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Research & Consultancy

Development of a rotorcraft causal risk model

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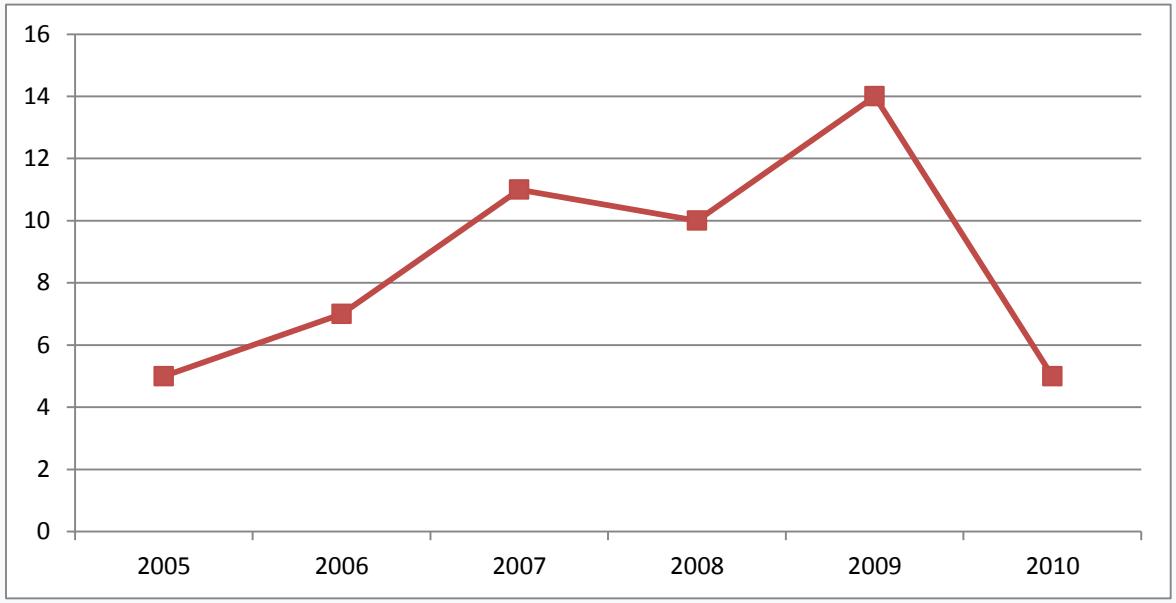
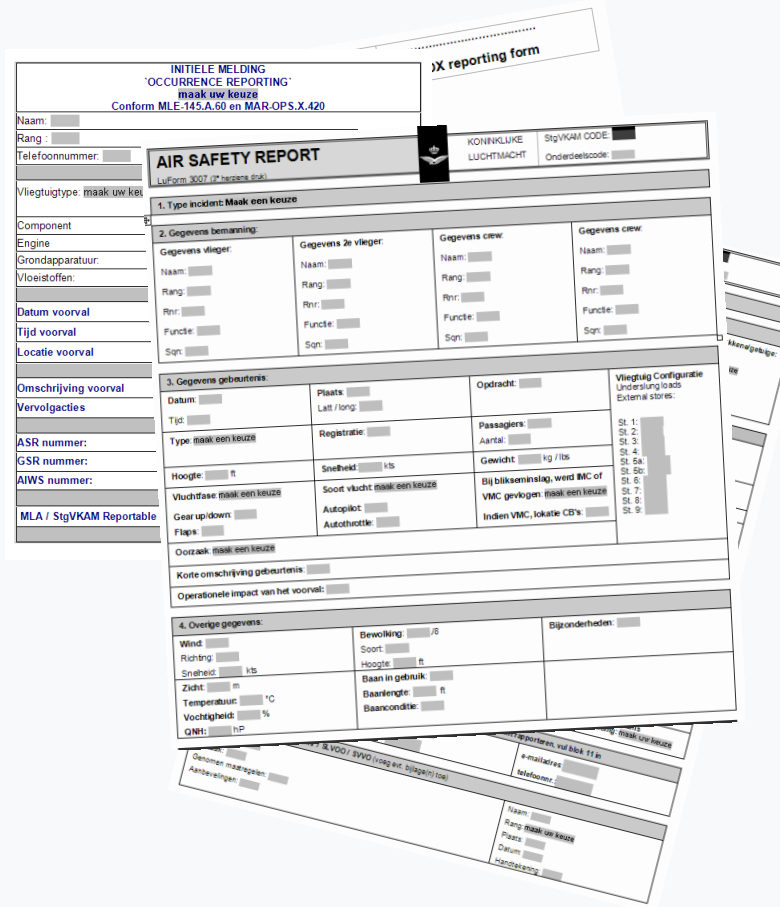
Rotorcraft Symposium, 4-5 December 2013

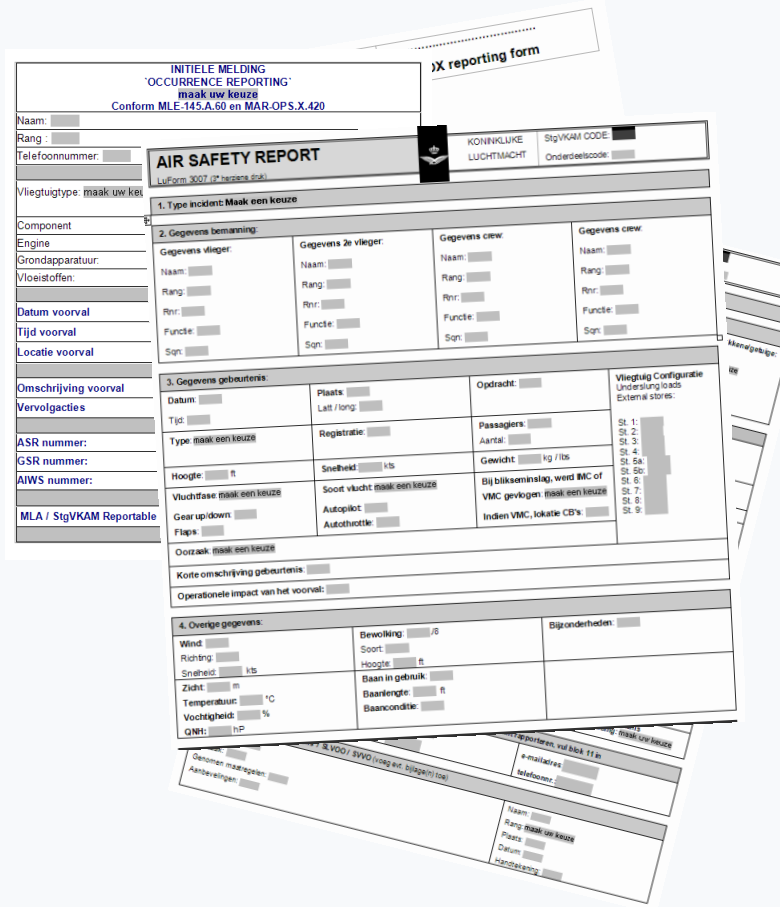
SMS – Some challenges





SMS – Some challenges

1. What is the relation between “small” occurrences and incidents/accidents?
2. What safety performance indicators do we select, and why these?
3. How can we get an integrated picture of the risks from different data sources? What is the contribution of occurrences to the risk profile?
4. Where can we get the most effective safety improvements?



Next step

Need risk models to build understanding & insight

- *Representation of relation hazards – controls – risks*
- *Use as much data as possible from operations*
- *Balance data and knowledge/expertise*

Risk based safety assurance & oversight

Decade of cooperation between FAA, CAA & MoT and NLR.

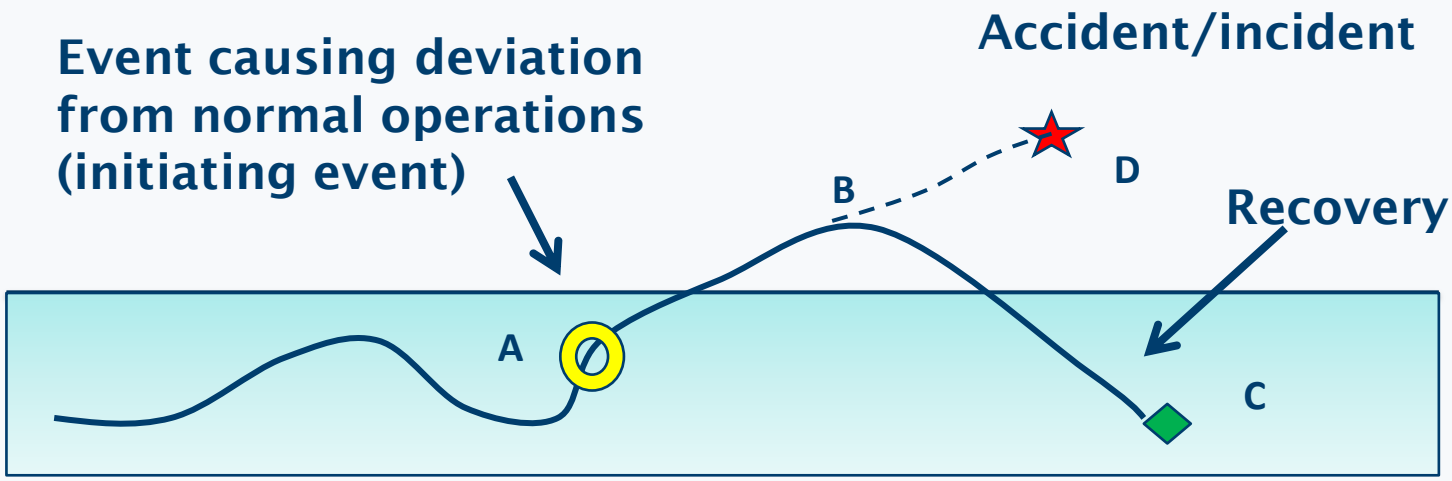
Causal risk model

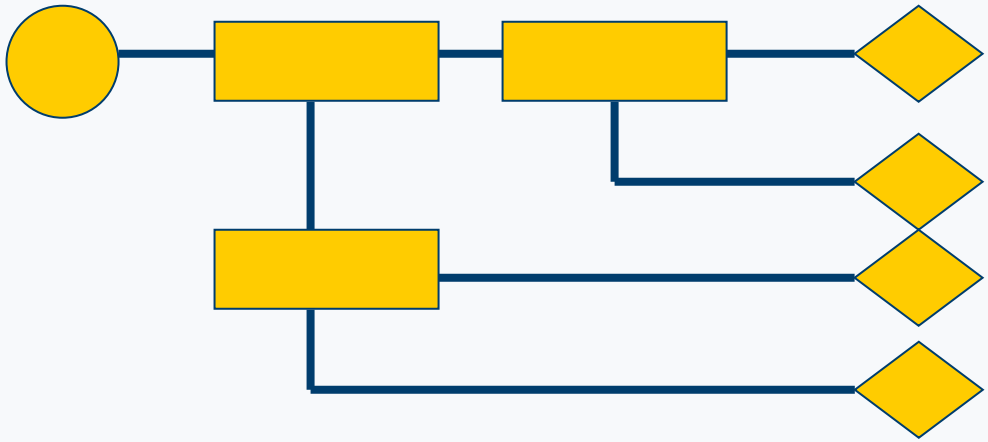
Explains functional and quantitative relationship between the various factors affecting risk in air transport system.

Event sequence models or accident scenarios.

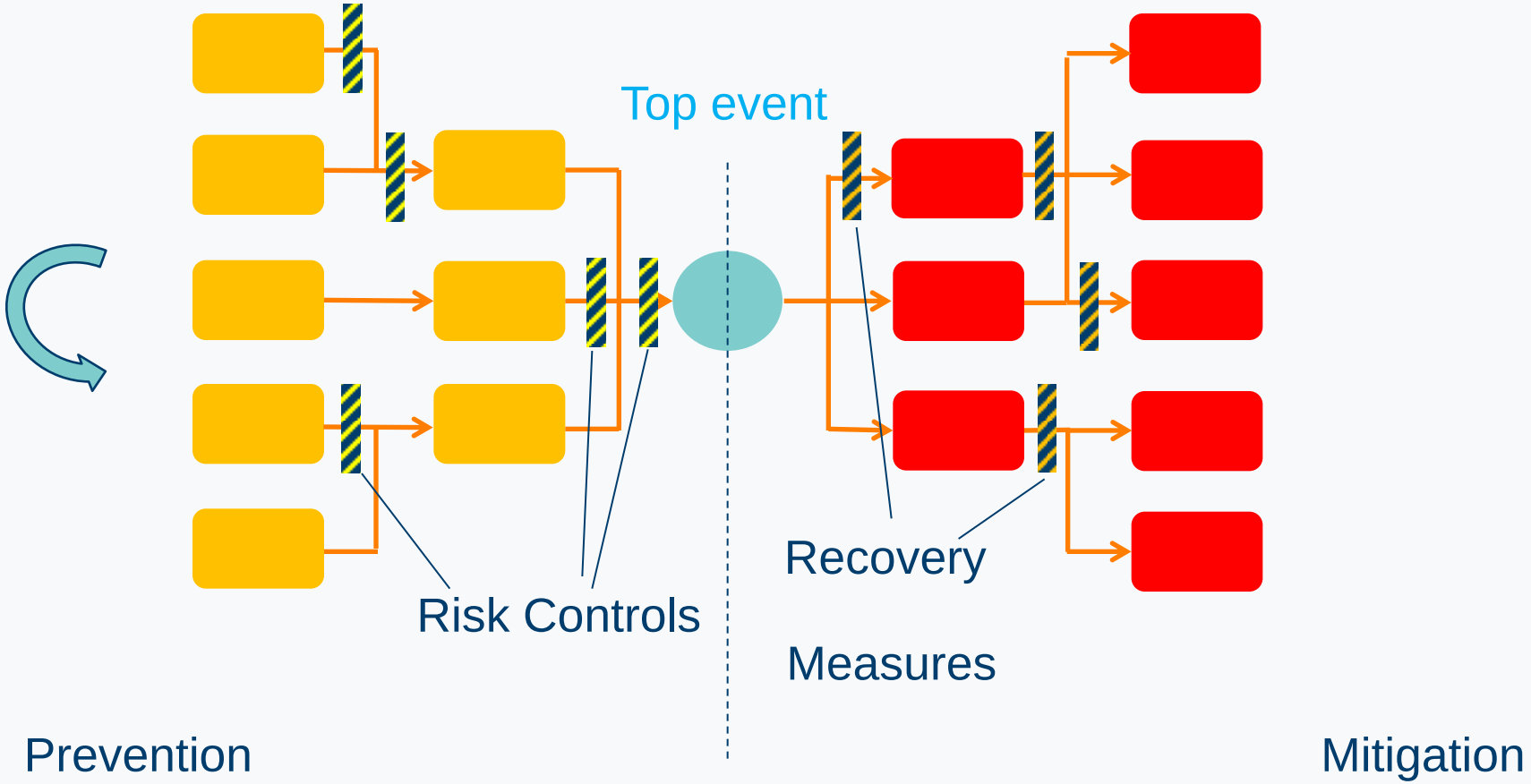
Accidents are not random

Operational variation

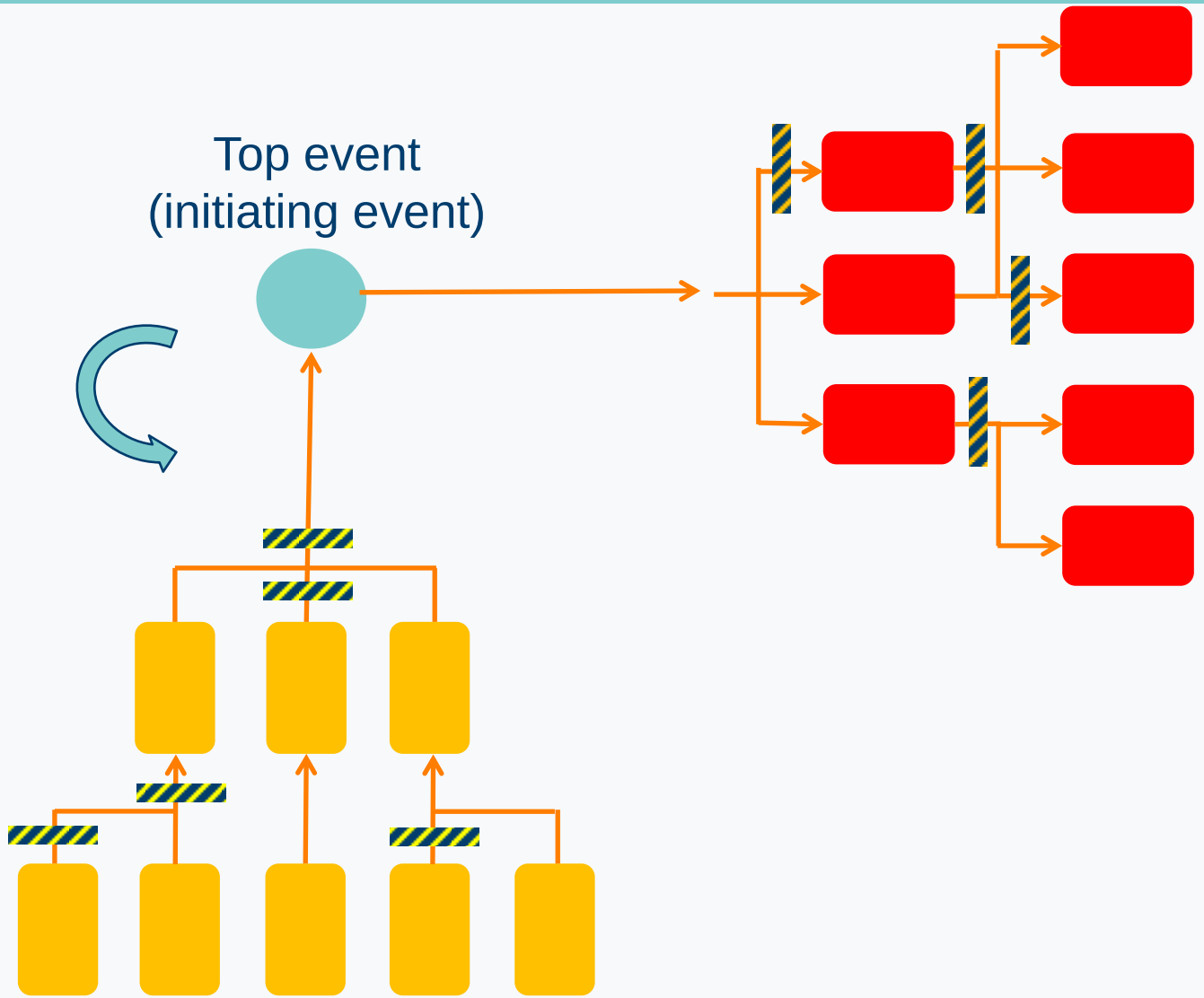




Bow-tie diagram



Bow-tie – Accident scenario diagram



FAA project

Task: Develop a limited rotorcraft causal risk model as a proof of concept to support risk analysis.

Scope: “air tour/sightseeing” & “emergency medical services”

Approach

NTSB
An Independent United States Federal Government Agency

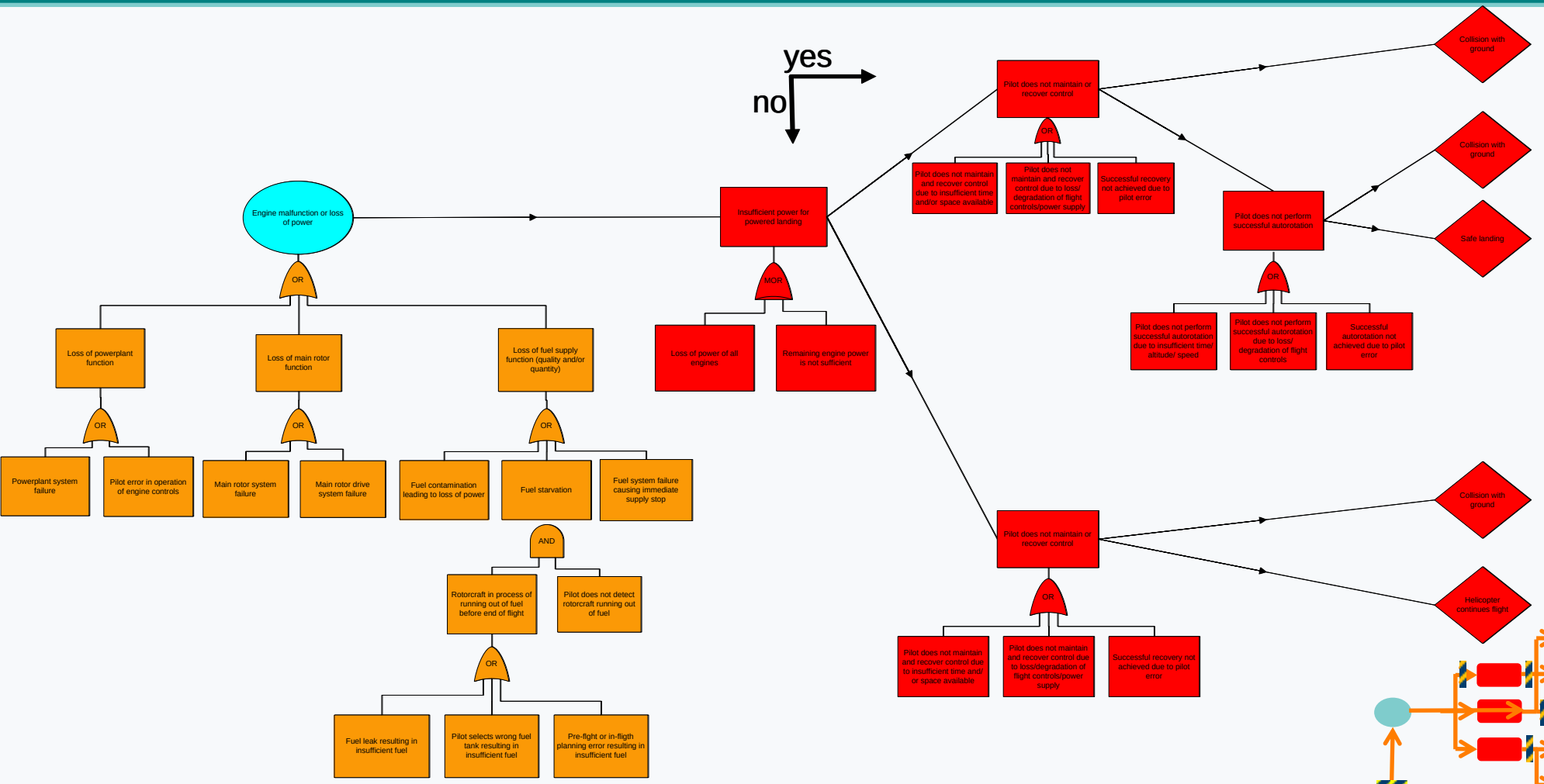
Accidents/incidents:

 # 125 HEMS & TO (2005 - 2010)

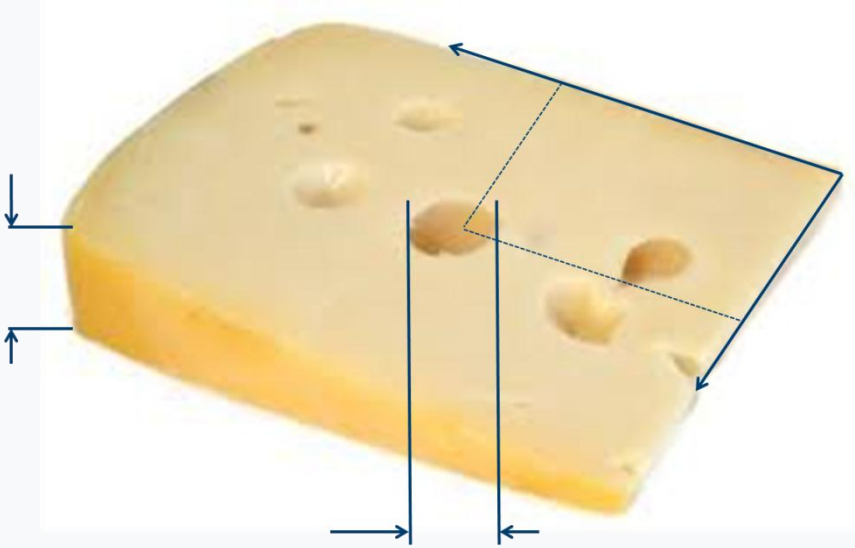
 # 246 Other operations (2009 - 2010)

19 generic accident scenarios

Example accident scenario model (ESD #14)



Quantification



Data sources & records used for quantification of 19 scenarios

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(2005-2010)

- **ASRS (54)**
- **Concern-Network (199)**
- **FAA SDR (± 2900)**
- **NTSB accident & incident data (125)**
- **Operational data**

Combination of accident and incident data

+

Math

NTSB data (125)

Conclusions

Proof of concept study successful in (FAA):

- *Insight into scenarios of rotorcraft accidents.*
- *A picture of EMS and Sightseeing rotorcraft safety.*
- *Foundation to continue effort towards the further improvement of rotorcraft safety.*

Quantification:

- *Balance the development of models with more details against the availability and quality of data for quantification.*
- *For many detailed events in the current model, data is limited or not available in the datasets used.*

Recommendations

Model development:

- *Expand scope to include other types of operations.*

'Model driven' data collection:

- *Encourage aviation professionals to report in more detail on relevant operational circumstances and causal factors.*
- *Consider a reporting form to capture data for risk model elements.*

DOT/FAA/TC-13/50.

Development of a Rotorcraft Causal Model Prototype.

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Project for FAA: Development of a rotorcraft causal risk model

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Rotorcraft Symposium, 4-5 December 2013

Risk model:
Event Sequence Diagram and Fault Trees

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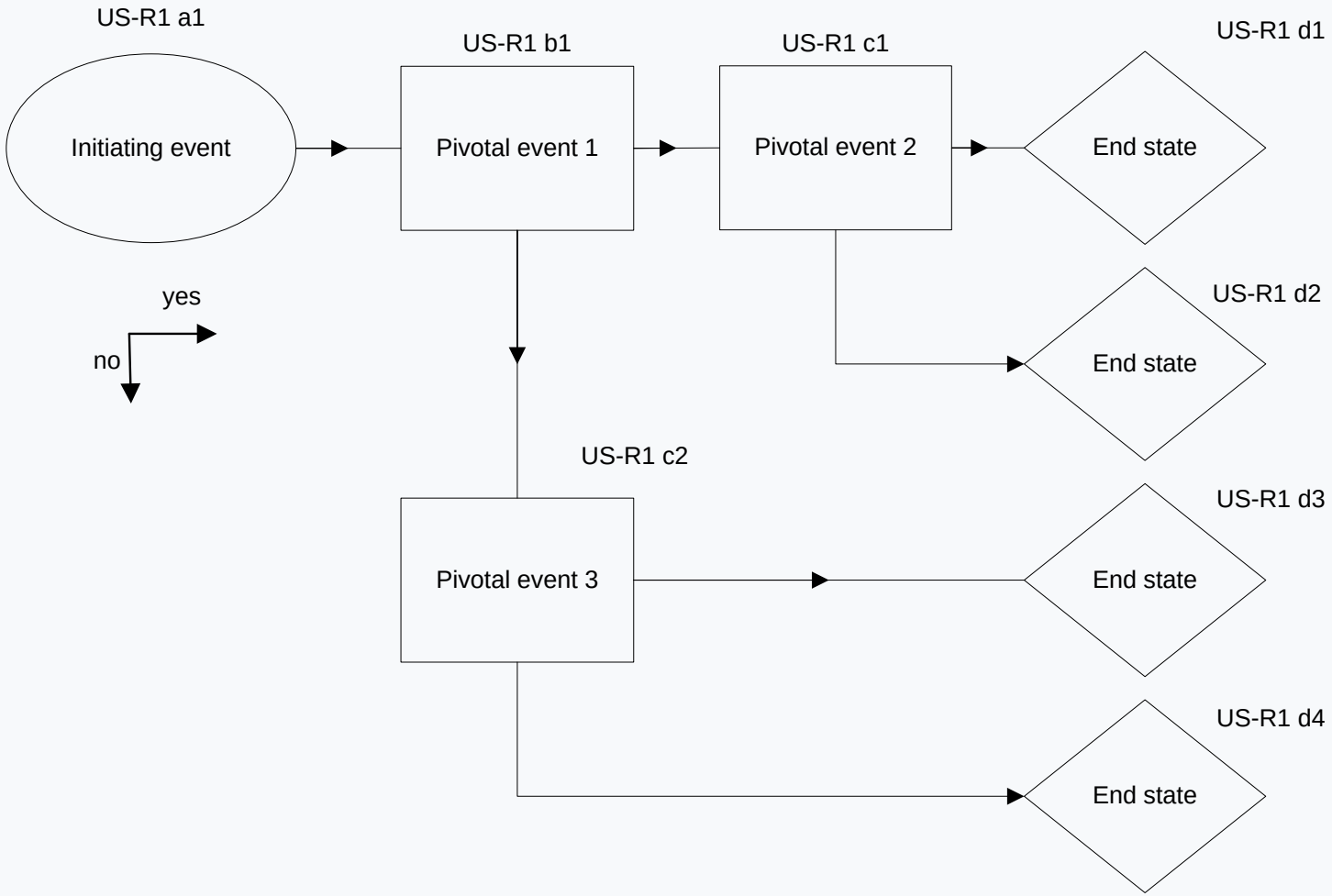

Top-5 HEMS accident scenarios by *accident outcome*

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#	Per million flight hrs	Initiating event
1	*10.1*	*R7: Fire on board helicopter*
2	*6.4*	*R14: Loss of power*
3	*4.3*	*R8: Loss of situational awareness in degraded visual environment*
4	*3.2*	*R17: Pilot judgment, decision, or action error*
5	*2.4*	*R13: Flight control system failure*

Ranking of accident scenarios based on cumulative frequency of occurrence of accident end states per scenario for HEMS operations.

Top-5 HEMS accident scenarios by *initiating event probability*

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#	Per million flight hrs	Initiating event	Conditional probability of accident outcome
1	53.5	R14: Loss of power	0.12
2	39.2	R18: Structural failure in flight	0
3	23.7	R13: Flight control system failure	0.1
4	14.1	R10: Deviation from safe flight path towards obstacle	0.08
5	11.9	R16: Aircraft are positioned on collision course in flight	0.07

Ranking of accident scenarios based on frequency of occurrence of the initiating event for HEMS operations.

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Project for FAA: Development of a rotorcraft causal risk model

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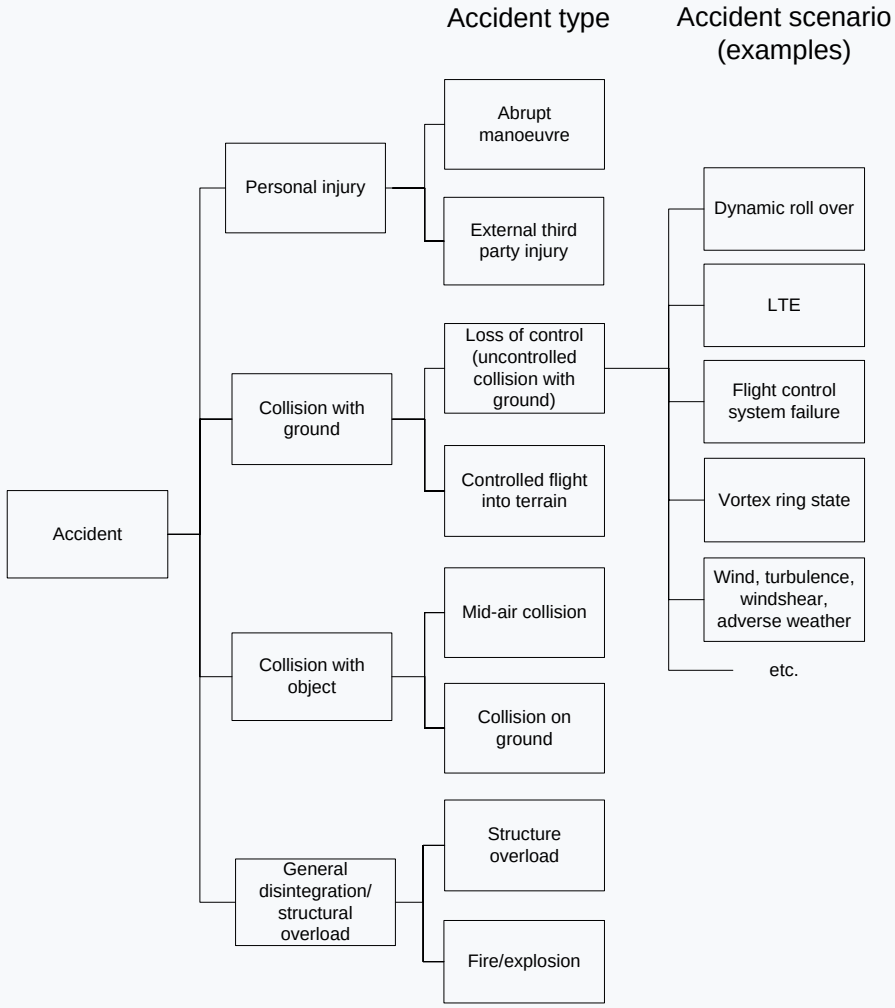
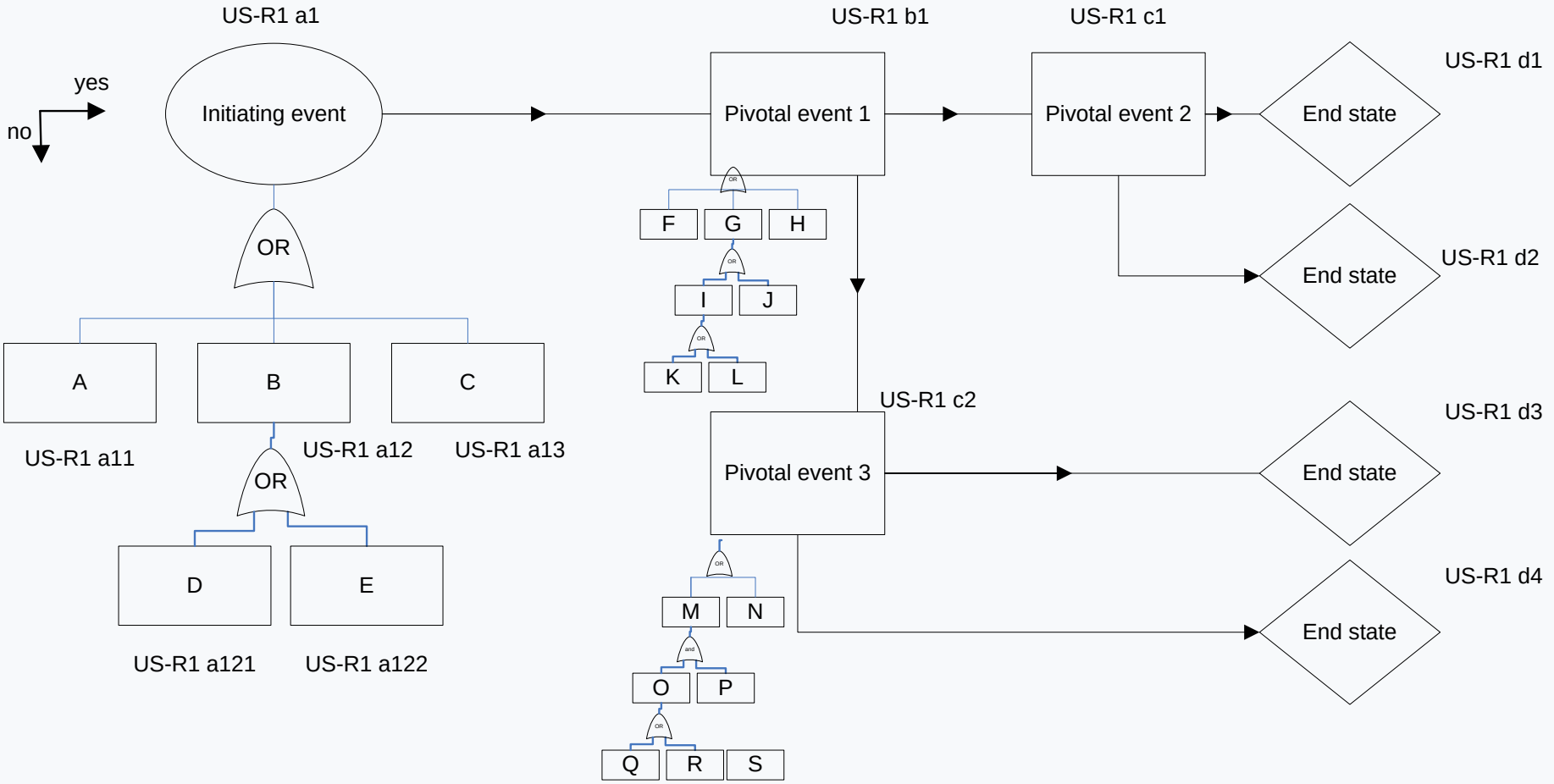
Accident

ICAO definition:

- **Injury or fatality**
- **Serious aircraft damage**



Example ESD with connecting Fault Trees



History

Cooperation between FAA, MoT/CAA-NL and NLR

Causal risk models development activities

- *2001-2004: Feasibility and exploration studies for FAA*
- *2002-2007: Development of IRIS for FAA SASO*
- *2005-2009: Development of CATS for Dutch MoT*
- *2009-2010: Support of FAA in ATM causal model quantification*
- *2009-2011: Causal modeling in support of FAA UAS research*
- *2012-2013: Rotorcraft causal model for FAA*
- *2012: General Aviation accident scenarios (EGAST)*
- *2010-ongoing: Development of NAS-specific causal models for FAA Integrated Safety Assessment Model (2009-2012)*
- *2010-ongoing: Management & maintenance of CATS*

Applications

Risk assessment:

- *Insight in interdependencies between parts of the complex aviation system; model and data-based.*
- *Estimate incident/accident probability based on integrated data for performance monitoring.*
- *What are the most critical pathways?*
- *Assessment of quality of risk controls?*

Selection safety performance indicators

- *Model-based indicators linked to accident risk.*

Risk mitigation

- *Identification of measures.*
- *Assessment of effectiveness of measures*
- *what is most cost efficient risk mitigation?*

Model coverage

2005-2010	#	mapped
air medical	86	84
tour oper	40	39
sum	126	123

Total data sample	#	mapped
All other occurrences, excl. HEMS & TO (2009-2010)	246	244
HEMS & TO (2005-2010)	126	123
	372	367

Quantification challenges

The availability, quality and level of detail of the data are important enablers for causal model development and quantification.

Quantification requires effort, data processing and knowledge on data analysis and operations.

For many detailed events in the current model data is limited or not available in the datasets used.

Take into account:

- *dependencies between the model elements.*
- *the context of the ESD, e.g. landing or take-off phase.*

Accident cat.	Main accident type	Rotorcraft model	
Personal injury	Abrupt manoeuvre	No ESD	
	Cabin environment	No ESD	
	External third party injury	US-R21	Presence of person nearby helicopter
Collision with ground	Loss of control (Uncontrolled collision with ground)	US-R2	Helicopter handling by pilot inappropriate
		US-R3	(Attempted take-off with) weight and/or cg outside limits
		US-R4	Loss of power
		US-R6	Loss of tail rotor effectiveness/unanticipated yaw
		US-R9	Loss of visual ref/ SD
		US-R11	Pilot incapacitation
		US-R12	Airspeed, altitude, attitude display failure
		US-R13	Flight control system failure
		US-R14	Loss of power
		US-R15	Helicopter encounters adverse weather
		US-R17	Poor airmanship and helicopter handling
		US-R20	Incorrect approach and/or flare (unstable approach)
	Collision with terrain	US-R8	Loss of situational awareness in degraded visual environment
		US-R10	Loss of SA / inadequate look out
Collision with object	Mid-air collision	US-R16	Aircraft are positioned on collision course
	Ground collision (on ground)	US-R5	Pilot does not maintain situational awareness on ground
General disintegration	In-flight fire	US-R7	Fire onboard helicopter
	Explosion	No ESD	Explosion (leading to disintegration/structural failure)
	Structure overload	US-R18	Structural failure
		US-R23	Helicopter enters ground resonance

Result ranking

AIR TOUR & HEMS OPS ONLY 2005-2010	
US-R14: Loss of power	30
US-R10: Loss of situational awareness or inadequate look out	18
US-R13: Flight control system failure	15
US-R8: Loss of situational awareness in degraded visual environment	10
US-R9: Loss of visual reference in degraded visual environment	9
US-R18: Structural failure	8
US-R6: Loss of tail rotor effectiveness/ unanticipated yaw	7
US-R16: Aircraft are positioned on collision course in flight	6
US-R17: Inappropriate helicopter handling/ poor airmanship	5
US-R2: Helicopter handling by pilot inappropriate during take-off	4
US-R15: Helicopter encounters adverse weather	3
US-R20: Improper approach and/or flare by pilot	3
US-R3: (Attempted take-off with) weight and/or cg outside limits	2
US-R7: Fire on board helicopter	1
US-R11: Pilot incapacitation	1
US-R23: Helicopter enters ground resonance	1
US-R5: Pilot does not maintain situational awareness on ground	0
US-R12: Airspeed, altitude or attitude display failure	0
US-R21: Presence of person nearby helicopter	0

ALL OPS 2009 &2010	
US-R14: Loss of power	66
US-R20: Improper approach and/or flare by pilot	49
US-R10: Loss of situational awareness or inadequate look out	45
US-R17: Inappropriate helicopter handling / poor airmanship	25
US-R13: Flight control system failure	20
US-R2: Helicopter handling by pilot inappropriate during take-off	16
US-R18: Structural failure	15
US-R6: Loss of tail rotor effectiveness/unanticipated yaw	10
US-R9: Loss of visual reference in degraded visual environment	9
US-R15: Helicopter encounters adverse weather	7
US-R8: Loss of situational awareness in degraded visual environment	6
US-R16: Aircraft are positioned on collision course in flight	5
US-R7: Fire on board helicopter	3
US-R3: (Attempted take-off with) weight and/or cg outside limits	2
US-R11: Pilot incapacitation	1
US-R23: Helicopter enters ground resonance	1
US-R12: Airspeed, altitude or attitude display failure	0
US-R21: Presence of person nearby helicopter	0
US-R5: Pilot does not maintain situational awareness on ground	0

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Conditional probability to accident given ini event	
0.12	R14: Loss of power
0.00	R18: Structural failure in flight
0.10	R13: Flight control system failure
0.08	R10: Deviation from safe flight path towards obstacle
0.07	R16: Aircraft are positioned on collision course in flight
1.00	R7: Fire on board helicopter
0.29	R9: Loss of visual reference in degraded visual environment
0.00	R12: Flight instrument failure
0.87	R8: Loss of situational awareness in degraded visual environment
0.89	R17: Pilot judgement, decision, or action error
0.29	R2: Helicopter handling by pilot inappropriate or handling impaired during take-off
0.17	R15: Helicopter enters adverse weather
1.00	R6: Loss of tail rotor effectiveness
1.00	R20: Improper approach and/or flare by pilot
0.33	R11: Pilot incapacitation
0.00	R21: Presence of person nearby helicopter with turning rotors
1.00	R23: Helicopter enters ground resonance
#DIV/0!	R3: Attempted flight with weight and/or cg outside limits
#DIV/0!	R5: Conflict on taxiway or runway area

Top-5 HEMS accident scenarios by *initiating event probability*

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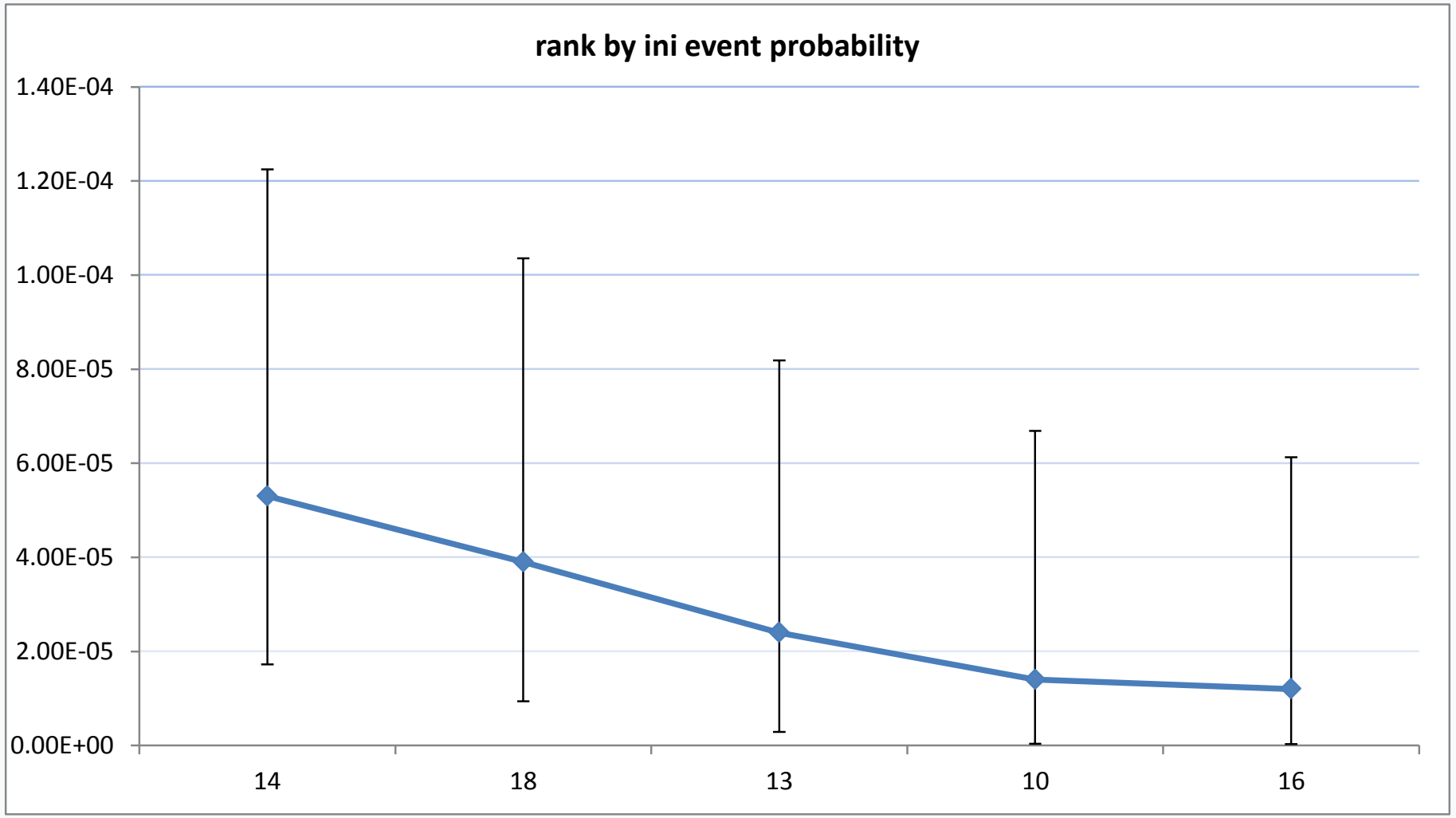

Top-5 HEMS accident scenarios by *accident outcome*

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