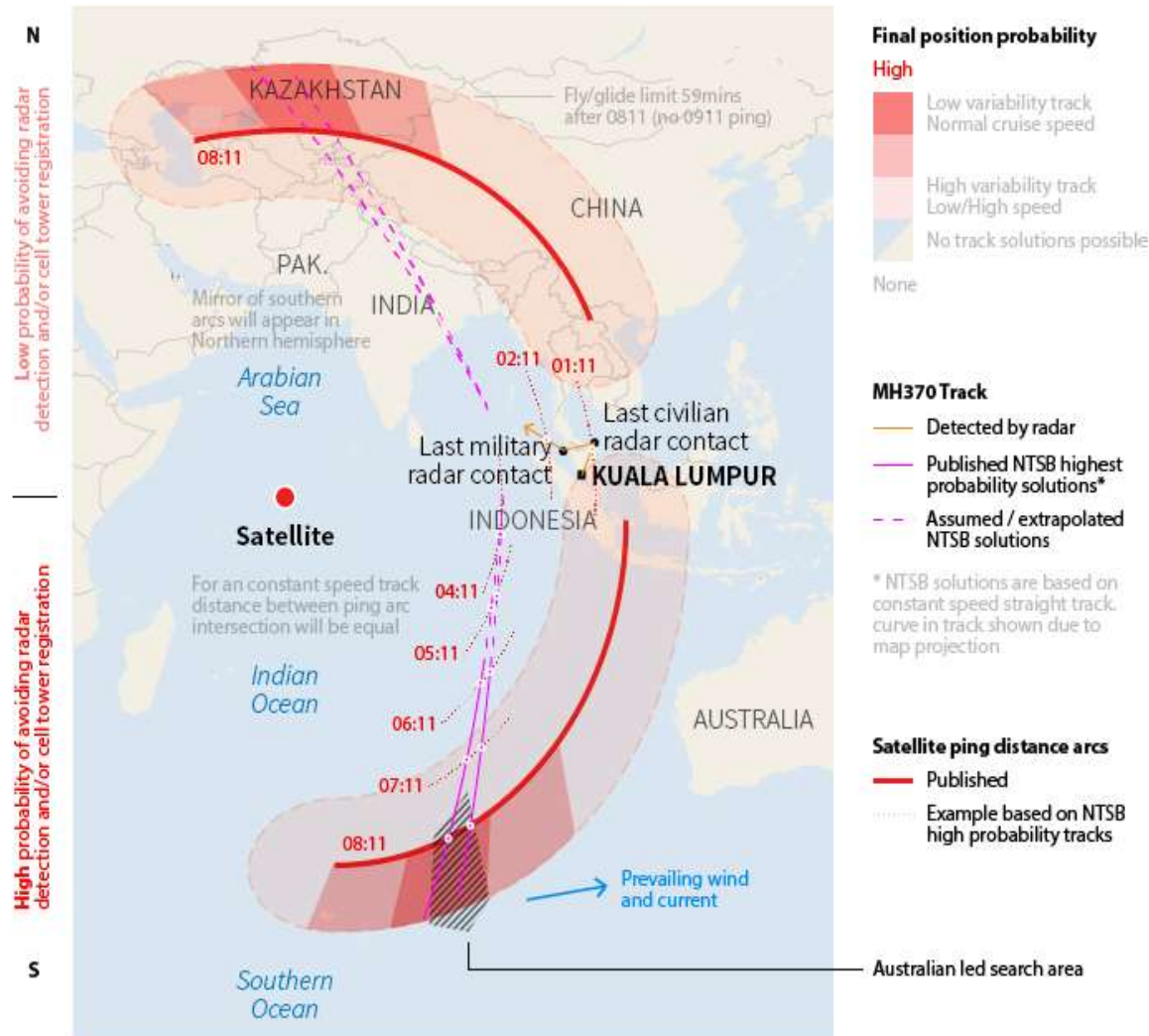
Graphics based on BBC source with AMSA supplied data overlaid
All tracks, arcs and probability zones are symbolic only / not accurate

8 minutes later

24:19 UT – SATCOM sends another "Logon Request" message, but fails to complete the sequence. Possible engine flameout from fuel exhaustion; power loss; APU powerup.

00:19:29 - Log-On Request (reported as a Partial Handshake), initiated from the aircraft terminal

8/03/2014 00:19:29.416	IOR-R600-0-36F8	IOR	305	10	R-Channel RX	0x10 - Log-on Request (ISU)/Log-on Flight Information (SSU)	182
8/03/2014 00:19:31.572	IOR-P600-0-36FC	IOR	305	10	P-Channel TX	0x11 - Log-on Confirm	
8/03/2014 00:19:32.212	IOR-P600-0-36FC	IOR	305	10	P-Channel TX	0x40 - P-/R-Channel Control (ISU)	
8/03/2014 00:19:32.212	IOR-P600-0-36FC	IOR	305	10	P-Channel TX	Subsequent Signalling Unit	
8/03/2014 00:19:32.852	IOR-P600-0-36FC	IOR	305	10	P-Channel TX	0x41 - T-Channel Control (ISU)	
8/03/2014 00:19:32.852	IOR-P600-0-36FC	IOR	305	10	P-Channel TX	Subsequent Signalling Unit	

00:19:37 - Note that the following R-Channel burst at 00:19:37.443 is the last transmission received from the aircraft terminal

8/03/2014 00:19:37.443	IOR-R1200-0-36F6	IOR	305	10	R-Channel RX	0x15 - Log-on/Log-off Acknowledge	-2

Signal suggests plane is in a steep descent. Aircraft is presumed to have crashed near the location of the final transmission.

CNN Developing Story ...

II. Aircraft Communications Systems

- Primary systems:
  - HF Radio
  - VHF radio
  - Mode S / ADS-B ("extended squitter") transponder
  - **Satellite Communications System (SATCOM)**
    - **Inmarsat**
    - Iridium

Inmarsat

- "International Marine Satellite" company

- Started 1979 to provide communications to ships out of reach of land stations

- Extended to cover land and air operations

- Operates fleet of geostationary satellites. Covers world up to 81 degrees latitude.

    - 3 generations (I3 to I5) in operation

Inmarsat Services

- Low bandwidth data

  - acars

  - SMS

- Voice (phone) / Fax

**Classic Aero-H
(Used by MH370)**

- ISDN

- Swift Broadband (internet; mobile circuit switched)

- **Service Providers**

  - **SITA** (no VHF in China)

  - ARINC

Service Allocation

1525 - 1660.5 MHz **L-Band**

| MARITIME | AERONAUTICAL | LAND-MOBILE |

Aero-H/H+ · Aero-I · Swift 64 · Aero-M · SBB

**Bandwidth about the same as a
dual frequency home wireless router**

System is constrained

- Bandwidth is limited
  - Channel width 2.5 khz
  - Requires tight frequency control. For aircraft, Doppler effect is important. AES are required to adjust transmit frequency to compensate.

- Timing is important
  - AES to GES R-channels are shared
  - "Slotted Aloha" - requires synchronization with GES to AES signal

- Pilot signals used extensively to monitor system

System Monitoring

- "Burst Frequency Offset" (BFO) – measures error in frequency from AES to GES

  - 1 hz resolution

- "Burst Timing Offset" (BTO) – measures error in signal timing from AES to GES.

  - 20 microsecond resolution

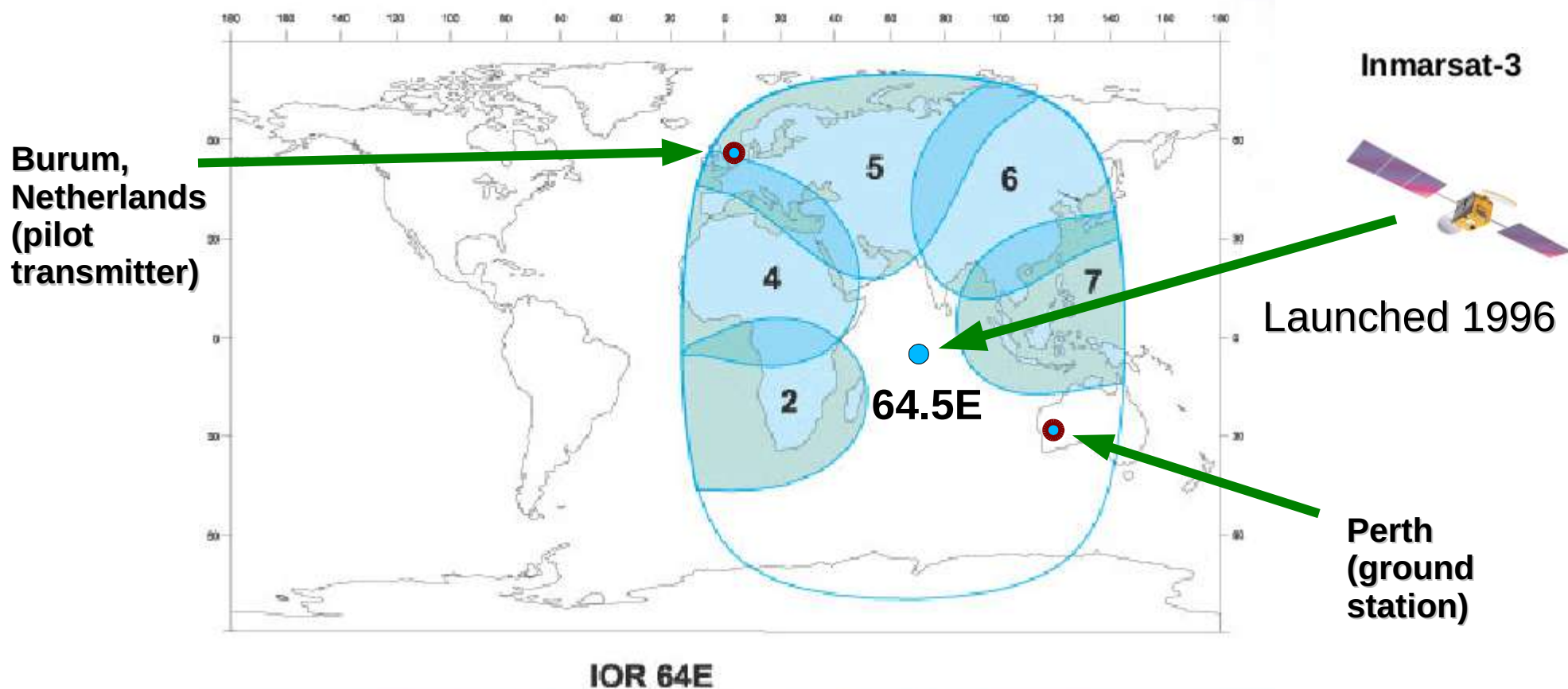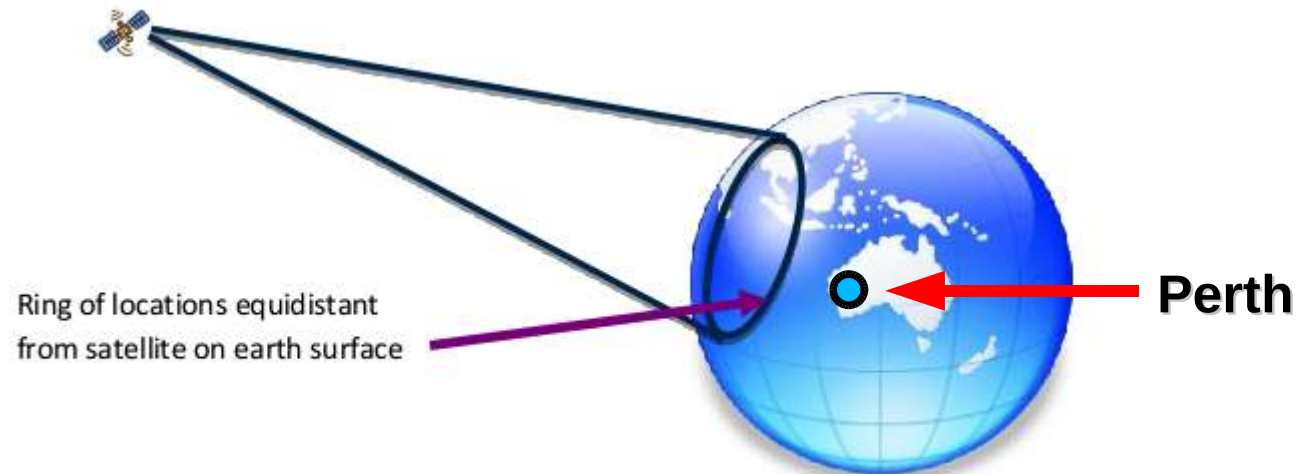- Both recorded along with data packets at ground station in Perth, Australia
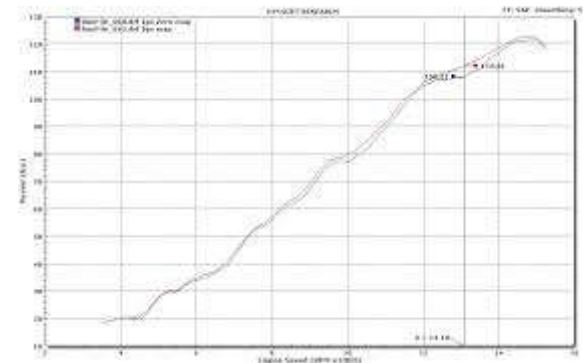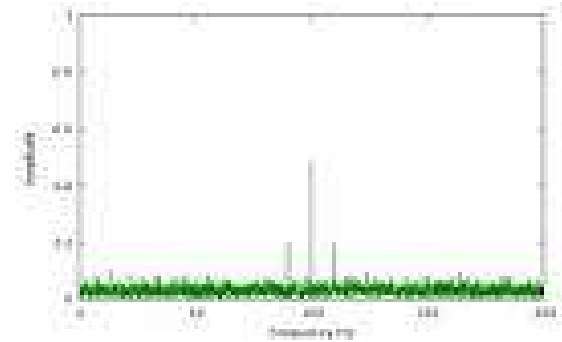
Inmarsat 3-F1

Indian Ocean Region
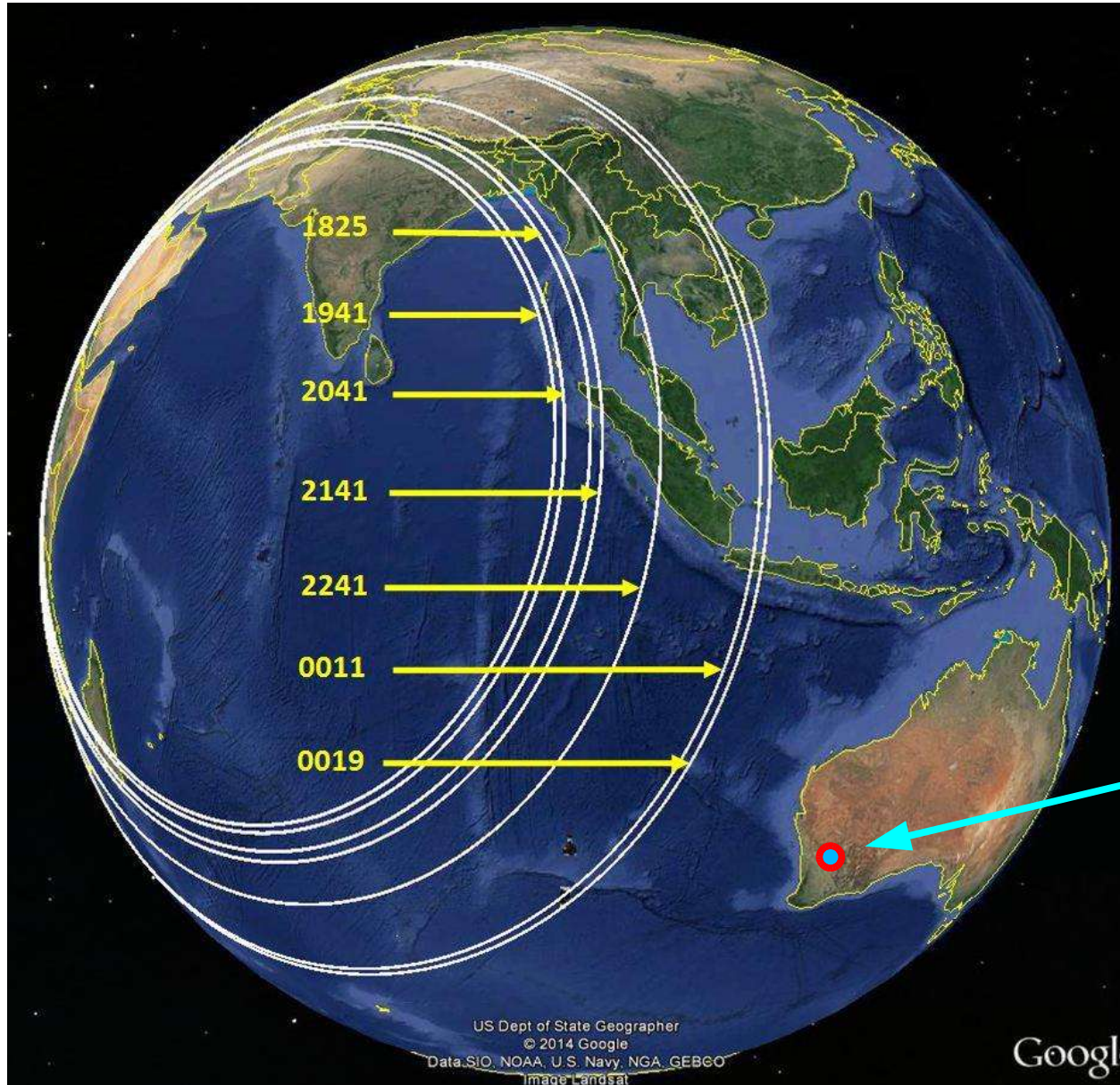
Inmarsat Generation 3

Burum, Netherlands (pilot transmitter)

Inmarsat-3

Launched 1996

64.5E

Perth (ground station)

IOR 64E

What we learn from BTOs

Ring of locations equidistant
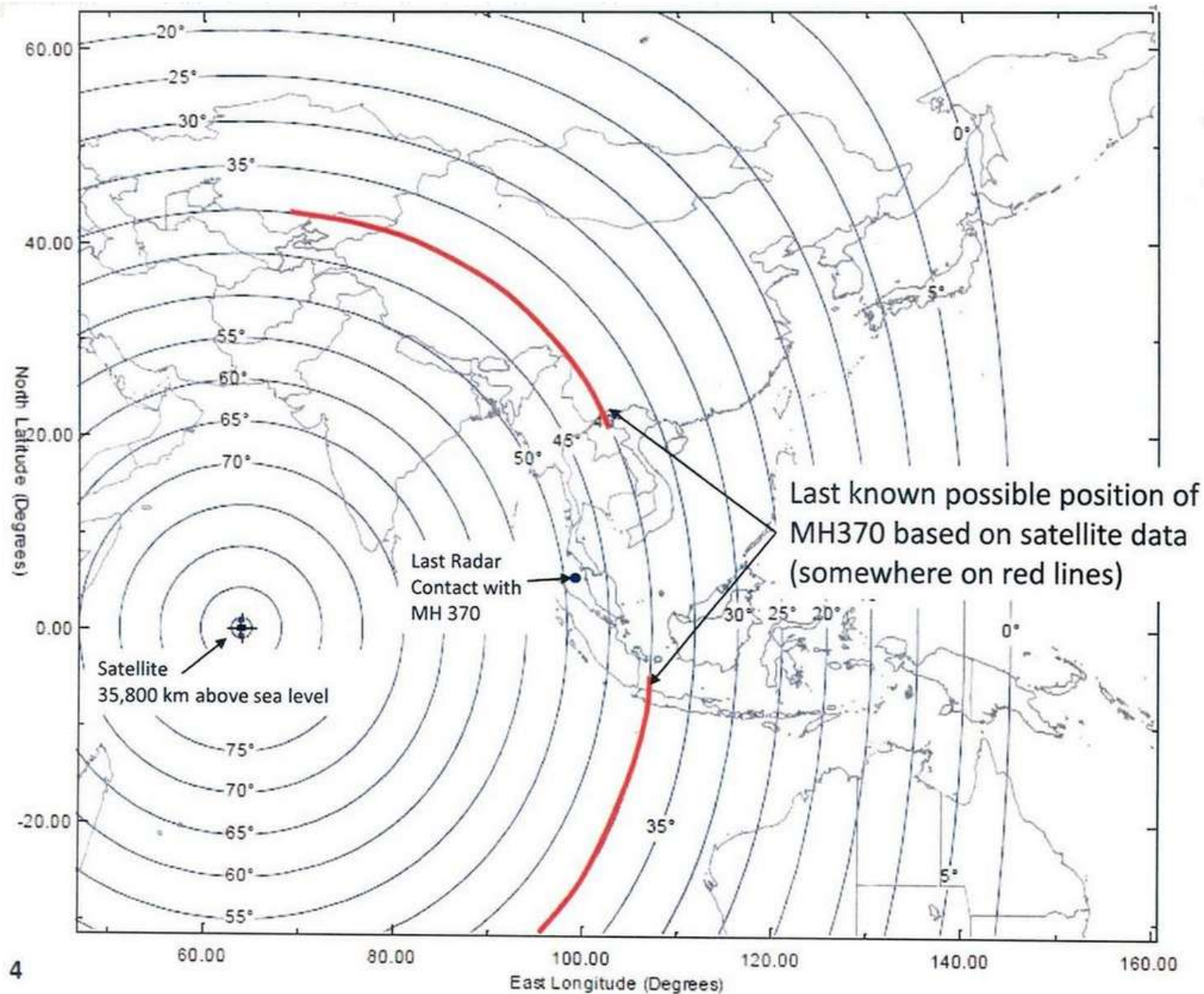from satellite on earth surface

Perth

**Light travel time (round trip) is ~ 0.5 seconds.
BTO depends on aircraft location on Earth.
Even sensitive to altitude.**

Initial Analysis

Seven sets of
BTOs define
7 "ping rings"
from 18:25 to
00:19 (24:19)

Perth

However, both North and South Corridors are possible

Last known possible position of MH370 based on satellite data (somewhere on red lines)

Last Radar Contact with MH 370

Satellite 35,800 km above sea level

Inmarsat-3

A Note on Geostationary Satellites

- Main perturbation on geostationary satellite orbit due to Moon - causes inclination to increase.

- Satellites carry hydrazine for station-keeping; ~equal in mass to satellite at launch to control orbit.

- 3-F1 is an old satellite – inclination no longer controlled.

  - **Inclination of 1.6 degrees on Mar 7, 2014 => Satellite oscillates above, below equator**
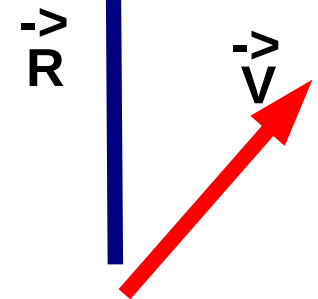
Orbital Inclination, i
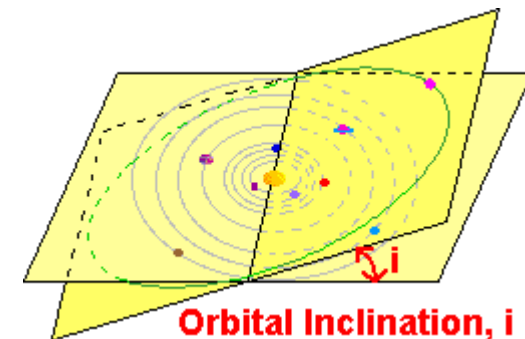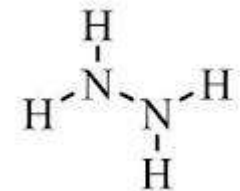
AES Doppler compensation mechanisms for aircraft

Inmarsat-3

- Doppler can be greater than 1 khz – exceeds tolerance of system.

- Compensation mechanism in MH370 SATCOM [Honeywell MCS-6000]

  – Use knowledge of plane's position, heading, and speed *along with knowledge of satellite position;* compute Doppler correction: $\vec{V} \cdot \vec{R}$

  – **Assumes satellite is exactly over equator**


-> R

-> V
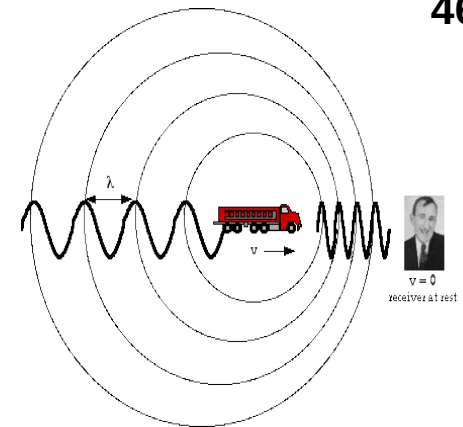
A fortuitous combination of circumstances

- **Because satellite orbit is inclined and AES assumes it is on the equator, the Doppler compensation is not perfect.** *Error includes contributions from satellite motion and from aircraft motion – sensitive to location and to speed & direction of travel of aircraft!*

- Full BFO analysis is complex (contributions from GES AFC; satellite oscillator drift; satellite-GES Doppler)
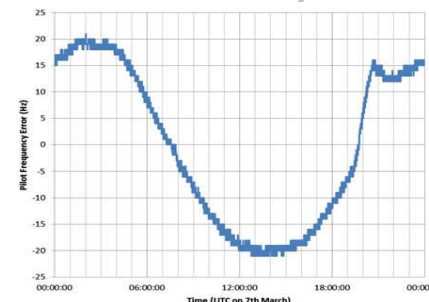
Original BFO Analysis
(cleaned up a bit)
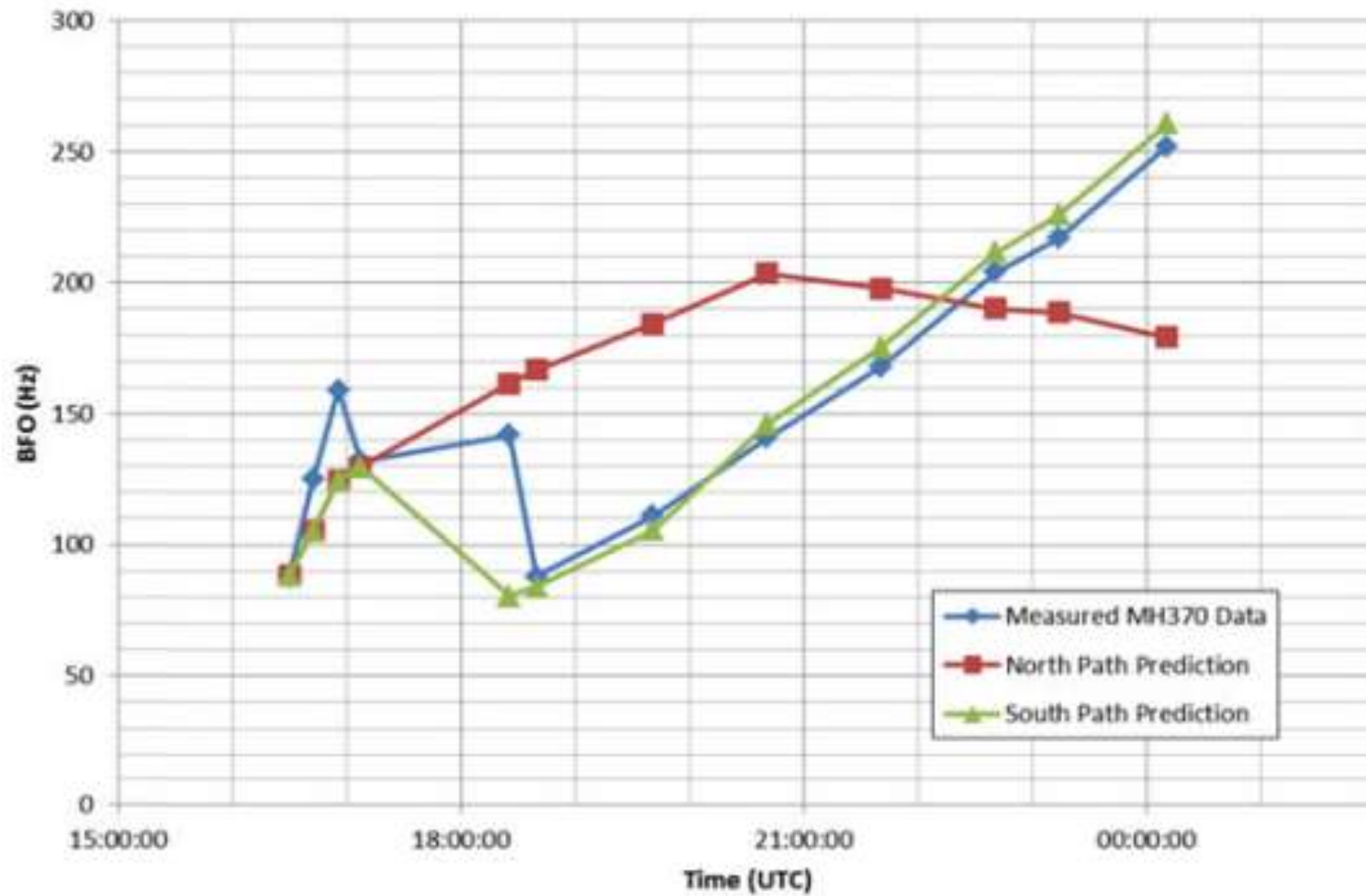
III. Investigation By the Public

Can We Reproduce Inmarsat's Result?

- Initially only figures available

- Many forums for discussion

  - tmfassociates.com

  - pprune.org

  - duncansteel.com

  - jeffwise.net

  - reddit.com

  - twitter.com

  - airliners.net

- Many people attempted to understand the ping ring; BFO plots poorly explained

  - Some features (e.g., AES Doppler) were decoded

  - Inaccuracies in published figures were detected

Public Data Release

- Authorities (Malaysian MOT and Australian ATSB) have been exceedingly reticent in sharing information. However, we now have
  - Inmarsat signal communication logs from 15:59 to end of flight
  - Documentation and calibration tables for BTO, BFO sufficient to understand and compute flight paths.

- Missing
  - Complete military radar data
  - Calibration data from similar and historical flights

**Selex
ES RAT-31DL
3-D Phased array
Western Hill,
Penang Island**

Example page - communications log

Time	Channel Name	Ocean Region	GES ID (octal)	Channel Unit ID	Channel Type	SU Type	Burst Frequency Offset (Hz) BFO	Burst Timing Offset (microseconds) BTO
7/03/2014 18:28:14.904	IOR-R1200-0-36ED	IOR	305	4	R-Channel RX	0x62 - Acknowledge User Data (R-channel)	143	12480
18:39 - Ground Initiated to Air Telephony Call - Zero Duration (Not Answered)								
7/03/2014 18:39:52.907	IOR-P10500-0-386B	IOR	301	10	P-Channel TX	0x20 - Access Request/Call Announcement Telephone/Circuit-Mode Data		
7/03/2014 18:39:52.907	IOR-P10500-0-386B	IOR	301	10	P-Channel TX	0x33 - C-Channel Assignment (Regularity)		
7/03/2014 18:39:52.907	IOR-P10500-0-386B	IOR	301	10	P-Channel TX	0x20 - Access Request/Call Announcement Telephone/Circuit-Mode Data		
7/03/2014 18:39:52.907	IOR-P10500-0-386B	IOR	301	10	P-Channel TX	0x33 - C-Channel Assignment (Regularity)		
7/03/2014 18:39:55.354	IOR-3730-21000	IOR	305	6	C-Channel RX	0x30 - Call Progress - Test	88	

....

84 C-Channel and 2 P-Channel messages moved into separate below table (see appendix 1) to ease the reading of key events. C-Channel messages have no BTO values

....

Time	Channel Name	Ocean Region	GES ID (octal)	Channel Unit ID	Channel Type	SU Type	Burst Frequency Offset (Hz) BFO	Burst Timing Offset (microseconds) BTO
7/03/2014 18:40:56.354	IOR-3730-21000	IOR	305	6	C-Channel RX	0x30 - Call Progress - Channel Release	90	
19:41 - Handshake Request, with response								
7/03/2014 19:41:00.910	IOR-P10500-0-386B	IOR	305	10	P-Channel TX	0x14 - Log Control - Log-on Interrogation		
7/03/2014 19:41:02.906	IOR-R1200-0-36ED	IOR	305	4	R-Channel RX	0x15 - Log-on/Log-off Acknowledge	111	11500
20:41 - Handshake Request, with response								
7/03/2014 20:41:02.907	IOR-P10500-0-386B	IOR	305	10	P-Channel TX	0x14 - Log Control - Log-on Interrogation		
7/03/2014 20:41:04.904	IOR-R1200-0-36ED	IOR	305	4	R-Channel RX	0x15 - Log-on/Log-off Acknowledge	141	11740
21.41 - Handshake Request, with response								
7/03/2014 21:41:24.907	IOR-P10500-0-386B	IOR	305	10	P-Channel TX	0x14 - Log Control - Log-on Interrogation		
7/03/2014 21:41:26.905	IOR-R1200-0-36ED	IOR	305	4	R-Channel RX	0x15 - Log-on/Log-off Acknowledge	168	12780
22:41 - Handshake Request, with response								
7/03/2014 22:41:19.907	IOR-P10500-0-386B	IOR	305	10	P-Channel TX	0x14 - Log Control - Log-on Interrogation		
7/03/2014 22:41:21.906	IOR-R1200-0-36ED	IOR	305	4	R-Channel RX	0x15 - Log-on/Log-off Acknowledge	204	14540
23:13 - Ground Initiated to Air Telephony Call - Zero Duration (Not Answered)								
7/03/2014 23:13:58.407	IOR-P10500-0-386B	IOR	305	10	P-Channel TX	0x20 - Access Request/Call Announcement Telephone/Circuit-Mode Data		
7/03/2014 23:13:58.407	IOR-P10500-0-386B	IOR	305	10	P-Channel TX	0x33 - C-Channel Assignment (Regularity)		
7/03/2014 23:14:00.904	IOR-3737-21000	IOR	305	6	C-Channel RX	0x30 - Call Progress - Test	216	

Publications

- www.malaysiaairlines.com/mh370 - Media releases

- Malaysia Ministry of Transport on Facebook

- Mar 22, 2014 - Cargo Manifest

  – https://s3.amazonaws.com/s3.documentcloud.org/documents/11511 53/mh370-cargo-manifest-and-airway-bill.pdf

- Mar 25, 2014 - Original BFO figures and explanation

  – http://www.mot.gov.my/en/Newsroom/Press Release/Year 2014/Information Provided To MH370 Investigation by UK Air Accidents Investigation Branch (AAIB).pdf

  – http://www.inmarsat.com/wp-content/uploads/2014/03/Inmarsat-Differential-Doppler-Study.pdf

Publications (cont.)

- Apr 1, 2014 - Transcript of cockpit / ATC communications

    – http://www.bbc.co.uk/news/special/2014/newsspec_7440/transcript.pdf

- Apr 27, 2014 - MH 370 Preliminary Report to ICAO

    – http://www.dca.gov.my/MH370/Preliminary%20Report.pdf

- May 1. 2014 - HISHAMMUDDIN HUSSEIN - Actions taken on March 8.

    – http://www.abc.net.au/4corners/documents/2014/MH370/MH370Report_Actions_Taken.pdf

- Maps

    – https://www.facebook.com/HishammuddinH2O/

Publications (cont.)

- May 20, 2014 - Data Communication logs

  - http://www.dca.gov.my/mainpage/MH370% 20Data%20Communication%20Logs.pdf

- ATSB (Australia)

  - http://www.atsb.gov.au/mh370.aspx

  - Includes links to June 26, 2014 report "MH370 Definition of Underwater Search Areas" (with updates Aug 18, 2014, Oct 8, 2014, and Dec 3, 2015)

- Oct 23, 2014 - "The Search for MH370" (Ashton et al.)

  - *Journal of Navigation* (2015), 68, 1

Publications (cont.)

INTERNATIONAL CIVIL AVIATION ORGANIZATION
A United Nations Specialized Agency

- Jan 29, 2015 - "SAR Response to MH370"

    - http://www.icao.int/APAC/Meetings/2015APSARTF3/WP05 ICAO Brief on the SAR Response to MH370.pdf

- Mar 8, 2015 - "Factual Information"

    - http://mh370.mot.gov.my/

- Nov 30, 2015 - "Bayesian Methods in the Search for MH370"

    - http://www.atsb.gov.au/media/5733804/Bayesian_Methods_MH370_Search_3Dec2015.pdf

The Malaysian ICAO Annex 13
Safety Investigation Team for MH370

FACTUAL INFORMATION

SAFETY INVESTIGATION FOR MH370

-

Malaysia Airlines MH370 Boeing B777-200ER (9M-MRO)
08 March 2014

By

The Malaysian ICAO Annex 13 Safety Investigation Team for MH370

Additional Documentation (partial)

- Wind, temp models (Air Resources Laboratory):

  - http://ready.arl.noaa.gov/gdas1.php

  - http://www.ecmwf.int/

- Magnetic declination maps (National Geophysical Data Center):

  - http://www.ngdc.noaa.gov/geomag/models.shtml

- Satellite orbital parameters

  - http://www.celestrak.com/

- Manual for Aeronautical Mobile Satellite (Route) Service (Inmarsat)

- Boeing 777 Flight Crew Operations Manual
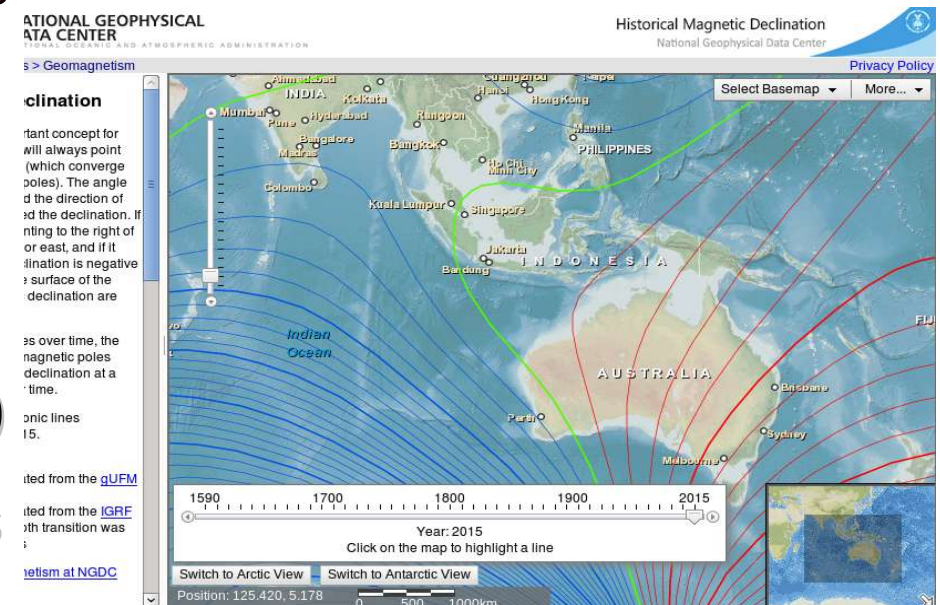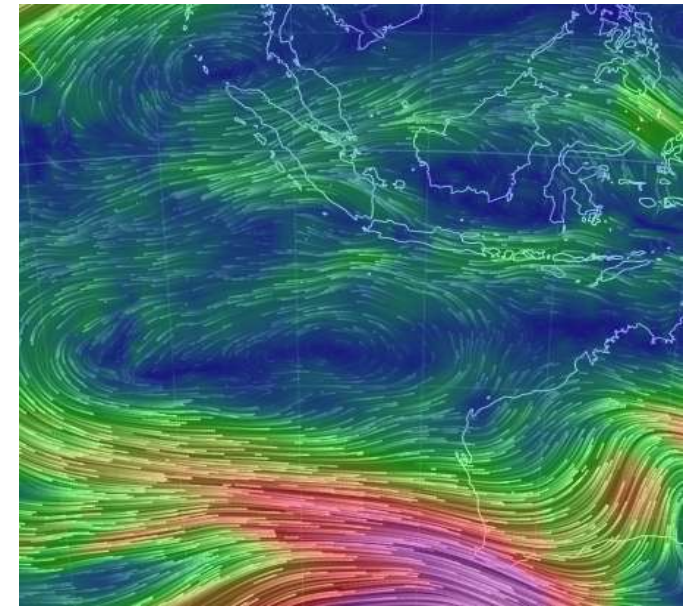
Additional details and information needed for models

- Spheroidal Earth

- Geodetic v. Geocentric latitude

- B-777 autopilot modes

- B-777 ranges v. fuel load

  - Amazing how much information is available on internet!
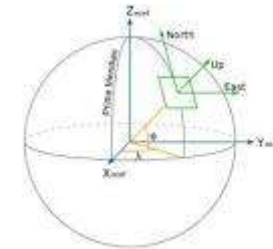
Public Data Analyses

- Once full logs and documentation were released, many people began computing potential flight paths (in parallel to official investigation)

- Key information not reverse-engineerable -

  - **Perth GES AFC does not support negative latitudes!**

  - **Satellite frequency unstable – monitor by Burum pilot signal. Tables were released.**

  - Some BTO and BFO values invalid

Table 4: Satellite and AFC values	
Time UTC	(δf sat + δf AFC) Hz
16:30:00	29.1
16:42:00	27.6
16:55:00	25.8
17:07:00	24.1
18:25:00	10.7
19:41:00	-0.5
20:41:00	-1.5
21:41:00	-18.0
22:41:00	-28.5
00:11:00	-37.7
00:19:00	-37.8

Analysis Software

- **Excel**

- STK (free, commercial satellite tracking program)

- python

- octave

Where do people "publish"?

- dropbox
- google docs
- imgur
- twitter
- photobucket
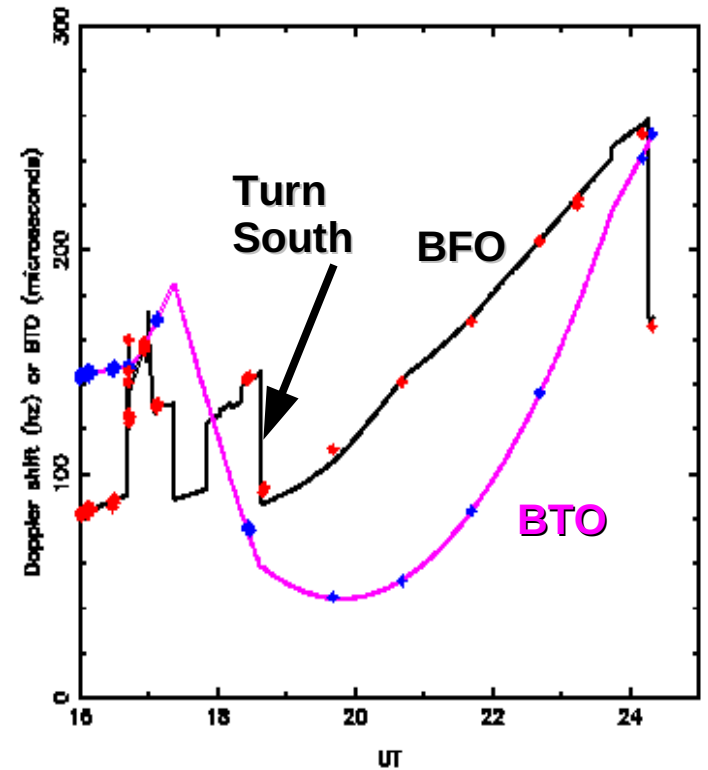- bitmath.org
- github
- Personal websites

Example: Magnetic track mode

Final latitude -34 deg.

Turn South

BFO

BTO

MH370 reconstruction

Initial ACARS data calibrate BTO, BFO and validate modeling

BFO (hz)
BTO/(20 microsec)
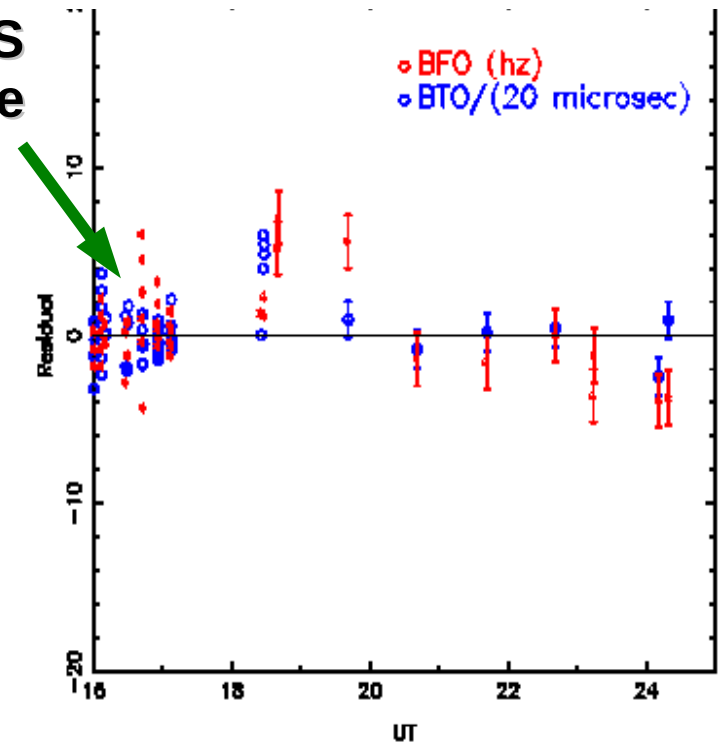
Example: Uncommanded Autopilot v. Active Pilot Flight Paths
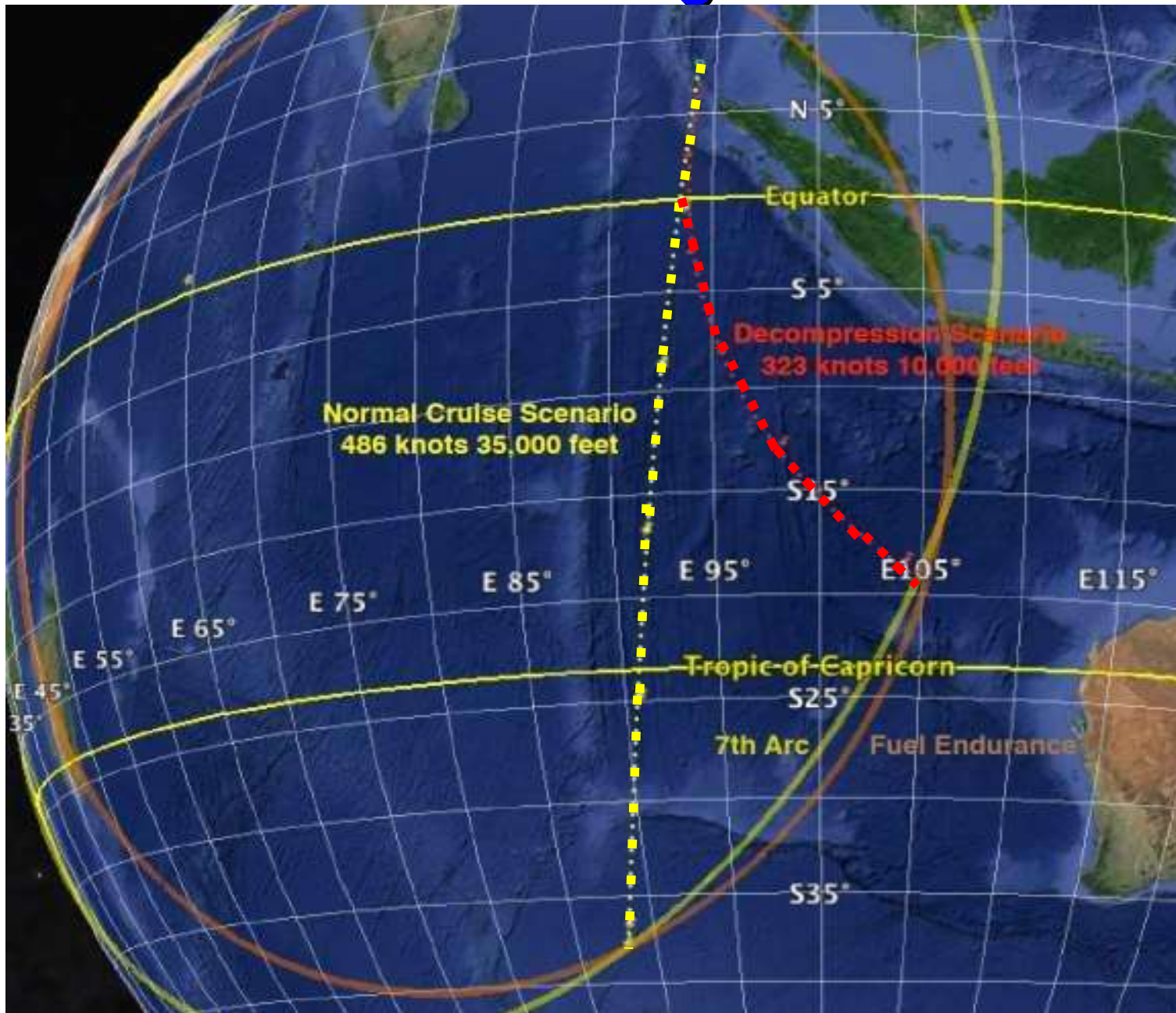
A Sample of Reports

"An Analysis of the Inmarsat Data from MH370" - R. Cole, June 20, 2014.

"MH370 Search Area Recommendation" - The Independent Group, Sept 9, 2014. **("We suggest you look *here.*")**

"The Location of MH370" - Bobby Ulich, Sept 25, 2014. **("I suggest you look *there.*")**

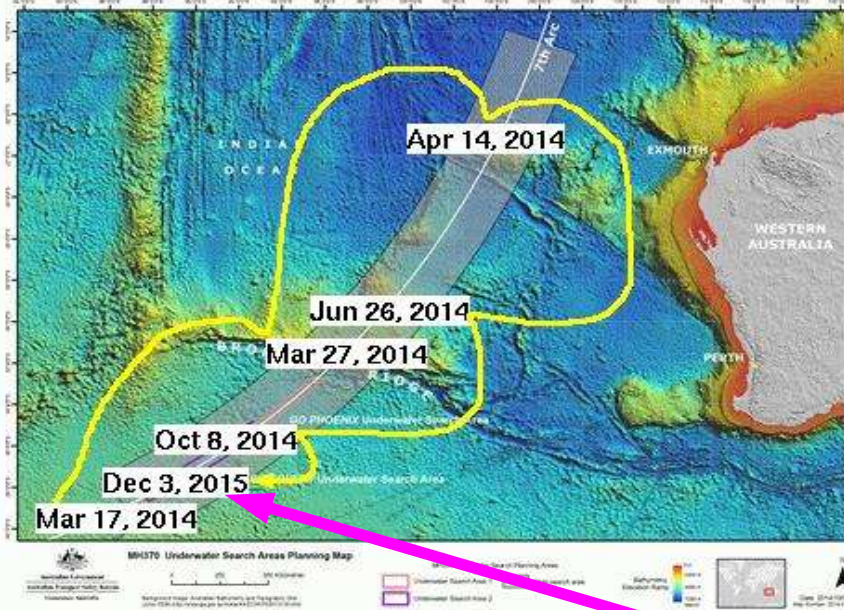**"Analytic Fuel Flow Model"** - B. Martin, Mar 3, 2015.

"Some Observations on the Radar Data for MH370" - V. Iannello, Aug 18, 2015.

"MH370: On the possible interpretation of the abnormal BFO values" - Oleksandr N, Oct 1, 2015.

"The Routes Taken by Floating Debris from MH370" - R. Godfrey, Apr 2, 2016.
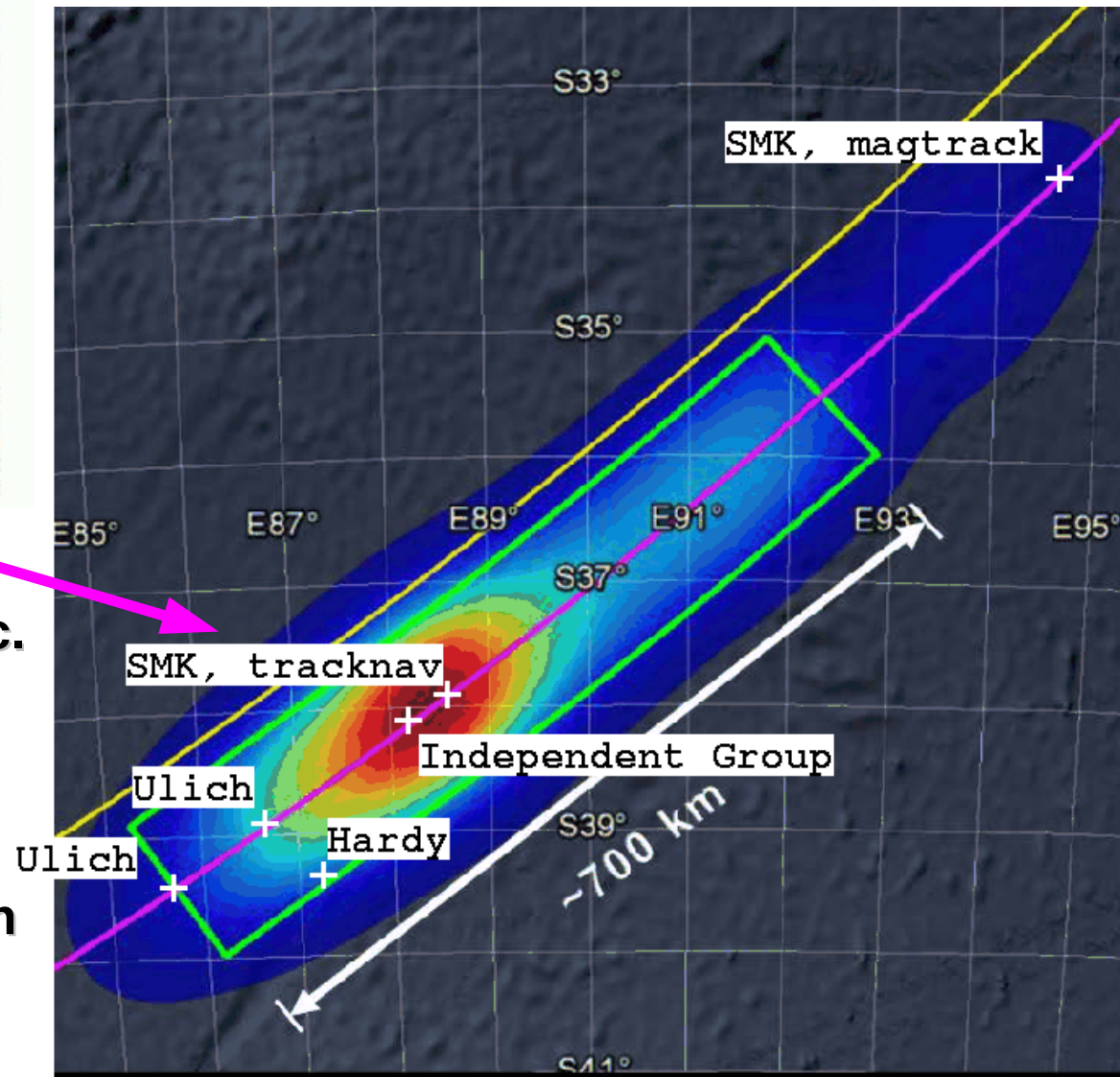
Predictions - JIT/JACC/ATSB v. Public

Early "official" search zones bounced up and down the 7th arc. Eventually settled on -35 to -39.

Nov 30, 2015: "Bayesian Methods in the Search for MH370" by DSTG.   Highest probability region at -38° latitude.
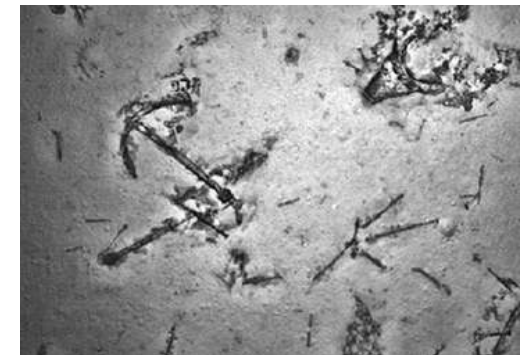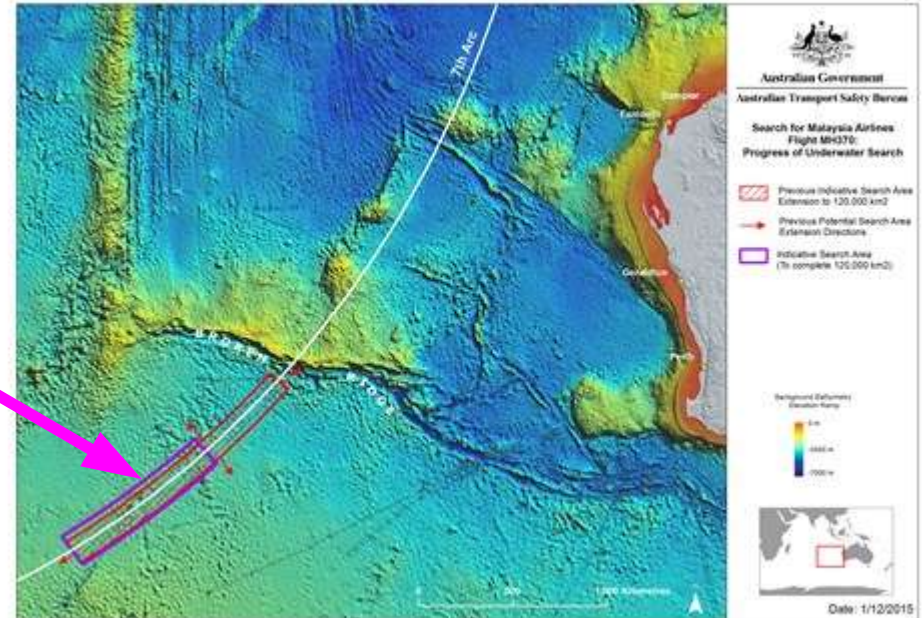
Underwater Search (Australian ATSB lead) Currently 3 ships

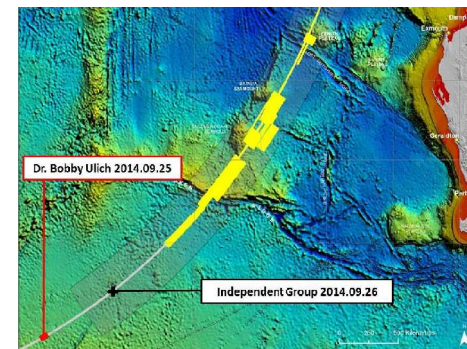Underwater search with towed side-scan sonar underway since Oct 2014.

High priority search area 120,000 sq. km. Cost US $100 million

Nothing found other than two unidentified shipwrecks.

Search will end ~July unless new evidence comes to light

Where are we now?
Where do we go next?

- Over a dozen people have modeled data.

- Large parameter space (speed, heading, timing, altitude, fuel model, etc.)

- Data-driven v. uncommanded autopilot-driven models

- End-of-flight scenarios studied - one person used a genuine B-777 simulator.
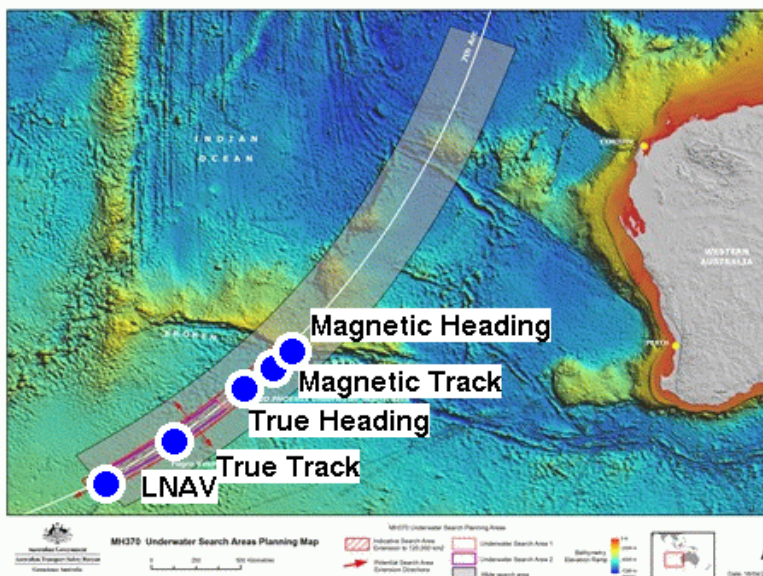
What if plane is not found?

- **Just missed in terrain?**

- **Revisit assumptions?**
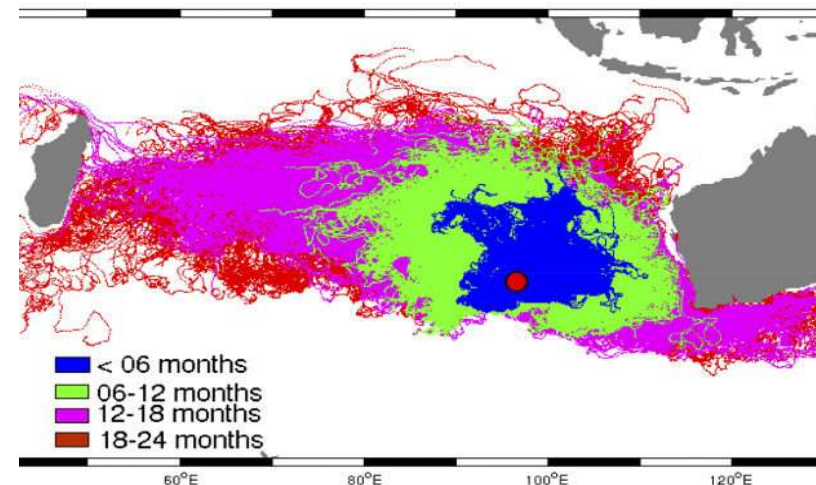
- **Actively piloted?**

- **Conspiracy theory time!**

IV. Breaking News ...

July 29, 2015 Piece of right wing ("flaperon") discovered on Reunion Island, East of Madagascar.

(flaperon = flap + aileron)

Confirming evidence that MH370 went down in South Indian Ocean

- < 06 months
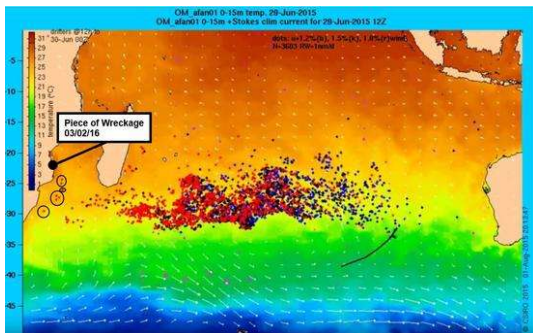- 06-12 months
- 12-18 months
- 18-24 months

Drift modeling not accurate but favors more Northerly impact point

Goose barnacles - which species?

More Breaking News ...

Feb 27, 2016 Piece of right horizontal stabilizer discovered on sand bank off coast of Mozambique

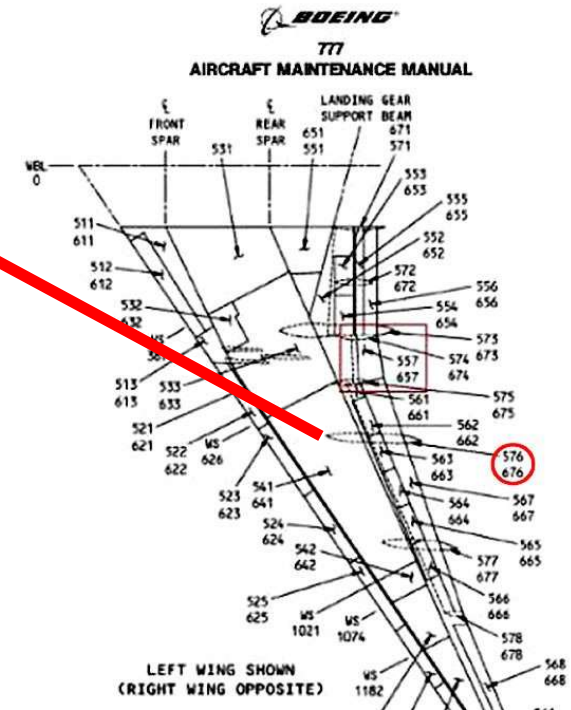**Glaser stencil font**

No Goose barnacles - why?

Even More Breaking News ...

676CR	Flap Support Fairing No. 7 Panel
676DB	Flap Support Fairing No. 7 Panel
676EB	Flap Support Fairing No. 7 - Aft
676FR	Flap Support Fairing No. 7 Panel
676GR	Flap Support Fairing No. 7 Panel
677AB	Flap Support Fairing No. 8 Fwd

weibo.com/606787403

Mozambique, Dec 27, 2015.
676EB (Glaser Stencil Font) is B-777 outboard
right wing flap track fairing.

Yet More Breaking News ...

Brenna Flaugher snapshot from plane window.

South Africa, Mossel Bay
Mar 22, 2016: Rolls Royce Engine logo from engine cowling. Same size and color scheme (grey letters on black background) as 9M-MRO (MH370).
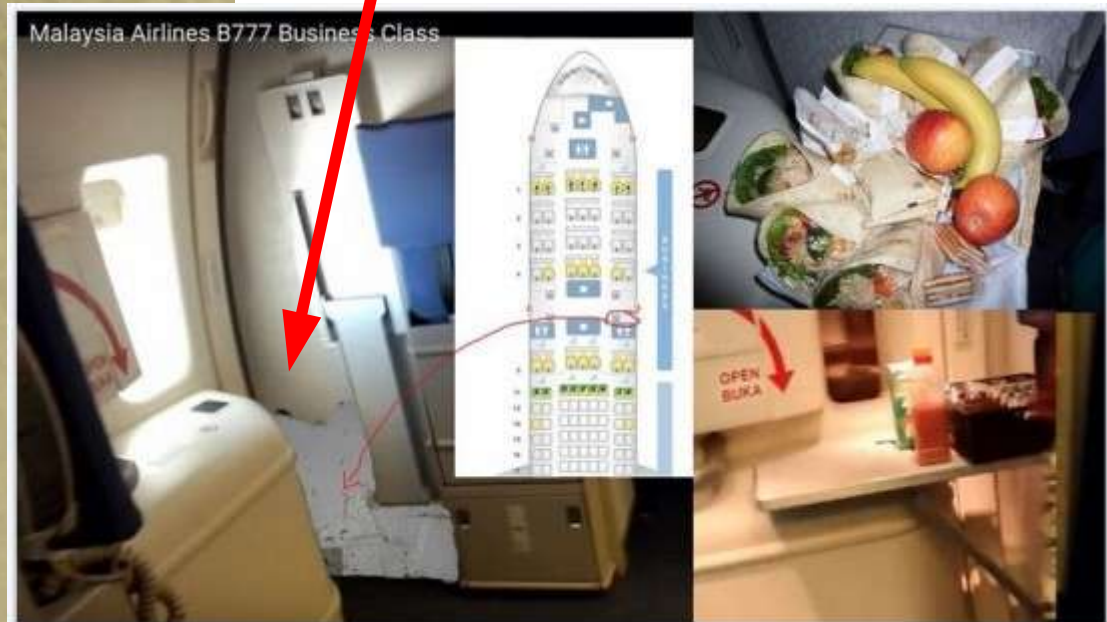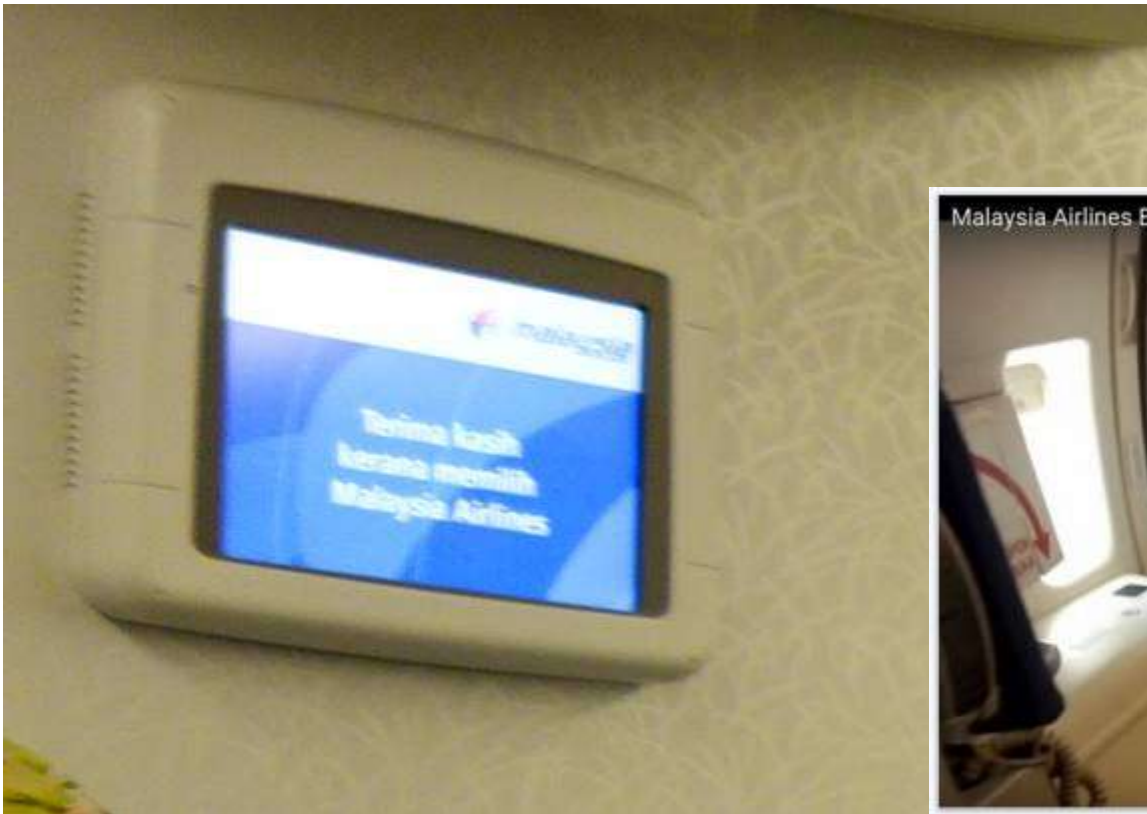
And Yet Still More Breaking News ...

Piece of debris from Rodrigues Island, Mauritius, March 30, 2016.

Intricate metallic design matches interior bulkhead of Malaysia Airlines fleet.

Proposed location: Door 2R in business class.

Malaysia Airlines B777 Business Class

What Happened on Board?

- We know more about Amelia Earhart than MH370

- Much speculation about accident (fire) v. deliberate hijacking. Beyond scope of this talk.

  - Disabling Transponder

  - Disabling ACARS

  - Disabling SATCOM

    - Instrument bay

    - Power buses

V. Summary – Lessons Learned

- **Public can make serious use of data from complex systems. Do not underestimate!**

- **In many ways, analysis of MH370 is similar to analyzing data from any experimental system:**

  - **Must understand how each part of system works (requires documentation)**

  - **Calibration data are crucial**

- **Do not hold back data that people might need - they will complain!**

Backup Slides

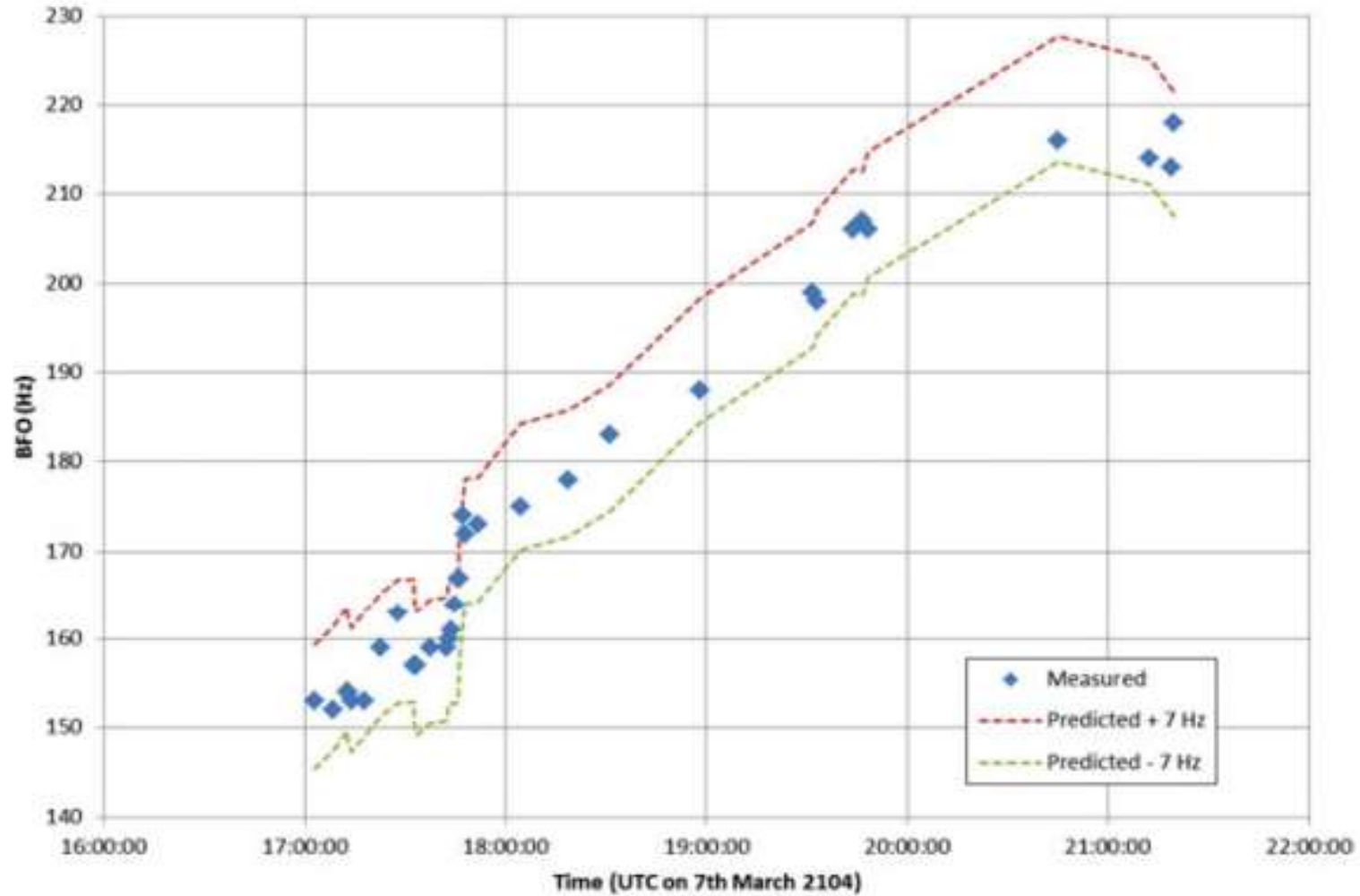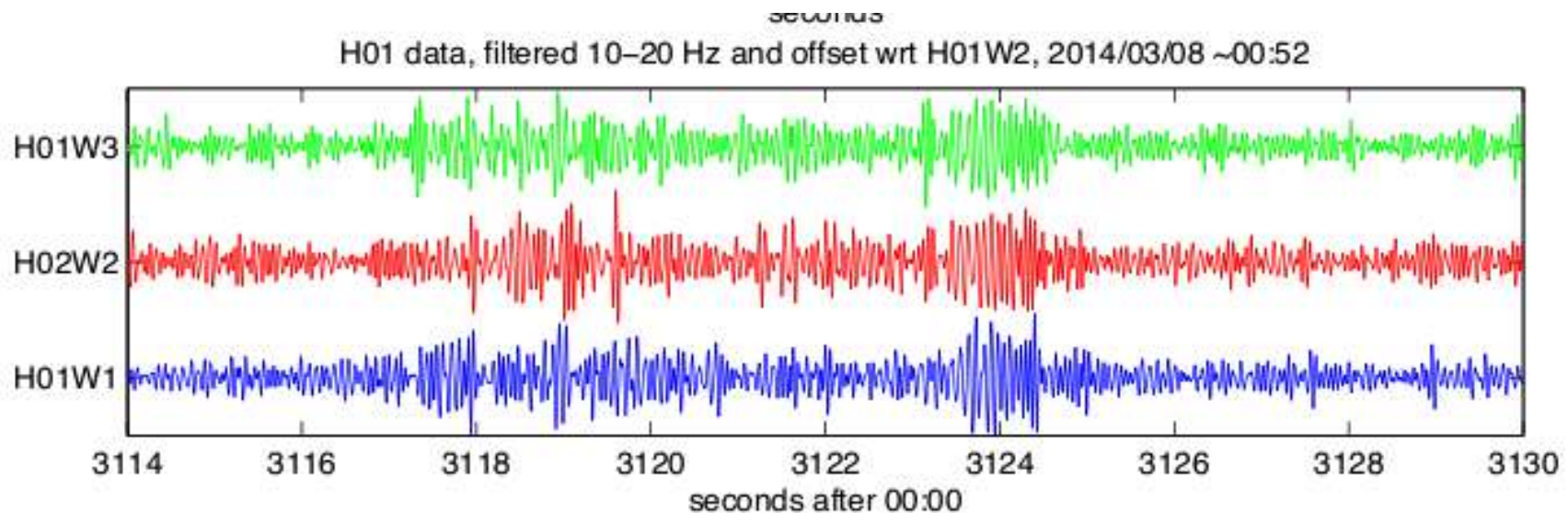# MH21 - Kuala Lumpur to Amsterdam
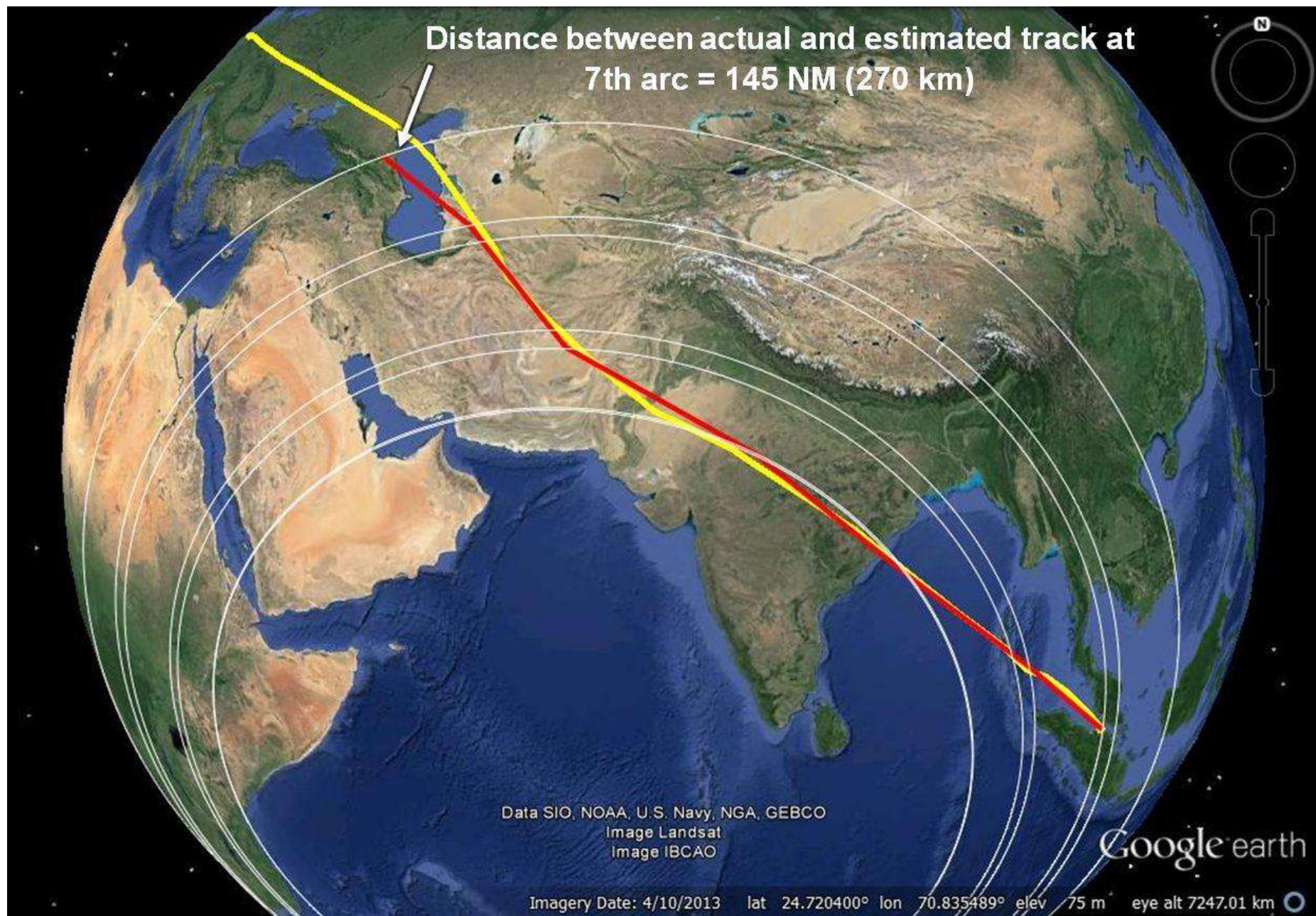
MH21 - BFO

Figure 15. Burst Frequency Offset Validation (Amsterdam Flight).

Recent Analysis -
Did Anyone Hear It Crash?

- ## Hydrophones

  - ### IMOS station Rottnest Island (W of Perth)

  - ### CTBTO station HA01 (Cape Leeuwin, Australia)

    - #### LANL claims detection at 00:52, bearing 246.9 deg

H01 data, filtered 10–20 Hz and offset wrt H01W2, 2014/03/08 ~00:52

Recent Analysis -
Did Anyone Feel It Crash?

- Seismic stations

  - Geoscope (French) and others - 11 stations around Indian Ocean

  - Data from IRIS-DMC