WORC 2024

World Overflight Risk Conference

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Practical Application of Probabilistic Risk Mitigations in Overflight Risk

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PRESENTED BY

OSPREY FLIGHT SOLUTIONS

EASA European Union Aviation Safety Agency

AGENDA

- Critical gaps in overflight risk management
- Academic approach: regression, probabilistic and causal models
- Integration of academics and industry: of risk mitigations and expert opinions
- Conclusions

CRITICAL GAPS IN OVERFLIGHT RISK MANAGEMENT

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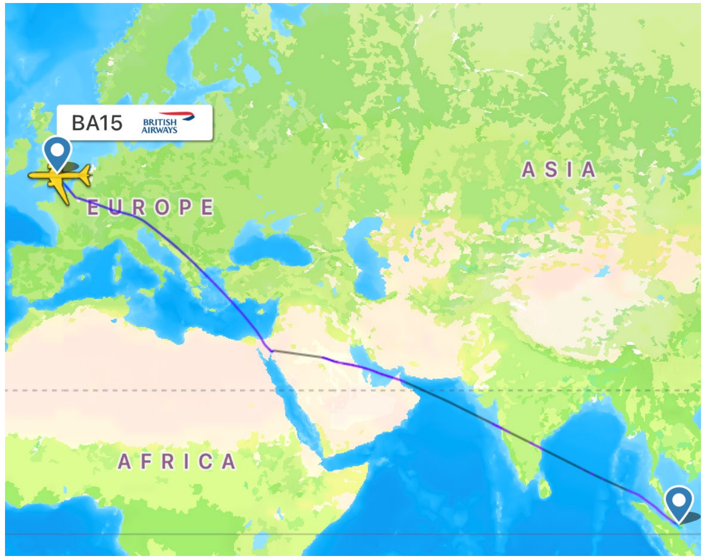

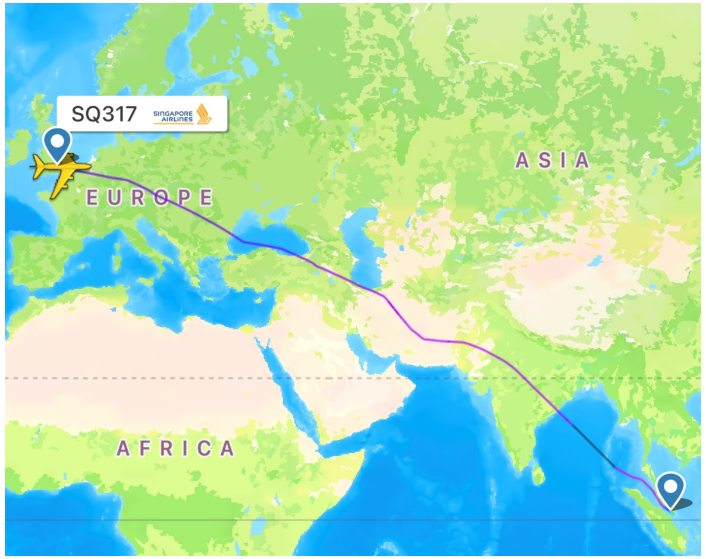

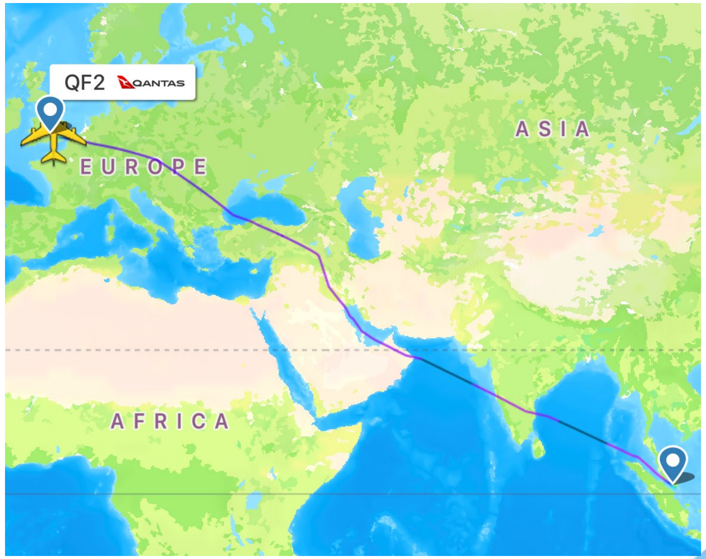

CRITICAL GAPS IN OVERFLIGHT RISK MANAGEMENT

Input likelihood and severity tables

Likelihood	*Meaning*	*Value*
Frequent	Likely to occur many times (has occurred frequently)	5
Occasional	Likely to occur sometimes (has occurred infrequently)	4
Remote	Unlikely to occur, but possible (has occurred rarely)	3
Improbable	Very unlikely to occur (not known to have occurred)	2
Extremely improbable	Almost inconceivable that the event will occur	1

Severity	*Meaning*	*Value*
Catastrophic	• Aircraft / equipment destroyed • Multiple deaths	A
Hazardous	• A large reduction in safety margins, physical distress or a workload such that operational personnel cannot be relied upon to perform their tasks accurately or completely • Serious injury • Major equipment damage	B
Major	• A significant reduction in safety margins, a reduction in the ability of operational personnel to cope with adverse operating conditions as a result of an increase in workload or as a result of conditions impairing their efficiency • Serious incident • Injury to persons	C
Minor	• Nuisance • Operating limitations • Use of emergency procedures • Minor incident	D
Negligible	• Few consequences	E

Output safety/security risk matrix and tolerability table

Safety Risk		*Severity*				
Probability		*Catastrophic A*	*Hazardous B*	*Major C*	*Minor D*	*Negligible E*
Frequent	5	5A	5B	5C	5D	5E
Occasional	4	4A	4B	4C	4D	4E
Remote	3	3A	3B	3C	3D	3E
Improbable	2	2A	2B	2C	2D	2E
Extremely improbable	1	1A	1B	1C	1D	1E

Safety Risk Index Range	*Safety Risk Description*	*Recommended Action*
5A, 5B, 5C, 4A, 4B, 3A	INTOLERABLE	Take immediate action to mitigate the risk or stop the activity. Perform priority safety risk mitigation to ensure additional or enhanced preventative controls are in place to bring down the safety risk index to tolerable.
5D, 5E, 4C, 4D, 4E, 3B, 3C, 3D, 2A, 2B, 2C, 1A	TOLERABLE	Can be tolerated based on the safety risk mitigation. It may require management decision to accept the risk.
3E, 2D, 2E, 1B, 1C, 1D, 1E	ACCEPTABLE	Acceptable as is. No further safety risk mitigation required.

CRITICAL GAPS IN OVERFLIGHT RISK MANAGEMENT

Input likelihood and severity tables

Output safety/security risk matrix and tolerability table

LACK OF INTEGRATION WITH DATA

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CRITICAL GAPS IN OVERFLIGHT RISK MANAGEMENT

1. Data of incidents and near misses is not directly used in current model
2. It is highly dependent on the expertise and personality of those taking part in decision making
3. There is no precise definitions and alignment among stakeholders regarding risk levels
4. It has low flexibility as it is limited to a small number of levels and options and, hence, possible outcomes
5. Dependencies between risks are not accounted for and it does not enable calculation of an overall risk figure
6. Taxonomy 'acceptable', 'tolerable', 'intolerable' is not good for risk estimation - different people interpret these risk classifications differently
7. There is no standardized approach to quantification of the impact of mitigation
8. Delegates a significant role in risk assessment to regulators/authorities

ACADEMIC APPROACH

How to improve aviation security risk management?

- Define what influences security risks – economical, geo-political factors / parameters
- Capture these parameters
- Calculate risk level as probability of an incident
- Develop data-driven predictive Bayesian Belief Network model and facilitate decision making process
- Apply machine learning algorithms for prediction of risk level (probability of an incident)
- Integrate risk mitigation methodologies into the model

Regression Approach

Data and Data classification

- Aviation Safety Network, covering the period 1931-2018, contains 619 cases of aircraft being shot down.
- Data considered from post-World War II period, a time of development of modern civil aviation under ICAO regulation.
- Conflict data was obtained from the Uppsala Conflict Data Program

Type of air operation	Category (numeric)
Scheduled	1
Other passenger	2
Cargo	3
Military	4
Aerial works	5
Other	6
Special flight	7
Non-scheduled	8

Type of conflict	Category
Extra-systemic+	1
Interstate	2
Internal	3
Internationalized internal	4

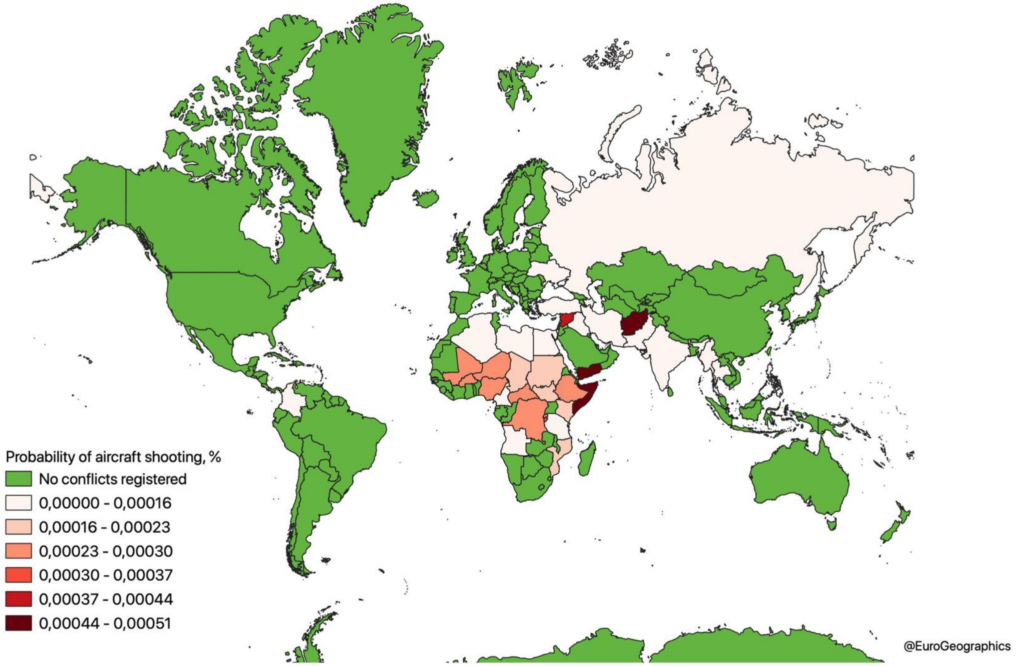
Intensity of the conflict	Category
Minor – 25-999 deaths	1
War – more than 1000 deaths	2

Data record attributes (columns) of security occurrences-aircraft shot down dataset	
Column title	Explanation
Date	Date of the event
Short type	Aircraft type
Operator	Air carrier that operated affected flight
Total_casualties	Number of casualties
Damage	Damage that aircraft sustained
Fate	The fate of the aircraft (whether the aircraft was written off or repaired)
Location_near	Distance from geographical location point
Location	Geographical location point
Country_name	Country of the incident
Phase	Phase of the flight where shooting occurred (enroute, take-off, landing etc)
Nature	Type of air operation
Airport-d	Airport of departure
Airport-a	Scheduled / planned airport of arrival
Flight number	Flight number
Narrative	Detailed explanation of occurrence
Accident_cause	The cause of the accident if known
ASN_id	Internal service number of the case

ACADEMIC APPROACH

Regression model

- A Generalised linear model gamma (with log link) was fit to the data
- Multi-collinearity analysis was conducted to reduce the model dimension
- Factors most affecting the risk are GDP per capita, conflict type and intensity, type of commercial air operation



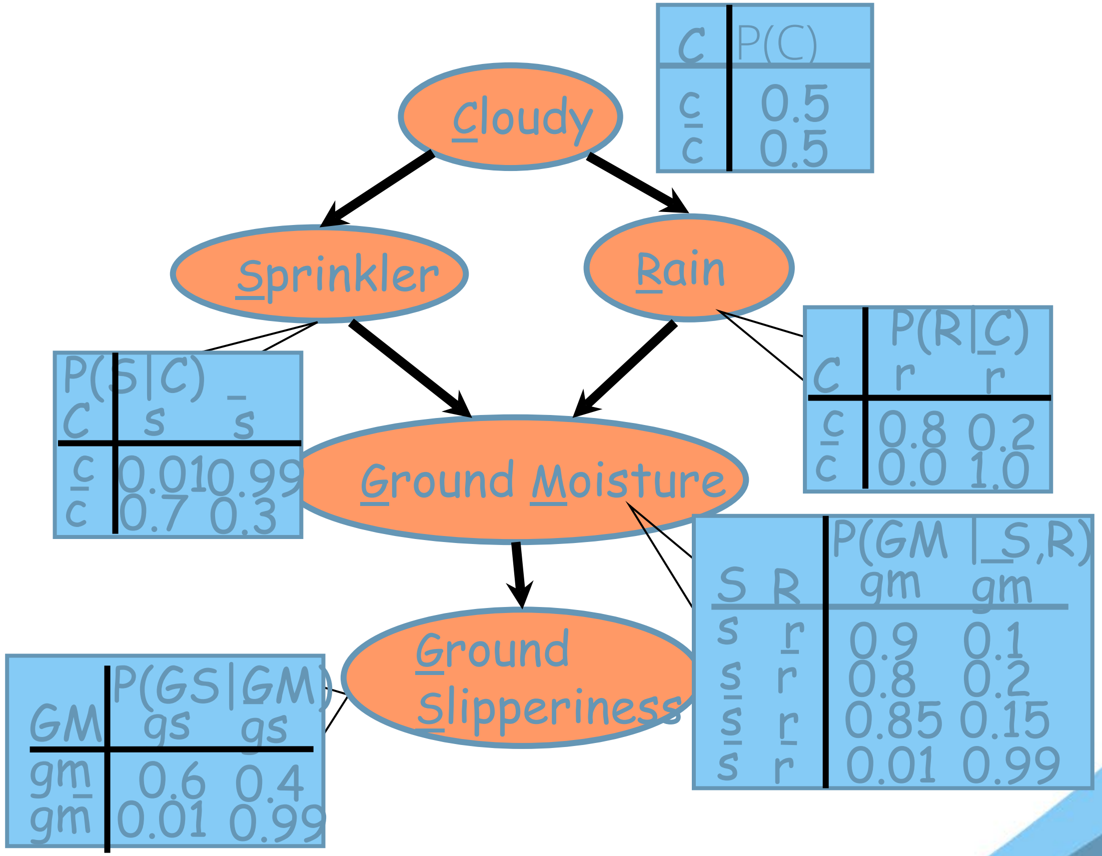
$$ln(P_{Attack}) = -6.21 + (-0.589)\,Intensity_{Level_1} + (-0.560)Type_{Conflict_2} + (-0.668)Type_{Conflict_3} + (-1.19)Nature_{Flight_1} + (-0.911)Nature_{Flight_2} + (-0.906)Nature_{Flight_3} + (-0.570)Nature_{Flight_4} + (-1.91)Nature_{Flight_5} + (-3.32)Nature_{Flight_6} + (-0.556)Nature_{Flight_7} + (-0.354)GDP_{PC\_1000}$$

Data Driven Causality Models

Bayesian Belief Networks - Representation of joint probability distributions via conditional independence

Network structure:

- Nodes - random vars
- Edges – causal (direct) influence
- Directed acyclic graph (DAG)
- Defines a unique distribution in the factored form:



$$P(C,S,R,GM,GS) = P(C)P(S|C)P(R|C)P(GM|S,R)P(GS|GM)$$

Brito, M.P. and Griffiths, G. (2013), Bayesian belief Networks for Predicting Autonomous Underwater Vehicles Risk. Reliability Engineering and Systems Safety, 40: 1928-1943. https://doi.org/10.1111/risa.13539

Data, BBN Structure learning and model validation

We have collected 3179 datapoints of airspace security events between 2009 and 2022. Data provided by Osprey Flight Solutions.

The data includes:

Type of event: missile launch, air and air defence activity, unmanned aerial vehicle (UAV) event, weapons test, projectile event

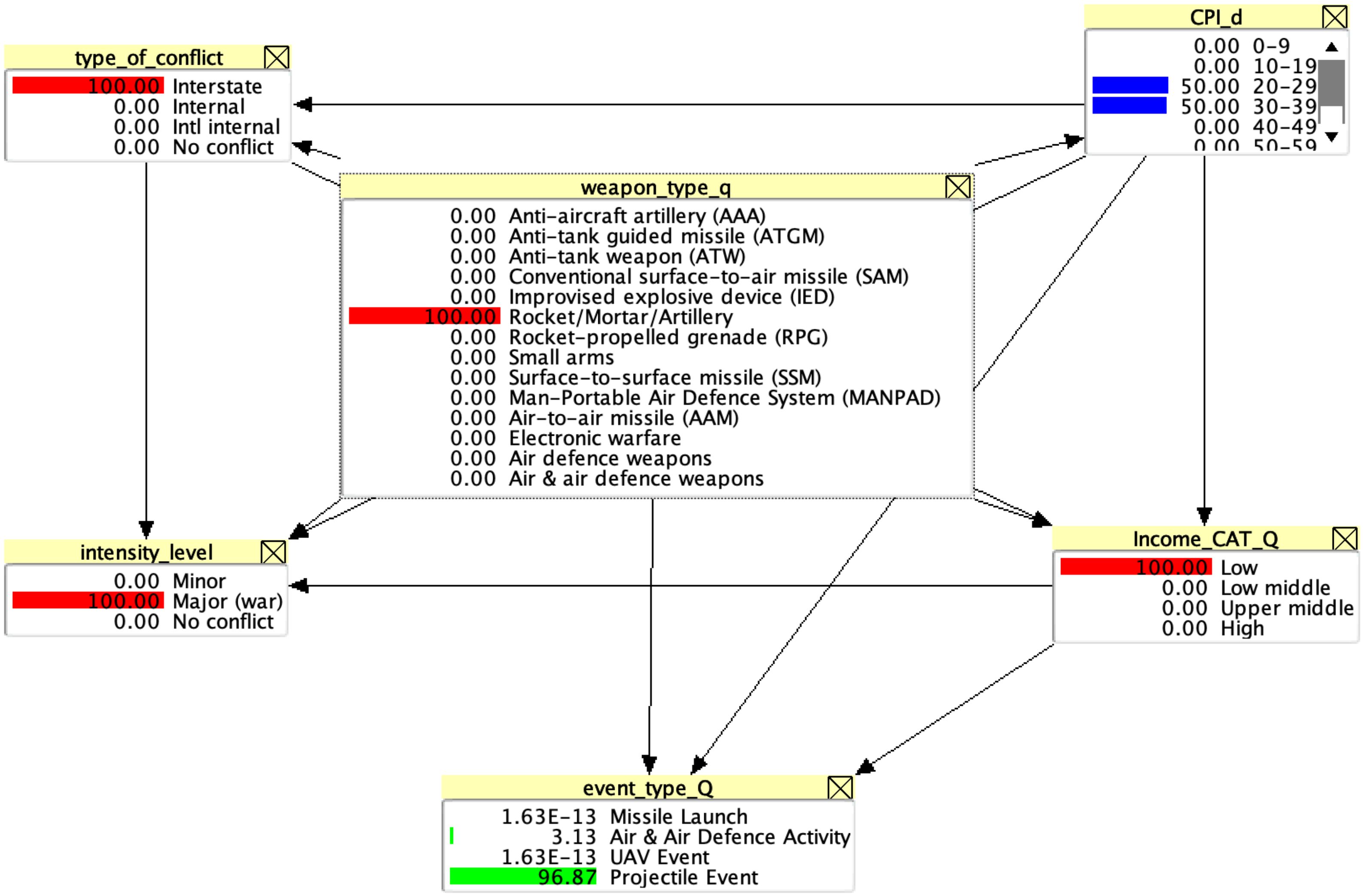
Type of weapon: anti-aircraft artillery (AAA), anti-tank guided missile (ATGM), anti-tank weapon (ATW), conventional surface-to-air missile system, improvised explosive device (IED), Rocket / Mortar / Artillery, rocket-propelled grenade (RPG), small arms, surface-to-surface missile (SSM), Man-Portable Air-Defence System (MANPADS), air-to-air missile, electronic warfare, air defence weapons, air & air defence weapons)

This data was completed with data about conflict type, intensity and country corruption index

Four structure learning algorithms: Necessary path algorithm (NPC), Greedy Search Score structure Learning (GSASSL) and GSASSL with Akaike Information criterion (AIC) and Rabane-Pearl Polytree

	NPC		GSASSL		GSASSL (AIC)		Rebane-Pearl Polytree	
	AUC	Error rate	AUC	Error rate	AUC	Error rate	AUC	Error rate
Event	0.984	1.07	0.981	1.8	0.984	1.82	0.989	1.92
Weapon type	0.830	14.69	0.741	16.73	0.779	15.89	0.708	16.17
Intensity of conflict	0.960	4.37	0.974	4.88	0.975	4.78	0.907	13.09
Type of conflict	0.978	5.54	0.945	7.77	0.957	7.77	0.642	10.44
income	0.838	21.99	0.817	25.29	0.823	23.94	0.787	33.82
CPI-d	0.768	7.30	0.739	10.19	0.761	10.19	0.732	16.92

Simulation results



Quantifying the Impact of Risk Mitigation

INTEGRATION OF ACADEMICS AND INDUSTRY

Risk management research

Coming back to experts?

Aim: quantify mitigating measures and assess impact on the risk

Problem: there is no data regarding application and impact of mitigation measures, so machine learning cannot be directly applied and trained.

Solution: elicitation of expert opinion

- Identify mitigating measures
- Elicit probabilities
- Integrate elicited quantitative probabilities into the model
- Calculate probabilities and assess the effect of mitigating measures
- Assess how mitigating measures change probability of an event occurring

YOUR INPUT WILL HELP TO IMPROVE SECURITY RISK MANAGEMENT

CONCLUSION

Risk management research

The risk of shooting down a civil aircraft over or in the vicinity of conflict zones is significant.

Current risk assessment methodologies are reactive, not efficient, not objective and subject to bias.

Our research provides shift from qualitative to quantitative methodology of risk management and employ cutting-edge probabilistic and causal model.

Integration of expert opinion into machine learning model will contribute to eliminate human-related biases while accommodating vast expertise of industry professionals.

This methodology can become a base for unified standard at airlines, governmental regulatory bodies, aviation insurance and industry advisory companies.

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