Abnormal Acceleration on Takeoff

EOFDM Conference 2016

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Safety Information Bulletin

Operations

SIB No.: 2016-02

Issued: 16 February 2016

Subject: **Use of Erroneous Parameters at Take-off**

Ref. Publications:

- U.S. National Air & Space Administration (NASA) Study NASA/TM-2012-216007 "Performance Data Errors in Air Carrier Operations: Causes and Countermeasures".
- Australian Transport Safety Bureau (ATSB) Research and Analysis Report AR-2009-052 "Take-off Performance Calculation and Entry Errors - A Global Perspective".
- Laboratory of Applied Anthropology, on behalf of BEA (Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile) and DGAC France: DOC AA 556/2008 "Use of erroneous parameters at take-off".
- EASA AMC 20-25 "Airworthiness and Operational consideration for Electronic Flight Bags (EFB)".
- European Commercial Aviation Safety Team (ECAST) European Operators Flight Data Monitoring:
  - Working Group A: "Review of Accident Precursors for Runway Excursions" and
  - Working Group B: "Study for Runway Excursion Precursors".
- European Authorities coordination group on Flight Data Monitoring (EAFDM) Document "Developing standardised FDM-based indicators".

Applicability:

Competent Authorities, Operators, Approved Training Organisations (ATO).

- Abnormal acceleration may not always be obvious to the crew
- Only the most serious cases get noticed and investigated
- Do we really understand the true scale of the problem?

Why not use FDM to get the full picture?

EOFDM Recommendation

Increasing "proximity" to the accident →			
Incorrect performance calculation		No liftoff after rotation	
Inappropriate aircraft configuration	slow acceleration	Slow rotation	Reduced runway remaining at liftoff
GC out of limits		Late rotation	
Reduced Elevator authority		Engine power increase	

Table 2: Precursor factors for accident scenario #2

WGA05 "Slow acceleration": Develop means to measure acceleration during the takeoff roll and detect abnormal values, taking in consideration the various factors that affect the takeoff performance.

Usefulness of “Abnormal Acceleration on Take-off” event:

For operators:

- Improved awareness of operational risk
- Opportunity to strengthen safety barriers (proactively)
- Data to support tactical/financial decisions about optional hardware

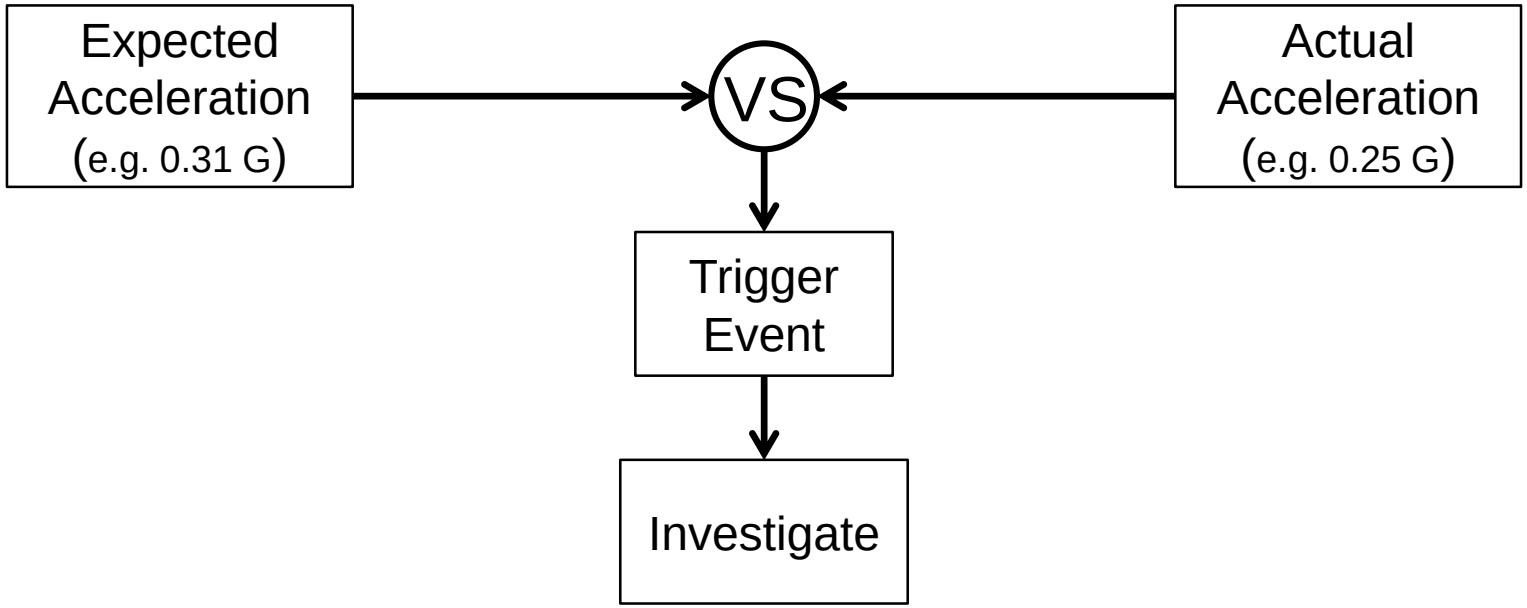
For regulators:

- Improved awareness of operational risk
- Promote adoption of best practices
- Data to support impact assessment of new regulation

Performance-related events are more challenging

- "Hard Landing" (trivial to implement)
- "Excessive speed on approach" (more complex)

FDM event for '<u>Abnormal Acceleration on Take-off</u>'



- How can we predict the expected acceleration?
  - Acceleration is not constant during the T/O roll
  - Acceleration depends on many factors and is not documented in AFM / FCOM

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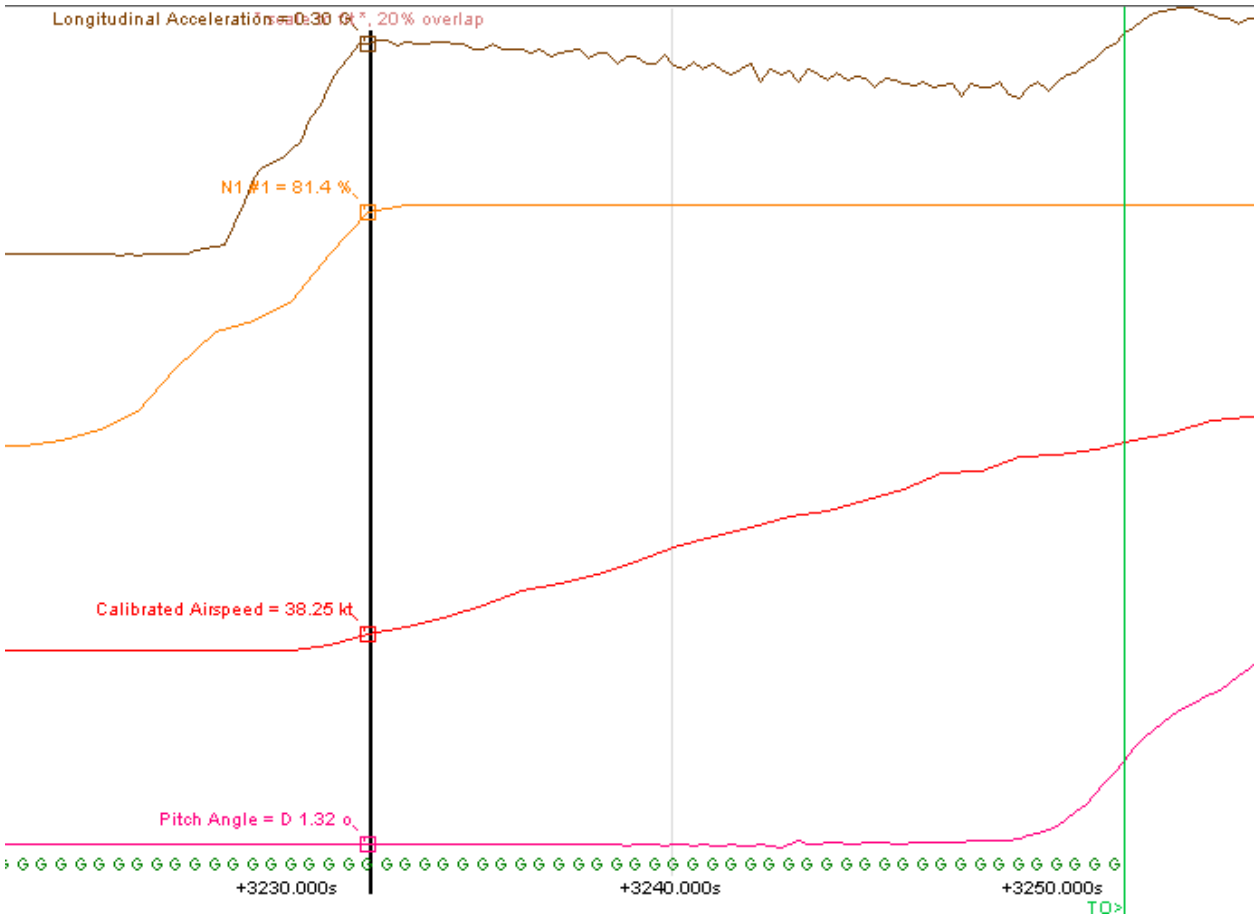
The typical acceleration profile



Peak Acceleration:
0.2 G ~ 0.4 G

Spool-up and rotation techniques are variable

Complex profile in general, but simple between “Power set” and “rotation”

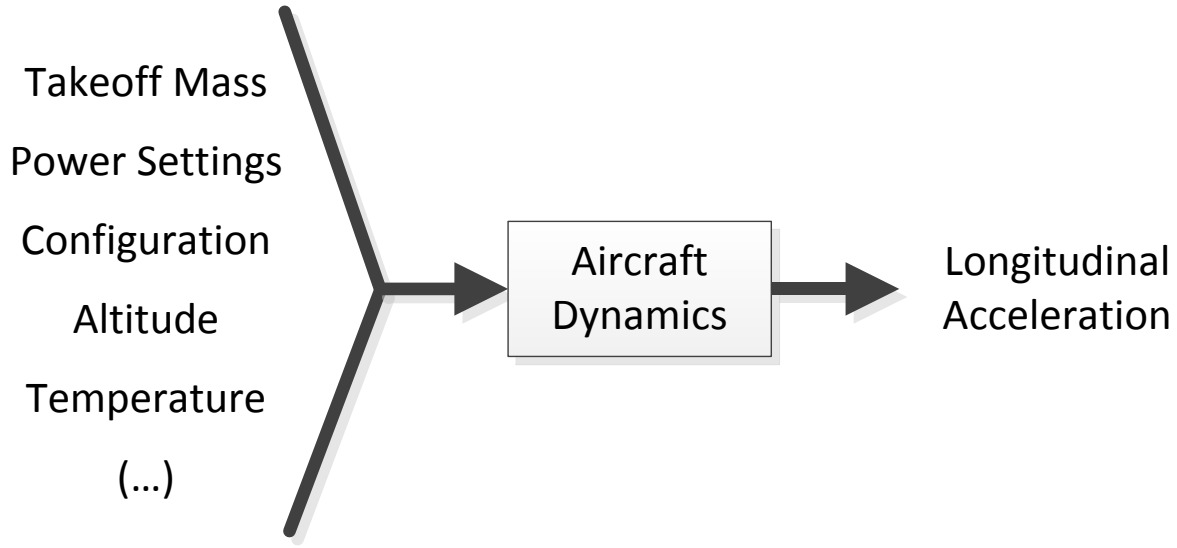
Use acceleration @80kt:

- Rolling take-offs
- Far enough from rotation

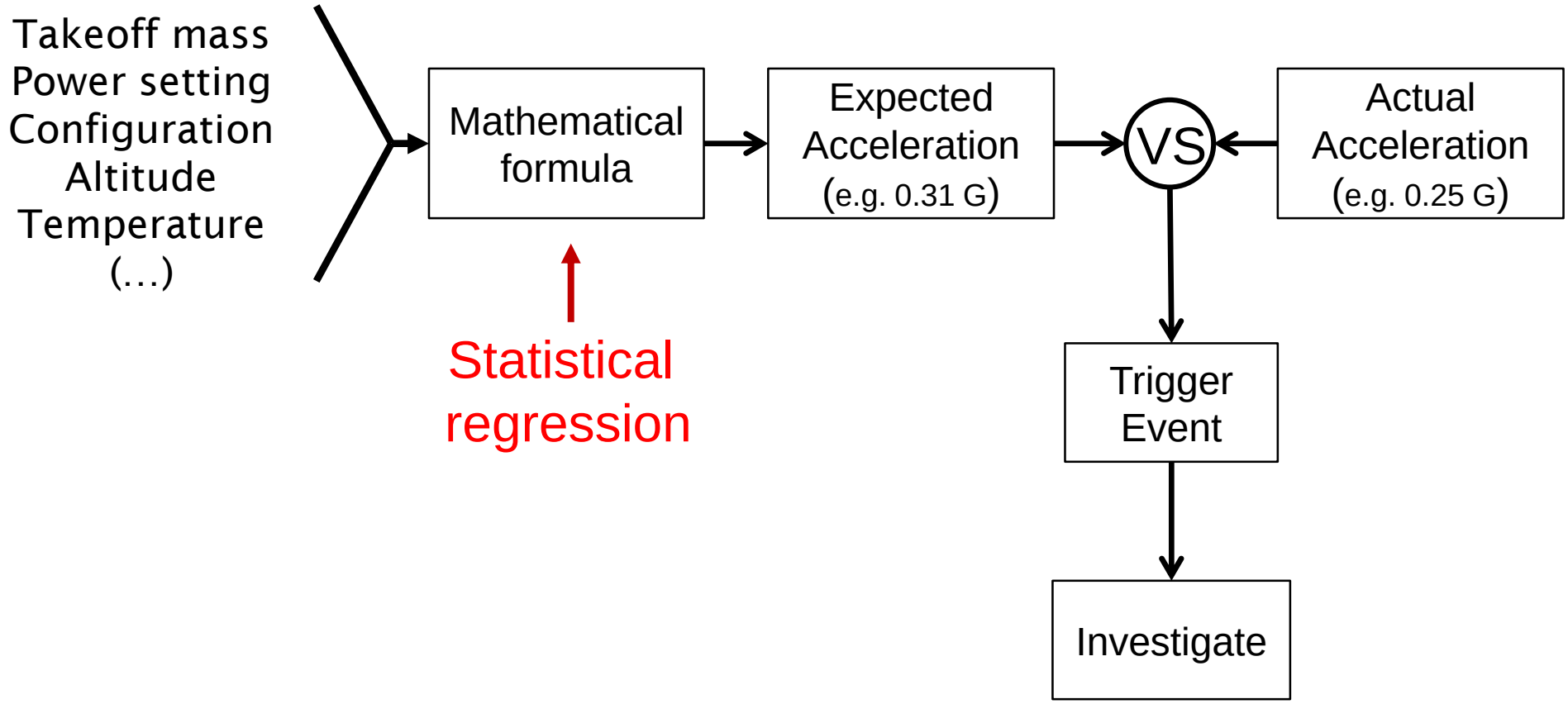
- How can we predict the expected acceleration?
  - Acceleration is not constant during the T/O roll
  - Acceleration depends on many factors and is not documented in AFM / FCOM

Between “Power Set” and “Rotation” @80kt:

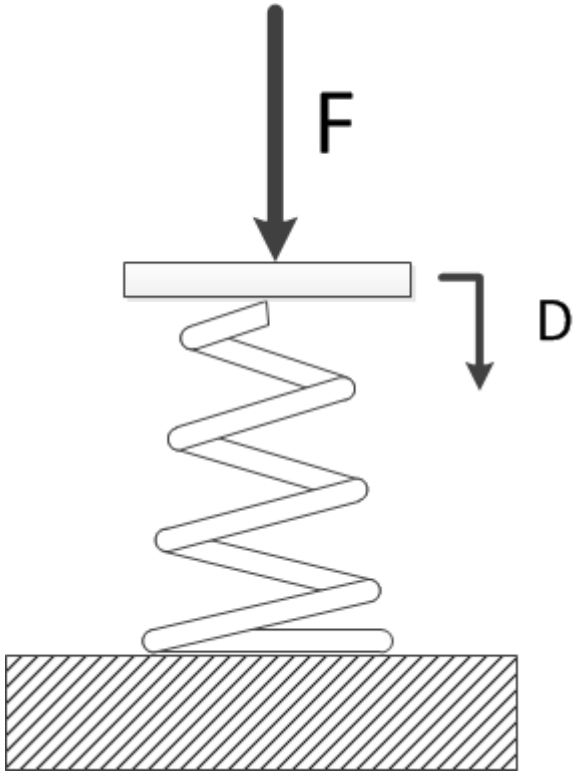
- acceleration is variable but solely dictated by physics (not pilot technique)
- We already have a basic idea about the most likely candidates

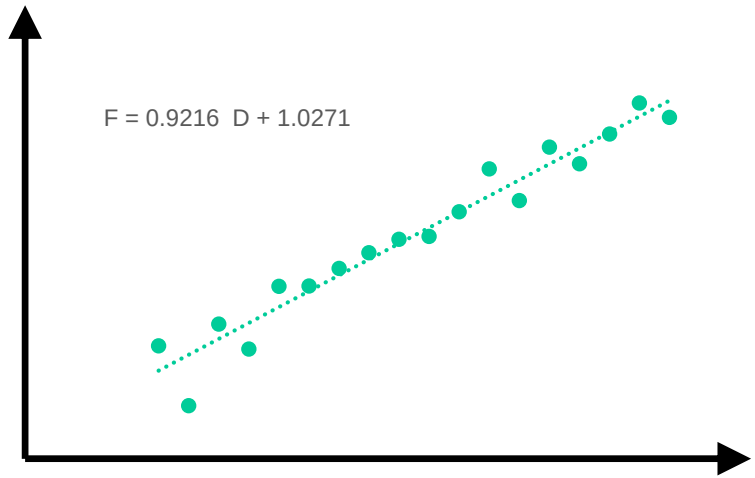


FDM event for ‘Abnormal Acceleration on Takeoff’

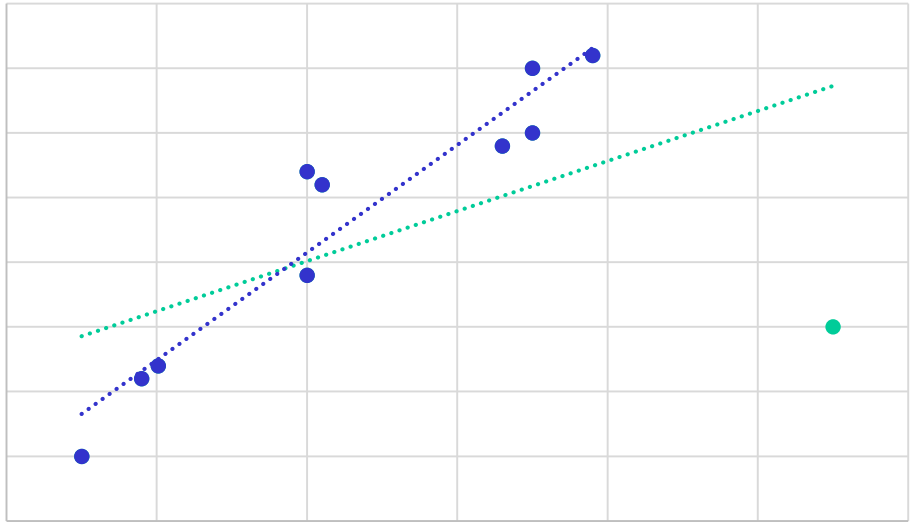


Statistical regression is not “rocket science”…





Statistical regression is not “rocket science”… but it’s not trivial either

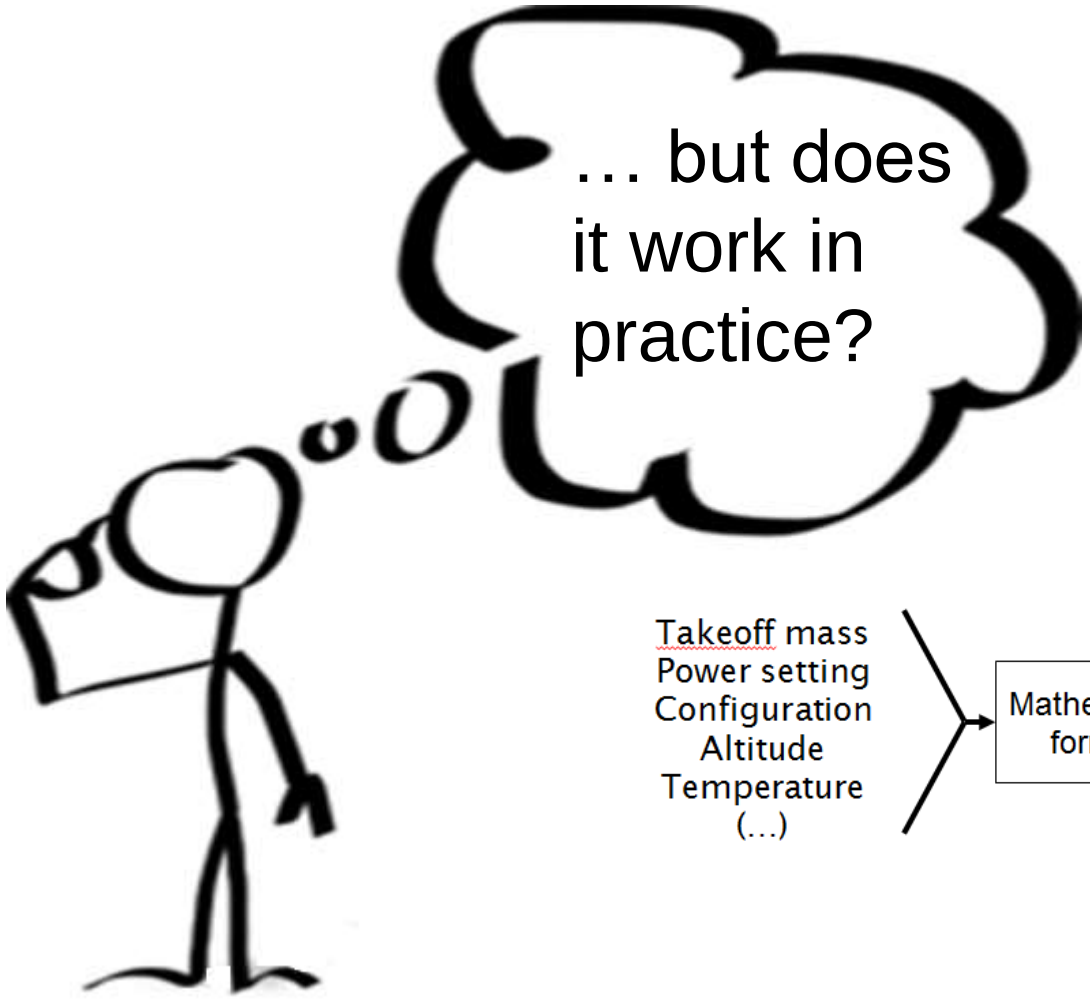


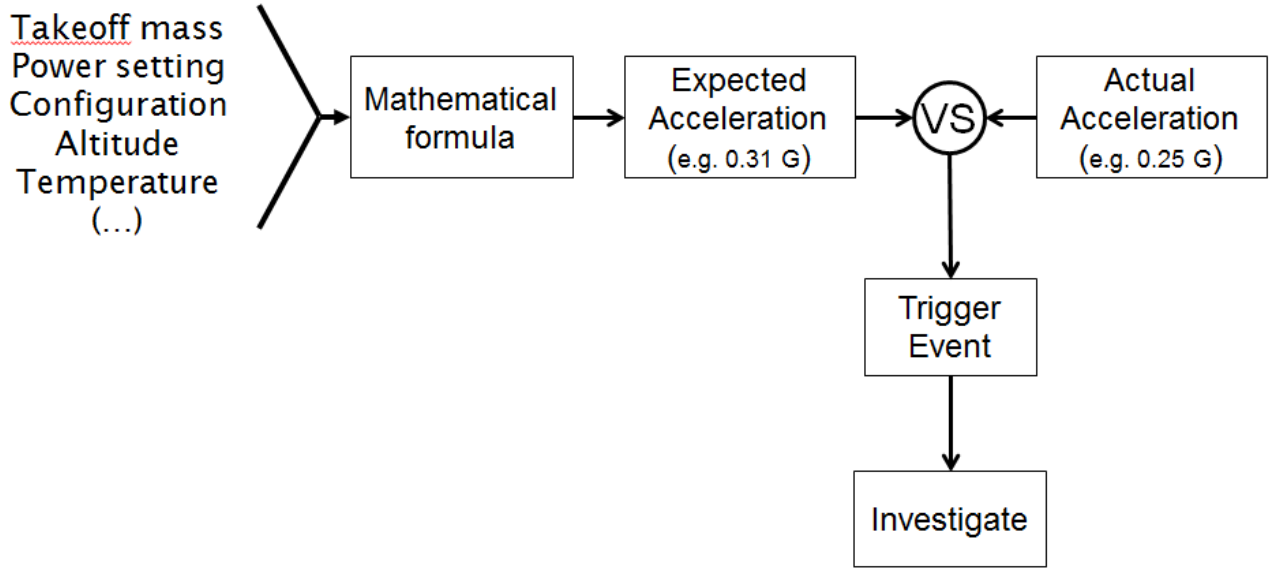
- Bad data / outliers / sensor bias
- Selection of variables relevant for the model
- Assessment of model quality & refinements

Using statistical regression techniques it is possible to derive a mathematical model to calculate the expected acceleration

WEIGHT	EPR	PALT	SAT	ACCEL	EXPECTED	DIFF
29165	1.55	-412	10.7	0.3432	0.3452	0.29%
27998	1.56	-32	18.1	0.3627	0.3655	0.78%
36635	1.56	-209	13.6	0.273	0.2684	-1.72%
33221	1.56	153	16.1	0.3015	0.298	-1.15%
28102	1.57	217	13.9	0.3677	0.3595	-2.27%
28484	1.56	165	22.1	0.3495	0.3575	2.24%

The mathematical model only needs to be calculated once (using historical flights)


… but does it work in practice?

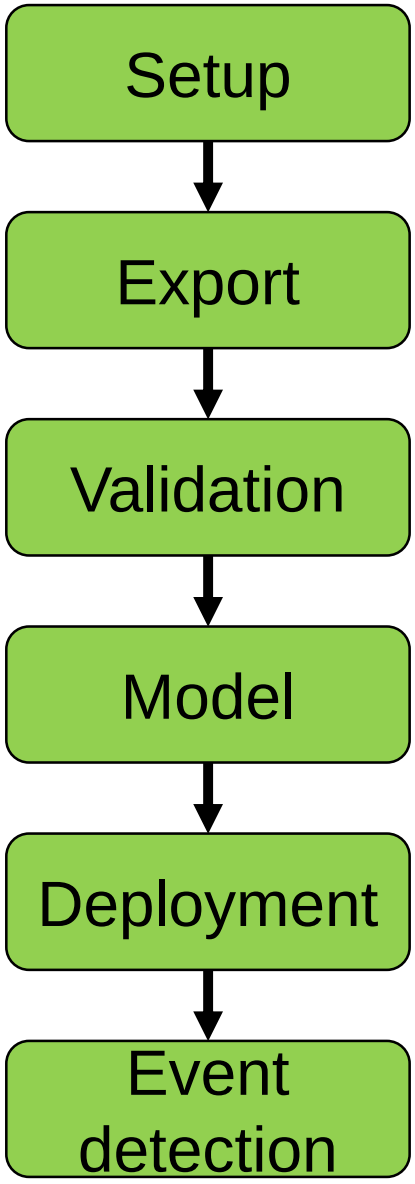

Takeoff mass
Power setting
Configuration
Altitude
Temperature
(…)
Mathematical formula
Expected Acceleration (e.g. 0.31 G)
VS
Actual Acceleration (e.g. 0.25 G)
Trigger Event
Investigate

Methodology tested and successfully deployed for:

Gulfstream 550

Airbus 320

Action plan



Setup FDM system to generate the relevant data for each takeoff

Export the data for statistical analysis

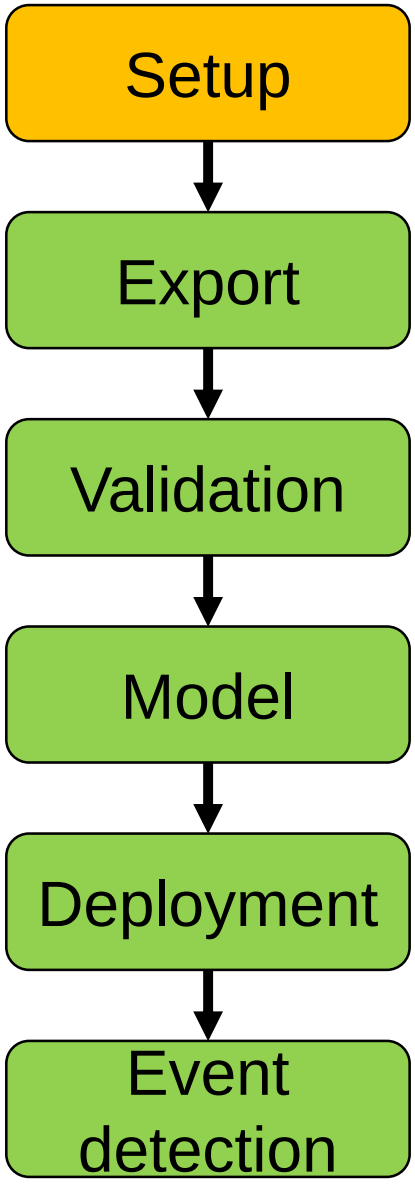
Validate and clean data

Create the mathematical model using statistical regression

Deploy model into ‘live’ FDM software

Detect abnormal acceleration events

Action plan



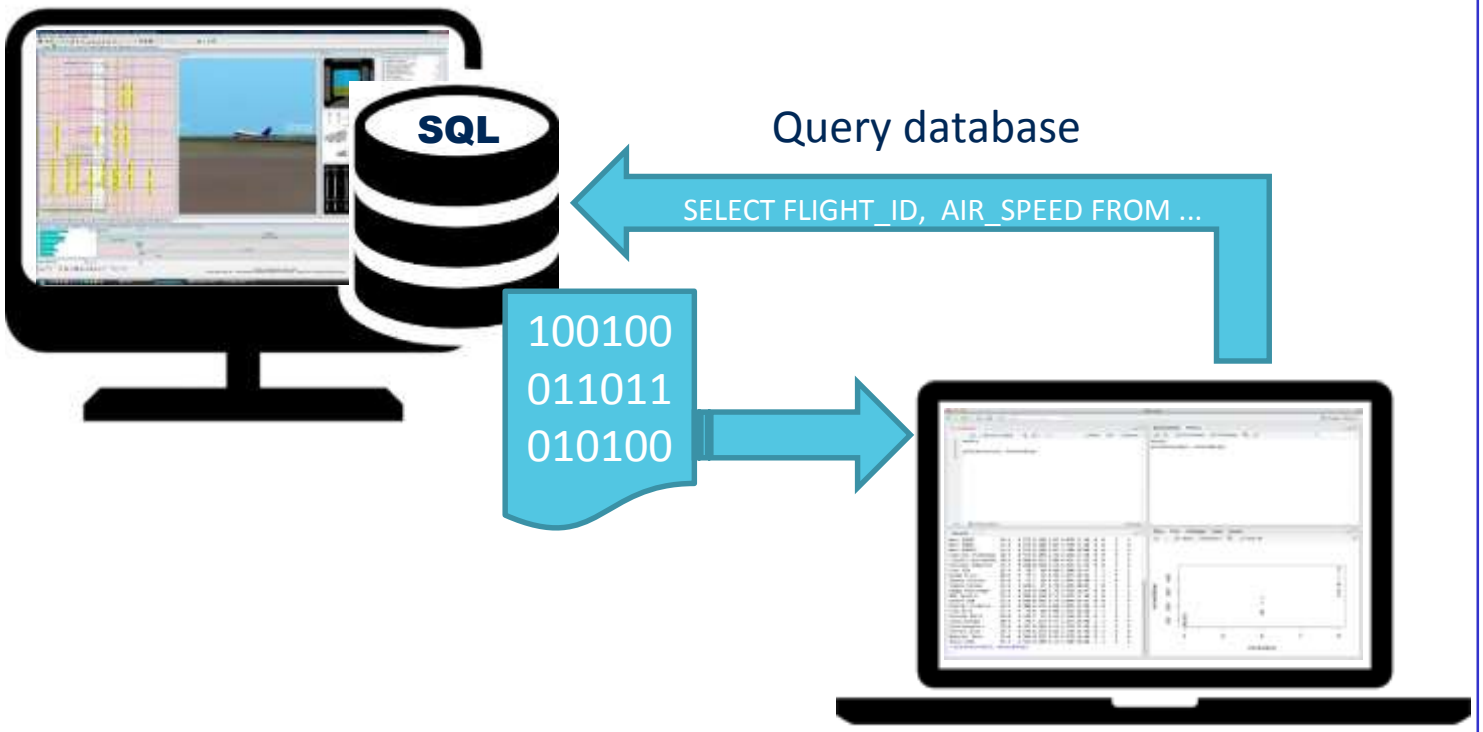
Setup FDM system to generate the relevant data for each takeoff

This may require configuration of the software as the model requires values on a specific instant in time

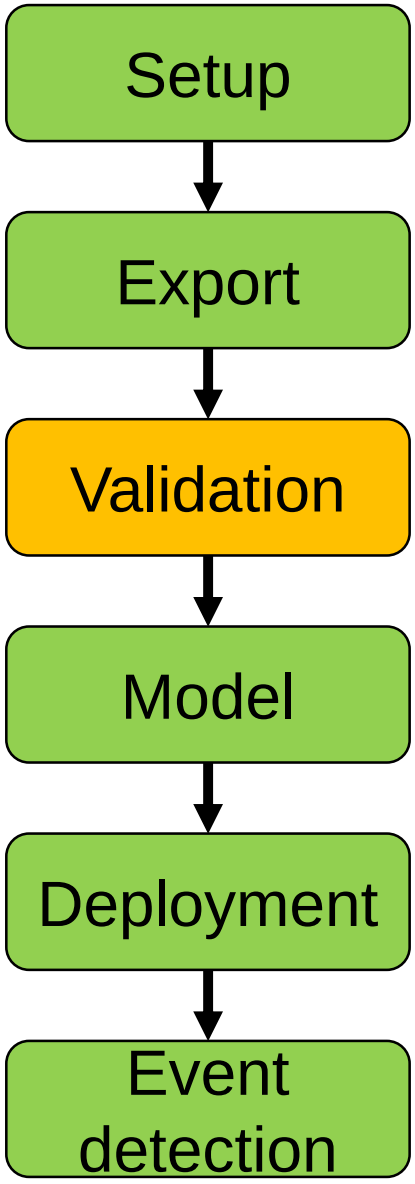
Action plan

- Setup
- Export
- Validation
- Model
- Deployment
- Event detection

Export the data for statistical analysis



Action plan

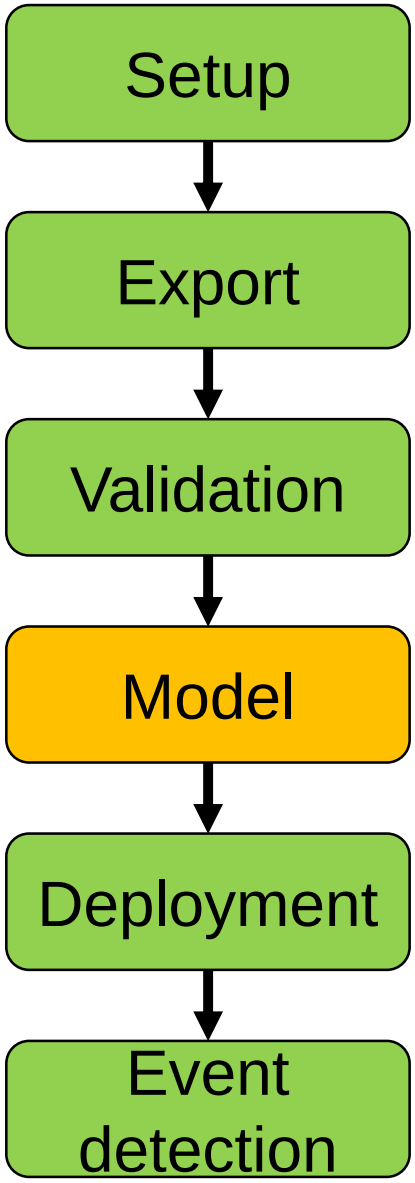


Validate and clean the data

Find “weird” cases in input data

ACCELAVG	TOW	PALT	TEMP	HEADW	N1	N2	EPR	FF	ICEENG	ICEWNG	BLEED	FLAP	STAB
0.34	29231	-412	10.7	9	90.7	93.8	1.54	2791	0	0	1	20	-3.6
0.35	28072	-319	13.5	11	88.4	93.4	1.50	2429	0	0	1	20	-3.6
0.36	0	-32	18.1	0	92.7	95.3	1.55	2861	0	0	1	20	-3.6
0.29	27202	5791	16.8	7	84.1	92.1	1.40	2123	0	0	1	20	-3.5
0.23	33830	393	18.6	6	84.7	92.4	1.41	2149	0	0	1	10	-2.7

Action plan



Create the mathematical model using statistical regression

- Acceleration
- Take-off Mass
- Configuration
- Altitude
- Temperature
- Wind
- Bleed status
- Anti-ice status
- N1, N2, EPR
- Fuel Flow
- ...

	ACCELAVG	TOW	PALT	TEMP	HEADW	N1	N2	EPR	FF	ICEENG	ICEWNG	BLEED	FLAP	STAB
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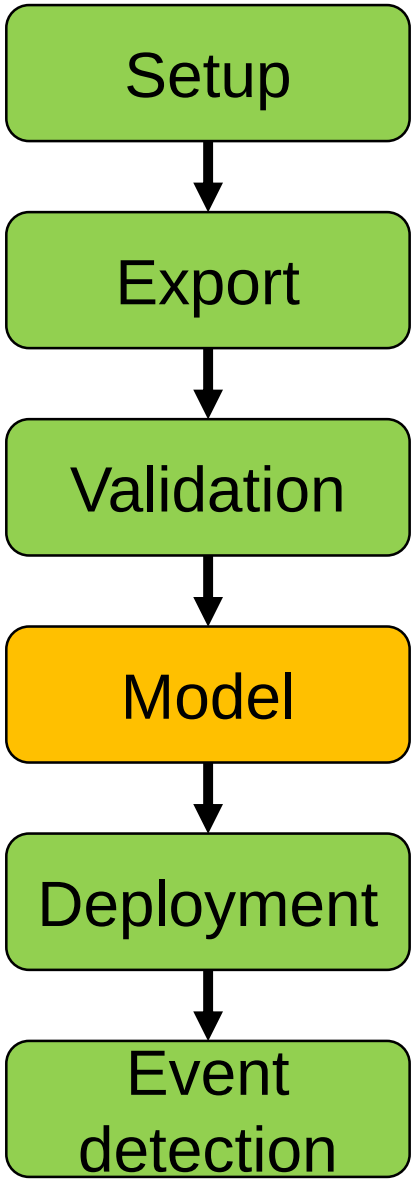
	0.35	28072	-319	13.5	11	88.4	93.4	1.50	2429	0	0	1	20	-3.6
	0.36	28104	-32	18.1	0	92.7	95.3	1.55	2861	0	0	1	20	-3.6
	0.29	27202	-147	16.8	7	84.1	92.1	1.40	2123	0	0	1	20	-3.5
	0.23	33830	393	18.6	6	84.7	92.4	1.41	2149	0	0	1	10	-2.7
	0.28	28936	-121	17.3	6	84.2	92.2	1.40	2041	0	0	1	10	-2.7
	0.27	36727	-209	13.6	6	90.7	94.3	1.54	2598	0	0	1	20	-3.6
	0.26	36733	-139	26.1	7	91.0	95.7	1.51	2545	0	0	1	20	-3.5
	0.30	26431	89	15.4	8	83.3	91.7	1.39	1988	0	0	1	10	-2.7
	0.34	29039	386	16.6	19	90.6	94.5	1.53	2489	0	0	1	20	-3.6
	0.36	27525	1183	17.4	8	93.1	95.4	1.57	2798	0	0	1	10	-2.7

$$Accel_{pr} = \left(\frac{3549}{WEIGHT}\right) - (1.3 \times 10^{-5} \times PALT) - (1.5 \times 10^{-3} \times SAT) + (9.7 \times 10^{-3} \times EPR) + 0.9417$$

Not all inputs are useful or relevant for the model

Action plan



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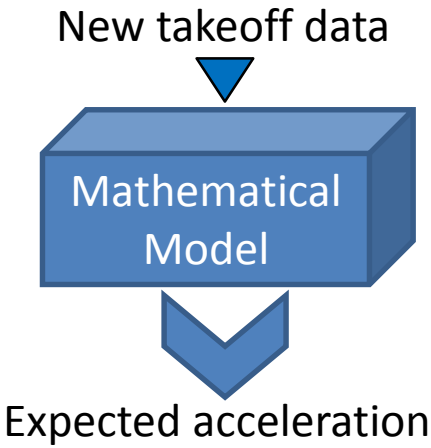

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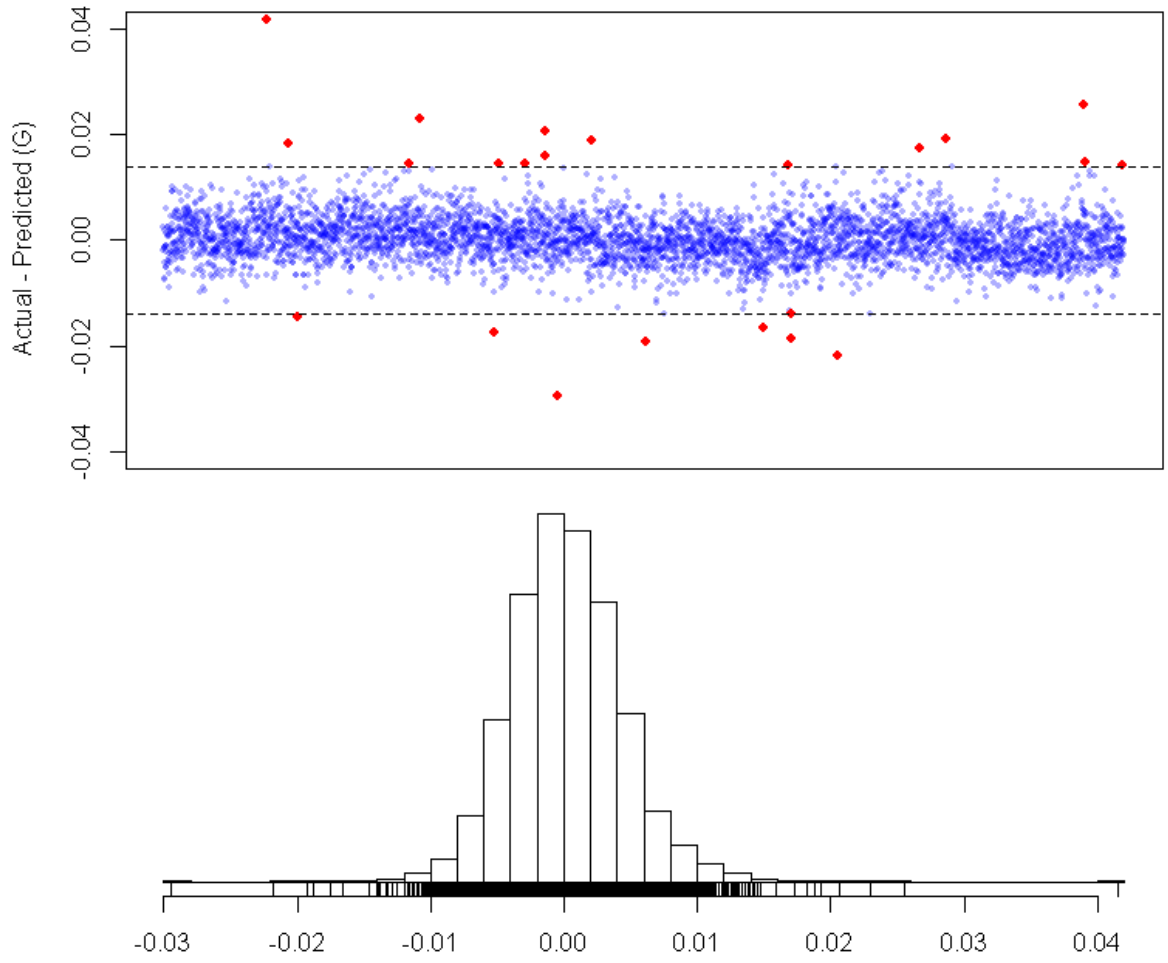
Create the mathematical model using statistical regression



Action plan

Setup

Export

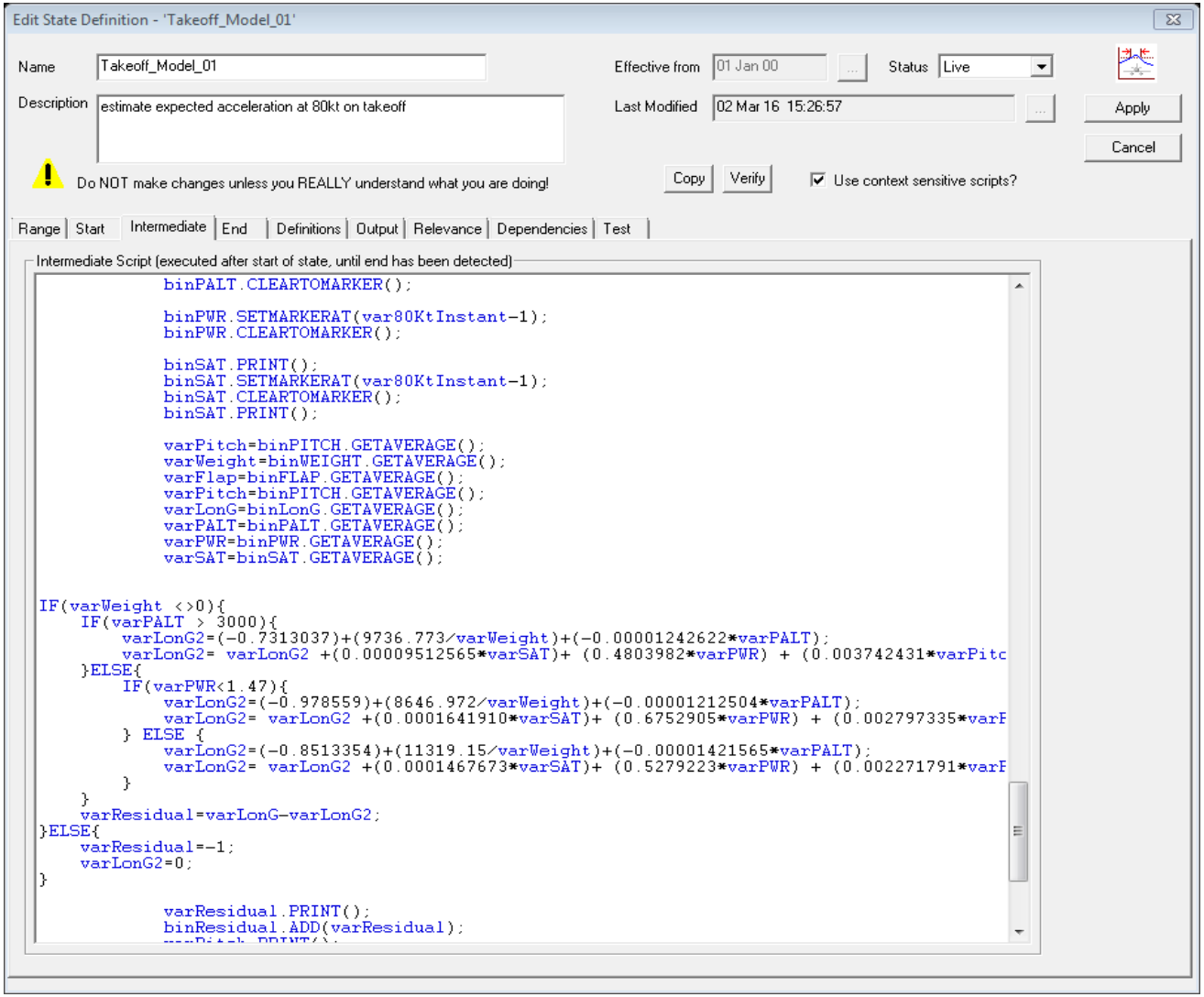
Validation

Model

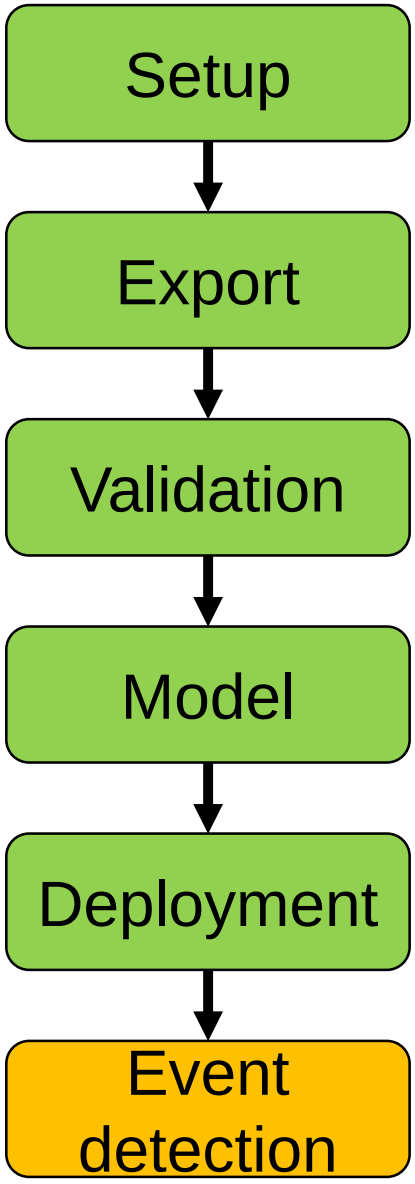
Deployment

Event detection

Deploy model into ‘live’ FDM software



Action plan



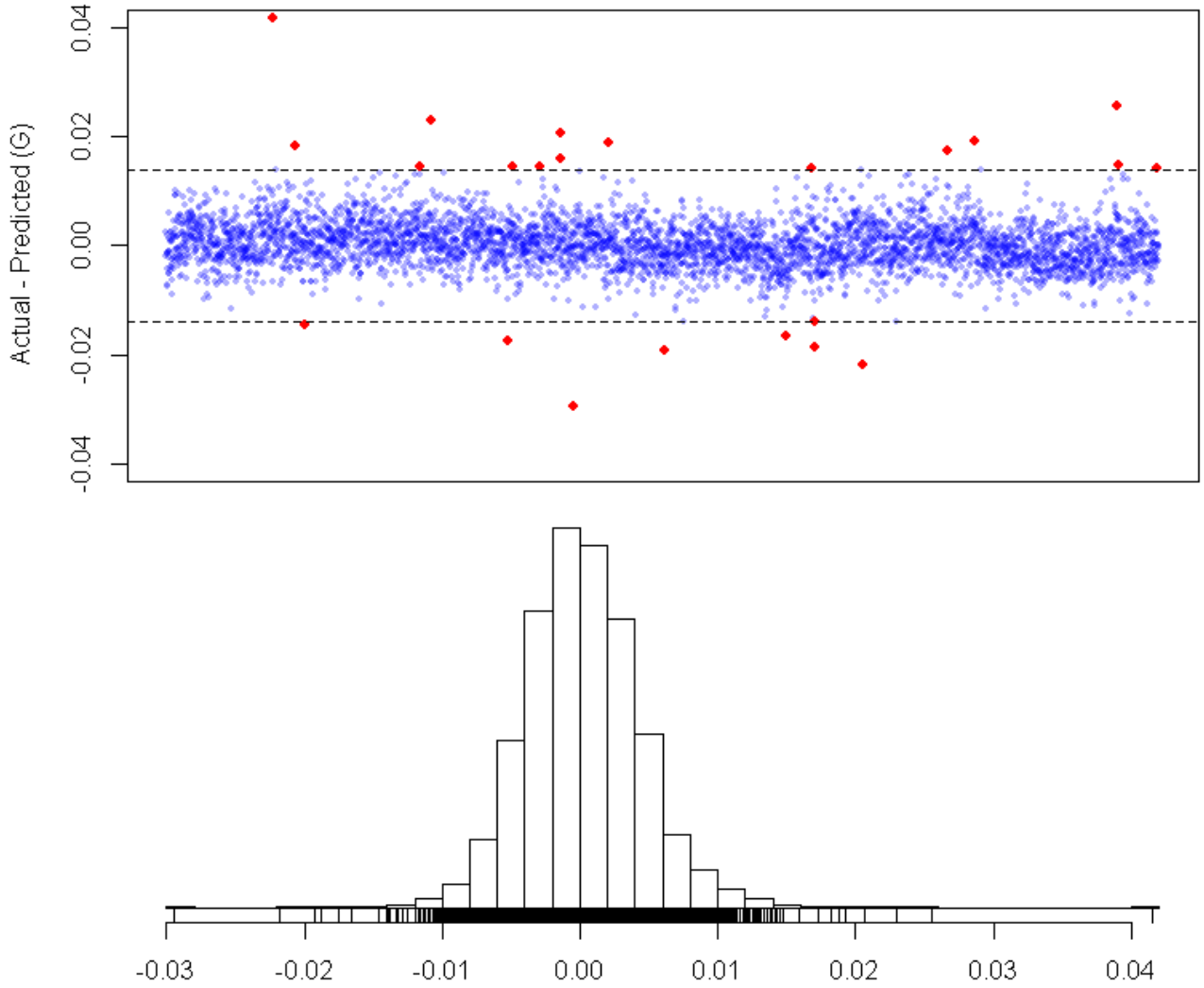
Detect abnormal acceleration events

Total Fuel (KG) - FMS1	17367
Total Fuel (KG) - FMS2	17367
Total Fuel (KG) - FMS3	17367
Low Takeoff Acceleration 27%	
LongG Residual @80kt	-0.10

Total Fuel (KG) - FMS1	10414
Total Fuel (KG) - FMS2	10414
Total Fuel (KG) - FMS3	10414
High Takeoff Acceleration 25%	
LongG Residual @80kt	0.03

Investigate

Findings


Actual - Predicted (G)
0.04
0.02
0.00
-0.02
-0.04
-0.03
-0.02
-0.01
0.00
0.01
0.02
0.03
0.04

Thank you

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