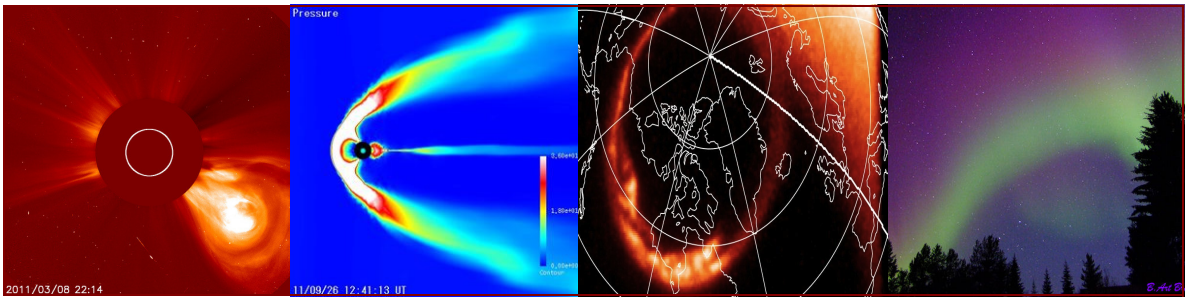
Workbook



What is Space Weather?

Susan Joy Rennison

JOYFIRE PUBLISHING

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Tuning the Diamonds: A Workbook

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Authors' Note

Space Weather is transforming our world. This workbook is designed to support a greater understanding of how the delivery of solar, cosmic and intergalactic energy impacts our modern technological world and the principles that dictate the process of transformation during this time of evolutionary change. The main focus is space weather generated by the Sun and the releases of vast amounts of energy in the form of electromagnetic and particulate radiation that has a tremendous influence on the near Earth space environment. Yet, there are also blasts coming from deep space, an orchestration of cosmic energy, which must be considered for a complete picture. As space weather has been intensifying for the last few decades, Russian scientists state that the transmitting properties of space have changed within our solar system. Consequently, this has serious consequences as Earth continues to receive bombardments of energy that can damage or destroy satellite, navigation, communication and power distribution systems, hence there is a new focus on understanding and mitigating societal and technological impacts.

Features

♦ This space weather workbook is aimed at those who are technically minded but the material presented at a pre-undergraduate level.

♦ Each section contains a list of key concepts that defines the underlying physical principles, and lists 'must watch' movies and highlights essential background reading, alongside references.

♦ Definitions of important terms are given throughout the text, but a glossary is provided of regular terms.

♦ The workbook has a revision section to help review and test readers' understanding.

Susan Joy Rennison

Notes

What Is Space Weather?

"Earth and space are about to come into contact in a way that's new to human history."

"I believe we're on the threshold of a new era in which space weather can be as influential in our daily lives as ordinary terrestrial weather. We take this very seriously indeed."

Richard Fisher, head of NASA's Heliophysics Division

1. The New Phenomenon of Space Weather

During a tempestuous solar fortnight in 2003, Earth experienced extreme space weather that has now become commonly known as the Halloween storms. The first solar flares began on 25th October, but 28th October was when the first of the really massive flares and eruptions struck. The citizens of Earth, though largely unaware, were lucky because a record breaking X28+ flare on 4th November, was actually directed away from the Earth. There are many different statistics swirling around on the internet but various space weather research papers state there were 140 solar flares and 80+ coronal mass ejections in about a fortnight. That is some heavy duty firing by the Sun and satellite controllers and astronomers were forced to take measures to protect satellites and space-based telescopes.

Space weather watchers are most concerned about Earth being engulfed in huge clouds of electrified particles that charge up

spacecraft, because as the charges build up on spacecraft, they can short-circuit and damage the electronics. This is probably the cause of the biggest casualty, the $640 million Japanese Meduri II weather satellite - it went silent during the storm on the 28th October, losing the $150 million National Aeronautics and Space Administration (NASA) SeaWinds instrument. NASA's Goddard Space Flight Center (GSFC) Space Science Mission Operations Team indicated that approximately 59% of the Earth and Space science missions were impacted. Most of these faults could be attributed to their positioning mechanism. Dr David Clarke gave a presentation that took place 12th September, 2007, at Gresham College in the United Kingdom, the birthplace of academic astronomy in the UK. Dr David Clark remarked:

> "The satellites of today hold themselves upright and in fixed orientation in space by having little telescopes on them called star trackers. These star trackers watch the night sky and they monitor the positions of the stars, and if they notice any slight movement in the stars, then they fire little thrusters to keep the satellite stable. When the satellites are surrounded by these great big clouds of electrified gas, however, it blinds the star trackers and they lose sight. However, the spacecraft will try to correct for that - it thinks, 'Oh goodness, where has the stars gone? I need to try this, I need to try that,' and it will just dangerously fire all these thrusters. So what spacecraft do is simply recognise that something has gone wrong like that and shut themselves down, and then they wait for ground controllers to send up resuscitating signals saying, 'The danger is over. Turn on - see if you are okay or if there really is anything wrong with you.'"

Figure 1.1: Artist's impression of an Iridium satellite. Credit: NASA

Dr Clarke also revealed a rather embarrassing snippet of information. Apparently, NASA had sent the Mars Odyssey spacecraft into orbit around Mars carrying a radiation monitor designed to measure the amount of solar radiation that would reach Mars due to space weather. Unlike Earth, with a large atmosphere protecting humans from radiation in space, Mars has a

very thin atmosphere with no ozone layer and this is one of the biggest problems for space exploration and a major consideration when deciding to send astronauts to Mars. Well, the Mars Odyssey radiation monitor was burnt out by the Halloween storms because NASA had completely miscalculated just how much radiation it was possible to receive at Mars. Due to the need for protection against the onslaught of cosmic radiation, astronauts onboard the International Space Station approximately 220 miles (350 km) above Earth, are forced to relocate to portions of the ISS which are most shielded from high levels of radiation. On Earth, there was a 20 - 50 minute electrical power blackout affecting 50,000 customers in Malmo, Sweden (30th October) and significant transformer damage in South Africa with over 15 transformers damaged, some beyond repair.

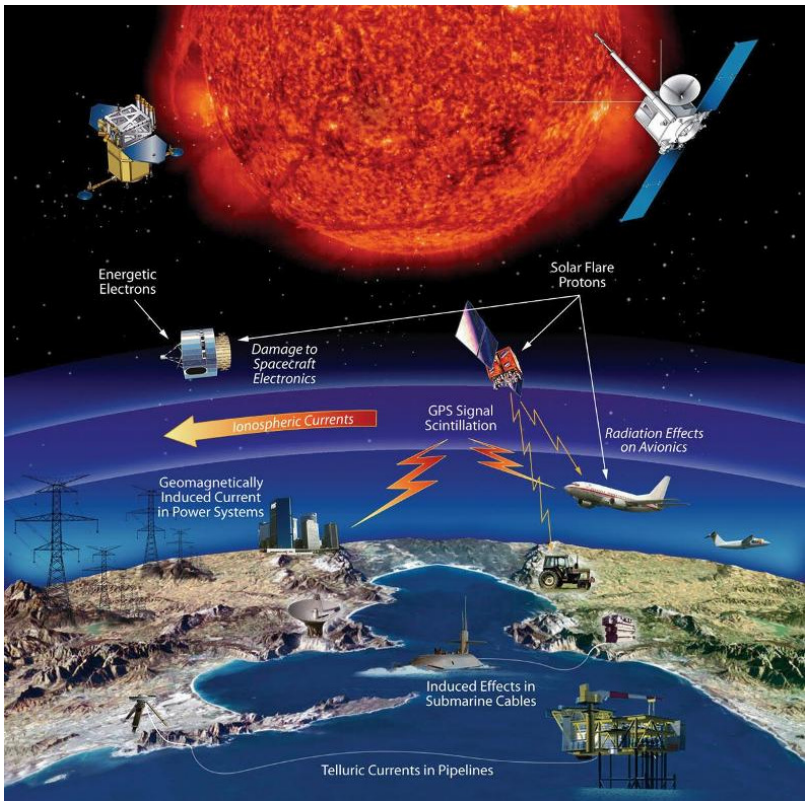

Figure 1.2: Technological infrastructure affected by space weather events. Credit: NASA

During the Halloween storms, there was a plethora of communications blackouts including: all of the expeditions on Mount Everest were lost contact with; there were forest fires in California at the time, and the radios would not work properly so they could not correctly coordinate their efforts to fight these fires; high latitude GPS receiver outages and the Federal Aviation Administration's (FAA) Wide-Area Augmentations System (WAAS) (built to improve GPS accuracy and augment signals), was degraded. At the height of the storm (29th October), space weather adversely affected the availability of the vertical navigation service throughout most of the United States. In fact, during the solar storm period, about 30 hours of vertical navigation service was lost, but lateral navigation service for non-precision approaches was maintained (this will be explained later); what's more, mobile phones and satellite television were also blacked out. The solar flares on the 28th October and again two days later on the 30th were so large, that the FAA decided that they would divert all aircraft away from the Polar Regions, to avoid the risk of high altitude radiation and high frequency (HF) radio blackouts.

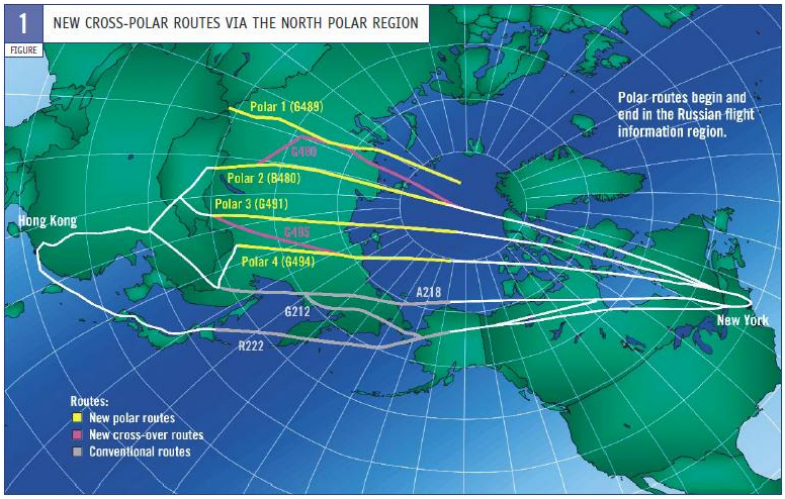

Figure 1.3: Polar routes. Credit: Boeing

Polar routes have become increasingly popular due to the thawing of relations between the countries that comprised the old Soviet Union and North America and the polar regions are no longer needed as a buffer zone. Hence, the only real issue is that

the magnetic field of the Earth funnels solar radiation down into the Earth's atmosphere around the poles, and so, when these storms hit, as a precaution, planes are diverted. This takes the form of planes routes being changed to below latitude 57 and brought down in altitude to below 25,000 ft (7620 m) to provide plane electronics and passengers with more atmospheric protection. This is a major decision as rerouting a plane costs airlines $10,000 to $100,000 per flight.

Even though the vast majority of Earth's citizens were unaware, our modern world survived this major onslaught, but it has focused more attention on the vulnerability of the world's technological infrastructure to space weather effects. The Great Magnetic Storm in March, 1989 and the Halloween Storm October – November 2003 are a reminder of even bigger geomagnetic storms that have taken place in the last 150 years. Efforts are being galvanised to systematically assess the societal and economic impacts of what is now known widely as "Space Weather."

1.1 Space Weather Defined

"Space Weather" has been defined as "conditions on the sun and in the solar wind, magnetosphere, ionosphere, and thermosphere that can influence the performance and reliability of space and ground-based technological systems and can endanger human life". It encompasses a broad range of phenomena impacting both space science and technology, but there is also a considerable radiation risk to astronauts, airline crew and frequent flyers. Examples of activities and systems affected by space weather include:

Figure 1.4: As cross-polar traffic increases, the aviation industry is becoming more aware of the impacts space weather can have on operations. Credit: American Meteorological Society

- Satellite communications and operations (including telephone, cable and internet services).
- General electrical control systems
- High-frequency communications, short-wave broadcasting & surveillance radars

- Aircraft & shipping navigation
- Oil & gas, drilling and related operations
- Mapping, construction, and surveying
- Vehicle transportation, delivery and courier services
- Atmospheric weather balloon monitoring
- Tracking animal and bird migration
- Computer network synchronisation
- Time-stamping financial transactions
- Agricultural applications
- Electricity power grid distribution
- Military Operations

1.2 Space Has Never Been Closer

The edge of space or where the Earth's atmosphere ends is difficult to define because the atmosphere does not end abruptly. Rather, it gradually becomes thinner and more tenuous. The upper layers of Earth's atmosphere are extremely important for radio communications, especially the ionosphere, a shell of electrons and electrically charged atoms and molecules (ions) that surround the Earth. The ionosphere owes its existence primarily to neutral atoms or molecules that have been ionized either by high energy photons (ultraviolet or X-rays with short wave lengths) from the Sun or energetic particles from the magnetosphere that precipitate into the atmosphere and collide with the surrounding gas. Ions exist everywhere in the atmosphere but they are most important in the thermosphere, see figure 1.5. It was previously reported as being ~400 miles (640 km) high at nighttime and ~600 miles (960 km) during the day. (Please note: The ionosphere is considered to be the ionized part of the thermosphere.) Hence, the significance in December 2008, when NASA admitted that Earth's defences against space weather had dropped. The headline at the website Science Daily read: *Boundary Between Earth's Upper Atmosphere And Space Has Moved To Extraordinarily Low Altitudes, NASA Instruments Document*. NASA revealed that the ionosphere had collapsed due to "the quietest solar minimum since the space age," but since this time, there have been no further announcements that the ionosphere has recovered.

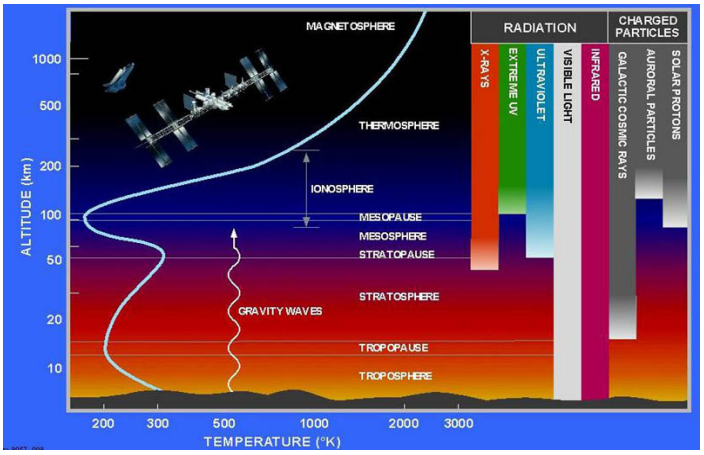

Figure1.5: The layers of the atmosphere, the temperature gradient, and the depth of penetration by radiation and charged particles.

The layers of the atmosphere are not always the same height around the Earth, as they expand and contract with temperature fluctuations throughout the year. Even so, the night ionosphere has collapsed from ~400 miles (640 km) at night and ~600 miles (960 km) during the day to ~260 miles (420 km) and barely rising above ~500 miles (800 km) during the day. This is a primary reason why space has never been closer to Earth and why Earth and space will be interacting in a way that is new to human history.

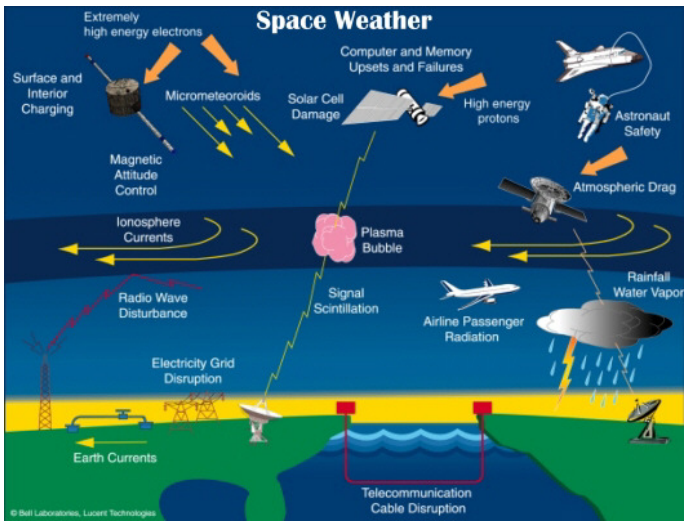

Figure 1.6: Space weather effects. Courtesy: Bell Laboratories

1.3 Space Weather Changes Our World

In mid June 2011, it was officially acknowledged that life on Earth has been permanently affected by space weather. This happened when the UK & US governments made a joint announcement about the decision to take down National Electricity Grids to prevent them being damaged in the event of a powerful geomagnetic storm. The UK Independent newspaper wrote:

> Officials in Britain and the United States are preparing to make controlled power cuts to their national electricity supplies in response to a warning of a possible powerful solar storm hitting the Earth.
>
> "In an interview with The Independent, Thomas Bogdan, director of the US Space Weather Prediction Centre, said that controlled power "outages" will protect the National Electricity Grids against damage which could take months or even years to repair should a large solar storm collide with the Earth without any precautions being taken."

Remarkably, this is the exact scenario outlined in the Discovery Channel documentary-drama, *Perfect Disaster: Solar Storm* (2006). Ominously, in this documentary, electrical engineer John Kappenman made the remark that any decision to take down power grids was akin to playing Russian roulette with the Sun. Presumably, the reason for this comment is because space weather forecasting is still in its infancy. Today, the procedures for how this will be implemented have not been disclosed, but current methods of collecting data to make important decisions is in itself vulnerable to space weather. The scenario of a dramatic increase in space weather was explained in the book Tuning the Diamonds: Electromagnetism & Spiritual Evolution (September 2006). The basic premise of this book was that space weather is the manifestation of predictions (based on known astronomical cycles) that we are entering a new era dominated by the ether (modern spelling aether) or space. Today, the facts reveal near-Earth space has been transformed in a period of about two decades, from being tranquil and "empty", into a furious and hostile operating environment for the world's satellite communication infrastructure.

In 1997, Dr. Alexey Dmitriev published a paper entitled,

Planetophysical State of the Earth and Life, which in 1998 was updated and translated into English. This authoritative and important report is now widely acknowledged as an early warning that "highly charged material" had "broken into the interplanetary area of our Solar System" and that this "donation" of energy was affecting all the planets in our solar system as well as our Sun. Most importantly, in terms of space weather, we are told that the properties of space have changed and there has been an increase in the "solar-planetary transmitting properties". This is a short, but relevant extract:

> **"**In its travel through interstellar space, the Heliosphere travels in the direction of the Solar Apex in the Hercules Constellation. On its way it has met (1960's) non-homogeneities of matter and energy […] This kind of interstellar space dispersed plasma is presented by magnetized strip structures and striations. The Heliosphere [solar system] transition through this structure has led to an increase of the shock wave in front of the Solar System from 3 to 4 AU, to 40 AU, or more. This shock wave thickening has caused the formation of a collusive plasma in a parietal layer, which has led to a plasma overdraft around the Solar System, and then to its breakthrough into interplanetary domains. This breakthrough constitutes a kind of matter and energy donation made by interplanetary space to our Solar System.
>
> In response to this "donation of energy/matter," we have observed a number of large scale events:
>
> A series of large PlanetoPhysical transformations.
>
> **A change in the quality of interplanetary space in the direction of an increase in its interplanetary, and solar-planetary transmitting properties.**
>
> The appearance of new states, and activity regimes, of the Sun.**" [Bold added for emphasis]**

Space weather is not new, but due to the changes in the properties of space becoming more "saturated" and "charged", combined with the weakening of Earth's magnetic field, it means that the impact of space weather on Earth is far more intense and problematic.