



Routes to Market Report
33 - Satellite Technologies for
Space Weather Services

Innovate UK



CATAPULT
Satellite Applications

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1. Market Opportunity Description and Overview

Space weather events, such as solar flares, can have a significant impact on the stability of the air and space environment around earth, threatening air travel and contributing to natural disasters. This has created the need for continuous monitoring of space weather events to predict and assess space weather anomalies that might impact the air and space environment around earth.

Space weather events such as solar flares and geo-magnetic disturbances will have varied levels of impacts on the temperature and radiation profiles of earth's air and space environment. Abnormal variation in the radiation/temperature profiles will have negative impacts on the earth's environment. Variation in temperature profiles will cause erratic pressure differences in the atmosphere, which in turn, will cause hurricanes and cyclones. Variation in radiation profiles will cause health issues for humans exposed to them and might also cause system failures in aircraft/satellites. The sudden variation in space radiation and temperature, especially where satellites operate, might result in the loss of satellite capability.

Table 1: Key Trend Aspects and Impacts on Potential services

EVENTS/ASPECTS	IMPACTS	PREDICTION & ASSESSMENT	SERVICES
Solar flares	Variation in cosmic radiation [in and outside atmosphere]	Near real-time	Public domain [limited]
Geo-magnetic disturbances etc.	Disruption & destruction of critical infrastructure	Continuous monitoring [frequency/intensity]	Private/proprietary [getting started/not there yet]
Variation in intensity & frequency of events	Lack of access to essential services	Weather/climate change	Domain specific
Rise in temperature [Air/Water/Land]	Increased vulnerability of security measures	Space mission risks	Customer specific
Evolution of jet-streams [Planetary winds]	Long-term health impact	Back-up estimates	Digital/web-based
Rise/spread of electromagnetic discharges	Volatile weather conditions	Recovery efforts planning	Digital/Web-based

Table 1 provides an overview of the space weather services trends and the impacts on potential services related to it. Whilst many public domain websites provide space weather event information and their measurements, they do not provide actionable insights for specific stakeholder groups, especially in the commercial domain.

Increasingly volatile solar flares will impact earth's ecosystems and this creating a higher demand for accurate information and forecasting among civilian and military stakeholders. While largely, space weather events are expected to impact earth's weather, the prediction service accounting for such

events is not widespread globally. Specific negative impacts of critical space weather events include the deactivation of satellites in earth orbits and increased radiation in earth's atmosphere. Other key impacts gaining traction are volatile weather systems such as thunderstorms/cyclones. Stakeholders, moving forward, will need such services which account for distant space weather events and present actionable insights relevant to the stakeholder groups. Key aspects of such services will be continuous monitoring of earth's current air and space environments where aircraft and spacecraft operate. A near-real-time access to such monitoring and prediction service will enable stakeholders design their respective contingency plans and recovery efforts in case of adverse space weather events causing catastrophic conditions in earth's ecosystems.

The need to assess, predict, and counter such weather events requires a reliable monitoring capability and tools to develop system resiliency, contingency plans & procedures, and risk assessments for air and space missions. Over time, the historical data collected through diagnostic detection and measurement of space weather events will have to support a predictive mechanism that will provide prognostic intelligence on approaching environmental anomalies as a result of abnormal space weather events.

The downstream services will have to deliver intelligence on the environmental parameters relevant to the customer groups targeted. In case of solar flares impacting the radiation environment in the earth's atmosphere, the service should provide the state of radiation and its historical versus projected variation. The intelligence covered should include the radiation relevant to the customer group, its past, current, and future states and indicators of potential abnormalities, probabilities of occurrence, and potential impacts.

1.1. Technology Involved

Terrestrial and space based sensing capabilities will deliver diverse data measurements which will be compiled, analyzed, and customer-relevant assessments will be developed through a big-data analytics engine which will be translated into actionable insights. The final solution delivery will have the processed data feed along with actionable insights as per customer requirements.

Upstream, the technology involved will cover land, space, and airborne sensors which monitor key environmental variables with respect to earth and distant entities including the sun. Downstream, the technology will cover Big Data analytics engines, large scale distributed storage mechanisms, and Web-based platforms accessible on diverse devices.

2. Customer and Value Proposition to Customer and End-user

The service needs to cover diverse environmental parameters and develop impact estimates, accounting for space weather data sets. The downstream delivery should be covering relevant parameters for the customer such as temperature, winds, precipitation, and relevant wavelengths. The customers will be interested in investing in services which deliver intelligence in actionable format in their relevant terms.

While space weather events are gaining prominence, they are not a big driver for any regional/global spending pattern at this point in time. However, in October, 2016, the US government issued an executive order demanding coordinating efforts toward preparation for space weather events. This indicates that the government stakeholders are beginning to acknowledge space weather events as potential root causes for natural disasters and long-term detrimental conditions that adversely affect environments, population, and economies.

As customer awareness of space weather events is only beginning to grow, it will be a 'push' scenario for solution and service providers. Sensor development & deployment, data collection, development of the analytics engine, and integration of existing and new data sets will remain the key operational areas for the market participants to engage in. Defense and government agencies might show interest, but will prefer proprietary systems to be used as such intelligence is often closely related to their respective security priorities. From that perspective, solution and service providers will have to understand the existing proprietary capabilities and develop solutions that can be integrated with those of the customer such that the customer realizes a comprehensive solution utilizing existing proprietary assets with the commercial contributions enhancing the solution.

Commercial industry customers will be interested in learning about how the space weather events impact the life and health of their respective systems and platforms before they consider investing in such a space weather monitoring service. The most interested customer groups includes satellite operators [big and small] and launch operators as they face high risk scenarios in their space operations, often resulting in high insurance costs. The insurers will also be interested in such services to support a data-driven risk assessment.

3. Customer and Value Proposition to the Customer and End-User

3.1. Space Customers

Satellite operators, launch operators, system developers, and insurance companies covering space businesses will be key target groups for these services. The key focus areas for these customers will be radiation and temperature profile monitoring in the atmosphere and the orbital space [LEO, MEO, and GEO] around earth. The objective of utilizing the service will be to primarily assess the existing and evolving risks for subsequent system design and contingency measures.

3.2. Commercial Aviation Customers

Airline operators, aircraft manufacturers, insurers, and aircraft system suppliers will be key customer groups who will be keen on learning more about the changing temperature/radiation profiles within the earth's atmosphere, especially the 30,000ft - 45,000ft altitudes, as that is where most commercial aircraft operate predominantly. The key focus areas for the service will cover changes in weather patterns [cyclones/thunderstorms/lightning] and radiation concentration. The users will be interested in setting their required 'danger-limit' for each variable and receive alerts when those variables cross a certain threshold or 'danger-limit' as marked by the key stakeholder. This will allow commercial aviation players understand the evolving environmental conditions in which their equipment is operating and

subsequently estimate the life of their respective systems depending on the intensity of elements they face during their normal operational lives. The service should support objectives that cover life-estimation and contingency planning for approaching anomalies, especially in high-risk areas.

3.3. Maritime Customers

Vessel operators, maritime system developers, and insurers will be interested in learning more about abnormal variation in the atmosphere and its impact on their operations. While the focus will largely be on weather monitoring, the inclusion of space weather monitoring data will help them stay aware of rare abnormalities that might cause large scale damage despite low probabilities of occurrence. The service, therefore, should be enhanced weather monitoring inclusive of space weather data for precision and versatility of risks covered. The objective of subscribing to such a service will be to clearly identify high risk areas [time-bound] and implement data-driven decision making for precise ETA assessments and voyage route planning.

3.4. Civil Government Customers

Government agencies will be interested in protecting their critical infrastructure such as the electrical power grid and a significant portion of their efforts will cover contingency planning, redundancy installation, and recovery procedures. These will require the intelligence on how and when abnormal space weather events will deliver dangerous weather conditions that can disrupt or destroy elements of critical infrastructure. The intelligence required will be covering variation of atmospheric conditions [predominantly] accounting for space weather data. The requirement will also cover long-term impact assessment of prolonged exposure to non-lethal radiation/temperature/weather variations for key elements of critical infrastructure. This intelligence, in an ongoing basis will support government initiatives to plan, develop, and implement preventive and corrective measures to counter the adverse impact of space weather events.

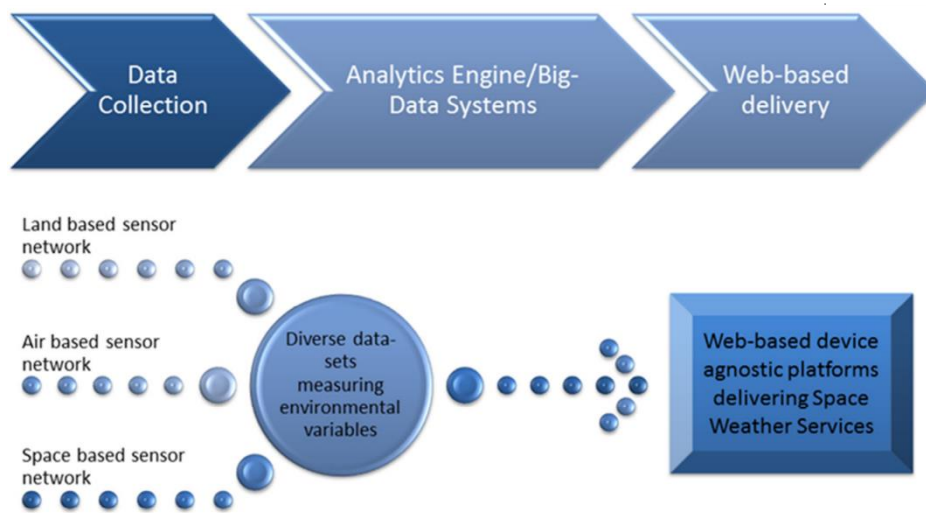


Figure 1: Space Weather Services: Capability Value Chain

Figure 1 highlights the capability value chain. The data collection is by far the most represented segment as of now in the market. There are very few Web based platforms in the public domain. As for the diverse analytics engines for specific customer groups, the market is yet to evolve.

Space Weather News <http://spaceweathernews.com/>

This service, operated by Space Weather News LLC, provides key space weather data plots and updates on their Website as a free-for-all public domain service. The Website receives data from multiple sources (private and government) and provides a compiled version of the data-sets. No extensive customer-specific actionable intelligence is provided and the users are expected to interpret the space weather data for their own requirements. The actionable intelligence provided covers the visibility line for aurora.

SolarHam <http://www.solarham.net/>

This Website is a public domain, open-to-all service presenting collated information from:

- NOAA Space Weather Prediction Center (SWPC)
- Solar Dynamics Observatory (SDO)
- Solar and Heliospheric Observatory (SOHO)
- Solar Terrestrial Relations Observatory (STEREO)
- Advanced Composition Explorer (ACE)
- Large Angle and Spectrometric Coronagraph Experiment (LASCO)

The service focuses on presenting graphical and numerical data-sets without any customer-specific actionable insights.

Space Weather Live <https://www.spaceweatherlive.com/>

Run by Astro Event Group vzw, a non-profit organization in Belgium, this Website is an open-to-all, public domain, free service operating on volunteer efforts. The service provides reports and forecasts on key space weather events focusing on real-time auroral activity and solar activity.

4. UK Company Role

As this market is predominantly covering free-to-all public domain services, the immediate role for a potential UK based business will be to develop a commercial business model focused on delivering relevant and actionable space weather insights to diverse customer groups. The differentiating area will be the analytics domain, where the service provider can compute, compare, and analyze diverse data sets [proprietary and public] and the service delivered covers intelligence that is currently not available in public domain.

5. Revenue Projections

Since there are no commercial services delivering space weather services, the market for such services does not exist as of now. Moreover, the concern of space weather events impacting space and weather conditions is just gaining prominence. Until the direct relationship between space weather events and adverse conditions such as natural disasters or hostile radiations in earth orbits are established, the risk perception will remain low and so will the intent to pay for such services.

Frost & Sullivan estimates that the potential market is small and the annual global market opportunity will not exceed \$2 million. Satellite operators, downstream weather service providers, launch operators and space insurers will be key customer groups for the market.

6. Market Enablers and Challenges

Government agencies are key data providers and public websites are the distributors. No actionable insights or services based on the same are available right now in the commercial domain.

For significant market growth there would need to be:

- Greater understanding and awareness of the financial or safety consequences of space weather
- Regulation that insists on commercial organisations, such as airlines, monitoring the effects of space weather on their operations and staff
- A higher volume of commercial deep space missions

The space weather services will require data from space and land based sensor networks. Downstream, the data-sets will be fed through suitable analytics engines to develop actionable insights as per customer requirements.

Here are the key challenges faced by this potential market:

- The risk perception of space weather events, while growing, is still nascent and the clarity among stakeholders in terms of the relationship between space weather events and phenomenon on and around earth is yet to grow further to warrant any investment in such services.
- Lack of commercially accessible land and space based sensor networks.
- Lack of regulatory framework to drive the development of contingency efforts to counter potential adverse space weather events that can cause natural disasters.
- The key steps to be taken to counter the challenges are:
- Supporting technology demonstration missions that can collect space weather events data to support the research that can establish the realistic threats posed by adverse space weather events will encourage participation of commercial players.
- Evolving regulatory framework to enable the development and installation of land and space based sensor networks that will enable space weather services will help establish the market in commercial format. Enabling commercial players establish their sensor networks for subsequent commercial distribution of the data to diverse customer groups will be a key step towards enabling the realisation of this market.
- Evolving regulatory framework to mandate government driven contingency efforts to counter potential adverse space weather events will enable future government spending on such efforts which will encourage and support participation of commercial industry participants.

7. Market Dynamics

As such the market for space weather monitoring and estimation services is in its nascence. The prominent players are public-domain open-source Websites which compile space weather data as published by prominent government and private research groups. The websites do not provide any actionable insights that can support risk estimation or contingency planning. The targeted end-users, for the most part, seem to be 'aurora' enthusiasts. Since the market is yet to see significant diversity in players and their capabilities, it is too early to discuss the dynamics and significance of the same. What can be substantial is the fact that space weather events and their measurements are available in the public domain and accessible to all.

8. Market Trends

Space Weather Prediction Centre, a division of National Oceanic and Atmospheric Administration under the Department of Commerce in the United States is a key player who collects, compiles, and publishes space weather event measurement data.

9. Recommendations for Additional Research

Key areas which are of customers' interest with respect to space weather events need to be identified and analyzed for the capability requirements to be installed in the analytics service that can be developed to meet the unmet needs.