



IIOT and Big Data at Qantas

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Qantas the Australian Airline

- Airline founded in 1920 in Australia by an two aviators, an engineer and a farmer-business man!
- Operates 118 aircraft to 37 destinations.
- Around 33,000 employees
- Circa >\$1B profit in 2016
- Strong Engineering heritage
- Deeply rooted in the “Aussie Spirit”: Spirit of Australia



*QANTAS = Queensland and Northern Territory Aerial Service
There is no “U” in QANTAS!!*

What is IIOT for an airline?

Hardware

Aircraft are producing more and more data:

A380: Up to 300,000 parameters, from 1Hz to 50Hz.

787: > 0.5TB per flight

Aircraft are becoming hypochondriacs!

Systems (virtual sensors):

Reservation Systems

Flight Planning

Maintenance Systems

And more...

Data collection and handling

Aircraft Data:

- Flight Safety data (1hz) wirelessly downloaded at gate after each flight.
- Threshold and Air Traffic based data sent in real time
- Large Engineering datasets ($\geq 1\text{Hz}$) downloaded via physical or wireless means.
- Operational data:
 - Reservation systems/ Flight Operations data
 - Ground Support equipment
 - System of Maintenance, logbooks etc.

Data collection and handling

- Mixture of sensor data and unstructured text.
- Data stored on multiple systems
 - Fusion data on ad-hoc basis
 - Data stored on cloud and/or local servers
- Push towards an API marketplace accessing multiple data ponds.

Example I: Aircraft Evaluation

- Qantas is a end point carrier.
- Our geography is challenging, we are surrounded by the world's two largest Oceans.
- Qantas is a world leader on Ultra Long Haul Routes.
- How do we push the frontier even further?
 - We evaluate new aircraft as if they are in real operations with actual constraints using probabilistic models.
 - We simulate over a decade of daily operations.
- Payload increased by up to 95% on long haul over traditional methods.

STANFORD UNIVERSITY – QANTAS LECTURE

Example I: Aircraft Evaluation

Qadra-X

ROUTE OPTIMISER

Load Case Mission Analysis View Result

Run ID: 2219

Planning Criteria

- Jetstar - Payload Statistical Winds
- Jetstar - Block Time Statistical Winds
- Jetstar - Block Fuel Statistical Winds
- Jetstar - Daily Winds
- Qantas - Payload Statistical Winds
- Qantas - Block Time Statistical Winds
- Qantas - Block Fuel Statistical Winds
- Qantas - Daily Winds
- ESAD
- FAR - Payload Statistical Winds
- JAR - Payload Statistical Winds
- Qantas - Daily Winds Unit Cost
- Qantas - Daily Winds(Payload)
- Qantas - Daily Winds(BlockFuel)

Date	Day	Operator	Aircraft	Altitude	Speed	Temperature	Time	Weight	Distance	Fuel Flow	Altitude	Speed	Temperature	Time	Weight		
0	26x	2004-2013, (85)	Y551-YM	OMAA-OM	AwayTrack	MAIN	8777-300ER	GEN0-158L	3.0	CHD	351550	351550	251200	231307	237640	224417	176702
0	Feb	2004-2013, (85)	Y551-YM	OMAA-OM	AwayTrack	MAIN	8777-300ER	GEN0-158L	3.0	CHD	351550	351550	251200	231173	237640	224444	176702
0	Mar	2004-2013, (85)	Y551-YM	OMAA-OM	AwayTrack	MAIN	8777-300ER	GEN0-158L	3.0	CHD	351550	351550	251200	230723	237640	223971	176702
0	Apr	2004-2013, (85)	Y551-YM	OMAA-OM	AwayTrack	MAIN	8777-300ER	GEN0-158L	3.0	CHD	351550	351550	251200	230522	237640	223736	176702
0	May	2004-2013, (85)	Y551-YM	OMAA-OM	AwayTrack	MAIN	8777-300ER	GEN0-158L	3.0	CHD	351550	351550	251200	230786	237640	223979	176702
0	Jun	2004-2013, (85)	Y551-YM	OMAA-OM	AwayTrack	MAIN	8777-300ER	GEN0-158L	3.0	CHD	351550	351550	251200	231307	237640	224200	176702
0	Aug	2004-2013, (85)	Y551-YM	OMAA-OM	AwayTrack	MAIN	8777-300ER	GEN0-158L	3.0	CHD	351550	351550	251200	231338	237640	224522	176702
0	Sep	2004-2013, (85)	Y551-YM	OMAA-OM	AwayTrack	MAIN	8777-300ER	GEN0-158L	3.0	CHD	351550	351550	251200	231143	237640	224345	176702
0	Oct	2004-2013, (85)	Y551-YM	OMAA-OM	AwayTrack	MAIN	8777-300ER	GEN0-158L	3.0	CHD	351550	351550	251200	231366	237640	224290	176702
0	Nov	2004-2013, (85)	Y551-YM	OMAA-OM	AwayTrack	MAIN	8777-300ER	GEN0-158L	3.0	CHD	351550	351550	251200	231266	237640	224517	176702
0	Dec	2004-2013, (85)	Y551-YM	OMAA-OM	AwayTrack	MAIN	8777-300ER	GEN0-158L	3.0	CHD	351550	351550	251200	231316	237640	224622	176702
0	Jan	2004-2013, (85)	Y551-YM	OMAA-OM	AwayTrack	MAIN	8777-300ER	GEN0-158L	3.0	CHD	351550	351550	251200	230479	237640	224741	176702
0	Feb	2004-2013, (85)	Y551-YM	OMAA-OM	AwayTrack	MAIN	8777-300ER	GEN0-158L	3.0	CHD	351550	351550	251200	231183	237640	224551	176702
0	Mar	2004-2013, (85)	Y551-YM	OMAA-OM	AwayTrack	MAIN	8777-300ER	GEN0-158L	3.0	CHD	351550	351550	251200	233306	237640	224669	176702
0	Apr	2004-2013, (85)	Y551-YM	OMAA-OM	AwayTrack	MAIN	8777-300ER	GEN0-158L	3.0	CHD	351550	351550	251200	234367	237640	224759	176702
0	May	2004-2013, (85)	Y551-YM	OMAA-OM	AwayTrack	MAIN	8777-300ER	GEN0-158L	3.0	CHD	351550	351550	251200	234004	237640	223790	176702
0	Jun	2004-2013, (85)	Y551-YM	OMAA-OM	AwayTrack	MAIN	8777-300ER	GEN0-158L	3.0	CHD	351550	351550	251200	233971	237640	224215	176702
0	Aug	2004-2013, (85)	Y551-YM	OMAA-OM	AwayTrack	MAIN	8777-300ER	GEN0-158L	3.0	CHD	351550	351550	251200	231316	237640	224622	176702
0	Sep	2004-2013, (85)	Y551-YM	OMAA-OM	AwayTrack	MAIN	8777-300ER	GEN0-158L	3.0	CHD	351550	351550	251200	231143	237640	224345	176702
0	Oct	2004-2013, (85)	Y551-YM	OMAA-OM	AwayTrack	MAIN	8777-300ER	GEN0-158L	3.0	CHD	351550	351550	251200	231366	237640	224290	176702
0	Nov	2004-2013, (85)	Y551-YM	OMAA-OM	AwayTrack	MAIN	8777-300ER	GEN0-158L	3.0	CHD	351550	351550	251200	231266	237640	224517	176702
0	Dec	2004-2013, (85)	Y551-YM	OMAA-OM	AwayTrack	MAIN	8777-300ER	GEN0-158L	3.0	CHD	351550	351550	251200	231316	237640	224622	176702

Aircraft Configurations

- Boeing
 - B737-400
 - CFM56-3-B1
 - CFM56-3B-2
 - CFM56-3C-1
 - B737-800
 - CFM56-7B24
 - CFM56-7B26/27
 - B747-400
 - CF6-80C2B1F
 - RB211-524G/H2
 - B747-400ER
 - CF6-80C2B1F
 - B747-8
 - GENX-2B67
 - B767-300
 - CF6-80C2B2
 - CF6-80C2B4
 - CF6-80C2B6

Aircraft Development

Ready

Mission ESAD

- AMERICAN SAMOA
- ARGENTINA
- AUSTRALIA
- AUSTRIA
- AZERBAIJAN
- BAHRAIN
- BELGIUM
- BRAZIL
- BRUNEI
- CAMBODIA
- CANADA
- CHAGOS ARCHIPELAGO
- CHILE
- CHINA, PR OF
- COOK IS
- CYPRUS
- DENMARK
- ETHIOPIA
- FIJI IS
- FINLAND
- FRANCE
- FRENCH PACIFIC OVERSEAS TERR.
- GERMANY
- GREECE
- GUAM
- HONG KONG, PR OF CHINA
- HUNGARY
- ICELAND
- INDIA
- INDONESIA
- IRAN
- IRELAND
- ISLANDIA DE BAZILIA

Route Options

Waypoints

- Waypoint WOLNB YM
- Waypoint RAZZI YM
- Waypoint YSCB YM
- Waypoint 3523S16Z7E
- Waypoint ANTA YM
- Waypoint 3555S11Z2E
- Waypoint RUMI YM
- Waypoint EBONY YM
- Waypoint 3537S14Z7E
- Waypoint Bulli
- Waypoint 3703S14530E
- Waypoint TAREX YM
- Waypoint YMUU YM
- Waypoint

Performance Graph

Graph: Max Avg Max Elevation: 400 (326.1185) ft
 Range: 11000 ft
 Range: 11000 ft
 Elevation: 10000 ft
 Max Speed: 271.11 (411) kts
 Avg Speed: 220 (320) kts

Example II: Total aircraft economics

- Beyond payload capability, how do we completely evaluate aircraft and network economics:
 - Optimize cabin via path search methods
 - Based on a mix of deterministic and machine learning.
 - Makes use of all actual revenue and cost data.
 - Run multiple competitive airline scenarios.
 - Check profit stability against changing economic conditions.

Example II: Total aircraft economics

- Bootstrapped optimizers.
 - Cabin layout
 - Payload
 - Maintenance Costs, including optimizing repair intervals
 - Revenue Modelling
 - Scheduling

Example II: Total aircraft economics

LOPA-X Inputs Library Outputs

HOME
AIRCRAFT
- AIRBUS
- A330-300
- A380-842
+ BOEING

Choose an Aircraft

Shell Outline

Level 1

Level 2

Business Rules:
Galley Ratio
Lavatory Ratio
Cabin Crew Ratio

Optimiser

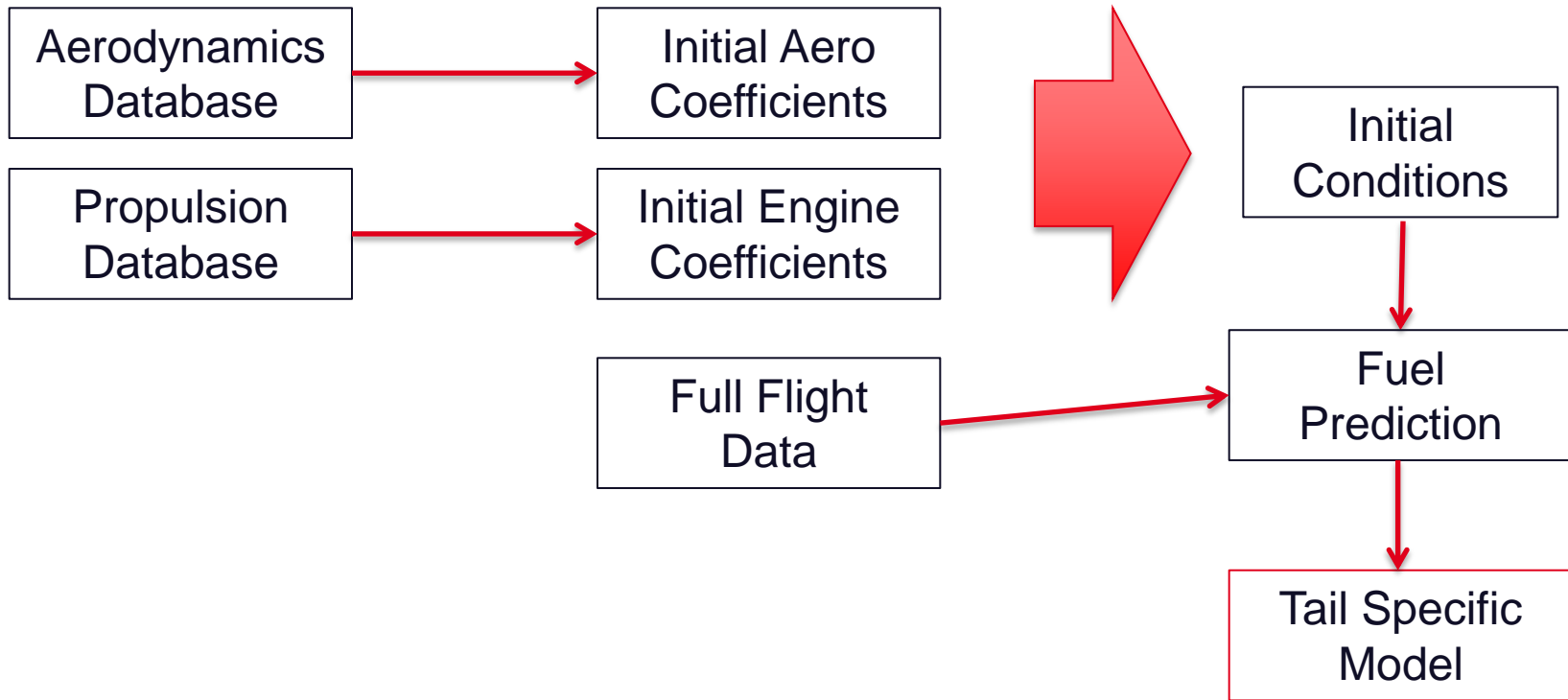
Qantas Current Layout

Pax Bag, LD3 Freight, POP/LD3 Bulk Hold

Example III: Operational Flight Planning

- Aircraft performance decks underpin the ability of an airline to sell seats and evaluate fuel burn.
- Daily accuracy of these decks are crucial for airline economics.
- However, these decks are *approximate*, and do not truly represent an airframe and its individual engines.
- Airlines operate in a very narrow band of the flight envelope.
 - Most airlines use a crude single fuel factor offset.
 - Answer: Use the Full Flight Data to create individual aircraft and engine decks.

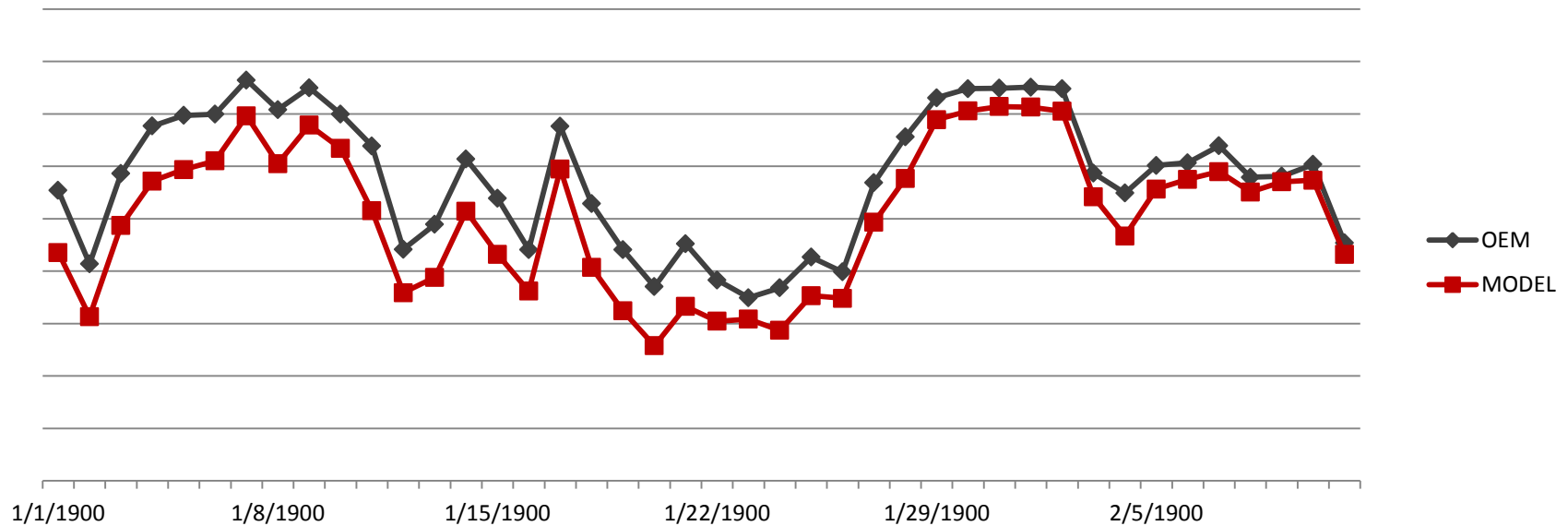
Example III: Operational Flight Planning



Example III: Operational Flight Planning

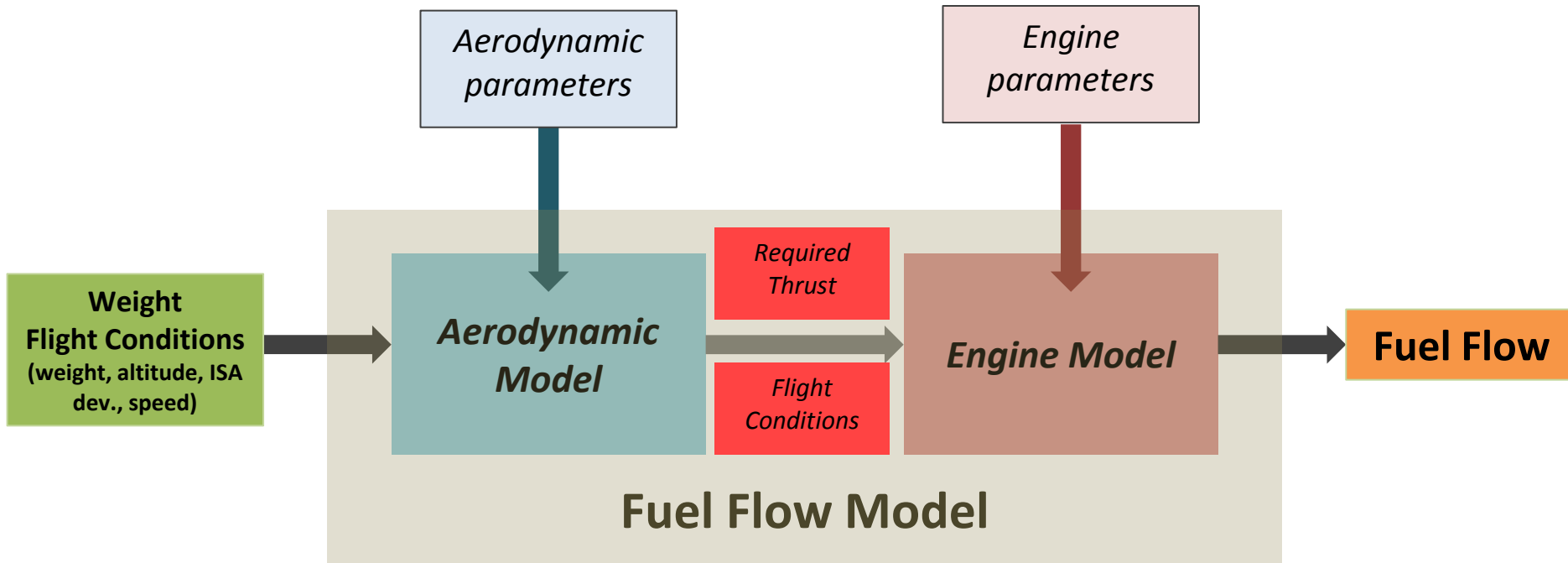
- Based on a 80% load Factor
- **0.97% reduction in flight fuel**

Flight fuel LAX - SYD



Example IV: Infer engine and airframe performance

- Using either OEM performance decks or actual Full Flight Data to infer
 - A detailed engine model
 - An detailed aerodynamic model



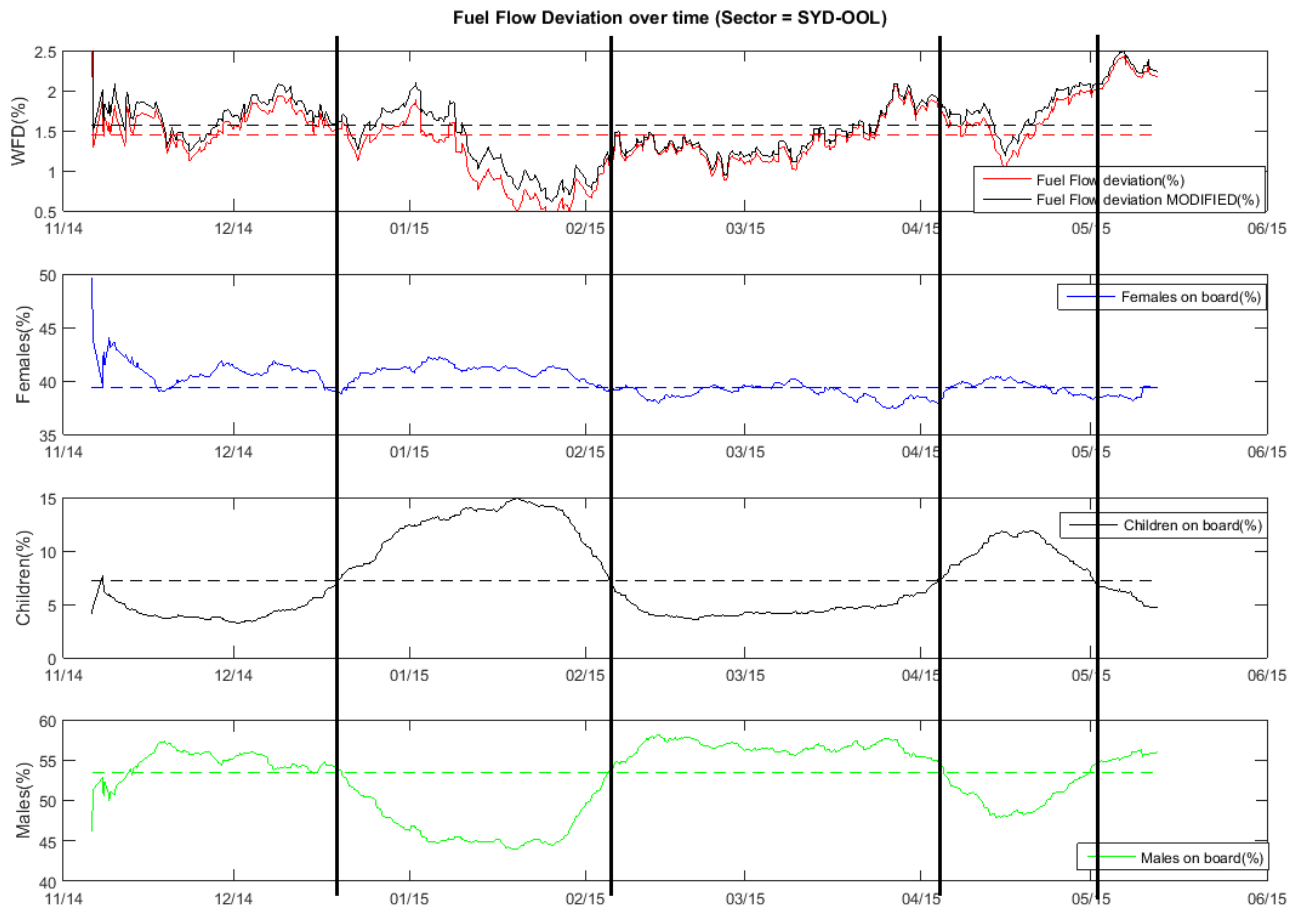
Example IV: Infer engine and airframe performance

- Inference of airframe and engine efficiency on a modular level (Drag, Thrust, Engine efficiencies) is possible thanks to big data and cloud computing.
- Provides critical insights to Qantas on the effect of OEM design changes on its overall network economics.
- Enables us to compare airframes and engines.
- Enables us to combine airframes with engines.
- *Help to influence aircraft and engine design to meet a network profit target.*

Example V: Aircraft Fuel Efficiency

- Traditionally, airlines use the Aircraft Performance Monitoring Tools supplied by OEMs.
- *However*
 - Uncertainties in weight (pax, fuel etc)
 - Does not account non standard flight conditions
 - Does not account for hardware changes (ie engine swaps)
- Qantas has created supplemental index called the Fuel efficiency index or FEI that removes all above effects.
- Ability to measure underlying aircraft deterioration.

Example VI: Passenger weight estimation



Example VII: Predictive Maintenance

- Problem:
- A380 has in-service faults
 - Aircraft has a large amount of data available
 - Tools provided are not predictive.
 - Can we detect a few cycles ahead these faults?
 - Airline does not have access to onboard logic
- Answer:
 - Use machine learning to detect patterns.
 - Used algorithms detecting hidden relationships between stocks on the stock market!

Conclusion

- Big data is the new frontier for Qantas.
- Requires fundamental changes in the way Engineers think:
 - Is fuzzy and not deterministic.
- Combination of Business knowledge, formal programming and machine learning *highly* desirable.
- Throwing lots of data at a problem does not help.

Thankyou!



Questions?