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Space hurricane as a mechanism of a motion of a spacecraft through MIRCE Space

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Abstract

Unlike Earth's weather, which is manifested through physical phenomena like wind, snow and rain, space weather is manifested through physical phenomena like evolving ambient plasma, magnetic fields, radiation and particle flows in space. Both types of weather have impact on the motion of functionable systems through MIRCE Space and their functionability performances. Terrestrial impacts of these meteorological phenomena are reasonably well understood and included in operational analysis of functionable systems. The effects of space weather are observed in the interruption or degradation of functionality and performance of space related systems during their in-service lives. The main objective of this paper is to draw attention to the recently discovered phenomenon of a space that was named as "space hurricane" and to analyse its impact on the motion of a spacecraft through MIRCE Space. Potential impacts of this new cosmic phenomenon on the motion of functionable systems through MIRCE Space and the consequences on functionability performances are examined and presented in this paper.

Key words

Space hurricane
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MIRCE Space
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1. Introduction

The Sun emits energy, as flares of electromagnetic radiation in frequencies of radio waves, infrared, light, ultraviolet, X-rays and as energetic electrically charged particles through coronal mass ejections and plasma streams. These particles travel outwards as the solar wind, carrying parts of the Sun's magnetic field with them. The electromagnetic radiation travels at the speed of light and takes about 8 minutes to move from Sun to Earth, whereas the charged particles travel more slowly, taking from a few hours to several days to move from Sun to Earth. The radiation and particles interact with the Earth's (geo)magnetic field and outer atmosphere in complex ways, causing concentrations of energetic particles to collect and electric currents to flow in regions of the outer atmosphere (magnetosphere and ionosphere). Thus, the term space weather has become accepted to refer to a collection of physical processes, beginning at the Sun and ultimately affecting human activities on Earth and in space [1].

Space weather phenomena have a variety of effects on technology. Energetic particles thrown out from the sun interact with the earth's magnetic field producing magnetic disturbances and increased ionisation in the ionosphere, 100 to 1000 km above the earth. The high-energy particles affect satellites causing miss-operation or equipment damage that can put the satellite out of operation. Radio waves used for satellite communications or GPS navigation are affected by the increased ionisation with disruption of the communication or navigation systems. The magnetic disturbances directly affect operations that use the magnetic field, such as magnetic surveys, directional drilling, or compass use. Magnetic disturbances also induce electric currents in long conductors such as power lines and pipelines causing power system outages or pipeline corrosion. Some of these harmful impacts of space weather will be discussed latter in the paper. [2,3]

The main objective of this paper is to expose the global community of design engineers and operational managers to a recent discovery made by scientists from China, the United States, Norway and the United Kingdom, which is the discovery of the space hurricane.[5]

While analysing satellite observations from August 2014 that orbited around the planet, they spotted signs of a massive disturbance in the upper atmosphere. Space hurricanes are made up of plasmas, consisting of extremely hot ionised gases that rotate at extremely high speeds, with rotational speeds reaching up to 7,560 kilometres per hour. In 2020, using observations that had been made in 2014, researchers identified a large space hurricane that had occurred over the Arctic, spanning 1,000 km in diameter at its base in the Ionosphere, at an altitude of 110–860 km, and roughly centred over the North Magnetic Pole. [4]

The flows of plasma going around looked like the winds of the space hurricane. They were strongest at the edge and decreased as towards the eye in the centre, before picking up again on the other side, just like the flow of air in a regular hurricane. However, that is perhaps where the similarities end. Unlike with regular hurricanes that can dump huge amounts of precipitation over Earth's surface, the scientists instead observed electrons raining into the upper atmosphere. [4]

The potential impacts of this new cosmic phenomenon on the motion of functionable systems through MIRCE Space and the consequences on functionability performances are examined in the paper.

2. A Few Words on MIRCE Science

In physics, motion is a change in position of an object with respect to time. Motion is typically described in terms of velocity, acceleration, displacement and time. Motion is observed by attaching a body to the frame of reference and measuring its change in position relative to another reference frame.

In MIRCE Science [5], motion is a change in functionability state of a functionable system[2] with respect to time. Motion is typically described in terms of a work done by a system and on a system. Motion is observed by attaching a functionable system to MIRCE Space, as a frame of reference, and measuring its change through probabilities of being in functionability states relative to calendar time.

From MIRCE Space[3] point of view, at any instant of time, a functionable systems can be in one of the following two states:

- Positive Functionability State (PFS) is the state in which a functionable system is able to deliver expected functionality and functionability performance
- Negative Functionability State (NFS) is the state in which a functionable system is not able to deliver expected functionality performance, for whatever reason whatsoever.

The motion of a functionable system through MIRCE Space, in respect to time, is generated by functionability actions, which are classified as:

- Positive Functionability Actions (PFA) are human activities or natural processes that compel the system to return to PFS.
- Negative Functionability Actions (NFA) are natural processes or human activities that compel the system to move NFS.

The motion of a functionable system through MIRCE Space is observed through occurrences of functionability events, which are classified as:

- Positive Functionability Events (PFE) well defined occurrences in time when transitions of functionable systems from NFS to PFS take place.
- Negative Functionability Events (NFE) well defined occurrences in time, when transitions of functionable systems from PFS to NFS take place.

MIRCE Science Equations are mathematical expressions of the motion of functionable systems through MIRCE Space, developed by Knezevic [5]. They enable predictions of the expected work to be done by an operationally defined functional system, together with the resources required, which when converted into monetary values present the expected cost and revenue, from the birth of the system to its retirement.

According to MIRCE Science the probability of a functionable system being in PFS, at a given instant of time t, is defined by the MIRCE Functionability

[5] https://www.nbcnews.com/science/space/space-hurricane-rained-electrons-observed-first-time-rcna328

[2] According to Knezevic [5], a functionable system is "a set of mutually related entities required for delivering work that is considered done when a measurable function is performed."

[3] According to Knezevic [5], MIRCE Space is a conceptual 3-dimensional space containing countably infinite set of possible discrete functionability states that a functionable system could be found in, at any instant of the calendar time, with corresponding probabilities.

Equation [3], which defined the motion of a functionable system through MIRCE Space, thus:

$$y(t) = P(PFS,t) = \sum_{i=1}^{\infty} P(PFS^i,t) = \sum_{i=1}^{\infty}\left[O^{i-1}(t) - F^i(t)\right], t \geq 0 \quad (1)$$

where: is the probability that the time to positive event i (PFE^I) will take place between the birth of a system and a given instant of time t, is the probability that the time to negative event i (NFE^I) will take place between the birth of a system and a given instant of time t.

The positive work done, PW(T), by a given functionable system, presents the amount of time it is expected to be in PFS consuming necessary operational resources (personnel, energy, material, facilities, equipment and similar) during the stated interval of a calendar time T, can be calculated by making a use of the following expression: [1]

$$PW(T) = \int_0^T y(t)dt \qquad [\text{Hr}] \qquad (2)$$

The numerical value of the above expression, when applied to an operationally defined functional system type, presents the amount of time it is expected to be in PFS delivering expected: function, performance and attributes.

Correspondingly, the negative work done, NW(T), on a given functionable system presents the amount of time it is expected to be in NFS consuming necessary maintenance resources (personnel, material, spares, facilities, energy, equipment and similar) during the stated interval of time T, can be calculated by making use of the following expression:

$$NW(T) = \int_0^T n(t)dt \qquad [\text{Hr}] \qquad (3)$$

where. $n(t) = P(NFS,t) = \sum_{i=1}^{\infty}\left[F^i(t) - O^i(t)\right].$

The numerical value of the above expression, when applied to an operationally defined functional system type, presents the amount of time it is expected to be in NFS not delivering expected: function, performance or attributes.

The main objective of MIRCE Science is the scientific understanding of mechanisms that generate positive and negative functionability events. For years, research studies, international conferences, summer schools and other events have been organised in order to explain and draw attentions to just the physical scale at which failure phenomena should be studied and understood. In order to understand the motion of functionability events it is necessary to understand the physical mechanisms that cause their occurrences. That represented a real challenge, as the answers to the question "what are the discrete physical processes or human actions that lead to the occurrence of given functionability events" have to be determined. Without accurate answers to those questions the prediction of their future occurrences is not possible, and without ability to predict the future, the use of the word science becomes inappropriate.

After numerous discussions, studies and trials, it has been concluded that any serious studies in this direction, from MIRCE Science point of view, have to be based between the following two boundaries:

- the "bottom end" of the physical world, which is at the level of the atoms and molecules that exists in the region of 10-10 of a metre,
- the "top end" of the physical world, which is at the level of the solar system that stretches in the physical scale around 10+10 of a metre.

This range is the minimum sufficient "physical scale" which enables scientific understanding of relationships between physical phenomena that take place in natural environment and the physical mechanisms that generate the failures of functionable systems.

3. A few words on Space Weather

The Sun is not a steady-state star. It continuously undergoes changes, which sometimes could be extremely violent. These changes are transferred by the solar wind to the Earth and disturb its magnetic field. Thus, Earth does not float in empty and quiet space, but is immersed in the escaping outer atmosphere of the Sun. This 'solar wind' consists of ionized particles, mostly protons and electrons with a small added mixture of helium ions. The density of solar wind is low, about 10 particles per cubic centimeter. Solar wind also carries the Sun's magnetic field, which at the Earth's orbit has the strength of only a few nT. The wind speed at the Earth's orbit is about 450 km/s or more. On its way the solar wind encounters the Earth's magnetic field, which deflects the particles and shields the Earth from the direct effects of the solar wind.

In the absence of solar wind the geomagnetic field can be approximated by a dipole field with an axis tilted about 11 degrees from the spin axis. The force of the solar wind modifies this field, creating a cavity called the magnetosphere. The boundary between the geomagnetic field and solar wind, the magnetopause, is located at a distance of about 10 Earth's radii from the Earth's centre, but can move closer during high solar activity periods. In the anti-sunward direction, the magnetosphere is extended into a long tail, of the length approximately 80 times of Earth' radii, filled with magnetic field lines that connect to the Polar Regions of the Earth. At the low-altitude limit, the magnetosphere ends at the ionosphere. The magnetosphere is filled with plasma that originates both from the ionosphere and the solar wind. [6]

Solar flares are magnetically initiated explosions that occur at or near the surface of the Sun that release intense bursts of electromagnetic radiation in the form of x-rays, ultraviolet and radio emissions that can cause disruptions to the Earth's ionosphere leading to radio and communications interference.

Geomagnetic storms are large disturbances in the Earth's magnetic field caused by changes in the solar wind and interplanetary magnetic field (IMF) structure. These changes in the solar wind arise from disturbances on the Sun, such as in powerful coronal mass ejections (CMEs). Their effect can be felt for a number of days. With the right magnetic configuration, increases in solar wind speed and density, large amounts of energy can be transferred into the Earth's geomagnetic system. The ability to predict the magnetic orientation of CMEs as they leave the Sun's surface and the time taken to travel to the Earth are key to improving space weather forecasts. [7]

3.1. Arrival Time of Solar storm components

To provide an appreciation of the dynamical characteristics of the Sun's effects on the radiation environment, the differences between the arrival times of each solar storm component is presented below:

- X-Rays and radio waves travel from the Sun at the same speed as visible light, hence they take approximately 8 minutes to reach Earth.
- The speed of protons during solar proton events (SPEs) is dependent on energy level and therefore typically takes between 15 minutes to a few hrs to generate atmospheric and ground level particle enhancements.
- The solar plasma cloud of CMEs takes between 2 and 4 days to impact the Earth's geomagnetic field and generate a geomagnetic storm that may take several days or even weeks to recover.

The Earth's magnetic field or magnetosphere is the first line of protection against energetic primary cosmic rays from space and is composed of electrons plus free ions held in place by magnetic and electric forces. This magnetic field surrounding the Earth acts on incoming charged particles like a shield directing particles below a threshold energy level[6] along the magnetic lines of force towards the Polar Regions.

3.2. Measuring the Impact of Space Weather

Different aspects of space weather have a variety of impacts on mankind and our technology. There are commonly accepted methods for the classification of space weather conditions that are used to communicate the impact on people and functional systems. These are numbered scales similar to those used to describe hurricanes or earthquakes. They describe the level of disturbance and possible impacts for three types of space weather by the following three scales:

- Radio blackouts, R scale that quantifies disturbances of the ionosphere caused by X-ray emissions from the Sun
- Geomagnetic storms, G scale that quantifies disturbances in the geomagnetic field caused by gusts in the solar wind that blows by Earth
- Solar radiation storms, S scale that signifies elevated levels of radiation that occur when the numbers of energetic particles increase

Each scale provides lists of possible effects seen with each category of activity, the physical measure that determines the category of an event, and a climatological assessment that explains how often it can be expected to see events of each magnitude during a solar cycle.

The level of impact is dependent on the technological systems in service that vary widely across the globe. For example, the UK power grid has much shorter and more highly connected transmission lines than those in North America so it is less susceptible to space weather.

3.3. Example of the Impact of Space Weather on Spacecraft

Japan's spacecraft, Nozomi[4] was planned to enter a highly elliptical orbit around Mars on 11th October 1999. Its mission was to conduct long-term investigations of the planet's upper atmosphere and its interactions with the solar wind, as well as, to track the escape trajectories of oxygen molecules from Mars' thin atmosphere. Also, it should have taken pictures of the planet and its moons from its operational orbit of 300×47,500 km. During perigee, Nozomi would have performed remote sensing of the atmosphere and surface. While close to apogee, the spacecraft would have studied ions and neutral gas escaping from the planet. Although designed and

[4] Nozomi (Japanese word for "Wish" or "Hope,") was orbiter that failed to reach Mars due to electrical failures. The mission was terminated on December 31, 2003.

built by Japan, the spacecraft carried a set of 14 instruments from Japan, Canada, Germany, Sweden and the United States.

After entering an elliptical parking orbit around Earth at 340×400,000 km, Nozomi was sent on an interplanetary trajectory that involved two gravity-assist flybys of the Moon on 24 September 1998 and 24 December 1998, at 2,809 km. It also did a flyby of Earth on 20 December 1998, at about 1,003 km. The gravitational assist from Earth as well as a seven-minute engine burn put Nozomi on an escape trajectory toward Mars. However, a faulty valve resulted in loss of propellant, leaving the spacecraft with insufficient acceleration to reach its nominal trajectory. Subsequently, because two midcourse corrections on 21 December used more propellant than expected, Nozomi's originally planned mission had to be completely reconfigured. Ground controllers commanded lower thrust attitude control thrusters to fire to ensure that Nozomi would not impact onto the Martian surface, which would have been a problem since the spacecraft had not been sterilised.

The new plan involved four additional years in heliocentric orbit, during which time it would conduct two more Earth flybys, in December 2002 and June 2003, leading to a Mars encounter in December 2003, four years later than originally planned.

On 21 April 2002, while heading toward Earth, powerful solar flares damaged Nozomi's communications and power systems, causing the hydrazine to freeze in the vehicle's attitude control system, but the spacecraft was recovered. Contact with the spacecraft was lost on 15 May, but controllers found the spacecraft's beacon, two months later. However, mission scientists were able to thaw the frozen fuel as the spacecraft approached Earth and the flybys were accomplished as intended: on 21 December 2002, at a range of about 29,510 km and once again on 19 June 2003, at a range of about 11,023 km.

As the spacecraft approached Mars in 2003 a series of intense solar flares damaged a power control circuit (current switch). The subject current switch-controlled power to both a telemetry modulator and the heaters for the main propulsion fuel tanks. What seemed to be an efficient design feature, one switch handles two functions, really exposed the spacecraft to a single point failure Switch failure was unrecoverable after 1000 power cycles Propellant for the main engines freezes solid. Soon after, the spacecraft's luck finally ran out. On 9 December 2003, in anticipation of the Mars orbit insertion planned for five days later, the main thruster failed, essentially ending the mission. Ground controllers commanded lower thrust attitude control thrusters to fire to ensure that Nozomi would not impact onto the Martian surface, as the spacecraft had not been sterilised. Japan Aerospace Exploration Agency (JAXA) engineers abandon Mars orbital insertion, adjust orbit to avoid collision with Mars using still operable attitude control jets. On 14 December 2003 Nozomi sailed past Mars at a range of about 1,000 km and into oblivion. Despite not accomplishing its primary mission, Nozomi provided important data from its suite of scientific instruments.

4. Mechanics of Space Hurricanes formation

A space hurricane is a form of environmental phenomenon where instead of wind and rain, charged electrons and plasma make up the majority of the storm. Until now, it was thought to be a theoretical event, but four satellites passing over the North Pole detected the space hurricane. Scientists at the Shandong University in China were the first to observe and record this real space hurricane event. [4] The authors of the academic paper reported that the hurricane was very much like a typical terrestrial hurricane in shape. It was shaped like a funnel with a quiet 'eye' at the centre surrounded by large amounts of plasma arms spinning counter-clockwise. The space hurricane rained down electrons into the Earth's upper atmosphere.

The space hurricane was characterised by a cyclone-like auroral spot with multiple spiral arms, due to precipitating electrons, strong circular plasma vorticity with zero horizontal flow at its centre, a negative-to-positive bipolar magnetic structure and a large and rapid deposition of energy and flux into the polar ionosphere. The storm extended from the Ionosphere upward along geomagnetic field lines to cover a large fraction of the dayside polar magnetosphere, in the Northern Hemisphere.

Additionally, the space hurricane had multiple spiral arms, similar to conventional hurricanes, and the storm also rotated in a counterclockwise direction. The large plasma storm rained electrons instead of water. In the calm central region, encircled by the rotating plasma, there was a persistent auroral spot, associated with a strong, upward, field-aligned current caused by precipitating electrons. The electron rain produced a gigantic, cyclone-shaped aurora below.

4.1. Plasma as a state of a matter

Plasma[5] is a state of matter that is often thought of as a subset of gases, but the two states behave very differently. Like gases, plasmas have no fixed shape or volume, and are less dense than solids or liquids. However, unlike ordinary gases, plasmas are made up of atoms in which some or all of the electrons have been stripped away and positively charged nuclei, called ions, roam freely. [11]

A gas is made of neutral molecules and atoms, which means that number of negatively charged electrons equals the number of positively charged protons. However, atoms or molecules can acquire a positive or negative electrical charge when they gain or lose electrons. This process is known as ionisation. Plasma that makes up the sun and stars, is the most common state of matter in the universe as a whole.

4.2. Charged particles

A typical gas, such as nitrogen or hydrogen sulphide, is made of molecules that have a net charge of zero, giving the gas volume as a whole a net charge of zero. Plasmas, being made of charged particles, may have a net charge of zero over their whole volume but not at the level of individual particles. That means the electrostatic forces between the particles in the plasma become significant, as well as the effect of magnetic fields. Being made of charged particles, plasmas can do things gases cannot, like conduct electricity. And since moving charges make magnetic fields, plasmas also can have them. [9]

In an ordinary gas, all the particles behave in the similar way. Hence, all the molecules of gas inside a container, let to cool to room temperature, on average, are moving at the same speed. If the speed of individual particles is measured a distribution curve obtained would show that lots of them moving near the average and only a few either exceptionally slowly or quickly. That is because in a gas the molecules hit each other and transfer energy between them. However, that doesn't happen in plasma, especially in an electric or magnetic field. A magnetic field can create a population of very fast particles. Most plasmas aren't dense enough for particles to collide with one another very often, so the magnetic and electrostatic interactions become more important.

Speaking of electrostatic interactions, because particles in plasma, electrons and ions, can interact via electricity and magnetism, they can do so at far greater distances than an ordinary gas. That in turn means waves become more important when discussing what goes on in plasma. One such wave is called an Alfvén wave[6], which happens when the magnetic field in plasma is disturbed, creating a wave that travels along the field lines. There is no[7] real analogy to this in ordinary gases. It is possible that Alfvén waves are the reason the temperature of the solar corona, also a plasma, is millions of degrees, while on the surface, it is only thousands.

Another characteristic of plasmas is that they can be held in place by magnetic fields. Most fusion power research is focused on doing just that. To create the conditions for fusion, one needs very hot plasma, at millions of degrees. Since no material can contain it, scientists and engineers have turned to magnetic fields to do the job. A newly patented device could use heated, ionised air to stop shock waves generated by explosions.

Plasma is in the auroras that surround the poles when the sun is particularly active. The solar wind is a stream of charged particles, mostly protons, which hit Earth's magnetic field. Those particles, being charged, follow magnetic field lines and move toward the poles, where they collide with and excite atoms in the air, mostly oxygen and nitrogen and give off light.

5. Potential Impacts of charged particles on Spacecraft Electronics

Spacecraft systems are vulnerable to space weather due to its influence on energetic charged particle and plasma populations, while aircraft electronics and aircrew are vulnerable to cosmic rays and solar particle events. These particles produce a variety of effects including total dose, lattice displacement damage, single event effects (SEE), noise in sensors and spacecraft charging. Examples of all the above effects are given from observed spacecraft anomalies or on-board dosimetry and these demonstrate the need for increased understanding and prediction accuracy for space weather, especially space hurricanes.

5.1. Single Event Effects

Charged particles reach the Earth’s atmosphere from all directions. These charged particles, with high energy, are called cosmic rays. When a single particle (neutron, proton or other heavy ion) interacts with the atoms that makeup a semiconductor contained within the electronic component of functionable systems containing them the phenomenon Single Event Effects (SEE) occur. It has been the primary radiation concern for avionics since the late 1980’s when the space weather phenomenon, which had previously only been observed in orbiting satellites, also began to appear in aircraft electronic systems. [10]

The principal SEE affecting avionics devices is the Single Event Upset (SEU) caused when a sole incident particle creates a charge disturbance of sufficient

[5] Jesse Emspak - Live Science Contributor May 05, 2016

[6] Named after Swedish physicist Hannes Alfvén (1908-1995), who received a Nobel Prize in 1970 for his work on magnetohydrodynamics.

magnitude in a memory cell, flip-flop, latch or register to reverse or flip its currently stored data state. Alternatively, in logic or support circuitry a transient voltage pulse can be generated that's dependent on the right conditions can propagate through the logic of the device and become latched into a memory cell. Voltage spikes on power supply lines and noise can also cause transient errors; however appropriate shielding and filtering design measures can suppress these types of disturbances.

Radiation can affect electronic devices as the consequence of a single energetic particle strike, termed 'single event' or as multiple strikes over an extended period of time. The effects due to multiple events, Total Ionisation Dose (TID) and displacement damage manifest gradually in electronic components as damage is accumulated over time. These total dose effects and hard SEEs whilst relevant to electronic systems operating in the harsher space environment have a negligible effect on current semiconductor devices used in the terrestrial environment.

5.2. Multiple Bit Upset

The second most prevalent SEE is the Multiple Bit Upset (MBU) that occurs when a single particle causes the upset of two or more memory cells. However, MBUs only form a fraction of the total number of SEUs, hence they have little significance except for memory architectures employing Error Detection and Correction (EDAC) techniques. In these circumstances, dependent on the type of error correction technique employed, multiple bit errors could have significant consequences if the protected memory is used for flight or mission critical applications. MBUs are generally assumed to attribute 3% of the total upset rate although rates as high as 5% have been reported. [13]

5.3. Single Event Functional Interrupt

Following MBU, Single Event Functional Interrupt (SEFI) and Single Event Latch ups (SEL) account for the majority of the remaining proportion of SEEs affecting avionics devices. SEFIs occur when an upset initiate an IC test mode or reset mode that causes the device to temporary loose functionality. SELs arise when an incident particle creates a charge disruption sufficient enough to effectively short circuit the device resulting in its permanent change of state or in some circumstances permanent damage if excessive current flows as a result of the latch-up.

5.4. Single Event Transient

The last SEE of avionics relevance that can generate soft errors in the core logic of microprocessors and microcontrollers is the Single Event Transient (SET). They are transient and non-destructive in nature and are capable of producing a soft error, (i.e. the storage of an erroneous data value in registers, memories or latches) only if it is propagated through the logic pathways of the device. This is dependent on the dynamic state of the logic at the time of the particle induced nodal voltage transition and the configuration of the logic pathways within the device. If a soft error occurs resetting or rewriting the incorrect data can restore normal system behaviour. [8]

6. Future Research

In order to create a SEE functionability prediction model, further research is required to understand the complex interactions involving the transport of incident particles through the spacecraft structure. This must also include the consequential device, circuit and the system level propagation mechanism(s) initiated by charge depositing particles and plasma.

Future work should therefore consist of two main objectives; the first should be to develop an SEE functionability prediction model, whilst incorporating as many of the issues highlighted in this paper, as practical. The second should be to use the model to investigate the impact of space weather, especially space hurricane, on the resultant distribution shape of SEE initiated NFE through time.

The end goal is to create an innovative SEE functionability prediction model that will enable the future behaviour of a spacecraft avionics system to be predicted for a whole host of different external parameters such as the extremes of space weather or space hurricanes. Furthermore, the model should allow system designers the flexibility to examine the full range of system design options such as device selection, system configuration and SEE reduction solutions to allow early functionability improving design decisions to be made.

As the future probabilities of SEE initiated NFEs are a function of time, simulation methods will be an essential element in the development of an SEE functionability prediction model that would be able to take advantages of the MIRCE Functionability Equations presented above. Each physical process from the generation of cosmic ray particles to the manifestation of an SEU initiated NFE, at the system level, has its own probabilistic shape dependent on the laws of physical causality and the magnitude of key input variables from the natural and human world. To solve the complex interactions between each process and to determine the influence each factor has on the functionability trajectory of a spacecraft through MIRCE Space a model of the complete avionics system should be the ultimate objective of the future research

7. Conclusions

The main objective of this paper is to draw attention to the recently discovered phenomenon in the space that was named as "space hurricane" and to analyse its impact on the motion of a spacecraft through MIRCE Space.

Potential impacts of this new cosmic phenomenon on the motion of functionable systems through MIRCE Space and the consequences on functionability performances are examined and presented in this paper.

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