

RISKS ASSOCIATED WITH AIRCRAFT MAINTENANCE IN EUROPEAN COMMERCIAL AIR TRANSPORT

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INTRODUCTION & CONTENT

- Background, two MSc projects, why?
- Analysis of Maintenance Related European Occurrence Reports (2012-2016)
 - Initial analysis
 - Taxonomies
 - Custom taxonomy
 - Validating the method
 - Conclusions
- Analysis of Maintenance Related Global Accidents & Incidents (2003-2017) & future plans
- Goals for today:
 - Explain why recategorising 3912 incident reports may have been a useful exercise.
 - Collect more data: **PolIEv.com/ICSC**

**What do you think the most significant risk in continuing
airworthiness / maintenance domain is?
(In no more than one sentence or short phrase)**

 Respond at **PolleEv.com/icsc**

“Limited handover if maintenance errors”

“Time pressure”

“From my experience with the RCAF, I would say the gap between the way it should be done and the way it is done by the maintenance personnel”

“Standardization”

“The legislative change throughout the industry and the (blurry) line between theory and practicality (therefore misinterpretation)”

“Drifting away from original design assumptions.”

“Disconnect between managerial decision making and management versus production pressure demands faced by engineers forced to make ends meet”

What do you think the most significant risk in continuing airworthiness / maintenance domain is? (In no more than one sentence or short phrase)



Respond at PollEv.com/icsc

“Manage the change/ re-integrate the system after maintaining it”

“Error design, updating systems, frequency of maintenance”

“maintenance engineer fatigue”

“Time and money”

“Incident reporting”

“Lack of resources”


“unclear maintenance instructions”

“Fatigue”

“Lack of understanding by front line staff as to why they need to report incidents ?”

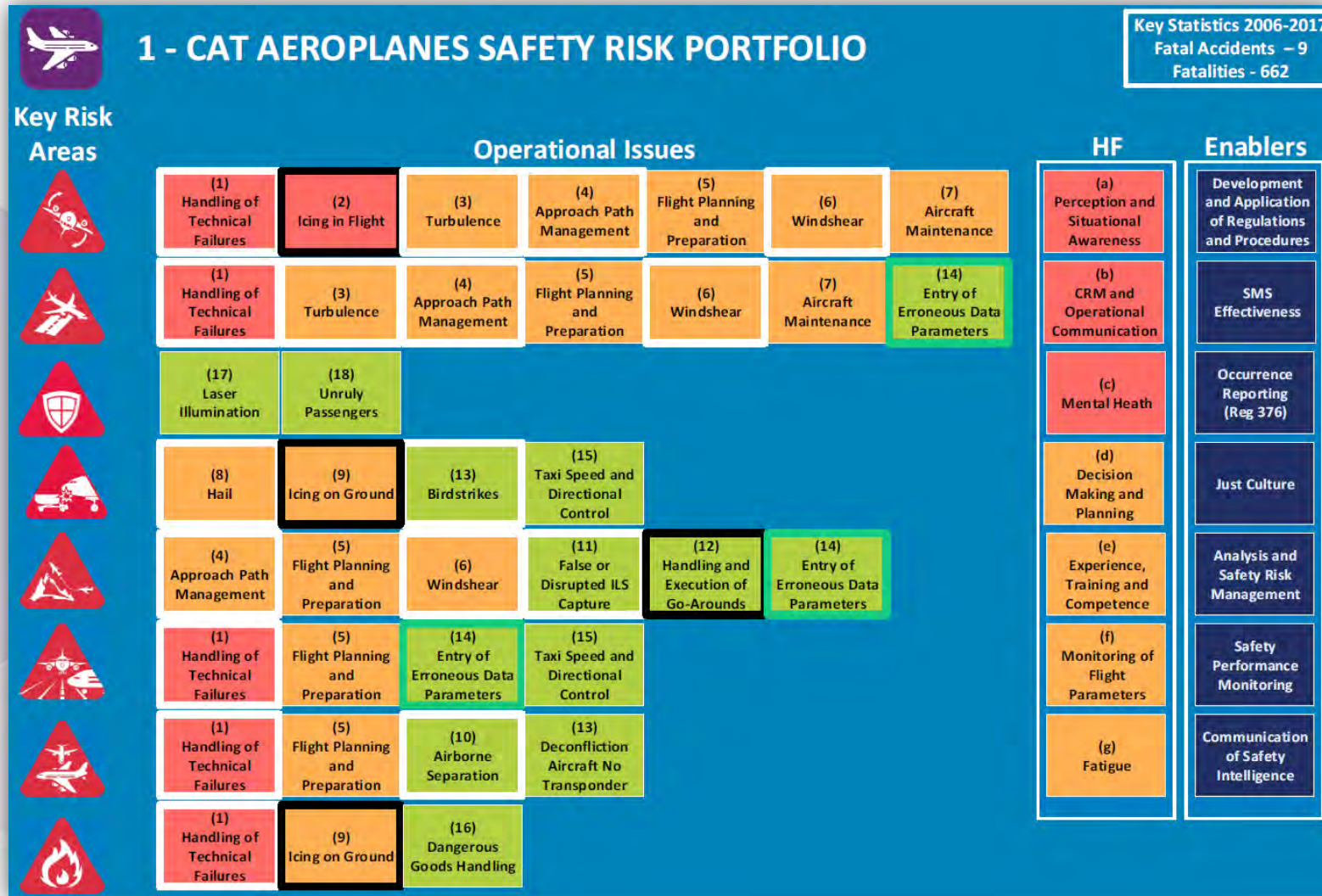
BACKGROUND

- Fortunately, accidents caused by maintenance errors are relatively rare.
- Incident reports, both mandatory and voluntary, are gathered in the European Central Repository (ECR).
- Analysis of this data is used to produce Annual Safety Reports (ASR).
- The 2016 review showed that Aircraft Maintenance (1318 incidents) was related to all key risk areas.

 Commercial air transport - aeroplanes														
Outcome Percentage of Fatal Accidents (2006-2015)		11	64%	45%	27%	18%	18%	9%	0%	0%				
Outcome Percentage of Non-Fatal Accidents (2006-2015)		283	7%	22%	36%	30%	5%	1%	5%	0%				
Safety Issues		Total number of occurrences in 2011-2015 per safety issue				Key Risk Areas (Outcomes and precursors)								
		Incidents (ECR data)	Serious Incidents	Total Accidents	Fatal Accidents	Aircraft Upset in Flight	System Failure	Ground Collisions and Ground Handling	Abnormal Runway Contact and Excursions	Terrain Conflict	Runway Incursions	Fire	Airborne Conflict	
Operat	Aircraft maintenance	1 318	7	1	—	■	■	■	■	■	■	■	■	



EASA ANNUAL SAFETY REVIEW 2017



Source: Annual Safety Review 2017 available @

https://www.easa.europa.eu/sites/default/files/dfu/209735_EASA_ASR_MAIN_REPORT_3.0.pdf



1 - CAT AEROPLANES SAFETY RISK PORTFOLIO

Key Risk Areas



LOSS OF CONTROL ACCIDENTS

(7)
Aircraft
Maintenance



RUNWAY EXCURSIONS

(7)
Aircraft
Maintenance



TWO INDEPENDENT / INTERTWINED MSC RESEARCH PROJECTS

Cranfield Safety & Accident Investigation Centre

Jelle Hieminga

MSc Airworthiness

&

Jennifer Insley

MSc Safety & Human
Factors in Aviation

3912 incident reports
from the European Central
Repository (2012-2016)

Less detail in the data but more
volume for trend analysis

**112 Accidents &
Serious Incidents**
from ASN & Skybrary
databases (2003-2017)

More detail in the data but still
challenging

THE CHALLENGE

- Thesis project was set up, using a download from the ECR that included raw (anonymous) data for 7158 incident reports (2012-2016), in the end 3912 were used.
- Aim was to see if this data could be used to:
 - Find a top-10 of safety issues in aviation maintenance
 - Compare this to previous analysis
- Steps:
 1. Initial analysis on the download.
 2. Background research into maintenance errors, possible taxonomies.
 3. Structuring and analysing the data.
 4. Develop a taxonomy that fits the brief for this project.
 5. Evaluate the taxonomy and validate the method.

1. INITIAL ANALYSIS

- Practical issues: 3 different worksheets, 2 categorisations (Outcomes and Causal & Contributory, or 'event type', factors), line numbers in the three sheets did not match up due to multiple categories per incident.
- Excel workbook was built so that the data from three sheets could be collated on one page, with options to either exclude the incident record, or categorise it.

Incident overview		Number:	3912	5013	7515			
		Mark	Return	3912	5014	7516	<<< >>>	
Date:	04/08/2014	Occurrence Class:	Incident			Not enough information in narrative ▼		
Aircraft type:	AIRBUS	Injury level:				Exclude incident		
Aircraft model:	A319	Damage level:				Clear		
Level 1	Occurrence Category: SCF-NP: System/component failure or malfunction [non-powerplant]							
Level 2	Occurrence Category: OTHR: Other							
		Occurrence Category:						
		Defect deferred with incorrect procedure/reference/follow up ▼		Store category		Clear		
				Exclude (language)		Exclude (unclear)		
Narrative:	<p>Informed via ACARS that the F/O Touchpad e-charts were out of date. I engaged MOC via email to establish if the touchpad had not been updated or if the internal date and time clock was set incorrectly. They confirmed via ACARS with the crew that the F/O touchpad had not been updated to the latest version as required by the first flight on 07th Aug. Software revision dates recorded. It would appear that the EFBs were both updated at base location for task card 'ELECTRONIC FLIGHT BAG TOUCHPAD' on the 2nd August. One of the EFBs was then replaced on the 4th August. It would appear that the ongoing touchpad was not updated at installation. The Captain's EFB was updated correctly and remained on board. Update of touchpads in store locations should be reviewed. Also check and update any software on components when being replaced. Corrective action was taken on work order.</p>							
		Event type level 1:		Equipment				
		Event type level 2:		2500 Cabin Equipment/ Furnishing				
		Event type level 3:		2510 Flight Compartment Equipment				
		Event type level 4:						
		Event type level 1:		Organisational				
		Event type level 2:		Regulatory				
		Event type level 3:		Aircraft Related Regulatory Events				
		Event type level 4:						

1. INITIAL ANALYSIS - CONTINUED

- A large percentage of reports could not be used (68% of 3912 reports). Main reasons:
 - Narrative is empty (28%)
 - Language not in English (21%)
 - Not enough information in narrative (8%)
 - Incident is not related to maintenance (5%)

22/07/2014 Airbus A330

According to the report(s) received by FCAA, incorrect defect logging procedures were used.

03/08/2014 Boeing 757

When a crew member reached for the handle on the entrance door on station two to close the door, and stepped out on the stair outside it started to move away from the aeroplane.

EXISTING TAXONOMY IN REPORTS

- Four-level breakdown covering everything under the sun, useful?
 - Operational (Level 1) and Aircraft Maintenance (Level 2) is used in 5046 of 14055 'event type' records (on average, two categories are used per incident) or 36%.
 - Out of these, 2704 include a level 4 category, the other 46% only use three levels of categorisation.
- Selecting Equipment (Level 1) allows the user to select a whole range of possible failures, structured using the ATA system. 25% of categorisations use this option but only 6,5% (out of all records) use this to level 4, which provides the best level of detail.

ATA

level 4 used

level 2

14055 records

2. POSSIBLE TAXONOMIES

- Several options:
 - CAA paper 2009/05 (developed for analysing MORs)
 - CAP 1367 (modified from above)
 - MEDA (Boeing tool to investigate maintenance events)
 - HFACS-ME (US Naval Safety Center, to investigate HF causes in maintenance events)
- The first two looked promising, but turned out to be restricted in the level of detail available.
- Both MEDA and HFACS are more suited to an immediate investigation than a retroactive analysis of reports. As both require selection of causes rather than facts, it may not fit a reporting system either.

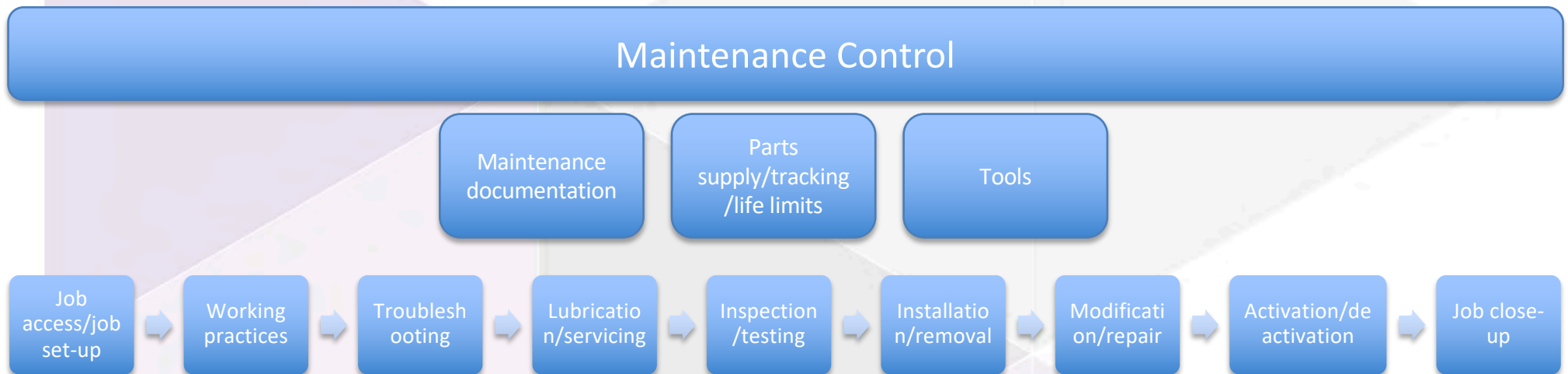
2. POSSIBLE TAXONOMIES

- Points to keep in mind for a good taxonomy (Wiegman & Shappell, 2001):
 - Reliability
 - Comprehensiveness ← 2.
 - Diagnosticity
 - Usability ← 1.
 - Validity
- In this case the taxonomy had to work well in two situations:



4. CUSTOM TAXONOMY

1. Base the taxonomy on familiar descriptions and the maintenance process (level 1):



2. Make sure that there is sufficient level of detail in the second level (67 different options provided).

The purpose was to categorise what went wrong, most reports do not allow analysis of the causes.

4. CUSTOM TAXONOMY

- Ideally, a taxonomy creates separate categories where one report fits into a single category only.
- This turned out to be impossible without sacrificing comprehensiveness.

01/04/2013 Boeing 737

After replacement of LHM on 1/4 engine

04/04/2013 Boeing 737

th

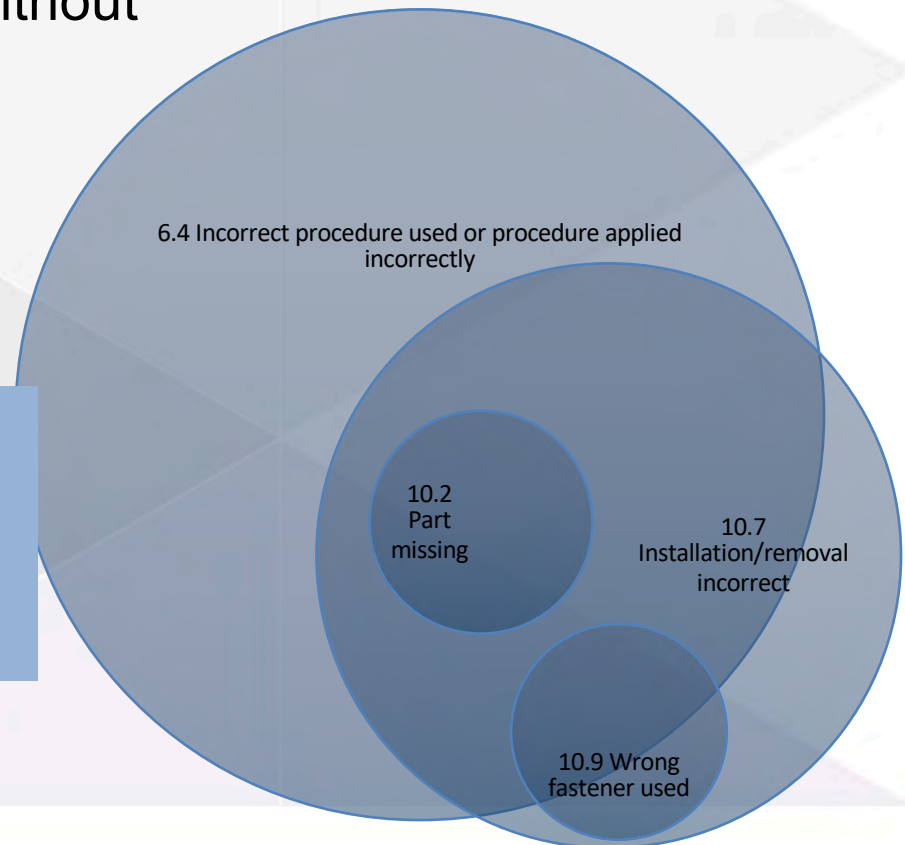
07/05/2013 ATR 42

wa

17/05/2013 Boeing 737

Data plates attached to engines using rivets drilled into fan case flanges.

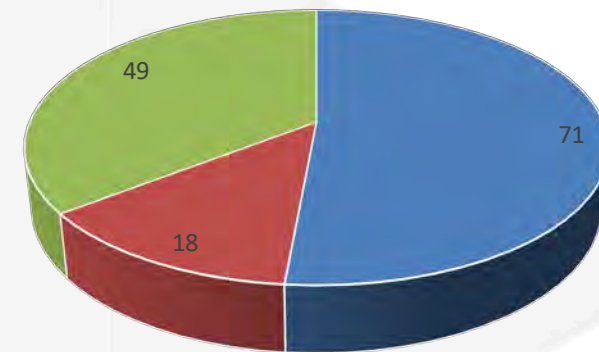
Modification documentation calls for 20 gauge locking wire.



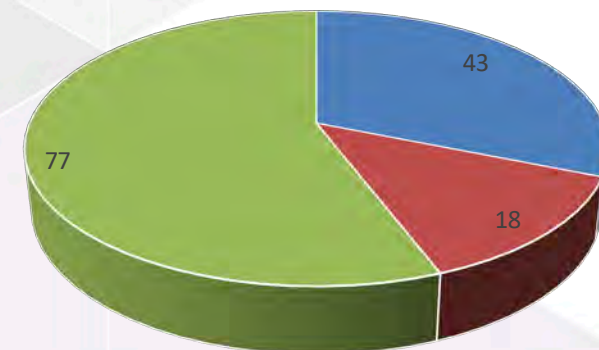
5. VALIDATING THE METHOD

- A survey showed that:
 - In a significant percentage of cases, the same level 1 category was selected (51% of 138 cases)
 - In 31% of the 138 cases, the level 2 classification was also the same.
 - Looking at just the 51% from the first graph, for 61% of these cases, the level 2 category matched with the original selection during this project.

Matching classifications - Level 1 only



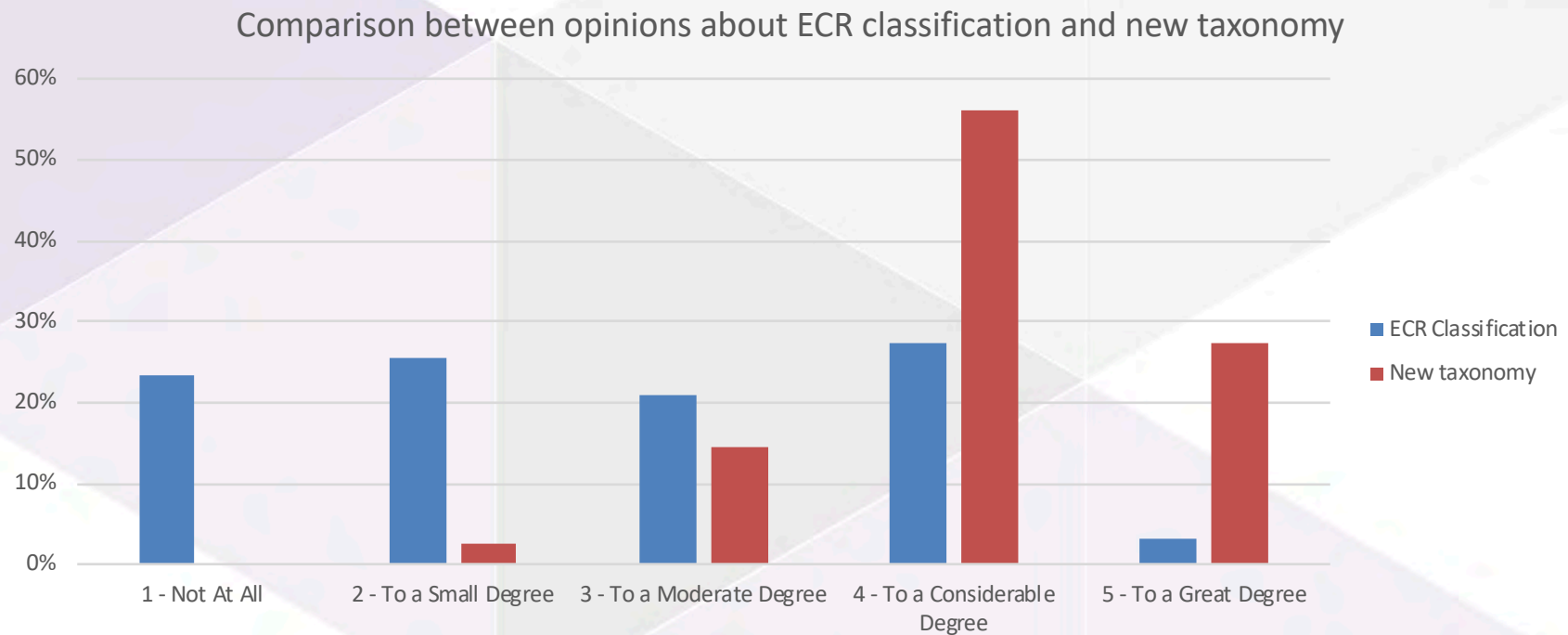
Matching classifications - Level 1 and 2



Matching L1 & L2 Excluded Different classification (for Level 2)

5. VALIDATING THE METHOD

- Opinions about the level to which the classification described the incident showed a significant preference for the new taxonomy.



TOP-10 ISSUES

- Based on the categorisation used, the top 10 occurring issues are:

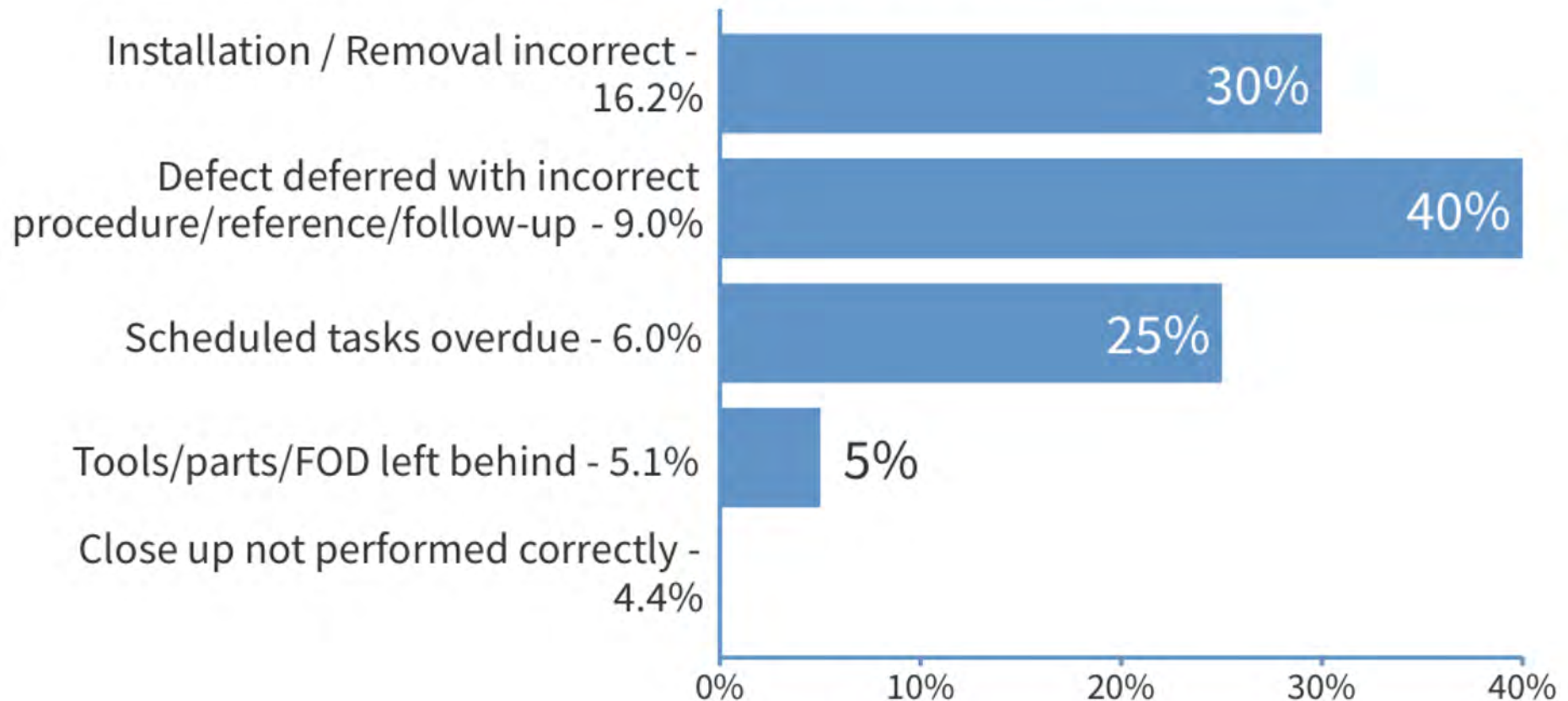
No.	Issue
1	10.7 Installation/removal incorrect
2	1.10 Defect deferred with incorrect procedure/reference/follow up
3	1.3 Scheduled tasks overdue
4	13.2 Tools/parts/FOD left behind
5	13.1 Close up not performed correctly
6	10.3 Part incorrect
7	6.4 Incorrect procedure used or procedure incorrectly
8	10.5 Installation/removal incomplete
9	11.5 Repair not carried out IAW AMM/S instructions
10	3.2 Parts supplied with incomplete/incomplete modification, configuration or condition

SOURCE	RANKING	ERROR TYPE
Airbus MBN June 2008	1	Installation
	2	Servicing
	3	Job set-up / preparation
	4	Pre-flight
	6	Slide
	7	Inspection
	8	Removal
	9	Test
	10	Repair
BASI	1	System operated unsafely during maintenance
	2	Incomplete installation
	3	Person contacted hazard
	4	Incorrect assembly
	5	Towing event
CAA 2007	1	Incorrect maintenance action (i.e. wrongly performed)
	2	Maintenance Control (i.e. failure of the management)
	3	Incomplete maintenance (unfinished, or not done at all)
CHIRP 2010	1	Installation error
	2	Approved data not followed
	3	Inspection error
Kanki & Hobbs	1	Incorrect installation
	2	Incorrect fault isolation
	3	Documentation problems
MEDA (NASA)	1	Incorrect servicing
	2	Documentation errors
	3	Wrong parts installed
Owen, Nicholas & Gill	1	Installation (48%)
	2	Transporting/driving (11%)
	3	Servicing (9%)
MAA Flight Ops Review	1	Ground Handling and Towing
	2	Procedures and Documentation
	3	Installation Errors
	4	Organisational Influences
	5	Supervision
	6	Other Preconditions
	7	FOD and Loose Articles

(Simmons/RAeS, 2011)

Considering the limited resources and budgetary constraints, which one of the following categories of occurrences would you further investigate and propose mitigation actions as a priority?

 **Poll locked.** Responses not accepted.



ANALYSIS OF MAINTENANCE RELATED GLOBAL ACCIDENTS & INCIDENTS

A Contemporary Analysis of Aircraft Maintenance-Related Accidents and Serious Incidents

Student: Jennifer Insley

Supervisor: Cengiz Turkoglu

MSc. Safety and Human Factors in Aviation 2017/2018.

Cranfield Safety and Accident Investigation Centre

Cranfield University

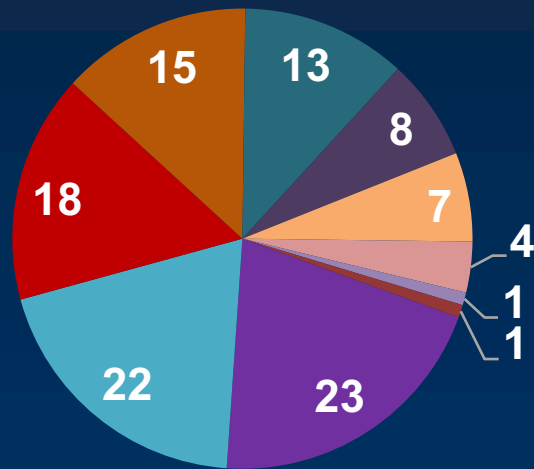
UK



ABSTRACT: Aircraft maintenance has been identified as a key point of concern within many high risk areas of aviation; still being a casual/contributory factor in a number of events. The purpose of this study is to investigate the nature of aircraft maintenance-related accidents and serious incidents for 2003-2017, to provide a modern-day understanding to the critical areas of concern, in addition to exploring the key risk areas. To achieve this, a dataset of maintenance-related accidents and serious incidents was compiled and then qualitatively analysed by thematic template analysis. This allowed for the development of an appropriate taxonomy, MxFACS, which was used to code these occurrences. The coded output was then evaluated by subject matter experts, and an inter-rater concordance value determined to assure research rigour. Subsequently, the occurrences were evaluated in terms of their relationship to fatal accidents, creating a picture of the associated risk. The most frequent maintenance occurrence consequences were found to be runway excursions and air turnbacks, with the most common associated events being related to engine and landing gear. The greatest maintenance factor issues were inadequate maintenance procedures and inspections not identifying defects. In terms of fatalities, collision occurrences were the most prominent consequence, engine-related events were the most significant event type, and inadequate maintenance procedures were the most concerning maintenance factor. The study's findings may be used in conjunction with existing risk analysis methodologies and taxonomies to aid in a Safety-II approach to understanding where barrier weaknesses lie within maintenance safety management systems, allowing stakeholders to better develop future targeted action or oversight.

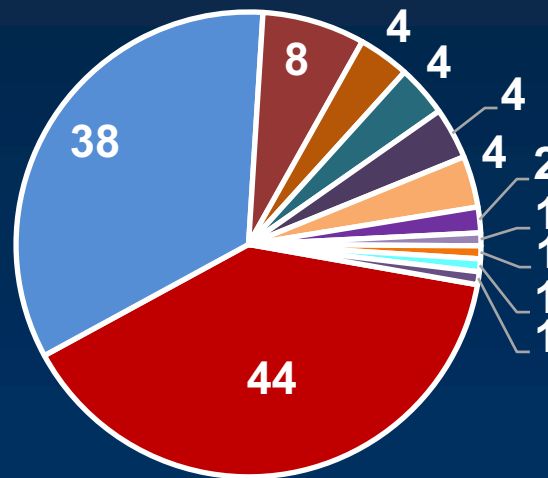
Review of Accidents & Serious Incidents – CODED OUTPUT

Level 1 - Occurrence Consequence



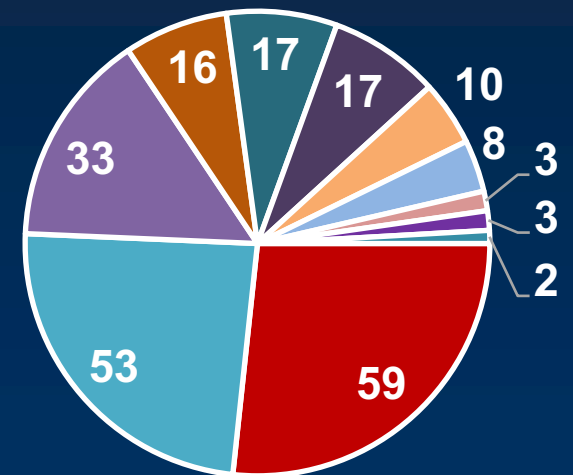
- Runway-related occurrence
- Diversion or Air Turnback
- Collision
- LG-related occurrence
- Landing-related occurrence
- Structural damage
- Fire
- Depressurisation

Level 2 - Associated Event System / Component



- Engine
- Landing gear
- Flight controls
- Electrical power
- Instrumentation and indication
- Steering
- Structure
- Fuel
- Insulation
- Insulation
- Insulation
- Insulation
- Insulation

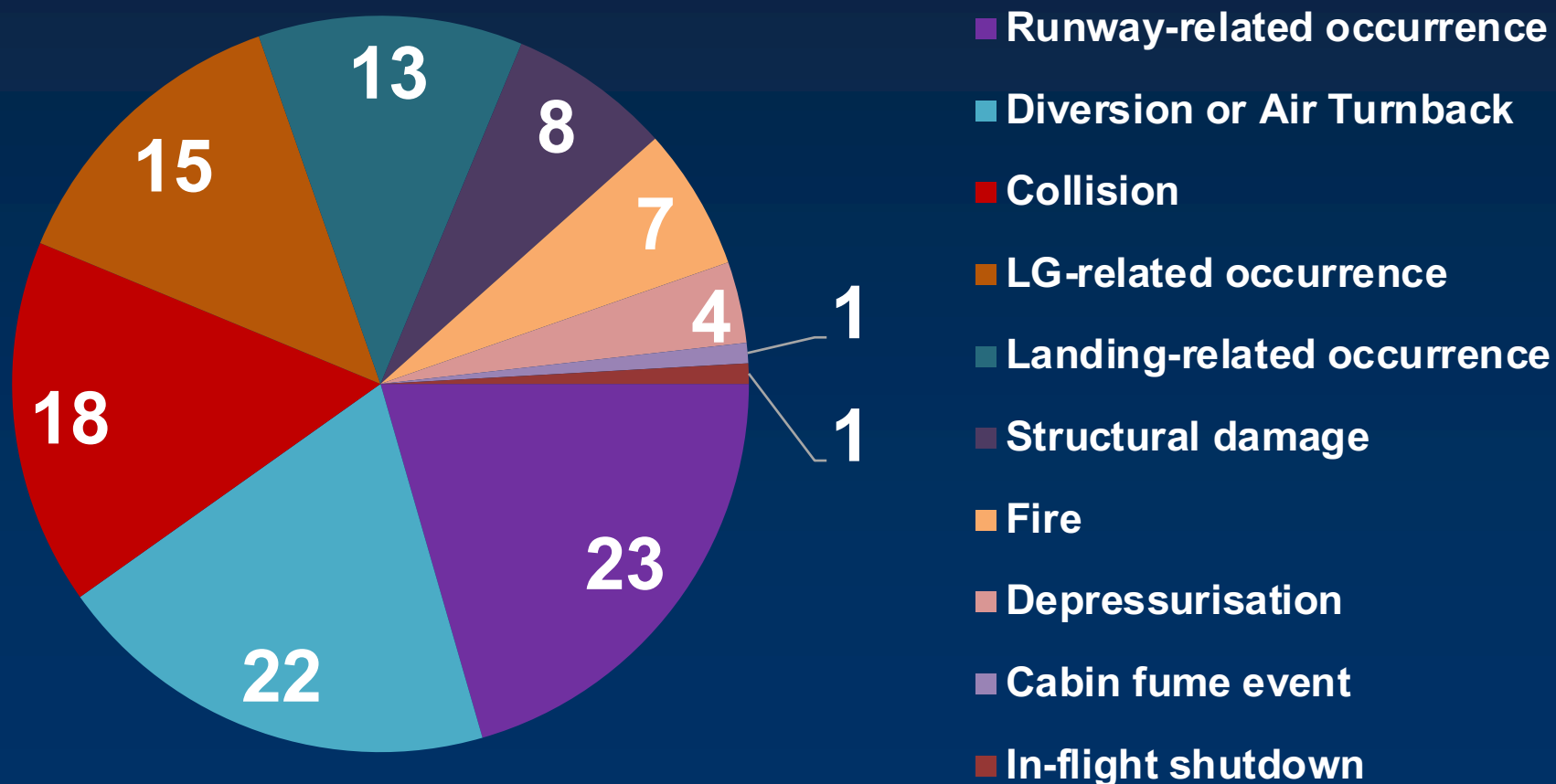
Level 3 - Maintenance Factors



- Inadequate maintenance
- Incorrect maintenance
- Inspection
- AMM
- Organisational
- Oversight
- Check
- Overhaul

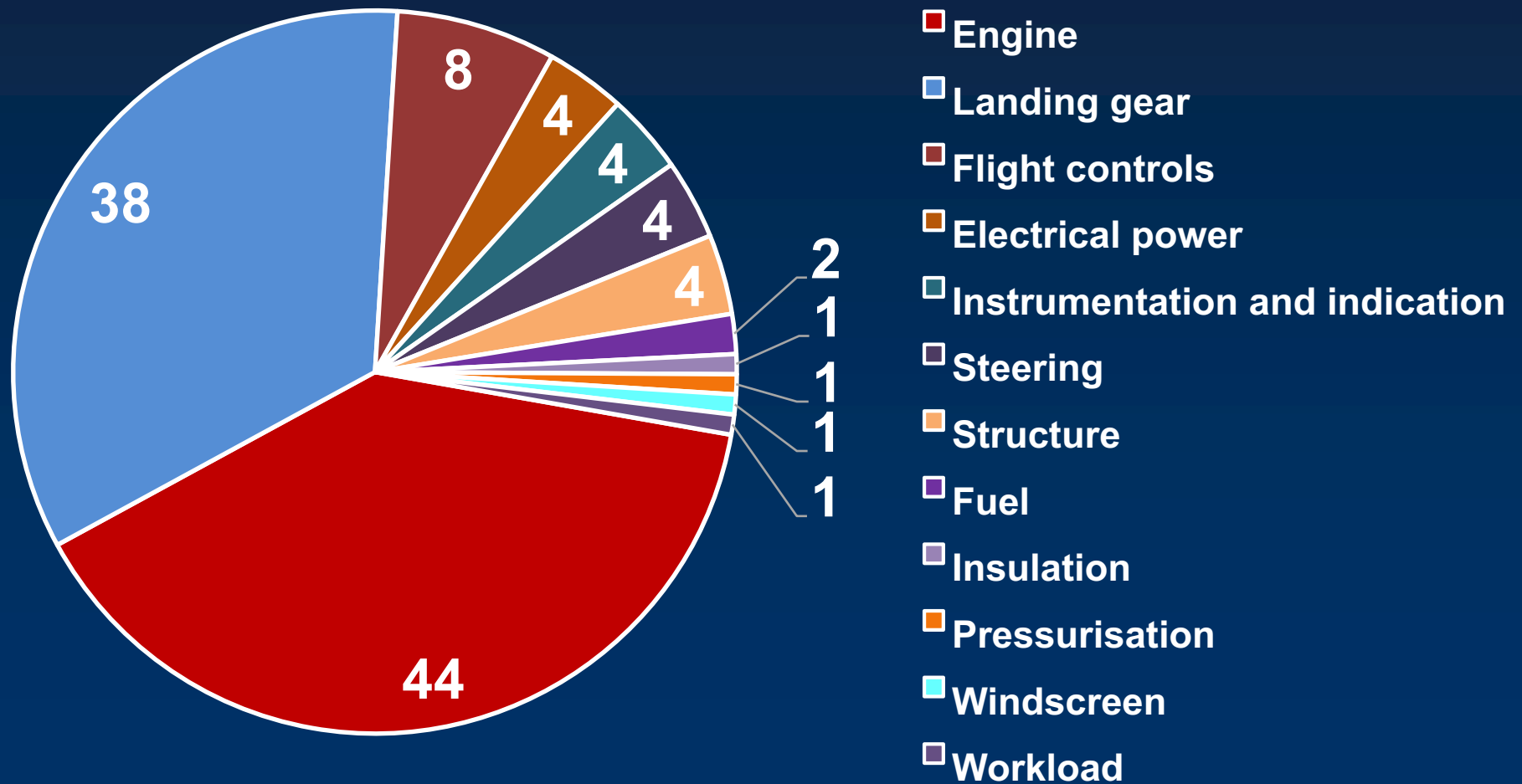
Review of Accidents & Serious Incidents – CODED OUTPUT

Level 1 - Occurrence Consequence



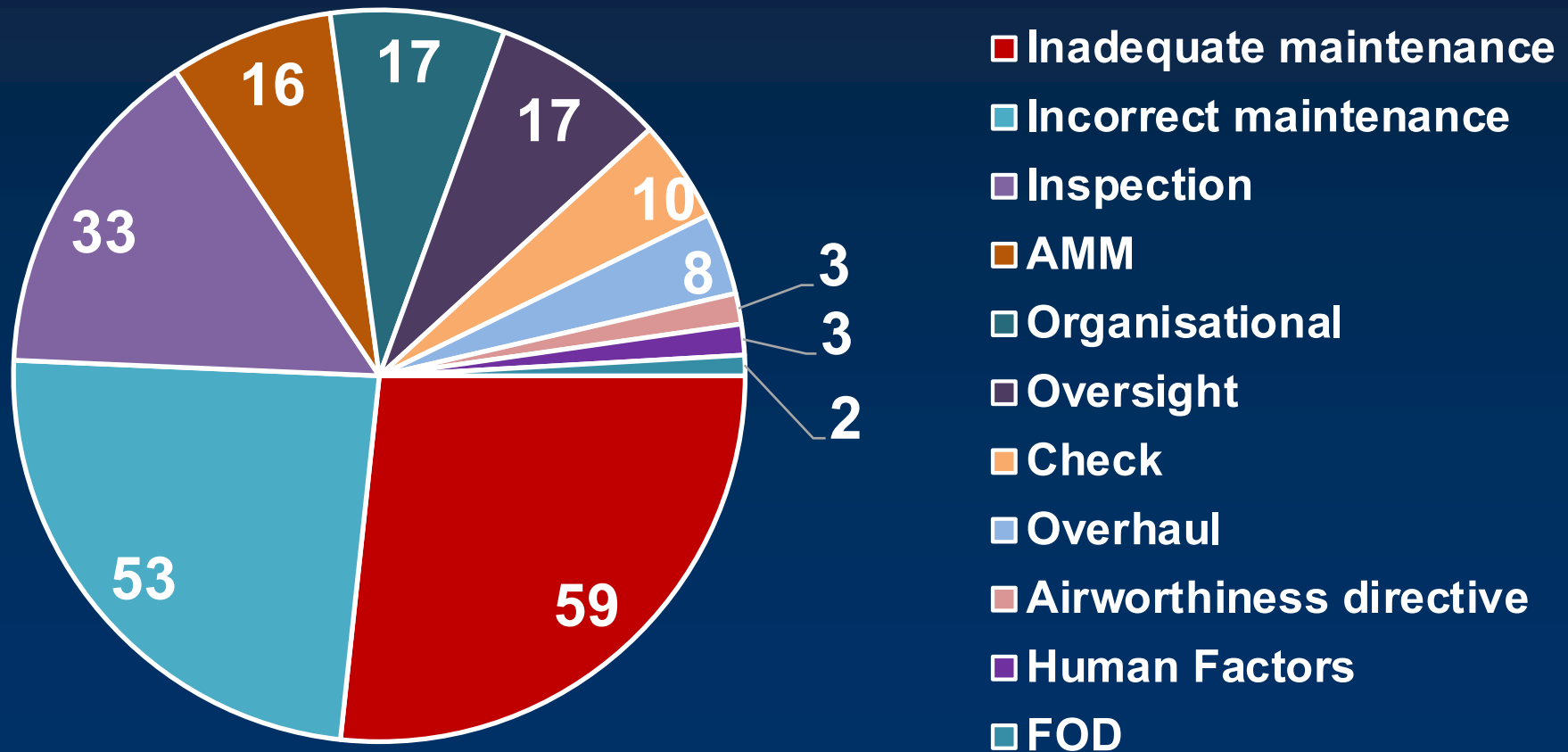
Review of Accidents & Serious Incidents – CODED OUTPUT

Level 2 - Associated Event System/Component



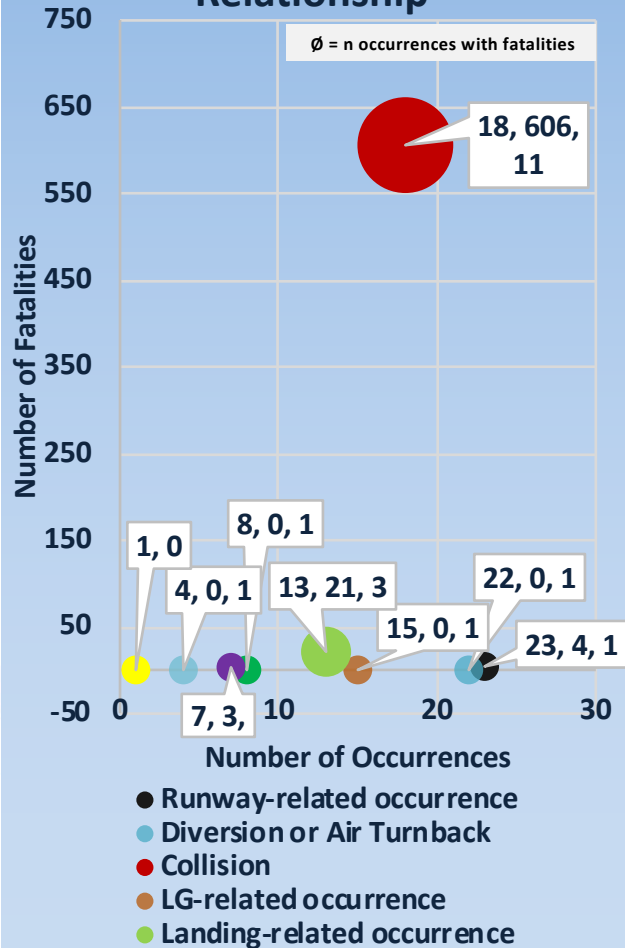
Review of Accidents & Serious Incidents – CODED OUTPUT

Level 3 - Maintenance Factors

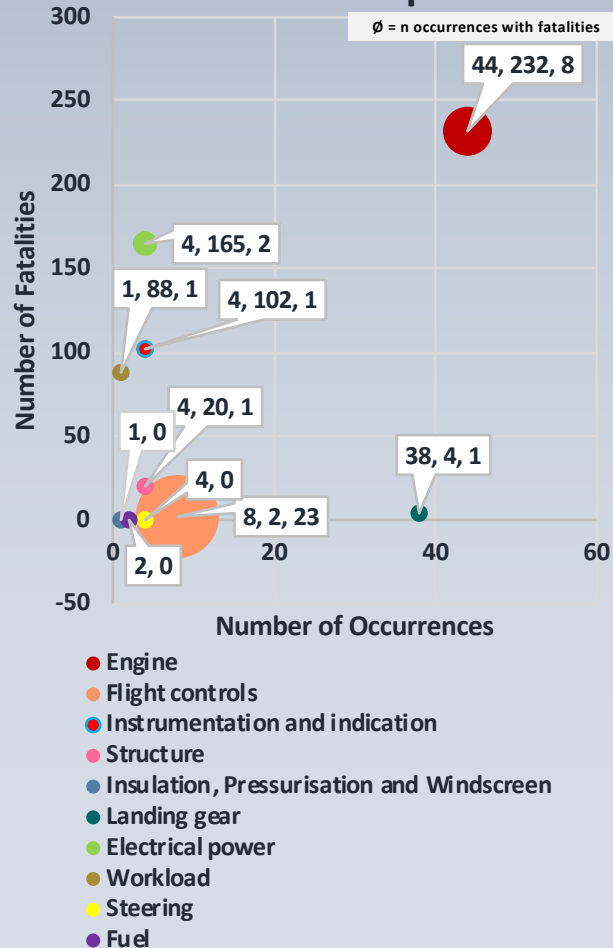


Review of Accidents & Serious Incidents – RESULTS

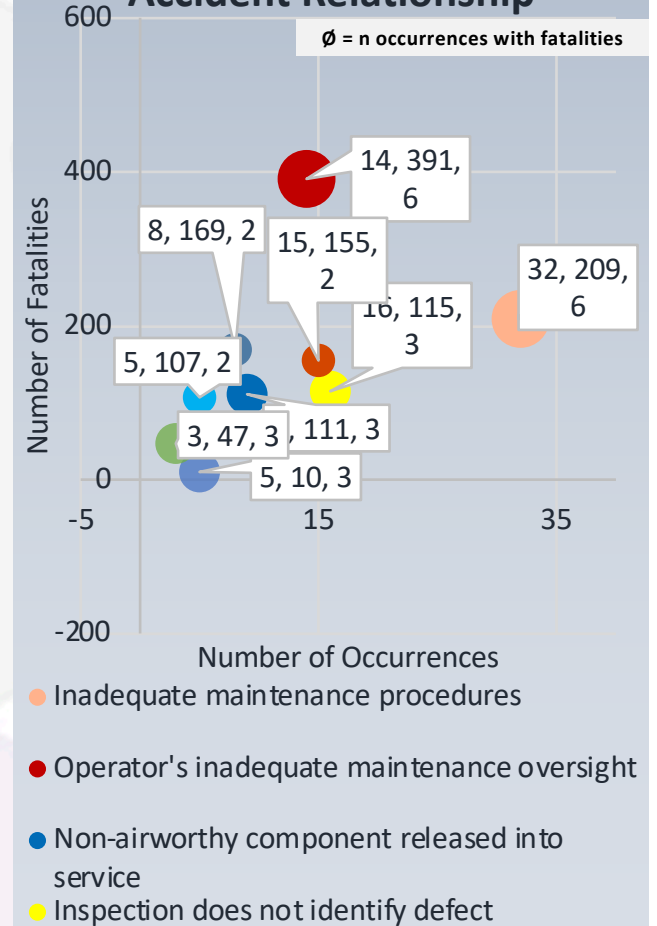
Level 1 Fatal Accident Relationship



Level 2 Fatal Accident Relationship

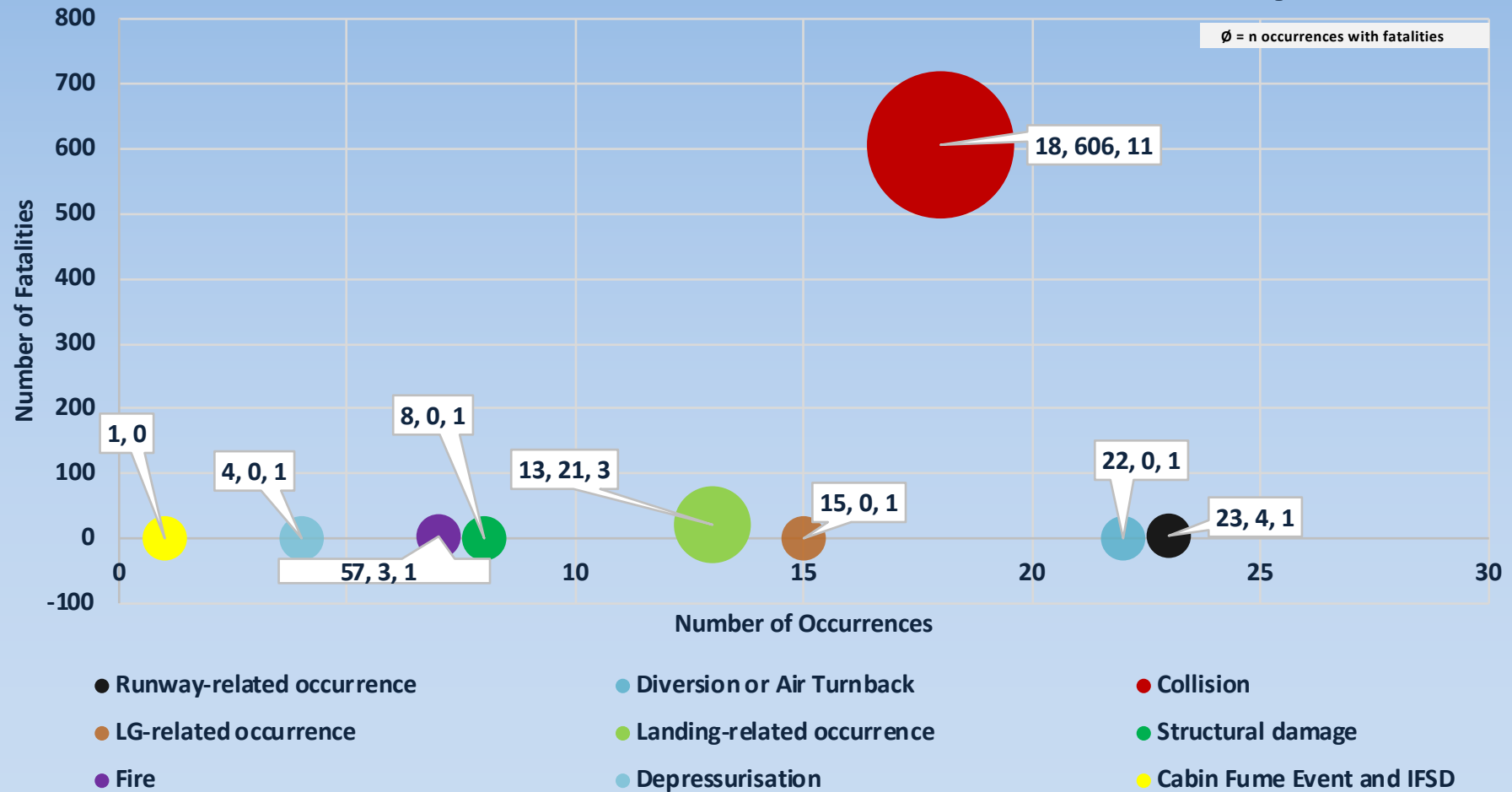


Level 3 Top 9 Fatal Accident Relationship



Review of Accidents & Serious Incidents – RESULTS

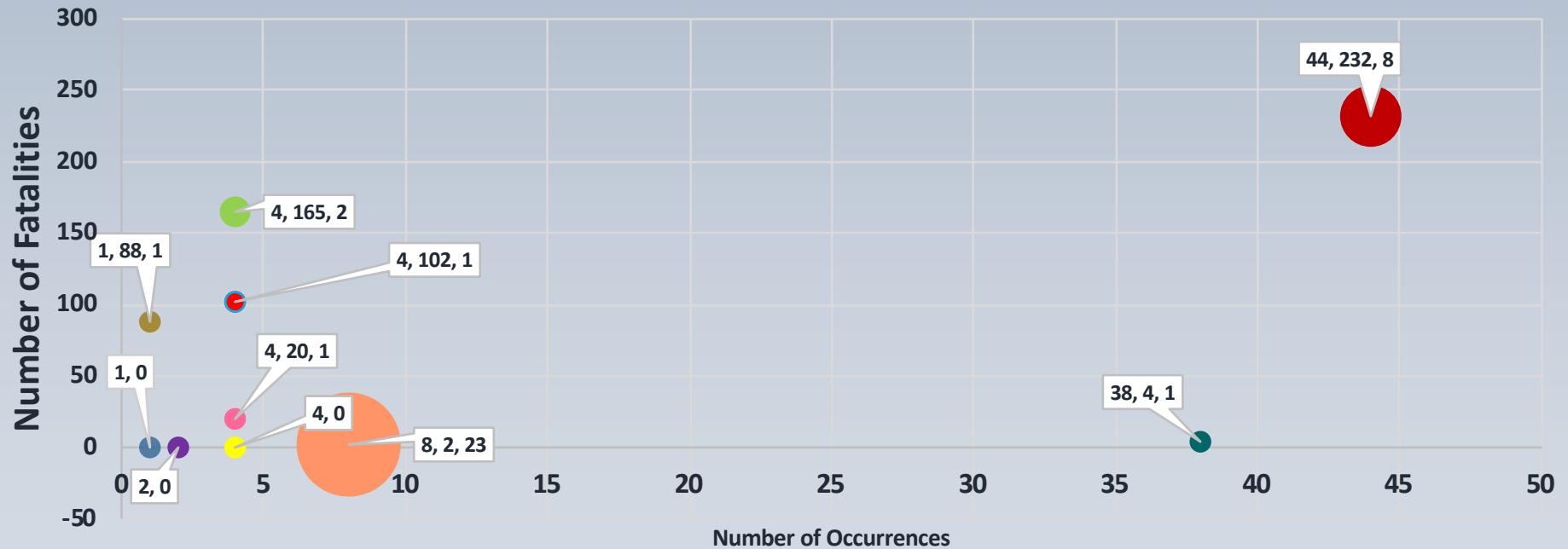
Level 1 Fatal Accident Relationship



Review of Accidents & Serious Incidents – RESULTS

Level 2 Fatal Accident Relationship

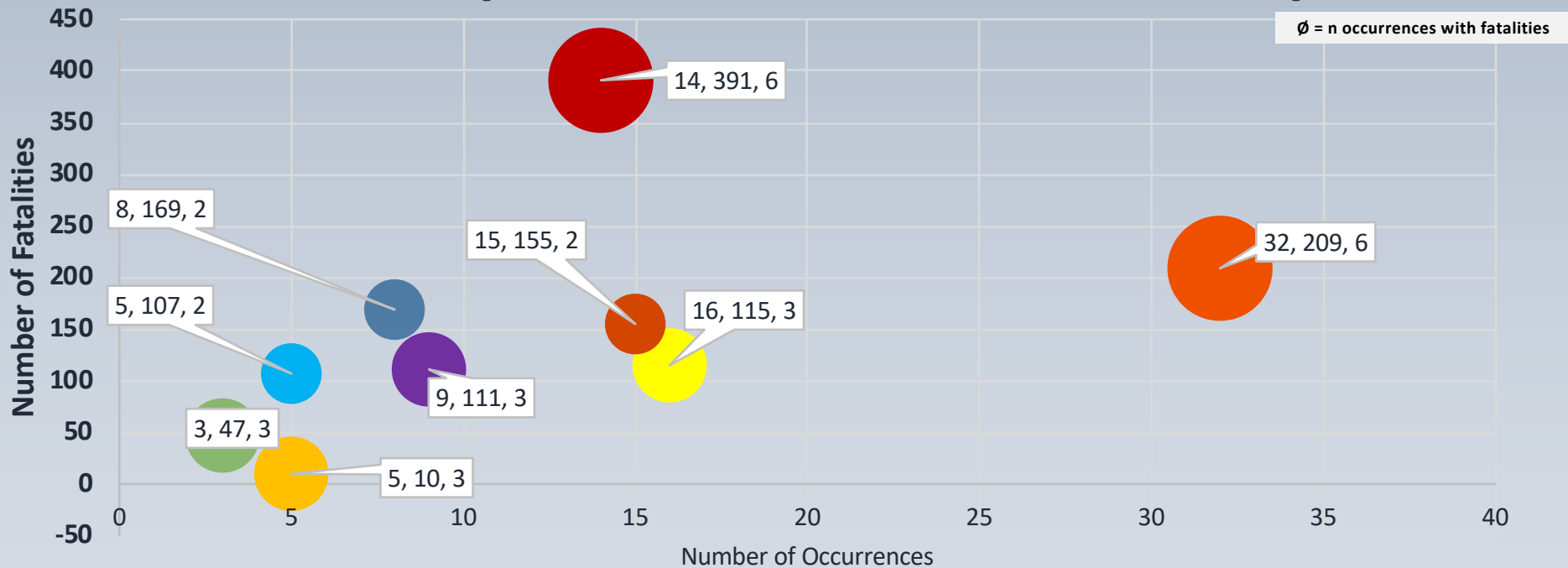
∅ = n occurrences with fatalities



- Engine
- Structure
- Electrical power
- Fuel
- Flight controls
- Insulation, Pressurisation and Windscreen
- Workload
- Instrumentation and indication
- Landing gear
- Steering

Review of Accidents & Serious Incidents – RESULTS

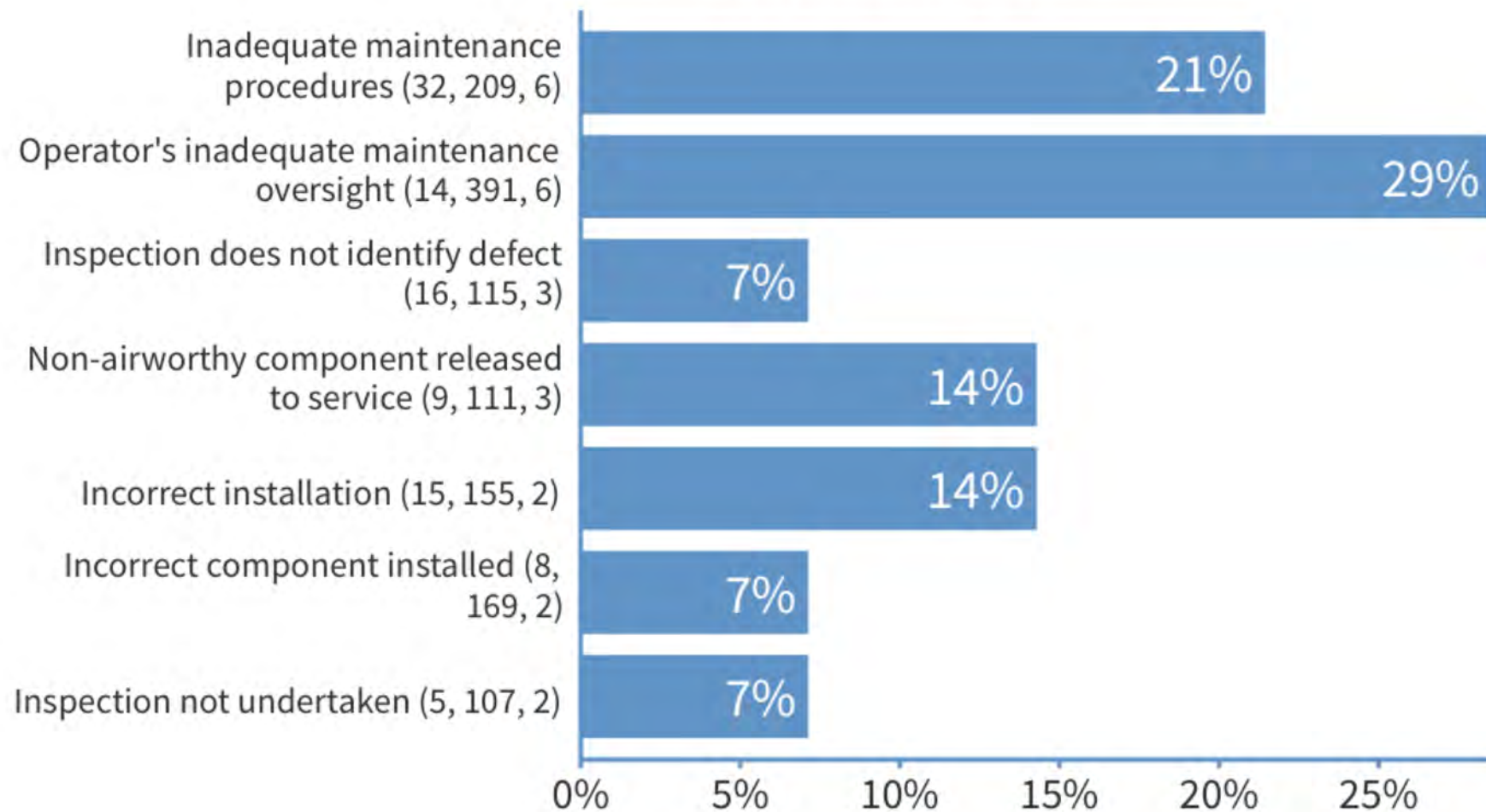
Level 3 Top 9 Fatal Accident Relationship



- Inadequate maintenance procedures
- Operator's inadequate maintenance oversight
- Non-airworthy component released into service
- Inspection does not identify defect
- Overhaul not undertaken
- Regulator's inadequate maintenance oversight
- Incorrect component installed
- Incorrect installation
- Inspection not undertaken

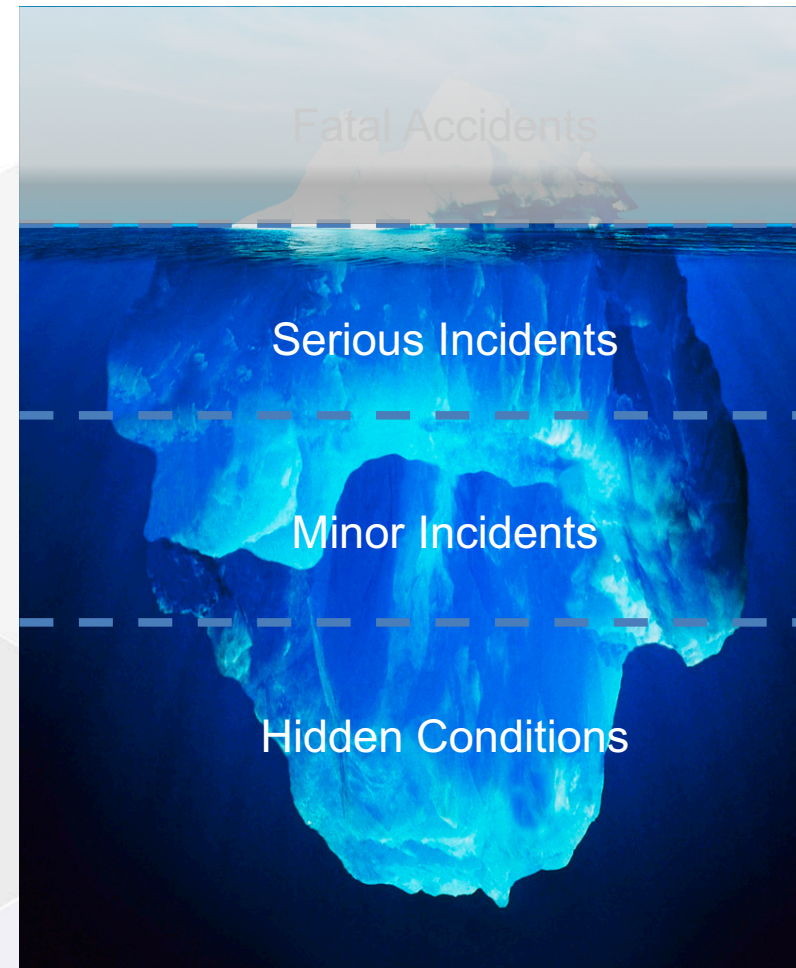
Which one of the event categories should be the focus of attention as a priority? (#total accidents, #fatalities, #fatal accidents)

Respond at [PollEv.com/icsc](https://www.poll-ev.com/icsc)



CONCLUSIONS

- Next to installation errors, the process for deferring defects and the job-close up phase could use some attention.
- The search continues for causes, or the 'why' behind these errors:
 - CHC Safety & Quality Summit
 - DGAC maintenance safety network advisory group
 - Next IFA event (Nov 2018)
- Several recommendations were made to improve the data quality for ECR reports.
- Several opportunities for additional research are available based on this project and the material used.
- For now, the tip of the iceberg is very small, or invisible. Is it hiding in the fog?



Based on Heinrich's safety pyramid

IMPROVING THE USEFULNESS OF REPORTS

- Insist on a narrative with sufficient detail when submitting a report.
- Modify the 'event types' taxonomy to shift maintenance related categories to a higher level in the taxonomy.
- Separate the ATA breakdown from the contributory causes taxonomy. Focus on the 'what' before insisting on listing causes.
- Regular analysis of the reports in the ECR to evaluate their usefulness.
- Inform the reporters in the industry about how to submit a report for maximum usefulness.

FURTHER RESEARCH

- Evaluate the narratives for the two high scoring categories to see if HF issues can be identified.
- Interview subject matter experts to see if the safety issues identified in this report are recognised.
- Further work on the taxonomy to avoid ambiguity in the descriptions of the categories.
- Use better descriptions of the taxonomies in the CAA papers to compare the results.
- Evaluate whether the input method for submitting reports to the ECR has an influence on the level of detail submitted.



THANK YOU FOR YOUR TIME AND ATTENTION

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