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The socio-economic impacts of adverse upper atmospheric effects on technological infrastructures: A review

PITHIA-NRF's Innovation Day 1

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Acknowledgements

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ROME

Overview

Literature review

Assessed studies breakout

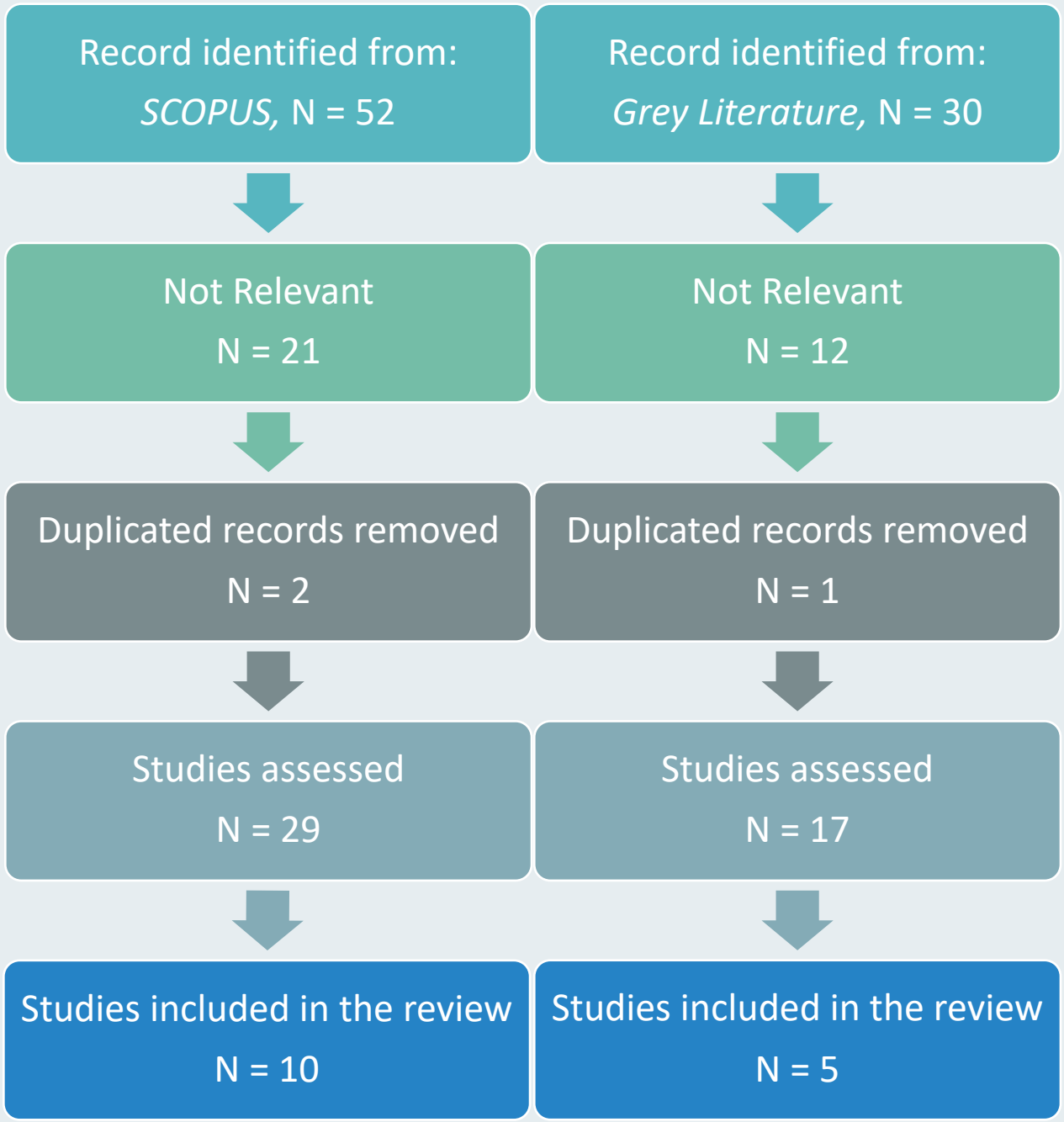
Map of impacts

Timeline of notable events

Costs Modeling

Remarks

Conclusions



Identification

Keywords used in searches:

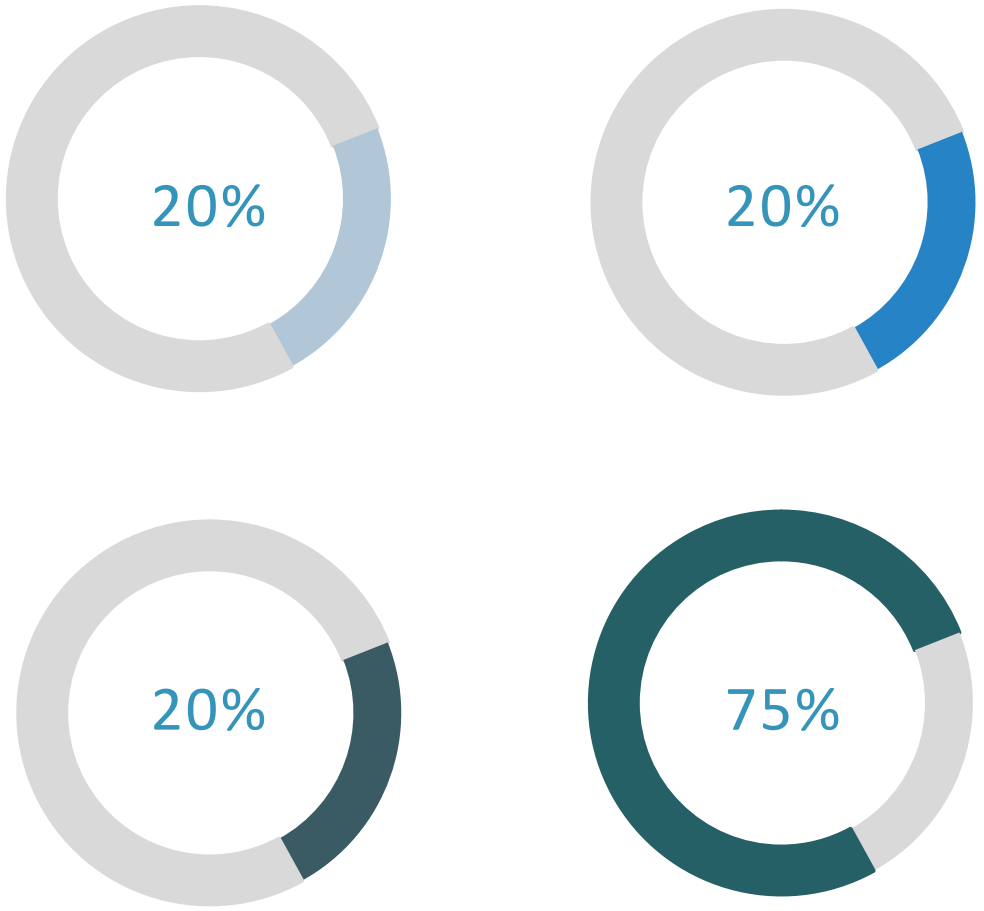
- *"impact"*
- *"space weather"*
- *"upper atmosphere"*
- *"ionosphere"*
- *"economic" or "socioeconomic"*

Only the ""***impact***" and "***space weather***"" keyword combination produced results with quantification of socioeconomic impacts.

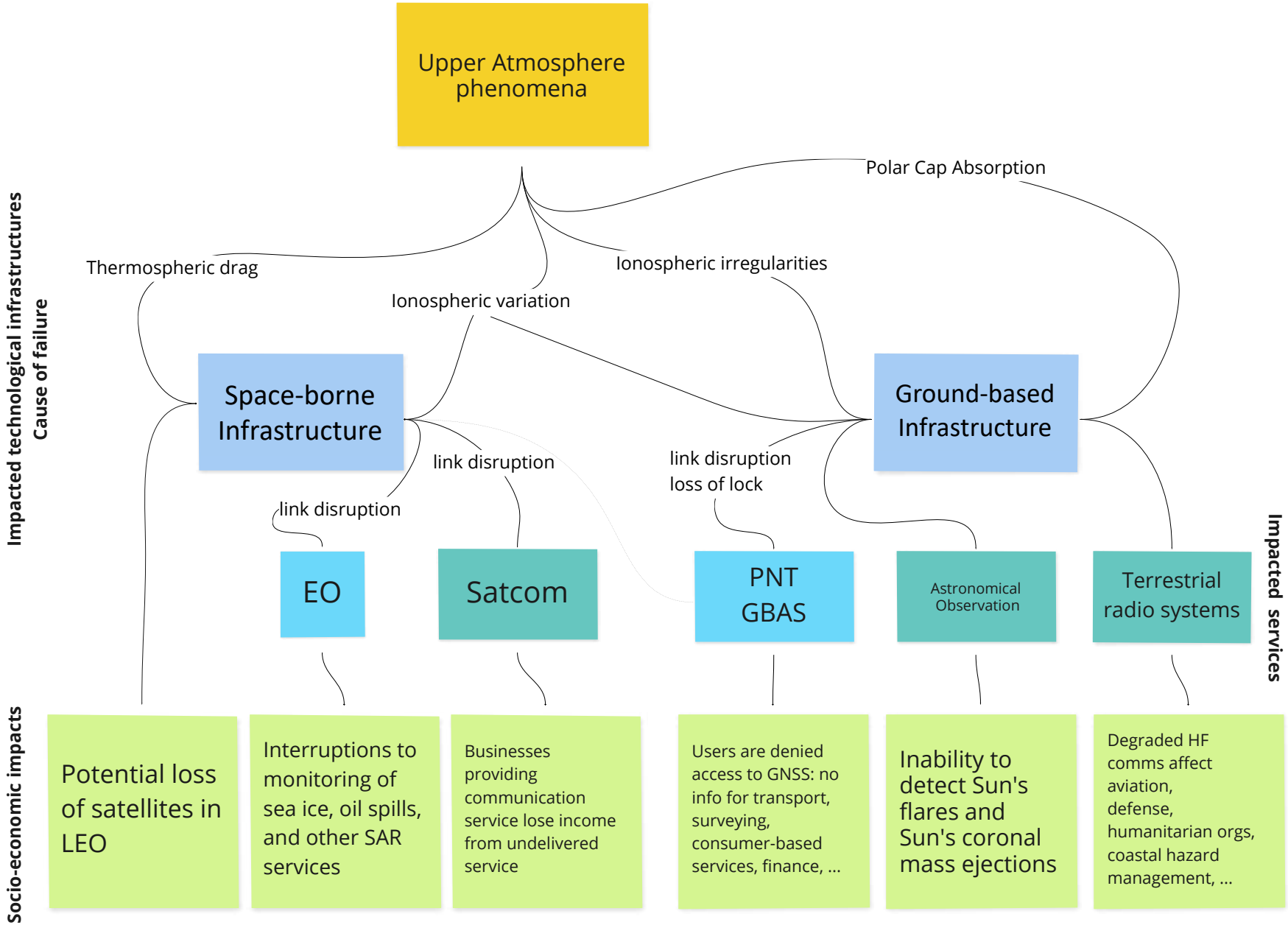
Map of countries assessed by reviewed literature

Percentage of studies investigating costs per infrastructure

- GNSS
- Electricity Transmission Systems
- Terrestrial Radio Systems
- Leo Satellites

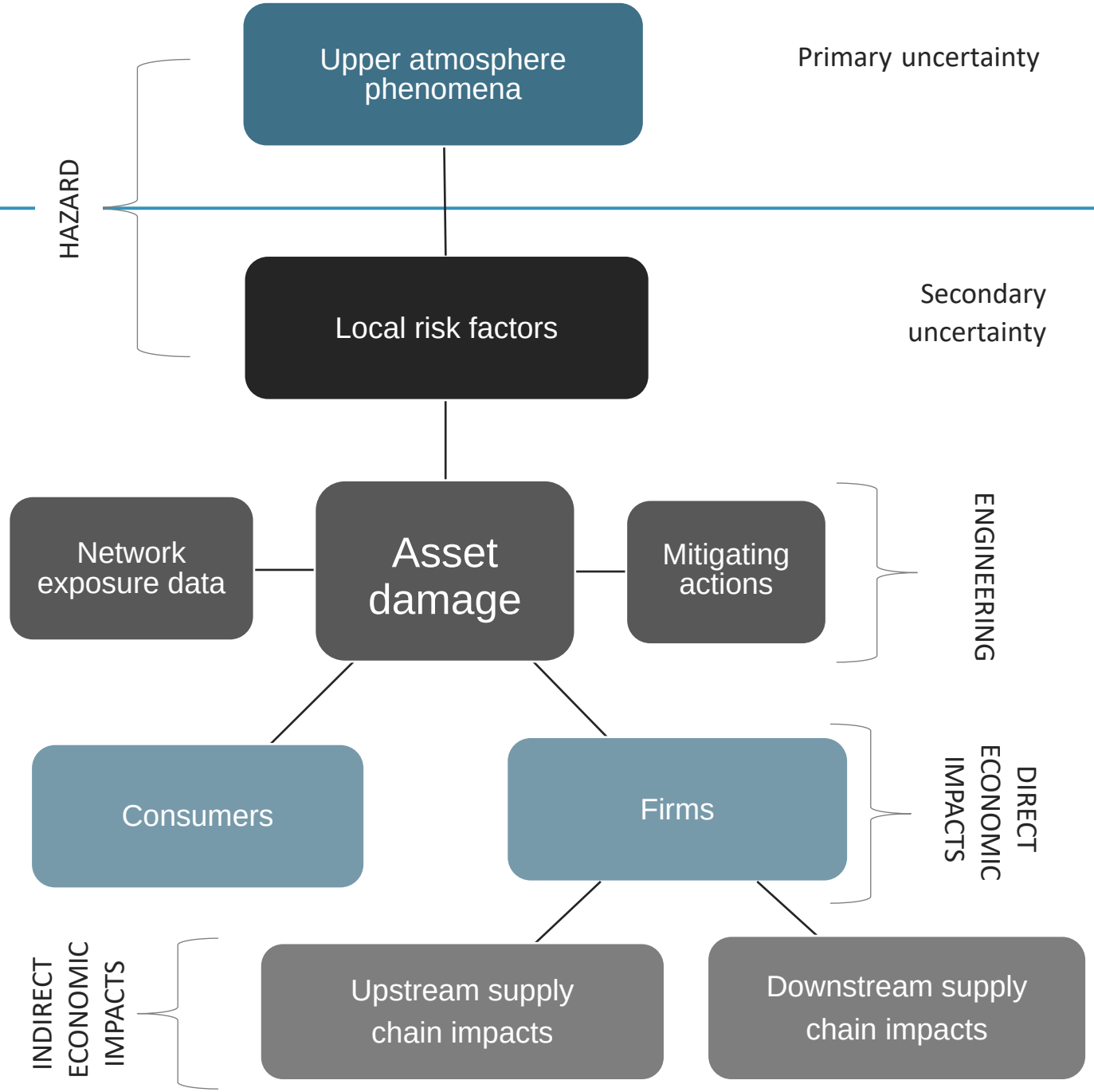


Map of impacts

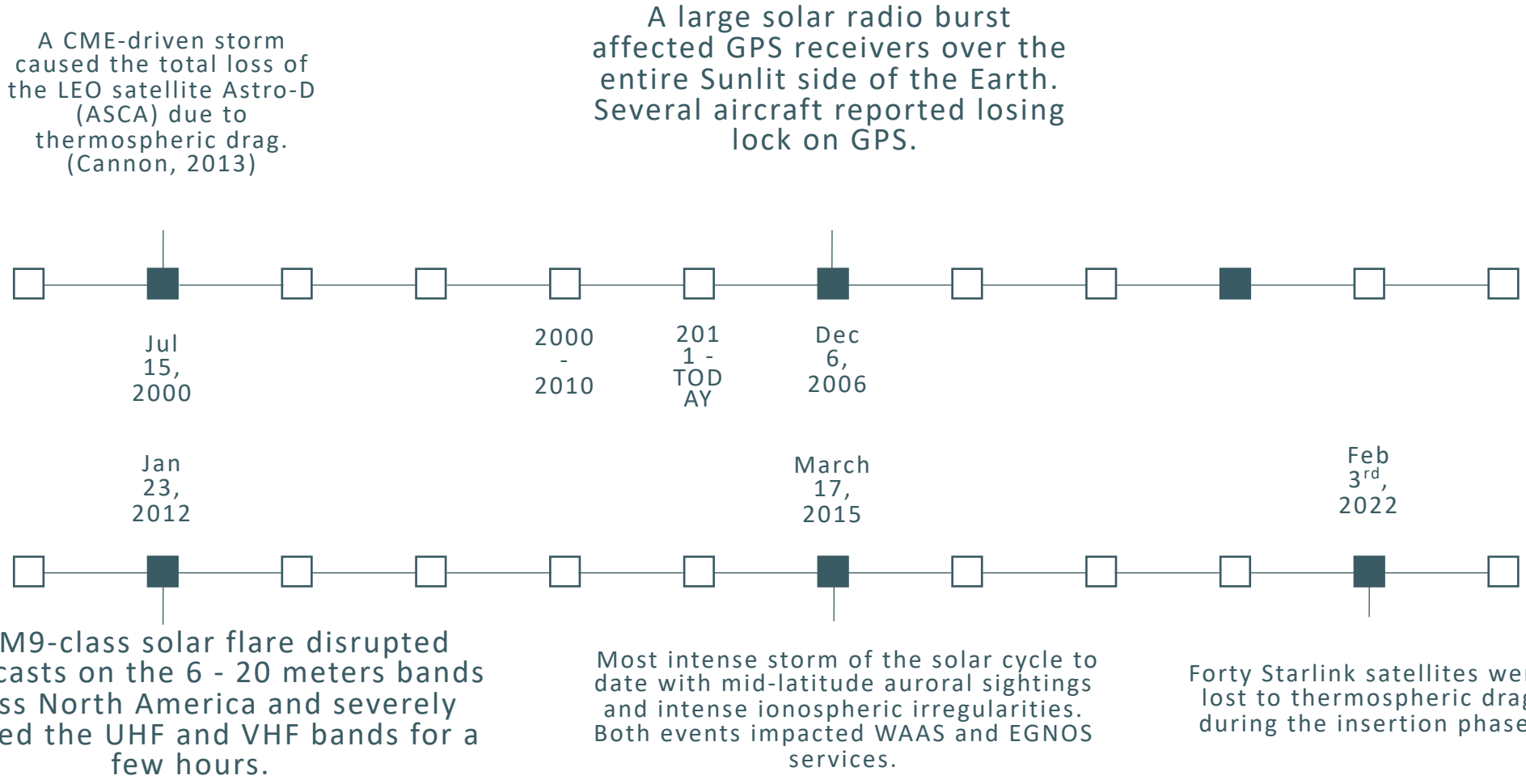


Background

The costs associated with upper atmospheric phenomena are of different types (direct, indirect, mitigation costs) and are borne by various economic actors (infrastructure operators, commercial and industrial customers, households) (Oughton, 2018).



Timeline of recent impacting events



LEO Satellites

UAP: Atmospheric drag

Scenario: Superstorm akin to the 1859-Carrington event causing the de-orbit of 97 LEO satellites, globally

Cost: USD 16 billion [Odenwald et al., 2006]

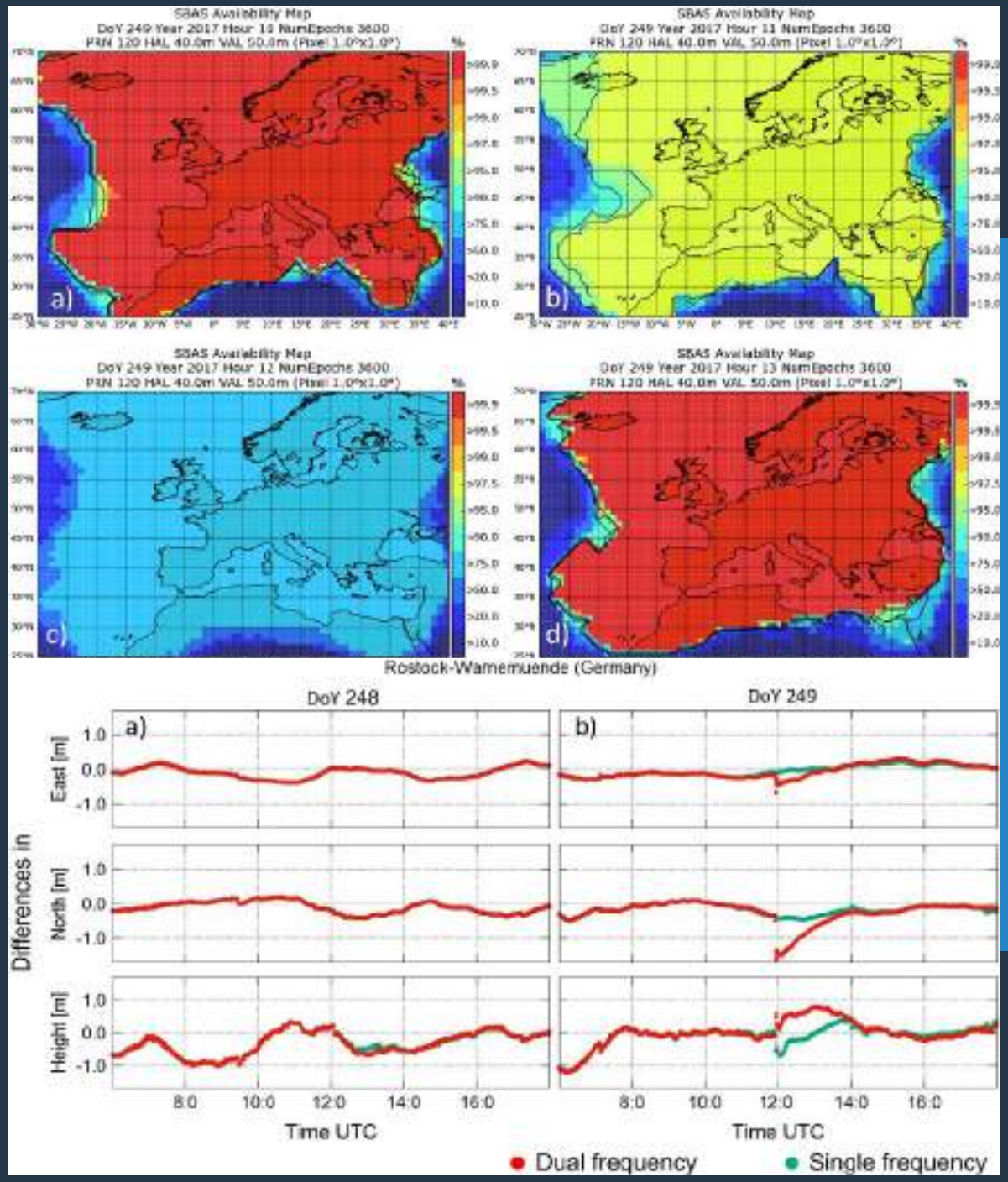
€900 billion [Pwc, 2016]

UAP: Atmospheric drag

Scenario: Superstorm causing the de-orbit of 10 -100 LEO satellites, globally

Cost modelled: Lost satellite assets' value and their lost service revenues

Cost: USD 4 – 200 billion [ATB Associates, 2017]



PNT with GNSS or GBAS

GNSS and GBAS are susceptible to UAP that, in a worst-case scenario, could render PNT services unavailable to users, commercial and not, for up to several days. Worst-hit sectors would be:

- Precision Agriculture
- Road Transport and Logistics
- Surveying
- Aviation

EXAMPLE

Ionospheric Response to the X9.3 Flare on 6 September 2017 and Its Implication for Navigation Services Over Europe

Space Weather, Volume: 16, Issue: 10, Pages: 1604-1615, First published: 04 October 2018, DOI: (10.1029/2018SW001933)

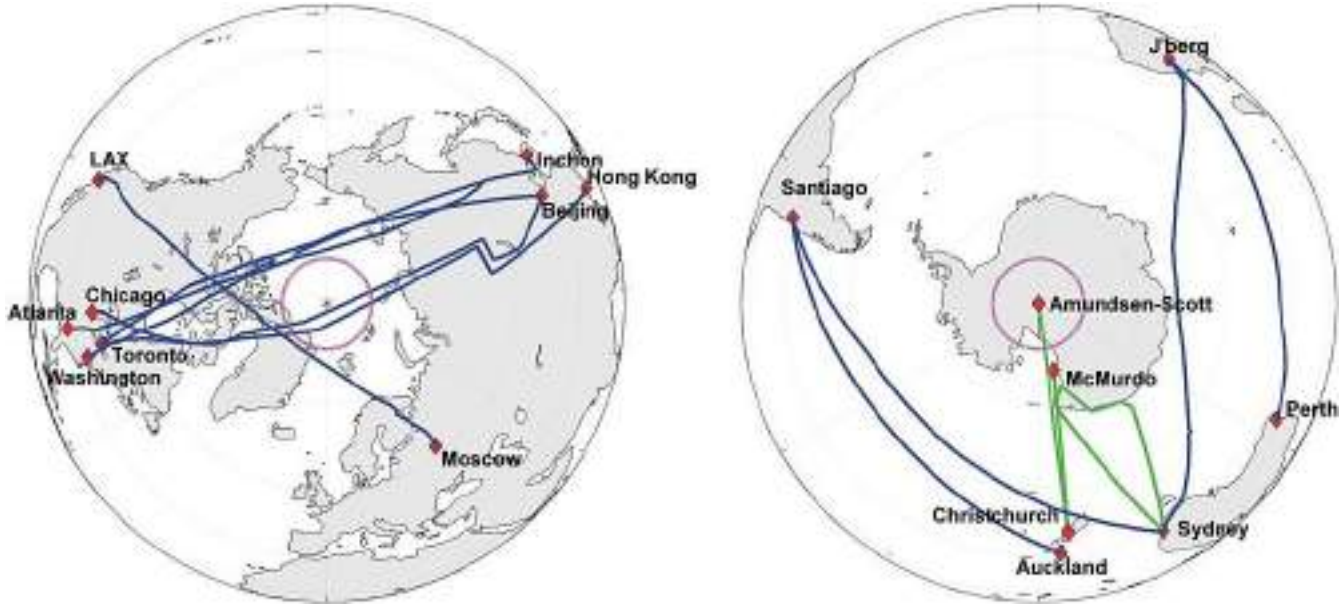
Costs PNT

Economic Impact	Cost Modelled	Sector	Country	Reference
197.500.000€	Impacts of suspensions of building/resources exploration activities in G5+ event	Surveying	Europe (EU28)	PwC, 2016
798.000.000€	Impact on GDP of 3 days GNSS outage	Road transport and Logistics		
9.800.000.000 €	Value of lost time of delayed passengers for 3hrs GNSS signal loss	Aviation		
4.000.000-8.000.000 USD	1 hr loss of lock/Signal disruption	Across sectors	USA	ABT Associates, 2017
100.000.000-600.000.000 USD	24 hrs loss of lock/Signal disruption			

Aviation

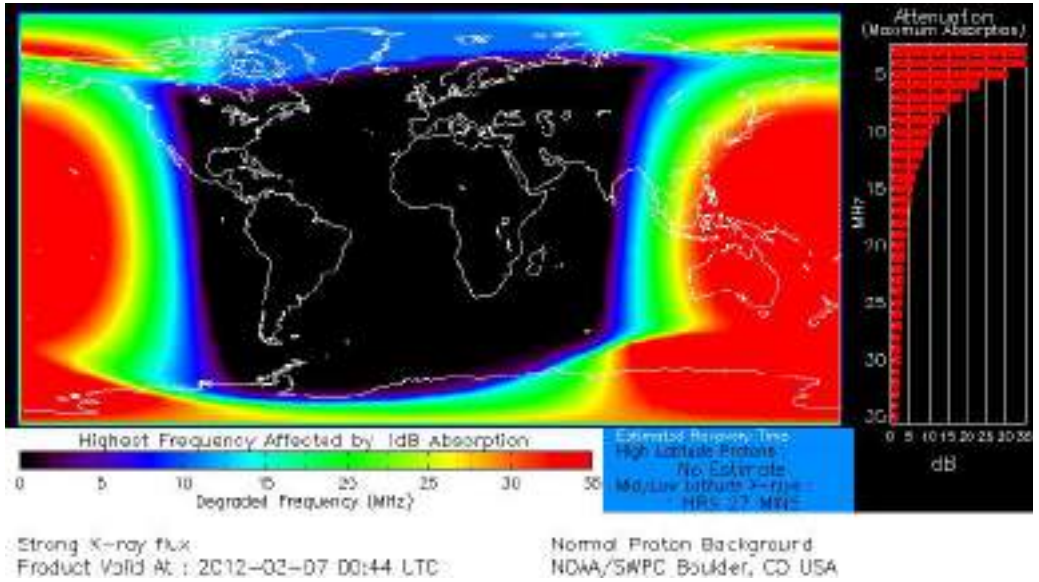
Depending on the intensity and type of UAP, the areas affected, and the time extension of the outage could vary: the blackout could last for **two or three hours in all low- and mid-latitude regions on the dayside of the Earth or several days at high-latitudes** (Hapgood et al., 2020).

A selection of high-latitude flight paths operated by commercial airlines in 2012. The magenta dashed line marks 82° latitude, above which geostationary satellite communications are unavailable.

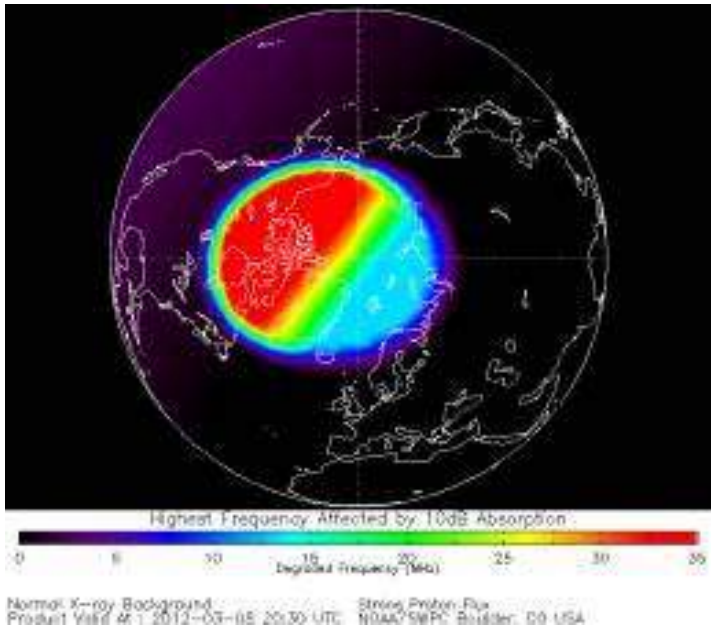


Space Weather, Volume: 11, Issue: 7, Pages: 420-433, First published: 19 June 2013, DOI: (10.1002/swe.20066)

Example
7 March 2012 SPE



- Limited reliable HF communications forced aircraft operators to use other communication methods
- Despite the availability of SATCOM in the latitudes of the flights' paths "at times, communications were impossible" [Federal Aviation Administration, 2012]
- Several polar flights altered.
- Numerous reports of HF communication outages on lower-latitude trans-oceanic flights.



Aviation

The findings concerning the costs of **delaying, canceling, or rerouting flights** for a **total blackout of HF radio** frequencies in Europe, the USA, and Canada.

	Country (Reference)		
Costs	Europe (Pwc, 2016)	USA (ABT Associates, 2017)	Canada (HAL, 2019)
Cost of delaying, canceling or rerouting flights	€812 million	USD 1-30 million	Not stated
Passengers' value of lost time	€14,7 million	USD 6-200 million	Not stated
Total	€0.83 billion	USD 7-230 million	CAN 1.75 billion

Remarks

The science of quantifying their socioeconomic impacts is not yet mature

A few notable studies have advanced our understanding of this under-researched hazard

They tend to focus only on a subset of infrastructures and phenomena affecting them

They often propose estimates of direct costs to commercial users without fully exploring the total costs associated with UAP

Entity	Cost Type	Type of estimated cost per infrastructure			
		Space-borne infrastructure	Ground-based infrastructure		
		LEO Satellites	PNT	AOS	TRS
Infrastructure network operator	Direct	☑	☑		
	Indirect				
	Mitigation	☑			
Commercial and industrial customers	Direct	☑	☑		☑
	Indirect		☑		☑
	Mitigation				
Households	Direct				☑
	Indirect				
	Mitigation				

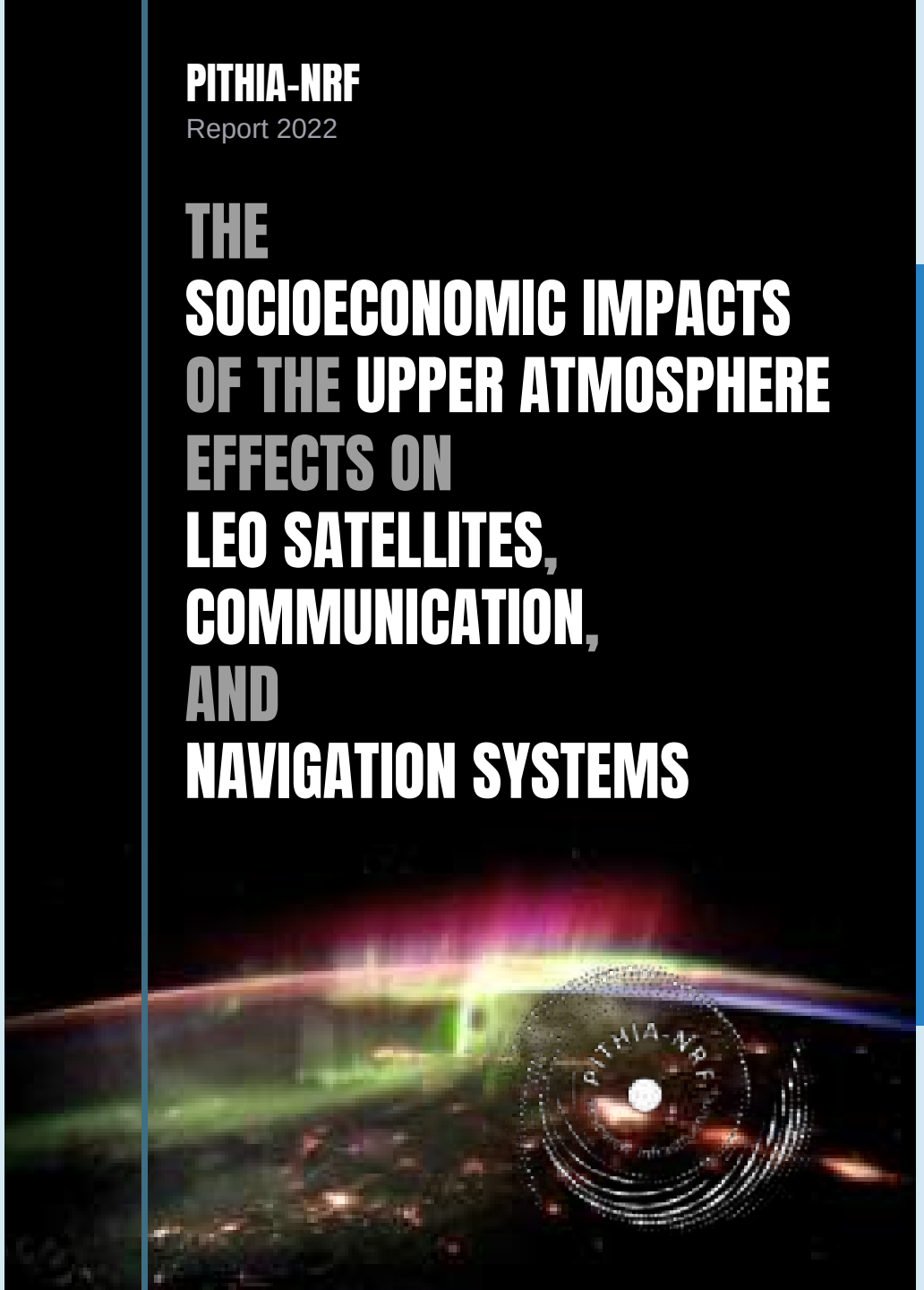
Conclusions

We identified the infrastructures vulnerable to upper atmosphere effects.

We quantified the impacts on **LEO satellites, systems offering PNT services, and radio systems** through a **systematic literature review**.

We found that the costs associated are high.

However, the **lack of important modeling information** and **modern society's lack of experience with extremely large events hinders advances in the science of socio-economic impacts quantification** needed by governments, asset owners, and business to mitigate the risks posed by upper atmosphere space weather.



Access the report from Zenodo

https://zenodo.org/record/6671425#.YrGNXC8RpQI

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Thank you

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