PROJECT FINAL REPORT

Grant Agreement number: 262468

Project acronym: SPACECAST

Project title: Protecting space assets from high energy particles by developing European dynamic modelling and forecasting capabilities

Funding Scheme: Seventh Framework Programme [Space]

Period covered: 01/03/2011 to 28/02/2014

Name, title and organisation of the scientific representative of the project's coordinator:

Professor Richard Horne,

British Antarctic Survey,

Natural Environment Research Council

Tel: +44 1223 221542

Fax: + 44 1223 362616

E-mail: R.Horne@bas.ac.uk

Project website address: **http://www.fp7-spacecast.eu**

CONTENTS

Final Publishable Report 2
Executive summary 3
Summary description of project context and objectives 4
Science and Technology Results 6
Forecasting high energy electrons 6
Nowcast of medium energy electrons 7
Real time radiation dose rate 8
Scientific highlights 8
Dissemination and Stakeholders engagement 14
Impact 16
Project References 17
Use and dissemination of foreground 19
Section A 19
Section B 42
Report on societal implications 43

EXECUTIVE SUMMARY

Space weather poses a serious threat to satellites on orbit. Radiation exposure to particles from the Sun and the Earth's radiation belts have been linked to service outages and in exceptional cases total satellite loss. In 2003, ten percent of the entire satellite fleet malfunctioned during a major geomagnetic storm caused by space weather. Since then, the number of operational satellites has risen from 450 to over 1000. Better designs have been introduced, but service outages associated with space weather still occur.

Europe plays a major role in the design, construction and launch of satellites, and the provision of satellite services. The EU is deploying the Galileo radio-navigation system consisting of 30 satellites and has an extensive Earth observation programme called Copernicus. As Europe has a major investment in space it is essential that it develops the means to protect it. In this context, the SPACECAST project was set up to help protect spacecraft from high energy particles from the Sun and the Earth's radiation belts by developing European models to analyse and forecast periods of high risk.

SPACECAST has delivered the first European system to forecast high energy charged particle radiation in the Earth's outer radiation belt, and a "nowcast" of medium energy electrons and radiation dose. The forecasts are provided freely via the web (www.fp7-spacecast.eu) and are updated every hour automatically. The system has three unique features: First, it uses state-of-the-art models that include the physics of wave-particle interactions. Second, the forecasts cover the whole of the outer radiation belt and include satellites in medium and geosynchronous orbits. Third, it is a truly international collaboration using satellite and ground based data from the USA, Antarctica, Europe and Japan, and a network European modelling centres. To help users interpret the forecasts they are also presented in the form of a risk index for internal satellite charging, surface charging and radiation dose.

The forecasts are primarily for satellite operators, although designers and space insurance underwriters can also use the system. However, European citizens benefit from the results of SPACECAST via better forecasting of satellite risk of damage, an improved delivery of satellite services, a more competitive space industry from the knowledge gained, and new research which will lay the foundation for future applications.

SPACECAST has delivered major pieces of scientific research. The highlights include:

- Demonstrating that electron acceleration by wave-particle interactions is a key process that helps forms the outer radiation belt
- Developing better forecasting models as a result of including wave-particle interactions
- Modelling how electrons can be transported to geosynchronous orbit by time dependent electric field
- Showing how electrons loss from the radiation belts into the atmosphere is controlled by geomagnetic activity
- Developing an innovative idea to measure electron transport across the magnetic field which shows how transport increases with geomagnetic activity
- Developing a semi-empirical model for particle acceleration by shock waves near the Sun
- Conducting detailed modeling of solar energetic particle events for use in future prediction models

The SPACECAST project team has developed a network of stakeholders including satellite operators, designers, and insurance underwriters. Team members provided briefings for policy makers, NATO MPs, the UK House of Commons, and evidence for the UK Government on space weather. They also appeared on BBC2 TV "Stargazing Live - Back to Earth", gave an interview for a Swedish TV documentary, a radio interview for the BBC World Service, participated in a podcast, issued three press releases, and the project results were covered by numerous newspaper and magazine articles. One press release in 2012 on the forecasting system led to 46 different press reports world-wide. Team members published 30 peer reviewed papers and gave numerous presentations at international conferences. They organised stakeholder discussion meetings with the European Space Agency each year at the European Space Weather Week.

Our modern society depends heavily on satellites and other space assets for a wide range of applications. These applications include communications such as mobile phones, television, and internet access. Satellites also provide accurate timing signals used for navigation in cars, ships and aircraft, as well as Earth observation which is used for agriculture, weather forecasting, security and defence, and many other areas. Over the last ten years satellite services have transformed business and have led to new innovations and economic growth [SIA, 2012]. For example, GPS timing signals are an essential part of high frequency trading on the London and New York stock markets, and are also used in agriculture to help farmers save fuel and fertiliser and hence reduce the chemical impact on the environment. The use of satellite services has also led to dependencies between different sectors of the economy in ways which were unforeseen.

Europe has always played a major role in the design, construction and launch of satellites, and the services that they provide. Two of the biggest satellite operators in the world (SES and Intelsat) are European; together they operate over 100 satellites. One of the major launch providers (Arianespace) is also European. Most of the financing of satellites for launch and in-orbit insurance is done through European financial centres. Europe is also deploying in the Galileo radio-navigation system consisting of 30 satellites and has an extensive Earth observation programme called Copernicus. To put this into context, the cost of a modern telecommunications satellite is around €200m to build and €80 – €100m to launch into geosynchronous orbit. With more than 380 operational satellites at geosynchronous orbit (more than 1,000 operational satellites on orbit altogether) and revenue of €65 billion a year from satellite TV alone [SIA, 2012] space is tremendously important. As Europe has a major share in this investment, it is essential that it develops the means to protect it.

Space weather poses a serious threat to satellites on orbit. Radiation exposure to particles from the Sun and the Earth's radiation belts have been linked to service outages and in exceptional cases total satellite loss. In 2003 ten percent of the entire satellite fleet malfunctioned during a major geomagnetic storm caused by space weather. Despite advances in design service outages still occur. For example, in 2012 three satellites suffered a service outage for a few hours to a few days during a large geomagnetic storm and solar energetic particle event. The problems encountered included electrostatic charging, loss of solar array power and disruption to electronic memory circuits, all of which are classical signatures of space weather events. In July 2012 the Sun emitted one of the largest coronal mass ejections on record which was recorded by the STEREO spacecraft. Fortunately the CME did not come towards the Earth but if it had, it could have triggered an event as large as the 1859 Carrington event with major consequences. In the UK the Government takes the risk seriously and has put severe space weather on the National Risk Register of Civil Emergencies with the same relative impact score as heat waves and heavy snow.

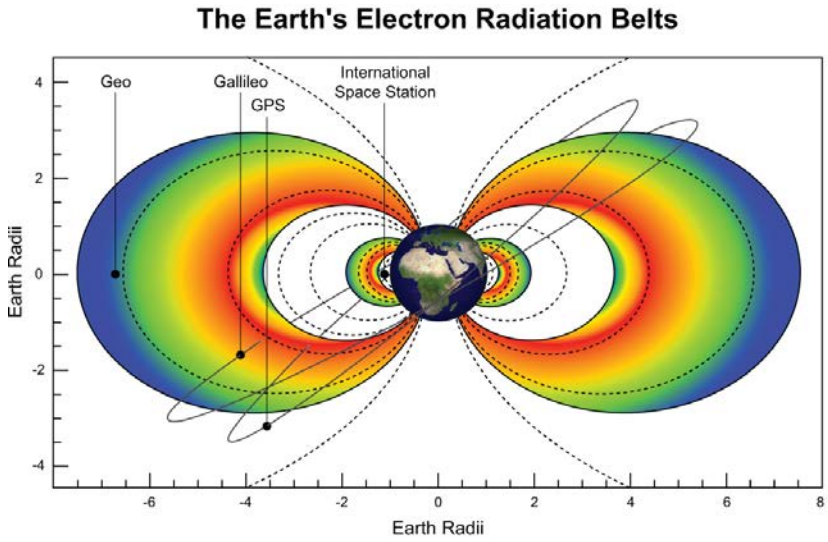

Figure 1. Satellite orbits in relation to the Earth's electron radiation belts. Satellites in geosynchronous, medium and elliptic orbits pass through the radiation belts. Those in low Earth orbit encounter the radiation belts at high latitudes.

Satellites are launched into four types of orbits (see Figure 1). Most telecommunications satellites are in geosynchronous orbit (GEO) which is about 36,000 km above the surface of the Earth. They maintain their position in longitude so that they are always in contact with a fixed point on the ground. Most Earth observation satellites, and the international space station, are in low Earth orbit (LEO) which lies between 400 and 1000 km. These satellites may take something like 90 minutes to orbit the Earth. Between these two orbits is medium Earth orbit (MEO) where most of the navigation and positioning satellites are located. The new Galileo radio-navigation satellites are in medium Earth orbit with an orbital period of approximately 14 hours. In addition to these orbits there are a few satellites in highly elliptic orbits (HEO) which are specially designed to maximize coverage over the high latitude and Polar Regions. Satellites in all these orbits (except low inclination LEO) pass through the Earth's van Allen radiation belts where particle radiation levels are severe and can increase rapidly due to space weather. Similarly, solar eruptions can cause a rapid increase in energetic particles which penetrate the Earth's magnetic field and cause damage to satellites in all orbits. These events are very difficult to predict and require more research to understand.

The goal of the SPACECAST project is to help protect space assets from high energy particles in the electron radiation belts and in solar energetic particle (SEP) events by developing European dynamic modelling and forecasting capabilities. The project addresses two of the most important radiation hazards for space vehicles and manned spacecraft. To achieve this goal the objectives of the SPACECAST project were:

- To forecast changes in the Earth's electron radiation belts in near real time using a suite of physics based research models and near real time data
- To provide warnings and alerts to stakeholders based on dynamic radiation belt forecasts
- To improve understanding of the key processes responsible for dynamic variations in the radiation belts, and improve our ability to represent these processes in forecasting models
- To test model predictions of solar energetic particle events at 1AU against data, and improve SEP event modelling
- To develop understanding of how SEPs are accelerated at interplanetary shocks driven by coronal mass ejections and their storage in the plasma turbulent region ahead of the shock
- To provide a legacy of tools, skills and understanding that will last long after the completion of the SPACECAST project.

The SPACECAST project began on the 1st March 2011 and ended on 28 Feb 2014. The project made major advances in three main areas

- Forecasting space weather
- Scientific research
- Dissemination and stakeholder engagement.

FORECASTING HIGH ENERGY ELECTRONS

For satellites on orbit one of the most important hazards is internal charging cause by high energy electrons at energies of a few hundred to several million electron Volts (eV). These electrons are trapped inside the Earth's magnetic field in the Van Allen radiation belts (see Figure 1). During space weather events the flux of these electrons can change by five orders of magnitude causing internal satellite charging, electrostatic discharge and permanent damage to electronic components. Several types of satellite anomalies have been related to electrostatic discharges and in some exceptional cases they have caused total satellite loss.

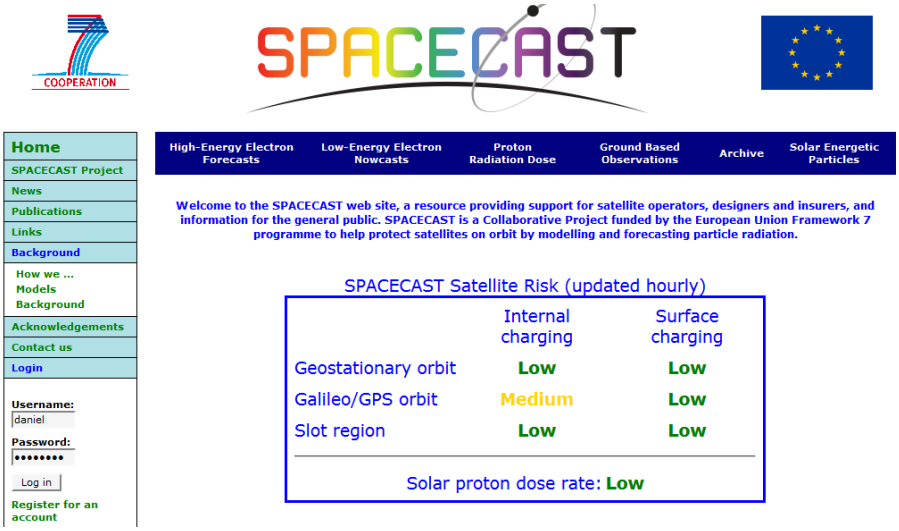

Figure 2. An example of satellite risk taken from the SPACECAST web site (www.fp7-spacecast.eu).

One of the major achievements of the SPACECAST project is to provide the first European system to forecast high energy charged particle radiation in the Earth's outer radiation belt [Horne, 2012; Horne et al., 2013]. The system uses a forecast of geomagnetic activity to drive two independent computer models, one in France and one in the UK. The models compute the electron flux and the 24 hour electron fluence at selected energies and present a forecast of up to 3 hours ahead. The forecasts are updated every hour automatically. To help users interpret the forecasts they are also presented in the form of a risk index (red, amber, and green – see Figure 2) for internal satellite charging and surface charging, for different orbit types. The forecasts are primarily for satellite operators, although satellite designers and space insurance underwriters are also known to use the system, and more technical information is also provided for scientists and engineers. The system was released after the first year of the project, in March 2012, and has been operating ever since. A major upgrade of the forecasting models was made in 2014 after input from the research studies described below.

The SPACECAST forecasting system has three unique features. First, it uses physics based models to make the forecasts which include the physics of wave-particle interactions (described below). Second, it makes a forecast of radiation levels for the whole of the outer radiation belt which includes satellites in medium and geosynchronous orbits, and third it is a truly international collaboration using satellite and ground based data from the USA, Europe and Japan, and a network European modelling centres.

One of the new innovations is to use a forecast geomagnetic activity derived from the ACE satellite to drive the forecasting models. ACE is located between the Sun and the Earth at the L1 position and measures the polarity of the interplanetary magnetic field which is essential for forecasting the severity of magnetic storms and the intensity of the radiation belts. Since it takes 30 to 60 minutes for the solar wind to reach the Earth from the ACE spacecraft this enables us to forecast ahead. In fact the time for the radiation belts to respond to the solar wind can be much longer than this, which is why the forecasting could be extended up to 3 hours ahead and possibly longer. The use of ACE data has helped to reduce false alarms. When ACE data is not available the system uses a forecast of geomagnetic activity derived from ground based magnetic observatories.

In the forecasting system satellite and ground based data are collected from sites in Sweden, Germany, Japan, UK and the USA by a system managed by a small company in Belgium. The data are used to drive the forecasting models at distributed sites and the results exported back to Belgium where they are displayed on the SPACECAST web site (see www.fp7-spacecast-eu). Supporting data from satellites in the solar wind and magnetosphere and ground based data from the Antarctic and are also displayed on the web site to help verify the forecasts and aid scientific interpretation. The feedback from one satellite engineer – unrelated to the project - was “the web site is an order of magnitude (maybe several) more sophisticated than the NOAA SEC one”.

The forecasting models used in the SPACECAST system are state-of-the-art physics based models. They are analogous to general circulation models used in climate research. They solve a diffusion equation that includes electron transport across the magnetic field, electron acceleration due to wave-particle interactions, losses to the atmosphere and losses to the outer boundary of the geomagnetic field.

The SPACECAST forecasting system has proved to be very robust. In March 2012 there was a large space weather event consisting of a geomagnetic storm and solar energetic particle event. During this event data from the ACE and GOES satellites, which are two of the primary satellites used to monitor space weather, became unreliable. GOES in particular was showing an exceptionally high electron flux which was contaminated by solar energetic particles. In contrast, the SPACECAST system continued to provide electron forecasts throughout the period [Horne et al., 2013]. The resilience of the SPACECAST system is due to its ability to switch between different sources of data to drive the forecasting models, and the distributed nature of the modelling centres so that the service can continue even if one of the links goes down.

NOWCAST OF MEDIUM ENERGY ELECTRONS

While high energy electrons at energies of a few hundred to several MeV cause internal satellite charging medium energy electrons, typically 1- 100 keV, are known to cause surface charging. Surface charging can also cause an electrostatic discharge, loss of solar array power, uncontrolled phantom commands and many other types of unwanted behavior. Surface charging is a particular hazard when there is a large increase in medium energy electrons which often occurs near local midnight and early morning at geosynchronous orbit. It is a particular hazard when satellites go into eclipse in March and September each year as this reduces photo-emission and the satellite can charge positive to very high levels, as high as several kV.

It is not possible to provide a forecast of medium energy electrons that cause surface charging since the basic science governing the timing and transport of these electrons is not understood and since there are a very limited number of measurements. Instead of a forecast, the SPACECAST project provides a “nowcast” of the electron flux in the energy range 40 – 150 keV based on a sophisticated electron transport model. A nowcast is very valuable since the flux of electrons can vary spatially and well as temporally, so that at a given time the electron flux along the geostationary orbit can vary by orders of magnitude depending on position.

The model that produces the nowcast is called IMPTAM [Ganushkina et al., 2013] and uses data on the solar wind to define the source population of medium energy electrons and to drive the model [Amariutei and Ganushkina, 2012]. The source population resides beyond geosynchronous orbit on the night side of the Earth. The model takes into account the solar wind interaction with the geomagnetic field to transport electrons from the source inwards

towards the Earth. The model calculates the differential electron flux at midnight for a range of orbits between approximately 2 and 7 Earth radii from the planet.

Comparisons between the IMPTAM model and the few satellites that do measure low energy electrons showed a correlation between satellite charging and periods of high electron flux, and that these events in space are related to magnetic field disturbances measured on the ground in the Antarctic. Again, the nowcast model works automatically and is updated every hour. Although there is a reasonable agreement between the model and data there is still more work to do to capture all the variability for very disturbed conditions. These studies offer very exciting new opportunities for satellite operators and scientists to work together.

REAL TIME RADIATION DOSE RATE

A third important step forward has been the real time calculation of the radiation dose rate at geostationary orbit due to solar energetic particles. Usually the dose is accumulated gradually but during a solar energetic particle event the dose rate can rise significantly for a period of a few days or more causing an increase in the number of single event upsets in electronic components. Radiation dose is one of the key factors that limit the operational life of satellites on orbit and must be carefully assessed at design stage. For a satellite with a design life of 15 years or more one of the major uncertainties is planning the number of solar energetic particle events that might take place and monitoring the accumulated dose.

During the project a new tool called Dosetool was developed to compute the radiation dose at different depths in various materials and for different thicknesses of shielding. The incident particles are assumed to be protons and are assumed to travel in a straight line in any material. The tool computes the dose [rad] and dose rate [rad/s] for 74 different materials for two shielding configurations; planar and spherical. The tool also enables the analysis of synthetic SEP events which are available from the SOLPENCO tool for more detailed event analysis.

A near-real time calculation of radiation dose rate was implemented on the SPACECAST web site. By using proton differential intensities measured by the GOES spacecraft at GEO orbit the dose rate is calculated by assuming a spherical shielding of 2mm of Aluminium for a silicon target, which is a typical value for geosynchronous orbit. The results are displayed on the SPACECAST web site and provide an immediate awareness of the hazard for satellite operators.

SCIENTIFIC HIGHLIGHTS

ACCELERATION AND LOSS BY WAVE-PARTICLE INTERACTIONS

Two of the major scientific problems in radiation belt physics are to understand how electrons are accelerated to very high energies to form the radiation belts, and what controls the variability of the radiation belts. Over the last few years it has been established that various types of very low frequency plasma waves can cause electron acceleration to very high energies. One of the major advances in the SPACECAST project was to include wave-particle interactions into a global model of the radiation belts and demonstrate that a particular type of electromagnetic waves, known as chorus waves, can accelerate electrons up to several MeV in energy. The results show that acceleration occurs mainly inside geostationary orbit.

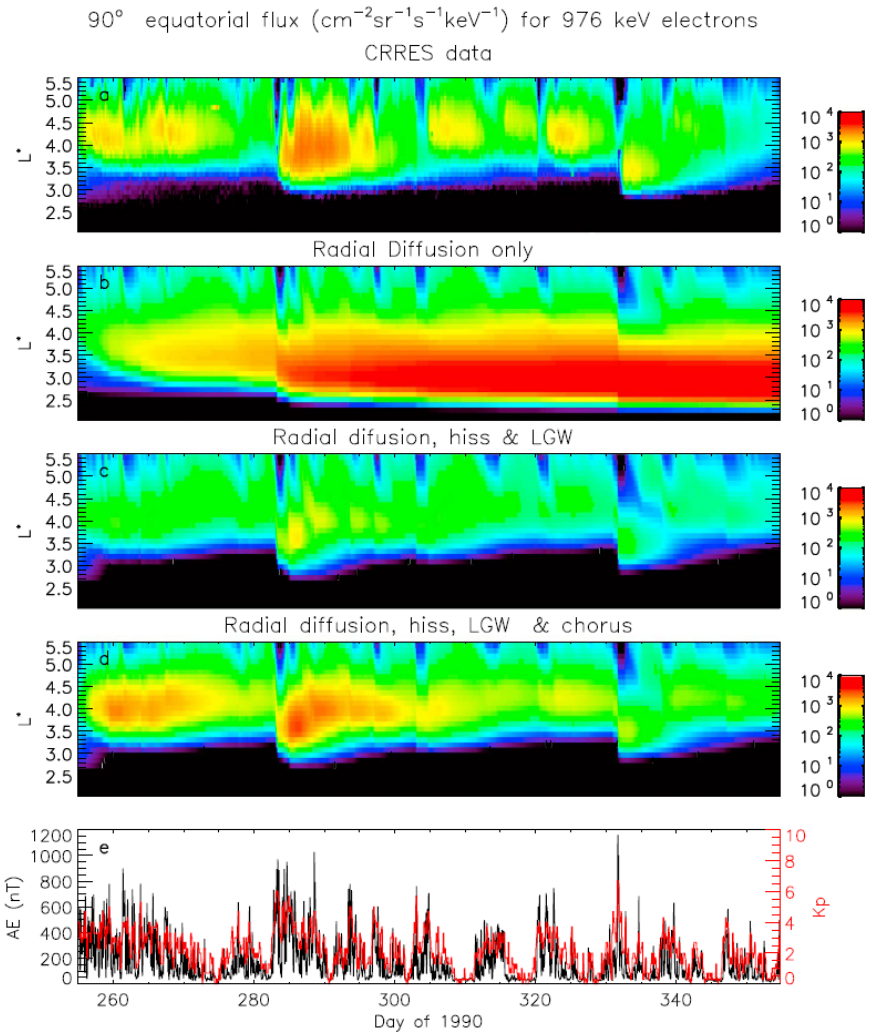

Figure 3. Comparison between electron data from the CRRES satellite (top panel) and three simulations. The best results are when wave-particle interactions are included (panel d). Geomagnetic activity is shown at the bottom.

Figure 3 shows a set of comparisons between satellite data and the computer model. The top panel (a) shows electron data from the CRRES satellite at an energy of 0.976 MeV for a period of 100 days or so in 1990. When the model was run using only radial transport the second panel (b) shows that there is very poor agreement between the model and the data and the model flux is too high. By including various types of plasma waves the third panel (c) shows that there is a much better agreement with the data but the peaks in the electron flux (red) are not well reproduced. The model showed that these waves contribute to electron loss into the atmosphere. When wave-particle interactions due to chorus waves are included the fourth panel (d) shows that there is a much better agreement between the model and data. The results show that chorus waves cause electron acceleration on a global scale. More generally, the variability of the radiation belts is better reproduced when wave-particle interactions are included [Glauert et al., 2014]. The results of this study were used to improve the forecasting models substantially in 2014.

Another major development in the research models was to study the rapid drop in the electron flux that is often observed during geomagnetic storms. By using data on the solar wind dynamic pressure and polarity of the interplanetary magnetic field, changes in the outer boundary of the Earth's magnetic field were incorporated into the research models. These studies showed that when the outer boundary moved inwards towards the Earth there was an increased outward transport of electrons and a rapid reduction in the radiation belt flux. In effect, the losses in the radiation belts were taking place at the outer boundary of the magnetic field. Again, this effect has been included into the forecasting models in 2014.

TRANSPORT OF MEDIUM ENERGY ELECTRONS

Time dependent changes in the Earth's magnetic field and corresponding induced electric fields are very important factors controlling the transport of medium energy (1 – 100 keV) electrons inside the magnetosphere. These time dependent fields are triggered suddenly by the solar wind interaction with the magnetosphere (a substorm), but how this is done, and the spatial and temporal scales over which it occurs are major scientific questions.

A series of studies were conducted using the IMPTAM model to assess the importance of the electric and magnetic fields. Using data on the interplanetary magnetic field and solar wind to drive the model [Amariutei and Ganushkina, 2012], the model could transport electrons for the outer region of the magnetosphere at 10 Re on the night side of the Earth to geostationary orbit. However, the flux was found to be substantially lower than that observed suggesting that improved boundary conditions are required. It was also found that the results were more sensitive to the choice of magnetic field model than the large scale electric field models [Ganushkina et al., 2013]. A series of electromagnetic pulses were also applied to the model to represent the effects of a substorm. These pulses resulting in a rapid change in the electron flux near geosynchronous orbit, but it was found that more work is required to match the timing and the magnitude of the flux observed by spacecraft [Ganushkina et al., 2014]. As a result of these studies a scaling of the source population was implemented and used to improve the nowcast model in 2014.

WAVE-PARTICLE INTERACTIONS

Wave particle interactions play a key role in radiation belt dynamics. They lead to particle heating and acceleration in the radiation belts and also particle scattering in direction (pitch angle) leading to loss from the radiation belts into the atmosphere. Dynamic global models of the radiation belts are diffusion models and require diffusion rates that depend on wave properties. Since wave properties can vary significantly with spatial location and geomagnetic activity the state of the art is to develop global models of the wave power for the various relevant wave modes using data from several satellites. Several types of plasma waves were studied in the SPACECAST project as described below.

WAVE DATABASE

In order to analyse wave data for research studies and use it in the forecasting models a comprehensive database of plasma waves in the inner magnetosphere was developed. Data from seven scientific satellites were obtained and used to extend the coverage and improve the statistics of existing models. Data from each of the satellites was combined and weighting by the number of samples to produce a database of the wave power as a function of frequency band, L*, magnetic local time (MLT), magnetic latitude λm, geomagnetic activity as measured by the AE and Kp indices, and location with respect to the plasmapause. Details of the instrumentation, data analysis techniques and binning method are described in detail in Meredith et al. [2012].

CHORUS WAVES

Chorus waves play a major role in the formation of the outer radiation belt by accelerating electrons to MeV energies. Under certain conditions they deplete the radiation belts by contributing to electron loss into the atmosphere. They are a special type of circularly polarised waves at frequencies of typically a few kHz, below the electron cyclotron frequency. The global distribution of these waves and how they change with space weather are essential for better forecasting of the radiation belts.

The wave database was used to determine the global distribution of chorus as a function of geomagnetic activity, magnetic local time, latitude and radial extent. The waves were split into an upper and lower frequency band as these waves had very different distributions. Figure 4 (middle panel) shows that in the equatorial region lower band chorus was most intense between 23:00 and 12:00 magnetic local time (MLT). In contrast, upper band chorus (right panel) is weaker and less extensive and is found between 00:00 and 11:00 MLT. The distributions at higher latitudes were somewhat different. At mid-latitudes lower-band chorus is restricted to the dayside and no significant upper band chorus wave power is observed at mid to high latitudes [Meredith et al., 2012]. While the magnetic local time

distribution of the waves is reasonably well understood it is still not clear why there is such a difference between waves observed near the equator and higher latitudes, and what controls the radial distribution of the waves.

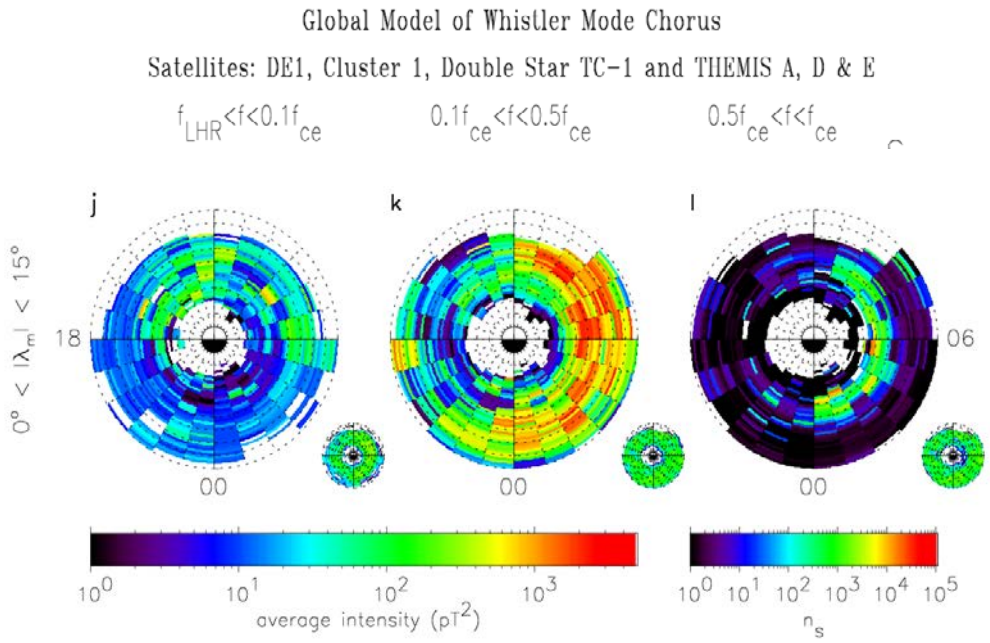

Figure 4. Average wave intensities for chorus waves around the Earth. The Earth is in the centre of each plot and midday is at the top. Low frequency waves (left) are most intense near noon whereas lower band waves (middle) are most intense from midnight through dawn to noon. The inset panels show the number of samples.

CHORUS DIFFUSION RATES

The results of the wave study were used to calculate new chorus diffusion matrix for use in the global radiation belt models. In general the frequency of maximum wave power was lower than that used in previous models and as a result energy diffusion was found to extend to several MeV at large pitch angles. The results indicated losses at low energies and net electron acceleration at high energies and large pitch angles. It was also found that diffusion due to upper band chorus is restricted to L* < 6 whereas that due to lower band chorus was significant even at L* = 8. The diffusion matrix includes more levels of geomagnetic activity, magnetic local time resolution and radial coverage than previous models and has enabled a much better evaluation of electron acceleration and loss rates [Horne et al., 2013a]. The matrix was incorporated into the forecasting model in 2014.

LOW FREQUENCY CHORUS

During the analysis of the wave database it was noticed that there is substantial wave power at much lower frequencies which has not received much attention. Lower frequency waves are potentially important since they could affect the highest energy electrons. Therefore the wave database was used to construct a new model of low frequency chorus in the frequency range between the lower hybrid resonance frequency and one tenth of the electron gyrofrequency [Meredith et al., 2014a]. These waves were strongest at mid-latitudes in the pre-noon sector (Figure 4, left panel). These waves are not currently included in radiation belt models, but the observed wave power suggests that they could be important for electron acceleration and loss and should be taken into account in radiation belt models.

PLASMASPHERIC HISS AND LIGHTNING-GENERATED WHISTLERS

Other types of plasma waves contribute to electron scattering and loss from the radiation belts into the atmosphere within about 25,000 km of the Earth. These waves are known as plasmaspheric hiss and lightning generated whistlers. Lightning generated whistlers are radio waves originating from lightning which leak out of the atmosphere and into space and in a frequency range from a few hundred Hz to a few kHz. Again the global distribution of these waves and how they change with space weather are essential for better forecasting of the radiation belts.

The wave database was used to determine the global distribution of plasmaspheric hiss and lightning generated whistlers as a function of geomagnetic activity. Figure 5 shows the average wave intensity for plasmaspheric hiss (bottom panels) and lightning-generated whistlers (top panels) for, from left to right, quiet, moderate and active conditions. Plasmaspheric hiss peaks largely on the day-side and afternoon (bottom panels) in the region 2 < L* < 4. This suggests that electron loss from the radiation belts into the atmosphere should be most important in this region.

Waves in the frequency band 2 < f < 4 kHz, (top panels) are attributed to lightning generated whistlers. On the dayside the intensity increases with increasing geomagnetic activity (left to right). However, at night the intensity is almost independent of geomagnetic activity. At night absorption by the ionosphere is weaker and so these waves are associated with signals originating from lightning. However, waves on the dayside as associated with geomagnetic activity which suggests that they are related to substorms and the injection of medium energy electrons.

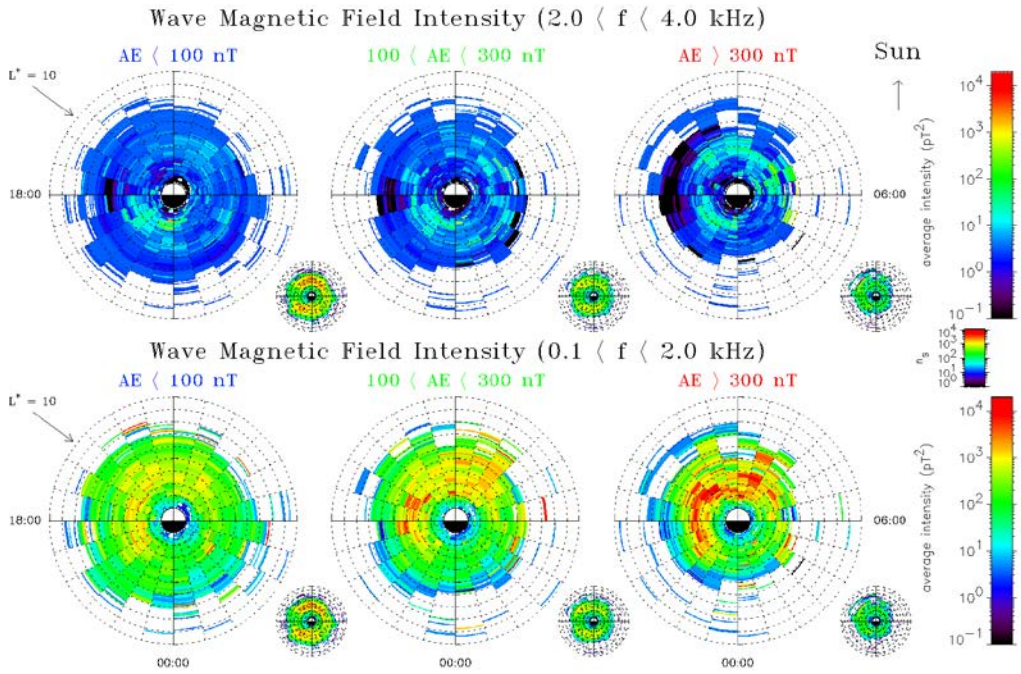

Figure 5. Average wave intensities for plasmaspheric hiss (bottom) and lightning generated whistlers (top). The Earth is at the centre and noon is at the top. Quiet, moderate and active conditions are shown left to right. The inset panels show the number of samples.

CHORUS AS A SOURCE OF PLASMASPHERIC HISS

Recently it has been proposed that chorus waves which are observed further out in the magnetosphere could be the source of plasmaspheric hiss that is observed much closer to the Earth. The idea is that chorus waves propagate along the magnetic field and then gain entry to the lower region at relatively high latitudes and then become trapped in the inner region. Using the wave database we were able to show that chorus does extend along the magnetic field to high latitudes in the pre-noon sector, and, that in the equatorial region, there is a clear gap of 1-2 Earth radii between plasmaspheric hiss at L* < 4 and chorus further out. The results of this analysis are consistent with other studies looking at the propagation of these waves. The observations confirmed two of the key predictions of the new theory and provided the first statistical evidence for chorus as the embryonic source of plasmaspheric hiss [Meredith *et al*., 2013].

EMIC WAVES

Theory suggests that electromagnetic ion cyclotron (EMIC) could cause major losses of radiation belt electrons during space weather events. However, there is very little data on these waves as only a few satellites carry the instruments needed to detect them. They are usually observed at frequencies of a few Hz, in space and on the

ground. To test the theory a new EMIC wave database was constructed using data from the CRRES satellite. The data are very sparse, but it was found that the wave power generally increased with geomagnetic activity in the afternoon sector with an average percentage occurrence of 2.6% [Meredith et al., 2014b]. The average spectral properties of the waves were used to determine the effects on scattering high energy electrons. It was found that the waves can cause losses to the atmosphere of electrons at very high energies, typically greater than 2 MeV, but not below. The work showed there should be a special type of signature in the distribution of the electrons left behind in space, namely that the distribution should become more peaked towards 90^{o} pitch angles as energy increases from 6 to 10 MeV. In addition, it was found that these waves could not be responsible for the complete reduction or 'drop-out' that is sometimes observed in the radiation belts since they cannot remove electrons at very large pitch angles.

RADIAL DIFFUSION

One of the most important processes that contribute to the increase or decrease of particles in the radiation belts is the transport of particles across the magnetic field. Usually high energy charged particles gyrate around the magnetic field and it is very difficult to transport them across the magnetic field. However, fluctuations in the magnetic and electric fields can cause a diffusion of particles across the magnetic field, and this process is known as radial diffusion. The diffusion is not driven by collisions between particles as these are very rare, but by the fluctuating fields.

Radial diffusion is an essential process that is included in the forecasting models. They key to improving the models is to measure the diffusion coefficients but this is exceptionally difficult. For example, the magnetic field can be measured on the ground but these measurements have to be mapped into space leading to large uncertainties. On the other hand satellites can only make point measurements in a vast area of space. In the spacecraft project a new and innovative approach was adopted. Theoretical work shows that if the Earth's magnetic field is separated into a part that is symmetric about the Earth and an asymmetric part then only the asymmetric part can drive the diffusion [Lejosne et al., 2012]. By using seven years of satellite measurements from the GOES satellites at geosynchronous orbit the symmetric and asymmetric components were identified and new diffusion coefficients were calculated. These calculations were performed for different levels of geomagnetic activity and for different particle energies. They show that the diffusion rates at energies less of a few hundred keV are higher than that used in current models, and at energies of several MeV they are lower [Lejosne et al., 2013]. These results are some of the best measurements to date and have been incorporated into the forecasting models.

INTERPLANETARY SHOCK ACCELERATION

Solar energetic particle events cause some of the highest proton radiation levels for satellites in Earth orbit and interplanetary missions. Some of the most intense events are caused when coronal mass ejections create a shock wave as they travel out into space. At the shock there are turbulent electromagnetic fields which accelerate protons to very high energies allowing them reach the Earth in tens of minutes. By modeling these events and understanding the acceleration and transport processes it is hoped to provide some measure of forecasting the intensity and duration of solar energetic particle events in future.

Current models of interplanetary shock waves are limited. In one class of models, known as MHD models, turbulent electromagnetic fields cannot be resolved but have to be represented by an empirical term leading to a lot of uncertainty. On the other hand kinetic plasma simulations can include the turbulence self-consistently but they require such large amounts of computer time they cannot be used for forecasting. In the SPACECAST project we have developed a semi-analytical model that describes particle scattering in the foreshock region, which has the potential of being applied in real time [Vainio et al., 2014].

The model calculates the energetic proton spectrum at various distances ahead of the travelling shock wave and the spectrum of turbulent fluctuations in the foreshock region ahead of the shock wave [Vainio et al., 2014]. The model is based on the theory of diffusive shock acceleration whereby the particles gain energy from the turbulent fields as they are scattered across the shock many times, but modified to take into account time dependence and a diverging

magnetic geometry in space. The model was tested against fully self consistent simulations to calibrate the results and showed that theoretical models over-estimate the upper energy limit at the shock by up to two orders of magnitude. The model also shows that the cut-off energy in the proton spectrum observed at the Earth can be used to obtain information on the resulting energetic storm event even when the shock is very close to the Sun and inaccessible to in-situ observations. The results can be used for SW modeling for future spacecraft missions such as Solar Orbiter and Solar Probe Plus as well as developing acceleration models for SEP events.

MODELLING LARGE SOLAR PROTON EVENTS

One of the large uncertainties in modelling solar energetic particle events is to understand how the shock wave evolves as it travels out into space and distorts the interplanetary magnetic field. The evolution affects how the Earth is connected to the shock via the interplanetary magnetic field which in turn affects the particle flux. To model these transport effects a two-dimensional solar wind model was developed using magnetohydrodynamic (MHD) theory. Figure 3 shows an example where the shock has travelled outwards from the Sun and shows how different locations at Earth orbit are connected to different locations on the shock front (the cob point) via the magnetic field (grey lines).

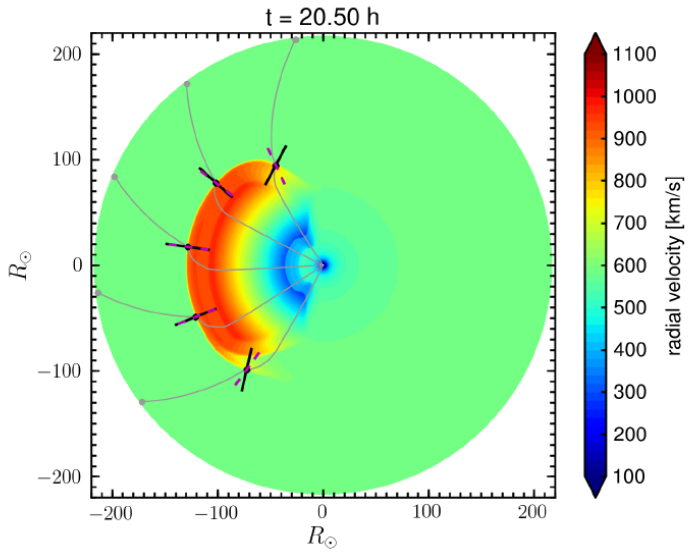

Figure 4. A shock wave travelling away from the Sun. Different parts of the shock front are connected via the magnetic field (grey lines) to different parts of the orbit of the Earth.

In contrast to previous models, the acceleration of the solar wind was included by assuming a source of heating in the solar corona. A new automated method to identify the cob point in the simulations was developed in order to extract plasma conditions at the cob point as the shock moves. Two simulations were performed for solar energetic particle events on 4th April 2000 and 13the December 2006. The simulations showed that the jump in the speed across the shock (VR) was very similar in these two events, and similar to other previously modeled events. By using a separate transport model to fit the particle intensity observed at the Earth as a function of time for the two solar proton events it was possible to obtain the jump in the shock speed and the particle injection rate at the shock. The key result is that a simple relation between the shock speed ratio VR and the particle injection rate Q could be established. The significance of this result is that it enables software tools to be developed to predict the peak intensity, fluence and proton-intensity time profiles of SEP events that cause damage to spacecraft.

DISSEMINATION AND STAKEHOLDERS ENGAGEMENT

Members of the SPACECAST team disseminated results widely via a number of channels. Team members provided briefings for policy makers, a presentation at the UK House of Commons for NATO MPs, and provided oral and written evidence for the UK Government on risk. They also appeared on the BBC2 program “Stargazing Live - Back to

Earth" in 2014, gave an interview for a Swedish TV documentary in 2013, a radio interview on the BBC World Service in 2012, a podcast, 3 press releases, and numerous newspaper and magazine articles. One press release in 2012 on the forecasting system led to 46 different press reports world-wide. Team members published 30 peer reviewed papers and gave numerous presentations at international conferences.

The SPACECAST project made a particular effort to engage with stakeholders in the satellite industry. Each year (2012-2014) the SPACECAST project held a special plenary session at the European Space Weather Week (ESWW) where commercial operators and agency representatives were invited to speak. A specially held business lunch-time discussion was held each year and organized jointly with the European Space Agency. Approximately 30 stakeholders from satellite design and construction, operators, space insurance and from Government agencies attended as well as scientists and members of the ESA. The lunch-time discussion was led alternately by SPACECAST and by ESA each year and covered all aspects of space weather as it affects satellites. Reports of these meetings were written jointly with the ESA and circulated to all stakeholders. Following feedback from these meetings the SPACECAST web site was re-organised to better meet the user's needs.

A close-out meeting was held in Cambridge UK in February 2014 specifically for stakeholders. This also included representatives from the USAF and the World Meteorological Organisation. One of the stakeholders subsequently wrote "The web site is an order of magnitude (maybe several) more sophisticated than the NOAA SEC one". All the stakeholders agreed that they wanted to continue meeting each year with the SPACECAST team as they found the work and the dialogue very useful. As SPACECAST has come to and end it was agreed to take this forward and meet each year at ESWW as part of the new EU SPACESTORM project which runs from March 2014 – March 2017 and where the most important elements of SPACECAST will continue and will be expanded to include work on extreme space weather events.

The SPACECAST project came to an end on the 28th February 2014. The project will have significant impact in four distinct areas:

1. Significantly contribute to the European capacity to prevent damage/protect space assets from space weather events

The space weather forecasting models developed in the SPACECAST project now provide Europe with a state-of-the-art forecasting capability of impending, disruptive, space weather events in the electron radiation belts, and have significantly improved engineering tools for SEP event modelling. The project now delivers a near real time forecasting and nowcasting capability for Europe and has significantly contributed to European capacity by developing the expertise and models of the European partners. Early warnings and alerts are now provided for stakeholders as a result of these forecasts. These warnings enable operators to take action to mitigate the effects of disruptive events to aerospace vehicles, satellites, and other vulnerable technologies in space and on the ground.

Forecasts from the SPACECAST models on the electron radiation belts are now accessed by the UK Met Office for their space weather forecasting.

The DOSETOOL provides the space weather user community with a new tool to calculate radiation dose and dose rates during SEP events, as demonstrated in the on-line plots already available in the Spacecast web server. The hourly dose rate estimate has been added to the spacecraft risk quantities on the web site. Used in conjunction with the synthetic SEP events data of the SOLPENCO tool, DOSETOOL can provide radiation doses and dose rates for different SEP events simultaneously detected at 0.4 AU and at 1.0 AU; i.e. it gives the possibility to easily obtain radiation doses in the inner heliosphere, including < 5 MeV proton population not considered in SOLPENCO2.

The Q(VR) relation permits the development of software tools, like SOLPENCO and SOLPENCO2, that are necessary for the prediction of peak intensities, fluences and proton intensity-time profiles of SEP events for energies that are relevant to space weather; that is, energies at which protons are capable of traversing typical shielding conditions, E > 10 MeV.

2. Significantly contribute to both improving forecasts and predictions of disruptive space weather events

The SPACECAST project has delivered basic research in scientific peer reviewed journals that has increased our understanding of the basic physical processes that control radiation belt dynamics and solar energetic particle events. These results have been used to update the forecasting models and improve forecasts of disruptive space weather events.

3. Identify best practices to limit the impacts on space- and ground-based infrastructures and their data provision.

Members of the SPACECAST project have worked closely with stakeholders by holding Stakeholder Discussion meetings at the annual European Space Weather Week Workshops, attending other user related meetings, and by including a stakeholder on the Steering Committee. This has enabled the consortium participants to better understand the problems encountered with satellites and other space assets. Two way discussions between the SPACECAST project team and Stakeholders have enabled greater awareness on the part of European companies and Government to assess impact of space weather events. For example, information from SPACECAST contributed directly to an assessment by the UK Government which led to Space Weather being included on the UK national risk register.

4. Facilitate and promote an open exchange of information on incidents potentially caused by space weather events between different European (and international) actors in the field.

Space weather forecasts provided by the models developed in the SPACECAST project are now available via the SPACECAST web site and provided to the ESA Space Weather Environment Network (SWENET) web portal for wider dissemination and the UK Meteorological Office. A historical record of space weather forecasts together with the

relevant satellite data are now archived on the SPACECAST web site and are openly available. These data will be available to help identify the cause of incidents potentially caused by space weather events and hence facilitate the open exchange of information. Some of the SPACECAST models are now being coupled to other space weather models as part of the work of the ESA Virtual Space Weather Modelling Centre.

PROJECT REFERENCES

2012

1. Amariutei, O. A., and N. Y. Ganushkina, (2012), On the prediction of the auroral westward electrojet index, Ann. Geophys., 30, 841–847 doi:10.5194/angeo-30-841-2012
2. Ganushkina, N., Y., M. W. Liemohn, and T. I. Pulkkinen, (2012), Storm-time ring current: model-dependent results, *Ann. Geophys*., 30, 177–202, doi:10.5194/angeo-30-177-2012
3. Horne, R. B. (2012), Forecasting the radiation belts in Europe, *Space Weather*, *10*, S08006, doi:10.1029/2012SW000808.
4. Meredith, N. P., R. B. Horne, A. Sicard-Piet, D. Boscher, K. H. Yearby, W. Li, and R. M. Thorne (2012), Global model of lower band and upper band chorus from multiple satellite observations, *J. Geophys. Res.*, *117*, A10225, doi: 10210.11029/12012JA017978.
5. Zuccarello, F. P., Z. Meliani, S. Poedts: "Numerical Modeling of the Initiation of Coronal Mass Ejections in Active Region NOAA 9415" *Astrophys. J.*, 758, Art.Nr. 117 (2012). doi:10.1088/0004-637X/758/2/117

2013

6. Chané, E., J. Saur, S. Poedts: "Modeling Jupiter's magnetosphere: Influence of the internal sources", J. Geophys. Res., 118 (5), 2157–2172 (2013). DOI: 10.1002/jgra.50258
7. Ganushkina, N. Y., O. A. Amariutei, Y. Y. Shprits, and M. W. Liemohn, (2013), Transport of the plasma sheet electrons to the geostationary distances, *J. Geophys. Res. Space Physics*, 118, 82–98 doi:10.1029/2012JA017923
8. Horne, R. B., S. A. Glauert, N. P. Meredith, D. Boscher, V. Maget, D. Heynderickx, and D. Pitchford (2013), Space weather impacts on satellites and forecasting the Earth's electron radiation belts with SPACECAST, *Space Weather*, *11*, doi: 10.1002/swe.20023.
9. Horne, R. B., S. A. Glauert, N. P. Meredith, H. Koskinen, R. Vainio, A. Afanasiev, N. Y. Ganushkina, O. A. Amariutei, D. Boscher, A. Sicard, V. Maget, S. Poedts, C. Jacobs, B. Sanahuja, A. Aran, D. Heynderickx, and D. Pitchford (2013), Forecasting the Earth's radiation belts and modelling solar energetic particle events: Recent results from SPACECAST, J. *Space Weather and Space Climate*, *3*, doi: 10.1051/swsc/2013042.
10. Horne, R. B., T. Kersten, S. A. Glauert, N. P. Meredith, D. Boscher, A. Sicard-Piet, R. M. Thorne, and W. Li (2013), A new diffusion matrix for whistler mode chorus waves, *J. Geophys. Res. Space Physics*, *118*, 6302–6318, doi:10.1002/jgra.50594.
11. Lazar M., S. Poedts, M. Michno (2013), The electromagnetic electron whistler-cyclotron instability in bi-Kappa distributed plasmas, Astron. Astrophys., 554, A64, DOI: 10.1051/0004-6361/201220550
12. Lazar, M., S. Poedts: "Instability of the parallel electromagnetic modes in Kappa distributed plasmas. II. Electromagnetic ion-cyclotron modes", Mon. Not. R. Astron. Soc., (2013). doi:10.1093/mnras/stt1914
13. Lejosne, S., D. Boscher, V. Maget, and G. Rolland (2013), Deriving electromagnetic radial diffusion coefficients of radiation belt equatorial particles for different levels of magnetic activity based on magnetic field measurements at geostationary orbit, *J. Geophys. Res. Space Physics*, 118, 3147–3156, doi:10.1002/jgra.50361.
14. Meredith, N. P., R. B. Horne, J. Bortnik, R. M. Thorne, L. Chen,W. Li, and A. Sicard-Piet (2013), Global statistical evidence for chorus as the embryonic source of plasmaspheric hiss, *Geophys. Res. Lett.*, *40*, doi:10.1002/grl.50593.
15. Pagano, P., D. H. Mackay, S. Poedts: "MHD simulations of the ejection of a magnetic flux rope", *Astron. Astrophys.*, 554, A77 (2013). DOI: 10.1051/0004-6361/201220947
16. Pagano, P., D. H. Mackay, S. Poedts (2013), "Effect of gravitational stratification on the propagation of a CME", Astron. Astrophysics, 560, A38 (2013). DOI: 10.1051/0004-6361/201322036.

17. Selwa, M., S. Poedts, and R.C. DeVore: "Numerical simulations of dome-shaped EUV waves from different active-region configurations", Solar Physics, 284, 515-539 (2013). DOI 10.1007/s11207-013-0302-z

2014

18. Ganushkina, N. Y., M. W. Liemohn, O. A. Amariutei, and D. Pitchford, (2014), Low-energy electrons (5–50 keV) in the inner magnetosphere, *J. Geophys. Res. Space Physics*, 119, doi:10.1002/2013JA019304
19. Glauert, S. A., R. B. Horne, and N. P. Meredith (2014), Three-dimensional electron radiation belt simulations using the BAS Radiation Belt Model with new diffusion models for chorus, plasmaspheric hiss, and lightning-generated whistlers, *J. Geophys. Res. Space Physics*, *119*, doi:10.1002/2013JA019281.
20. Lazar, M., S. Poedts, R. Schlickeiser, D. Ibscher, (2014), The Electron Firehose and Ordinary-Mode Instabilities in Space Plasmas, Solar Physics, 289 (1), 369-378, DOI: 10.1007/s11207-013-0348-y
21. Meredith, N. P., R. B. Horne, W. Li, R. M. Thorne, and A. Sicard-Piet (2014), Global model of low-frequency chorus (fLHR < f < 0.1 $f$ce) from multiple satellite observations, *Geophys. Res. Lett.*, *41*, doi:10.1002/2013GL059050.
22. Rodríguez-Gasén, R., A. Aran, B. Sanahuja, C. Jacobs, S. Poedts: "Variation of proton flux profiles with the observer's latitude in simulated gradual SEP events", Solar Physics, 289 (5), 1745–1762 (2014). DOI 10.1007/s11207-013-0442-1
23. Vainio, R., A. Pönni, M. Battarbee, H. E. J. Koskinen, A. Afanasiev, and T. Laitinen, (2014), A semi-analytical foreshock model for energetic storm particle events inside 1 AU, J. Space Weather and Space Climate, 4 (2014) A08.
24. Zuccarello, F. P., D.B. Seaton, M. Mierla, S. Poedts, L.A. Rachmeler, P. Romano, F. Zuccarello (2014), "Observational evidence of torus instability as trigger mechanism for coronal mass ejections: the 2011 August 4 filament eruption'', Astrophys. J., 785 (2), 88 (11 pp.), DOI: 10.1088/0004-637X/785/2/88.
25. Lazar, M., J. Pomoell, S. Poedts, C. Dumitrache, N.A. Popescu (2014), "Solar Wind Electron Strahls Associated with a High-latitude ICME: Ulysses Observations", Solar Phys., Online at Springer Link, DOI 10.1007/s11207-014-0558-y.

Submitted or in press

26. Horne, R. B., N. P. Meredith, S. A. Glauert and T. Kersten (2014), Wave Driven Diffusion in Radiation Belt Dynamics, book chapter.
27. Meredith, N. P., R. B. Horne, T. Kersten, B. J. Fraser and R. S. Grew (2014), Global morphology and spectral properties of EMIC waves derived from CRRES observations, J. Geophys. Res., submitted.
28. Glauert, S. A., R. B. Horne, and N. P. Meredith (2014), Simulating the Earth's radiation belts: internal acceleration and continuous losses to the magnetopause, J. Geophys. Res., submitted.
29. Pomoell, J., A. Aran, C. Jacobs, R. Rodrıguez-Gasen, S. Poedts, and B. Sanahuja, (2014), Modelling solar proton events: extracting the characteristics of the MHD shock front at the cobpoint, J. Space Weather and Space Climate, submitted.
30. Sicard-Piet, A., D. Boscher, R. B. Horne, N. P. Meredith and V. Maget, (2014), Effect of plasma density on diffusion rates due to wave particle interactions with chorus 1 and plasmaspheric hiss: Extreme event analysis, Anales Geophysicae, submitted.

SECTION A

This section should describe the dissemination measures, including any scientific publications relating to foreground. **Its content will be made available in the public domain** thus demonstrating the added-value and positive impact of the project on the European Union.

A1: LIST OF SCIENTIFIC (PEER REVIEWED) PUBLICATIONS, STARTING WITH THE MOST IMPORTANT ONES

No.	Title	Main author	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of pub.	Relevant pages	Permanent identifier	Open access ?
1	Storm-time ring current: model-dependent results	N. Y. Ganushkina	Annales Geophysicae	Vol. 30, Number 1	European Geosciences Union	Germany	2012	177-202	10.5194/angeo-30-177-2012	Yes
2	On the prediction of the auroral westward electrojet index	O. A. Amariutei	Annales Geophysicae	Vol. 30, Number 5	European Geosciences Union	Germany	2012	841- 47	10.5194/angeo-30-841-2012	Yes
3	Forecasting the Radiation Belts in Europe	R. B. Horne	Space Weather	Vol. 10, Issue 8	American Geophysical Union	United States	2012	N/A	10.1029/2012SW000808	Yes
4	Numerical modeling of the initiation of coronal mass ejections in active region NOAA 9415	S. Poedts	Astrophysical Journal	Vol. 758, Number 2	Institute of Physics Publishing	United States	2012	117-129	10.1088/0004-637X/758/2/117	Yes
5	Global model of lower band and upper band chorus from multiple satellite observations	N. P. Meredith	Journal of Geophysical Research	Vol. 117, Issue A10	American Geophysical Union	United States	2012	N/A	10.1029/2012JA017978	Yes
6	Transport of the plasma sheet electrons to the geostationary distances	N. Y. Ganushkina	Journal of Geophysical Research	Vol. 118, Issue 1	American Geophysical Union	United States	2013	82 - 98	10.1029/2012JA017923	Yes
7	Forecasting the Earth's radiation belts and modelling solar energetic particle	R. B. Horne	Journal of Space	Vol. 3	EDP Sciences	France	2013	A20	10.1051/swsc/2013042	Yes

	events: Recent results from SPACECAST		Weather and Space Climate							
8	Magnetohydrodynamic simulations of the ejection of a magnetic flux rope	S. Poedts	Astronomy and Astrophysics	Vol. 554	EDP Sciences	France	2013	A77	10.1051/0004-6361/201220947	Yes
9	Modeling Jupiter's magnetosphere: Influence of the internal sources	S. Poedts	Journal of Geophysical Research	Vol. 118, Issue 5	American Geophysical Union	United States	2013	2157 – 2172	10.1002/jgra.50258	Yes
10	Space weather impacts on satellites and forecasting the Earth's electron radiation belts with SPACECAST	R.B. Horne	Space Weather	Vol. 11, Issue 4	American Geophysical Union	United States	2013	169 – 186	10.1002/swe.20023	Yes
11	Numerical Simulations of Dome-Shaped EUV Waves from Different Active-Region Configurations	S. Poedts	Solar Physics	Vol. 284, Issue 2	Springer Netherlands	Netherlands	2013	515 – 539	10.1007/s11207-013-0302-z	Yes
12	Deriving electromagnetic radial diffusion coefficients of radiation belt equatorial particles for different levels of magnetic activity based on magnetic field measurements at geostationary orbit	S. Lejosne	Journal of Geophysical Research	Vol. 118, Issue 6	American Geophysical Union	United States	2013	3147-3156	10.1002/jgra.50361	No
13	Electromagnetic electron whistler-cyclotron instability in bi-Kappa distributed plasmas	S. Poedts	Astronomy and Astrophysics	Vol. 554	EDP Sciences	France	2013	A64	10.1051/0004-6361/201220550	Yes
14	Global statistical evidence for chorus as the embryonic source of plasmaspheric hiss	N. P. Meredith	Geophysical Research Letters	Vol. 40, Issue 12	American Geophysical Union	United States	2013	2891-2896	10.1002/grl.50593	Yes
15	A new diffusion matrix for whistler mode chorus waves	R.B. Horne	Journal of Geophysical Research	Vol. 118, Issue 10	American Geophysical Union	United States	2013	6302-6318	10.1002/jgra.50594	Yes

16	Effect of gravitational stratification on the propagation of a CME	S. Poedts	Astronomy and Astrophysics	Vol. 560	EDP Sciences	France	2013	A38	10.1051/0004-6361/201322036	No
17	A semi-analytical foreshock model for energetic storm particle events inside 1 AU	R. Vainio	Journal of Space Weather and Space Climate	Vol. 4	EDP Sciences	France	2014	A08	10.1051/swsc/2014005	Yes
18	Three-dimensional electron radiation belt simulations using the BAS Radiation Belt Model with new diffusion models for chorus, plasmaspheric hiss, and lightning-generated whistlers	S. A. Glauert	Journal of Geophysical Research	Vol. 11, Issue 1	American Geophysical Union	United States	2014	268-289	10.1002/2013JA019281	Yes
19	Low-energy electrons (5-50 keV) in the inner magnetosphere	N. Y. Ganushkina	Journal of Geophysical Research	Vol. 119, Issue 1	American Geophysical Union	United Stated	2014	246-259	10.1002/2013JA019304	No
20	The Electron Firehose and Ordinary-Mode Instabilities in Space Plasmas	S. Poedts	Solar Physics	Vol. 289, Issue 1	Springer Netherlands	Netherlands	2014	369-378	10.1007/s11207-013-0348-y	No
21	Instability of the parallel electromagnetic modes in Kappa distributed plasmas - II. Electromagnetic ion-cyclotron modes	S. Poedts	Monthly Notices of the Royal Astronomical Society	Vol. 437, Issue 1	Blackwell Publishing	United Kingdom	2014	641-648	10.1093/mnras/stt1914	Yes
22	Global model of low-frequency chorus (fLHR<f<0.1fce) from multiple satellite observations	N. P. Meredith	Geophysical Research Letters	Vol. 41, Issue 2	American Geophysical Union	United States	2014	280-286	10.1002/2013GL059050	Yes
23	Observational evidence of torus instability as trigger mechanism for coronal mass ejections: the 2011 August 4 filament eruption	S. Poedts	Astrophysical Journal	Vol. 78, Issue 2	Institute of Physics Publishing	United Kingdom	2014	88	10.1088/0004-637X/785/2/88	Yes

24	Variation of Proton Flux Profiles with the Observer's Latitude in Simulated Gradual SEP Events	A. Aran	Solar Physics	Vol. 289, Issue 5	Springer Netherlands	Netherlands	2014	1745-1762	10.1007/s11207-013-0442-1	No
25	Effect of plasma density on diffusion rates due to wave particle interactions with chorus 1 and plasmaspheric hiss: Extreme event analysis	A. Sicard-Piet	Annales Geophysicae	In press	European Geosciences Union	Germany	2014	In press	In press	Yes
26	Global morphology and spectral properties of EMIC waves derived from CRRES observations	N.P. Meredith	Journal of Geophysical Research	Submitted	American Geophysical Union	United States	2014	Submitted	Submitted	Yes
27	Simulating the Earth's radiation belts: internal acceleration and continuous losses to the magnetopause	S.A. Glauert	Journal of Geophysical Research	Submitted	American Geophysical Union	United States	2014	Submitted	Submitted	Yes
28	Modelling solar proton events: extracting the characteristics of the MHD shock front at the cobpoint	J. Pomoell	Journal of Space Weather and Space Climate	Submitted	EDP Sciences	France	2014	Submitted	Submitted	Yes
29	Solar Wind Electron Strahls Associated with a High-Latitude CME: *Ulysses*Observations	S. Poedts	Solar Physics	Vol. 289, Issue TBC	Springer Netherlands	Netherlands	2014	TBC	10.1007/s11207-014-0558-y	No

A2: LIST OF DISSEMINATION ACTIVITIES

NO.	Type of activities	Main leader	Title	Date/Period	Place	Type of audience	Size of audience	Countries addressed
1	Articles published in the popular press	NERC-BAS	The Icesheet	01/03/2011	Cambridge, UK	Scientific community (higher education, Research) - Civil society	400	UK
2	Presentations	FMI	N. Yu. Ganushkina, S. Dubyagin, M. Liemohn, M. Kubyshkina, J. Perez, A. Runov, Resolving the ring cu	23/03/2011	JOINT THEMIS-TWINS Science Workshop, March 21 - 25, 2011, UCLA, CA, USA	Scientific community (higher education, Research)	100	USA, UK, France, Germany, Sweden,

								Japan, Canada, Austria
3	Press releases	NERC-BAS	MAJOR EU-FUNDED SPACE WEATHER INITIATIVE LAUNCHED AND MANAGED IN UK	28/03/2011	Cambridge, UK	Scientific community (higher education, Research) - Industry - Civil society - Policy makers - Medias		UK
4	Interviews	NERC-BAS	BBC, World Today Programme	28/03/2011	UK	Civil society - Medias		World wide
5	Presentations	NERC-BAS	Scientific Research to Help Protect Satellites on Orbit	07/04/2011	16th International Conference on Space Activities Development, Rome, Italy	Industry - Policy makers - Medias	200	UK, USA, China, Japan, France, Germany, Switzerland, Spain, Italy, Netherlands
6	Interviews	NERC-BAS	Planet Earth podcast	07/04/2011	16th International Conference on Space Activities Development, Rome, ItalyRome, Italy	Scientific community (higher education, Research) - Civil society - Policy makers - Medias		UK
7	Media briefings	NERC-BAS	Panel discussion on Monitoring Weather & Climate from Space: what does it take to cope	07/04/2011	16th International Conference on Space Activities Development, Rome, ItalyRome, Italy	Industry - Policy makers - Medias	250	UK, USA, China, Japan, France, Germany, Spain, Switzerland, Italy, Netherlands
8	Articles published in the popular press	NERC-BAS	Cambridge Evening News	25/04/2011	Cambridge, UK	Civil society	5000	UK
9	Presentations	KUL	Coronal Mass Ejections (CMEs) and Interplanetary Dynamics: initial objectives and global results	09/05/2011	Göttingen, Germany	Scientific community (higher education, Research)	100	USA, UK, France, Spain, Germany, Belgium, Austria, Norway,The Netherlands, ...

10	Presentations	KUL	Space weather: mathematical modeling at the CPA/K.U.Leuven	25/05/2011	Leuven, Belgium	Scientific community (higher education, Research)	25	Belgium
11	Presentations	FMI	N. Yu. Ganushkina, S. Dubyagin, M. Kubyshkina, M. Liemohn, Inner magnetosphere response to CIR storm	26/06/2011	Joint CEDAR-GEM Workshop,26 June - 01 July 2011, Santa Fe, NM, USA.	Scientific community (higher education, Research)	150	USA, UK, Egypt, Taiwan, Argentina, Brazil, Germany, Sweden, Peru, Japan, Australia, Canada, Austria
12	Presentations	FMI	N. Y. Ganushkina, IMPTAM: Including self-consistent magnetic field in ring current modeling, Oral pr	27/06/2011	Joint CEDAR-GEM Workshop,26 June - 01 July 2011, Santa Fe, NM, USA.	Scientific community (higher education, Research)	150	USA, UK, Egypt, Taiwan, Argentina, Brazil, Germany, Sweden, Peru, Japan, Australia, Canada, Austria
13	Presentations	FMI	N. Yu. Ganushkina, and M. Liemohn, IMPTAM: Dst calculated in ring current modeling: Two methods, DPS	27/06/2011	Joint CEDAR-GEM Workshop,26 June - 01 July 2011, Santa Fe, NM, USA	Scientific community (higher education, Research)	150	USA, UK, Egypt, Taiwan, Argentina, Brazil, Germany, Sweden, Peru, Japan, Australia, Canada, Austria
14	Presentations	FMI	N. Y. Ganushkina; I. Dandouras; Y. Shprits; J. Cao, Locations of	28/06/2011	Joint CEDAR-GEM Workshop,26 June - 01	Scientific community (higher education,	150	USA, UK, Egypt,

			Boundaries of Outer and Inner Radi		July 2011, Santa Fe, NM, USA.	Research)		Taiwan, Argentina, Brazil, Germany, Sweden, Peru, Japan, Australia, Canada, Austria
15	Presentations	KUL	Simulations of coronal mass ejections	28/06/2011	Strasbourg, France	Scientific community (higher education, Research)	50	USA, UK, France, Spain, Germany, Belgium, Austria, Norway,The Netherlands, ...
16	Presentations	KUL	A new paradigm for solar coronal loop heating	30/06/2011	Palma de Mallorca, Spain	Scientific community (higher education, Research)	100	USA, UK, France, Spain, Germany, Belgium, Austria, Norway,The Netherlands, ...
17	Presentations	NERC-BAS	Meredith, CRRES Plasma Wave Observations	18/07/2011	AGU Chapman Conference, St John's, Newfoundland, Canada	Scientific community (higher education, Research)	100	USA,Canada, France, Germany, Belgium, Russia, Japan, Korea, Australia, South Africa
18	Presentations	NERC-BAS	Ion Heating by Fast Magnetosonic Waves and Ring Current-Electron Radiation Belt Coupling	16/08/2011	URSI General Asembly, Istanbul, Turkey	Scientific community (higher education, Research)	150	Turkey, USA, UK, New Zealand, Australia, China, Japan,

								Canada, India, Czech Republic, France, German
19	Presentations	NERC-BAS	A European Perspective on Modelling and Forecasting the Radiation Belts	12/10/2011	US-UK Space Weather Workshop, Boulder, USA	Scientific community (higher education, Research) - Policy makers	70	USA, UK
20	Presentations	FMI	Amariutei, O. A., and N.Yu. Ganushkina, On the prediction of the auroral westward electrojet index,	30/10/2011	n/a	Scientific community (higher education, Research)		n/a
21	Interviews	NERC-BAS	Oral evidence to the House of Commons Defence Select Committee	09/11/2011	House of Commons, London, UK	Policy makers	10	UK
22	Presentations	KUL	The MHD model (magnetic flux, conservation laws, discontinuities, model problems)	21/11/2011	Miramare, Trieste, Italy	Scientific community (higher education, Research)	60	USA, UK, France, Spain, Germany, Belgium, Austria, Norway,The Netherlands, Africa..
23	Presentations	KUL	MHD waves and instabilities	21/11/2011	Miramare, Trieste, Italy	Scientific community (higher education, Research)	60	USA, UK, France, Spain, Germany, Belgium, Austria, Norway,The Netherlands, Africa..
24	Presentations	NERC-BAS	Radiation Belts at the Earth and Planets: A Hot Topic	25/11/2011	MIST meeting, London, UK	Scientific community (higher education, Research)	250	UK
25	Posters	NERC-BAS	3-d Modelling of the Radiation Belts with the BAS Global Radiation Belt Model	25/11/2011	MIST meeting, RAS, Burlington House Piccadilly, London, UK	Scientific community (higher education, Research)	50	UK
26	Presentations	UBARCELONA	A new model for gradual SEP Events and the SEPEM SOLPENCO2 tool	28/11/2011	8th European Space Weather Week, Namur (Belgium)	Scientific community (higher education, Research) - Industry	200	European Union, ESA's member

								states, United States of America
27	Presentations	FMI	N. Y. Ganushkina, Inner Magnetosphere Particle Transport and Acceleration Model (IMPTAM): Modeling f	28/11/2011	Eighth European Space Weather Week, November 28 - December 02, 2011 - Namur, Belgium.	Scientific community (higher education, Research) - Industry - Policy makers - Medias	400	UK, France, Finland, Italy, Russia, USA, Germany, Belgium, Hungary, Austria, Greece, Netherlands, Sw
28	Posters	FMI	O.A. Amariutei and N.Yu. Ganushkina: On the Challenges of AL prediction using solar wind parameters,	28/11/2011	Eighth European Space Weather Week, November 28 - December 02, 2011 - Namur, Belgium.	Scientific community (higher education, Research) - Industry - Policy makers - Medias	400	UK, France, Finland, Italy, Russia, USA, Germany, Belgium, Hungary, Austria, Greece, Netherlands, Sw
29	Posters	NERC-BAS	Key Scientific Challenges in Modelling High Energy Charged Particles:	28/11/2011	8th European Space Weather Week, Namur, Belgium, Hungary, Greece, Russia	Scientific community (higher education, Research) - Industry - Policy makers	250	UK, USA, France, Germany, Belgium, Spain, Finland, Italy, Netherlands, Sweden
30	Posters	NERC-BAS	Meredith et al., Global Model of Chorus from CRRES, Double Star TC1 and THEMIS Observations	28/11/2011	Eighth European Space Weather Week, Namur, Belgium	Scientific community (higher education, Research) - Industry - Policy makers	250	UK, USA, France, Germany, Belgium, Spain, Finland, Italy, Netherlands,

								Sweden
31	Presentations	KUL	Theoretical models for plasma physics	28/11/2011	Namur, Belgium	Scientific community (higher education, Research) - Industry	200	USA, UK, France, Spain, Germany, Belgium, Austria, Norway,The Netherlands, ...
32	Posters	NERC-BAS	3-d Modelling of the Radiation Belts with the BAS Global Radiation Belt Model	28/11/2011	ighth European Space Weather Week, Namur, Belgium	Scientific community (higher education, Research) - Industry - Policy makers	200	UK, USA, France, Belgium, Spain, Finland, Italy, Sweden, Netherlands, Greece,
33	Presentations	UHELSINKI	Understanding the Origin of extreme Solar energetic Particle Events using Modeling and Observations	28/11/2011	Eighth European Space Weather Week, November 28 - December 02, 2011 - Namur, Belgium.	Scientific community (higher education, Research)	200	EU, USA
34	Oral presentation to a scientific event	UHELSINKI	Importing plasma physics of shock acceleration to engineering models of solar proton storms	28/11/2011	8th European Space Weather Week	Scientific community (higher education, Research)	200	Worldwide
35	Posters	FMI	N. Y. Ganushkina, Formation of Low Energy Electron Population in the Inner Earth's Magnetosphere, O	01/12/2011	Eighth European Space Weather Week, November 28 - December 02, 2011 - Namur, Belgium.	Scientific community (higher education, Research) - Industry - Policy makers - Medias	400	UK, France, Finland, Italy, Russia, USA, Germany, Belgium, Hungary, Austria, Greece, Netherlands, Sw
36	Organisation of Workshops	NERC-BAS	SPACECAST Stakeholder Discussion Meeting:Protecting Satellites by Modelling High Energy Charged Part	01/12/2011	8th European Space Weather Week, Namur, Belgium	Scientific community (higher education, Research) - Industry - Civil	200	UK, USA, France, Belgium,

						society - Policy makers		Spain, Finland, Italy, Sweden, Netherlands, Greece,
37	Articles published in the popular press	NERC-BAS	Warning: Space can damage your health	01/12/2011	UK	Scientific community (higher education, Research) - Industry - Civil society - Policy makers - Medias		UK
38	Presentations	FMI	N. Ganushkina, M. W. Liemohn, Formation of Low Energy Electron Population in the Inner Earth's Magn	06/12/2011	2011 Fall American Geophysical Union meeting, 5-9 December 2011, San Francisco, CA, USA	Scientific community (higher education, Research) - Policy makers - Medias	200	USA
39	Presentations	NERC-BAS	Ion Heating by Fast Magnetosonic Waves and their role in Ring Current Radiation Belt Coupling	06/12/2011	Fall AGU meeting, San Francisco, USA	Scientific community (higher education, Research)	250	USA
40	Presentations	UBARCELONA	Sucesos de partículas solares y el tiempo espacial	12/12/2011	Alcalá de Henares (Spain)	Scientific community (higher education, Research)	20	Spain
41	Publication	KUL	Euro'solar'physicsnews	15/12/2011	EPN, The magazine of the European Physical Society, 46/6, 8-10 (2011)	Scientific community (higher education, Research) - Policy makers		EU
42	Presentations	FMI	Ganushkina, N. Yu, Liemohn, M. W., and Pulkkinen, T. I., Storm-Time Ring Current: Model-Dependent Re	17/01/2012	n/a	Scientific community (higher education, Research)		n/a
43	Interviews	NERC-BAS	Personal briefing to the UK Government Chief Scientific Advisor	17/01/2012	Department of Business, Innovation and Skills, London, UK	Policy makers	6	UK
44	Interviews	UBARCELONA	L'activitat solar durant el 2012	21/01/2012	Ràdio l'Escala, Empúries (Spain)	Civil society		Spain
45	Articles published in the popular press	UBARCELONA	Activitat solar i temps espacial	23/01/2012	BTV Night News, Barcelona (Spain)	Civil society		Spain
46	Presentations	FMI	N. Yu. Ganushkina, Relationships Between the Ring and Tail Currents in the Inner Earth's Magnetosphe	24/01/2012	ISSI International Team "Resolving Current Systems in Geospace",	Scientific community (higher education, Research)	15	K, France, Finland, Greece,

					January 23-27, 2012, International			Japan, Russia, USA, Norway
47	Interviews	UBARCELONA	Solar storm in January 24th 2012	26/01/2012	Radio Nacional de España 4 (Barcelona, Spain)	Civil society		Spain
48	Presentations	KUL	A new paradigm for solar coronal heating	09/02/2012	Univ. of Hawaii at Manoa, USA	Scientific community (higher education, Research)	25	USA
49	Press releases	NERC-BAS	NEW SYSTEM TO FORECAST SPACE WEATHER LAUNCHED	01/03/2012	UK	Scientific community (higher education, Research) - Industry - Civil society - Policy makers - Medias		UK, USA, Australia, New Zealand, Japan, France, Germany, Spain, Belgium, Finland, Canada
50	Interviews	NERC-BAS	Reuters, London	01/03/2012	London, UK	Civil society - Medias		world wide
51	Interviews	NERC-BAS	The Engineer	02/03/2012	Cambridge, UK	Medias		UK
52	Articles published in the popular press	NERC-BAS	Reuters Science News Summary	02/03/2012	Chicago Tribune	Civil society		Worldwide
53	Articles published in the popular press	NERC-BAS	UK scientists to help satellites dodge sun storms	02/03/2012	Public Broadcasting - Online	Civil society		Worldwide
54	Articles published in the popular press	NERC-BAS	UK scientists to help satellites dodge sun storms	02/03/2012	NewsDaily - Online	Civil society		Worldwide
55	Articles published in the popular press	NERC-BAS	REFILE-UK scientists to help satellites dodge sun storms	02/03/2012	London South East - Online	Civil society		Worldwide
56	Articles published in the popular press	NERC-BAS	UK scientists to help satellites dodge sun storms	02/03/2012	WSAU.com	Civil society		Worldwide
57	Articles published in the popular press	NERC-BAS	UK scientists to help satellites dodge sun storms	02/03/2012	Khaleej Times - Online	Civil society		Worldwide
58	Articles published in the popular press	NERC-BAS	Scientists to help satellites dodge sun storms	02/03/2012	International Business Times Australia - Online	Civil society		Worldwide
59	Articles published in the popular press	NERC-BAS	UK scientists to help satellites dodge sun storms	02/03/2012	wtaq.com - Online	Civil society		Worldwide
60	Articles published in the popular press	NERC-BAS	UK scientists to help satellites dodge sun storms	02/03/2012	KDAL-AM - Online	Civil society		Worldwide

61	Articles published in the popular press	NERC-BAS	UK scientists to help satellites dodge sun storms	02/03/2012	bayoubuzz.com - Online	Civil society		Worldwide
62	Articles published in the popular press	NERC-BAS	Shelter from the solar storm? U.K. lab creates system to protect satellites from nasty space weather	03/03/2012	National Post	Civil society		Worldwide
63	Articles published in the popular press	NERC-BAS	UK scientists to help sattelites dodge sun storms	03/03/2012	DAWN.com - online	Policy makers		Worldwide
64	Articles published in the popular press	NERC-BAS	UK scientists to help satellites dodge sun storms	03/03/2012	Thomson Reuters - India	Civil society		Worldwide
65	Articles published in the popular press	NERC-BAS	Scientists to help satellites dodge sun storms	03/03/2012	Yahoo! News UK and Ireland	Civil society		Worldwide
66	Articles published in the popular press	NERC-BAS	UK scientists to help satellites dodge sun storms	03/03/2012	New Zealand & World News - Yahoo	Civil society		Worldwide
67	Articles published in the popular press	NERC-BAS	UK scientists to help satellites dodge sun storms	03/03/2012	Yahoo! India	Civil society		Worldwide
68	Articles published in the popular press	NERC-BAS	UK Scientists to Help Satellites Dodge Sun Storms	03/03/2012	International Business Times	Civil society		Worldwide
69	Articles published in the popular press	NERC-BAS	UK Scientists to Help Satellites Dodge Sun Storms	03/03/2012	International Business Times - Hong Kong	Civil society		Worldwide
70	Articles published in the popular press	NERC-BAS	Solar storm forecast system developed	03/03/2012	Radio New Zealand National	Civil society		Worldwide
71	Articles published in the popular press	NERC-BAS	UK scientists to help satellites dodge sun storms	03/03/2012	World Bulletin	Civil society		Worldwide
72	Articles published in the popular press	NERC-BAS	UK Scientists to Help Satellites Dodge Sun Storms	03/03/2012	IBTimes	Civil society		Worldwide
73	Articles published in the popular press	NERC-BAS	New system to forecast space weather launched	03/03/2012	FirstScience.com	Civil society		Worldwide
74	Articles published in the popular press	NERC-BAS	UK scientists to help satellites dodge sun storms	03/03/2012	Yahoo! News Australia	Civil society		Worldwide
75	Articles published in the popular press	NERC-BAS	UK scientists to help satellites dodge sun storms	03/03/2012	Thomson Reuters - UK - Online	Civil society		Worldwide
76	Articles published in the popular press	NERC-BAS	British Antarctic Survey (BAS)... Reconnoitering Radiation (System + Satellites)	04/03/2012	SatNews Publishers	Industry		UK
77	Articles published in the popular press	NERC-BAS	New system to help satellites dodge devastating sun storms	04/03/2012	UK - Press TV	Civil society		Worldwide
78	Articles published in the popular press	NERC-BAS	UK scientists to help satellites dodge sun storms	04/03/2012	UK - Bdnews24	Civil society		Worldwide

79	Articles published in the popular press	NERC-BAS	System to help satellites dodge solar storms	04/03/2012	Gulf Times Online	Civil society		Worldwide
80	Articles published in the popular press	NERC-BAS	Scientists have developed a system to help protect navigation and communications satellites from pot	05/03/2012	Business News - Balkans	Civil society		Worldwide
81	Presentations	KUL	Space weather!	07/03/2012	Antwerp, Belgium	Scientific community (higher education, Research)	40	Belgium
82	Interviews	UBARCELONA	Solar activity on March 7 2012	07/03/2012	Catalunya Ràdio, Barcelona	Civil society		Spain
83	Interviews	KUL	Zonnestorm scheert langs aarde	09/03/2012	Leuven, Belgium (newspaper De Morgen)	Civil society - Medias		Belgium
84	Articles published in the popular press	UBARCELONA	Es posa en marxa el projecte Spacecast per pronosticar el temps espacial	12/03/2012	University of Barcelona webpage	Civil society - Medias		Spain
85	Articles published in the popular press	UBARCELONA	Se pone en marcha el proyecto Spacecast para pronosticar el tiempo espcacial	12/03/2012	University of Barcelona Website	Civil society - Policy makers		Spain
86	Articles published in the popular press	UBARCELONA	La peor tormenta solar de la historia causaria ahora 22860 millones de perdidas	12/03/2012	www.canarias7.es website	Civil society		Spain
87	Articles published in the popular press	UBARCELONA	La tempesta solar mes gran registrada causaria ara 23000 milions d'euros de perdues	12/03/2012	elperiodico.cat website	Civil society		Spain
88	Articles published in the popular press	UBARCELONA	La UB colabora en una investigacion european papa pronosticar la meterologica epacial	12/03/2012	europapress.es Website	Civil society		Spain
89	Articles published in the popular press	UBARCELONA	Se pone en marcha el proyecto Spacecast para pronosticar el tiempo espcacial	12/03/2012	www.alphagalileo.org website	Civil society		Worldwide
90	Articles published in the popular press	UBARCELONA	La peor tormenta solar causaria ahora 30 mil mdd en perdidas	12/03/2012	Noticas MVS website	Civil society		Spain
91	Articles published in the popular press	UBARCELONA	Si se repitiera ahora la peor tormenta solar de la historia generaria perdidas de 22860 millones	12/03/2012	ABC.es	Civil society		Spain
92	Articles published in the popular press	UBARCELONA	La peor tormenta solar causaria hoy 30000 millones de dolares en perdidas	12/03/2012	edunenewscolombia.com website	Civil society		Spain
93	Articles published in	UBARCELONA	La peor tormenta solar causaria hoy	12/03/2012	quedice.net website	Civil society		Spain

	the popular press		30000 millones de dolares en perdidas					
94	Articles published in the popular press	UBARCELONA	De repetirse las peor tormenta solar cuasaria £us 30000 millones de perdidas	12/03/2012	opinion.com.bo website	Civil society		Spain
95	Articles published in the popular press	UBARCELONA	Si se repitiera ahora la peor tormenta solar de la historia generaria perdidas de 22860 millones	12/03/2012	eleconomista.es website	Civil society		Spain
96	Articles published in the popular press	UBARCELONA	La peor tormenta solar causaria 30 mmdd en perdidas	12/03/2012	vanguardia website	Civil society		Spain
97	Articles published in the popular press	UBARCELONA	La UB colabora en una investigacion european papa pronosticar la meterologica epacial	12/03/2012	teinteresa.es website	Civil society		Spain
98	Articles published in the popular press	UBARCELONA	?Que tiempo va a hacer hoy?	12/03/2012	caosyciencia.com website	Civil society		Spain
99	Articles published in the popular press	UBARCELONA	La peor tormenta solar de la historia causaria ahora 22860 millones de perdidas	13/03/2012	La Vanguardia.com website	Civil society		Spain
100	Articles published in the popular press	UBARCELONA	Una tempesta solar record causaria danys per valor de 22000 milions d'euros	13/03/2012	www.regio7.cat website	Civil society		Spain
101	Articles published in the popular press	UBARCELONA	Arranca el proyecto 'Spacecast' para pronosticar el tiempo espacial	13/03/2012	sinc website	Scientific community (higher education, Research) - Civil society		Spain
102	Articles published in the popular press	UBARCELONA	Arranca proyecto europeo para analizar explosiones que ocurren en el Sol	13/03/2012	prensa.com Website	Civil society		Spain
103	Articles published in the popular press	UBARCELONA	La peor tormenta solar causaria 30 mmdd en perdidas	13/03/2012	El Universo website	Civil society		Spain
104	Articles published in the popular press	UBARCELONA	Una tempesta solar record causaria danys per valor de 22000 milions d'euros	15/03/2012	Newspaper article	Civil society		Spain
105	Presentations	NERC-BAS	Meredith et al., Global Model of Whistler Mode Chorus from Multiple Satellite Observations	21/03/2012	Inner Magnetosphere Coupling Workshop 2, UCLA, Los Angeles	Scientific community (higher education, Research)	75	USA, Canada, France, Japan, China, Korea
106	Articles published in the popular press	NERC-BAS	Space weather - a threat to our infrastructure?	21/03/2012	http://www.publicserviceeurope.com/	Civil society - Policy makers	1000	EU
107	Presentations	NERC-BAS	Briefing to Department for Business	22/03/2012	London, UK	Policy makers	1	UK

			Industry and Skills Minister					
108	Publication	FMI	Ganushkina, N. Yu., O. Amariutei, and M. Liemohn, Roles of large- and small-scale electric and magne	30/03/2012	n/a	Scientific community (higher education, Research)		n/a
109	Presentations	NERC-BAS	Spacecast	12/04/2012	Metereological Office, Exeter, UK	Scientific community (higher education, Research) - Civil society	6	UK
110	Presentations	NERC-BAS	Horne, Protecting space assets from high energy particles by developing European dynamic modelling a	12/04/2012	Exeter, UK	Scientific community (higher education, Research)	7	UK
111	Presentations	NERC-BAS	Spacecast	23/04/2012	Boulder Colorado	Scientific community (higher education, Research) - Industry - Policy makers	150	USA, UK, Belgium, Japan, China
112	Presentations	NERC-BAS	A new european service to forecast the high energy electron flux in the radiation belts	24/04/2012	Boulder Colorado USA	Scientific community (higher education, Research) - Industry - Policy makers	400	USA, UK, Belgium, China, Japan, Germany, Italy
113	Organisation of Workshops	NERC-BAS	UK-USA collaboration on radiation belt forecasting	28/04/2012	Boulder Colorado, USA	Scientific community (higher education, Research) - Policy makers	30	USA, UK
114	Articles published in the popular press	NERC-BAS	UK scientists to help satellites dodge sun storms	02/05/2012	Yahoo! Canada	Civil society		Worldwide
115	Presentations	FMI	The Interplay of Processes Within Inner Magnetosphere and the Near-Earth Plasma Sheet	03/05/2012	5th Isradynamics Conference, April 29 - May 7, 2012, Jerusalem, Israel 2012	Scientific community (higher education, Research)	100	Finland, UK, USA, Italy, Germany, Israel, Greece, Russia, Japan, Belgium
116	Presentations	NERC-BAS	Space Weather	09/05/2012	British Antarctic Survey, UK	Policy makers	3	UK
117	Presentations	NERC-BAS	Forecasting the Earth's radiation belts	13/06/2012	University of Leeds, School of Earth and Environment	Scientific community (higher education, Research)		UK
118	Presentations	FMI	Transport of the plasma sheet electrons to the geostationary	18/06/2012	GEM Workshop, 17 – 22 June 2012, Snowmass,	Scientific community (higher education,	240	USA, Finland, Canada,

			distances		CO, USA	Research)		Japan, France, South Korea,
119	Presentations	FMI	How important is to include self-consistent magnetic field in inner magnetosphere modeling	18/06/2012	GEM Workshop, 17 – 22 June 2012, Snowmass, CO, USA	Scientific community (higher education, Research)	240	USA, Finland, Canada, Japan, France, South Korea,
120	Presentations	FMI	Inner Magnetosphere Modelling: Dependence on the Boundary Conditions in the Plasma Sheet	21/06/2012	GEM Workshop, 17 – 22 June 2012, Snowmass, CO, USA	Scientific community (higher education, Research)	240	USA, Finland, Canada, Japan, France, South Korea,
121	Presentations	ONERA	Salammbô-3D radiation belt model used as the core of a forecasting tool – benefits and limitations	15/07/2012	COSPAR Assembly 12, Mysore, India	Scientific community (higher education, Research)	2000	Worldwide
122	Presentations	DHC	Forecasting High Energy Electron Fluxes at GEO: A New Service From the EU FP7 Project SPACECAST	16/07/2012	COSPAR Assembly 39, Mysore, India	Scientific community (higher education, Research)	50	global
123	Publication	NERC-BAS	Forecasting the Radiation Belts in Europe	09/08/2012	Space Weather The International Journal of Research and Applications	Scientific community (higher education, Research)		UK, worldwide
124	Presentations	UBARCELONA	Influence of the interplanetary shock on the heliocentric radial variations of gradual SEP events	13/09/2012	5th Solar Orbiter Workshop, Brugge, Belgium	Scientific community (higher education, Research)	100	European countries, USA
125	Presentations	FMI	Interhemispheric Magnetic Conjugacy, ISSI International Team "Resolving Current Systems in Geospace"	18/09/2012	September 17-21, 2012, International Space Science Institute, Bern, Switzerland.	Scientific community (higher education, Research)	20	France, Finland, Greece, Japan, Russia, USA, Norway
126	Presentations	FMI	Links between the plasmapause and the radiation belt boundaries from Cluster measurements	02/10/2012	3RD CLUSTER THEMIS WORKSHOP, Boulder, Colorado, 1 - 5 October 2012	Scientific community (higher education, Research)	150	UK, USA, France, Belgium, Spain, Finland, Italy, Sweden, Netherlands,

								Greece
127	Publication	NERC-BAS	Meredith et al., Global model of lower band & upper band chorus from multiple satellite observations	20/10/2012	JGR Space Physics	Scientific community (higher education, Research)		Worldwide
128	Presentations	NERC-BAS	Horne, Forecasting the Earth's Radiation Belts with SPACECAST to help Protect Satellites on Orbit	22/10/2012	Oslo, Norway	Scientific community (higher education, Research) - Industry - Civil society - Policy makers - Medias	300	Norway
129	Posters	NERC-BAS	Meredith, Global model of lower band and upper band chorus from multiple satellite observations	05/11/2012	ESWW9, Brussels, Belgium	Scientific community (higher education, Research) - Industry - Policy makers	200	UK, USA, France, Germany, Belgium, Spain, Finland, Italy, Netherlands, Sweden
130	Posters	NERC-BAS	Recent developments in the radiation belt models used for SPACECAST forecasts	05/11/2012	ESWW9, Brussels, Belgium	Scientific community (higher education, Research) - Industry - Policy makers	200	UK, USA, France, Germany, Belgium, Spain, Finland, Italy, Netherlands, Sweden
131	Presentations	FMI	Calculation of the satellite surface charging using forecasted low energy electron fluxes	06/11/2012	Ninth European Space Weather Week, November 5 - 9, 2012, Brussels, Belgium	Scientific community (higher education, Research) - Industry - Civil society - Policy makers	320	UK, USA, France, Belgium, Spain, Finland, Italy, Sweden, Netherlands, Greece
132	Posters	FMI	Space Weather Drivers: Outstanding Scientific Questions and Modelling Challenges of the Inner Magnet	06/11/2012	Ninth European Space Weather Week, November 5 - 9, 2012, Brussels, Belgium	Scientific community (higher education, Research) - Industry - Civil society - Policy makers	320	UK, USA, France, Belgium, Spain, Finland, Italy,

								Sweden, Netherlands, Greece
133	Posters	UBARCELONA	The SEPEM statistical solar energetic particle model away from 1 AU	06/11/2012	ESWW9, Brussels, Belgium	Scientific community (higher education, Research) - Industry	400	European Union, ESA's member states, USA
134	Organisation of Workshops	NERC-BAS	End user Lunch: Spacecraft Operations and Space Weather: Service User Dialogue	08/11/2012	ESWW9, Brussels, Belgium	Scientific community (higher education, Research) - Industry	25	UK, Germany, Netherlands, Luxembourg, France, Belgium
135	Presentations	NERC-BAS	Meredith, Scientific requirements for space environment forecasting models - Plasma waves	08/11/2012	ESWW9, Brussels, Belgium	Scientific community (higher education, Research) - Industry - Policy makers	50	UK, USA, France, Germany, Belgium, Spain, Finland, Italy, Netherlands, Sweden
136	Posters	DHC	Integrating data collection and distribution services with physical models for near real time foreca	08/11/2012	ESWW9, Brussels, Belgium	Scientific community (higher education, Research)	400	EU, ESA member states, USA
137	Presentations	NERC-BAS	Horne, Space Weather and Satellites	27/11/2012	NATO MPs, House of Commons, UK	Policy makers	15	UK, Greece, France, Netherlands, Turkey, Germany
138	Presentations	NERC-BAS	Horne et al., Forecasting the Earth's electron radiation belts with SPACECAST	30/11/2012	London MIST meeting	Scientific community (higher education, Research)		UK
139	Posters	NERC-BAS	Meredith et al., Global model of lower band & upper band chorus from multiple satellite observations	30/11/2012	London MIST Meeting, Royal Astronomical Society	Scientific community (higher education, Research)	75	United Kingdom
140	Posters	NERC-BAS	Recent developments in the radiation belt models used for SPACECAST forecasts	30/11/2012	London MIST Meeting, Royal Astronomical Society	Scientific community (higher education, Research)	75	United Kingdom
141	Publication	KUL	Zuccarello F. P., Z. Meliani, S. Poedts,	01/12/2012	Astrophys. J., (peer	Scientific community		Worldwide

			Numerical Modeling of the Initiation of Coronal		reveiwed Journal)	(higher education, Research)		
142	Presentations	NERC-BAS	Horne, Forecasting the High Energy Electron Radiation Belts Using Physics Based Models	04/12/2012	Fall AGU, San Francisco	Scientific community (higher education, Research) - Policy makers	100	USA,Canada, France, Germany, Belgium, Russia, Japan, Korea, Australia, South Africa
143	Presentations	NERC-BAS	Meredith et al., Global model of lower band & upper band chorus from multiple satellite observations	04/12/2012	Fall AGU, San Francisco	Scientific community (higher education, Research) - Policy makers	100	USA,Canada, France, Germany, Belgium, Russia, Japan, Korea, Australia, South Africa
144	Presentations	NERC-BAS	Horne, Forecasting the High Energy Electron Radiation Belts Using Physics Based Models	04/12/2012	San Francisco, USA	Scientific community (higher education, Research)	250	USA
145	Posters	UBARCELONA	Influence of the interplanetary shock on the heliocentric radial variations of gradual SEP events	04/12/2012	FALL AGU, San Francisco	Scientific community (higher education, Research)	1000	Worldwide
146	Presentations	FMI	Transport of the plasma sheet electrons to the geostationary distances	06/12/2012	Fall AGU Meeting, December 3-7, 2012, San Francisco, CA, USA	Scientific community (higher education, Research) - Policy makers - Medias	100	USA,Canada, France, Germany, Belgium, Russia, Japan, Korea, Australia, South Africa
147	Posters	FMI	Particle transport in the plasma sheet under the influence of substorm-associated electromagnetic fi	07/12/2012	Fall AGU Meeting, December 3-7, 2012, San Francisco, CA, USA	Scientific community (higher education, Research) - Policy makers - Medias	100	USA,Canada, France, Germany, Belgium, Russia, Japan, Korea,

								Australia, South Africa
148	Presentations	NERC-BAS	Horne, Space Weather	12/12/2012	Swindon, UK	Policy makers	30	UK
149	TV clips	NERC-BAS	Documentary on Space Weather	17/12/2012	TV2 Sweden	Medias		Sweden
150	Presentations	NERC-BAS	Meredith, Local Acceleration and Loss of Relativistic Electrons in the Earth's Outer Radiation Belt	10/01/2013	Burlington House, London	Scientific community (higher education, Research)	100	UK
151	Publication	FMI	Transport of the plasma sheet electrons to the geostationary distances	28/01/2013	J. Geophys. Res.: Space Physics	Scientific community (higher education, Research)		worldwide
152	Oral presentation to a scientific event	FMI	Low energy electrons in the inner magnetosphere	13/03/2013	International Space Science Institute, Bern, Switzerland	Scientific community (higher education, Research)	15	USA, UK, France, Germany, Sweden, Japan, Canada, Austria
153	Organisation of Workshops	NERC-BAS	The Earth's Radiation Belts: Physical Processes and Dynamic Modeling	18/03/2013	International Space Science Institute, Bern, Switzerland	Scientific community (higher education, Research)	22	UK, Belgium, USA, France, Canada, Japan
154	Presentations	ONERA	Determination of the radial diffusion coefficients from magnetic field measurements at geosynchronou	08/04/2013	EGU General Assembly, Vienna, Austria	Scientific community (higher education, Research)	11167	Worldwide
155	Posters	ONERA	Influence of electronic plasma density distribution on wave particle interaction	08/04/2013	EGU General Assembly, Vienna, Austria	Scientific community (higher education, Research)	100	UK, USA, France, Belgium, Spain, Finland, Italy, Sweden, Netherlands, Greece
156	Posters	NERC-BAS	Meredith et al., Global Model of Lower Band & Upper Band Chorus from Multiple Satellite Observations	09/04/2013	EGU 2013, Vienna	Scientific community (higher education, Research)	100	UK, USA, France, Belgium, Spain, Finland, Italy, Sweden,

								Netherlands, Greece,
157	Posters	NERC-BAS	New Chorus Diffusion Matrix	09/04/2013	EGU 2013, Vienna	Scientific community (higher education, Research)	100	UK, USA, France, Belgium, Spain, Finland, Italy, Sweden, Netherlands, Greece
158	Posters	ONERA	Determination of the radial diffusion coefficients from magnetic field measurements at geosynchronous orbit for different levels of magnetic activity	09/04/2013	EGU General Assembly 2013	Scientific community (higher education, Research)	11000	Worldwide
159	Posters	ONERA	Influence of electronic plasma density distribution on wave particle interaction	09/04/2013	EGU General Assembly 2013	Scientific community (higher education, Research)	11000	Worldwide
160	Publication	NERC-BAS	Horne et al. Space weather impacts on satellites and forecasting the Earth's electron radiation...	11/04/2013	Space Weather (peer reviewed journal)	Scientific community (higher education, Research) - Industry		Worldwide
161	Publication	NERC-BAS	Horne et al., Forecasting the Earth's electrons radiation belts and modeling solar energetic particl	25/04/2013	J Space Weather and Space climate	Scientific community (higher education, Research) - Industry		Worldwide
162	Publication	NERC-BAS	Meredith et al. Global statistical evidence for chorus as the embryonic source of plasmaspheric hiss	18/06/2013	Geophysical Research Letters	Scientific community (higher education, Research)		Worldwide
163	Oral presentation to a scientific event	UBARCELONA	¿Pueden los protones fastidiar nuestras misiones?: Modelización de sucesos de protones solares y modelos estadísticos para predicción de radiación durante una misión espacial: Una aplicación a Solar Orbiter	21/06/2013	IV Spanish meeting of heliospheric and solar physics, Alcalá de Henares, Spain	Scientific community (higher education, Research)	70	Spain
164	Posters	ONERA	Effect of plasma density on diffusion rates for wave particle interactions with chorus, plasmaspheric hiss and EMIC waves: Extreme event analysis	01/07/2013	MAARBLE-SPACECAST Joint Meeting	Scientific community (higher education, Research)		EU

165	Oral presentation to a scientific event	UHELSINKI	Coupling of particle and wave transport simulations	07/11/2013	9th European Space Weather Week	Scientific community (higher education, Research)	200	Worldwide
166	Posters	UHELSINKI	A Semi-analytical Foreshock Model for Space Weather Applications	19/11/2013	Tenth European Space Weather Week	Scientific community (higher education, Research) - Industry	300	Worldwide
167	Posters	NERC-BAS	Validating the BAS Radiation Belt Model with Giove-B satellite data	21/11/2013	European Space Weather Week 10	Scientific community (higher education, Research) - Industry	300	Worldwide
168	Oral presentation to a wider public	UBARCELONA	Les tempestes solars i com ens afecten	30/11/2013	Montsec Observatory, Ager (Lleida), Spain	Civil society	40	Spain
169	Oral presentation to a scientific event	UHELSINKI	Modeling Particle Acceleration and Turbulence Generation in CME-driven Shocks in the Solar Corona and Interplanetary Medium	11/12/2013	American Geophysical Union Fall Meeting	Scientific community (higher education, Research)	100	Worldwide
170	Posters	NERC-BAS	Validating the BAS Radiation Belt Model with Giove-B satellite data	13/12/2013	Royal Astronomical Society, Burlington House, London	Scientific community (higher education, Research)	100	UK
171	Oral presentation to a wider public	UBARCELONA	Modelling Solar Energetic Particle Events	07/02/2014	Cambridge, UK	Industry	30	Europe

SECTION B

This section should specify the exploitable foreground and provide the plans for exploitation. All these data can be public or confidential; the report must clearly mark non-publishable (confidential) parts that will be treated as such by the Commission. Information under Section B that is not marked as confidential **will be made available in the public domain** thus demonstrating the added-value and positive impact of the project on the European Union.

B1: LIST OF APPLICATIONS FOR PATENTS, TRADEMARKS, REGISTERED DESIGNS, ETC.					
Type of IP Rights:	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Application reference(s) (e.g. EP123456)	Subject or title of application	Applicant (s) (as on the application)
NOT APPLICABLE TO PROJECT SPACECAST					

B2: EXPLOITABLE FOREGROUND								
Type of Exploitable Foreground	Description of exploitable foreground	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
Forecasting service	A forecast of space weather events that pose a risk to space assets	No	N/A	Forecasting service	1. Space insurance 2. Satellite design 3. Satellite operators	In current use	None, service is freely available	Equal ownership among all beneficiaries in the project

REPORT ON SOCIETAL IMPLICATIONS

A General Information (completed automatically when Grant Agreement number is entered.	
Grant Agreement Number:	262468
Title of Project:	Spacecast: Protecting space assets from high energy particles by developing European dynamic modelling and forecasting capabilities
Name and Title of Coordinator:	Prof. Richard Horne

B Ethics	
1. Did your project undergo an Ethics Review (and/or Screening)? • If Yes: have you described the progress of compliance with the relevant Ethics Review/Screening Requirements in the frame of the periodic/final project reports? Special Reminder: the progress of compliance with the Ethics Review/Screening Requirements should be described in the Period/Final Project Reports under the Section 3.2.2 *'Work Progress and Achievements'*	***No***
2. Please indicate whether your project involved any of the following issues (tick box) :	
RESEARCH ON HUMANS	
• Did the project involve children?	
• Did the project involve patients?	
• Did the project involve persons not able to give consent?	
• Did the project involve adult healthy volunteers?	
• Did the project involve Human genetic material?	
• Did the project involve Human biological samples?	
• Did the project involve Human data collection?	
RESEARCH ON HUMAN EMBRYO/FOETUS	
• Did the project involve Human Embryos?	
• Did the project involve Human Foetal Tissue / Cells?	
• Did the project involve Human Embryonic Stem Cells (hESCs)?	
• Did the project on human Embryonic Stem Cells involve cells in culture?	
• Did the project on human Embryonic Stem Cells involve the derivation of cells from Embryos?	
PRIVACY	
• Did the project involve processing of genetic information or personal data (eg. health, sexual lifestyle, ethnicity, political opinion, religious or philosophical conviction)?	
• Did the project involve tracking the location or observation of people?	
RESEARCH ON ANIMALS	
• Did the project involve research on animals?	
• Were those animals transgenic small laboratory animals?	
• Were those animals transgenic farm animals?	
• Were those animals cloned farm animals?	
• Were those animals non-human primates?	

RESEARCH INVOLVING DEVELOPING COUNTRIES	
• Did the project involve the use of local resources (genetic, animal, plant etc)?	
• Was the project of benefit to local community (capacity building, access to healthcare, education etc)?	
DUAL USE	
• Research having direct military use	No
• Research having the potential for terrorist abuse	No

C Workforce Statistics

3. Workforce statistics for the project: Please indicate in the table below the number of people who worked on the project (on a headcount basis).

Type of Position	Number of Women	Number of Men
Scientific Coordinator	0	1
Work package leaders	3	6
Experienced researchers (i.e. PhD holders)	6	9
PhD Students	0	0
Other	3	3

4. How many additional researchers (in companies and universities) were recruited specifically for this project?	0
Of which, indicate the number of men:	0

D Gender Aspects

5. Did you carry out specific Gender Equality Actions under the project?	✓ ○	Yes No

6. Which of the following actions did you carry out and how effective were they?

		Not at all effective				Very effective
✓	Design and implement an equal opportunity policy	○	○	○	●	○
❑	Set targets to achieve a gender balance in the workforce	○	○	○	○	○
❑	Organise conferences and workshops on gender	○	○	○	○	○
✓	Actions to improve work-life balance	○	○	○	○	●
○	Other:					

7. Was there a gender dimension associated with the research content – i.e. wherever people were the focus of the research as, for example, consumers, users, patients or in trials, was the issue of gender considered and addressed?

○ Yes- please specify

● No

E Synergies with Science Education

8. Did your project involve working with students and/or school pupils (e.g. open days, participation in science festivals and events, prizes/competitions or joint projects)?

● Yes- please specify: The Coordinating institution hosted vacation students (undergraduates) throughout the project

○ No

9. Did the project generate any science education material (e.g. kits, websites, explanatory booklets, DVDs)?

- ○ Yes- please specify
- ● No

F Interdisciplinarity

10. Which disciplines (see list below) are involved in your project?

●	Main discipline[1]: 1.2		
●	Associated discipline[1]: 2.3	○	Associated discipline[1]:

G Engaging with Civil society and policy makers

11a Did your project engage with societal actors beyond the research community? *(if 'No', go to Question 14)*	●	Yes
	○	No

11b If yes, did you engage with citizens (citizens' panels / juries) or organised civil society (NGOs, patients' groups etc.)?

- ● No
- ○ Yes- in determining what research should be performed
- ○ Yes - in implementing the research
- ○ Yes, in communicating /disseminating / using the results of the project

11c In doing so, did your project involve actors whose role is mainly to organise the dialogue with citizens and organised civil society (e.g. professional mediator; communication company, science museums)?	○	Yes
	●	No

12. Did you engage with government / public bodies or policy makers (including international organisations)

- ○ No
- ● Yes- in framing the research agenda
- ○ Yes - in implementing the research agenda
- ● Yes, in communicating /disseminating / using the results of the project

13a Will the project generate outputs (expertise or scientific advice) which could be used by policy makers?

- ○ Yes – as a **primary** objective (please indicate areas below- multiple answers possible)
- ● Yes – as a **secondary** objective (please indicate areas below - multiple answer possible)
- ○ No

[1] Insert number from list below (Frascati Manual).

13b If Yes, in which fields?					
Agriculture		Energy		Human rights	
Audiovisual and Media		Enlargement		Information Society	
Budget		Enterprise		Institutional affairs	
Competition		Environment		Internal Market	
Consumers		External Relations		Justice, freedom and security	
Culture		External Trade		Public Health	✓
Customs		Fisheries and		Regional Policy	✓
Development Economic and Monetary Affairs		Maritime Affairs		Research and Innovation	
		Food Safety		Space	
Education, Training, Youth		Foreign and		Taxation	
		Security Policy		Transport	
Employment and Social Affairs		Fraud			
		Humanitarian aid			

13c If Yes, at which level?

- ○ Local / regional levels
- ● National level
- ● European level
- ○ International level

H Use and dissemination	
14. How many Articles were published/accepted for publication in peer-reviewed journals?	**29**
To how many of these is open access[2] provided?	**25**
How many of these are published in open access journals?	**20**
How many of these are published in open repositories?	**5**
To how many of these is open access not provided?	**4**
Please check all applicable reasons for not providing open access:	
☒ publisher's licensing agreement would not permit publishing in a repository ❑ no suitable repository available ❑ no suitable open access journal available ☒ no funds available to publish in an open access journal ❑ lack of time and resources ❑ lack of information on open access ❑ other[3]: ……	
15. How many new patent applications ('priority filings') have been made? *("Technologically unique": multiple applications for the same invention in different jurisdictions should be counted as just one application of grant).*	**0**

[2] Open Access is defined as free of charge access for anyone via Internet.
[3] For instance: classification for security project.

16. Indicate how many of the following Intellectual Property Rights were applied for (give number in each box).	Trademark	**0**
	Registered design	**0**
	Other	**0**
17. How many spin-off companies were created / are planned as a direct result of the project?		**0**
Indicate the approximate number of additional jobs in these companies:		**0**

18. Please indicate whether your project has a potential impact on employment, in comparison with the situation before your project:

❑	Increase in employment, or	❑	In small & medium-sized enterprises
❑	Safeguard employment, or	❑	In large companies
❑	Decrease in employment,	☒	None of the above / not relevant to the project
❑	Difficult to estimate / not possible to quantify		

19. For your project partnership please estimate the employment effect resulting directly from your participation in Full Time Equivalent (*FTE = one person working fulltime for a year*) jobs:	*Indicate figure:*
Difficult to estimate / not possible to quantify	☒

I Media and Communication to the general public

20. As part of the project, were any of the beneficiaries professionals in communication or media relations?

○ Yes ● No

21. As part of the project, have any beneficiaries received professional media / communication training / advice to improve communication with the general public?

○ Yes ● No

22 Which of the following have been used to communicate information about your project to the general public, or have resulted from your project?

☒	Press Release	☒	Coverage in specialist press
☒	Media briefing	☒	Coverage in general (non-specialist) press
☒	TV coverage / report	☒	Coverage in national press
☒	Radio coverage / report	❑	Coverage in international press
❑	Brochures /posters / flyers	☒	Website for the general public / internet
❑	DVD /Film /Multimedia	❑	Event targeting general public (festival, conference, exhibition, science café)

23 In which languages are the information products for the general public produced?

☒	Language of the coordinator	☒	English
☒	Other language(s)		