New Zealand DEFENCE FORCE
Te Ope Kātua O Aotearoa
NAVY NZARMY AIR FORCE

Flight Data Monitoring

ANZSASI Seminar, 6 June 2015
Auckland, New Zealand

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Presentation Outline

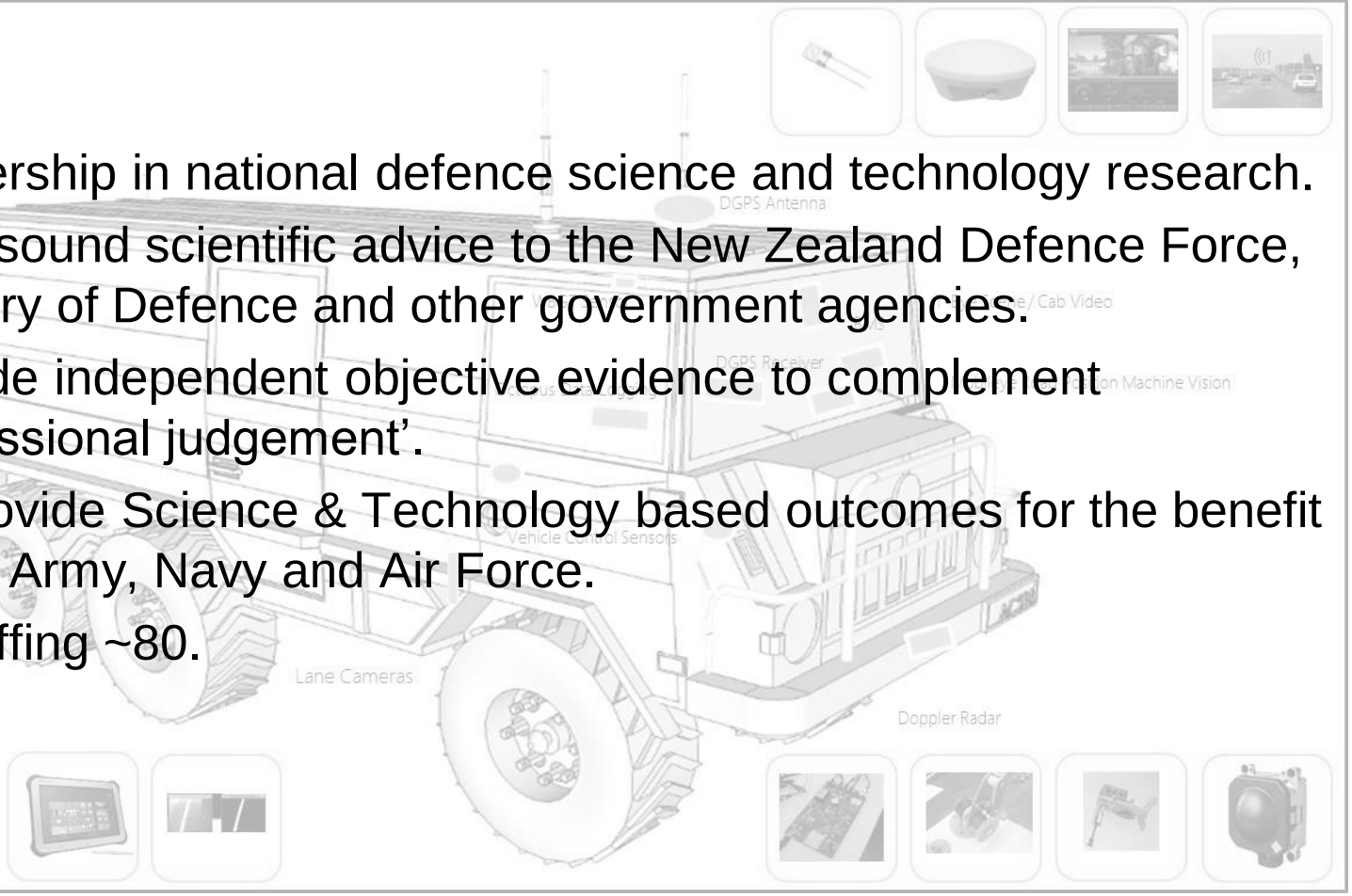
- Defence Technology Agency – quick overview
- Flight Data Monitoring (FDM) – wider context
- FDM Case Study - RNZAF C-130H(NZ)
  - Data recording system
  - Data challenges
  - Single flight data processing
  - Fleet analysis – Dataset
  - Fleet analysis - Results and outcomes
- Challenges of Flight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

Defence Technology Agency (DTA)

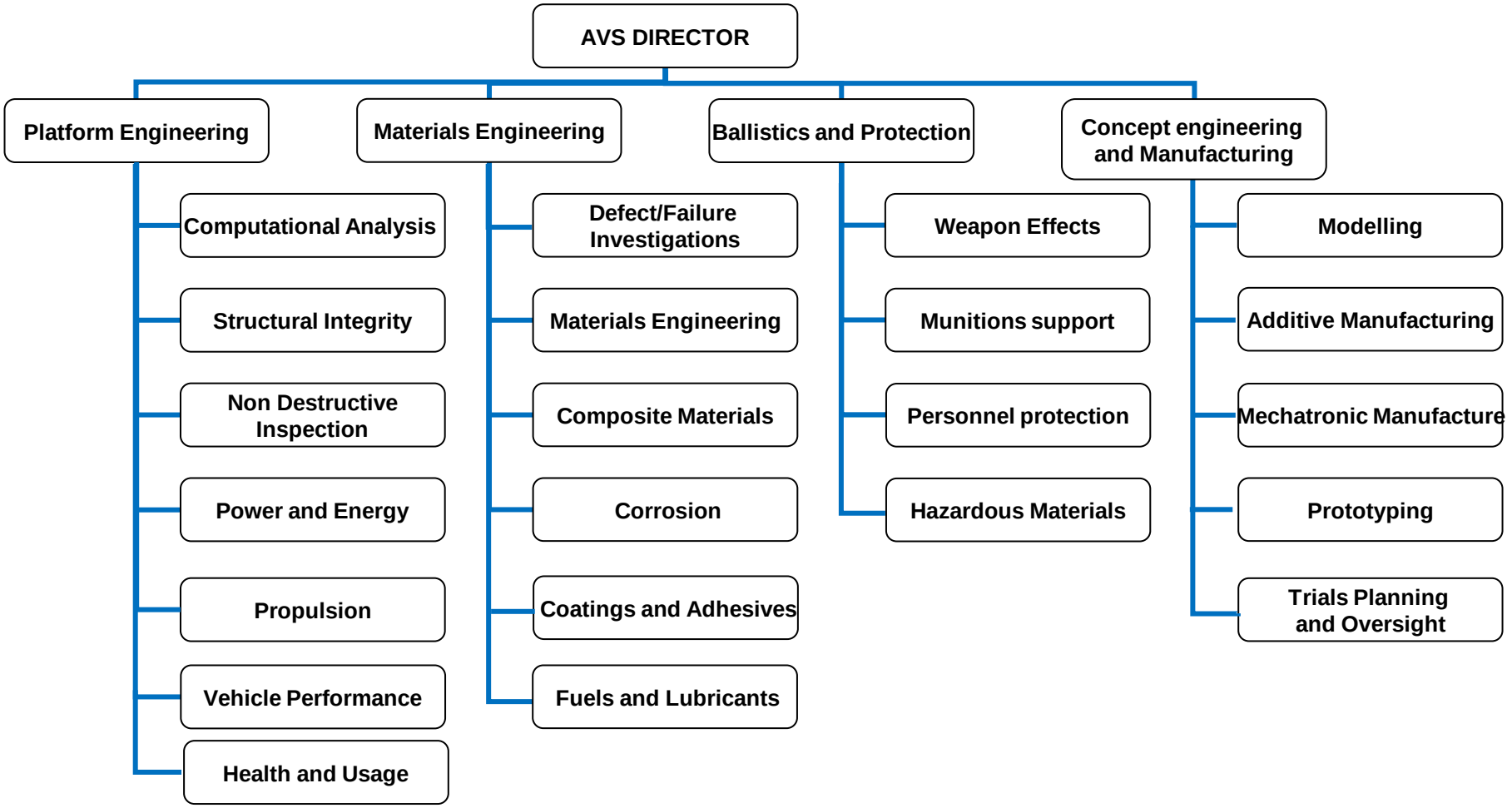
DTA Role:

- 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.

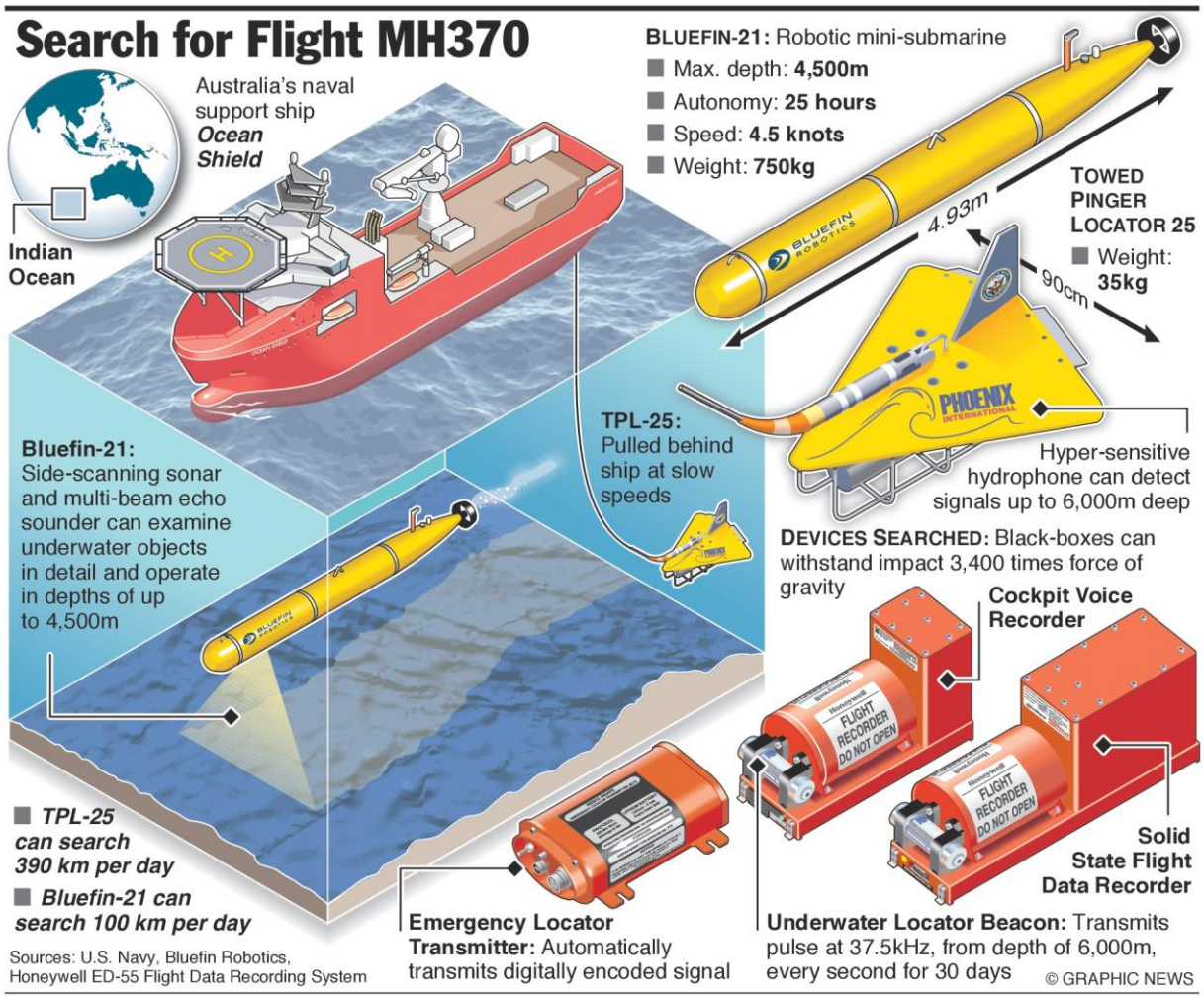
Current Staffing ~80.



Defence Technology Agency (DTA)



Flight Data Monitoring – wider context



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

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FDM Case Study – RNZAF C-130(H)NZ

FDM Case Study – RNZAF C-130(H)NZ

Data Recording System

Source: Teledyne Controls

- 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

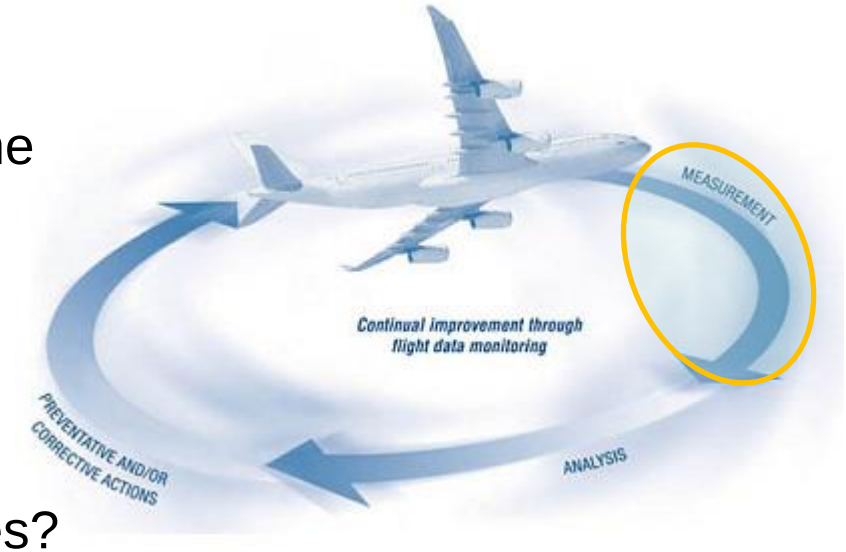
FDM Case Study – RNZAF C-130(H)NZ

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

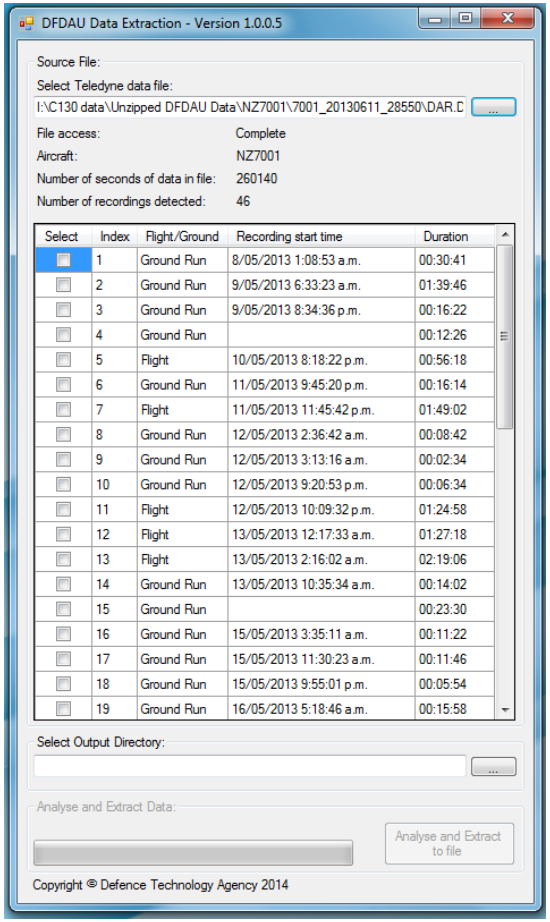
FDM Case Study – RNZAF C-130(H)NZ

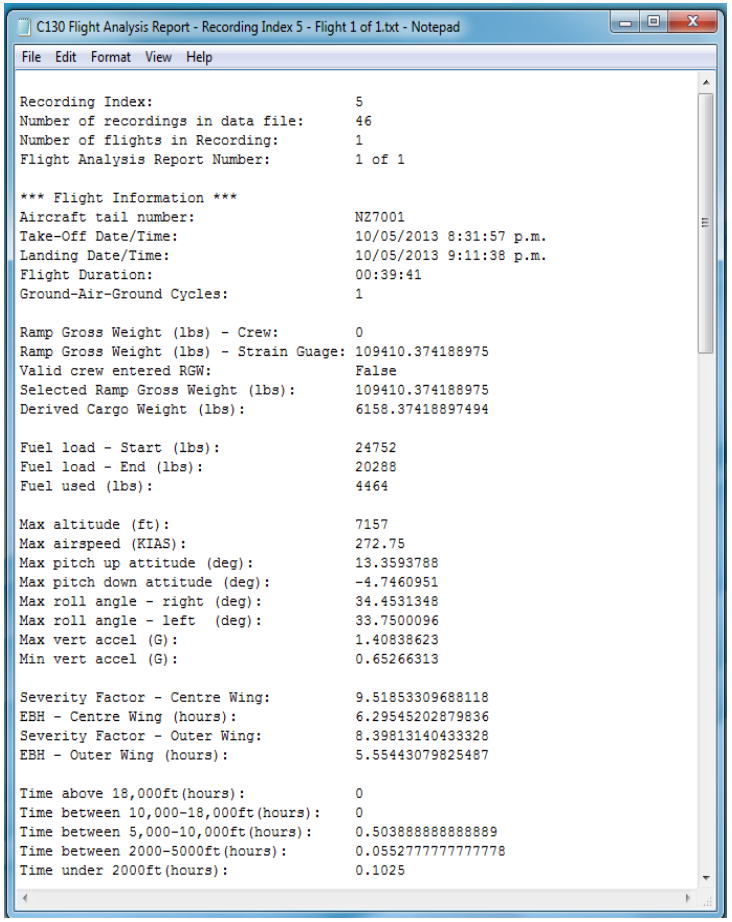
Single flight data processing

- 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





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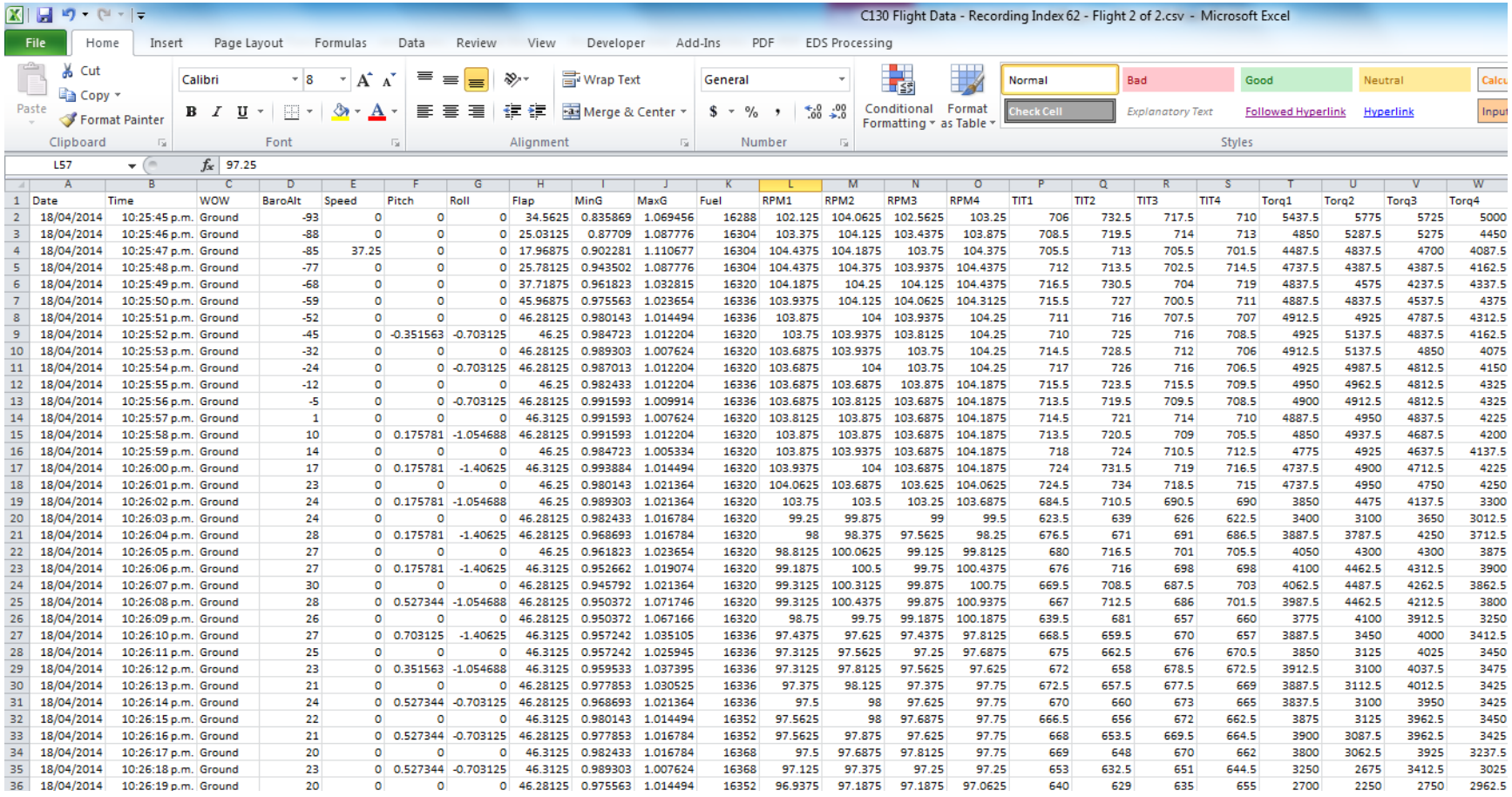
FDM Case Study – RNZAF C-130(H)NZ

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	Date	Time	WOW	BaroAlt	Speed	Pitch	Roll	Flap	MinG	MaxG	Fuel	RPM1	RPM2	RPM3	RPM4	TIT1	TIT2	TIT3	TIT4	Torq1	Torq2	Torq3	Torq4
2	18/04/2014	10:25:45 p.m.	Ground	-93	0	0	0	34.5625	0.835869	1.069456	16288	102.125	104.0625	102.5625	103.25	706	732.5	717.5	710	5437.5	5775	5725	5000
3	18/04/2014	10:25:46 p.m.	Ground	-88	0	0	0	25.03125	0.87709	1.087776	16304	103.375	104.125	103.4375	103.875	708.5	719.5	714	713	4850	5287.5	5275	4450
4	18/04/2014	10:25:47 p.m.	Ground	-85	37.25	0	0	17.96875	0.902281	1.110677	16304	104.4375	104.1875	103.75	104.375	705.5	713	705.5	701.5	4487.5	4837.5	4700	4087.5
5	18/04/2014	10:25:48 p.m.	Ground	-77	0	0	0	25.78125	0.943502	1.087776	16304	104.4375	104.375	103.9375	104.4375	712	713.5	702.5	714.5	4737.5	4387.5	4387.5	4162.5
6	18/04/2014	10:25:49 p.m.	Ground	-68	0	0	0	37.71875	0.961823	1.032815	16320	104.1875	104.25	104.125	104.4375	716.5	730.5	704	719	4837.5	4575	4237.5	4337.5
7	18/04/2014	10:25:50 p.m.	Ground	-59	0	0	0	45.96875	0.975563	1.023654	16336	103.9375	104.125	104.0625	104.3125	715.5	727	700.5	711	4887.5	4837.5	4537.5	4375
8	18/04/2014	10:25:51 p.m.	Ground	-52	0	0	0	46.28125	0.980143	1.014494	16336	103.875	104	103.9375	104.25	711	716	707.5	707	4912.5	4925	4787.5	4312.5
9	18/04/2014	10:25:52 p.m.	Ground	-45	0	-0.351563	-0.703125	46.25	0.984723	1.012204	16320	103.75	103.9375	103.8125	104.25	710	725	716	708.5	4925	5137.5	4837.5	4162.5
10	18/04/2014	10:25:53 p.m.	Ground	-32	0	0	0	46.28125	0.989303	1.007624	16320	103.6875	103.9375	103.75	104.25	714.5	728.5	712	706	4912.5	5137.5	4850	4075
11	18/04/2014	10:25:54 p.m.	Ground	-24	0	0	-0.703125	46.28125	0.987013	1.012204	16320	103.6875	104	103.75	104.25	717	726	716	706.5	4925	4987.5	4812.5	4150
12	18/04/2014	10:25:55 p.m.	Ground	-12	0	0	0	46.25	0.982433	1.012204	16336	103.6875	103.6875	103.875	104.1875	715.5	723.5	715.5	709.5	4950	4962.5	4812.5	4325
13	18/04/2014	10:25:56 p.m.	Ground	-5	0	0	-0.703125	46.28125	0.991593	1.009914	16336	103.6875	103.8125	103.6875	104.1875	713.5	719.5	709.5	708.5	4900	4912.5	4812.5	4325
14	18/04/2014	10:25:57 p.m.	Ground	1	0	0	0	46.3125	0.991593	1.007624	16320	103.8125	103.875	103.6875	104.1875	714.5	721	714	710	4887.5	4950	4837.5	4225
15	18/04/2014	10:25:58 p.m.	Ground	10	0	0.175781	-1.054688	46.28125	0.991593	1.012204	16320	103.875	103.875	103.6875	104.1875	713.5	720.5	709	705.5	4850	4937.5	4687.5	4200
16	18/04/2014	10:25:59 p.m.	Ground	14	0	0	0	46.25	0.984723	1.005334	16320	103.875	103.9375	103.6875	104.1875	718	724	710.5	712.5	4775	4925	4637.5	4137.5
17	18/04/2014	10:26:00 p.m.	Ground	17	0	0.175781	-1.40625	46.3125	0.993884	1.014494	16320	103.9375	104	103.6875	104.1875	724	731.5	719	716.5	4737.5	4900	4712.5	4225
18	18/04/2014	10:26:01 p.m.	Ground	23	0	0	0	46.25	0.980143	1.021364	16320	104.0625	103.6875	103.625	104.0625	724.5	734	718.5	715	4737.5	4950	4750	4250
19	18/04/2014	10:26:02 p.m.	Ground	24	0	0.175781	-1.054688	46.25	0.989303	1.021364	16320	103.75	103.5	103.25	103.6875	684.5	710.5	690.5	690	3850	4475	4137.5	3300
20	18/04/2014	10:26:03 p.m.	Ground	24	0	0	0	46.28125	0.982433	1.016784	16320	99.25	99.875	99	99.5	623.5	639	626	622.5	3400	3100	3650	3012.5
21	18/04/2014	10:26:04 p.m.	Ground	28	0	0.175781	-1.40625	46.28125	0.968693	1.016784	16320	98	98.375	97.5625	98.25	676.5	671	691	686.5	3887.5	3787.5	4250	3712.5
22	18/04/2014	10:26:05 p.m.	Ground	27	0	0	0	46.25	0.961823	1.023654	16320	98.8125	100.0625	99.125	99.8125	680	716.5	701	705.5	4050	4300	4300	3875
23	18/04/2014	10:26:06 p.m.	Ground	27	0	0.175781	-1.40625	46.3125	0.952662	1.019074	16320	99.1875	100.5	99.75	100.4375	676	716	698	698	4100	4462.5	4312.5	3900
24	18/04/2014	10:26:07 p.m.	Ground	30	0	0	0	46.28125	0.945792	1.021364	16320	99.3125	100.3125	99.875	100.75	669.5	708.5	687.5	703	4062.5	4487.5	4262.5	3862.5
25	18/04/2014	10:26:08 p.m.	Ground	28	0	0.527344	-1.054688	46.28125	0.950372	1.071746	16320	99.3125	100.4375	99.875	100.9375	667	712.5	686	701.5	3987.5	4462.5	4212.5	3800
26	18/04/2014	10:26:09 p.m.	Ground	26	0	0	0	46.28125	0.950372	1.067166	16320	98.75	99.75	99.1875	100.1875	639.5	681	657	660	3775	4100	3912.5	3250
27	18/04/2014	10:26:10 p.m.	Ground	27	0	0.703125	-1.40625	46.3125	0.957242	1.035105	16336	97.4375	97.625	97.4375	97.8125	668.5	659.5	670	657	3887.5	3450	4000	3412.5
28	18/04/2014	10:26:11 p.m.	Ground	25	0	0	0	46.3125	0.957242	1.025945	16336	97.3125	97.5625	97.25	97.6875	675	662.5	676	670.5	3850	3125	4025	3450
29	18/04/2014	10:26:12 p.m.	Ground	23	0	0.351563	-1.054688	46.3125	0.959533	1.037395	16336	97.3125	97.8125	97.5625	97.625	672	658	678.5	672.5	3912.5	3100	4037.5	3475
30	18/04/2014	10:26:13 p.m.	Ground	21	0	0	0	46.28125	0.977853	1.030525	16336	97.375	98.125	97.375	97.75	672.5	657.5	677.5	669	3887.5	3112.5	4012.5	3425
31	18/04/2014	10:26:14 p.m.	Ground	24	0	0.527344	-0.703125	46.28125	0.968693	1.021364	16336	97.5	98	97.625	97.75	670	660	673	665	3837.5	3100	3950	3425
32	18/04/2014	10:26:15 p.m.	Ground	22	0	0	0	46.3125	0.980143	1.014494	16352	97.5625	98	97.6875	97.75	666.5	656	672	662.5	3875	3125	3962.5	3450
33	18/04/2014	10:26:16 p.m.	Ground	21	0	0.527344	-0.703125	46.28125	0.977853	1.016784	16352	97.5625	97.875	97.625	97.75	668	653.5	669.5	664.5	3900	3087.5	3962.5	3425
34	18/04/2014	10:26:17 p.m.	Ground	20	0	0	0	46.3125	0.982433	1.016784	16368	97.5	97.6875	97.8125	97.75	669	648	670	662	3800	3062.5	3925	3237.5
35	18/04/2014	10:26:18 p.m.	Ground	23	0	0.527344	-0.703125	46.3125	0.989303	1.007624	16368	97.125	97.375	97.25	97.25	653	632.5	651	644.5	3250	2675	3412.5	3025
36	18/04/2014	10:26:19 p.m.	Ground	20	0	0	0	46.28125	0.975563	1.014494	16352	96.9375	97.1875	97.1875	97.0625	640	629	635	655	2700	2250	2750	2962.5

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

	Start Date	*Finish Date*	*No. Flights*	*No. Flight Hours*	*Mean Flight Time (hrs)*	*No. Ground Runs*	*No. Ground Run Hours*	*Mean Ground Run Time (hrs)*
NZ7001	16-Feb-13	17-May-14	264	580.4	2.20	240	80.8	0.34
NZ7003	15-Jul-10	15-May-14	545	1049.8	1.93	351	104.5	0.30
NZ7004	17-Sep-10	9-Jun-14	557	1141.4	2.05	255	77.8	0.31
Fleet totals			1366	2771.6	2.06	846	263.0	0.31

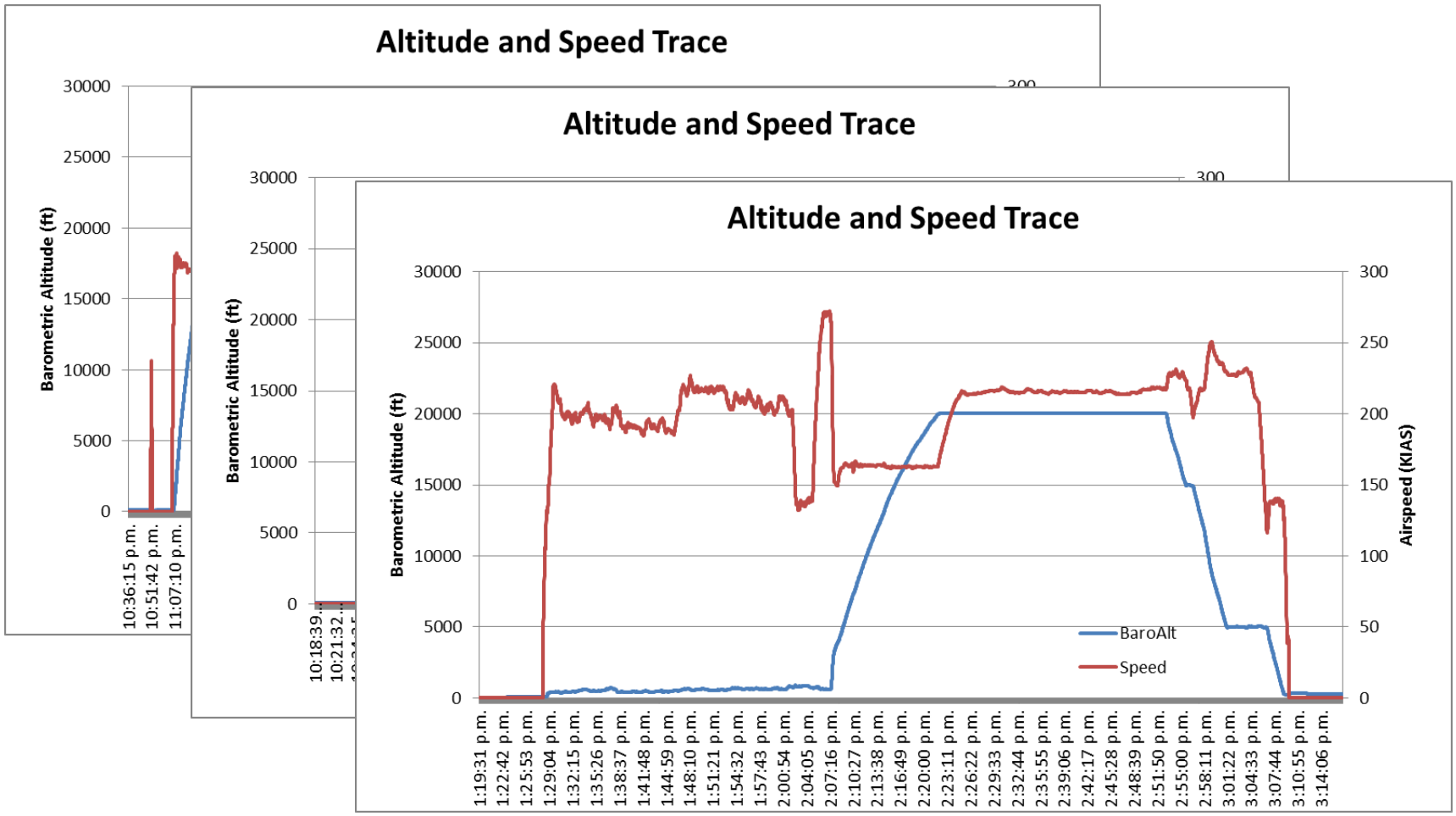
FDM Case Study – RNZAF C-130(H)NZ

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.

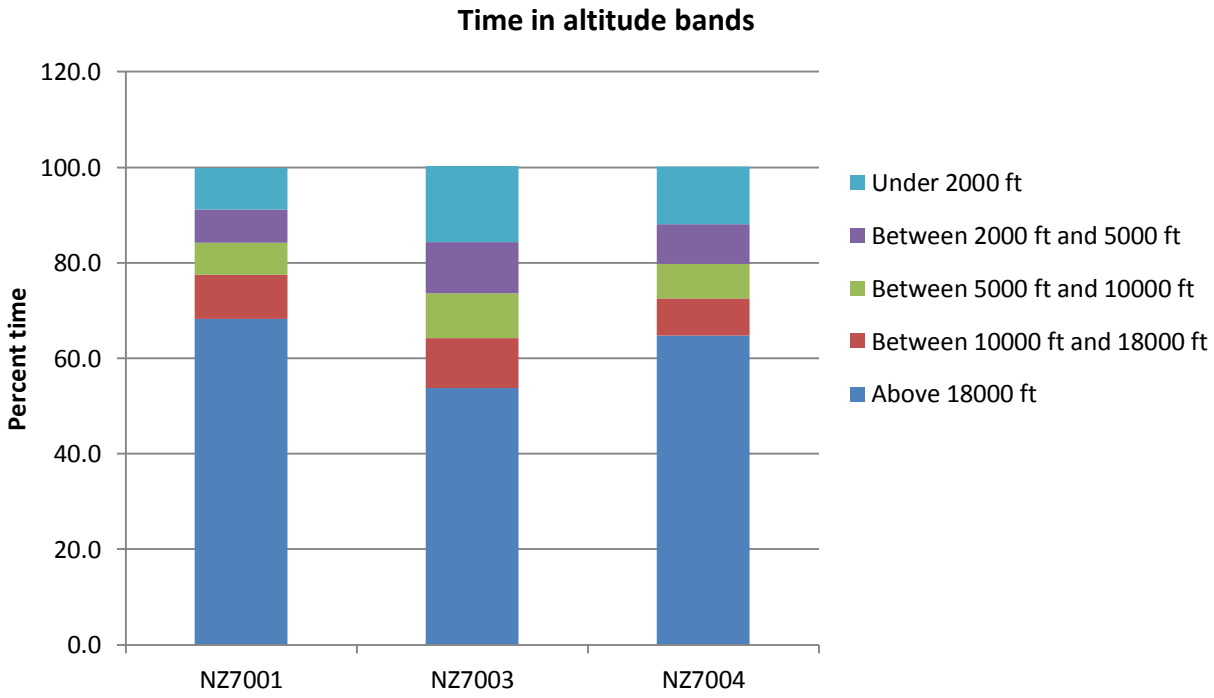
FDM Case Study – RNZAF C-130(H)NZ

Fleet Analysis – Results - Usage



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.

	Cyclic Exchange Rate (Hrs/Cycles)	*Includes Ground Running*
USAF	[redacted]	Yes
RAF		-
USN		No
RNZAF (2007)	2.17	No
RNZAF (2014)	1.81	Yes

- 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.

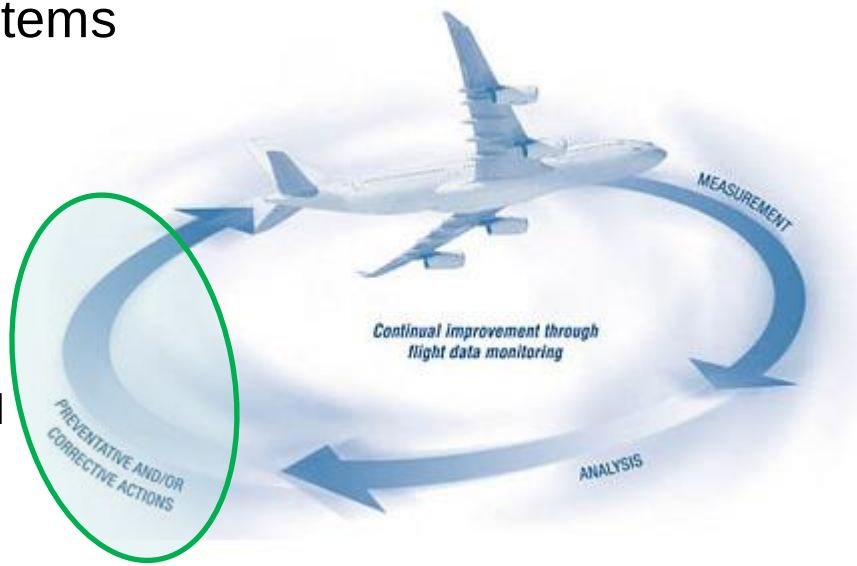
FDM Case Study – RNZAF C-130(H)NZ

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.