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THE JOHNS HOPKINS UNIVERSITY
APPLIED PHYSICS LABORATORY
11100 JOHNS HOPKINS ROAD, LAUREL, MARYLAND 20723-6099

Radiation Belt Storm Probes (RBSP) Space Weather Interface Control Document

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	88898	A	7417-9100	-
	SCALE	DO NOT SCALE PRINT	SHEET 1 of 36	

Technical Content Approval

Prepared/Approved by:

Nicola J. Fox
RBSP Deputy Project Scientist

Michele B. Weiss
RBSP Space Weather Lead

Approved by:

Richard J. Fitzgerald
RBSP Project Manager

James M. Stratton
RBSP Mission Systems Engineer

Kim A. Cooper
RBSP Deputy Project Manager, Instrument

Raymond J. Harvey
RBSP Ground Segment Systems Engineer

Dipak K. Srinivasan
RBSP RF Telecommunications Lead

Barry H. Mauk
RBSP Project Scientist

Debbie A. Clancy
RBSP Software Systems Engineer

David A. Artis
RBSP Data Systems Engineer

W. Mark Reid
RBSP Flight Software Lead

Richard J. Pfisterer
RBSP System Assurance Manager

Technical Content Approval (continued)

The following personnel have reviewed/approved by display of e-mail response/signature for this release as cited below:

Harlan Spence
ECT PI

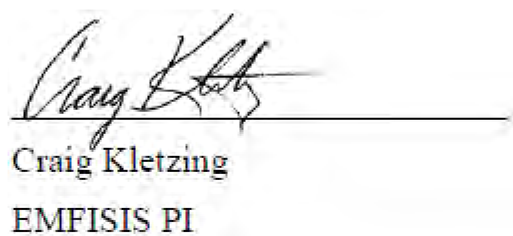
----- Original Message -----
From: Harlan Spence <Harlan.Spence@unh.edu>
To: Cooper, Kim
Cc: Suther, Lora L.
Sent: Tue Mar 13 16:51:41 2012
Subject: Re: ACTION: Space Weather ICD ready for approval

Kim,

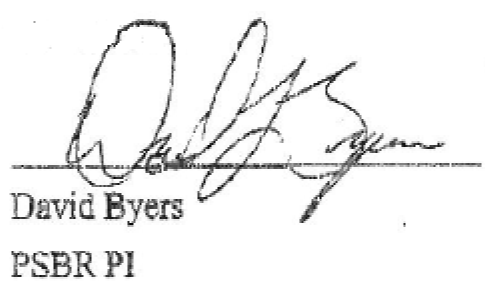
I approve the 7417-9100 RBSP Space Weather ICD, Rev -, distributed on 3/13/12.

Thank you,
- Harlan

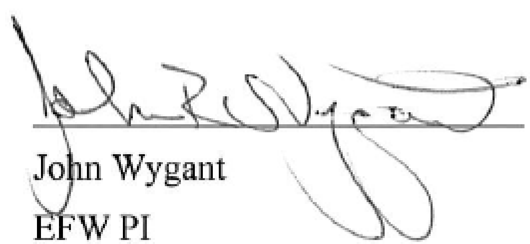
Craig Kletzing
EMFISIS PI



David Byers
PSBR PI



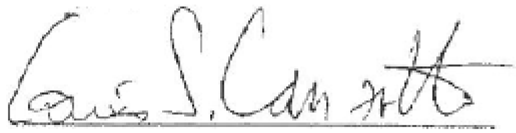
John Wygant
EFW PI



Technical Content Approval (continued)

The following personnel have reviewed/approved by display of e-mail response/signature for this release as cited below:

Louis Lanzerotti
RBSPICE PI



Louis Lanzerotti

RBSPICE PI

Keith Goetz
EFW Project Manager

----- Original Message -----
From: Keith Goetz <goetz@umn.edu>
To: Cooper, Kim
Sent: Tue Mar 20 14:07:35 2012
Subject: PDF-File-Verify-Sender:Re: ACTION: Space Weather ICD ready for approval

"I approve the 7417-9100 RBSP Space Weather ICD, Rev -, distributed on 3/13/12"

Here we are.
K

A Release stamp electronically affixed at bottom of the pages of this document certifies that the above personnel or designated alternates have approved this initial release. Please refer to the APL Product Lifecycle Management System (PLM) for record of these approvals.

Revision Log

Revision	Date	Author	Description of Change
Draft	10/09/2009	Nicola J. Fox	Draft
Draft a	12/28/2011	Michele B. Weiss	Updated RBSPICE telemetry packets wit actual energies. Added ECT/MagEIS Med35 packet. Updated ECT/HOPE packet definitions.
Draft b	2/1/2012	Michele B. Weiss	Clarification that the ECT/MagEIS medium 35 or 75 instrument can generate space weather data.
Draft c	2/14/12	Michele B. Weiss	Update EMFISIS packet definitions.
Draft d-	2/15/12	Michele B. Weiss	Updated when the Ephemeris Prediction available
-		Michele B. Weiss	Original Release
		Michele B. Weiss	Added references to the CCSDS Blue Books, updated acronyms
-	4/24/12	Michele B. Weiss	Updated EMFISIS data rate
-	6/11/12	Michele B. Weiss	Initial Release

TABLE OF CONTENTS

1 INTRODUCTION

1.1 PURPOSE

The Radiation Belt Storm Probe (RBSP) Space Weather ICD presents a high-level strategy for the generation and broadcasting of real-time space weather data from the RBSP instruments. The space weather data to be broadcast from RBSP comprises a small fraction of the scientific data obtained by the instruments. The broadcasts are intended to be received by ground stations supplied, operated, and funded by interested parties external to the RBSP Program and Project.

1.2 SCOPE

The ICD defines the data products from each RBSP instrument, data products to be supplied by the Mission Operations Center (MOC), and the necessary information needed by a ground station for the capturing the broadcasted data.

Specific aspects addressed in this ICD are:

1. Space weather broadcast data
2. Implementation and limitations of the space weather broadcast
3. Information on how to receive the space weather data
4. Downlink and telemetry formats
5. Data packet definitions
6. Space asset protection policy implications
7. Institutional responsibilities

1.3 CONFIGURATION MANAGEMENT

The data contained in this document represents the current definition of the Radiation Belt Storm Probe Mission Space Weather Interface Control Document. This document, after formal release, shall be revised only through the formal change control procedures as described in the RBSP Configuration Management Plan.

1.4 APPLICABLE DOCUMENTS

	Level 1 Requirements for the Radiation Belt Storm Probes Mission
7417-9013	RBSP Mission Requirements Document (MRD)
7417-9148	RBSP Science Team Allocated Requirements Document (STARD)
7417-9016	RBSP Concept of Operations
7417-9050	RBSP Mission Operations Center (MOC) to RBSP Science Operations Center (SOC) and Interface Control Document (ICD)
7417-9129	RBSP Science Data Management Plan (SDMP)

7417-9105	RBSP Mission Operations Center (MOC) Data Products Document
7417-9097	RBSP Spacecraft to Satellite Communications Facility (SCF) to Mission Operations Center (MOC) Interface Control Document (ICD)
7417-9609	RBSP Ground Software to Flight Software Interface Control Document

1.5 REFERENCES

1. CCSDS 133.0-B-1 Space Packet Protocol. Blue Book. Issue 1. September 2003.
2. CCSDS 132.0-B-1 TM Space Data Link Protocol. Blue Book. Issue 1. September 2003.

2 RBSP PROJECT OVERVIEW

2.1 PAYLOAD AND MISSION

The RBSP mission targets Earth's radiation belts of magnetically trapped, very high energy electrons and ions. Its scientific objective is to understand, ideally to the point of predictability, how populations of high energy relativistic electrons and penetrating ions in space are produced and change in response to the variable inputs of energy from the Sun. The mission comprises 2 near-sun oriented observatories, which are spin stabilized ~5 rpm with a spin-axis oriented 16°-20° from the Earth-Sun line, and that reside in nearly identical, highly elliptical, near equatorial orbits with apogees just below 6 Earth radii geocentric (Figure 1). The observatories have an operational design life of 2 years. The understanding gained by RBSP will enable us, in the future, to better protect space assets in near-Earth environment. In addition to the scientific data returned to achieve this understanding, the RBSP mission provides a 1 kbps space weather broadcast in support of real time space weather modeling, forecast and prediction efforts.

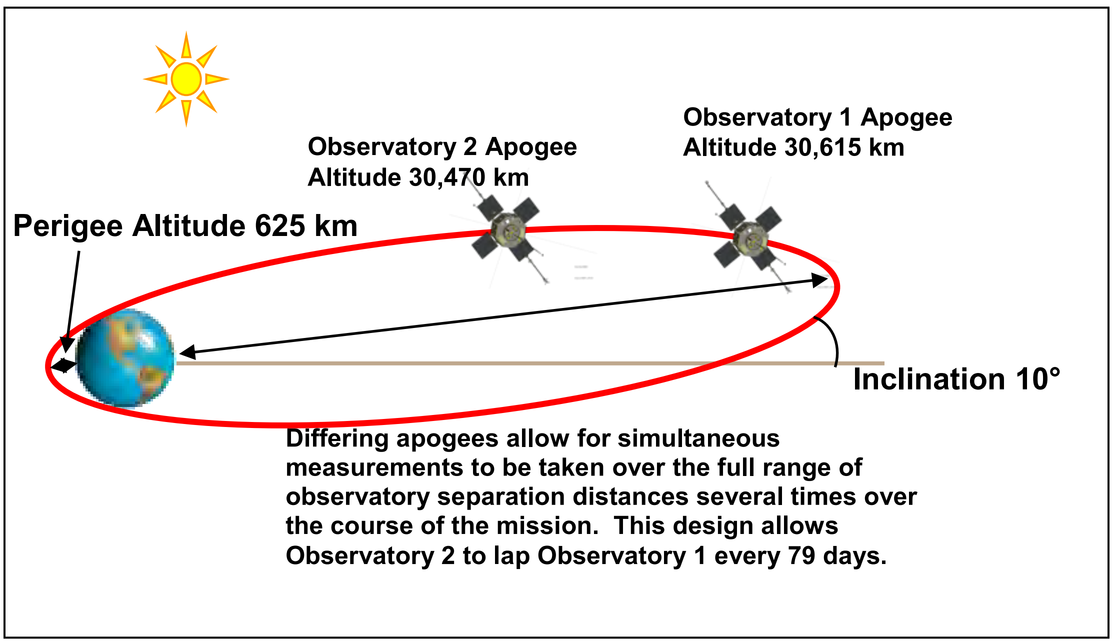


Figure 1. Orbit configuration of the RBSP spacecraft

The unusual orbit of the RBSP spacecraft will provide great insight into many regions of the radiation belts. The highly elliptical orbit of RBSP will provide data from the non-traditional orbital locations - operational monitoring satellites are usually at or near geosynchronous orbit. For 3-D specification models, these altitude-varying profiles will provide greater sampling of Earth's radiation environment

It has always been an important objective that the space weather broadcasts not become a cost driver on the mission. Thus, there is no dedicated space weather beacon or transmitter aboard the spacecraft, but rather the space weather data will be broadcast in real-time through the primary spacecraft RF system, used for the science downlink. The observatory will broadcast space weather when it is not in a primary mission-related ground contact. The data will be received by users that maintain and fund their own ground station antennas. NASA headquarters is responsible for the identification of users and for programmatic interfaces between the users and the RBSP Project.

It is desirable that as much of the Space Weather Broadcast data be captured in real-time as possible. Because of the geometry of the mission configuration of spacecraft orientations and orbits, the RBSP mission presents challenges for generating broadcasts that can be received continuously by ground stations, in the fashion of the ACE and STEREO missions. The data capture is limited by the availability of space weather ground stations and the poor downlink geometry for portions of the mission. Additionally, the real time coverage will be reduced by an average of 2.5 hours for each observatory per day due to primary mission contacts. Often one of the two observatories will still be available because many contacts with each observatory do not overlap.

Each of the RBSP payload instruments will be participating in the real-time space weather broadcast. The RBSP payload includes the following science investigations:

1. The Energetic Particle, Composition and Thermal Plasma Suite (ECT). This investigation will determine the spatial, temporal, and pitch angle distributions of electrons and ions over a broad and continuous range of energies, from a few eV to > 10 MeV for electrons, and from a few eV to many 10's of MeV for ions. It is designed to differentiate the causes of particle acceleration mechanisms, understand the production of plasma waves, determine how the inner magnetospheric plasma environment controls particle acceleration and loss, and characterize source particle populations and their transport. The investigation will provide a complete complement of data analysis techniques, case studies, theory, and modeling, along with expertise to define particle acceleration mechanisms, radiation belt particle enhancement and loss, and determine how the near-Earth environment controls those acceleration and loss processes.

2. The Electric and Magnetic Field Instrument Suite and Integrated Science (EMFISIS). This investigation will provide the observations needed to determine the origin of important plasma wave classes and their role in particle acceleration and loss processes. The investigation will also quantify the evolution of the magnetic field that defines the basic coordinate system controlling the structure of the radiation belts and the storm-time ring current. EMFISIS will provide calculations of on board spectra, including spectral matrices, making it possible to determine wave normal angles and Poynting fluxes for the plasma waves of interest and providing information for wave mode identification and propagation modeling which are

essential for understanding and modeling of radiation particle physics. EMFISIS will also measure the upper hybrid frequency, permitting accurate determination of the electron plasma density required for analysis of wave propagation and instability growth rates.

3. Electric Field and Waves (EFW) Instrument. The investigation will provide the observations needed to understand the electric field properties associated with particle energization, scattering and transport, and the role of the large-scale convection electric field in modifying the structure of the inner magnetosphere. EFW measurements of the spacecraft potential will be used to infer the ambient plasma density.

4. Radiation Belt Storm Probes Ion Composition Experiment (RBSPICE). This investigation will provide observations that accurately resolve the ring current pressure distribution needed to understand how the inner magnetosphere changes during geomagnetic storms and how that storm environment supplies and supports the acceleration and loss processes involved in creating and sustaining hazardous radiation particle populations.

5. The Proton Spectrometer Belt Research (PSBR). This investigation will determine the upper range of proton fluxes, up to ~2 GeV, in the inner magnetosphere and develop and validate models of the Van Allen radiation belts.

3 SPACE WEATHER BROADCAST DATA

3.1 APPROACH

The RBSP instrument suites will select space weather data to be broadcast from their collected science data on board the observatories. The instruments will choose space weather data from measurements based on information normally available to the instrument. The data subset includes particle fluxes, at a variety of energies, and magnetic and electric field data as detailed in the table below. The exact energy and frequency ranges are subject to review as the instrument teams continue to refine their selection of data products.

The implementation for PSBR/RPS is different than for the other RBSP instruments. Their housekeeping packet will be broadcast once every second and the space weather products are embedded within this packet. The details of their housekeeping packet are in Section 7. Packet size = 38 bytes @ 1 per second = 304 bps. The two space weather products are given in bytes 10, 12 and 34. Specifically these are PEN and CHE rates - 1-second coincidence rates as fluxes (>50 ~MeV, and > ~400 MeV protons) – and the onboard dosimeter data which come in as multiplexed voltages from a linear (quick rollover) and logarithmic (slow rollover) dose accumulator. An algorithm for unpacking these data will be provided to the users by the PSBR team.

In addition to the real-time products, it is a goal for a "quick look" product to be produced by each of the individual instrument Science Operations Centers (SOC). These products will essentially "fill in the gaps" caused by times when the broadcast data cannot be received and also provide a more complete data set for use in the diagnostics of anomalies at LEO and MEO.

3.2 SPACE WEATHER DATA SET

Table 1 shows the space weather data products that will be generated by the various sensors on RBSP and included in the space weather broadcasts.

Table 1. RBSP Real Time Data Set

Instrument	***Measurement***	***Energy***	***Cadence***	***Data Rate (bps)***	***Space Weather APID***
EMFISIS/ MAG	Vector Magnetic Field	NA	1 vector/12 seconds	24	0x28C
EMFISIS/ Waves	VLF Wave Power	NA	Electric field spectral density at 3 frequencies every 12 seconds; Magnetic field spectral density at 3 frequencies every 12 seconds		
EFW	Vector Electric Field	NA	1 vector/spin	18.66	0x26A
	Spacecraft Potential	NA	Once/spin		
ECT/HOPE	Electrons	24.54 eV, 281 eV, 10.9 keV, 42.9 keV **	Once/24 seconds*	76	0x22C (ions) 0x22D (electrons)
	Protons	24.54 eV, 281 eV, 10.9 keV, 42.9 keV	Once/24 seconds* * Ions and electrons are sampled alternately every other spin		
	Oxygen Ions	24.54 eV, 281 eV, 10.9 keV, 42.9 keV			
	Helium Ions	24.54 eV, 281 eV, 10.9 keV, 42.9 keV			
ECT/ MagEIS	Energetic Electrons	30 keV 60 keV, 100 keV, 300 keV, 600 keV, 1 MeV, 2 MeV	Once/spin	105.6	0x34A (Low electrons) 0x36A (Med75 electrons) 0x375 (High electrons) 0x382 (High protons)
	Energetic Protons	1 MeV			
ECT/REPT	Very Energetic Electrons	2 MeV, 5 MeV, 10 MeV	Once/spin	14.4	0x201
	Energetic Protons	>20 MeV, >50 MeV, >70 MeV			
RBSPICE	Energetic Protons	50 keV, 100 keV, 150 keV, 300 keV, 1 MeV, 10 MeV	Once/spin	136	0x311

PSBR/RPS	Energetic Protons	>50 MeV, >400 MeV	Once/1 seconds	304	0x2C1
	Dosimeter Data	Linear and Log outputs (Volts)			

** ECT/HOPE has 16 different energy sweep tables, with table 0 being the nominal sweep. Picking data off for space weather is based solely on the step number within the in-use sweep table, so when HOPE is not using the nominal table (table 0) the selected energies may not be 25, 300, 10k, and 40kev. The ESA sweep table that was in use when the space weather data was generated is reported in the ESA_TABLE field included in each packet.

4 IMPLEMENTATION AND LIMITATIONS OF THE SPACE WEATHER BROADCAST

The RBSP mission observatories will communicate with the ground via S-Band using an 8W Solid State Power Amplifier (SSPA) transmitters. The observatory pointing geometry, orbit, and spin stabilization determines communication system requirements. Earth location, as viewed from the spacecraft, covers a very broad angle space (mast angle) as shown in the required RBSP antenna angle coverage plot below (Figure 2). Contact geometry necessitates onboard antennas that have broad angular coverage and low gain.

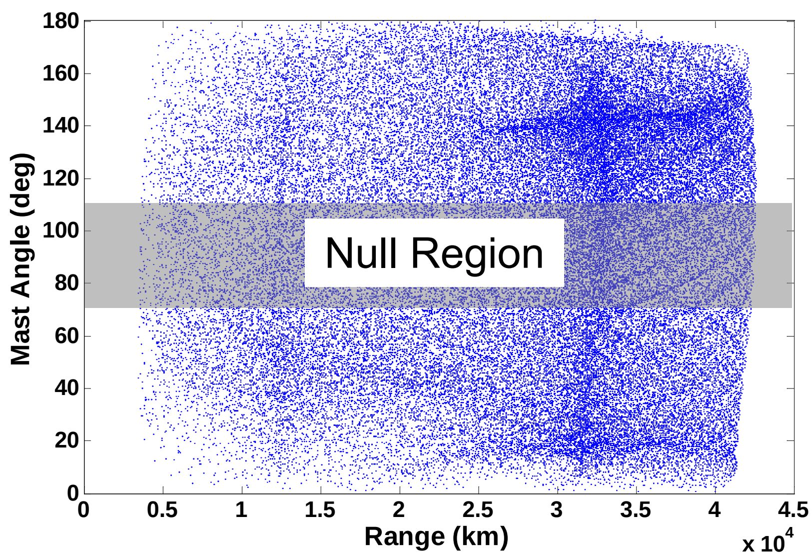


Figure 2: Required RBSP Antenna Angle Coverage

The coverage is maximized within practical limits using two low gain antennas. The two RF antennas' boresights are aligned with the spacecraft spin- and anti-spin-axes, providing coverage from their boresight to 70º. Despite maximizing the antenna coverage, there is still a 40° null band, depicted in Figure 2 as the gray patch in the antenna angle coverage plot. Both antennas are active at all times, as there is no active switching between antennas. Instead, a passive splitter/combined sums the antenna patterns. The top antenna and bottom antenna generate circularly polarized emissions with RBSP A using Right Hand Circular Polarization and RBSP B using Left Hand Circular Polarization. The spacecraft and antenna patterns are illustrated in Figure 3.

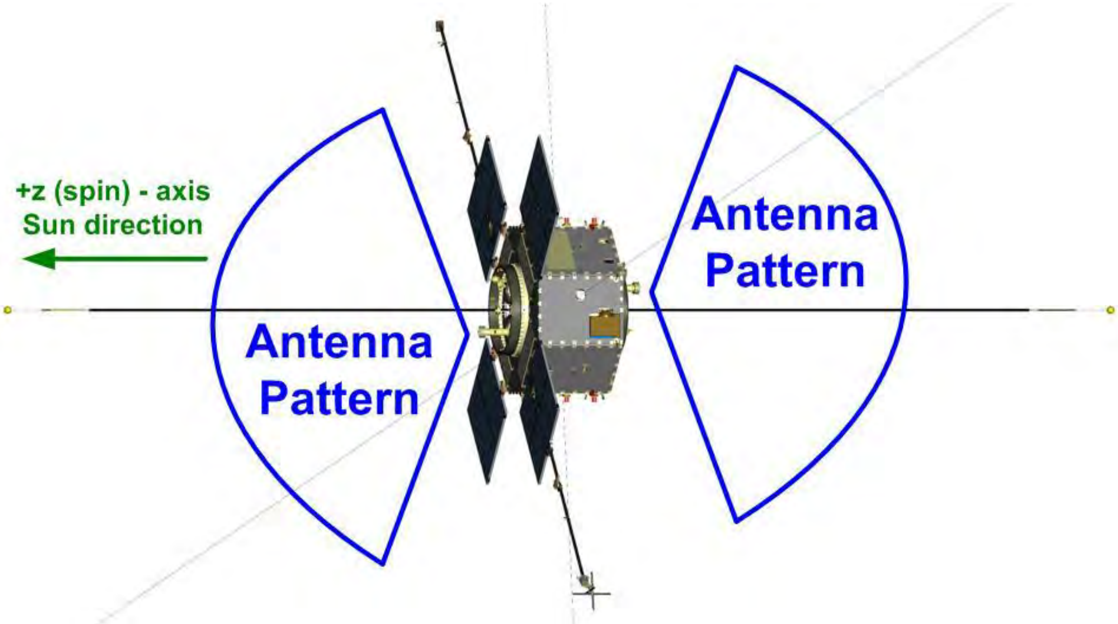


Figure 3: RBSP RF Antenna Covereage

The antenna coverage to Earth depends on orbit geometry that seasonally varies as illustrated in Figure 4 – a view of the orbit changes as seen from a vantage pointing looking down on the Earth from the North Pole. Although antenna coverage is large, there are times when the antenna patterns are not aligned with the Earth. The large eccentricity of the orbit causes larger periods of time when antennas are not in view during certain times of the year because the relative angle between the observatory and Earth changes slowly over long periods of time. Observatory orbits are at a low inclination (10°) and the orbit harmonics cause the apogee and perigee to drift between northern and southern hemispheres. Stations near the equator will have the best year-around coverage while high latitude stations may have some limits in coverage over portions of the orbit for parts of the year.

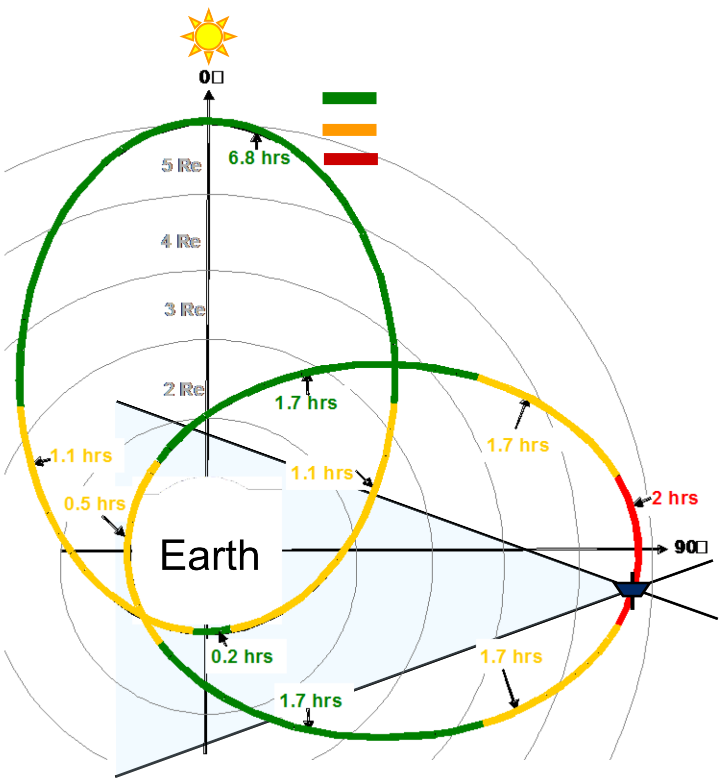
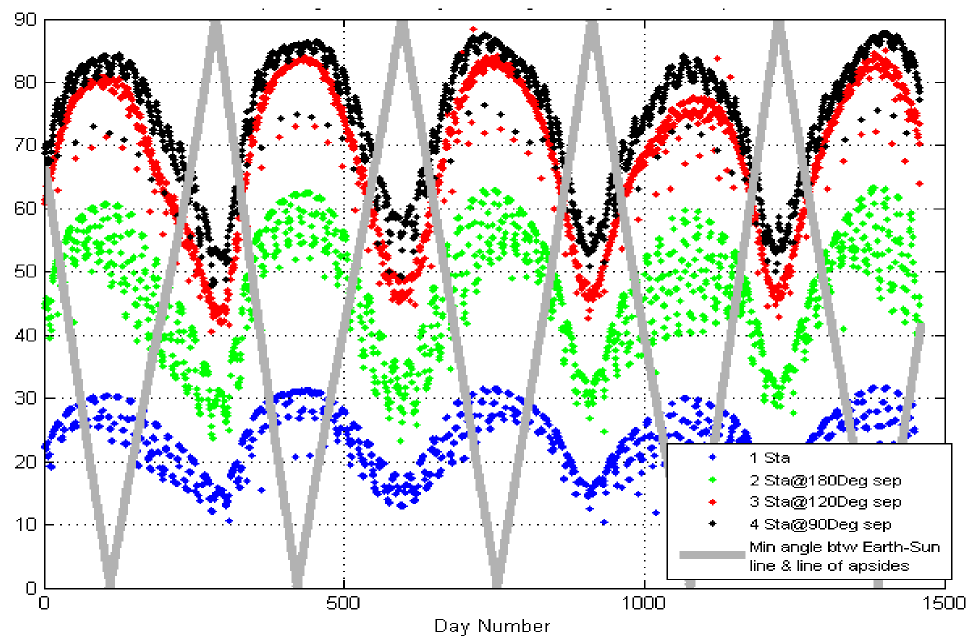


Figure 4: Degree of antenna coverage due to seasonal variations

For the potential ground reception of the space weather broadcast, the maximum observatory contact duration as a function of the number of ground stations can be maximized by using multiple stations with longitudinal diversity. The plot below (Figure 5) shows the coverage for 1, 2, 3 and 4 ground stations with maximum angular separation – i.e. 2 are separated by 180°; 3 by 120°; and 4 by 90°. The peaks and valleys in potential contact periods are primarily due to seasonal effects on observatory antenna coverage. Normal observatory contacts (i.e. downlinking of science data and uplinking commands etc.) would reduce available time for space weather by an average of 2.5 hours per observatory per day (~10% per observatory).



Assumptions:

- **Visibility averaged over 3 day increments**
- **Two 70° half angle antennas**
- **Generic ground stations assumed at 35° N latitude**

Figure 5: Average Contact Time per Day (%)

Min. Angle Between Earth-Sun Line & Line of Apsides (deg)

5 RECEIVING THE SPACE WEATHER BROADCAST DATA

Each RBSP spacecraft provides a 1 kbps space weather broadcast–rate, 1/2 convolutionally encoded, direct-on-carrier phase modulation, bi-phase data. The mission will use a modulation index of 0.9 radians during space weather broadcast (Table 2). This choice enables a 5-m ground station dish with a noise temperature of 390K to close out the space weather link when the spacecraft are at apogee. Table 3 provides the broadcast carrier frequencies.

Table 2: Telemetry Mode for Space Weather

Bit Rate (bps)	Encoding	Symbol Rate (ksps)	Carrier Modulation	Data Format	Network
1000	Conv. 1/2	2000	PM, 0.9 rad peak	Biphase	Space Weather

The RBSP Command and Data Handling (C&DH) subsystem will provide real-time space weather packets in CCSDS telemetry packets downlinked as CCSDS frames. The frame format is defined in Table 4. The space weather packets will be broadcast in real time when not in a ground contact. The space weather data will not be recorded on the on-board Solid State Recorder. Each RBSP instrument will provide their space weather data in separate CCSDS telemetry packets (the same scenario that is used for the STEREO mission). Each packet has a unique APID. RBSP Mission Operations controls when Space Weather is downlinked and what packets are provided. Nominally, at the end of a ground contact, the C&DH subsystem is configured to flow Space Weather data in real-time at the downlink configuration and rates mentioned in this ICD.

Table 3. RF Downlink Parameters.

Parameter	RBSP-A	RBSP-B
Spacecraft ID	16A	16B
	Downlink	
Transmit frequency	S-band	S-band

6 DOWNLINK AND TELEMETRY FORMATS

6.1 TELEMETRY TRANSFER FRAME

The transfer frame contains a primary header and secondary header followed by a frame data field which consists of one or more telemetry packets. This structure is shown below in figure 6. The frame ends with a 16-bit Frame Error Control Field and the 32-bit Command Link Control Word (CLCW) for the virtual channel.

Telemetry packets contained within the transfer frame may be variable length. Thus telemetry packets may span across transfer frames and the start of a new transfer frame will not ordinarily be aligned with the start of a telemetry packet.

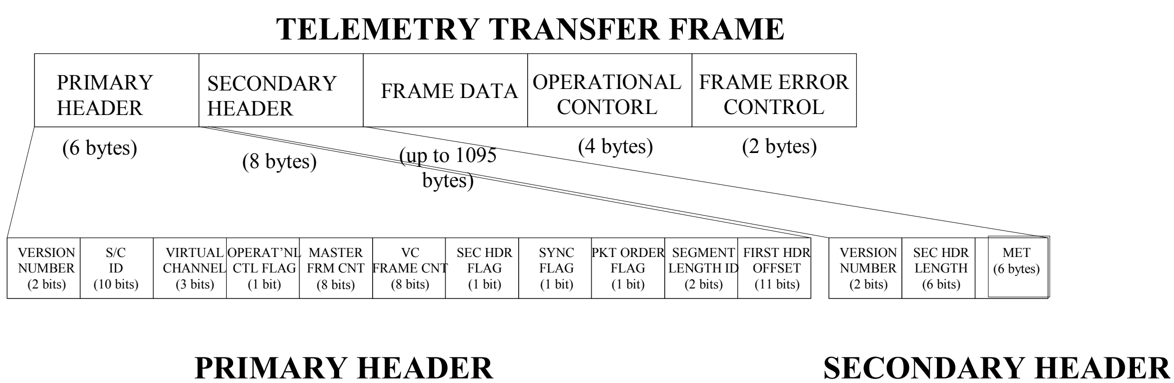


Figure 6: Telemetry Transfer Frame Format

6.2 TELEMETRY FRAME DEFINITION

Table 4 provides the contents of the Space Weather telementry frames and the CCSDS telemetry protocol is defined in Reference 2.

Table 4: Telemetry Frame Contents

Bit Field	Length (bits)	Value (binary)	Description
Transfer Frame Primary Header			**6 bytes**
Transfer Frame Version No	2	00	
Spacecraft ID	10	0101101010 or 0101101011	RBSP ID (0x16A OR 0x16B)
Virtual Channel	3	101	VC05 for 8920 bit space weather

ID			
Oper. Controlled Field Flag	1	1	Oper. Controlled Field Used
Master Channel Frame Count	8	0 - 255 (decimal)	Incrementing counter
Virtual Channel Frame Count	8	0 - 255 (decimal)	Incrementing counter
Transfer Frame Secondary Header Flag	1	1	Secondary header present
Synch. Flag	1	0	
Packet Order Flag	1	0	
Segment Length ID	2	11	
First Header Pointer	11	Variable	Pointer to first byte in data field
Transfer Frame Secondary Header			**8 bytes**
Transfer Frame Secondary Header Version	2	00	
Transfer Frame Secondary Header Length	6	000111	07 = 8 bytes - 1 (CCSDS std def)
MET Source	8	0 1	MET latched MET calculated
MET Seconds	32		MET Seconds
MET Subseconds	16	0-50000 (decimal)	MET subseconds (LSB = 20 usec)
Frame Data	1095 bytes	Variable	1115 bytes/frame - 6 bytes (Prim. hdr) - 8 bytes (Sec. hdr.) - 4 bytes (Oper. Ctl. Wd.) - 2 bytes (Err. Ctl. Fld.) = 1095 bytes
Transfer Frame Operational Control Field	32		Required - contains CLCW
Transfer Frame Error Control Field Data	16		Appended by H/W as documented in the CCSDS Blue Book, Reference 1

6.3 FRAME VIRTUAL CHANNEL

Space Weather will use Virtual Channel (VC) 5. The frame length is of 8920 bits (1115 bytes)

6.4 FRAME SECONDARY HEADER

The definition of fields for the downlink telemetry frame secondary header is defined in Table 4.

7 SPACE WEATHER PACKET DEFINITIONS

Tables 6-17 containing details for each APID in Table 1 are provided here

7.1 EMFISIS SPACE WEATHER DATA

Table 6. EMFISIS Space Weather Packet (APID 0x28C)

Field Description	*Start Bit*	*Size (bits)*	*Note*
CCSDS Version	0	3	Value is always zero (0)
Pkt Type	3	1	0=telemetry
Sec. Hdr. Flag	4	1	1=has secondary header
Application ID	5	11	***EMFISIS*** APID
Grouping Flags	16	2	CCSDS definition of grouping flags: 3 – not part of group
Sequence Count	18	14	Increments with each new packet. Value is 0 - 16383
Packet Length	32	16	Data size, number of bytes following the "Packet Length" minus 1, (value is always ODD)
MET Seconds	48	32	Packet Time (sec). Value is 0 - 4294967295
MET SubSeconds	80	16	50 microseconds/tic. Value is 0 - 19999
Spin Phase at 1 PPS	96	16	Spin Phase @ 1 PPS from Time and Status Messages
MET of Spin Phase 1 PPS	112	16	Low 16 bits of MET from the 1 PPS associated with the Spin Phase in the Time and Status Message
Magnetometer Calibration Signal State	128	1	0=off, 1=on
Magnetometer Range	129	2	00: 256 nT 01: 4096 nT 10: not used 11: 65536 nT
Spare	131	13	
Mag X Component	144	16	
Mag Y Component	160	16	
Mag Z Component	176	16	
Waves Parameter 1	192	16	
Waves Parameter 2	208	16	
Waves Parameter 3	224	16	
Waves Parameter 4	240	16	
Waves Parameter 5	256	16	
Waves Parameter 6	272	16	

7.2 EFW SPACE WEATHER DATA

Table 7. EFW Space Weather Packet (APID 0x26A)

Description	*Start Bit*	*Size (bits)*	*Mnemonic*
CCSDS Version	0	3	Value is always zero (0)
Pkt Type	3	1	0=telemetry
Sec. Hdr. Flag	4	1	1=has secondary header
Application ID	5	11	EFW APID
Grouping Flags	16	2	CCSDS definition of grouping flags:3 – not part of group
Sequence Count	18	14	Increments with each new packet
Packet Length	32	16	Data size, number of bytes following the "Packet Length" minus 1, (value is always ODD)
MET Seconds	48	32	Packet Time (sec)
Shared Status	*80*	*8*	*(ISDM0)*
	80	4	TBD (ISDM0)
Sweep State [0..3] = Off, V12, V34, V56 sweeping	84	2	SWEEP_STATE (ISDM0)
AXB Aft Illumination Mode	86	2	AFT_ILLUM (ISDM0)
Requested Burst Support Bits	88	8	EXT_SUPPORT_REQ
Configuration and Evaluation Function	96	8	EXT_STATUS FUNC
Value Calculated by Evaluation Function	104	8	EXT_STATUS_VAL
Spacecraft Potential = AVG (0.5*(V1+V2))	112	16	SC_POTENTIAL
Vector E-Field Offset A	128	24	Ex_OFFSET
Vector E-Field Cosine Term B	152	24	Ex_COSINE
Vector E-Field Sine Term C	176	24	Ex_SINE
Vector E-Field Standard Deviation of the Fit	200	24	Ex_STDDEV
Used to make quad word length	224	0	Spare

7.3 ECT/HOPE SPACE WEATHER DATA

Table 8. ECT/HOPE Space Weather Packet for ions (APID 0x22C)

Description	*Start bit*	*Size (bits)*	*Notes*
CCSDS Version (always 0)	0	3	
CCSDS Packet Type (0=telemetry)	3	1	
Has secondary header (always 1)	4	1	
Application ID	5	11	
Packet grouping flags	16	2	0=intermediate, 1=first, 2=last, 3=no group
Packet Sequence Counter	18	14	
Packet Length	32	16	Packet Length: Number of bytes following this field - 1
Mission Elapsed Time	48	32	
Whole second start of HOPE Spin (sec)	80	8	
Subsecond start of HOPE Spin (msec)	88	16	
Whether STARTs are included	104	1	Denotes whether start counts are included in the data product. 0=No, 1=Yes

Whether STOPs are included	105	1	Denotes whether stop counts are included in the data product. 0=No, 1=Yes
Start no Stop	106	1	Denotes whether start-no-stop counts are included in the data product. 0=No, 1=Yes
Stop no Start	107	1	Denotes whether stop-no-start counts are included in the data product. 0=No, 1=Yes
TOF 0	108	1	Denotes whether TOF0 (H+) counts are included in the data product. 0=No, 1=Yes
TOF 1	109	1	Denotes whether TOF1 (He+) counts are included in the data product. 0=No, 1=Yes
TOF 2	110	1	Denotes whether TOF2 (O+) counts are included in the data product. 0=No, 1=Yes
TOF Unknown	111	1	Denotes whether TOF_UNK (unclassified valids) counts are included in the data product. 0=No, 1=Yes
Number of Energies	112	8	Number of energies that were sampled
Header Checksum	120	8	8-bit XOR checksum of the packet header
Hydrogen, Energy Bin 0	128	96	See Table 10 for bin format
Hydrogen, Energy Bin 1	224	96	See Table 10 for bin format
Hydrogen, Energy Bin 2	320	96	See Table 10 for bin format
Hydrogen, Energy Bin 3	416	96	See Table 10 for bin format
Helium, Energy Bin 0	512	96	See Table 10 for bin format
Helium, Energy Bin 1	608	96	See Table 10 for bin format
Helium, Energy Bin 2	704	96	See Table 10 for bin format
Helium, Energy Bin 3	800	96	See Table 10 for bin format
Oxygen, Energy Bin 0	896	96	See Table 10 for bin format
Oxygen, Energy Bin 1	992	96	See Table 10 for bin format
Oxygen, Energy Bin 2	1088	96	See Table 10 for bin format
Oxygen, Energy Bin 3	1184	96	See Table 10 for bin format
Spare	1280	3	
ESA Table	1283	4	Which ESA table was used during the acquisition of this data. ESA table 0 is the nominal table; if any table other than 0 is reported here, then the preceding data may not correspond to the expected energy values.
Parity Error	1287	1	Whether or not a parity error was detected when reading the science data out of the acquisition buffer. 0=no error, 1=error
Checksum	1288	8	8-bit xor checksum of all preceding data (including CCSDS header)

Table 9. ECT/HOPE Space Weather Packet for electrons (APID 0x22D)

Description	***Start bit***	***Size (bits)***	***Notes***
CCSDS Version (always 0)	0	3	
CCSDS Packet Type (0=telemetry)	3	1	
Has secondary header (always 1)	4	1	

Application ID	5	11	
Packet grouping flags	16	2	0=intermediate, 1=first, 2=last, 3=no group
Packet Sequence Counter	18	14	
Packet Length	32	16	Packet Length: Number of bytes following this field - 1
Mission Elapsed Time	48	32	
Whole second start of HOPE Spin (sec)	80	8	
Subsecond start of HOPE Spin (msec)	88	16	
Whether STARTs are included	104	1	Denotes whether start counts are included in the data product. 0=No, 1=Yes
Whether STOPs are included	105	1	Denotes whether stop counts are included in the data product. 0=No, 1=Yes
Start no Stop	106	1	Denotes whether start-no-stop counts are included in the data product. 0=No, 1=Yes
Stop no Start	107	1	Denotes whether stop-no-start counts are included in the data product. 0=No, 1=Yes
TOF 0	108	1	Denotes whether TOF0 (H+) counts are included in the data product. 0=No, 1=Yes
TOF 1	109	1	Denotes whether TOF1 (He+) counts are included in the data product. 0=No, 1=Yes
Electron, Energy Bin 0	128	96	See Table 10 for bin format
Electron, Energy Bin 1	224	96	See Table 10 for bin format
Electron, Energy Bin 2	320	96	See Table 10 for bin format
Electron, Energy Bin 3	416	96	See Table 10 for bin format
Spare	512	3	
ESA Table	515	4	Which ESA table was used during the acquisition of this data. ESA table 0 is the nominal table; if any table other than 0 is reported here, then the preceding data may not correspond to the expected energy values.
Parity Error	519	1	Whether or not a parity error was detected when reading the science data out of the acquisition buffer. 0=no error, 1=error
Checksum	520	8	

Table 10. ECT/HOPE Contents of Energy Bins

Description	***Start bit***	***Size (bits)***
Pixel 1, Azimuth 0	0	8
Pixel 2, Azimuth 0	8	8
Pixel 3, Azimuth 0	16	8
Pixel 3, Azimuth 45	24	8
Pixel 3, Azimuth 90	32	8
Pixel 3, Azimuth 135	40	8
Pixel 3, Azimuth 180	48	8
Pixel 3, Azimuth 225	56	8
Pixel 3, Azimuth 270	64	8
Pixel 3, Azimuth 315	72	8

Pixel 4, Azimuth 0	80	8
Pixel 5, Azimuth 0	88	8

7.4 ECT/MAGEIS SPACE WEATHER DATA

Space Weather data is output from three of the MagEIS instruments. The Low instrument, Med75, and High instrument will generate Space Weather packets. The Med35 will not generate Space Weather but will retain the capability to do so in the flight software. The output is compressed from 24 to 10 bits. Each data packet will be output once per spin and will contain data for 8 spin sectors. The cadence for Space Weather can be set by a Parameter command.

The MagEIS Space Weather format for the Low, Med75 and Med35 instruments is shown in the table 11. The data following the header consists of 4 bytes corresponding to three 10-bit space-weather words packed together in order from lowest energy channel to highest energy channel and then followed by two zeros. Each 4-byte set corresponds to one sector starting from the first sector following the spin boundary. Note (red asterisk below) that the data is compressed into 4 packed bytes per sector. The last two bits of each sector are padded zero and should be ignored.

Table 11. ECT/MagEIS Space Weather Packet for Low (APID 0x34A), Medium 35 (0x35A), and Medium 75 (APID 0x36A) (electrons)

Field Description	Start bit	Size (bits)	Note
CCSDS Version	0	3	Value is always zero
Packet Type	3	1	0 = telemetry
Secondary Header Flag	4	1	1 = has secondary header
APID	5	11	APID is value plus offset based on MAGEIS' allocated APID range
Grouping Flags	16	2	3 = not part of group
Sequence Count	18	14	Increments with each new packet
Packet Length	32	16	Data size, number of bytes following the "Packet Length" minus 1, (value is always ODD)
MET seconds	48	32	Spin time in MET
MAGEIS fine time	80	16	fine time (ms) from MET
e-Space Weather Data*	96	256	Sector -> Channel -> 10 bits

The MagEIS High instrument contains two Space Weather packets: one for Electrons and one for Protons. The Electron Packet is shown in Table 12. The packing of the electron data is different for the High than the Low and Medium instruments. In the High instrument, there is only one electron channel and the 10-bit data items are output sequentially for each sector, starting from the first sector after the spin boundary. This requires exactly 10 bytes for the entire spin's worth of data, so there is no zero fill. The Proton Packet is shown in Table 13. The packing of proton data is identical as the electron data in the High instrument.

Table 12. ECT/MagEIS Space Weather Packet for High (electrons) (APID 0x375)

Field Description	Start bit	Size (bits)	Note
CCSDS Version	0	3	Value is always zero
Packet Type	3	1	0 = telemetry
Secondary Header Flag	4	1	1 = has secondary header
APID	5	11	APID is value plus offset based on MAGEIS' allocated APID range
Grouping Flags	16	2	3 = not part of group
Sequence Count	18	14	Increments with each new packet
Packet Length	32	16	Data size, number of bytes following the "Packet Length" minus 1, (value is always ODD)
MET seconds	48	32	Spin time in MET
MAGEIS fine time	80	16	fine time (ms) from MET
e-Space Weather Data*	96	80	Sector -> Channel -> 10 bits

Table 13. ECT/MagEIS Space Weather Packet for High (protons) (APID 0x382)

Field Description	Start bit	Size (bits)	Note
CCSDS Version	0	3	Value is always zero
Packet Type	3	1	0 = telemetry
Secondary Header Flag	4	1	1 = has secondary header
APID	5	11	APID is value plus offset based on MAGEIS' allocated APID range
Grouping Flags	16	2	3 = not part of group
Sequence Count	18	14	Increments with each new packet
Packet Length	32	16	Data size, number of bytes following the "Packet Length" minus 1, (value is always ODD)
MET seconds	48	32	Spin time in MET
MAGEIS fine time	80	16	fine time (ms) from MET
e-Space Weather Data*	96	80	Sector -> Channel -> 10 bits

The MagEIS Space Weather data is compressed from 24 bits to 10 bits. The conversion is shown in table 14.

Table 14. ECT/MagEIS Compression Data (applies to all MagEIS instruments)

Compression #	Compression Name	Compression Type	Bits	Conversion	Units
1	24 bits to 10 bits	5 bit Exponent followed by 5 bit Significand	10	S x 2^E	counts

7.5 ECT/REPT SPACE WEATHER DATA

Table 15. ECT/REPT Space Weather Packet (APID 0x201)

Field Name	*Start Bit*	*Size (bits)*	*Description*
CCSDS Version	0	3	Value always 0

Packet Type	3	1	0 = telemetry
Sec. Hdr. Flag	4	1	1 = secondary header included
Application ID	5	11	0x200 – 0x20A = indicates type of packet
Grouping Flags	16	2	3 = Not part of group
Sequence Count	18	14	Increments with each packet
Packet Length	32	16	Size of data and secondary header minus 1
MET Seconds	48	32	Time of packet transmission
Singles Counter 2	80	12	
Singles Counter 4	92	12	
Singles Counter 9	104	12	
REPT_INST_ID	116	2	
Pad	118	10	
Checksum	128	16	

7.6 RBSPICE SPACE WEATHER DATA

Table 16. RBSPICE Space Weather Packet (APID 0x311)

Name	**Start bit**	**Length (bits)**	**Description**
Version	0	3	Designates a source packet
Type	3	1	Designates a telemetry packet
Secondary?	4	1	Secondary header is present
APID	5	11	Application Process ID
Grouping	16	2	Grouping flags
Sequence Count	18	14	Continuous sequence count for each Application Process ID
Length	32	16	Packet length (bytes) – 1
Secondary Header	48	32	Time tag (MET)
Spin	80	16	Spin number of integration
No. Fast	96	8	Number of fast values (NF)
No. Slow	104	8	Number of slow values (NS)
Fast 0 Chans – 45KeV	112	NF * 10	Low energy, high-time resolution space weather rates. There are 4*NF values where NF = 36
Fast 1 Chans – 100KeV	472	NF * 10	Low energy, high-time resolution space weather rates. There are 4*NF values where NF = 36
Fast 0 Chans – 148 KeV	832	NF * 10	Low energy, high-time resolution space weather rates. There are 4*NF values where NF = 36
Fast 0 Chans – 269 KeV	1192	NF * 10	Low energy, high-time resolution space weather rates. There are 4*NF values where NF = 36
Slow 0 Chans – 1 MeV(TBR)	1552	NS * 10	High energy, low-time resolution space weather rates. There are 2*NS values where NS = 4
Slow 1 Chans - 10 MeV(TBR)	1592	NS * 10	High energy, low-time resolution space weather rates. There are 2*NS values where NS = 4
Pad	1632	0 - 15	Zero pad to 16-bit boundary

7.7 PSBR/RPS SPACE WEATHER DATA

Table 17. PSBR/RPS Rate & Housekeeping Packet (& Space Weather) (APID 0x2C1)

Description	Start bit	Size bit
CCSDS Version = 0	*0*	*3*
Packet Type = 0 (telemetry)	*3*	*1*
Secondary Header Flag = 1 (set)	*4*	*1*
Application ID = 0x2C1	*5*	*11*
Grouping Flags = 3 (not part of group)	*16*	*2*
Sequence Count (increment with each output packet)	*18*	*14*
Packet Length = 31	*32*	*16*
MET Seconds = packet time	48	32
PEN rate	80	16
CHE rate	96	16
Various RPS Housekeeping Data	112	160
Spare (Dosimeter1 linear mon.) *	272	8
Spare (Dosimeter1 log mon.) *		
Spare (Dosimeter2 linear mon.) *		
Spare (Dosimeter2 log mon.) *		
RPS Housekeeping Data.	280	8
Spare = 0xA5	288	8
Checksum	296	8

* The dosimeter data is multiplexed over 4 packets

8 PREDICTED EPHEMERIS FILES

The predicted ephemeris files will be available from the RBSP MOC 60 days in advance. The details of this file are given below in Table 18:

Table 18: Predicted Ephemeris

Name	Ephermeris Prediction
File Name	scid_yyyy_doy_##.peph.bsp; peph_scid_yyyy_doy_##.peph.xsp (where yyyy_doy is the first date in the file)
Originator	Navigation
User	MOC, Ground Stations, TDRSS, SOC, SDP
Transfer Protocol	sftp from MOC Data Server
Availability	1-2 times per week
Frequency	1-2 times per week
Initiation	Automatic
Action	Generate, Store
Format	SPICE Planetary Ephemerides Kernel (SPK), binary (nominal) (bsp) and transfer (xsp) formats
Contents	Position and velocity of each spacecraft as a function of time. Will likely be Earth-centered inertial vectors (i.e. vectors expressed in EME2000 reference frame) SPICELIB tools allow querying for vectors in many other coordinate systems. Data extrapolated for 60 days.
Purpose	To predict where the two satellites will be in the future

9 SPACE ASSET PROTECTION POLICY IMPLICATIONS

Space asset protection policy will have an impact on RBSP space weather data. The spacecraft position information (which must be provided to other ground stations to receive the data) will need to have a control process (e.g. signed MOU with other organizations to restrict access to this data). Making the agreements with the ground station providers is the responsibility of NASA HQ.

The space weather measurements made on the spacecraft will have to be combined (by the user of the data) with spacecraft position in order to be useful. It is expected that the data users will download the predicted spacecraft ephemeris files for this purpose. Since the predict file will be produced 60 days in advance, this information will have some uncertainties, but will be sufficiently accurate for scientific purposes. For the real-time broadcast, the complete spacecraft tracking information will be provided to the participating ground stations who will use this information to track the spacecraft.

10 INSTITUTIONAL RESPONSIBILITIES

10.1 RADIATION BELT STORM PROBES MISSION

The responsibility of the RBSP Mission is to broadcast the selected space weather data at all times through the primary spacecraft science downlink antennas when an observatory is not in a primary mission-related ground contact. It is a goal for the instrument SOCs to provide a space weather product from their prime science data within a few days to compensate for any data gaps due to unavailability of observatory or poor orbit geometry.

10.2 NASA PROGRAM OFFICE

The responsibility of the program office at NASA headquarters is to recruit ground stations to participate in receiving and relaying RBSP Space Weather Broadcast data consonant with the arrangements described above. NASA HQ also provides the programmatic interface between the users and the RBSP Project.

10.3 GROUND STATION PARTNERS

The responsibility of each ground station will be the subject of an agreement between NASA and the ground station operator. The Space Weather data customer is responsible for working with their selected ground station to maintain the RF link analyses, including the determination of receiver loop bandwidth settings based on orbit geometry and carrier tracking requirements.

11 COMMUNICATION BETWEEN RBSP AND THE PARTICIPATING GROUND STATIONS

Technical communications between the RBSP mission and the participating ground station partners will be by email and telephone during normal business hours.

The RBSP Mission Operations Center (MOC) is designed to operate without human interaction. MOC personnel will only be available on a regular basis during normal business hours. The MOC will supply the ground station partners with contact information, in case of problems, which will be addressed as rapidly as feasible.

APPENDIX A: ACRONYMS

ACE	Advanced Composition Explorer
APID	Application Identifier (in a CCSDS telemetry packet header)
C&DH	Command and Data Handling
CCSDS	Consultative Committee for Space Data Systems
CHE	1-second coincidence rates as fluxes >400 ~MeV protons
CLCW	Command Link Control Word
ECT	Energetic Particle Composition and Thermal Plasma Investigation
EFW	Electric Field and Waves Instrument
EMFISIS	Electric and Magnetic Field Instrument Suite and Integrated Science Investigation
GSFC	Goddard Space Flight Center
HOPE	Helium-Oxygen-Proton-Electron Spectrometer Instrument
ICD	Interface Control Document
JHU/APL	Johns Hopkins University Applied Physics Laboratory
LEO	Low Earth Orbit
LWS	Living With a Star
MagEIS	Magnetic Electron Ion Spectrometer
MEO	Medium Earth Orbit
MET	Mission Elapsed Time
MOU	Memorandum of Understanding
MOC	Mission Operation Center
MRD	Mission Requirements Document
NASA	National Aeronautics and Space Administration
PEN	1-second coincidence rates as fluxes >50 ~MeV protons
PSBR	Proton Spectrometer Belt Research
RBSP	Radiation Belt Storm Probes
RBSPICE	Radiation Belt Storm Probes Ion Composition Experiment
REPT	Relativistic Electron Proton Telescope Instrument

RPS	Relativistic Proton Spectrometer Instrument
RF	Radio Frequency
SDMP	Science Data Management Plan
SOC	Science Operation Center
SSPA	Solid State Power Amplifier
STARD	Science Team Allocated Requirements Document
STEREO	Solar TErrestrial RElations Observatory
TBD	To Be Determined
TBR	To Be Revised
UTC	Universal Time Coordinated
VC	Virtual Channel