Flight Data Monitoring

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Presentation Outline

• Defence Technology Agency – quick overview
• Flight Data Monitoring (FDM) – wider context
• FDM Case Study - RNZAF C-130H(NZ)
  • Data recording system
  • Data challenges
  • Single flight data processing
  • Fleet analysis – Dataset
  • Fleet analysis - Results and outcomes
• Challenges of Flight Data Monitoring
• FDM and Safety Investigations
DTA Role:

- Leadership in national defence science and technology research.
- Offer sound scientific advice to the New Zealand Defence Force, Ministry of Defence and other government agencies.
- Provide independent objective evidence to complement ‘professional judgement’.
- To provide Science & Technology based outcomes for the benefit of the Army, Navy and Air Force.

Current Staffing ~80.
Flight Data Monitoring – wider context

Search for Flight MH370

Australia’s naval support ship
Ocean Shield

Bluefin-21: Side-scanning sonar and multi-beam echo sounder can examine underwater objects in detail and operate in depths of up to 4,500m

TOWED PINGER LOCATOR 25
- Weight: 35kg

BLUEFIN-21: Robotic mini-submarine
- Max. depth: 4,500m
- Autonomy: 25 hours
- Speed: 4.5 knots
- Weight: 750kg

TPL-25: Pulled behind ship at slow speeds

Hyper-sensitive hydrophone can detect signals up to 6,000m deep

Devices searched: Black-boxes can withstand impact 3,400 times force of gravity

Emergency Locator Transmitter: Automatically transmits digitally encoded signal

Cockpit Voice Recorder

Solid State Flight Data Recorder

Underwater Locator Beacon: Transmits pulse at 37.5kHz, from depth of 6,000m, every second for 30 days

Source: Engineering and Technology Magazine website
Flight Data Monitoring – Benefits

- Flight Data Monitoring (FDM) is the proactive use of digital flight data from routine operations to improve aviation safety – **UK CAA CAP 739**
  - ICAO requirement for Commercial Transport Aeroplanes with a take-off mass in excess of 27,000kg. Whilst New Zealand is a signatory to the ICAO convention FDM is one of the NZ exemptions – **NZ CAA ‘Electronic Filing Of Differences’ 10 Jan 2014**
  - ICAO recommend FDM for helicopters with a take-off mass in excess of 7000kg or passenger seating of more than 9 - **UK CAA CAP 739**
  - ICAO guidance with effect from 2005 onwards.

- Other benefits of FDM include:
  - Identification of fuel savings strategies
  - High fidelity usage monitoring, important for military aircraft due to varying operational profiles
  - Improved fleet management
  - Reduced maintenance
  - Fault detection
FDM Case Study – RNZAF C-130(H)NZ
FDM Case Study – RNZAF C-130(H)NZ

Data Recording System

• Centred around a Teledyne Digital Flight Data Acquisition Unit (DFDAU)
• Records up to 512 channels at 1Hz
• Parameters include:
  – Flight data including altitude, airspeed, heading, pitch angle, roll angle, fuel quantity, aircraft weight.
  – Engine data including engine speed, torque, fuel flow and turbine inlet temperature.
  – Control column position for elevator, aileron and rudder as well as actual flap position.
  – Acceleration data in the vertical, lateral and longitudinal aircraft axes.
  – Discrete data including weight-on-wheels.
  – Strain gauge data from the centre wing, outer wing, fuselage, vertical fin and horizontal stabiliser

Source: Teledyne Controls
FDM Case Study – RNZAF C-130(H)NZ

Data Recording System

• Data stored in a proprietary format on a PCMCIA memory card.
• Memory card periodically removed from the aircraft and the data file copied across onto the defence network and then stored.

Data Challenges

• Proprietary software for converting the raw data into engineering values is inefficient.
• There is too much data to process manually.
• More fundamentally, how do you use the data to achieve tangible outcomes?

Source: Teledyne Controls
FDM Case Study – RNZAF C-130(H)NZ

Single flight data processing

- Custom software tools were developed:
  - That efficiently decode the raw data into an Excel compatible format.
    - Extraction time reduced significantly e.g. 45 mins down to 45 secs making the data more accessible.
  - That can look at the data file on the PCMCIA memory card and segment the data file into individual flights or engine ground runs.
    - Allows the user to extract only the data for the flight of interest, rather than having to data mine the entire file.
  - That automatically analyse the flight data to:
    - Derive usage information for fleet management
    - Detect exceedances
FDM Case Study – RNZAF C-130(H)NZ

Single flight data processing
| A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R | S | T | U | V | W |
| 1 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 2 | 18/04/2014 | 10:25:45 p.m. | Ground | -03 | 0 | 0 | 0 | 34.5625 | 0.358569 | 1.004656 |
| 3 | 18/04/2014 | 10:25:46 p.m. | Ground | -06 | 0 | 0 | 0 | 25.00125 | 0.87729 | 1.877292 |
| 4 | 18/04/2014 | 10:25:47 p.m. | Ground | -08 | 0 | 0 | 0 | 17.98785 | 0.082281 | 1.110687 |
| 5 | 18/04/2014 | 10:25:48 p.m. | Ground | -10 | 0 | 0 | 0 | 28.78125 | 0.916895 | 1.8777 |
| 6 | 18/04/2014 | 10:25:49 p.m. | Ground | -12 | 0 | 0 | 0 | 37.70125 | 0.651823 | 1.93238 |
| 7 | 18/04/2014 | 10:25:50 p.m. | Ground | -14 | 0 | 0 | 0 | 2.842188 | 0.97563 | 0.2286 |
| 8 | 18/04/2014 | 10:25:51 p.m. | Ground | -16 | 0 | 0 | 0 | 48.28125 | 0.931821 | 1.00449 |
| 9 | 18/04/2014 | 10:25:52 p.m. | Ground | -18 | 1 | 0 | 0 | 103.95785 | 1.00457 | 1.712 |
| 10 | 18/04/2014 | 10:25:53 p.m. | Ground | -20 | 1 | 0 | 0 | 103.95785 | 1.00457 | 1.712 |
| 11 | 18/04/2014 | 10:25:54 p.m. | Ground | -22 | 1 | 0 | 0 | 103.95785 | 1.00457 | 1.712 |
| 12 | 18/04/2014 | 10:25:55 p.m. | Ground | -24 | 1 | 0 | 0 | 103.95785 | 1.00457 | 1.712 |

FDM Case Study  RNZAF C-130(H)NZ  
Single flight data processing
FDM Case Study – RNZAF C-130(H)NZ

Single flight data processing

- Exceedance Information:
  - Positive (+3G) and negative (0G) exceedances.
  - Flap overspeed and overstress occurrences.
  - Ramp and door overspeed occurrences.
  - Aircraft roll angle exceedances (with and without flap extended).
  - Maximum Turbine Inlet Temperature exceedances.
  - Maximum Torque exceedances.
  - Time at temperature exceedances:
    • Max TIT for longer than 5 seconds.
    • Take-off TIT for longer than 5 minutes.
    • Military TIT for longer than 30 minutes.
  - Hot start occurrences.
FDM Case Study – RNZAF C-130(H)NZ

Fleet Analysis (3 out of 5 aircraft reviewed)

| Data files | 62 |
| Hours of recorded data | 3430 |
| Seconds of recorded data | 12,347,280 |
| Individual data points | 6,087,209,040 |

<table>
<thead>
<tr>
<th>Start Date</th>
<th>Finish Date</th>
<th>No. Flights</th>
<th>No. Flight Hours</th>
<th>Mean Flight Time (hrs)</th>
<th>No. Ground Runs</th>
<th>No. Ground Run Hours</th>
<th>Mean Ground Run Time (hrs)</th>
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<td>NZ7001</td>
<td>16-Feb-13</td>
<td>17-May-14</td>
<td>264</td>
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<td>15-May-14</td>
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<tr>
<td>NZ7004</td>
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<td>9-Jun-14</td>
<td>557</td>
<td>1141.4</td>
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<td>Fleet totals</td>
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<td>2.06</td>
<td>846</td>
<td>263.0</td>
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FDM Case Study – RNZAF C-130(H)NZ

Fleet Analysis – Results - Usage

• High fidelity usage monitoring to track the overall severity of aircraft usage.
  – Particularly important for military aircraft where the operating profile can change daily.
  – Wing fatigue life is directly related to severity.
  – Less important for airline operations as the airlines flight profiles remain relatively constant.
FDM Case Study – RNZAF C-130(H)NZ
Fleet Analysis – Results - Usage
• Usage can change over time and risk is incurred if this is not conservatively captured.
FDM Case Study – RNZAF C-130(H)NZ

Fleet Analysis – Results - Usage

- Engine usage was also examined and the RNZAF hours to cycles ratio was found to be non-conservative.

<table>
<thead>
<tr>
<th></th>
<th>Cyclic Exchange Rate (Hrs/Cycles)</th>
<th>Includes Ground Running</th>
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<tbody>
<tr>
<td>USAF</td>
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<td>Yes</td>
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<tr>
<td>RAF</td>
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<td>-</td>
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<tr>
<td>USN</td>
<td></td>
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<tr>
<td>RNZAF (2007)</td>
<td>2.17</td>
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</tr>
<tr>
<td>RNZAF (2014)</td>
<td>1.81</td>
<td>Yes</td>
</tr>
</tbody>
</table>

- The actual engine turbine temperature profiles were lower than the Rolls Royce’s analytical temperature profiles due to the aircrew using lower engine power settings where possible.
FDM Case Study – RNZAF C-130(H)NZ

Fleet Analysis – Outcomes and Discussions

• Changes to engine hours to cycles ratio
• Discussions around implementing higher fidelity usage tracking
• Implementation of exceedance trend monitoring
• Discussions with the Operating Airworthiness Directorate on FDM and Safety Management Systems

Key Benefits for RNZAF

• Risk identification
• Improved fleet management
  – Improved usage tracking affecting cost, maintenance and availability.
  – Quantitative data for Flight Safety Event investigations.
Challenges of Flight Data Monitoring

• FDM can produce vast quantities of data which may require additional IT infrastructure/resource to manage or integrate.

• Data quality can be a challenge, and robust processing is needed to identify and cleanse erroneous data, otherwise the results can be misleading (e.g. false positive exceedances)

• Identifying the specific outcomes from FDM as these can vary between operators and aircraft types, and maybe quite different for military operators due to the unique roles of the aircraft. The outcomes should drive the analysis.

• Organisationally FDM is a challenge. It is still a relatively new concept and to achieve the outcomes, organisations need to wrestle with how to implement a contemporary system within their own well understood historical systems.
FDM and Safety Investigations

- If FDM has been adopted by an operator, then the data could be used as a good source of quantitative information for the event itself, but also for the recent history leading up to the event.
  - DTA contributed to the investigation of the Airtrainer crash in 2010.
  - ATSB recovered the digital data from usage monitoring equipment.
  - Flight reconstruction was used to aid the investigation team. Previous flights were also examined.

- Can be used to quantify/validate/understand flight conditions around an event, including establishing an objective timeline.
- Can be used to understand the recent usage severity.
- Other aircraft in the fleet may also have data recording equipment fitted which may be of value in establishing trends leading up to an event.