Machine Learning Enabled Quantitative Risk Assessment of Aerial Wildfire Response

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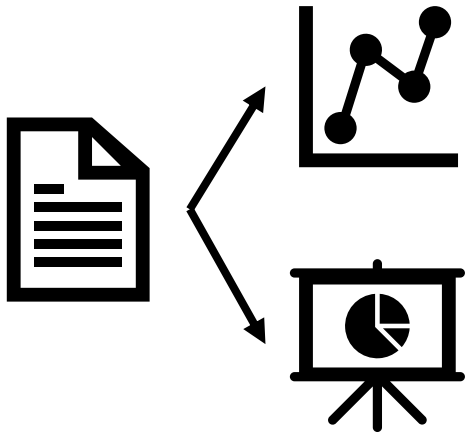
Motivation

- Wildfires are becoming more ***frequent***, ***complex***, and ***destructive***, resulting in increases of aerial operations[1]
- ***Aerial*** wildfire operations accounted for 60% of ***firefighter deaths*** in 2020
- There is very ***limited research***[2] analyzing aerial wildfire mishap reports in comparison to Aviation Safety Reporting System (ASRS) research

Motivation

- How can we use ***machine learning*** to systematically leverage ***mishap reports*** to produce meaningful, safety-relevant, risk-informed analysis?

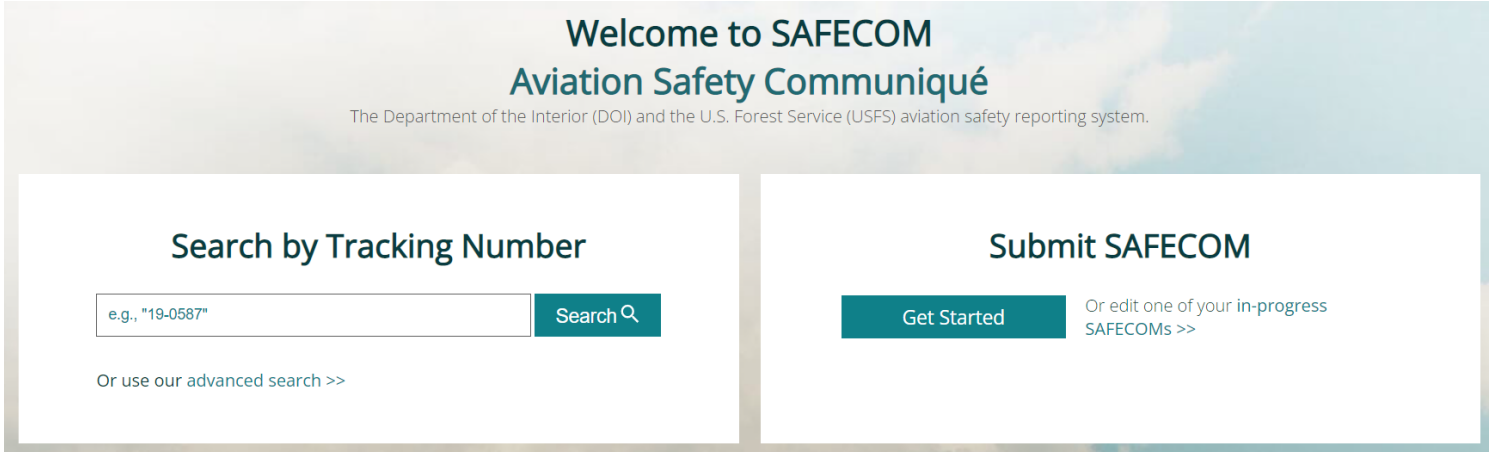


Contribution

- Hazard Extraction and Analysis of Trends (HEAT) framework for ***machine learning*** enabled ***quantitative risk assessment***
- Apply HEAT to ***aerial wildfire mishap reports*** to get a risk assessment

SAFECOM Data Set

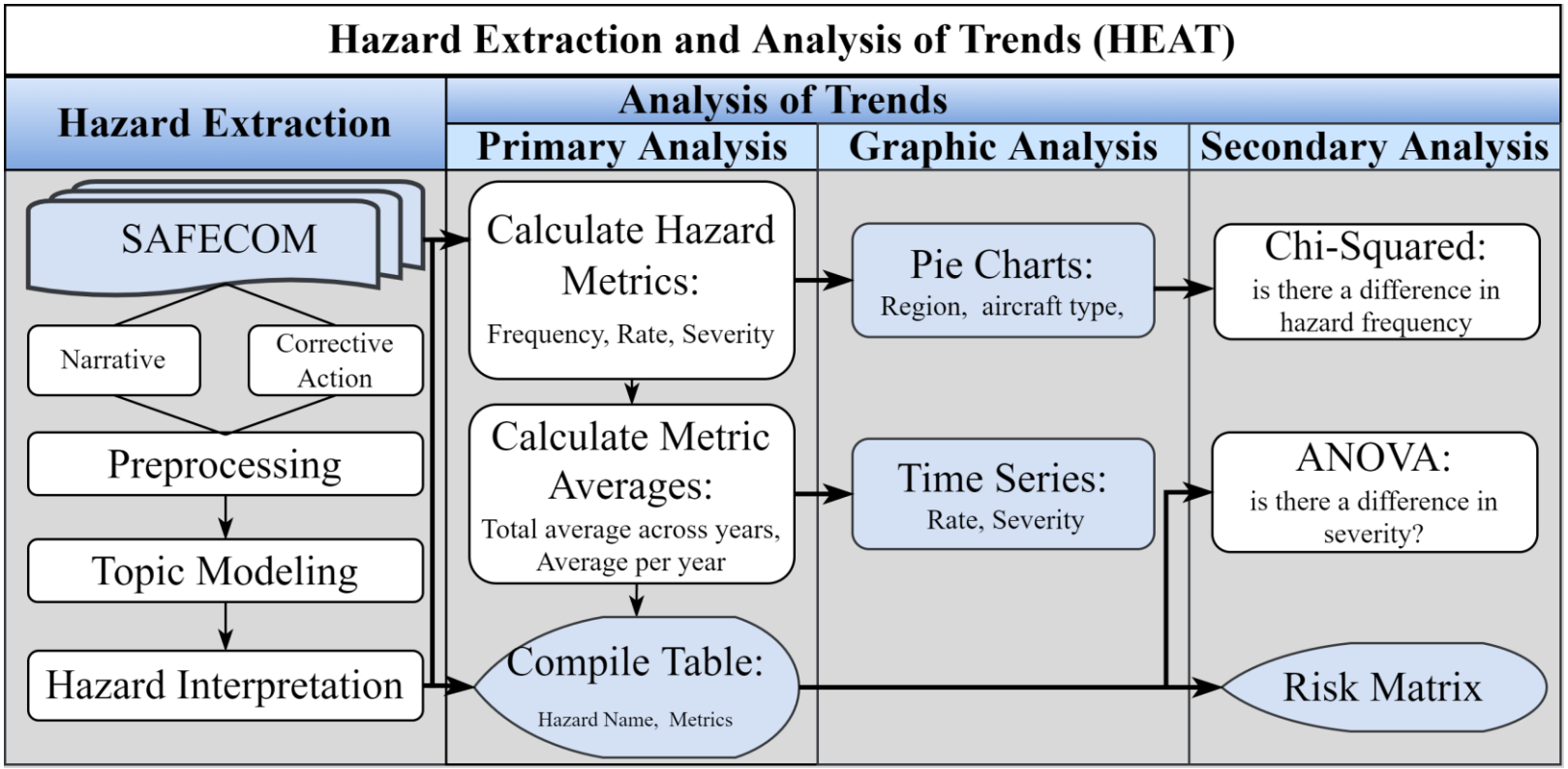
- Aviation Safety Communique (SAFECOM) is a system for reporting aerial hazards, mishaps, and near misses[3][4]



SAFECOM Data Set

Aircraft Type	Aircraft Model	Mission Type	SAFECOM ID	Mishap Description	Mishap Category
Airplane	Beech-craft BE20	Fire, Lead plane	20-1145	The radio frequencies of two aircraft were too close, resulting in static and noise when monitoring both. This resulted in a degradation of situational awareness.	Communications
Airtanker	DouglasDC -10	Fire, Retardant Drop	20-1313	A Tanker was leaking retardant during take-off. The leak was due to built up residue on the tank and floats preventing a proper seal.	Mission Equipment
Helicopter	Bell UH/1H	Fire, Water Drop	20-1258	In route to a water drop, a helicopter pilot felt a “dragging feeling” prior to seeing the snorkel fall off the aircraft. Mechanic determined the snorkel hose detached from the coupling and found some damage to the electric pump wiring.	Dropped Load (Mechanical)

Method Overview: HEAT



Hazard Extraction

- LDA Topic Modeling:
  - $For\ each\ document, d \in \{1,2,3, \dots\ D\}$, $there\ exists\ a\ distribution\ of\ topics$:
    $$\theta_d \in dir(\alpha)$$
  - $For\ each\ topic, k \in \{1,2,3, \dots, K\}$, $there\ exists\ a\ distribution\ of\ words$:
    $$\emptyset_k \in dir(\beta)$$

Primary Analysis

- **Metrics**: frequency, severity, rate

$$\boldsymbol{Severity = P * (I + D)}$$

$$\boldsymbol{I = \begin{cases} 1\ if\ injuries = True \\ 0\ if\ injuries = False \end{cases};\ D = \begin{cases} 1\ if\ damages = True \\ 0\ if\ damages = False \end{cases}}$$

$$\boldsymbol{P = \#\ of\ Passegers}$$

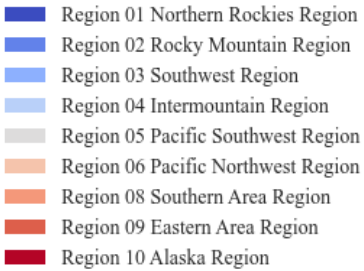
Hazard Extraction: Results

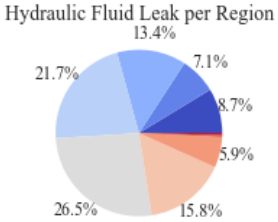
Hazard Category	Hazard Subcategory	Hazard	Frequency	Rate	Severity	Precision
Airspace	Intrusion	Intrusion	227	0.016	0.000	1.000
Hazard	Communications	Radio Malfunction	21	0.001	0.238	0.933
	Communications	Jumper Operations Hazards	57	0.004	3.561	0.800
	Communications	Helitorch Operations Failure	35	0.002	0.171	0.800
	Other	Cargo Letdown Failure	459	0.032	0.229	0.800
	Pilot Action	Bucket Drop Failure	1063	0.073	0.464	0.733
	Weather	Severe Weather	158	0.011	0.848	0.800
Maintenance	Engine	Tanker Loading Failure	84	0.006	0.214	0.733
	Hydraulic	Hydraulic Fluid Leak	258	0.018	0.147	0.933

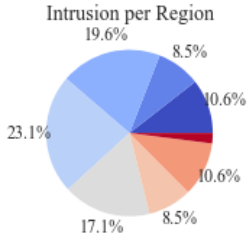
Analysis of Trends

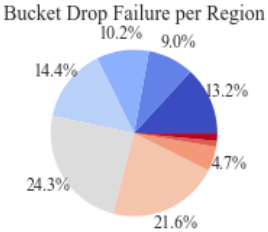
- **Graphic Analysis**
  - **Pie charts:** how does hazard frequency vary across predictors?
  - **Time series:** how do hazard metrics change over time?
- **Secondary Analysis**
  - **Statistics:** Does hazard frequency vary significantly across predictors? Does hazard severity vary significantly between hazards?
  - **Risk Matrix:** what is the quantitative risk for each hazard?

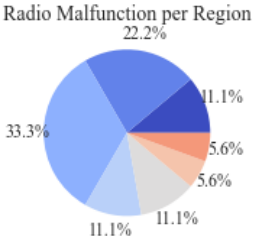
Analysis of Trends: Graphic Analysis

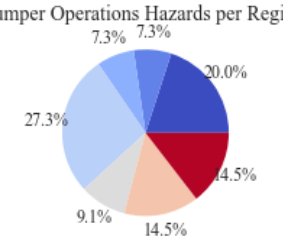


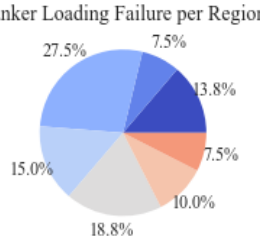


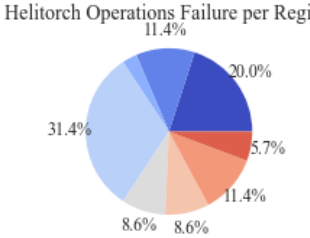


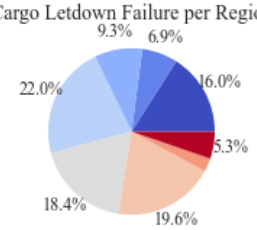


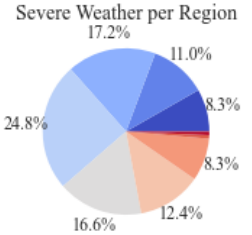




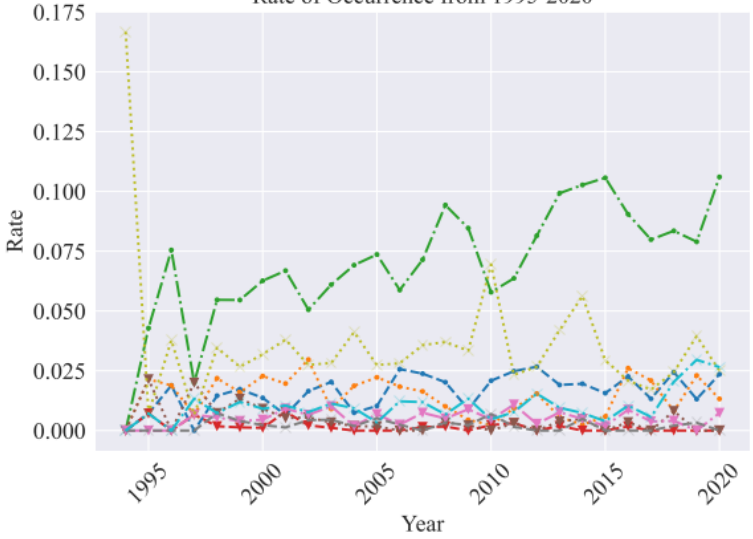




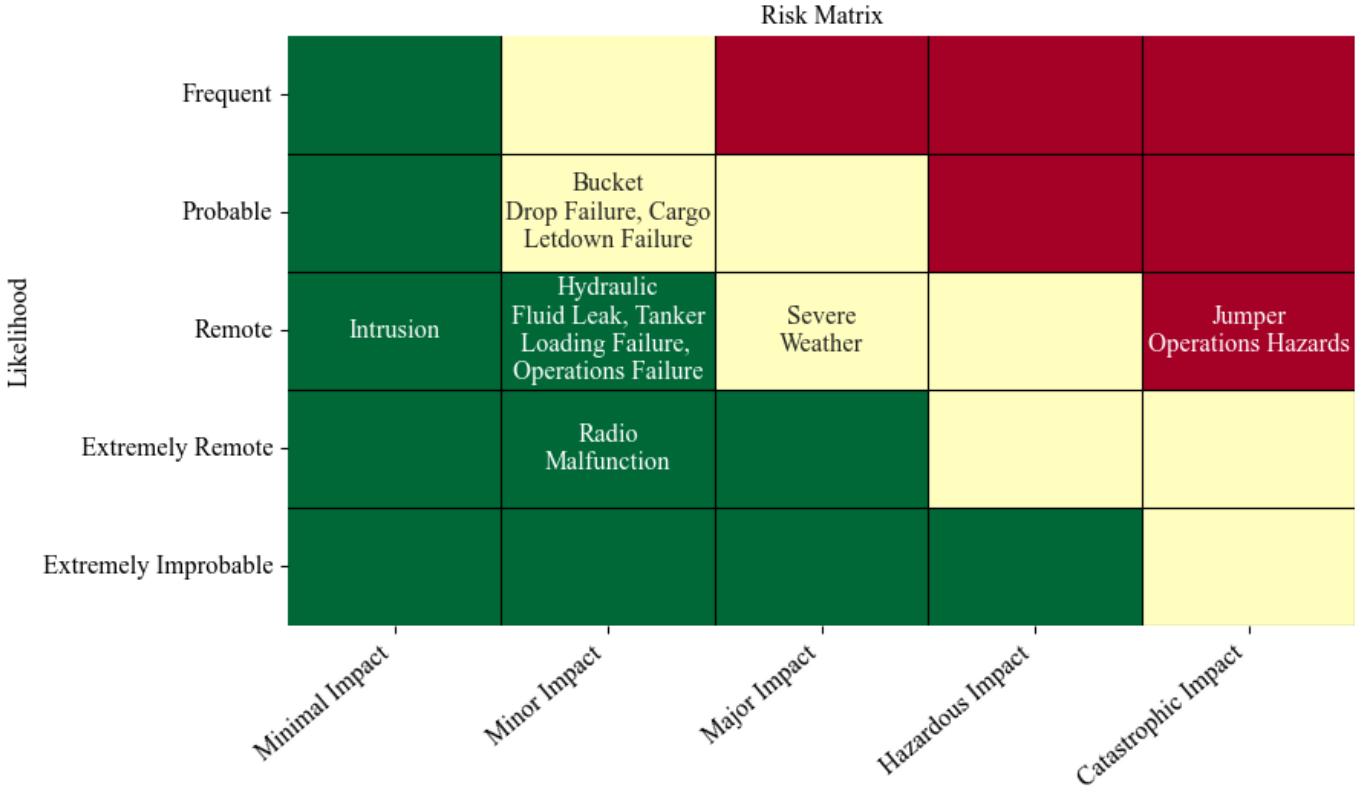




Analysis of Trends: Graphic Analysis



Analysis of Trends: Secondary Analysis



Conclusion and Future Work

- Presented a framework for machine learning enabled quantitative risk assessment using hazard extraction and analysis of trends (HEAT)
- Applied this to SAFECOM wildfire aviation mishaps to generate risk assessment
- Future work:
  - How does this generalize to other data sets?
  - What additional analyses can we perform on this data?
  - How can we combine this data with external data sources (i.e., weather data)?

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- Additional Resources:
  - Robust Software Engineering: https://ti.arc.nasa.gov/tech/rse/

References

- [1] P. E. Dennison, S. C. Brewer, J. D. Arnold, and M. A. Moritz, “Large wildfire trends in the western united states, 1984–2011,” Geophysical Research Letters, vol. 41, no. 8, pp. 2928–2933, 2014.
- [2] “2020 Incident Review Summary,” Tech. rep., Wildland Fire Lessons Learned Center, 2021.
- [3] White, G., “Evaluation of systems to recognise and address safety issues promptly, effectively and universally and evaluation of systems which promote safe fire fighting behaviours and initiatives.” Tech. rep., Department of Natural Resources and Environment, 2002.
- [4] https://www.safecom.gov/search

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