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

13 minutes later
17:07 UT - MH370 cruising at 35,000 feet
469 knots GS, heading for waypoint IGARI.
Last ACARS message.
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)
17:20:33 UT – Aircraft symbols start dropping off Secondary Radar at HCM, KL, and Bangkok ATCC. Plane becomes invisible to ATC.

2-42 seconds later
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
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.

1 minute later

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.
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.

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Code</th>
<th>Identification</th>
<th>Channel</th>
<th>Frequency</th>
<th>Power</th>
<th>Channel Mode</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>7/03/2014</td>
<td>18:03:41.405</td>
<td>IOR-P10500-0-3859</td>
<td>IOR</td>
<td>305</td>
<td>10</td>
<td>P-Channel TX</td>
<td>0x71 - User Data (ISU) - RLS</td>
<td></td>
</tr>
</tbody>
</table>

“PLS CONTACT HO CHI MING ATC ASAP THEY COMPLAIN CANNOT TRACK YOU ON THEIR RADAR”
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.

10 minutes later
18:25 UT – SATCOM reactivated; logs on to satellite network. Plane appears to be continuing WNW track

3 minutes later
18:28 – 18:39 UT – Sometime in here plane makes sharp turn South

3-14 minutes later
18:40 UT – Satellite call from Malaysian Airlines to MH370 attempted. SATCOM acknowledges, but call not answered.

1 minute later
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

109 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

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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)

47 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.

<table>
<thead>
<tr>
<th>Time</th>
<th>Log-On Request (reported as a Partial Handshake), initiated from the aircraft terminal</th>
</tr>
</thead>
<tbody>
<tr>
<td>00:19:29</td>
<td>IOR-R600-0-36F8 IOR 305 10 R-Channel RX 0x10 - Log-on Request (ISU)/Log-on Flight Information (SSU)</td>
</tr>
<tr>
<td>00:19:31.572</td>
<td>IOR-P600-0-36FC IOR 305 10 P-Channel TX 0x11 - Log-on Confirm</td>
</tr>
<tr>
<td>00:19:32.212</td>
<td>IOR-P600-0-36FC IOR 305 10 P-Channel TX 0x40 - P-/R-Channel Control (ISU)</td>
</tr>
<tr>
<td>00:19:32.212</td>
<td>IOR-P600-0-36FC IOR 305 10 P-Channel TX Subsequent Signalling Unit</td>
</tr>
<tr>
<td>00:19:32.852</td>
<td>IOR-P600-0-36FC IOR 305 10 P-Channel TX 0x41 - T-Channel Control (ISU)</td>
</tr>
<tr>
<td>00:19:32.852</td>
<td>IOR-P600-0-36FC IOR 305 10 P-Channel TX Subsequent Signalling Unit</td>
</tr>
<tr>
<td>00:19:37</td>
<td>Note that the following R-Channel burst at 00:19:37.443 is the last transmission received from the aircraft terminal</td>
</tr>
<tr>
<td>00:19:37.443</td>
<td>IOR-R1200-0-36F6 IOR 305 10 R-Channel RX 0x15 - Log-on/Log-off Acknowledge</td>
</tr>
</tbody>
</table>

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

BOEING 777 WILL STRUGGLE TO MAINTAIN ALTITUDE ONCE THE FUEL TANKS ARE EMPTY

LIVE CNN

6:51 AM PT
II. Aircraft Communications Systems
Primary systems:

HF Radio
VHF radio
Mode S / ADS-B ("extended squitter") transponder
Satellite Communications System (SATCOM)

Inmarsat
Iridium
“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

ISDN

Swift Broadband (internet; mobile circuit switched)

Service Providers
- SITA (no VHF in China)
- ARINC

Classic Aero-H (Used by MH370)
Service Allocation

1525 - 1660.5 MHz L-Band

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

Launched 1996

Burum, Netherlands (pilot transmitter)

Perth (ground station)

IOR 64E
What we learn from BTOs

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.
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
AES Doppler compensation mechanisms for aircraft

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: $V \cdot R$

Assumes satellite is exactly over equator
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)

Turn South
III. Investigation By the Public
Can We Reproduce Inmarsat's Result?

Initially only figures available

Many forums for discussion

\texttt{tmfassociates.com}
\texttt{pprune.org}
\texttt{duncansteel.com}
\texttt{jeffwise.net}
\texttt{reddit.com}
\texttt{twitter.com}
\texttt{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.
- Complete military radar data
- Calibration data from similar and historical flights
### Example page - communications log

<table>
<thead>
<tr>
<th>Time</th>
<th>Channel Name</th>
<th>Ocean Region</th>
<th>GES ID (octal)</th>
<th>Channel Unit ID</th>
<th>Channel Type</th>
<th>SU Type</th>
<th>Burst Frequency Offset (Hz)</th>
<th>Burst Timing Offset (microseconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7/03/2014 18:28:14.904</td>
<td>IOR-R12000-0-36ED</td>
<td>IOR</td>
<td>305</td>
<td>4</td>
<td>R-Channel RX</td>
<td>0x62 - Acknowledge User Data (R-channel)</td>
<td>143</td>
<td>2480</td>
</tr>
<tr>
<td>18:39 - Ground Initiated to Air Telephony Call - Zero Duration (Not Answered)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7/03/2014 18:39:52.907</td>
<td>IOR-P10500-0-386B</td>
<td>IOR</td>
<td>301</td>
<td>10</td>
<td>P-Channel TX</td>
<td>0x20 - Access Request/Call Announcement Telephone/Circuit-Mode Data</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7/03/2014 18:39:52.907</td>
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<td>IOR</td>
<td>301</td>
<td>10</td>
<td>P-Channel TX</td>
<td>0x33 - C-Channel Assignment (Regularity)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7/03/2014 18:39:52.907</td>
<td>IOR-P10500-0-386B</td>
<td>IOR</td>
<td>301</td>
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<td>0x33 - C-Channel Assignment (Regularity)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7/03/2014 18:39:55.354</td>
<td>IOR-3730-21000</td>
<td>IOR</td>
<td>305</td>
<td>6</td>
<td>C-Channel RX</td>
<td>0x30 - Call Progress - Test</td>
<td>18</td>
<td></td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Time</th>
<th>Channel Name</th>
<th>Ocean Region</th>
<th>GES ID (octal)</th>
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<th>Channel Type</th>
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<th>Burst Frequency Offset (Hz)</th>
<th>Burst Timing Offset (microseconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7/03/2014 18:40:56.354</td>
<td>IOR-3730-21000</td>
<td>IOR</td>
<td>305</td>
<td>6</td>
<td>C-Channel RX</td>
<td>0x30 - Call Progress - Channel Release</td>
<td>90</td>
<td></td>
</tr>
<tr>
<td>19:41 - Handshake Request, with response</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7/03/2014 19:41:00.910</td>
<td>IOR-P10500-0-386B</td>
<td>IOR</td>
<td>305</td>
<td>10</td>
<td>P-Channel TX</td>
<td>0x14 - Log Control - Log-on Interrogation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7/03/2014 19:41:02.906</td>
<td>IOR-R12000-0-36ED</td>
<td>IOR</td>
<td>305</td>
<td>4</td>
<td>R-Channel RX</td>
<td>0x15 - Log-on/Log-off Acknowledge</td>
<td>111</td>
<td>1500</td>
</tr>
<tr>
<td>20:41 - Handshake Request, with response</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7/03/2014 20:41:02.907</td>
<td>IOR-P10500-0-386B</td>
<td>IOR</td>
<td>305</td>
<td>10</td>
<td>P-Channel TX</td>
<td>0x14 - Log Control - Log-on Interrogation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7/03/2014 20:41:04.904</td>
<td>IOR-R12000-0-36ED</td>
<td>IOR</td>
<td>305</td>
<td>4</td>
<td>R-Channel RX</td>
<td>0x15 - Log-on/Log-off Acknowledge</td>
<td>111</td>
<td>1740</td>
</tr>
<tr>
<td>21:41 - Handshake Request, with response</td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7/03/2014 21:41:24.907</td>
<td>IOR-P10500-0-386B</td>
<td>IOR</td>
<td>305</td>
<td>10</td>
<td>P-Channel TX</td>
<td>0x14 - Log Control - Log-on Interrogation</td>
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<td></td>
</tr>
<tr>
<td>7/03/2014 21:41:26.905</td>
<td>IOR-R12000-0-36ED</td>
<td>IOR</td>
<td>305</td>
<td>4</td>
<td>R-Channel RX</td>
<td>0x15 - Log-on/Log-off Acknowledge</td>
<td>168</td>
<td>2780</td>
</tr>
<tr>
<td>22:41 - Handshake Request, with response</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7/03/2014 22:41:29.907</td>
<td>IOR-P10500-0-386B</td>
<td>IOR</td>
<td>305</td>
<td>10</td>
<td>P-Channel TX</td>
<td>0x14 - Log Control - Log-on Interrogation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7/03/2014 22:41:31.906</td>
<td>IOR-R12000-0-36ED</td>
<td>IOR</td>
<td>305</td>
<td>4</td>
<td>R-Channel RX</td>
<td>0x15 - Log-on/Log-off Acknowledge</td>
<td>204</td>
<td>4540</td>
</tr>
<tr>
<td>23:13 - Ground Initiated to Air Telephony Call - Zero Duration (Not Answered)</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7/03/2014 23:13:58.407</td>
<td>IOR-P10500-0-386B</td>
<td>IOR</td>
<td>305</td>
<td>10</td>
<td>P-Channel TX</td>
<td>0x20 - Access Request/Call Announcement Telephone/Circuit-Mode Data</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7/03/2014 23:13:58.407</td>
<td>IOR-P10500-0-386B</td>
<td>IOR</td>
<td>305</td>
<td>10</td>
<td>P-Channel TX</td>
<td>0x33 - C-Channel Assignment (Regularity)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7/03/2014 23:14:00.904</td>
<td>IOR-3737-21000</td>
<td>IOR</td>
<td>305</td>
<td>6</td>
<td>C-Channel RX</td>
<td>0x30 - Call Progress - Test</td>
<td>216</td>
<td></td>
</tr>
</tbody>
</table>
Publications

www.malaysiaairlines.com/mh370 - Media releases

Malaysia Ministry of Transport on Facebook

Mar 22, 2014 - Cargo Manifest


Mar 25, 2014 - Original BFO figures and explanation


Publications (cont.)

Apr 1, 2014 - Transcript of cockpit / ATC communications

Apr 27, 2014 - MH 370 Preliminary Report to ICAO

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

Maps
  https://www.facebook.com/HishammuddinH2O/
May 20, 2014 - Data Communication logs


ATSB (Australia)


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

Journal of Navigation (2015), 68, 1
Publications (cont.)

Jan 29, 2015 - “SAR Response to MH370”
http://www.icao.int/APAC/Meetings/2015 APSARTF3/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”
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/model.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>
<thead>
<tr>
<th>Time (UTC)</th>
<th>(Δf sat + Δf AFC) Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td>16:30:00</td>
<td>29.1</td>
</tr>
<tr>
<td>16:42:00</td>
<td>27.6</td>
</tr>
<tr>
<td>16:55:00</td>
<td>25.8</td>
</tr>
<tr>
<td>17:07:00</td>
<td>24.1</td>
</tr>
<tr>
<td>18:25:00</td>
<td>10.7</td>
</tr>
<tr>
<td>19:41:00</td>
<td>-0.5</td>
</tr>
<tr>
<td>20:41:00</td>
<td>-1.5</td>
</tr>
<tr>
<td>21:41:00</td>
<td>-18.0</td>
</tr>
<tr>
<td>22:41:00</td>
<td>-28.5</td>
</tr>
<tr>
<td>00:11:00</td>
<td>-37.7</td>
</tr>
<tr>
<td>00:19:00</td>
<td>-37.8</td>
</tr>
</tbody>
</table>
Analysis Software

Excel

STK (satellite tracking program)

python

octave
Where do people “publish”? 

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

aqqa.org

AQA REPORTS  GODFREY MODEL
Example: Magnetic track mode

Initial ACARS data calibrate BTO, BFO and validate modeling

Final latitude -34 deg.
Example: Uncommanded Autopilot v. Active Pilot Flight Paths
A Sample of Reports


"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.")


Predictions - JIT/JACC/ATSB v. Public

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

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

Drift modeling not accurate but favors more Northerly impact point

Goose barnacles - which species?
Feb 27, 2016  Piece of right horizontal stabilizer discovered on sand bank off coast of Mozambique

Glaser stencil font

No Goose barnacles - why?
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 ...


Intricate metallic design matches interior bulkhead of Malaysia Airlines fleet.

Location: Door 1R in business class.
And It Be Rainin' Debris!

Mauritius Bernache
May 24, 2016

Mauritius Gris Gris
May 25, 2016

Mozambique
May 26, 2016

Macaneta, Mozambique
May 22, 2016
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
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

Distance between actual and estimated track at 7th arc = 145 NM (270 km)
Figure 15. Burst Frequency Offset Validation (Amsterdam Flight).
Why no barnacles? ... Oh wait

December 23, 2014
Mossel Bay
Klein Brak Beach

March 22, 2014
Mossel Bay
Klein Brak River

Snails have done their work
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
Recent Analysis - Did Anyone Feel It Crash?

Seismic stations

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

Data from IRIS-DMC