MH 370: STPA Supporting Possible Improvements in Air-Ground Tracking & Communication Systems

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MS Business Intelligence

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MIT, MA
MH370 highlights

Current status

• Search still ongoing (26 countries, hundreds of millions of USD so far…)

• Uncertainty about
  • What happened
  • Why/How it happened
  • Where is the A/C
    • Unknown underwater area

• Unacceptable Losses
  • ALARA (As Low As ?Reasonably? Acceptable)
    • Human Losses (239 Passengers & Crew)
    • Aircraft
    • Impacts on
      • Victims’ families & friends
      • Airline…

• Unacceptable to have an aircraft missing (in the 21st century…)

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MH370 highlights

ICAO Annex 13: Factual Information – 03.08.2015

Timeline (selected events):
• 0119:30 MYT: last verbal communication
• 0121:13 MYT: last Secondary Radar signal around IGARI
• Slight variations in speed, altitude & heading after IGARI
• Between VAMPI & MEKAR it followed route N571…
• 0222:12: lost by military radar after MEKAR
• 0632 MYT: 1st DETRESFA message for Search and Rescue: 5h11min LATER
• 0819 MYT: last SATCOM received from MH370 by Inmarsat IOR I3
• 1130 MYT: first SAR aircraft took off

Last communications: Appendix 1.18 (E, F…)

Other
• SSFDR ULB battery: expiry date: December 2012
• SSCVR ULB battery: expiry date: June 2014
MH370 highlights

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Figure 1.1A - Chronological Sequence of Events of Disappearance of MH370

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## MH370 highlights

### ICAO Annex 13: Factual Information – 03.08.2015


<table>
<thead>
<tr>
<th></th>
<th>Event Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>P3362: Appeared at 1730:37 UTC [0130:37 MYT]</td>
</tr>
<tr>
<td>2</td>
<td>P3362: Coasted at 1737:12 UTC [0137:12 MYT] \nDropped at 1737:22 UTC [0137:22 MYT]</td>
</tr>
<tr>
<td>3</td>
<td>P3401: Appeared at 1738:56 UTC [0138:56 MYT]</td>
</tr>
<tr>
<td>4</td>
<td>P3401: Coasted at 1744:42 UTC [0144:42 MYT] \nDropped at 1744:52 UTC [0144:52 MYT]</td>
</tr>
<tr>
<td>5</td>
<td>P3415: Appeared at 1747:02 UTC [0147:02 MYT]</td>
</tr>
<tr>
<td>6</td>
<td>P3415: Coasted at 1748:29 UTC [0148:29 MYT] \nDropped at 1748:39 UTC [0148:39 MYT]</td>
</tr>
<tr>
<td>7</td>
<td>P3426: Appeared at 1751:45 UTC [0151:45 MYT]</td>
</tr>
<tr>
<td>8</td>
<td>P3426: Coasted at 1752:25 UTC [0152:25 MYT] \nDropped at 1752:35 UTC [0152:35 MYT] \nP3426 last seen on radar display approximately 6Nm South of Penang</td>
</tr>
<tr>
<td>9</td>
<td>The primary target (military radar) appeared to track west-northwest direction joining RNAV Route N571 at waypoint VAMPI then to 10Nm north MEKAR</td>
</tr>
<tr>
<td>10</td>
<td>The primary target ended at 10Nm after MEKAR at 1822:12 UTC [0222:12 MYT]</td>
</tr>
</tbody>
</table>

**Figure 1.1B – Diversion from Filed Flight Plan Route (not to scale)**
System Theoretic Process Analysis (STPA)
Leveson, 2011

• Identify the potential for inadequate control actions leading to hazardous states
  • Action is not provided
  • Unsafe action is provided
  • Safe action is provided:
    • too soon
    • too late

• Determine how each potentially hazardous control actions could occur…
MH370 highlights: STPA

**Color Codes: “Italian Flag”**
Sir Beddington et al., 2011

- Proposed for **categorizing levels of certainty/uncertainty of system states** in STPA
- ORANGE used instead of RED since evidence is not yet 100%...

<table>
<thead>
<tr>
<th>State: OK</th>
<th>State: Unknown</th>
<th>State: NOT OK = KO)</th>
</tr>
</thead>
<tbody>
<tr>
<td>evidence that A is successful</td>
<td>incompleteness of knowledge</td>
<td>evidence that A is not successful</td>
</tr>
</tbody>
</table>

```
GREEN    WHITE    RED
```

ORANGE
MH370 highlights: STPA

Environment/Situation
State: NIGHT

Aircraft & Pilots
State: UNCERTAIN
Transponders: OFF
Communication: OFF
Flight Path/Location: ABNORMAL

Ground: Civil: HCM ATCC
State: Supposed to be IN CHARGE
Transponders: OFF
Communication: OFF
Flight Path/Location: ABNORMAL

Ground: Civil: KL ATCC
State: IN CHARGE
Transponders: OFF
Communication: OFF
Flight Path/Location: ABNORMAL

Ground: Military
State: NOT IN CHARGE...
Radar: INFO...

Process: FLYING
State: OK
Execution: ?

Process: MONITORING
State: UNCERTAIN
Execution: ?
MH370 highlights: STPA

Environment/Situation | Procedures
---|---
Night | ?

**Human Agents: PF, PNF**
- Control Action
- Model of Process

**Controls**

**Instruments**

**Automated Agents**
- Algorithms
- Processes

**Actuators**

**Sensors**

**Process: FLY**

**Inputs**

**Outputs**

**Disturbances**

PF, PNF Possible State(s):
- Incapacitated?
- Hijacked?
- Intentional?
- Non-intentional?

Instruments Possible State(s)?:
- Malfunction?
- Communication off?

Automated Agents Possible State(s)?
- Malfunction?
- Communication off?

Actuators/Sensors Possible States?:
- Malfunction?
MH370 highlights: STPA

<table>
<thead>
<tr>
<th>Environment/Situation</th>
<th>Procedures/Organization</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Night</strong></td>
<td><strong>?</strong></td>
</tr>
</tbody>
</table>

**Possible State(s)?**:
- Rotation?
- Miscommunication?
- High Workload?
- Low Awareness?

**Instruments State(s)**:
- OK

**Automated Agents State(s)**:
- OK

**Actuators/Sensors Possible States**:
- Malfunction in the A/C?
- Off in the A/C?
“With ADS-B, both pilots and controllers can see radar-like displays of traffic –[...] next to real time and do not degrade with distance or terrain.”

- Gains in safety, capacity, and efficiency as a result of moving to a satellite-based system
- Air-to-air surveillance
- Surveillance to remote or inhospitable areas that do not currently have coverage with radar
- Real-time traffic & aeronautical information in the cockpit
WP3

• **Collaborative Information Exchange (CIX)** – increased situational awareness and improved constraint prediction by the incorporation of data made available via System Wide Information Management (SWIM) mechanisms…

**Data Comm** (Data Communications)

www.faa.gov/about/office_org/headquarters_offices/ato/service_units/techops/atc_comms_services/datacomm/general/

- First phase of the transition from the current analog voice system to an International Civil Aviation Organization (ICAO) compliant digital system
- **Introduction of air/ground trajectory automation capabilities [...] that depends on efficient data communications between aircraft and air traffic management**
**NVS (NAS Voice System)**

www.faa.gov/nextgen/programs/nvs/

- Voice capability which supplements data communications for tactical situations and emergencies, operating in controlled airspace
- Air-to-ground voice communication is no longer limited by geographical facility boundaries

**Weather**

www.faa.gov/nextgen/programs/weather/

- NextGEN Weather Processor (NWP)
- Aviation Weather Display
- Common Support Services via SWIM
Swim (System Wide Information Management)

www.faa.gov/nextgen/programs/swim/overview/

- Separation of information provision & consumption for allowing number and nature of the consumers to evolve through time
- Loose system coupling
- Uses publicly available open standards
- The use of Service Oriented Architecture (SOA) concepts within the design of a suite of interoperable web-services

- Promotes International Harmonization (Ngo, 2014)
SWIM infrastructure allows more efficient data sharing among aviation partners

Two major SWIM features:
1. SWIM streamlines connections among different data systems so users can access multiple systems through one connection.
2. SWIM translates data from different systems into standard data formats, supporting collaboration among industry and governments (US & International).

- Global Exchange Models
  - FIXM (Flight Information Exchange Model)
  - WIXM (Weather Information Exchange Model)
  - AIXM (Aeronautical Information Exchange Model)

- Traffic Flow Management System: provides subscribers with Aircraft Situation Display to Industry (ASDI) data access to traffic flow information.
March 30, 2014

Paul Hudson (Aviation Consumer Action Project – ACAP)

“Mr. Hudson stated a tasking should include issues related to the MH370 incident, specifically pilots’ ability to avoid tracking by turning off transponders.

He explained current black box technology is dated, and the industry should implement new data streaming capabilities in black boxes to avoid negative repercussions.” (p. 8)
FLYHT Stream
flyht.com/investors/videos/

- Automated Flight Information Reporting Systems (AFIRS)
- **Real-time ‘virtual black box’ emergency data streaming** activated by pilots, ground
  or triggered automatically by flight events
- **Air-Ground voice & text messages**
- Uses the **Iridium satellite system** infrastructure
- 64 units (60 for 12 Chinese companies; 4 in the US – 2 military, 2 commercial…)
STAR In Flight Monitoring System (ISMS)
www.star-navigation.com/product/StarISMS

- Online Remote Aircraft Safety Monitoring = ‘virtual window’ into aircraft
- Early warning system
- Instant Alert Notifications
- Transmits up to 3000+ Parameters per Minute (depending on bandwidth): more than twice compared to MH370 SSFDR…
- Universal Access via Internet (anytime)
- Stand-Alone System or 24/7 Star Monitoring

STAR Airborne Data Service (ADS)
www.star-navigation.com/service/StarADS

- Real Time FOQA / FDM / MOQA and End of Flight (EOF) Analysis reports
- Secure SatCom transmission
- Real time satellite global coverage from pole to pole
- Emergency data transmission display for DFDR parameter and Emergency streamed position reports (SPR)
Inmarsat (Colledge & Ibnyahya, 2014)
www.faa.gov/about/office_org/headquarters_offices/ato/service_units/systemops/ato_intl/documents/cross_polar/cpwg18/cross%20polar%20wg18_inmarsat%20update%20dec%202014.pdf

ADS-C (Automatic Dependent Surveillance-Contract)

“Since the tragic disappearance of MH370, Inmarsat has been working with our Distribution Partners (including SITA and Rockwell Collins/ARINC), and a number of other industry partners to assist in defining solutions for aircraft flight tracking”

Need for an industry wide solution:
• Locate aircraft more systematically & accurately
• Increase reactivity in case of abnormal route deviation or event

“Inmarsat is working with its partners to offer a Basic Tracking ADS-C message for free, every 15 minutes”
Inmarsat + Qatar Airways
www.runwaygirlnetwork.com/2015/01/07/qatar-airways-signals-intent-adopt-black-box-streaming/

January 7, 2015

“Inmarsat – whose SwiftBroadband aeronautical service supports inflight Wi-Fi on Qatar’s Boeing 787s and now the A350 – is known to be offering a ‘black box in the cloud’ service, under which – on the back of certain defined trigger events (such as an unapproved course deviation) – historic and real-time flight data recorder and cockpit voice recorder information can be streamed off an aircraft to defined aviation safety recipients.”
January 8, 2015

“Inmarsat distribution partner OnAir’s full inflight connectivity suite is being installed as line fit on Qatar Airways’ brand new Airbus A350 fleet.

Passengers can now choose between mobile phone connectivity and Wi-Fi using Mobile OnAir or Internet OnAir, powered by Inmarsat SwiftBroadband.

[...]

OnAir’s next generation inflight connectivity services, using Inmarsat GX Aviation, will be launched on the A350 in 2016.

Inmarsat’s ground-breaking global Ka-band network will provide up to 50Mbs to the aircraft – and deliver a consistent service across the globe.”
OnAir (Airbus & SITA)
www.onair.aero/en/commercial-airlines-products

Several InFlight secured services including air-ground connectivity for:
- Mobile phones
- Internet (up to 50Mbs)
- Link OnAir (various applications…)

onair.aero/en/commercial-airlines-how-it-works-mobile-onair
onair.aero/en/commercial-airlines-how-it-works-internet-onair

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State of the Art: Synthesis

- Improved Satellite Communications
- Improved Air-Ground streaming (up to 50Mbs)
  - TEXT & NUMERIC messages
  - VOICE
- Black Box streaming to ground
  - Flight Parameters
  - Vocal Communications in the cockpit
- ‘Virtual Window’ into aircraft

⇒ Who is supposed to process all this data & information?

- Big Data...
- Information overload...
- Infrastructure similar to SARSAT?
Possible Futures...

Possible features
accident investigations, training, flight tests, operations...

- Single Pilot...
- UAV...

⇒ Streaming & Remote Immersion
  - Pictures 360 & 3D
  - Videos 360 & 3D
    - 1 stream instead of n

Adloori, 2015: Cockpit Simulator: Voice & Video analysis for training purposes performed with ATLAS.ti

Stephane, 2015: Cockpit Simulator: Experimental 360 Picture for Shared Immersive Risk/Situation Awareness (planar & spherical views).
Samsung Gear VR/Oculus Mobile VR Headset used for remote visual immersion.
Possible Futures…

**Possible features**
similar to current military solutions/UAV already using large bandwidth

- Single Pilot...
- UAV...

⇒ Remote Control of Aircraft
  - In unusual/emergency situations?
  - Other…

**Emerging**

- Issues
  - Acceptability in communities of practice...
  - Security – hacking, take over A/C...
  - Viruses
  - Infrastructure availability...

- Benefits
  - Distributed features & responsibilities...
  - Crowdsourcing (i.e. passengers,...)
Perspectives: STAMP & STPA for Safety Governance

Improvements

Organizational
• Globalized harmonization
• Investments in infrastructure

Operational
• Evolutions in technology
• Evolutions in practice
  • Inter-organization choreography

!! In Particular !!
• Apply and Use in accident investigation reports

Leveson, 2004, 2011
Discussion…

Thanks for your feedback & feedforward

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References