Social & Economic Impacts of Space Weather (US Project)

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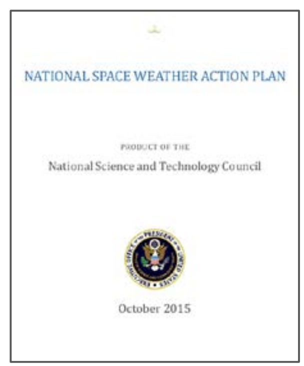
Space Weather As A Global Challenge, Embassy of Japan, Washington, D.C. July 24, 2018

Study Goals

- Identify, describe and quantify social and economic impacts:
  - Moderate & extreme space weather events
  - Across 4 sectors

www.weather.gov/news/171212_spaceweatherreport


NATIONAL SPACE WEATHER ACTION PLAN

PRODUCT OF THE

National Science and Technology Council

October 2015


FINAL REPORT

Social and Economic Impacts of Space Weather in the United States

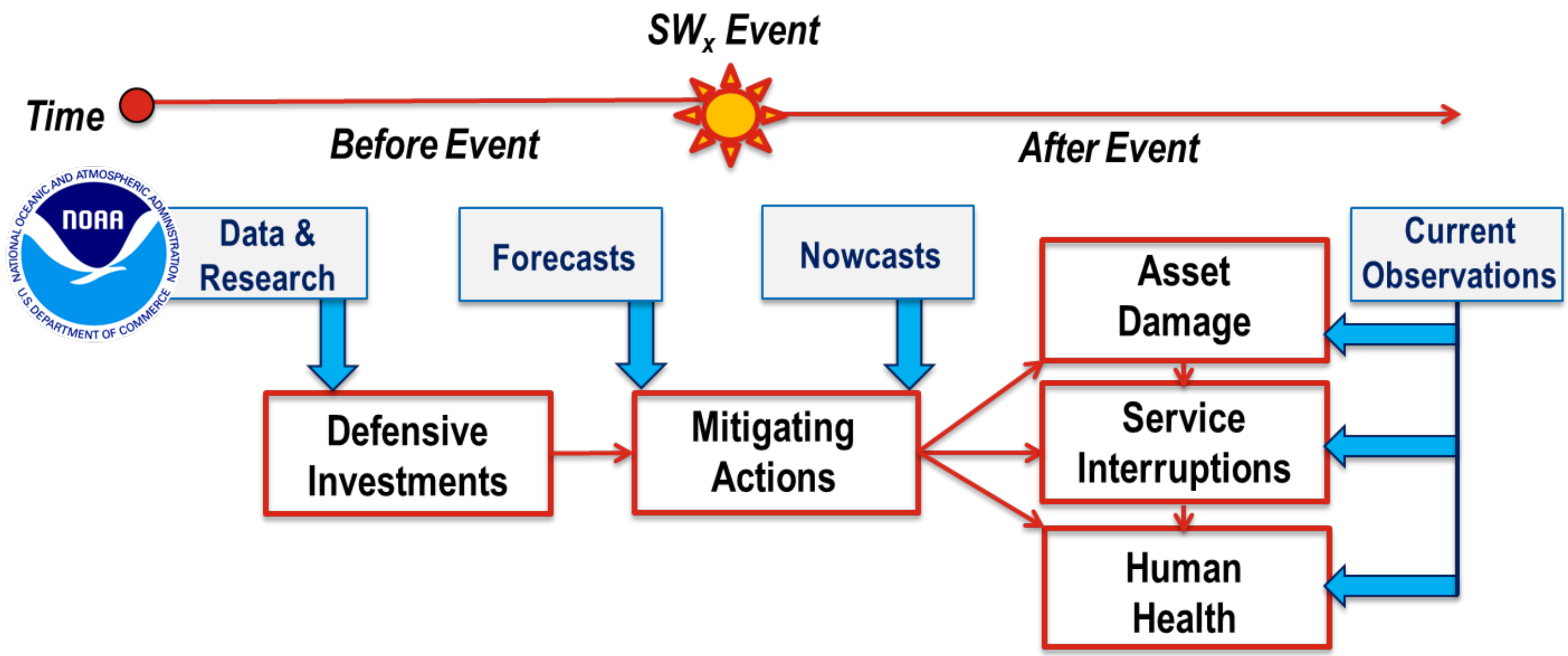
September 2017

Abt Associates
Bethesda, Maryland

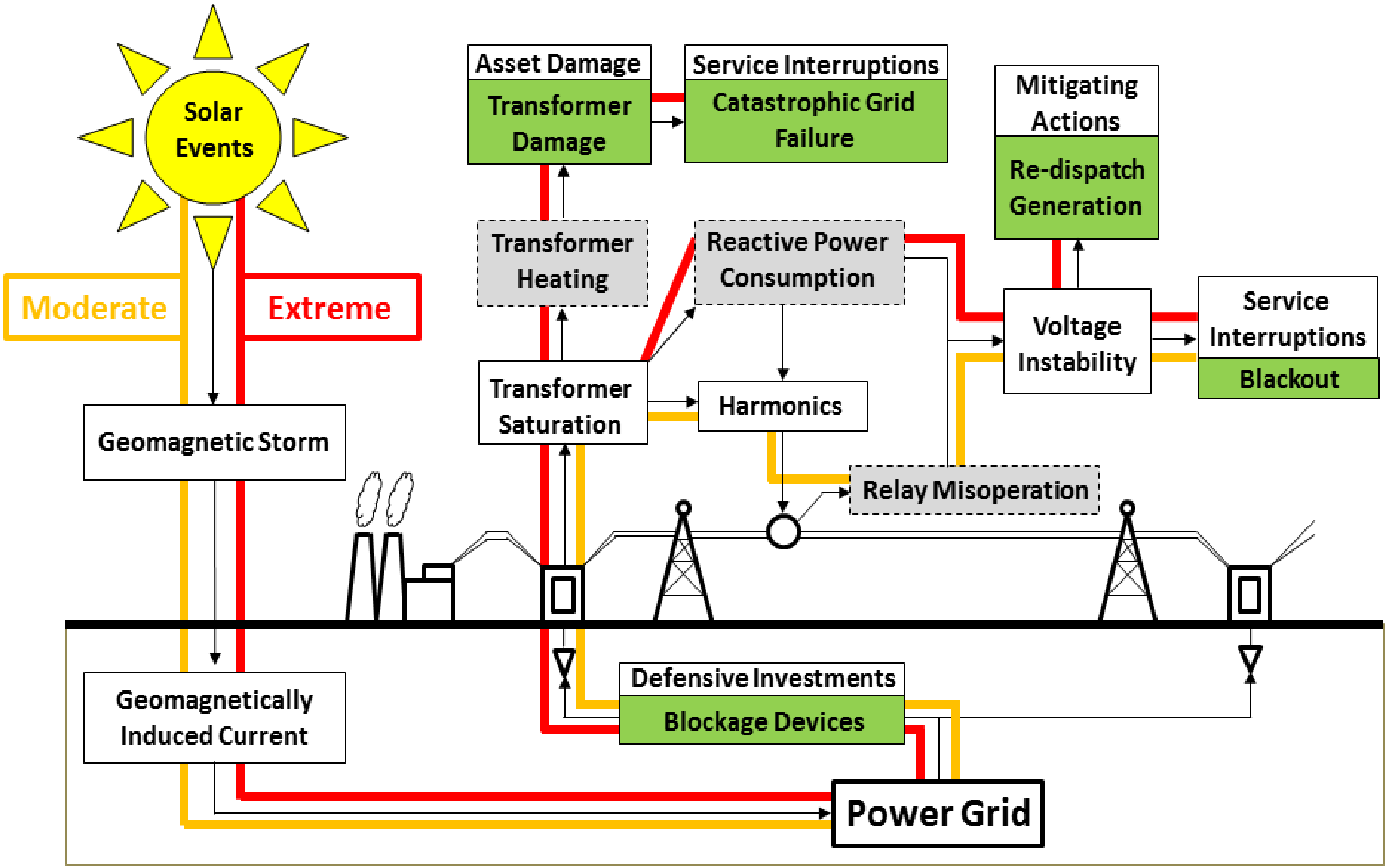
Written under contract for the NOAA National Weather Service
www.nws.noaa.gov

Approach Overview

Identify	Describe	Quantify
Literature Review	Stakeholder Outreach	Cost Estimate



Impact Mechanism Diagrams



Impact Matrix

		Social and Economic Impact Categories				
Sector	Physical Effects	Defensive Investments	Mitigating Actions	Asset Damages	Service Interruptions	Health Effects
Power Grid	Reactive Power Loss	●	●		○	
	Transformer Heating	●	●	●	○	
	Relay Mis-operation	●	●		●	
	Power Imbalances		●		●	
	Generator Tripping	●	●		●	
	Loss of Precision Timing	●			○	
Aviation	Communication	●	●	○	●	
	Navigation	●	●	○	●	○
	Human Exposure		●		○	○
	Avionic Upsets	●	○	○	○	○
Satellites	Cumulative Dose	●		●	●	
	Anomalies	●	●	●	●	
	Link Disruptions	●	●		●	
	Loss of Orientation	●	●	●	●	
	Loss of Altitude	●	●	●	●	
GNSS Users	Loss of Lock	●	○		●	
	Ranging Errors	●	○		●	

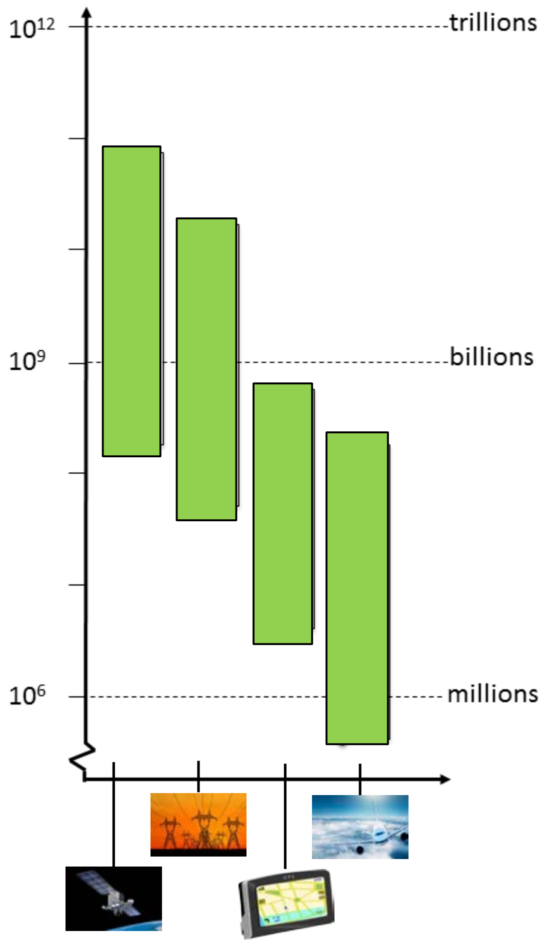
Impact Details

Physical Effect	Definition	Notes from Stakeholder Outreach
Reactive Power Consumption	Reduction in amount of reactive power flowing through grid due to the increased consumption of reactive po	• This is problematic because it depresses the system voltage and may lead to voltage collapse. • Reactive power losses occur at transformers but “VAR loss” is a grid metric.
Transformer Heating	Substantial transforme cause acce perhaps ev damage.	
Improper	Improper f systems tha	

Impact Categories	Examples	Definition	Notes from Stakeholder Outreach
Defensive Investments	Infrastructure hardening	A range of engineering and design modifications that reduce grid vulnerability such as installing GIC absorbing or blocking devices (e.g. neutral ground connections, series line capacitors) or replacing aging or vulnerable transformers.	• Understanding what to do requires many analyses. Installing blocking device, for example, can reroute current in unexpec and devastating ways. • This is the subject of the new FERC regulations. The types c investments that need to be made are understood but unclear how widely or where they will be required.
	Situational Awareness & Preparedness	Utilizing a range of data and tools to stay aware of current and anticipated future conditions. Data can come from GIC monitoring networks (e.g. magnetometers, internal-instruments within transformers) or transformer monitors and be fed into grid simulators and management systems. This	• This Defensive Investment is critical to being able to implem real-time Mitigating Actions. • Operators have training to prevent key downstream impacts b they need to be made aware of the situation, day ahead SWx warnings are most important. • Operators monitor SWx products and pay extra attention to o data when they receive alerts at the upper end of scales (K7 o

Physical Effect	Definition	Notes from Stakeholder Outreach
Reactive Power Consumption	Reduction in amount of reactive power flowing through grid due to the increased consumption of reactive power by transformers.	• This is problematic because it depresses the system voltage and may lead to voltage collapse. • Reactive power losses occur at transformers but “VAR loss” is a grid metric. • Voltages are controlled within tight bands. When system gets to ~10-20% of normal voltage, this triggers a concern for blackouts. • Reactive power does not like to travel so highest vulnerability in areas farthest away from generation and highest loads. Eastern part of PJM Grid? Kevin says biggest in the spring? • Increasing problem as we rely on higher voltage power lines (long distance transfers) • Relying more heavily on local generation can help mitigate but trend is for it to be shut down in favor of long distance transfers. • Renewables, which tend to be local and more distributed, may be helpful for these reasons.

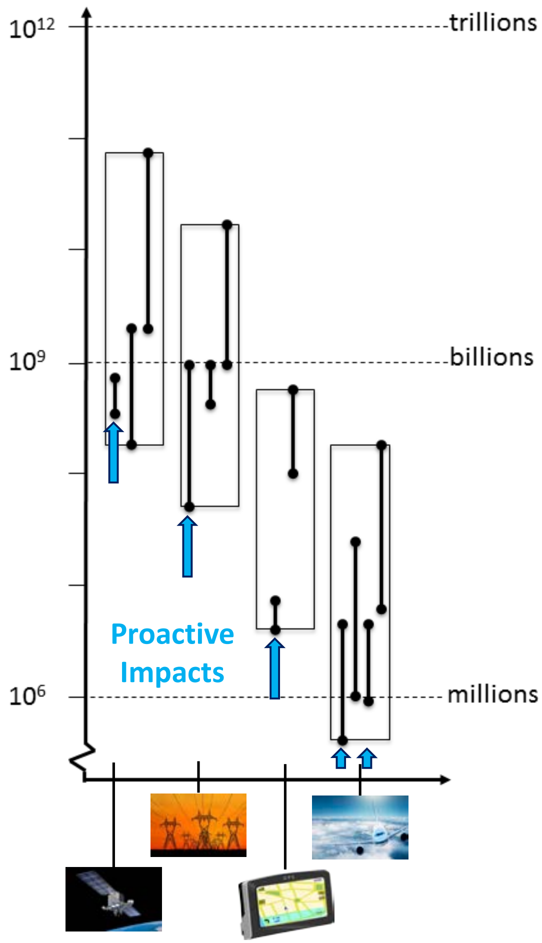
Findings



- **Estimates span many orders of magnitude**
- **Compare across sectors cautiously**
- Many impacts to estimate
- Mitigation may be relatively inexpensive
- Costs escalate with storm size
- Simple and transparent first pass estimates

Findings

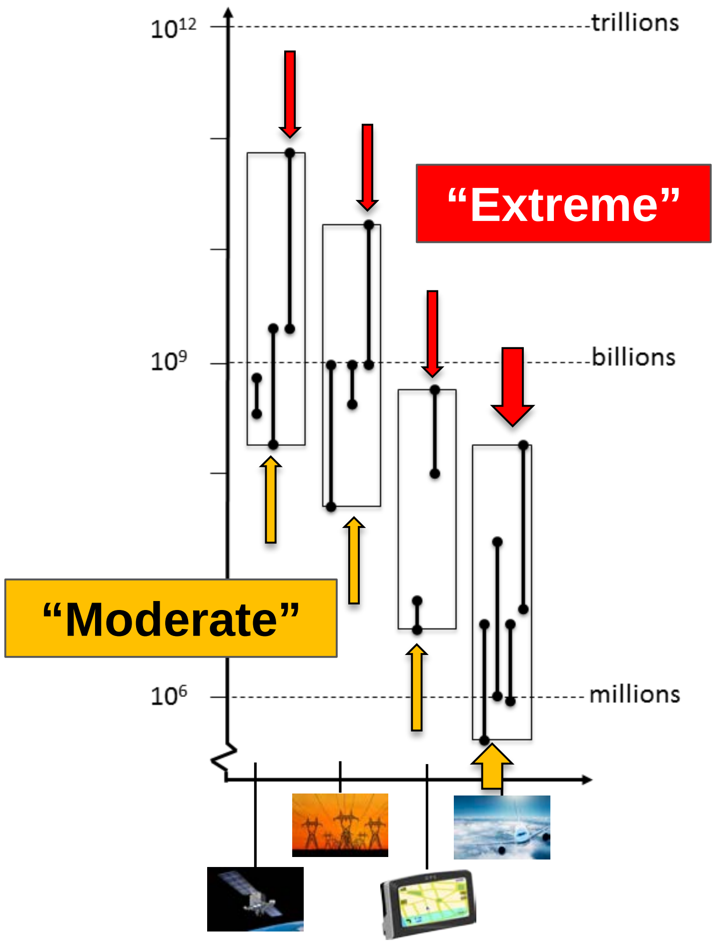
- Many impacts to estimate
- Mitigation may be relatively inexpensive



Impacts estimated in this study

		Proactive		Reactive		
		Impact Categories				
Sector	Physical Effects	Defensive Investments	Mitigating Actions	Asset Damages	Service Interruptions	Health Effects
Power Grid	Reactive Power Loss	•	•		•	
	Transformer Heating	•	•	•	○	
	Relay Misoperation	•	•		•	
	Power Imbalances		•		•	
	Generator Tripping	•	•		•	
	Precision Timing	•	•		○	
Aviation	Communications	•	•	○	•	
	Navigation	•	•	○	•	○
	Human Exposure		•		○	○
	Avionic Upsets	•	○	○	○	○
Satellites	Cumulative Dose	•		○	○	
	Anomalies	•	•	•	•	
	Link Disruptions	•	•		•	
	Loss of Orientation	•	•	•	•	
	Loss of Altitude	•	•	•	○	
GNSS Users	Loss of Lock	•	○		•	
	Ranging Errors	•	○		•	

Findings



- Costs escalate with storm size
- Simple and transparent first pass estimates

Annual cost of engineering

"Moderate" → 1 lost satellite

"Extreme" → 10 -100 satellites

One time cost of TPL-007-1

"Moderate" → Quebec 1989 scale

"Extreme" → 9 hours, US power markets

Users efficiencies reduced

User susceptibilities differ

"Moderate" → 1 hour outages
"Extreme" → 1-3 day outages

Cost to airlines and passengers

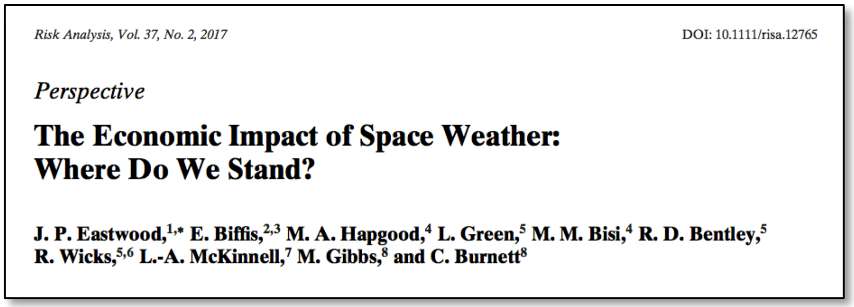
"Moderate" → 1 day, polar flights

"Extreme" → 1-3 days, 1-10% of US flights

Summary

Recommended Next Steps	Ongoing Work
• Critical Review and Discuss Findings • Establish Best Practices • Conduct Case Studies and Analyze Sensitivities • Add Context • Update Estimates • Explore Interdependencies	SWAP Actions 4.4.1 & 5.1.1 • Improve operational impact forecasting and communications • Improve understanding of user needs for SWx forecasting to establish lead-time and accuracy goal

In addition to anonymous contributors, individuals contributing to this effort included (listed in alphabetical order): Paul Cripwell, Geoff Crowley, Mark Dickinson, Gary Edwards, Joaquim Fortuny-Guasch, Henry Garrett, Trevor Gaunt, Greg Ginrich, Mark Gunzelman, Ewan Haggarty, Tom Helms, Frank Koza, Elisabeth Krausmann, Justin Likar, Jeffrey J. Love, Yahya Memarzadeh, Pat Murphy, Tim Murphy, NERC, Paul O'Brien, Dr. Sten Odenwald, Antti Pulkkinen, Graham Rennie, Klaus Sievers, Mike Steckelberg, Mike Stills, Markos Trichas, and Hans Visser.



Risk Analysis, Vol. 37, No. 2, 2017 DOI: 10.1111/risa.12765

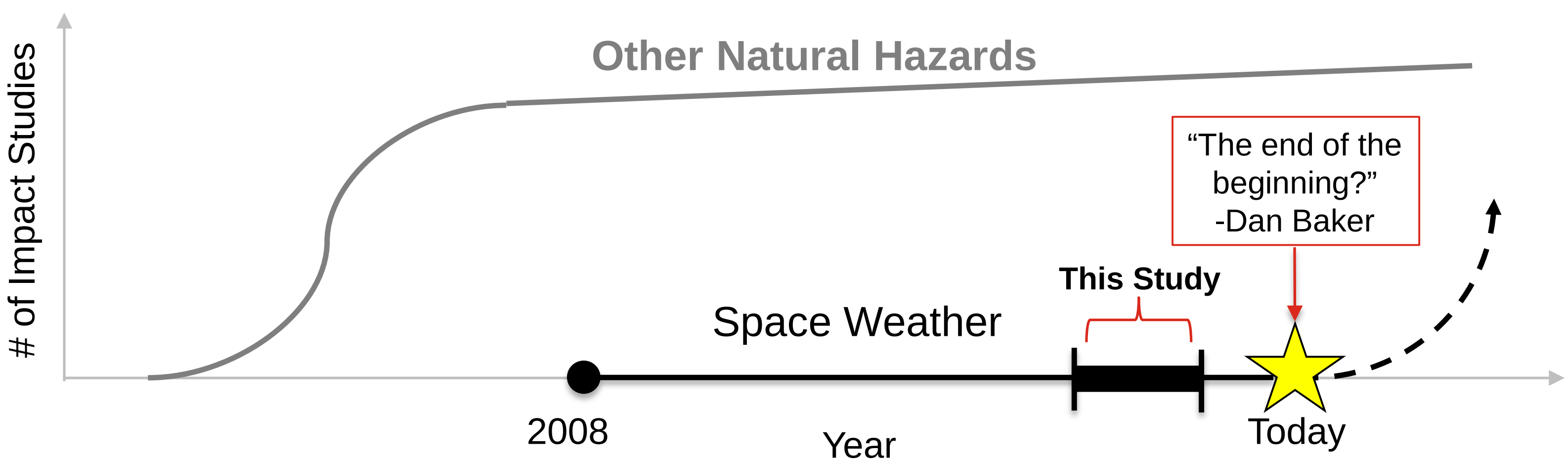
Perspective

The Economic Impact of Space Weather: Where Do We Stand?

J. P. Eastwood,[1,*] E. Biffis,[2,3] M. A. Hapgood,[4] L. Green,[5] M. M. Bisi,[4] R. D. Bentley,[5] R. Wicks,[5,6] L.-A. McKinnell,[7] M. Gibbs,[8] and C. Burnett[8]

"Although space weather is growing rapidly as a field, work rigorously assessing the overall economic cost of space weather appears to be in its infancy."

Takeaway Message



Final report available at NOAA's website:

www.weather.gov/news/171212_spaceweatherreport

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or email me for link/copy

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IMPACT