RBSP Conjunction Framework and Selected Coordinate Systems

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This document describes a framework for defining and predicting conjunctions of the RBSP vehicles with other missions of interest. This document has been developed by the Coordinated Coordinates Committee (CooCoo) of the RBSP Science Working Group.

Predicted conjunctions of RBSP with other missions will be computed based on constraints placed on the coordinate locations of the two vehicles: Vehicle 1 is either RBSP-A or RBSP-B, and Vehicle 2 is any vehicle for which the Science Data Portal has predicted ephemeris, including the other RBSP vehicle, DSX, THEMIS, GOES, LANL-GEO, or BARREL.

The coordinates for the predicted conjunctions will be defined against one of several Cartesian coordinate systems, or magnetic coordinates. The Cartesian locations of Vehicle A and Vehicle B will be computed using SPICE, augmented with a MAG coordinate system definition based on time-dependent IGRF/DGRF coefficients (epoch 2010 with linear predictive secular drift terms).The magnetic coordinates of the vehicles will be computed using the IRBEM library or equivalent. Three magnetic field models will be used for the calculation of magnetic coordinates: QUIET (T89 with Kp=0), MODERATE (T89 with Kp=3), and ACTIVE (T89 with Kp=6). These three field models span the inner magnetospheric configurations from quiet to active. Superior field models exist; however, such models require more complex inputs that the simple Kp required by T89. [An option the project can consider is to replace these three configurations with a more sophisticated magnetic field model evaluated for pre-determined moments of quiet, moderate, and active configuration]. To allow for non-simultaneity, time (decimal modified Julian date, MJD) will be considered a coordinate.

A conjunction is defined as having two vehicles meet a set of constraints on the coordinates of either vehicle and on the difference between the coordinates of the vehicles. The constraints will be defined in a simple table (see Table 2). A minimum and maximum value can be defined for each coordinate, and these constraints will be applied with a boolean "AND" operation. Empty entries will be ignored.

The spatial coordinate systems will be X, Y, and Z in GEI/ECI, GEO, GSM, GSE, and SM, with the coordinate values given in Earth Radii. The magnetic coordinates are defined in Table 1.

Table 1. Magnetic Coordinates

Coordinate	Definition
Lmeq	McIlwain L of an equatorially mirroring particle on the same field line as the vehicle
Lstar	L* of a particle mirroring at the vehicle
INVLAT	Invariant latitude computed from Lmeq
B	Local field strength in nT
Bmin	Minimum field strength along the line through the vehicle
BoverBeq	B/Bmin
K	Kaufmann invariant for particle mirroring at the vehicle
MAGLAT	Magnetic latitude computed from BoverBeq (see note)

MLTeq	Local Time at minimum B on field line
MLTN	Local Time at fixed altitude (100 km) in the Northern hemisphere along the field line through the vehicle
MLTS	Local Time at fixed altitude (100 km) in the Southern hemisphere along the field line through the vehicle

Note: Magnetic latitude is defined as the latitude in a dipole magnetic field that would give the same value for BoverBeq as whatever non-dipole model is being used.

For the purposes of the conjunction constraint table, a coordinate is defined as the combination of a coordinate system (e.g., ECI or T89KP0) and a coordinate name (e.g., Xor Lmeq). Each coordinate will appear in the constraint table three times: once for each vehicle (with suffixes 1 and 2) and once for the absolute value of the difference (with suffix DIFF).

Tables 2 and 3 provide an example of a constraint for a magnetic conjunction between RBSP-A and DSX. Table 2 provides an abbreviate form (omitting unconstrained coordiantes), while Table 3 provides the complete template. The conjunction is required to have a time offset of less than 6 hours (MJD_DIFF < 0.25), with both vehicles in the dawn local time sector (MLTeq 3 to 9) and with the two vehicles being within 0.1 Lmeq and 1 hour of local time of each other. In the example, the magnetic coordinate constraints are for the QUIET configuration. There is no constraint on position along the field line for either vehicle. Presumably, the interested parties would define similar, possibly looser, constraints for MODERATE and ACTIVE configurations.

Table 2. Example of an abbreviated conjunction definition table

Conjunction Name	RBSPA-DSX-Dawn-Quiet	
Vehicle1	RBSP-A	
Vehicle2	DSX	
Coordinates	**Min**	**Max**
MJD_DIFF		0.25
QUIET_Lmeq_DIFF		0.2
QUIET_MLTeq_1	3	9
QUIET_MLTeq_2	3	9
QUIET_MLTeq_DIFF		1

The CooCoo envisions a computer program that will routinely compare the predicted locations of the vehicles to all constraint tables provided by the teams. The program will then post alerts to the Science Data Portal and/or send email to subscribers.

Each team will be responsible for defining conjunctions it finds interesting by submitting tables to the Science Data Portal for inclusion in the conjunction search set. The Science Data Portal is encouraged to retain the ability to update the conjunction sets during the mission, and, therefore, to develop a computer program that will ensure that the submitted tables are valid; e.g., by checking that the Name and Vehicle 1, Vehicle 2 fields are provided, that the Vehicles match vehicles in the Portal's database, by validating that each coordinate variable provided in the constraints is a valid variable name, and by validating that the value of each Min/Max constraint is a valid number or is empty.

References:

SPICE: a NASA toolkit for time, ephemeris, attitude. http://naif.jpl.nasa.gov/naif/toolkit.html

IRBEM: A COSPAR toolkit for radiation belt coordinates and models. Manual is here: http://irbem.svn.sourceforge.net/viewvc/irbem/trunk/manual/user_guide.html. Download latest source code http://irbem.svn.sourceforge.net/viewvc/irbem.tar.gz?view=tar

Table 3. Example of a full conjunction definition table

Conjunction Name	RBSPA-DSX-Dawn-Quiet	
Vehicle1	RBSP-A	
Vehicle2	DSX	
Coordinates	**Min**	**Max**
MJD_1		
MJD_2		
MJD_DIFF		0.25
GEI_X_1		
GEI_X_2		
GEI_X_DIFF		
GEI_Y_1		
GEI_Y_2		
GEI_Y_DIFF		
GEI_Z_1		
GEI_Z_2		
GEI_Z_DIFF		
GSM_X_1		
GSM_X_2		
GSM_X_DIFF		
GSM_Y_1		
GSM_Y_2		
GSM_Y_DIFF		
GSM_Z_1		
GSM_Z_2		
GSM_Z_DIFF		
GSE_X_1		
GSE_X_2		
GSE_X_DIFF		
GSE_Y_1		
GSE_Y_2		
GSE_Y_DIFF		
GSE_Z_1		
GSE_Z_2		
GSE_Z_DIFF		
SM_X_1		
SM_X_2		
SM_X_DIFF		
SM_Y_1		
SM_Y_2		
SM_Y_DIFF		
SM_Z_1		
SM_Z_2		
SM_Z_DIFF		
QUIET_Lmeq_1		
QUIET_Lmeq_2		
QUIET_Lmeq_DIFF		0.2
QUIET_Lstar_1		
QUIET_Lstar_2		
QUIET_Lstar_DIFF		
QUIET_INVLAT_1		
QUIET_INVLAT_2		
QUIET_INVLAT_DIFF		
QUIET_B_1		
QUIET_B_2		
QUIET_B_DIFF		
QUIET_Bmin_1		
QUIET_Bmin_2		
QUIET_Bmin_DIFF		
QUIET_BoverBeq_1		
QUIET_BoverBeq_2		
QUIET_BoverBeq_DIFF		
QUIET_K_1		
QUIET_K_2		
QUIET_K_DIFF		
QUIET_MAGLAT_1		
QUIET_MAGLAT_2		
QUIET_MAGLAT_DIFF		
QUIET_MLTeq_1	3	9
QUIET_MLTeq_2	3	9
QUIET_MLTeq_DIFF		1
QUIET_MLTN_1		
QUIET_MLTN_2		
QUIET_MLTN_DIFF		
QUIET_MLTS_1		
QUIET_MLTS_2		
QUIET_MLTS_DIFF		
MODERATE_Lmeq_1		
MODERATE_Lmeq_2		
MODERATE_Lmeq_DIFF		
MODERATE_Lstar_1		
MODERATE_Lstar_2		
MODERATE_Lstar_DIFF		
MODERATE_INVLAT_1		
MODERATE_INVLAT_2		
MODERATE_INVLAT_DIFF		
MODERATE_B_1		
MODERATE_B_2		
MODERATE_B_DIFF		
MODERATE_Bmin_1		
MODERATE_Bmin_2		

MODERATE_Bmin_DIFF		
MODERATE_BoverBeq_1		
MODERATE_BoverBeq_2		
MODERATE_BoverBeq_DIFF		
MODERATE_K_1		
MODERATE_K_2		
MODERATE_K_DIFF		
MODERATE_MAGLAT_1		
MODERATE_MAGLAT_2		
MODERATE_MAGLAT_DIFF		
MODERATE_MLTeq_1		
MODERATE_MLTeq_2		
MODERATE_MLTeq_DIFF		
MODERATE_MLTN_1		
MODERATE_MLTN_2		
MODERATE_MLTN_DIFF		
MODERATE_MLTS_1		
MODERATE_MLTS_2		
MODERATE_MLTS_DIFF		
ACTIVE_Lmeq_1		
ACTIVE_Lmeq_2		
ACTIVE_Lmeq_DIFF		
ACTIVE_Lstar_1		
ACTIVE_Lstar_2		
ACTIVE_Lstar_DIFF		
ACTIVE_INVLAT_1		
ACTIVE_INVLAT_2		
ACTIVE_INVLAT_DIFF		
ACTIVE_B_1		
ACTIVE_B_2		
ACTIVE_B_DIFF		
ACTIVE_Bmin_1		
ACTIVE_Bmin_2		
ACTIVE_Bmin_DIFF		
ACTIVE_BoverBeq_1		
ACTIVE_BoverBeq_2		
ACTIVE_BoverBeq_DIFF		
ACTIVE_K_1		
ACTIVE_K_2		
ACTIVE_K_DIFF		
ACTIVE_MAGLAT_1		
ACTIVE_MAGLAT_2		
ACTIVE_MAGLAT_DIFF		
ACTIVE_MLTeq_1		
ACTIVE_MLTeq_2		
ACTIVE_MLTeq_DIFF		

ACTIVE_MLTN_1		
ACTIVE_MLTN_2		
ACTIVE_MLTN_DIFF		
ACTIVE_MLTS_1		
ACTIVE_MLTS_2		
ACTIVE_MLTS_DIFF		