Space Weather Scenario Toolkit

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What is Space Weather and Why is it important?

- Space weather is created from activity on the Sun's surface that affects satellites and technology in Earth as well as human life.
- Impacts of Space Weather:
  - Solar flares can block radio waves used for communication
  - Solar Energetic Particles (SEP) can cause electrical failures in satellites
  - Coronal Mass Ejections (CMEs) can cause Geomagnetic Storms at Earth and cause widespread black outs and interrupt GPS signals
  - Geomagnetic Storms produce the auroras seen all over the world

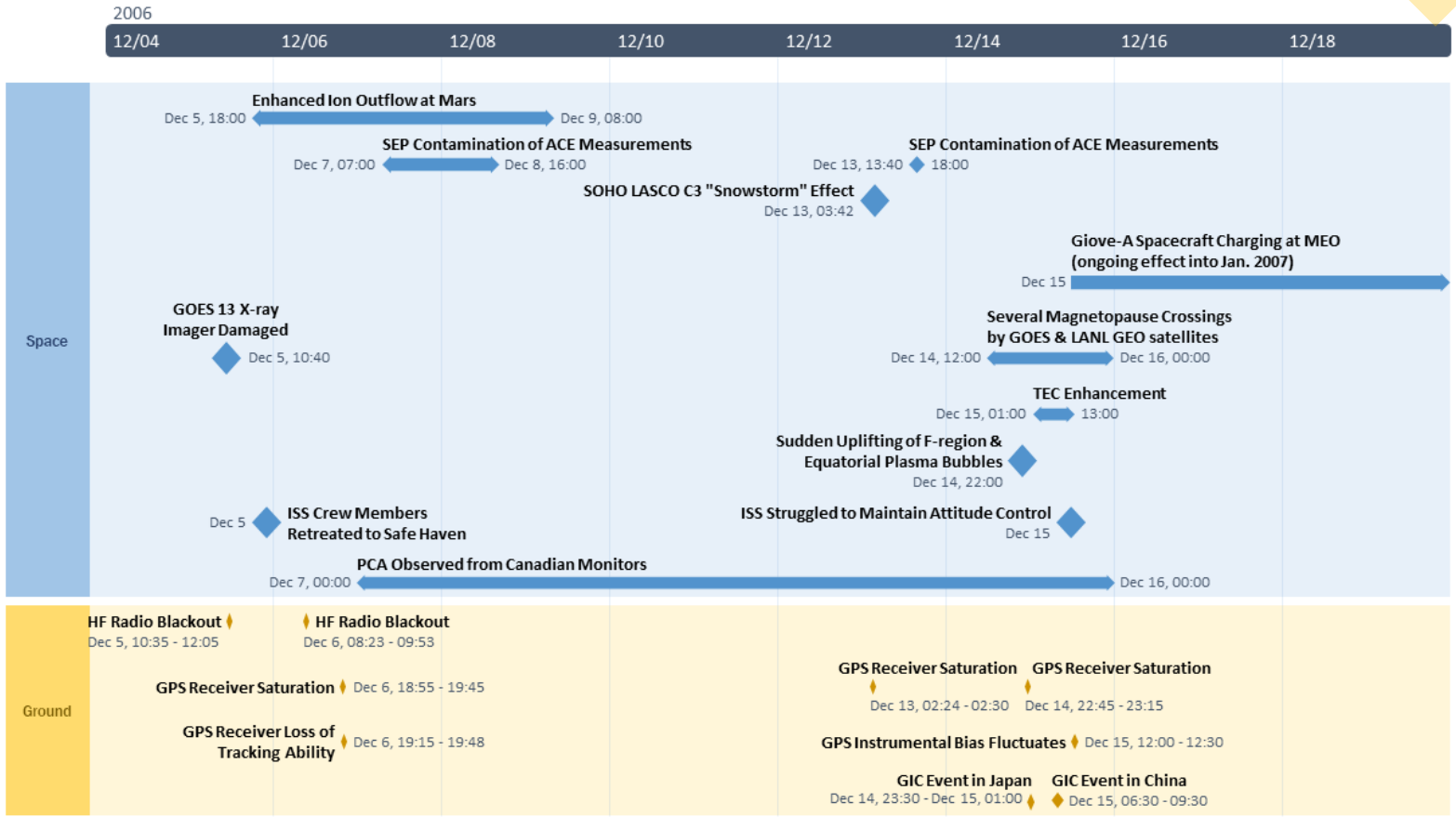
https://www.forbes.com/sites/jamiecartereurope/2020/09/24/did-you-see-the-northern-lights-last-night-massive-display-of-aurora-borealis-ushers-in-new-solar-cycle/?sh=734eeacdb629

Introduction to Space Weather Toolkit

- We wanted to create a toolkit that would help space weather trainees and operators see what space weather events cause different engineering problems and distinguish between the physical causes of space weather, observations, human and technology impacts
- Different components of the project
  - Literature review of two major storms from 2006 and 1938
  - Create timeline from the two events (had a journal article accepted for publication about timelines)
  - Create visualization that shows cause and effect relationship between events

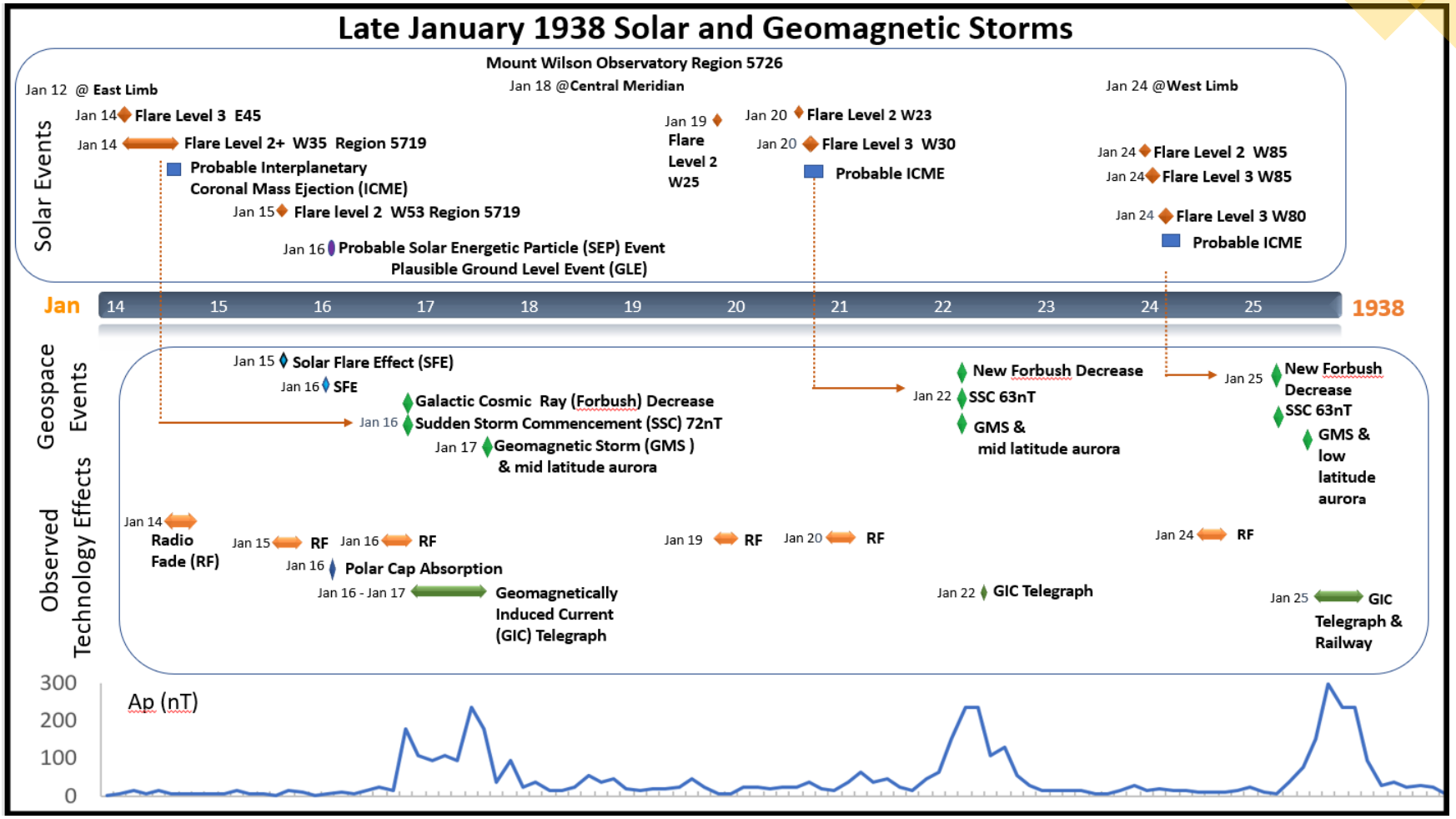
Timeline 2006

- Researched extreme space weather events from 2006
- From various resources put together a timeline of events and published a paper about timelines for 2006 and 1938
  - Knipp DJ, Bernstein V, Wahl K & Hayakawa H 2021. Timelines as a tool for learning about space weather storms.J. Space Weather Space Clim. https://doi.org/10.1051/ swsc/2021011.



Timeline 1938

- Used tables from Hisashi Hayakawa *et al* 2021 *ApJ* **909** 197 to organize event and create timeline
- Used two case studies from 1938 and 2006 to use as basis for toolkit and timeline



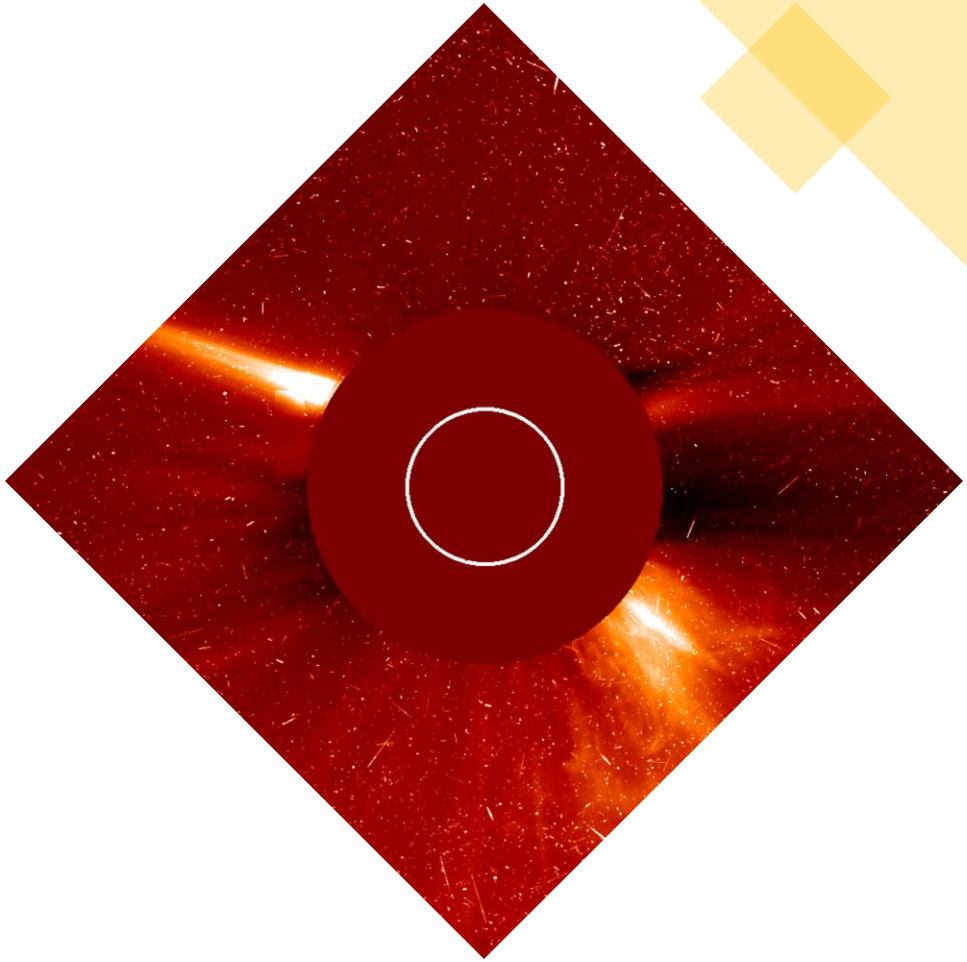
Building the Toolkit: Mind Dump

- Take information from timelines and create a table showing what event caused the following events
- Became the base of how the toolkit would be organized
- Color coded to define type of effect/ impact caused

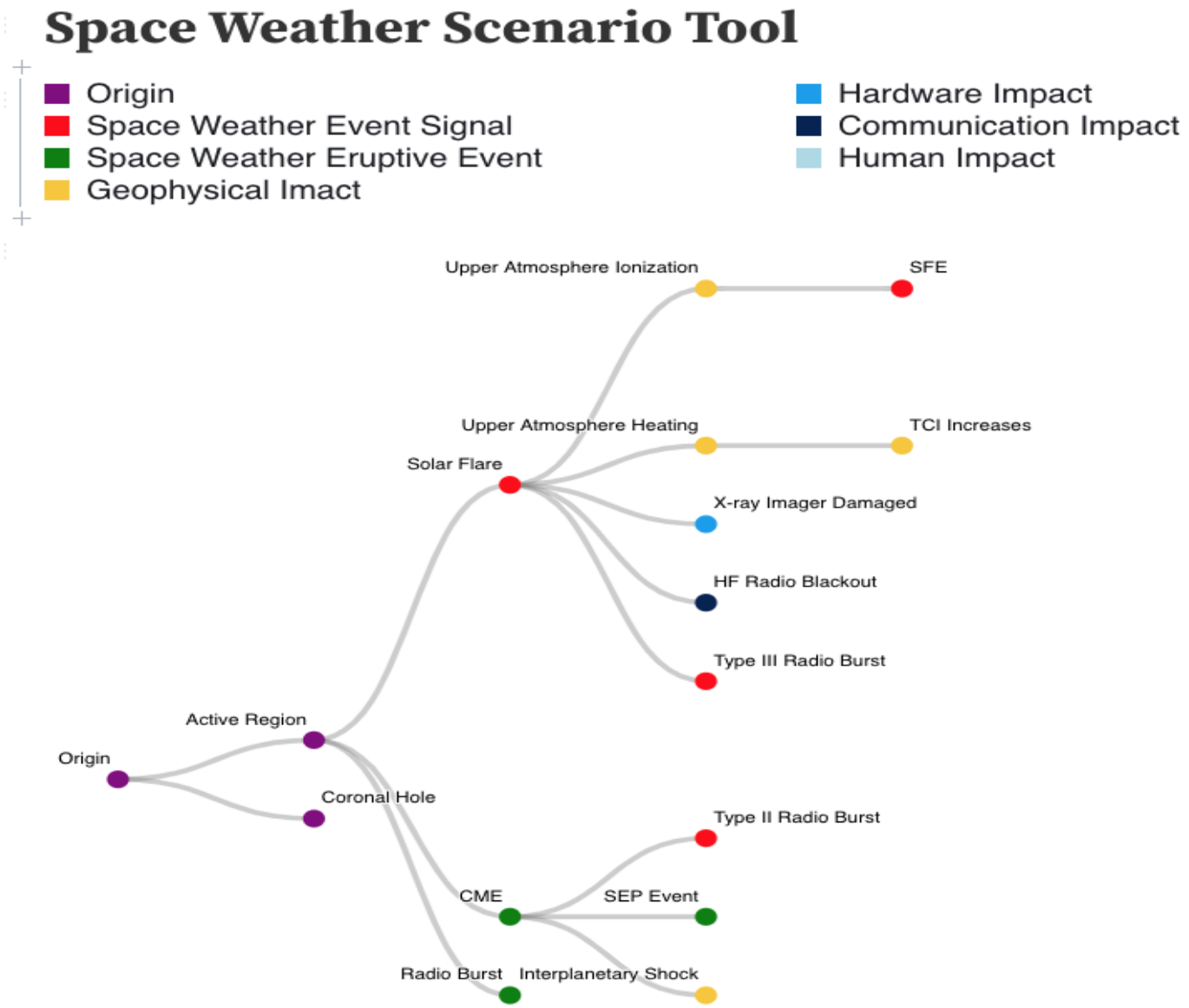
Active region appears on the sun	**Solar Flare** Characteristics: Multiple M-class flares; X6.3 at 12/6 18:40	**Upper atmosphere ionization**		**Solar Flare Effect (SFE)** Characteristics: seen from ground magnetometer	
		Upper atmosphere heating	**Thermosphere Climate Index (TCI) increases** Characteristics: geomagnetic indices remain flat		
		Type III radio burst Characteristics: 'radio loud;' signal of magnetic reconnection, maybe not enough intensity to have technology effects, narrow frequency range			
					Hardware Characteristics: GOES 13 X-ray imager damaged 12/5; imager was on for 3 seconds & CCD was affected

Scenario Toolkit

- Medium: D3.js to create a visualization that would go through the flow of the storms
- Try to map out order of events (not based on when they happened but based on cause and effect)
  - Show how one event branches out and creates different effects



https://youtu.be/u18F45ry_cI



Conclusion

- Will help people better understand complicated space weather events
- Made for beginner level knowledge (people who are getting introduced to space weather)
- Distinguishes between causes of events, geospace impacts, and technology impacts
- Toolkit is meant to display real life progression of space weather events
- Timeline meant to show duration of events

Next Steps

- Create Visualization for 1938 event using the same mind dump method to create organized table
- Share timeline with space weather community as educational tool
- Edit format to allow for better user experience
- Add link to Space Weather Glossary
  Developed by K.Wahl, V,Bernstein, D.Knipp, K.Tobiska

Thank you!

Questions?