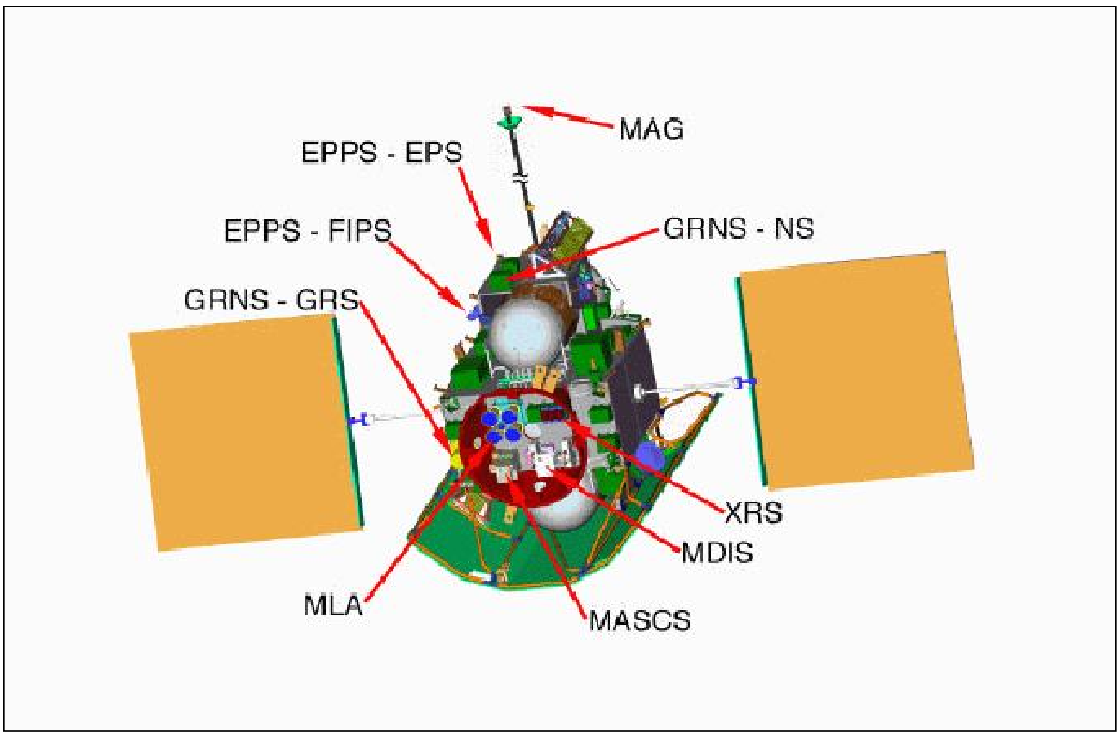
MESSENGER:

SoftwareInterfaceSpecificationforthe DerivedDataRecordsoftheEnergeticParticle andPlasmaSpectrometer

Version1M



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Document Review

Thisdocumentandthearchiveitdescribeshavebeenthroughp PDSPeerReviewandhavebeen acceptedintothePDSarchive.

GeorgeHo,MESSENGEREPPSInstrumentScientist,hasreviewedandapprovedthisdocument.

JimRaines,MESSENGERFIPSInstrumentScientist,hasreviewedandapprovedthisdocument.

SusanEnsor,MESSENGERScienceOperationsCenterLead,hasreviewedandapprovedthis document.

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Table 1 Revision History

Version	Author	Date	Description	Sections
1A	L.Nguyen	5/22/2012	Initialrevision	All
1B	M.Gannon	5/25/2012	MinorupdatesfromAPLteamreview	All
1C	J.Raines M.Gannon	10/17/2012	UpdatesfromtheEPPSPDSPeerReviewofthe SampleArchiveforDDR	All
1D	P. Bedini	1/29/2013	Editorialupdates	All
1E	M.Reid	1/29/2013	Replacedtextindicatingadraftversionofthis documentwithapproved&releaseversion.	Document Review,pg. 2
1F	J.Raines M.Gannon	11/06/2013	UpdatestoincorporatenewFIPSAdvanced Products	
1G	G.Ho J.Raines S.Ensor	1/17/2014	Updatesto DDRdescriptions andapplicable documents	1.2, 2, 5.2.1
1H	J.Raines M.Reid	6/13/2014	AddedinformationabouttheFIPSViewing Normalizationproducts ;fixedlargerdocument formatting.	5.2.2, 5.3.4,6.5, 6.8, 8.7, 8.8
1I	M.Reid	7/16/2014	Removedreferencestothe FIPS PixelFOVtable. TheywereremovedtotheCDRSIS. Corrected documentvolumedirectorystructurediagram.	5.2.2.6, 5.3,6.5, 6.7,8
1J	J.M.Raines M.Reid	11/19/2014	Modifiedtoincorporate substitution of FIPS_ARRDIR productwith FLUXMAPand additionofERPCHANGproduct. Added ERPCHANGproduct.Rem ovedFIPS_FOVPIX directory (FIPA_*filesmovedtoDocumentVol. CALIBRATION). ModificationstoROTSMOlabel. Formatting.	5.1.1, 5.2,5.3. 4, 6.8,8.3, 8.7.

Version	Author	Date	Description	Sections
1K	J.M.Raines M.Gannon	1/27/2015	EditstoFIPSFluxMapandFIPSPitchAngle productdescriptions. Correctionofminor typographicalerrors.	5.2.2.3, 5.2.2.5
1L	S.Ensor	1/16/2016	Finaledits(partial)	All
1M	J.M. Raines M.Gannon	1/28/2016	Finaledits	1.1.4and others

1 Purpose and Scope of Document

1.1 Purpose

ThisdocumentservestoprovideusersoftheMErcurySurface,SpaceENvironment,GEochemistry, andRanging(MESSENGER)EnergeticParticleandPlasmaSpectrometer(EPPS)dataproductswith adetaileddescriptionoftheEPPSinstrument,dataproductgeneration,validation,andstorage . NotethattheEPPSismadeupoftwoinstrumentsubsystems,theFastImagingPlasma Spectrometer(FIPS),andtheEnergeticParticleSpectrometer(EPS) . TheFIPSandEPSare describedinindividualsectionswithinthisdocument.Theyarereferredtoseparatelywhen necessaryandreferredtoastheEPPSinstrumentwhendealingwithareascommontoboth instruments. TheFIPScoversthelowerenergyrangeofparticlesandmeasuresthemasspercharge (m/q),energypercharge(E/q),andincomingdirectionofeachchargedparticle.TheEPScovers thehigherenergyrangeandmeasuresmass,energy,andincomingdirectionofeachparticle.The MESSENGEREPPSdataproductsaredeliverablestothePlanetaryDataSystem(PDS)andthe scientificcommunitythatitsupports.AlldataformatsarebasedonthePDSstandard.

1.2 Scope

TheEPPSsciencedataaredividedintotwocategories:Level2editedrawdata(referredtoas experimentdatarecordsorEDRs)andprocesseddata(referredtoasreduceddatarecordsor RDRs).RDRsaregeneratedfromEDRs,andrepresentdatacalibratedtoaphysicalunitsuchas particleintensity(Level3),resampledLevel4dataproducts,orderivedLevel5dataproducts. RDRsconsistofCalibratedDataRecords(CDRs),DerivedDataRecords(DD Rs),andDerived AnalysisProducts(DAPs) . ThisSoftwareInterfaceSpecification(SIS)describestheEPPSDDRdata products.

ForEPS,DDRsconsistoftwoproducts:pitchanglevalues,andpitchangledistribution spectrogramsoverselectedrangesofenergiesforselectedtimeperiods.ForFIPS,DDRsconsistof sevenproductsthatprovidedataforspatialandtemporaldistributionsofobserveddensityfor majorionspecies,andforselectedionspeciesandtimeperiods,energyspectra,pitchangle distributions,ionflux,density,temperature,andpressure,andviewingnormalizationsforeach energyscan . TheD DRdataweredeliveredtothePDSasCODMAC(CommitteeonDataManagement andComputation)Level4 data. EPPS's DDRsareformattedtoincludestandardPDSlabels.A detaileddescriptionofalldataproductsintheEPPSDDRfollows.

Inaddition,thisSISdescribestheEPPSdocumentationvolume,whichcontainsproductsrelatedto boththeEDR-andR DR-levelarchives.Thecontentsofthedocumentationvolumeenablesoneto conductusefulanalysisoftheDDRs.Thedocumentationvolumeisdescribedingreaterdetailin section 6.6.

2 Applicable Documents

TheMESSENGEREPPSSISisresponsivetothefollowingdocuments:

1. PlanetaryDataSystemStandardsReference,Feb27,2009,Version3.8.JPLD-7669,Part- 2.
2. MESSENGERDataManagementandArchivingPlan.TheJohnsHopkinsUniversity,APL. DocumentIDnumber7384-9019
3. MESSENGERMercury:Surface,SpaceEnvironment,Geochemistry,Ranging;Amissionto OrbitandExplorethePlanetMercury,ConceptStudy,March1999.DocumentIDnumber FG632/99- 0479
4. [PLR]Appendix7tothediscoveryprogramPlan;ProgramLevelRequirementforthe MESSENGERDiscoveryproject;June20,2001.

ThefollowingdocumentsmaybereferencedfordetailsontheEPPSinstruments:

5. Livietal.(Theenergeticparticlespectrometer(EPS)onMESSENGER:Instrument description,characterization,andcalibration,MESSENGERProjectreport,2004)
6. Zurbuchenetal.(TheFastIonPlasmaSpectrometer(FIPS)calibrationreport,MESSENGER Projectreport,2004)
7. Andrewsetal.(TheEnergeticParticleandPlasmaSpectrometerInstrumentonthe MESSENGERSpacecraft,SpaceScienceReviewsVolume131,Numbers1-4,August2007)
8. Raines et al. (Distribution and compositional variations of plasma ions in Mercury's space environment:ThefirstthreeMercuryyearsofMESSENGERobservations,Journalof GeophysicalResearch,118,p1604-1619,2013)
9. Gilbertetal.(Backgroundnoiseinspace-basedtime- of-flightsensors,ReviewsofScientific Instrumentation,inreview,2014)

10. Gershmanetal.(Post-processingmodelingandremovalofbackgroundnoiseinspace-based time-of-flightsensors,DeepBlue,2013, http://hdl.handle.net/2027.42/100358)

11. Rainesetal.(MESSENGERobservationsoftheplasmaenvironmentnearMercury,Planetary andSpaceScience59,p2004-2015,2011)

12. Ho et al. (Spatial distribution and spectral characteristics of energetic electrons in Mercury's magnetosphere, *J.Geophys.Res.*,doi:10.1029/2012JA017983,117,2012)

13. Gershmanetal.(MagneticFluxPile- up and Plasma Depletion in Mercury's Subsolar Magnetosheath,JournalofGeophysicalResearch:SpacePhysics,118,p7181-7199,2013)

14. Slavin et al. (MESSENGER Observations of Extreme Loading and Unloading of Mercury's MagneticTail,Science,329,p665-668,2010,doi:10.1126/science.1188067)

3 Relationships with Other Interfaces

TheEPPSDDRdataproductswerestoredattheMESSENGERScienceOperationsCenter(SOC) duringtheMESSENGERmission.ThedataproductsweretransferredtothePDSPlanetaryPlasma Interactions(PPI)Nodeaccordingtothedeliveryscheduleinsection 7.ThedataintheDDRfiles is storedinPDSASCIITABLEobjectsunlessstatedotherwise(section 5.2).

4 Roles and Responsibilities

Therolesandresponsibilitiesoftheinstrumentteams,TheJohnsHopkinsUniversityApplied PhysicsLaboratory(APL),AppliedCoherentTechnologyCorporation(ACT),andthePlanetaryData System(PDS),arediscussedinsections 5.3.2and 5.3.3.

5 Data Product Characteristics and Environment

5.1 Instrument Overview

5.1.1 FIPS Overview

TheFastImagingPlasmaSpectrometer(FIPS)measurestheenergypercharge(E/q),time- of-flight (TOF),andincidentanglesforplasmaionsenteringthesensor . Intensities,velocitydistributions, andmasspercharge(m/q)distributionsarederivedfromthesemeasurementsandmakeupFIPS primarysciencedata . Thesedataareusedtounderstandthekineticproperties,angular distributions,andcompositionofMercurymagnetosphericions,andcontributetothe characterizationoftheplanetarymagneticfield.

IonsmeasuredbyFIPSpassthroughanelectrostaticanalyzer(ESA),locatedattheentrancetothe sensor;apost-accelerationchamberbetweentheoutputoftheESAandthecarbonfoil;andati me-of-flighttelescope . TheESAattheentrancetoFIPSactsasawide-anglelensforions,witha1.4sr fieldofview.ItallowsonlyionswithaspecificE/qbandtoenterthroughitsoutputplane . This bandissteppedthrough64valuestocompleteonemeasurementcycle(scan),nominallyfrom 0.046-13.3keV/e . FIPSisnormallyoperatedinoneoftwosteppingrates:onesteppersecond (normalmode),oronestepper100milliseconds(burstmode). Whendelaysduetohigh-voltage ramp-upsareincluded,theseresultincycletimesof64secand8sec,respectively . Theoperationof FIPSishighlyconfigurableviatableupload . Thetimespentineachstepcan,inprincipal,besetto arbitraryvalues,differentforeachstep . AssociatedwitheachE/qstepisadeflectionvoltage, a threshold,asettlingtime,andanintegration(dwell)time .

IonsexittheoutputplaneoftheESAandarethenacceleratedinthepostaccelerationchamber . Thisaccelerationisdonetogivelow-energyionssufficientenergytopenetratethecarbonfoil . The accelerationalsohelpstoreduceenergystragglingandangularscattering –effectsthatcause degradationinmassresolutionandimaging . Whenionsexitthecarbonfoil,secondaryelectronsare liberated. TheseelectronstraveltotheStartMCP(microchannelplate),providingatiming-start signalandincidentangleinformationviaimpactlocationonaposition-sensinganode.Theionthen travelsthroughtheTOFchamberandstrikestheStopMCP,providingatiming-stopsignaland allowingcomputationofTOF . FromE/qandTOF,m/qcanbecomputed . FIPScanmeasurespecies fromHtoFe,1-60amu/e(orhigher).

IndividualionsareidentifiedinFIPSdatafromtheir *E/q*andTOFmeasurements . Asimplemodelis usedtopredicttheTOFrangeexpectedforeachionasafunctionof *E/q,* referredtoasthe *E/q*-TOF trackforthation.Thismodelincludestheeffectsofenergylostuponpassagethroughthecarbon foil,aswelldelaysduetoelectronflighttimeandelectronicprocessing.Alleventswithmeasured TOFwithinthepredictedrangeforaparticularionareassignedtothation.Toimprovesignalto noise, *E/q*-TOFtracksforsomeionsaregroupedtogether.Inthisdataset,H^+,He^+, and$He^{2+}$are assignedfromtheirrespectiveindividualiontracks.Twoiongroupsaredefined:O^+group(*m/q*= 16 –20;includingO^+ andwatergroupions)andNa^+group(*m/q*=21-30;includingNa^+,Mg^+,and Si^+).Additionaldetailsconcerningthisprocessaregivenin[8].

FIPSusesadoublecoincidencetechniquetogreatlyreducebackgroundnoise.However,spurious double-coincidencecountsstilldooccur.Thesecountscomefromtwomainsources:theextension ofveryhighcountprotonmeasurementsintoothertimesofflight,andthereleaseofsmallnumbers ionsfromsurfaceprocesseswithintheinstrument[9].Whileallmajorionspeciesreportedhere canbeanalyzedfromtherawdata,accuracyissignificantlyimprovedbyremovingthesespurious counts.Adetailednoisemodelandremovalmethodhasbeendeveloped[10]andisemployedon thedatainth isworkattheindividualscanlevel.

Afterspeciesareidentifiedin E/q-TOFspaceandnoisecountsremoved,theresultingcountsfor speciess ($C_{i,s}$)ateachmeasured($(E/q)_i$ aretransformedtophasespacedensity($f_{i,s}$)inunitsofs ^{3}m $^{-6}$. UsingtheCDRfluxes($J_{i,s}$)insec $^{-1}$ cm $^{-2}$ sr $^{-1}$,thisconversionisachievedusingthefollowing relationship:

$$f_{i,s} = J_{i,s}\frac{m_s}{v_{i,s}^2 C}$$

where $v_{i,s}$isvelocity, $m_s$isionmass(inamu)and Cisaunitconversionfactor,1.6022×10 $^{-20}$(cm ^{2} s keV)$^{-1}$.

ThedetailsoftheconversionofcountstophasespacedensityareprovidedintheEDR2CDR document,availableintheCALIBRATIONdirectoryoftheEPPSdocumentationvolume.

DetailsofFIPSoperationscanbefoundin[7].

5.1.2 EPS Overview

EPSisacompactTOFtelescopewithtwomaincomponents:aTOFsectionandaSolidState Detectors(SSD)array.TheSSDarraycomprisessixion-implantedplanarsilicondetectors,each withfourpixels(twodedicatedtoionmeasurementsandtwotoelectronmeasurements)foratotal of24SSDelements.Particlesenterthesystemthroughamechanicalcollimatorthatdelimitsthe lookdirectionintotheinstrument. Particlesthatpassthroughthecollimatorthentransitthrougha thin,compositeStartfoil(polyimide+aluminum,10 μg/cm^2)andontotheTOFregionofthe instrument.

ElectronsarereleasedfromtheinnersurfaceoftheStartfoilandfocusedtoawell-definedregion ona n MCPtogeneratetheSTARTsignalinadedicatedanode.Theincidentionsarenot significantlyaffectedbytheelectricfieldsofthefocusingoptics.After a 6cmflightpath,ions traversetheStopfoil,whichisapolyimide+palladium(19 μg/cm^2)compositefoil.Thesecondary electronsreleasedbythestopfoilaresteeredtotheMCPandgeneratetheSTOPsignal.Electron trajectorysimulationsshowthatthereislessthan2nsdispersioninthetransittimeofthe secondaryelectronfromthefoiltotheMCP.Sub-nanoseconddispersionisrequiredsoasnotto misidentifyionspecies.IfbothaSTARTandSTOPsignal(doublecoincidence)areregistered,then thetime,t ,fortheparticletotravelaknowndistance(d=6cm)canbedetermined.Fortriple coincidencewemusthavetheSTART,STOP,andalsotheenergymeasured(E_{meas})bytheSSDs . Usingthesemeasuredparameters,wecancalculatethemass(M)andtheincidentenergy(E)of eachionusingthefollowingequations:

$$E_{true} = E_{meas} / \gamma$$

$$E_{ToF} = \beta\, E_{true}$$

$$M = 2(T / d)^2 E_{ToF} = 2(t / d)^2 (\beta\, E_{meas} / \gamma)$$

E_{true} takesintoaccountthesmallenergylossoftheionspassingthroughthestopfoil,andthe energylossandpulse-heightdefectintheSSDs. E_{ToF}takesintoaccounttheevensmallerenergyloss orgaininthestartfoil,andmayalsoincludeupto~2.5keVelectrostaticpre-accelerationofions thatremainchargedonexitingthestartfoil . Iftheenergyoftheincidentparticleisnotlargeenough totriggertheSSD,thenonly$t$ ismeasuredandthepulseheightofthestartanode isusedto discriminatewhetheritisalight(M~1amu),orheavy(M >1amu)ion.AtthesamevalueofTOF, heavyionshavebeenshowntogeneratesubstantiallymoresecondaryelectronsthandoprotons.

Besides composition measurements, the particle's angular direction can be determined. Thepairof startandstopanodesprovidethepolarentranceangleoftheincidentparticle.Thepolarangleof +80ºto-80ºisdividedintosixequalsectors(nominally27º).

5.1.2.1 Electronmeasurements

Energeticelectronshavehigherpenetrationpowerthanionsatthesameenergy . TheSSDs dedicatedtoelectrondetectioninEPSarecoveredbyathinlayer(flashing)of1 μmofaluminum. Thisdeadlayerstopsprotonswithenergylessthen~250keV;Electrons,ontheotherhand,lose lessthan10keVbytheinteractionwiththisdeadlayer.ElectronsareidentifiedinEPSbythe presenceofanenergysignal.TheTOFspectracollectedintheadjacentSSD(withoutflashing)are usedduringgrounddataanalysisforcheckingandcorrectingfortheprotoncontamination.

"Calibration" for a particle instrument like EPS means determining the following:

1. Transferfunctionfromcountsintoflux(physicalunits)
2. Characteristic of "Rate-out" versus "Rate-in"
3. Responsetolowenergyandhighenergyparticlebackground
4. Responsetovisibleandultravioletlight
5. Responsetohighmagneticfield

Allthesefunctionsneedtobecharacterizedandtherelevantparametersneedtobedetermined beforeflight.

5.1.2.2 TransferFunction

Flux,differentialintensity,andphasespacedensity

ThenumberofparticlesNthattraverseanareaAduringatimetcanbecharacterizedbytheflux F [1/cm2/s]

$$N=A*t*F$$

orbytheintensityI[1/cm2/s/sr]

$$N=A*t* \int I\cos(\hat{u})d\Omega$$

where Ωissolidangleandûisangletotheareanormal . Here,thegeometriccharacteristicsofthe sensordeterminethelimitsontheintegration.

Oftenusedisthequantitydifferentialintensityf[1/cm2/s/sr/keV],definedasthenumberof particles with energy between E and E+ΔE that traverse the area A during the timet,where

$$N(E)=f(E)*A*t* \quad \Delta\Omega * \Delta E$$

In three dimensions, with θ being the polar angle and φ the azimuthal angle of a polar reference system:

$$d3N(E,\theta,\varphi)=f(E, \theta, \varphi) * A \cos(\hat{u}) * t * dE \cos\theta\, d\theta\, d\varphi$$

Note that f(E, θ, φ) is related to the phase-spacedensitypsd(numberofparticlesinthe configurationspaceelementd3Randwithvelocitybetweenvandv+d3v)bythesimple relationshipinthenon-relativisticlimit(validforionsmeasuredbyEPSbutnotforthehigher energyelectrons):

$$psd(s3/cm6)=f(1/cm2/s/sr/keV)*m/v2$$

Forrelativisticparticles,onegenerallyutilizesmomentumspaceratherthanvelocityspace,andthe correspondingexpressionis:

$$psd(s3/gm.cm6)=f(1/cm2/s/sr/keV)/p2$$

Where “p” is momentum.

Definitionofsensortransferfunctionandgeometricfactor

ThenumberofcountsNofparticlesofmassm,intheenergybandaroundmeanenergyE,angular band Δθ around mean polar direction θ, and angular band Δφ around the mean azimuthal direction φ, measured by the instrument during the time δt can be expressed as:

$$N(E, \theta, \varphi; m) = \delta t * \int\Delta E \int\Delta\theta \int\Delta\varphi \quad f(E, \theta, \varphi; m) * A \cos(\hat{u}) * dE \cos\theta\, d\theta\, d\varphi$$

If $f(E, \theta, \varphi)$ is a Dirac δ function (monoenergetic, infinitely narrow beam), then

$$N(E, \theta, \varphi; m) = \delta t * f(E, \theta, \varphi; m) * G(E, \theta, \varphi; m)$$

Where $G(E, \theta, \varphi; m)$ [cm2 sr keV] is the transfer function of the instrument.

Intheotherlimit,whenthefluxiscompletelyisotropic(alldirectionsthesame)

$$N(E; m) = \delta t * f(E; m) * GF(E; m)$$

GFiscalledgeometricfactorandrepresentsameasureoftheefficiencyofthesystem(count rate/flux),andtypicallyisafunctionofenergyandspecies.

Thegoalofthecalibrationistocharacterizethefunction$G(E, \theta, \varphi; m)$, so that from measurements of the count rates it is possible to constrain $f(E, \theta, \varphi; m)$. Note that an exact inversion of the integral is rarely possible, and we can compute only the coefficients of some tailored expansion of $f(E, \theta, \varphi; m)$,suchasinsphericalharmonics(Legendrepolynomials).Theaccuracyofthesecoefficients dependsonboththerastercoverageofthemeasurementsandonthecalibration.

5.1.2.3 Collimator

TheEPScollimatorconsistsoffourconcentrichalfcircularplatesthathaveholesalignedwitha commonpointoforiginatthecenteroftheEPSTOFtelescope . Thesizeandnumberofcollimator holesdefinethegeometricfactorGFoftheinstrument . Themany-holescollimatordesign minimizesthescatteringofionsandelectronsatthecollimatorwhilerestrictingthefield- of-view (FOV)oftheinstrument .

GEANT4simulationshowsthatthegeometryfactorforthetotalSSDareatobe0.016cm2sr.The simulationaccountedforgapsbetweenthedetectors,butdidnotallowfortheguardringdeadarea betweenthelargeandsmallpixelsorthelossesinthetwogridsusedtomountthethinfoils . Hence, beforegridlosses,thetotallargepixelgeometryfactoristhereforeGFSSD=0.0152cm2sr,andthe smallpixelswouldbe0.0008cm2 sr. Thegridlossesareactualblockages,sotheseshouldbe includedinthegeometryfactor . EPSused40-lines-per-inchgridsonthefoilsthatare86% transmissive. Therefore,forthe12largepixels,wehaveatotalgeometryfactorof0.862x0.0152,or 0.011cm2sr,andeachlargepixel is1/12ofthat,orGFSSD-Large=0.001cm2sr . Forthe12small pixels,wehaveatotalgeometryfactorof5.6x10-4cm2sr,orGFSSD-Small=4.7x10-5cm2srper pixel.Thecurrentsimulationdoesnotmodelthescatteringoflowenergyionandelectroninthe collimator;hencethecurrentvalueofGFSSDisconstantwithenergyandlookdirection . The instrumentteammayrevisethevalueofGFSSDatalatertimewhenwedevelopafurther understandingoftheinstrumentresponseasafunctionofdirection,energyandspecies.

GFTOFfortheLowEnergyIons(TOF-only)isroughlytwicetheSSDvalues,or~0.03cm2sr . Note thattheneededTransferFactorGdependsalsoonthecountingefficiency εkjwhichdepends,in turn,onspeciesandinstrumentmode.However,thesevalueswereneverconclusivelydetermined . During the time of instrument check out shortly after launch, EPS's TOF section suffered a failure; subsequently,EPSlostitsabilitytomeasureionsbyelementalmassspecies . Allin-flightEPSdata containsnullTOFvalues,hence,EPScannowonlymeasure

$$N(E) = \delta t * f(E) * GFSSD$$

GFSSDisnowthegeometricfactorandrepresentsameasureoftheefficiencyofthesystem(count rate/flux),andisconstantwithlookdirection,energyandspecies.Thisisthestandardapproximate conversionofcountratetointensityassumingthechannelefficiencyispartofthegeometryfactor. Theshapeoftheenergyspectrumalsoaffectstheresponse.

5.2 Data Product Overview

TheDDRdataproductsgeneratedbytheEPSandFIPSsubsystemsaredescribedinthissection . For alloftheDDRproductsthereisadetachedPDSlabelfile,whichdescribesthecontentsofonedata file.Eachlabelfilehas the same base name as the data file it is describing, with the extension ".LBL" todenotealabelfile.Thelabelfiledefinesthestarttimeandendoftheobservation,product creationtime,andthestructureoftheASCIItables . Eachdatafilecontainsthedatacollectedona givenEarthday.

5.2.1 EPS Data Products

TheEPSportionofthedataarchiveconsists of tablesofEPSpitchanglevaluesandpitchangle distributionfunctionspectrogramsintheformofbrowseplots.

5.2.1.1 PitchAngleComputation

Thepitchangleisdefinedastheinstantaneousanglebetweentheparticleflowdirectionandthe measuredin-situmagneticfield,with0degreesbeingwheretheparticleistravelingalongthefield and180degreeswheretheparticleistravelingintheoppositedirection.Bothvectors(theparticle flowdirectionandthemagneticfield)aremeasuredinthespacecraftframe.Theparticleflow directionforeachofthe sixEPSlookdirectionsisobtainedbyusingtheMESSENGERSPICE pointingkernels(c-kernels)andtheEPSframekernel.Themagneticfieldmeasurementsaretaken fromMESSENGERMagnetometer(MAG)Level11-secondaveragedddata;seetheMAGinstrument DDRSIS.

5.2.1.2 PitchAnglesProduct

Thepitchanglevaluetablescontainthepitchangleforeachofthesixlookdirectionsreportedat thesamecadenceastheEPSLoResSpectralratemeasurements(seeEPPSCDRSISdocument). Eachfilethushasaone- to-onerelationshipwithacorrespondingLoResspectralfile . Thepitch anglevaluesarecalculatedusingtheodd-shapedchannels.Thesehardwarechannelscorrespond toionsorelectronsthatareabovetheinstrumentthreshold(nominally~30keV),andarenot affectedbyprioritizationintheinstrumentsoftware.Forarapidlyfallingenergyspectrum,these countswouldbedominatedatthelowestenergies . Thesevaluesshouldbeusedinconjunctionwith theratechannelsforwhichintensityiscomputed.Constantnormalizationfactorsandbackground subtractionshavebeenappliedtothesechannelstooffsetanybiasinthethresholdsetting.The formulausedisAdjustedValue=Scaling*RawValue+Offset.Theconstantscalingandoffset valuesaregivenin Table2.

5.2.1.3 PitchAngleDistributionSpectrogramBrowseProduct

Thepitchangledistributionshowninthepitchanglespectrogrambrowseplotsisplottedusingthe pitchanglevaluesandaveragedaccordingly.

Weaveragedtheparticlemeasurementin120-secondbins.Pitchanglebinsare22.5degreeswide, andrunfrom0to180degrees.Forthepitchangledistributionspectrogram,t hecolorscaleis normalizedtothemaximumfluxforthetimeintervalcoveredbythecurrentplot(i.e.theintensity colorscalevariesbetweenplots) . Theeventsareselectedbasedontheselectioncriteriaasoutlined byHoetal.[JGR,2012]onselectingeventsthatareatleast10timesabovetheinstrument backgroundatthelowestenergychannel36-57keV.Note:Thepitchangledistribution spectrogramproductisaone-timedelivery.

ChannelName	Scaling	Offset
SHAPED_COUNTSD00	1.0412691533565521	15.11127820611
SHAPED_COUNTSD01	1	0
SHAPED_COUNTSD02	0.7014738321304321	10.141375184059143

SHAPED_COUNTSD03		
SHAPED_COUNTSD04	1.338530421257019	18.39651709794998
SHAPED_COUNTSD05	1.3527332693338394	7.795897737145424
SHAPED_COUNTSD06	1.4293411076068878	27.3230662047863
SHAPED_COUNTSD0 7	0.805070623755455	3.0807372108101845
SHAPED_COUNTSD0 8	0.9233275651931763	32.62595450878143
SHAPED_COUNTSD09	0.5404207110404968	-0.39973045140504837
SHAPED_COUNTSD10	0.31776440143585205	22.942654877901077
SHAPED_COUNTSD11	0.15649390034377575	-22.306587459519506

Table2Constantvaluesusedtoadjustthecountratefortheshapedchannels.D01isthechanneltowhichallotherswerefitinordertoarriveatthesevalues,whileD03isunliketheothersandcannotbefit,soitremainsunadjusted.

5.2.2 FIPS Data Products

Exceptwherenotedbelow,thesedataproductsarederivedfromindividualevent(PHA)words,whichhavefullangleandTOFinformation.UsingPHAwordsenablesthefinestpossibleseparationintoionspeciesaswellasdistinguishingincidentangles.Noiseremovalin *E/q* –TOFspaceisperformedbeforeaccumulationforallionsexceptH^+,forwhichnoiseremovalisnotneeded.

Theorbitalregionsforwhichdataisprovidedvariesbyproduct,asdescribedbelow.Withinthese,dataisprovidedfortimestepswhenevertheinstrumentwasoperatinginanominalmodeandwhenthedatawasofsufficientqualityforscientificanalysis. Theseconditionsaremetforthevastmajorityoftimesthroughoutthemission.Inparticular,manyoftheseproductsareprovidedinregionsdeterminedbyhand-pickedormodeledbowshockandmagnetopauseboundaries.BoundarypickingwasdonebytheMAGteamatalevelofaccuracysufficientfortherelativelylowtimeresolutionFIPSdata(10s-60s).Wherethesewerenotavailable,themodelgivenbySlavinetal.[14]isused.

5.2.2.1 DifferentialEnergyFluxSpectra

Differentialenergyfluxspectrainunitsof(keV/e)$^{-1}$ sec^{-1} cm^{-2} sr^{-1}areprovidedforall5ionspeciesthroughouttheentiremagnetosphereandmagnetosheathregionscrossedbythespacecraftduringeachorbit.ThesespectracoverthefullenergyperchargerangeofFIPS,whichws0.046 – 13.3 keV/eduringmostofthemission.SeetheFIPA_EYYYYDOY.DATfileforexactenergyrange.TheyarederivedinamannercompletelyanalogoustoCDRdifferentialenergyfluxspectra($dJ_{i,s}/dE_i$)exceptthatthetotalnumberofPHAeventwordsforagivenspeciesateach *E/q*stepisusedinplaceofon-boardaccumulatedcountrates(exceptprotons).SeeEPPS_FIPS_EDR2CDR.DOCXformoredetails.Forprotons,thisproductisderivedfromon-boardaccumulatedratesjustasfortheCDRversion,sothatfor***protonsonly***thisproductisaduplicateoftheCDRversion.ThisduplicationismadetoallowuserstoprimarilyuseDDRdataonlyintheirscientificanalysis.

$$\frac{dJ_{i,s}}{dE} = \frac{J_{i,s}}{(E/q)_i}$$

5.2.2.2 Observed Density

Observed density ($n_{obs,s}$, in cm^{-3}) for all ion species is provided for all 5 ion species throughout all orbit regions. This product serves to determine the spatial and temporal distribution of these ions and is the foundation DDR data product for FIPS. For protons, this product is derived from on-board accumulated rates rather than PHA event words, for much higher signal to noise ratio.

Observed densities are computed from differential energy flux spectra $J_{i,s}$ in two stages: First, $dJ_{i,s}/dE_i$ is converted to phase-space density ($f_{i,s}$, s^3 m^{-6})

$$f_{i,s} = 6.2414 \times 10^{19} \left(\frac{m_s}{v_{i,s}^2}\right)\left(\frac{dJ_{i,s}}{dE_i}\right)$$

Second, $f_{i,s}$ integrated over all velocities ($v_{i,s}$) and solid angle ($\Delta\Omega$) for a full scan to yield observed density ($n_{obs,s}$) for species s

$$n_{obs,s} = \sum_i f_{i,s} v_{i,x}^2 (\mathrm{D}v)_{i,s} (\mathrm{DW})$$

It is important to note that no correction has been made for limited field of view in this calculation. This correction requires knowledge of the true velocity distribution function in which the measured particles reside and is therefore beyond the scope of this data product. The net result is that nobs values reported are not in general equal to the ambient plasma density. More information about calculation of n_{obs} and the limited FIPS field of view can be found in [10, 11].

5.2.2.3 Angular Flux Maps

Integrated ion flux, $J_s(\theta,\phi)$, as a function of flow direction in MSO coordinates are provided for all 5 ion species throughout the entire magnetosphere and magnetosheath regions crossed by the spacecraft during each orbit. This product replaces the Arrival Direction Histogram (ARRDIR) product as it more a more useful representation of plasma behavior. Angular Flux Maps may be used in conjunction with pitch angle distributions to understand the location and motion of ions relativetoMercury.Thediscreteintegrationofphasespacedensity(f)isperformedoverionspeed (v)inthestandardway,leavingthetwoangulardimensionsunchanged:

$$J_s(\theta,\phi) = \sum_i f_{i,s}\,(\theta,\phi) v_{i,s}^3 dv_i$$

Verylowcountratescanmakethisproductdifficulttointerpret.Forsomeions,thissituationis mitigatedbysummingoverseveral,oftenmany,FIPSscansuntilsufficientcountsareavailable.In othercases,countsforaparticularionaresolowtherequirednumberofcountswouldrequire summationoverlargeregionsofspace,makingthearrivaldirectionsagaindifficulttointerpret. Therefore,thesecasesarenotincludedinthedata.

Summingovermultiplescansbringswithittheneedtonormalizethearrivaldirection distributionsfortheamountoftimethataparticularincidentanglecouldbeobserved.Innormal operations,theMESSENGERspacecraftrotatesaroundthespacecraftY-axis(Y_{MSGR})tooptimize viewingfordifferentinstruments.FIPSorientationisfixedrelativetothespacecraft,sothatthe FIPSFOVrotateswiththeMESSENGERspacecraft.Thisresultsinsignificantvariationinobserving timeforlookdirectionsinMSOcoordinates.Thesevariationsinobservingtimehavebeen normalizedoutofthefluxesincludedinthisdataproduct.Despitethisnormalization,thefinite sensitivityofFIPScanstillresultinreducedmeasuredionfluxfromarrivaldirectionswithlow observingtime.Inpractice,thisdoesnotusuallyaffectthetypicallyqualitativeinterpretationof thesemaps.Theusercouldmitigatethiseffectbyreducingthevariabilityofobservingtime:Only fluxfromdirectionsthatareviewedwithinafixedfraction(e.g.0.1)ofthemaximumobservation timeforagiventimeaccumulationcouldbeincludedinarrivaldirectionhistograms.This restrictionisnotappliedtodelivereddatafromthisdataproduct.

TheFLUXMAPdataproductisconstructedandnormaliz edasfollows:

1. Two arrays representing a full 4π steradian FOV are created at the 10° native angle binning ofFIPS.Thisresultsinan18x36elementarrayforthepolarandazimuthalanglebins, respectively.Thefirstoftheseisusedfortheaverageflux,FLUX,whilethesecondisused fortheaveragemeasurementtime,VIEWTIME.

    a. TheFLUXmatrixforeachenergyscaniscreatedfromPHAasfollows:

   i. Findtherotationmatrix,ROTMSO,(describedbelow)fortheday (YYYYDOY)andindexwhichcorrespondstothescan

   ii. Formtheunitvelocityvector:

      1. Converttheincidentpolarandazimuthalanglesoftheeventfrom FIPSsphericalcoordinatestoFIPSCartesiancoordinates.Usethe usualmannerforsphericaltoCartesianconversion,using1forther component.

      2. Invertbymultiplyingallcomponentsby-1.ThischangestheFOV coordinatestoflowdirection.

   iii. RotatetoMSOviamultiplicationbytheROTMSO.

   iv. ConverttheresultantMSOvectortosphericalcoordinates.Roundangles downtothenearest10°.

   v. AddthefluxvaluemultipliedbythePHAsolidangleintoatemporary18x 36matrixusingtherounded-downangles.

   vi. ConvertentireFIPSsphericalMCPmaptoMSOusingthestepsfrom(ii)for eachcoordinatepair.Roundanglesdowntothenearest10°.

   vii. AddtheMCPpixelsolidanglesintoasecondtemporary18x36matrixusing therounded-downangles.

   viii. Dividethetemporaryfluxbythetemporarysolidangle,,element- by- element.

b. TheVIEWTIMEmatrixforeachenergyscaniscreatedasfollows:

   i. Calculatetheaveragestepmeasurementtimeforthescan

   ii. AddthatvalueintoeveryelementoftheVIEWTIMEmatrix

   iii. Setto0anymatrixlocationforwhichthecorrespondingsolidanglematrix valueis0(thiswillremoveunobservedlocationsfromtheresult).

2. SumFLUXandVIEWTIMEoverallaccumulationscans

3. Formtheproperlynormalizedproductbydividing(elementbyelement)theFLUX (summedoverscans)andVIEWTIME(summedoverscans).

$$FLUXMAP = \frac{\sum FLUX}{\sum VIEWTIME}$$

5.2.2.4 ArrivalDirection(RetiredProduct)

ThisproductclasswasretiredaftertheMercuryOrbitYear2missionphase.TheAngularFluxMap productsdescribedintheprevioussectionsupersedeit.SincetheArrivalDirectionproducts remaininversionV1.0ofthedatasetintheFIPSDDRarchivevolumeatthePDS,adescriptionof themisretainedinthisdocument.

Thisproductprovidesobserveddensityasafunctionofarrivaldirectionintheinstrumentframe (incidentpolarandazimuthalangle)inMSOcoordinatesforselectedionsandregionsaround Mercury. Thediscreteintegrationofphasespacedensity(f)isperformedinthevelocitydimension (v)only,leavingthetwoangulardimensionsunchanged:

$$n_{obs,s}(\theta,\phi) = \sum_i f_{i,s}(\theta,\phi) v_{i,s}^2 dv_i$$

Theabove quantity, termed “observed density”,isanalogoustodensityineachangularbinformed onlyfromthecountsobservedinthatbin.ItdiffersfromthatperformedintheAngularFluxMap productbyonepowerof $v$whichintroducedinthatproducttochangefromadensitytoaflux quantity.

TheArrivalDirectionHistogramproductisidenticalinseveralwaystotheAngularFluxMaps productthatreplacedit:Itcanbedifficulttointerpretduetoverylowcountrates,aproblem whichispartiallymitigatedbysummingoverFIPSscans.Thissummingthenrequiresproper normalization,performedinexactlythesamemannerasdescribedindetailforAngularFluxMaps. Thisproductmaybeusedinconjunctionwithpitchangledistributionstounderstandthelocation andmotionofionsrelativetoMercury.

TheARRDIRdataproductisconstructedandnormaliz edexactlyasdescribedabovefortheAngular FluxMaps,withtwoexceptions(withtheARRDIRarrayreplacingtheFLUXMAParray):

1. ThevelocityvectormustNOTbeinvertedbyreversingthesignofeachcomponent.

2. MultiplytheweightfromeachPHAisaddedintotheARRDIRarray.Itis ***not***multipliedby theparticlespeed. (Modifystep2.b.iv.above.)

5.2.2.5 PitchAngleDistributions

Foranioninthepresenceofamagneticfield,theanglebetweenthevelocityvectorandthelocal magneticfielddirectionisreferredtoaspitchangle . Forpopulationsofplasmaions,pitchangle distributionhistogramscanbeformedbycountingthenumberofionswithinagivenpitchangle range(PCHANGdataproduct).Thishistogrammayalsobeseparatedintomeasured *E/q*bins, formingenergy-resolvedpitchangledistributions(ERPCHANGdataproduct) . Pitchangle distributionsgiveinformationonthevelocityofionsalongmagneticfieldlines,characterof velocitydistributionsandthegeneralplasmaenvironment. Caremustbetakenwheninterpreting pitchangledistributionsintheinstrumentframe(suchasthese)whentheplasmahasanon-negligiblebulkvelocity.BoththePCHANGandERPCHANGproductsareprovidedfor all 5ion speciesthroughouttheentiremagnetosphereandmagnetosheathregionscrossedbythespacecraft duringeachorbit.

Thepitchangledistributionforagiventimeperiodconsistsofahistogramoftheseanglesin 10° binsforalltheionevents(PHAwords)inthetimeperiod.Energy-resolvedpitchangle distributionsarealsoseparatedintothenativeFIPS *E/q*steppingbins.Pitchangledistributionsare providedforselectedionsandtimeperiods,whensufficientstatisticsexisttomaketheproduct meaningfulforscientificstudies.

ThePCHANGdataproductisnormaliz edasfollows:

1. Twoarraysrepresentingpitchangles0-180°arecreatedat10°binning,resultingintwo18-elementarrays.Thefirstoftheseisusedfortheaverageflux,FLUX,whilethesecondis usedforviewingnormalization,VIEWTIME.
    a. TheFLUXarrayforeachenergyscaniscreatedfromPHAsasfollows:
        i. Findtherotationmatrix,ROTMSO,(describedbelow)fortheday (YYYYDOY)andindexwhichcorrespondstothescan
        ii. Formtheunitvelocityvector:
            1. Converttheincidentpolarandazimuthalanglesoftheeventfrom FIPSsphericalcoordinatestoFIPSCartesiancoordinates.Usethe

usualmannerforsphericaltoCartesianconversion,using1forther component.

2. Invertbymultiplyingallcomponentsby-1.ThischangestheFOV coordinatestoflowdirection.

iii. RotatetoMSOviamultiplicationbytheROTMSO.

iv. AveragetheMAGCDRvectors(alreadyinMSO)thatfallwithintheFIPSscan timetoonevalue

v. CalculatetheangularseparationbetweenthisvectorandtheaverageMAG vector.Rounddownangletonearest10°.

vi. AddthefluxvaluemultipliedbythePHAsolidangleintoatemporary18 elementarrayusingtherounded-downangles.

vii. ConvertentireFIPSsphericalMCPmaptoMSOusingthestepsfrom(ii)for eachcoordinatepair.Roundanglesdowntothenearest10°.

viii. CalculatetheangularseparationbetweentheMCPvectorsandtheaverage MAGvector.Rounddownangletonearest10°.

ix. AddtheMCPpixelsolidanglesintoasecondtemporary18elementarray usingtherounded-downangles.

x. Dividethefluxtempbythesolidangletemp,element- by-element.

b. TheVIEWTIMEarrayforeachenergyscaniscreatedasfollows:

i. Calculatetheaveragestepmeasurementtimeforthescan

ii. AddthatvalueintoeveryelementoftheVIEWTIMEarray.

iii. Setto0anyarraylocationforwhichthecorrespondingsolidanglearray valueis0(thiswillremoveunobservedlocationsfromtheresult).

2. SumFLUXandVIEWTIMEoverallaccumulationscans

3. Formtheproperlynormalizedproductbydividing(elementbyelement)theFLUX (summedoverscans)andVIEWTIME(summedoverscans).

$$PCHANG = \frac{\sum FLUX}{\sum VIEWTIME}$$

The ERPCHANG product is formed in an analogous fashion, with the additional separation by E/q step. In this case, the weighting value in the 'FLUX' numerator is average phase space density.

5.2.2.6 Kinetic Properties

Under several conditions, full number density, n, temperature, T, and pressure, P, can be calculated directly from counts. (In contrast, when these conditions are not fulfilled, only the partial, observed densities, described above in 5.2.2.2, can be determined.) The conditions are as follows:

1) There must be sufficient counts to produce a well-defined energy spectrum. When necessary, counts from multiple scans are summed to meet this criterion.

2) The plasma must be subsonic. That is,

$$\frac{v_b}{v_{th}} < 0.5$$

where v_b is the plasma bulk velocity and V_{th} is the plasma thermal velocity.

3) The plasma must be nearly isotropic. That is,

$$0.5 < T_{\wedge}/T_{||} < 5$$

where $T_{\perp}$ is the plasma temperature perpendicular to the magnetic field and $T_{||}$ is the plasma temperature parallel to the magnetic field.

This data is provided where these assumptions are most likely to hold: a) throughout the magnetosphere and b) the dayside magnetosheath within a 45° cone angle around the X_{MSO} axis. Furthermore, the data are averaged over multiple FIPS scans so as to minimize the effect on the recovered n and T of transients (e.g. high speed flows) which violate the assumptions. **However**, for studies involving features near the time scale of the averaged data and/or inside the magnetosheath, **users are strongly cautioned** to evaluate the validity of the assumptions themselves. This is most easily done by comparing velocity distribution functions, computed from differential energy flux spectra and averaged to the same period as this data, to those formed from a non-drifting Maxwell-Boltzmann velocity distribution formed from the recovered n and T (with bulk speed of zero).

For protons, this product is derived from on-board accumulated rates rather than PHA event words, for much higher signal to noise ratio. Data is summed over multiple scans to increase signal to noise. Furthermore, this data is produced only those accumulations which exceed a minimum countlevel(20counts).ExtensivetestinghasshownthatcomputingtheseproductsfromPHA eventwordsforionsheavierthanprotonsisnotpracticalatfixedtimestepsoftheorderofafew minutes.Therefore,theseionsarenotincludedinthisproduct.

Whentheseconditionsarefulfilled,wecompute *n*and v_{th} directlyfrommeasuredvelocity distributionfunctions(formedfromdifferentialenergyfluxspectra)usinganumericalmethodof solvingthesystemofmomentequations[*Gershmanetal.* ,2013]. *T*and *P*arethencalculatedusing theusualrelations:

$$T = m v_{th}^2 / k_b$$
$$P = n k_b T$$

where $k_b$istheBoltzmannconstant.Theunitsoftherecoveredplasmaparametersarecm $^{-3}$,MK, andnPaforn,T,andP,respectively.Thequoteduncertaintiesoftheseparametersareafunctionof onlynumberofcountsusedtocreateeachdistribution,followingGershmanetal.,2013.Thereare smalladditionaluncertaintiesthatresultasthemeasuredenergyspectraapproachthelimitsof conditions(2)and(3)above.Theseadditionaluncertaintiesaredifficulttoquantifyandnot includedinthereporteduncertainties.

5.2.2.7 ViewingNormalization

TheFIPSViewingNormalizationdataproductcontainsarotationmatrix(ROTMSO)fromFIPS cartesiantoMSOcoordinates,foreachFIPSenergyscan.Thismatrixcanbeusedtorotateion incidentanglesinCDRPHAdataintoMSOcoordinatesneededforproducingnormalizeddirectional maps(e.g.FLUXMAPorPCHANG)forarbitrarytimeresolutions,inmultiplesof10s.

5.3 Data Processing

5.3.1 Data Processing Level

There isoneEPPSPDSDocumentationArchiveVolumeandoneEPPSPDSDataArchiveVolume. Thedatavolumecontainslevel4CODMACdataproducts,alsoknownasDDRs.Eachproducthas a uniquefilenameandconformstothefilenamingconventioninsection 6.5.AllDDRproductswere storedattheMESSENGERScienceOperationsCenter(SOC)duringtheMESSENGERmission . VolumesweretransferredtothePDSPPINodefollowingtheprocedureinsection 5.3.3.

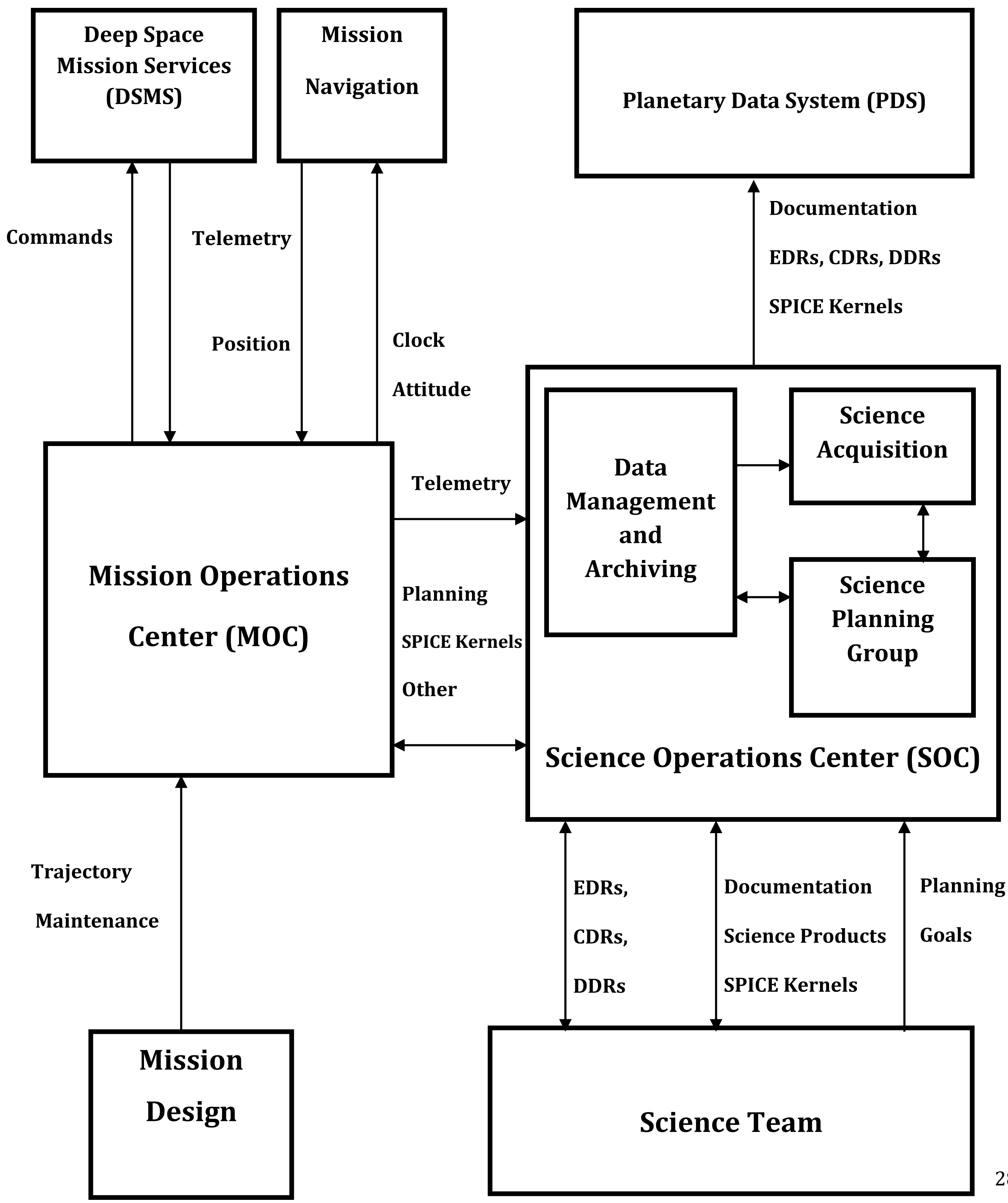
5.3.2 Data Product Generation

TheEPPSDDRfileswereproducedbytheEPSandFIPSteams.AJavaprogramderivedfromthe MIDL(MissionIndependentDataLayer)analysissoftwaredevelopedbyAPLwasusedtogenerate theDDRs . TheFIPSdatawereproducedusingInteractiveDataLanguage(IDL)softwareroutines developedattheUniversityofMichigan.TheDDRdataproductsweremadeavailabletothe MESSENGERScienceTeamforinitialevaluationandvalidation.Attheendoftheevaluationand validationperiod,thedatawereorganizedandstoredinthedirectorystructuredescribedin section 6.8fortransfertothePPINode.Thetransmittalprocessisdescribedinsection, 5.3.3. An initialreleaseofthedocumentationvolumeaccompaniedtheinitialreleaseofthedatavolume. Thereafter,updatestothedocumentationvolumeweremadewitheachdatadeliverytodocument thedataqualityforthedelivery,changestoproductsincludingcalibrationupdates,andother updatesasappropriate.PDSprovidespublicaccesstothedataproductsthroughitsonline distributionsystem.Theseproductssupportengineeringanalysis,directscienceanalysis,and constructionofotherscienceproducts.

5.3.3 Data Flow

TheMESSENGERSOCoperatesundertheauspicesoftheMESSENGERProjectScientisttoplandata acquisition,generate,andvalidatedataarchives.TheSOCsupportsandworkswiththeMission OperationsCenter(MOC),theScienceTeam,instrumentscientists,andthePDS.

Figure1MESSENGERdataflow showstheflowofdatawithintheMESSENGERprojectandoutto PDS.TheMOChandlesrawdataflowtoandfromtheMESSENGERspacecraftandtheSOCconverts therawtelemetryintoEDRs,whicharesubsequentlyconvertedintoCDRsandDDRsbytheScience Team.Documentation,CDRs,andDDRsaredeliveredtothePDSPlanetaryPlasmaInteractions (PPI)node.AllSPICEkernelsusedinCDRandDDRprocessingaredeliveredtothePDSNavigation andAncillaryInformation(NAIF)node.Thedeliveryprocessisdetailedbelow.


Deep Space Mission Services (DSMS)
Mission Navigation
Planetary Data System (PDS)
Commands
Telemetry
Position
Clock
Attitude
Documentation
EDRs, CDRs, DDRs
SPICE Kernels
Mission Operations Center (MOC)
Telemetry
Planning
SPICE Kernels
Other
Data Management and Archiving
Science Acquisition
Science Planning Group
Science Operations Center (SOC)
Trajectory
Maintenance
EDRs,
CDRs,
DDRs
Documentation
Science Products
SPICE Kernels
Planning
Goals
Mission Design
Science Team

TheMESSENGERSOCdelivereddatafortheEPPSDDRdatavolumetothePDSPPINodein standardproductpackages.Eachpackagecomprisesdataandancillarydatafiles,organizedinto directorystructuresconsistentwiththevolumedesigndescribedinsection 6.8.Theinitialrelease containedthedocumentsandrequiredfilesfortheEPPSdocumentationvolume,organizedinto directorystructuresasdescribedinsection 6.7.SubsequentreleasestotheEPPSdocumentation volumecontainedupdatesasappropriate.

In preparation for delivery, the directory structure is compressed into a single “zip archive” file for transfertothePDSnode.Theziparchivepreservesthedirectorystructureinternallysothatitcan berecreatedafterdeliverytothePDSnode.Alsoincludedinthetransferisachecksumfilecreated usingtheMD5algorithm.Thisprovidesanindependentmethodofverifyingtheintegrityofthezip fileafterithasbeensent.WithindaysofreceiptofthedeliverythePDSnodeacknowledgesreceipt ofthearchiveandchecksumfile.Ifacknowledgementisnotreceived,orifproblemsarereported, theMESSENGERSOCimmediatelytakescorrectiveactiontoaffectsuccessfultransfer.Deliverysize determinesthetransfermechanism:electronicorshippingaharddrive.

ThePDSnodeuncompressestheziparchivefileandchecksfordataintegrityusingthechecksum file.ThenodeperformsanyadditionalverificationandvalidationofthedataprovidedandreportsanydiscrepanciesorproblemstotheMESSENGERSOC.Thenodeperformsthesecheckswithin abouttwoweeksfromreceiptofthedelivery.Afterinspectionhasbeencompletedtothe satisfactionofthePDSnode,thenodeissuesanacknowledgementofsuccessfulreceiptofthedata totheMESSENGERSOC.

FollowingreceiptofadatadeliverythePDSnodeorganizesthedataintoaPDSvolumearchive structurewithinitsonlinedatasystem.NewlydelivereddataaremadeavailablepubliclyfromPDS onceaccompanyinglabelsandotherdocumentationhavebeenvalidated.

5.3.4 Labeling and Identification

ThePDSlabelconformstoPDSversion3.8standards.Formoreinformationaboutthisstandard consultthePDSStandardsReferenceDocument.ThelabelisdetachedandinaseparatePDSlabel file.ThepurposeofthePDSlabelistodescribethedataproductandprovideancillaryinformation aboutthedataproduct.ThereisaPDSlabelfileforeveryEPPSDDRdatafile.Thereisone DATA_SET_IDassignedtotheEPPSDDRdata.TheDDRsarefurthergroupedintodataproductsand areidentifiedbytheSTANDARD_DATA_PRODUCT_IDkeywordandthefilenamingconvention, section 6.5. ExamplelabelfilecontentisshownhereforeveryDDRdataproduct.Notethatthedata arecontainedwithinanASCIItableandthedetailsofthetablestructurearedescribedbyan externalASCIIformatfile(*.FMT).Thecolumnsineachformatfilearedescribedseparatelyinthe Appendix.

5.3.4.1 EPSPitchAnglesLabel

AsampleEPSPitchAnglesDDRfilelabelisshownbelow:

```
PDS_VERSION_ID              =  "PDS3"

/* ** FILE FORMAT ** */
FILE_RECORDS                =  5798
RECORD_TYPE                 =  FIXED_LENGTH
RECORD_BYTES                =  167

/* ** GENERAL DATA DESCRIPTION PARAMETERS ** */
PRODUCT_ID                  =  "EPSP_A2012010DDR_V1"
PRODUCT_VERSION_ID          =  "V1"
PRODUCT_CREATION_TIME       =  2012-05-09T21:04:27
PRODUCT_TYPE                =  "DDR"
STANDARD_DATA_PRODUCT_ID    =  "EPS_PITCH_ANGLES_DDR"
SOFTWARE_NAME               =  "MIDLMessengerDDRGenerator"
SOFTWARE_VERSION_ID         =  "1.0"
INSTRUMENT_HOST_NAME        =  "MESSENGER"
INSTRUMENT_NAME             =  "ENERGETIC PARTICLE SPECTROMETER"
INSTRUMENT_ID               =  "EPS"
DATA_SET_ID                 =  "MESS-E/V/H/SW-EPPS-3-EPS-DDR-V1.0"
DATA_SET_NAME               =  "MESSENGER E/V/H/SW EPPS CALIBRATED EPS DDR
V1.0"
MISSION_PHASE_NAME          =  "MERCURY ORBIT"
TARGET_NAME                 =  "MERCURY"
START_TIME                  =  2012-010T00:00:49
STOP_TIME                   =  2012-010T23:59:45
```

```
SPACECRAFT_CLOCK_START_COUNT   = "234641115"
SPACECRAFT_CLOCK_STOP_COUNT   = "234727451"
^HEADER                    =  ("EPSP_A2012010DDR_V1.TAB", 1)
^ASCII_TABLE               =  ("EPSP_A2012010DDR_V1.TAB", 2)

OBJECT                     =  HEADER
  HEADER_TYPE                =  TEXT
  INTERCHANGE_FORMAT         =  "ASCII"
  RECORDS                    =  1
  BYTES                      =  167
  DESCRIPTION                  = "The first record of this
    file is the header section. The header contains column
    headings to improve usability."
END_OBJECT                 =  HEADER

OBJECT                     =  ASCII_TABLE
  COLUMNS                    =  7
  INTERCHANGE_FORMAT         =  ASCII
  ROW_BYTES                  =  167
  ROWS                       =  5798
  DESCRIPTION                = "
    This table contains Pitch Angles between the measured flow vector
    direction and the magnetic field for each of the 6 sectors of
    the MESSENGER EPS instrument. The complete column definitions are
    contained in an external file found in the LABEL directory of the
    archive volume. Additional details are contained in the DDR SIS
    document."
  NOTE                       =  "Data Quality: 0"
```

```
  ^STRUCTURE                = "EPS_PITCH_ANGLES.FMT"
END_OBJECT                  =  ASCII_TABLE

END
```

5.3.4.2 EPSPitchAngleSpectrogramLabel

AsampleEPSPitchAngleSpectrogramDDRfilelabelisshownbelow:

```
PDS_VERSION_ID              =  "PDS3"

/* ** FILE FORMAT ** */
RECORD_TYPE                     = UNDEFINED
INTERCHANGE_FORMAT              = BINARY

/* ** GENERAL DATA DESCRIPTION PARAMETERS ** */
PRODUCT_ID                  =  "EPS_PAS_2012074205045_V1"
PRODUCT_VERSION_ID          =  "V1"
PRODUCT_CREATION_TIME       =  2012-05-09T17:00:00
PRODUCT_TYPE                =  "BROWSE"
STANDARD_DATA_PRODUCT_ID    =  "EPS_PITCH_ANGLE_SPECTROGRAM_DDR"
SOFTWARE_NAME               =  "MIDLMessengerDDRGenerator"
SOFTWARE_VERSION_ID         =  "1.0"
INSTRUMENT_HOST_NAME        =  "MESSENGER"
INSTRUMENT_NAME             =  "ENERGETIC PARTICLE SPECTROMETER"
INSTRUMENT_ID               =  "EPS"
DATA_SET_ID                 =  "MESS-E/V/H/SW-EPPS-3-EPS-DDR-V1.0"
 DATA_SET_NAME               =  "MESSENGER E/V/H/SW EPPS CALIBRATED EPS DDR V1.0"
MISSION_PHASE_NAME          =  "MERCURY ORBIT"
TARGET_NAME                 =  "MERCURY"
```

```
START_TIME                 =  2012-03-14T20:50:45
STOP_TIME                  =  2012-03-15T00:23:45
SPACECRAFT_CLOCK_START_COUNT   = "240245710"
SPACECRAFT_CLOCK_STOP_COUNT   = "240258490"

^DOCUMENT                = "EPS_PAS_2012074205045_V1.PNG"
OBJECT                   = DOCUMENT
  DOCUMENT_NAME        = "EPS_PAS_2012074205045_V1"
  DOCUMENT_FORMAT      = PNG
  DOCUMENT_TOPIC_TYPE = "BROWSE IMAGE"
  INTERCHANGE_FORMAT  = BINARY
  PUBLICATION_DATE    = 2012-05-09T17:00:00
  SOURCE_PRODUCT_ID   = {
       "EPSL_R2012074EDR_V1.DAT",
       "MAGSC_SCIAVG12075_01_V00.TAB",
       "MAGSC_SCIAVG12074_01_V00.TAB",
       "EPSL_R2012075EDR_V1.DAT"
}
  LINES                = 400
  LINE_SAMPLES         = 850
  SAMPLE_TYPE          = MSB_UNSIGNED_INTEGER
  SAMPLE_BITS          = 8
  DESCRIPTION          = "PNG file containing a spectrogram representation of
the summation of the shaped count rates in detectors 0-10 except detector 3. The
counts are binned in time (120 s) and pitch angle (22.5 deg). Constant normalization
factors and background subtractions (see SIS for Table) have been applied to these
rates."
END_OBJECT             = DOCUMENT
END
```

5.3.4.3 FIPSPitchAnglesLabel(PCHANG)

AsampleFIPSPitchAnglesDDRfilelabelisshownbelow:

```
PDS_VERSION_ID                = "PDS3"

/* ** FILE FORMAT ** */
FILE_RECORDS                  = 1350
RECORD_TYPE                   = FIXED_LENGTH
RECORD_BYTES                  = 2799

/* ** GENERAL DATA DESCRIPTION PARAMETERS ** */
PRODUCT_ID                    = "FIPS_PCHANG_2012001_DDR_V01"
PRODUCT_VERSION_ID            = "V1"
PRODUCT_CREATION_TIME         = 2012-05-08T23:35:42
PRODUCT_TYPE                  = "DDR"
STANDARD_DATA_PRODUCT_ID      = "FIPS_PCHANG_DDR"
SOFTWARE_NAME                 = "mfips_decode_pha.pro"
SOFTWARE_VERSION_ID           = "1.0"
INSTRUMENT_HOST_NAME          = "MESSENGER"
INSTRUMENT_NAME               = "FAST IMAGING PLASMA SPECTROMETER"
INSTRUMENT_ID                 = "FIPS"
DATA_SET_ID                   = "MESS-E/V/H/SW-EPPS-3-FIPS-DDR-V2.0"
DATA_SET_NAME                 = "MESSENGER E/V/H/SW EPPS CALIBRATED FIPS DDR
V2.0"
SOURCE_PRODUCT_ID             = "FileByFile"
MISSION_PHASE_NAME            = "MERCURY ORBIT"
TARGET_NAME                   = "MERCURY"
START_TIME                    = 2012-01-01T00:00:00
```

```
STOP_TIME                    =  2012-01-01T23:59:59
SPACECRAFT_CLOCK_START_COUNT =  "233863466"
SPACECRAFT_CLOCK_STOP_COUNT  =  "233949802"
^HEADER                      =  ("FIPS_PCHANG_2012001_DDR_V01.TAB", 1)
^ASCII_TABLE                 =  ("FIPS_PCHANG_2012001_DDR_V01.TAB", 4)

OBJECT                       =  HEADER
  HEADER_TYPE                  =  TEXT
  INTERCHANGE_FORMAT           =  "ASCII"
  RECORDS                      =  3
  BYTES                        =  8397
  DESCRIPTION                  = "The first 3 records of this
    file are the header section. The header contains column
    headings to improve usability."
END_OBJECT                   =  HEADER

OBJECT                       =  ASCII_TABLE
  COLUMNS                      =  3
  INTERCHANGE_FORMAT           =  ASCII
  ROW_BYTES                    =  2799
  ROWS                         =  1350
  DESCRIPTION                   = "
    This table contains FIPS Flux-Pitch angle histograms."
  ^STRUCTURE                   =  "FIPS_PCHANG_DDR.FMT"
END_OBJECT                   =  ASCII_TABLE

END
```

5.3.4.4 Energy-ResolvedPitchAngleDistributions(ERPCHANG)Label

AsampleFIPSERPCHANGDDRfilelabelisshownbelow:

```
PDS_VERSION_ID                = "PDS3"


/* ** FILE FORMAT ** */

FILE_RECORDS                  = 5

RECORD_TYPE                   = FIXED_LENGTH

RECORD_BYTES                  = 16218


/* ** GENERAL DATA DESCRIPTION PARAMETERS ** */

PRODUCT_ID                    = "FIPS_ERPCHANG_2011174_V1"

PRODUCT_VERSION_ID            = "1"

PRODUCT_CREATION_TIME         = 2014-11-06T16:00:00

PRODUCT_TYPE                  = "DDR"

STANDARD_DATA_PRODUCT_ID      = "FIPS_ERPCHANG"

SOFTWARE_NAME                 = "MFIPS_DDR_SAMPLE.PRO"

SOFTWARE_VERSION_ID           = "0.1"

INSTRUMENT_HOST_NAME          = "MESSENGER"

INSTRUMENT_NAME               = "ENERGETIC PARTICLE AND PLASMA SPECTROMETER"

INSTRUMENT_ID                 = "EPPS"

DATA_SET_ID                   = "MESS-E/V/H/SW-EPPS-3-FIPS-DDR-V2.0"

DATA_SET_NAME                 = "MESSENGER E/V/H/SW EPPS CALIBRATED FIPS DDR

V2.0"

MISSION_PHASE_NAME            = "MERCURY ORBIT"

TARGET_NAME                   = "MERCURY"

START_TIME                    = 2011-06-23T10:45:40.419666

STOP_TIME                     = 2011-06-23T22:53:43.420605

SPACECRAFT_CLOCK_START_COUNT  = "1/217313408.800"
```

```
SPACECRAFT_CLOCK_STOP_COUNT   =  "1/217357091.000"
^HEADER                       =  ("FIPS_ERPCHANG_2011174_DDR_V01.TAB", 1)
^ASCII_TABLE                  =  ("FIPS_ERPCHANG_2011174_DDR_V01.TAB", 4)

OBJECT                        =  HEADER
  HEADER_TYPE                   =  TEXT
  INTERCHANGE_FORMAT            =  "ASCII"
  RECORDS                       =  3
  BYTES                         =  48654
  DESCRIPTION                 = "The first four records of this
    file are the header section. The header contains column
    headings to improve usability."
END_OBJECT                    =  HEADER


OBJECT                        =  ASCII_TABLE
  COLUMNS                       =  7
  INTERCHANGE_FORMAT            =  ASCII
  ROW_BYTES                     =  16218
  ROWS                          =  2
  DESCRIPTION                    = "
This table contains 2 dimensional pitch angle histograms as
described in EPPS DDR SIS."
  ^STRUCTURE                    =  "FIPS_ERPCHANG_DDR.FMT"
END_OBJECT                    =  ASCII_TABLE

END
```

5.3.4.5 FIPSEnergySpectraLabel

AsampleFIPSEnergySpectraDDRfilelabelisshownbelow:

```
PDS_VERSION_ID                = "PDS3"

/* ** FILE FORMAT ** */
FILE_RECORDS                  = 1350
RECORD_TYPE                   = FIXED_LENGTH
RECORD_BYTES                  = 4824

/* ** GENERAL DATA DESCRIPTION PARAMETERS ** */
PRODUCT_ID                    = "FIPS_ESPEC_2012001_DDR_V01"
PRODUCT_VERSION_ID            = "V1"
PRODUCT_CREATION_TIME         = 2012-05-08T23:35:41
PRODUCT_TYPE                  = "DDR"
STANDARD_DATA_PRODUCT_ID      = "FIPS_ESPEC_DDR"
SOFTWARE_NAME                 = "mfips_decode_pha.pro"
SOFTWARE_VERSION_ID           = "1.0"
INSTRUMENT_HOST_NAME          = "MESSENGER"
INSTRUMENT_NAME               = "FAST IMAGING PLASMA SPECTROMETER"
INSTRUMENT_ID                 = "FIPS"
DATA_SET_ID                   = "MESS-E/V/H/SW-EPPS-3-FIPS-DDR-V2.0"
DATA_SET_NAME                 = "MESSENGER E/V/H/SW EPPS CALIBRATED FIPS DDR
V2.0"
SOURCE_PRODUCT_ID             = "FileByFile"
MISSION_PHASE_NAME            = "MERCURY ORBIT"
TARGET_NAME                   = "MERCURY"
START_TIME                    = 2012-01-01T00:00:00
```

```
STOP_TIME                      =  2012-01-01T23:59:59
SPACECRAFT_CLOCK_START_COUNT   =  "233863466"
SPACECRAFT_CLOCK_STOP_COUNT    =  "233949802"
^HEADER                        =  ("FIPS_ESPEC_2012001_DDR_V01.TAB", 1)
^ASCII_TABLE                   =  ("FIPS_ESPEC_2012001_DDR_V01.TAB", 4)

OBJECT                         =  HEADER
  HEADER_TYPE                    =  TEXT
  INTERCHANGE_FORMAT             =  "ASCII"
  RECORDS                        =  3
  BYTES                          =  19094472
  DESCRIPTION                  = "The first 3 records of this
    file are the header section. The header contains column
    headings to improve usability."
END_OBJECT                     =  HEADER

OBJECT                         =  ASCII_TABLE
  COLUMNS                        =  7
  INTERCHANGE_FORMAT             =  ASCII
  ROW_BYTES                      =  4824
  ROWS                           =  1350
  DESCRIPTION                     = "
    This table contains FIPS energy spectra for selected ion species."
  ^STRUCTURE                     =  "FIPS_ESPEC_DDR.FMT"
END_OBJECT                     =  ASCII_TABLE

END
```

5.3.4.6 FIPSObservedDensityLabel

AsampleFIPSObservedDensityDDRfilelabelisshownbelow:

```
PDS_VERSION_ID                = "PDS3"

/* ** FILE FORMAT ** */
FILE_RECORDS                  = 1350
RECORD_TYPE                   = FIXED_LENGTH
RECORD_BYTES                  = 216

/* ** GENERAL DATA DESCRIPTION PARAMETERS ** */
PRODUCT_ID                    = "FIPS_NOBS_2012001_DDR_V01"
PRODUCT_VERSION_ID            = "V1"
PRODUCT_CREATION_TIME         = 2012-05-08T23:35:42
PRODUCT_TYPE                  = "DDR"
STANDARD_DATA_PRODUCT_ID      = "FIPS_NOBS_DDR"
SOFTWARE_NAME                 = "mfips_decode_pha.pro"
SOFTWARE_VERSION_ID           = "1.0"
INSTRUMENT_HOST_NAME          = "MESSENGER"
INSTRUMENT_NAME               = "FAST IMAGING PLASMA SPECTROMETER"
INSTRUMENT_ID                 = "FIPS"
DATA_SET_ID                   = "MESS-E/V/H/SW-EPPS-3-FIPS-DDR-V2.0"
DATA_SET_NAME                 = "MESSENGER E/V/H/SW EPPS CALIBRATED FIPS DDR
V2.0"
SOURCE_PRODUCT_ID             = "FileByFile"
MISSION_PHASE_NAME            = "MERCURY ORBIT"
TARGET_NAME                   = "MERCURY"
START_TIME                    = 2012-01-01T00:00:00
```

```
STOP_TIME                        =  2012-01-01T23:59:59
SPACECRAFT_CLOCK_START_COUNT     =  "233863466"
SPACECRAFT_CLOCK_STOP_COUNT      =  "233949802"
^HEADER                          =  ("FIPS_NOBS_2012001_DDR_V01.TAB", 1)
^ASCII_TABLE                     =  ("FIPS_NOBS_2012001_DDR_V01.TAB", 4)

OBJECT                           =  HEADER
  HEADER_TYPE                      =  TEXT
  INTERCHANGE_FORMAT               =  "ASCII"
  RECORDS                          =  3
  BYTES                            =  648
  DESCRIPTION                    = "The first 3 records of this
    file are the header section. The header contains column
    headings to improve usability."
END_OBJECT                       =  HEADER

OBJECT                           =  ASCII_TABLE
  COLUMNS                          =  20
  INTERCHANGE_FORMAT               =  ASCII
  ROW_BYTES                        =  216
  ROWS                             =  1350
  DESCRIPTION                       = "
    This table contains FIPS differential energy intensities for selected ion
species."
  ^STRUCTURE                       =  "FIPS_NOBS_DDR.FMT"
END_OBJECT                       =  ASCII_TABLE

END
```

5.3.4.7 FIPSArrivalDirectionLabel(RetiredProduct)

AsampleFIPSArrivalDirectionDDRfilelabelisshownbelow:

```
PDS_VERSION_ID                = "PDS3"

/* ** FILE FORMAT ** */
FILE_RECORDS                  = 42
RECORD_TYPE                   = FIXED_LENGTH
RECORD_BYTES                  = 9158

/* ** GENERAL DATA DESCRIPTION PARAMETERS ** */
PRODUCT_ID                    = "FIPS_ARRDIR_2012054_DDR_V01"
PRODUCT_VERSION_ID            = "01"
PRODUCT_CREATION_TIME         = 2013-06-04T21:22:22
PRODUCT_TYPE                  = "DDR"
STANDARD_DATA_PRODUCT_ID      = "FIPS_ARRDIR_DDR"
SOFTWARE_NAME                 = "mfips_ddr_sample.pro"
SOFTWARE_VERSION_ID           = "0.1"
INSTRUMENT_HOST_NAME          = "MESSENGER"
INSTRUMENT_NAME               = "FAST IMAGING PLASMA SPECTROMETER"
INSTRUMENT_ID                 = "FIPS"
DATA_SET_ID                   = "MESS-E/V/H/SW-EPPS-3-FIPS-DDR-V1.0"
DATA_SET_NAME                 = "MESSENGER E/V/H/SW EPPS CALIBRATED FIPS DDR
V1.0"
SOURCE_PRODUCT_ID             = "FileByFile"
MISSION_PHASE_NAME            = "MERCURY ORBIT"
TARGET_NAME                   = "MERCURY"
```

```
SPACECRAFT_CLOCK_START_COUNT  =  "1/238523075.000"
START_TIME                    =  2012-02-23T22:20:08.845
SPACECRAFT_CLOCK_STOP_COUNT   =  "1/238524872.000"
STOP_TIME                     =  2012-02-23T22:50:05.845
^HEADER                       =  ("FIPS_ARRDIR_2012054_DDR_V01.TAB", 1)
^ASCII_TABLE                  =  ("FIPS_ARRDIR_2012054_DDR_V01.TAB", 4)

OBJECT                        =  HEADER
  HEADER_TYPE                   =  TEXT
  INTERCHANGE_FORMAT            =  "ASCII"
  RECORDS                       =  3
  BYTES                         =  9158
  DESCRIPTION                   = "The first three records of this
    file are the header section. The header contains column
    headings to improve usability."
END_OBJECT                    =  HEADER


OBJECT                        =  ASCII_TABLE
  COLUMNS                       =  7
  INTERCHANGE_FORMAT            =  ASCII
  ROW_BYTES                     =  9158
  ROWS                          =  39
  DESCRIPTION                    = "
This table contains FIPS ion flux as a function of arrival
direction which have been accumulated in time enough to be
meaningfully interpreted."
  ^STRUCTURE                    =  "FIPS_ARRDIR_DDR.FMT"
```

```
END_OBJECT                  =  ASCII_TABLE

END
```

5.3.4.8 FIPSAngularFluxMapLabel

AsampleFIPSAngularFluxMapDDRfilelabelisshownbelow:

```
PDS_VERSION_ID              =  "PDS3"

/* ** FILE FORMAT ** */
FILE_RECORDS                =  5
RECORD_TYPE                 =  FIXED_LENGTH
RECORD_BYTES                =  9162

/* ** GENERAL DATA DESCRIPTION PARAMETERS ** */
PRODUCT_ID                  =  "FIPS_FLUXMAP_2011174_V1"
PRODUCT_VERSION_ID          =  "1"
PRODUCT_CREATION_TIME       =  2014-11-06T16:00:00
PRODUCT_TYPE                =  "DDR"
STANDARD_DATA_PRODUCT_ID    =  "FIPS_FLUXMAP"
SOFTWARE_NAME               =  "MFIPS_DDR_SAMPLE.PRO"
SOFTWARE_VERSION_ID         =  "0.1"
INSTRUMENT_HOST_NAME        =  "MESSENGER"
INSTRUMENT_NAME             =  "ENERGETIC PARTICLE AND PLASMA SPECTROMETER"
INSTRUMENT_ID               =  "EPPS"
DATA_SET_ID                 =  "MESS-E/V/H/SW-EPPS-3-FIPS-DDR-V2.0"
DATA_SET_NAME               =  "MESSENGER E/V/H/SW EPPS CALIBRATED FIPS DDR
V2.0"
MISSION_PHASE_NAME          =  "MERCURY ORBIT"
```

```
TARGET_NAME                   =  "MERCURY"
START_TIME                    =  2011-06-23T10:45:40.420458
STOP_TIME                     =  2011-06-23T22:53:43.420605
SPACECRAFT_CLOCK_START_COUNT  =  "1/217313408.800"
SPACECRAFT_CLOCK_STOP_COUNT   =  "1/217357091.000"
^HEADER                       =  ("FIPS_FLUXMAP_2011174_DDR_V01.TAB", 1)
^ASCII_TABLE                  =  ("FIPS_FLUXMAP_2011174_DDR_V01.TAB", 4)

OBJECT                        =  HEADER
  HEADER_TYPE                   =  TEXT
  INTERCHANGE_FORMAT            =  "ASCII"
  RECORDS                       =  3
  BYTES                         =  27486
  DESCRIPTION                 = "The first four records of this
    file are the header section. The header contains column
    headings to improve usability."
END_OBJECT                    =  HEADER


OBJECT                        =  ASCII_TABLE
  COLUMNS                       =  7
  INTERCHANGE_FORMAT            =  ASCII
  ROW_BYTES                     =  9162
  ROWS                          =  2
  DESCRIPTION                    = "
This table contains angular flux map data as
described in EPPS DDR SIS."
  ^STRUCTURE                    =  "FIPS_FLUXMAP_DDR.FMT"
```

```
END_OBJECT                   =  ASCII_TABLE

END
```

5.3.4.9 FIPSKineticPropertiesLabel

AsampleFIPSKineticPropertiesDDRfilelabelisshownbelow:

```
PDS_VERSION_ID               =  "PDS3"

/* ** FILE FORMAT ** */
FILE_RECORDS                 =  42
RECORD_TYPE                  =  FIXED_LENGTH
RECORD_BYTES                 =  176

/* ** GENERAL DATA DESCRIPTION PARAMETERS ** */
PRODUCT_ID                   =  "FIPS_NTP_2012054_DDR_V01"
PRODUCT_VERSION_ID           =  "01"
PRODUCT_CREATION_TIME        =  2013-06-04T21:22:22
PRODUCT_TYPE                 =  "DDR"
STANDARD_DATA_PRODUCT_ID     =  "FIPS_NTP_DDR"
SOFTWARE_NAME                =  "mfips_ddr_sample.pro"
SOFTWARE_VERSION_ID          =  "0.1"
INSTRUMENT_HOST_NAME         =  "MESSENGER"
INSTRUMENT_NAME              =  "FAST IMAGING PLASMA SPECTROMETER"
INSTRUMENT_ID                =  "FIPS"
DATA_SET_ID                  =  "MESS-E/V/H/SW-EPPS-3-FIPS-DDR-V2.0"
DATA_SET_NAME                =  "MESSENGER E/V/H/SW EPPS CALIBRATED FIPS DDR
V2.0"
SOURCE_PRODUCT_ID            =  "FileByFile"
MISSION_PHASE_NAME           =  "MERCURY ORBIT"
```

```
TARGET_NAME                    =  "MERCURY"
SPACECRAFT_CLOCK_START_COUNT   =  "1/238523075.000"
START_TIME                     =  2012-02-23T22:20:08.845
SPACECRAFT_CLOCK_STOP_COUNT    =  "1/238524872.000"
STOP_TIME                      =  2012-02-23T22:50:05.845
^HEADER                        =  ("FIPS_NTP_2012054_DDR_V01.TAB", 1)
^ASCII_TABLE                   =  ("FIPS_NTP_2012054_DDR_V01.TAB", 4)

OBJECT                         =  HEADER
  HEADER_TYPE                    =  TEXT
  INTERCHANGE_FORMAT             =  "ASCII"
  RECORDS                        =  3
  BYTES                          =  176
  DESCRIPTION                  = "
This table contains FIPS ion number densities and temperatures,
as well as the pressure calculated from their product.
Quantities are calculated after sufficient time accumulation
to allow meaningful interpretation."
END_OBJECT                     =  HEADER


OBJECT                         =  ASCII_TABLE
  COLUMNS                        =  13
  INTERCHANGE_FORMAT             =  ASCII
  ROW_BYTES                      =  176
  ROWS                           =  39
  DESCRIPTION                      = "
    This table contains FIPS NTP values."
```

```
  ^STRUCTURE                    =  "FIPS_NTP_DDR.FMT"
END_OBJECT                    =  ASCII_TABLE

END
```

5.3.4.10 FIPSViewingNormalizationProductsLabels

5.3.4.10.1 FIPS Cartesian to MSO Coordinates Rotation Matrix (ROTMSO)

```
PDS_VERSION_ID                =  "PDS3"

/* ** FILE FORMAT ** */
FILE_RECORDS                  =  1303
RECORD_TYPE                   =  FIXED_LENGTH
RECORD_BYTES                  =  195

/* ** GENERAL DATA DESCRIPTION PARAMETERS ** */
PRODUCT_ID                    =  "FIPS_ROTMSO_2010001_DDR_V01"
PRODUCT_VERSION_ID            =  "01"
PRODUCT_CREATION_TIME         =  2014-06-04T10:00:00
PRODUCT_TYPE                  =  "DDR"
STANDARD_DATA_PRODUCT_ID      =  "FIPS_ROTMSO_DDR"
SOFTWARE_NAME                 =  "MFIPS_DDR_SAMPLE.PRO"
SOFTWARE_VERSION_ID           =  "0.1"
INSTRUMENT_HOST_NAME          =  "MESSENGER"
INSTRUMENT_NAME               =  "ENERGETIC PARTICLE AND PLASMA SPECTROMETER"
INSTRUMENT_ID                 =  "EPPS"
DATA_SET_ID                   =  "MESS-E/V/H/SW-EPPS-3-FIPS-DDR-V2.0"
DATA_SET_NAME                 =  "MESSENGER E/V/H/SW EPPS CALIBRATED FIPS DDR
V2.0"
MISSION_PHASE_NAME            =  "MERCURY 4 CRUISE"
```

```
TARGET_NAME                    =  "MERCURY"
SPACECRAFT_CLOCK_START_COUNT   =  "1/170791497.000"
START_TIME                     =  2010-01-01T00:00:23.676
SPACECRAFT_CLOCK_STOP_COUNT    =  "1/170877732.000"
STOP_TIME                      =  2010-01-01T23:57:38.677
^HEADER                        =  ("FIPS_ROTMSO_2010001_DDR_V01.TAB", 1)
^ASCII_TABLE                   =  ("FIPS_ROTMSO_2010001_DDR_V01.TAB", 4)

OBJECT                         =  HEADER
  HEADER_TYPE                    =  TEXT
  INTERCHANGE_FORMAT             =  "ASCII"
  RECORDS                        =  3
  BYTES                          =  585
  DESCRIPTION                  = "The first three records of this
    file are the header section. The header contains column
    headings to improve usability."
END_OBJECT                     =  HEADER


OBJECT                         =  ASCII_TABLE
  COLUMNS                        =  5
  INTERCHANGE_FORMAT             =  ASCII
  ROW_BYTES                      =  195
  ROWS                           =  1300
  DESCRIPTION                     = "
This table contains rotation matrix from FIPS cartesian
 to MSO for each energy scan."
  ^STRUCTURE                     =  "FIPS_ROTMSO_DDR.FMT"
```

```
END_OBJECT                    =  ASCII_TABLE

END
```

5.4 Standards Used in Generating Data Products

5.4.1 PDS Standards

TheEPPSDDRdataproductsareconstructedaccordingtothedataobjectconceptsdevelopedby thePDS . ByadoptingthePDSformat,thedataproductsareconsistentincontentandorganization withotherplanetarydatacollections . InthePDSstandard,theDDRdatafileisgroupedintoobjects withPDSlabelsdescribingtheobjects.EachDDRdataproductconsistsoftwofiles:

- AdatafilecontaininganASCIItableobject(theprimarydata),infixedfieldformat.ASCII tableobjectsareineithercommaseparatedvalue(CSV)format(EPS)orarewhitespace delimited(FIPS).ThismakestheASCIIdataextremelyeasytoreadbymanycommercialoff-the-shelfprograms.TheoneexceptionistheEPSPitchAngleSpectrogram,whichisabinary PNGfile.
- Alabelfilewhichservesasahigh-leveldescriptionoftheparametersofwhichcorrespond tothedatafile.Thelabelfilecontainsapointertoanexternalformatfile,whichdetailsthe structureofthetableobjectinthedatafile.

5.4.2 Time Standards

OneofthetimefieldsintheFIPStableobjectsreferencestheMissionElapsedTime(MET).This METisthespacecrafttimeinintegersecondsthatistransmittedtoMESSENGERsubsystemsbythe IntegratedElectronicsModule(IEM).MET=0isonAugust3,2004,at05:59:16UTC(coordinated universaltime),whichis1000secondspriortotheMESSENGERlaunch.Relativisticeffectsand circumstancesoccurringduringthemissionwouldresultinMETnotbeingatrueaccountof secondssincelaunch.Followingaplannedspacecraftclockresetinearly2013,partitionnumbers (1/,or2/)wereaddedtoproductlabelstodisambiguateMETsecondsafterthespacecraftclock reset(ifpartitionnumberisnotpresent,SPICEdefaultstopartition1/).Forthesereasonsthe MESSENGERspacecraftclockcoefficientsfileisarchivedatthePDSNAIFNode.Thisfileisusedin conjunctionwiththeleapsecondskernelfileinordertocalculatetheconversionbetweenMETand UTC.

TheconversioniseasilydonethroughtheuseofSPICEkernelsandtheCHRONOSUtility.CHRONOS isautilityincludedwiththeSPICEpackagethatisdistributedbythePDSNAIFnode.TheSPICE kernelsarefilesthatcontaintheinformationneededtoperformtheconversion.TwoSPICEkernels arerequired.OneistheLeapSecondsKernel(LSK)andtheotheristheMESSENGERSpacecraft

ClockKernel(SCLK).TheSCLKfileisusedbyCHRONOStoconvertbetweenspacecraftclocktime andephemeristime,whiletheLSKfileisusedtoconvertfromephemeristimetoUTCtime.The CHRONOSutilityisself-documentingandtheSPICEpackageitselfcontainsfulldocumentationon eachoftheutilities(includingCHRONOS)andhowtheyareused.

EPPSDDRdataistime-taggedwithspacecrafteventtime(SCET)inthefollowingUTCformat: CCYY-DDDTHH:MM:SS.sss.Thisformatrepresentsaconcatenationoftheconventionaldateand timeexpressionswiththetwopartsseparatedbytheletterT:

CC -century(00- 99)

YY -year(00- 99)

DDD -dayofyear(001-366)

T -date/timeseparator

HH-hour(00- 23)

MM -minute(00-59)

SS -second(00- 59)

sss-fractionsofsecond(000- 999)

5.4.3 Coordinate Systems

Therearetwocoordinatesystemsinuseinthe EPPSDDRdataproducts:1)theMercury-centric SolarOrbital(MSO,definedintheMESSENGERSPICEDynamicFramesKernel)usedforspacecraft positionvectors;and2)theFIPSSphericalcoordinatesystem,usedforFIPSincidentanglessinceit representsnaturalcoordinatesforthesensor . ThelatterisasphericalversionoftheFIPSCartesian coordinatesystem(FIPS_CART),whichisdefinedintheMESSENGERSPICEFramesKernel . FIPS Sphericalcoordinates(FIPS_SPH)consistofaradius(r),zenithangle(theta)andazimuthalangle (phi). ThezenithangleisdefinedastheanglebetweenthevectorandthezaxisintheFIPS Cartesiancoordinatesystem . Itrangesfrom0to180degrees. Theazimuthalanglerangesfrom0to 360degreesandisdefinedastheanglebetweenthevectorandthexaxisintheFIPSCartesian coordinatesystem . TheradiusisdefinedasusualasthemagnitudeoftheFIPSCartesianvector.

5.4.4 Data Storage Conventions

ThedataareorganizedfollowingPDSstandardsandstoredonharddiskattheMESSENGERSOC. TheSOCtransfersdatatoPDSasdetailedinsection 5.3.3. AfterverificationofthedatatransferPDS providespublicaccesstoMESSENGERsciencedataproductsthroughitsonlinedatadistribution system.

5.5 Data Validation

TheEPPSDDRdataarchivevolumesetincludesalldataacquiredduringtheMESSENGERmission. Thearchivevalidationproceduredescribedinthissectionappliestodataproductsgenerated duringallpostlaunchphasesofthemission.Tobeclear,thereisoneandonlyonedocumentation volumeandoneandonlyoneEPPSdataarchivevolumecreatedoverthewholemission.Release datesarestatedintheschedulein section 7.Updatestothedatavolumeoccurredaccordingtothe sameschedule.Updatestothedocumentationvolumeoccurredaccordingtothisscheduleandat thediscretionoftheEPPSteam.

PDSstandardsrecommendthatalldataincludedintheformalarchivebevalidatedthroughapeer-reviewprocess.Thisprocessisdesignedtoensurethatboththedataanddocumentationareof sufficientqualitytobeusefultofuturegenerationsofscientists.Theprocessispresentedasseveral steps,mostofwhichoccurinthePDSpeerreview.Thispeerreviewisconductedbeforeany volumesareproducedandreleasedtoPDS.

ThepeerreviewpanelconsistsofmembersoftheEPPSteam,thePPInodeofPDS,andatleastone outsidescientistactivelyworkinginthefieldofenergeticparticlesresearch.ThePDSpersonnelare responsibleforvalidatingthatthevolumesarefullycompliantwithPDSstandards.Theinstrument teamandoutsidereviewer(s)areresponsibleforverifyingthecontentofthedataset,the completenessofthedocumentation,andtheusabilityofthedatainitsarchiveformat.

Thepeerreviewvalidatesthedocumentationanddataarchivevolumes.Firstthepanelreviewsthis documentandverifiesthatthevolumesandDDRsproducedtothisspecificationwillbeuseful.The peerreviewalsovalidatestheEPPSDDRdatainatwostepprocess.Thefirststepconsistsof reviewingasampledatasetforcompliancewiththePDSstandards.Thesampledatasetis deliveredandreviewedinconjunctionwithdeliveryandreviewofthisSISdocument.Thesecond stepisexaminationofthedatatoensureusabilityandcompleteness.ThePDSpersonnelare responsibleforvalidatingthattheDDRdatasetisfullycompliantwithPDSstandards.The instrumentteamandtheoutsidesciencereviewer(s)areresponsibleforverifyingthecontentof thedataset,thecompletenessofthedocumentation,andtheusabilityofthedatainitsarchive format.

Anydeficienciesinthearchivedataordocumentationvolumesarerecordedasliensagainstthe productbythereviewpanel.ThesampledatasetiscreatedusingsoftwareprovidedbyAPLandthe UniversityofMichigan.Oncethesampledataarevalidated,andallliensplacedagainsttheproduct orproductgenerationsoftwareareresolved,thesamesoftwarewillbeusedtogenerate subsequentdataproductsinanautomatedfashion.

Duringautomatedproduction,thedatafilecontent isspotcheckedbymembersoftheEPPSteam. “Quick look” products generated by software provided by ACT and the EPPS team areproduced routinelyandexaminedbymembersoftheteam.Inaddition,thedataareactivelyusedbyteam memberstoperformtheiranalysis.Anydiscrepanciesinthedatanotedduringtheseactivitieswill beinvestigated.Ifthediscrepancyisadataerror,theresponsedependsonthesourceoftheerror. Iftheerrorisinthesoftwareproducingthedataproduct,theerror iscorrectedandthedata affected isreproduced,replacingthedatafile.Ifthereisacorrectableerrorinadatafile,thefile is replaced.Ifanerrorinadatafileisuncorrectable,theerror isdescribedinthecumulativeerrata fileincludedinthearchivevolume.Thestructureofdatafilesandlabelswillbespotcheckedbythe PPInodeforcompliancewithPDSstandardsandthisSIS.

6 Detailed Data Product Specification

6.1 Data Product Structure and Organization

TheMESSENGEREPPSDDRdataproductsarearchivedatthePDSPPINode.Theautomated productionandreleaseofDDRslendsitselftotheregularreleasescheduleoutlinedinsection 7.If errorsarediscoveredthedataarereplacedwithcorrectedDDRsonthenextscheduleddelivery date.

CalibrationtablesandcalibrationproceduresarerequiredtoproperlyanalyzeDDRs.These ancillarydataarearchivedatthePDSPPINodeaspartoftheEPPSdocumentationvolume.The documentationvolumeisreferencedbyallEPPSdataarchivevolumes.Thedocumentationvolume thereforeincludestheEPPSEDRSIS,theEPPSCDRSIS,andtheEPPSDDRSISinadditiontothe calibrationtables,calibrationprocedures,andotherdocumentsapplicabletothedataarchive volumes.AfirstreleaseoftheEPPSdocumentationvolumeaccompaniedtheinitialreleaseofthe EPPSEDRdataarchive.AnupdatetotheEPPSdocumentationvolumewillaccompanytheinitial releaseoftheDDRdataarchive.AftertheinitialreleasesoftheDDRleveldocumentationthere wereupdatestothedocumentationvolumetodocumentdataqualityandasneededforproduct andcalibrationupdates.

6.2 Handling Errors

Thepossibilityexiststhaterrorsmaybeintroducedintothearchiveevenwithvalidation proceduresappliedtothearchivevolumes.AnERRATAreportfileismaintainedtotrackand documentalldiscovereduncorrectableerrorsthatmayoccurduringthemission.Correctable errors,suchasrevisedDDRsorDDRsthatweremissingfromapreviousPDSdeliveryareprovided atthenextscheduledPDSdeliveryoratthefinaldeliverydate(scheduleinsection 7).PDSthen replacestheoutdatedfileswiththerevisedDDRfilesinthedatadirectoriesofthearchivevolume. Filerevisionsarealsorecordedinthedataproductlabelkeywords PRODUCT_VERSION_IDand PRODUCT_CREATION_TIME,whichcanbeusedinadditiontoERRATA.TXTtodetectupdates.The ERRATAreportfileisarchivedintheROOTdirectoryoftheEPPSDDRdatavolume.

6.3 Data Format Description

DataarestoredinASCIItableformat.AdetachedPDSlabelfileprovidesadetaileddescriptionof thestructureofeachtable.

6.4 Label and Header Descriptions

ThefollowingarethekeyworddefinitionsforthedetachedPDSlabelfile,whichaccompaniesthe instrumentdatafile . ThedetachedPDSlabelfilehasthesamenameasthedatafileitdescribes, exceptfortheextension.LBLtodistinguishitasalabelfile.

PDS_VERSION_ID

RepresentstheversionnumberofthePDSstandardsdocumentsthatisvalidwhena dataproductlabeliscreated.PDS3isusedfortheMESSENGERdataproducts.

FILE_RECORDS

Indicatesthenumberofphysicalfilerecords,includingbothlabelrecordsanddata records.

RECORD_TYPE

Indicatestherecordformatofafile . Note:InthePDS,whenrecord_typeisusedina detachedlabelfileitalwaysdescribesitscorrespondingdetacheddatafile,notthe labelfileitself . Theuseofrecord_typealongwithotherfile-relateddataelementsis fullydescribedinthePDSStandardsReference.

RECORD_BYTES

Indicatesthenumberofbytesinaphysicalfilerecord,includingrecordterminators andseparators . Note:InthePDS,theuseofrecord_bytes,alongwithotherfile-related dataelementsisfullydescribedintheStandardsReference.

PRODUCT_ID

Representsapermanent,uniqueidentifierassignedtoadataproductbyitsproducer.

PRODUCT_CREATION_TIME

DefinestheUTCsystemformattimewhenaproductwascreated.

PRODUCT_VERSION_ID

Identifiestheversionofanindividualproductwithinadataset.

Example:1.0,2.0,3.0 .

Product_version_idisincrementedifagivenDDRhastoberegeneratedandsentto PDStor eplaceapreviouslysubmittedDDR.

PRODUCT_TYPE

Identifiesthetypeorcategoryofaproductwithinadataset.

STANDARD_DATA_PRODUCT_ID

UsedtolinkanEPPSDDRfiletooneofthe12typesofEPPSdataproductsdefined withintheEPPSDDRSIS.

SOFTWARE_NAME

IdentifiesthedataprocessingsoftwareusedtoconvertfromCDRintoDDRproducts.

SOFTWARE_VERSION_ID

IndicatestheversionofthedataprocessingsoftwareusedtogeneratetheDDR products.

MD5_CHECKSUM

UsedtoverifythesuccessfulelectronictransferoftheDDRfromtheSOCtothePDS-PPINode.

INSTRUMENT_HOST_NAME

Thefullnameofthehostonwhichaninstrumentisbased . Inthiscaseitisthe MESSENGERspacecraft.

INSTRUMENT_NAME

Providesthefullnameoftheinstrument.

INSTRUMENT_ID

Providesanabbreviatednameoracronymwhichidentifiesaninstrument.

DATA_SET_ID

Thedata_set_idelementisauniquealphanumericidentifierforadatasetoradata product.Thedata_set_idvalueforagivendatasetorproductisconstructedaccording toflightprojectnamingconventions . Thereisonlyonedata_set_idfortheEPPSDDRs.

MISSION_PHASE_NAME

Providesthecommonlyusedidentifierofamissionphase.

TARGET_NAME

Thetarget_nameelementidentifiesatarget . Thetargetmaybeaplanet,satellite,ring, region,feature,asteroidorcomet.

START_TIME

Providesthedateandtimeofthebeginningofaneventorobservation(whetheritbea spacecraft,ground-based,orsystemevent)inUTCsystemformat .

STOP_TIME

Providesthedateandtimeoftheendofanobservationorevent(whetheritbea spacecraft,ground-based,orsystemevent)inUTCsystemformat .

SPACECRAFT_CLOCK_START_COUNT

Providesthevalueofthespacecraftclockatthebeginningofatimeperiodofinterest .

SPACECRAFT_CLOCK_STOP_COUNT

Providesthevalueofthespacecraftclockattheendofatimeperiodofinterest .

^TABLE

PointertotheDDRfile,whichcontainsthedatainASCIItableformat.Thestructureof thedatafileisdefinedinareferencedformatfile.

OBJECT

SpecifiesthattheDDRisaPDSTABLEobject.Thisobjectcontainsitsownelements, whicharedefinedbelow.NOTE:theendoftheobjectdefinitionisalwaysmarkedwith anEND_OBJECTline.

COLUMNS

Identifiesthenumberofcolumns(fields)inthetable.

INTERCHANGE_FORMAT

ThiselementspecifiesthatthetableisinASCIIformat.

ROW_BYTES

Specifiesthenumberofbytesforeachrowinthetable.

ROWS

Identifiesthenumberofrows(records)inthetable.

^STRUCTURE

Thisisapointertotheexternalfilewhichprovidesthestructuredefinitionforthe tableobject.

ThefollowingdescribesthekeywordsusedtodescribethePDSTableObject.Thesekeywordsare containedintheFORMAT(.FMT)filesforeachDDRdataproduct.

COLUMN_NUMBER

Identifiesthelocationofthecolumnwithinthelargerdataobject(suchasatable).For tablesconsistingofrows(I=1,N)andcolumns(j=1,M)thecolumn_numberisthej-th indexofanyrow .

NAME

Indicatesaliteralvaluerepresentingthecommontermusedtoidentifyanelementor object.NOTE:inthePDSdatadictionary,nameisrestrictedto30charactersandmust conformtoPDSnomenclaturestandards.

BYTES

Specifiesthenumberofbytesallocatedforthisparticularcolumnelement.

DATA_TYPE

Specifiestheinternalrepresentationand/ormathematicalpropertiesofthevalue beingstoredinthiscolumn.

START_BYTE

Identifiesthelocationofthefirstbyteoftheparticularcolumn,countingfrom1.

ITEMS

Definesthenumberofmultiple,identicaloccurrencesofasingleobject.Usedmainlyin columnscontainingspectralorhistogramdata.

ITEM_BYTES

Thesizeinbytesofindividualitemsinacolumn.ITEMS*ITEM_BYTESshouldequal thevalueintheBYTEScolumn.

Theformatfilecontainsthefulltextfordescribingeachcolumnofthetable.SeeAppendicesfor a listingofeachfieldintheindividualformatfiles.

6.5 File Naming Conventions

ThefilenamesdevelopedforPDSdatavolumesarerestrictedtoamaximum 36-characterfilename anda 3-characterextensionnamewithaperiodseparatingthefileandextensionnames.

ThegeneralformoftheEPPSEPSfilenameforpitchangledatais "EPSP_AyyyydddDDR_V#.TAB" where

EPS Instrumentname

P_A PitchAngle

yyyy Fourdigityear

ddd Threedigitdayofyear

DDR CODMACprocessinglevel

V# Versionnumber

ThegeneralformoftheEPPSEPSfilenameforpitchanglespectrogramsis

"EPS_PAS_yyyydddhhmmss _V#.PNG" where

EPS Instrumentname

PAS PitchAngleSpectrogram

yyyy Fourdigityear

ddd Threedigitdayofyear

hhmmss Hour,minute,second

V# Versionnumber

PNG PortableNetworkGraphicsfileextension

Thedateinthefilenameisthestarttimeofthedatacontainedinthefile.

ThegeneralformoftheEPPSFIPSfilenameforDDRs is “FIPS_<TYPE>_yyyyddd_DDR_V#.TAB” where

FIPS Instrumentname

<TYPE> Referstothetypeofdatacontainedinthefile.Possiblevaluesare

ESPEC-EnergySpectra

NOBS –ObservedDensity

PCHANG –PitchAngle

ERPCHANG –Energy-ResolvedPitchAngle

ARRDIR –ArrivalDirection

FLUXMAP –AngularFluxMap

NTP –KineticProperties

ROTMSO –ViewingNormalizationrotationmatrixtoMSO

yyyy Fourdigityear

ddd Threedigitdayofyear

DDR CODMACprocessinglevel

V# Versionnumber

ForallEPPSdata,theinitialversionnumber is “V1”(EPSandFIPS_FOVPIX) or “V01” (allother FIPS).Theversionnumberincrementsforeachsuccessiveversionofthe DDRproductthatis produced.AnewversionoftheDDRproductmaybeproducedasaresultofanerrorintheproduct orasaresultoferrorsdiscoveredintheproductgenerationprocess.

For all EPPS data except the EPS Pitch Angle Spectrogram:

TAB the file extension is dependent on the file type

.TAB, EPS and FIPS Instrument Data in ASCII table

.LBL, Detached PDS label file

6.6 Archive Volume and File Size

Twoarchivevolumesarecreatedtoarchivebooth theEPPSDDRdataandthedocumentation,which isneededtoanalyzetheDDRs.ThefirstvolumeistheEPPSDocumentationVolume,havingvolume IDMESSEPPS_DOC.ThisdocumentationvolumecontainsproductsrelatedtotheEPPSEDR,CDR , andDDRdataarchivesincluding:

1. AllrequiredPDScatalogfilesfortheEDR,CDR,andDDRarchives.
2. TheEDR,CDR,andDDRSISdocuments.
3. TheSpaceSciencesReview(SSR)instrumentpaperoncecopyrightpermissionisobtained. Thismaynotbeincludedintheinitialreleaseforcopyrightreasons.
4. TheEPPScalibrationreport.
5. TheEPPScalibrationproceduresdocument.
6. Calibrationtables.
7. OtherdocumentsconsideredusefulbytheMESSENGERprojectortheEPPSteam.

Thedataarchivevolume,designatedtheEPPSDataArchiveVolumeandhavingvolumeID MESSEPPS_DDR,containstheDDRdataandrequiredfilesforconformingtoPDSvolumearchive standards.Thisincludestheindexfiles,AAREADME.TXTfile,etc.Theapproximatedataarchive volumesizeis11GB.

6.7 Directory Structure and Contents for EPPS Documentation Volume

ThefollowingillustrationshowsthedirectorystructureoverviewfortheEPPSdocumentation volume.

```
                         <ROOT>
          _______________________|______________________
         |                       |                      |
   <CALIBRATION>            <DOCUMENT>              <CATALOG>
                                 |
                  _______________|_______________
                 |               |               |
             <EDR_SIS>       <CDR_SIS>       <DDR_SIS>
```

Figure2DocumentationVolumeStructure

6.7.1 Directory Contents

<ROOT>Directory

This is the top-level volume directory. The following are files contained in the root directory.

AAREADME.TXT - General information file. Provides users with an overview of the contents and organization of the associated volume, general instructions for its use, and contact information.

VOLDESC.CAT - PDS file containing the VOLUME object. This gives a high-level description of the contents of the volume. Information includes: production date, producer name and institution, volume ID, etc.

ERRATA.TXT - Text file for identifying and describing errors and/or anomalies found in the current volume, and possibly previous volumes of a set. Any known errors for the associated volume are documented in this file.

<CALIBRATION>Directory

This contains the calibration tables needed to analyze the EPPS CDR data. The calibration tables are in ASCII format. Format files for the calibration tables are also located here, as are the following files.

CALINFO.TXT–Briefdescriptionofthedirectorycontentsandnamingconventions.

EPPS_*_EDR2CDR.PDF: Describes the procedure used to convert EDRs to CDRs for each instrument, (as indicated by the * text).

FIP*.TAB:TheFIPSenergyperchargetables.

<CATALOG>Directory

This subdirectory contains the catalog object files for the entire volume. The following files are included in the catalog subdirectory.

CATINFO.TXT: Identifies and describes the function of each file in the catalog directory.

EPPS*DATASET.CAT: Describes the general content of the EDR data set for each instrument (as indicated by the * text) and includes information about the duration of the mission and the person or group responsible for producing the data.

EPPS*DATASET_CDR.CAT: Describes the general content of the CDR data set for each instrument (as indicated by the * text) and includes information about the duration of the mission and the person or group responsible for producing the data.

EPPS*DATASET_DDR.CAT: Describes the general content of the DDR data set for each instrument (as indicated by the * text) and includes information about the duration of the mission and the person or group responsible for producing the data.

INSTRUMENT.CAT: Describes physical attributes of the EPPS instrument and provides relevant references to published literature.

INSTHOST.CAT: Describes the MESSENGER spacecraft.

MISSION.CAT: Describes the scientific goals and objectives of the MESSENGER program. It also identifies key people and institutions.

PERSON.CAT: Lists and provides contact information for the people involved in the MESSENGER mission, including those involved with EPPS.

REF.CAT: Provides references to scientific papers and other publications of interest to those using the data, both for EPPS and the mission as a whole.

< DOCUMENT > Directory

This subdirectory contains the documentation that is needed in order to understand and analyze the EDR, CDR, and DDR data volumes. The documents are separated into individual subdirectories according to the document type. The document types are not restricted to the four shown in the graphical depiction of the directory structure. There are additional document types as needed to categorize each document. The following file is included in the subdirectory.

DOCINFO.TXT: Identifies and describes the function of each file in the DOCUMENT directory.

6.8 Directory Structure and Contents for EPPS Data Volume

```
                                  <ROOT>

        ___________________________|__________________________

        |                      |                 |             |

    <DATA>               <GEOMETRY>          <INDEX>       <LABEL>

        |

      __|________________________________________________________________

      |             |        |        |       |      |      |       |    |

<EPS_PITCH_ANGLES> |   <FIPS_PCHANG>  |  <FIPS_NOBS> |  <FIPS_NTP> |    |

   |                |          <FIPS_ESPEC>          |              |    |

   | <EPS_PITCH_ANGLES_SPECTROGRAM>       <FIPS_ARRDIR>  <FIPS_ROTMSO>   |

   |                                          __________________________|

   |                                          |               |

   |                                  <FIPS_ERPCHANG>   <FIPS_FLUXMAP>

 _|_______________

|        |        |

<2008>   <2009>   <2010> ...

           |
```

```
        ___|____________
       |         |         |
     <JAN>     <FEB>     <MAR>
```

Figure 3 Data Volume Directory Structure

6.8.1 Directory Contents

<ROOT>Directory

This is the top-level directory of a volume. The following are files contained in the root directory.

AAREADME.TXT - General information file. Provides users with an overview of the contents and organization of the associated volume, general instructions for its use, and contact information.

VOLDESC.CAT - PDS file containing the VOLUME object. This gives a high-level description of the contents of the volume. Information includes: production date, producer name and institution, volume ID, etc.

ERRATA.TXT - Text file for identifying and describing errors and/or anomalies found in the current volume, and possibly previous volumes of a set. Any known errors for the associated volume are documented in this file. This includes revised DDRs meant to replace DDRs in a previous PDS delivery.

<DATA>Directory

Thistopleveldirectorycontainsthesubdirectoriescorrespondingtothesevendata products(section 5.2)andsupportingproducts.Thedirectoriesarefurthersubdividedinto YEARandMONTHdirectories.TheFIPS_FOVPIXdirectorycontainsthePixelFieldOfView ancillaryproducts.

<GEOMETRY>Directory

This subdirectory contains information about the files (e.g. SPICE kernels, etc) needed to describe the observation geometry for the data.

GEOMINFO.TXT:IdentifiesanddescribestheSPICEkernelsthatausermusthaveinorder todetermineobservationgeometryforthedata.TheSPICEkernelfilesarearchivedwith thePDSNAIFnode.

<INDEX>Directory

This subdirectory contains the indices for all data products on the volume. The following files are contained in the index subdirectory.

INDXINFO.TXT – Identifies and describes the function of each file in the index subdirectory. This includes a description of the structure and contents of each index table in the subdirectory AND usage notes.

INDEX.TAB - The DDR index file is organized as a table: there is one entry for each of the data files included in the EPPS data set; the columns contain parameters that describe the observation and instrument and spacecraft parameters. These parameters include state information, such as integration time, spacecraft clock count, time of observation, and instrument modes.

INDEX.LBL - Detached PDS label for INDEX.TAB. It contains the INDEX_TABLE object which identifies and describes the columns of the EPPS index table.

MD5.TAB - The MD5 checksum file that contains MD5 hash values for every file in the volume.

MD5.LBL - Detached PDS label for MD5.TAB.

<LABEL>Directory

This subdirectory contains the “label fragments” (i.e., the *.FMT files) for all data products on the volume. These format files describe the table and data objects which store the data.

7 Archive Release Schedule to PDS

TheMESSENGEREPPSdataandvolumearchivesweretransferredfromtheSOCtothePDSPPI Nodeusingtheprocessdetailedinsection 5.3.3.TheSPICEkernelsweretransferredtotheNAIF node.Thetransfertookplaceaccordingtotheschedulein[2].

8 Appendices

8.1 EPS_PITCH_ANGLES.FMT Table Columns

ThefollowingarethecolumnsasdefinedbytheEPS_PITCH_ANGLES.FMTstructurefile.Thisfile definestheASCIItablecontainingtheEPSpitchangledata.Thearchivevolumeisoptimizedby definingthetablestructureonceandprovidingareferencetoitinthePDSlabelfile.Thecolumns arenumberedaccordingtotheircolumnorderinthetable . DataTypereferstothePDSstandards datatypeforaparticularcolumninthetable .

Table 3 EPS_ PITCH_ANGLES.FMT Columns

Length (bytes)	Data Type	Column Name	Summary (see full text for column description)
21	TIME	TIME	Spacecrafteventtime(UTC)for thisdatarecord.
22	ASCII_REAL	PITCH_ANGLE_S0	Pitchangle (degrees) forsector 0.
22	ASCII_ REAL	PITCH_ANGLE_S1	Pitchangle(degrees)forsector 1.
22	ASCII_ REAL	PITCH_ANGLE_S2	Pitchangle(degrees)forsector 2.
22	ASCII_ REAL	PITCH_ANGLE_S3	Pitchangle(degrees)forsector 3.
22	ASCII_ REAL	PITCH_ANGLE_S4	Pitchangle(degrees)forsector 4.
22	ASCII_ REAL	PITCH_ANGLE_S5	Pitchangle(degrees)forsector 5.

8.2 FIPS_PCHANG_DDR.FMT Table Columns

ThefollowingarethecolumnsasdefinedbytheFIPS _ PCHANG_DDR.FMTstructurefile.Thisfile definestheASCIItablecontainingtheFIPSpitchangledata.Thearchivevolumeisoptimizedby definingthetablestructureonceandprovidingareferencetoitinthePDSlabelfile.Thecolumns arenumberedaccordingtotheircolumnorderinthetable.DataTypereferstothePDSstandards datatypeforaparticularcolumninthetable.

TheINDEXfieldvaluesareuniqueforagivendayandmaybeusedtomatchdatainthisfiletothat intheotherFIPSDDRfilesforthesameday. Thisfactisusedtoavoiddataduplication : Universal Time(UTC)andMESSENGERpositionsaregivenonlyintheFIPS_NOBS_DDRfile.

Table 4 FIPS_PCHANG_DDR.FMT

Length (bytes)	Data Type	Field Name	Summary (see full text for column description)
7	ASCII Integer	INDEX	Uniqueidentifierforthecurrentdatasample.
14	ASCIIReal	MET	MissionElapsedTimeinseconds.
554	ASCIIReal	H_PA	H+flux -pitchanglehistogram.Pitchanglerange=0 - 180inclusive,where0isparalleltomagneticfield. Binsizeis5degrees .
554	ASCIIReal	HE2_PA	He2+flux -pitchanglehistogram.Pitchanglerange= 0 - 180inclusive,where0isparalleltomagnetic field.Binsizeis5degrees.
554	ASCIIReal	HE_PA	He+flux -pitchanglehistogram.Pitchanglerange= 0 - 180inclusive,where0isparalleltomagnet ic field.Binsizeis5degrees.
554	ASCIIReal	NAGROUP_PA	Na+groupflux -pitchanglehistogram.Pitchangle range=0 - 180inclusive,where0isparallelto magneticfield.Binsizeis5degrees.
554	ASCIIReal	OGROUP_PA	O+groupflux -pitchanglehistogram.Pitchangle range=0 - 180inclusive,where0isparallelto magneticfield.Binsizeis5degrees.

8.3 FIPS_ERPCHANG_DDR.FMT Table Columns

ThefollowingarethecolumnsasdefinedbytheFIPS_ERPCHANG_DDR.FMTstructurefile.Thisfile definestheASCIItablecontainingtheFIPSenergy-resolvedpitchangledata.Thearchivevolumeis optimizedbydefiningthetablestructureonceandprovidingareferencetoitinthePDSlabelfile. Thecolumnsarenumberedaccordingtotheircolumnorderinthetable.DataTypereferstothe PDSstandardsdatatypeforaparticularcolumninthetable.

TheSTART_INDEXandSTOP_INDEXfieldvaluesareuniqueforagivendayandmaybeusedto matchdatainthisfiletothatintheotherFIPSDDRfilesforthesameday.Thisfactisusedtoavoid dataduplication:UniversalTime(UTC)andMESSENGERpositionsaregivenonlyinthe FIPS_NOBS_DDRfile.

Table 5 FIPS_ERPCHANG_DDR.FMT

Length (bytes)	Data Type	Field Name	Summary (see full text for column description)
14	ASCIIInteger	START_INDEX	Uniqueidentifierforthe startofthecurrent samplerange .
14	ASCIIInteger	STOP_INDEX	Uniqueidentifierforthe endofthecurrent samplerange .
14	ASCIIReal	START_MET	MissionElapsedTimeinseconds atthebeginning oftheaccumulation .
14	ASCIIReal	STOP_MET	MissionElapsedTimeinseconds attheendofthe accumulation.
16	CHARACTER	TIME_RESL	Timeresolutionlabel.
16	CHARACTER	ION	Iongrouplabel.
1152	ASCIIReal	ERPCHANG	2Dmatrix(Pitchangle,DSHVstep).Pitchangle range:0 - 180inclusive dividedover10degree bins.Matrixisorderedbysequential64element pitchanglevectors(elements0 -63 arepitchangle 0,DSHVsteps0to63; elements64 -127arepitch angle10,steps0to63;andsoon).

8.4 FIPS_ESPEC_DDR.FMT Table Columns

Thefollowingarethecolumnsasdefinedbythe FIPS_ESPEC_DDR.FMTstructurefile.Thisfile definestheASCIItablecontainingtheFIPSenergyspectradata.Thearchivevolumeisoptimizedby definingthetablestructureonceandprovidingareferencetoitinthePDSlabelfile.Thecolumns arenumberedaccordingtotheircolumnorderinthetable.DataTypereferstothePDSstandards datatypeforaparticularcolumninthetabl e.

TheINDEXfieldvaluesareuniqueforagivendayandmaybeusedtomatchdatainthisfiletothat intheothertwoFIPSDDRfilesforthesameday . Thisfactisusedtoavoiddataduplication: UniversalTime(UTC)andMESSENGERpositionsaregivenonlyintheFIPS_NOBS_DDRfile.

Table 6 FIPS_ ESPEC_DDR.FMT Columns

Length (bytes)	**Data Type**	**Field Name**	**Summary (see full text for column description)**
7	ASCII Integer	INDEX	Uniqueidentifierforthecurrentdatasample.
14	ASCII Real	MET	MissionElapsedTimeinseconds.
959	ASCIIReal	H	H+ fluxpere/q in1/(cm ^{2} skV).
959	ASCIIReal	HE2	He2+fluxpere/q in1/(cm ^{2} skV) .
959	ASCIIReal	HE	He+ fluxpere/q in1/(cm ^{2} skV) .
959	ASCIIReal	NA_GROUP	Na+ group fluxpere/q in1/(cm^2 skV) .
959	ASCIIReal	O_GROUP	O+ group fluxpere/q in1/(cm ^{2} skV) .

8.5 FIPS_NOBS_DDR.FMT Table Columns

ThefollowingarethecolumnsasdefinedbytheFIPS_NOBS_DDR.FMTstructurefile.Thisfile definestheASCIItablecontainingtheFIPSobserveddensitydata.Thearchivevolumeisoptimized bydefiningthetablestructureonceandprovidingareferencetoitinthePDSlabelfile.The columnsarenumberedaccordingtotheircolumnorderinthetable.DataTypereferstothePDS standardsdatatypeforaparticularcolumninthetable.

TheINDEXfieldvaluesareuniqueforagivendayandmaybeusedtomatchdatainthisfiletothat intheothertwoFIPSDDRfilesforthesameday . Thisfactisusedtoavoiddataduplication: UniversalTime(UTC) andMESSENGERpositionsaregivenonlythisfile.

Table 7 FIPS_NOBS_DDR.FMT Columns

Length (bytes)	Data Type	Field Name	Summary (see full text for column description)
7	ASCII Integer	INDEX	Uniqueidentifierforthecurrentdata sample.
14	ASCIIReal	MET	MissionElapsedTimeinseconds.
7	ASCIIReal	ACCUM	Accumulationtimeforthecurrentdatasample.
15	ASCIIReal	YFR	Timeatendoftheaccumulationinfloatingpoint year.
8	ASCII Real	DOYFR	Timeatendoftheaccumulationin floatingpoint dayofyear .
5	ASCII Integer	HOURS	Hourattheendoftheaccumulation .
7	ASCII Integer	MINUTES	Minuteattheendoftheaccumulation .
7	ASCII Real	SECONDS	Secondattheendoftheaccumulation .
10	ASCIIReal	MSOX	MESSENGERX -coordinate inMSGR_MSOframe inkm.
10	ASCIIReal	MSOY	MESSENGERY -coordinateinMSGR_MSOframe inkm.
10	ASCIIReal	MSOZ	MESSENGERZ -coordinateinMSGR_MSOframe inkm.
6	ASCII Real	LAT	MESSENGERpositioninMercurylatitudein degrees.
6	ASCII Real	MLT	MESSENGERpositioninmagneticlocaltimein hourfraction .
9	ASCII Real	ALT	MESSENGERaltitudeinkm .
14	ASCIIReal	H	H^+ observeddensityincm^{-3}.
14	ASCIIReal	HE2	He^{2+} observeddensityincm^{-3}.
14	ASCIIReal	HE	He^+ observeddensityincm^{-3}.

14	ASCIIReal	NA	Na+ observeddensityincm^{-3}.
14	ASCIIReal	O	O+ observeddensityincm^{-3}.
4	ASCII Integer	QUAL	Dataqualityflag(0=good,1=bad) .

8.6 FIPS_ARRDIR_DDR.FMT Table Columns

ThefollowingarethecolumnsasdefinedbytheFIPS_ARRDIR_DDR.FMTstructurefile.Thisfile definestheASCIItablecontainingtheFIPSarrivaldirectiondata.Thearchivevolumeisoptimized bydefiningthetablestructureonceandprovidingareferencetoitinthePDSlabelfile.The columnsarenumberedaccordingtotheircolumnorderinthetable.DataTypereferstothePDS standardsdatatypeforaparticularcolumninthetable.

TheSTART_INDEXandSTOP_INDEXfieldvaluesareuniqueforagivendayandmaybeusedto matchdatainthisfiletothatintheotherFIPSDDRfilesforthesameday.Forexample,the START_INDEXcorrespondstotheINDEXforthefirstlineintheFIPSNOBSdatausedforthis accumulation.TheSTOP_INDEXcorrespondstothelastline.Thisfactisusedtoavoiddata duplication:UniversalTime(UTC)andMESSENGERpositionsaregivenonlythisfile.

Table 8 FIPS_ARRDIR_DDR.FMT Columns

Length (bytes)	**Data Type**	**Field Name**	**Summary (see full text for column description)**
14	ASCII Integer	START_INDEX	Unique identifierforthestartofthecurrent samplerange .
14	ASCII Integer	STOP_INDEX	Uniqueidentifierfortheendofthecurrent samplerange.
14	ASCII Real	START_MET	MissionElapsedTimeatthebeginningofthe accumulation.
14	ASCII Real	STOP_MET	MissionElapsedTimeattheendofthe accumulation.
14	ASCII	TIME_RESL	Stringlabelfortimeresolutionofcurrentline.
14	ASCII	ION	Nameofionoriongroup .

9072	ASCII Real	DIRECTIONAL_FLUX	Ionfluxasafunctionofarrivaldirection.Units: (cm^2skeV/keVsr)^ -1.

8.7 FIPS_FLUXMAP_DDR.FMT Table Columns

ThefollowingarethecolumnsasdefinedbytheFIPS_FLUXMAP_DDR.FMTstructurefile.Thisfile definestheASCIItablecontainingtheFIPSarrivaldirectiondata.Thearchivevolumeisoptimized bydefiningthetablestructureonceandprovidingareferencetoitinthePDSlabelfile.The columnsarenumberedaccordingtotheircolumnorderinthetable.DataTypereferstothePDS standardsdatatypeforaparticularcolumninthetable.

TheSTART_INDEXandSTOP_INDEXfieldvaluesareuniqueforagivendayandmaybeusedto matchdatainthisfiletothatintheotherFIPSDDRfilesforthesameday.Forexample,the START_INDEXcorrespondstotheINDEXforthefirstlineintheFIPSNOBSdatausedforthis accumulation.TheSTOP_INDEXcorrespondstothelastline.Thisfactisusedtoavoiddata duplication:UniversalTime(UTC)andMESSENGERpositionsaregivenonlythisfile.

Table 9 FIPS_FLUXMAP_DDR.FMT Columns

Length (bytes)	**Data Type**	**Field Name**	**Summary (see full text for column description)**
14	ASCII Integer	START_INDEX	Uniqueidentifierforthestartofthecurrent samplerange.
14	ASCII Integer	STOP_INDEX	Uniqueidentifierfortheendofthecurrent samplerange.
14	ASCII Real	START_MET	MissionElapsedTimeatthebeginningofthe accumulation.
14	ASCII Real	STOP_MET	MissionElapsedTimeattheendofthe accumulation.
14	ASCII	TIME_RESL	Stringlabelfortimeresolutionofcurrentline.
14	ASCII	ION	Nameofionoriongroup.
9072	ASCII Real	DIRECTIONAL_FLUX	Ionfluxasafunctionofarrivaldirection.Units: (cm^2skeV/keVsr)^ -1.

8.8 FIPS_NTP_DDR.FMT Table Columns

ThefollowingarethecolumnsasdefinedbytheFIPS_NTP_DDR.FMTstructurefile.Thisfiledefines theASCIItablecontainingtheFIPSarrivaldirectiondata.Thearchivevolumeisoptimizedby definingthetablestructureonceandprovidingareferencetoitinthePDSlabelfile.Thecolumns arenumberedaccordingtotheircolumnorderinthetable.DataTypereferstothePDSstandards datatypeforaparticularcolumninthetable.

TheSTART_INDEXandSTOP_INDEXfieldvaluesareuniqueforagivendayandmaybeusedto matchdatainthisfiletothatintheotherFIPSDDRfilesforthesameday.Forexample,the START_INDEXcorrespondstotheINDEXforthefirstlineintheFIPSNOBSdatausedforthis accumulation.TheSTOP_INDEXcorrespondstothelastline.Thisfactisusedtoavoiddata duplication:UniversalTime(UTC)andMESSENGERpositionsaregivenonlythisfile.

Table 10 FIPS_NTP_DDR.FMT Columns

Length (bytes)	**Data Type**	**Field Name**	**Summary (see full text for column description)**
14	ASCII Integer	START_INDEX	Uniqueidentifierforthestartofthecurrent samplerange.
14	ASCII Integer	STOP_INDEX	Uniqueidentifierfortheendofthecurrent samplerange.
14	ASCIIReal	START_MET	MissionElapsedTimeatthebeginningofthe accumulation.
14	ASCIIReal	STOP_MET	MissionElapsedTimeattheendofthe accumulation.
14	ASCII	TIME_RESL	Stringlabelfortimeresolutionofcurrentline.
14	ASCII	ION	Nameofionoriongroup.
14	ASCIIReal	N	Ionnumberdensityinunitsofcm^ -3.
14	ASCIIReal	T	IontemperatureinunitsofMK .
14	ASCIIReal	P	IonpressureinunitsofnPa.

14	ASCIIReal	N_ERR	Errorinionnumberdensityinunitsofcm^ -3.
14	ASCIIReal	T_ERR	ErroriniontemperatureinunitsofMK.
14	ASCIIReal	P_ERR	ErrorinionpressureinunitsofnPa. .
6	ASCII Integer	QUAL	QualityFlag .0=Good;non -0=Bad.Non -zeroflag valuesTBD.

8.9 FIPS_ROTMSO_DDR.FMT Table Columns

ThefollowingarethecolumnsasdefinedbytheFIPS_ROTMSO_DDR.FMTstructurefile.Thisfile definestheASCIItablecontainingtheFIPSCartesiantoMSOrotationmatrixdefinition . Thearchive volumeisoptimizedbydefiningthetablestructureonceandprovidingareferencetoitinthePDS labelfile.Thecolumnsarenumberedaccordingtotheircolumnorderinthetable.DataTyperefers tothePDSstandardsdatatypeforaparticularcolumninthetable.

TheINDEXfieldvaluesareuniqueforagivendayandmaybeusedtomatchdatainthisfiletothat intheothertwoFIPSDDRfilesforthesameday.Thisfactisusedtoavoiddataduplication: UniversalTime(UTC)andMESSENGERpositionsaregivenonlythisfile.

Table 11 FIPS_ROTMSO_DDR.FMT Columns

Length (bytes)	**Data Type**	**Field Name**	**Summary (see full text for column description)**
11	ASCII Integer	INDEX	Uniqueidentifierforthecurrentdatasample.
20	ASCIIReal	MET	MissionElapsedTimeatthe end ofthe correspondingFIPSscan .
54	ASCIIReal	MATRIX_ROW_0	FIPSFOVtoMSGRMSO rotationmatrixrow0 .
54	ASCIIReal	MATRIX_ROW_1	FIPSFOVtoMSGRMSOrotationmatrixrow1 .
54	ASCIIReal	MATRIX_ROW_2	FIPSFOVtoMSGRMSOrotationmatrixrow2 .

8.10 SPICE Kernel Files Used in MESSENGER Data Products

ThefollowingSPICEkernelfileswereusedtocomputetheUTCtimeandanygeometricquantities foundinthePDSlabels . Kernelfilesweregeneratedthroughoutthemissionwithafilenaming conventionspecifiedbytheMESSENGERproject.

*.bsp:

MESSENGERspacecraftephemerisfile. Also knownasthePlanetarySpacecraftEphemerisKernel (SPK)file.

*.bc:

MESSENGERspacecraftorientationfile.AlsoknownastheAttitudeC-Kernel(CK)file.

*.tf:

MESSENGERreferenceframefile.AlsoknownastheFramesKernel.ContainstheMESSENGER spacecraft,scienceinstrument,andcommunicationsantennaeframedefinitions.

*.ti:

MESSENGERinstrumentkernel(I-kernel).Containsreferencestomountingalignment,operation modes,andtimingaswellasinternalandfieldofviewgeometryfortheEPPS.

*.tsc:

MESSENGERspacecraftclockcoefficientsfile.AlsoknownastheSpacecraftClockKernel(SCLK) file.

*.tpc:

Planetaryconstantsfile.AlsoknownasthePlanetaryConstantsKernel(PcK)file.

*.tls:

NAIFleapsecondskernelfile.UsedinconjunctionwiththeSCLKkerneltoconvertbetween UniversalTimeCoordinated(UTC)andMESSENGERMissionElapsedTime(MET).Alsocalledthe LeapSecondsKernel(LSK)file.

8.11 CODMAC/NASA Definition of Processing Levels

CODMAC/NASADefinitionofprocessinglevelsforsciencedatasets

CODMAC Level	Proc.Type	DataProcessingLevelDescription
1	RawData	Telemetrydatastreamasreceivedatthegroundstation,with scienceandengineeringdataembedded.CorrespondstoNASA packetdata.
2	Edited Data	Instrumentsciencedata(e.g.rawvoltages,counts)atfull resolution,timeordered,withduplicatesandtransmission errorsremoved.ReferredtointheMESSENGER programas Experiment DataRecords(EDRs).CorrespondstoNASALevel0 data.
3	Calibrated Data	Editeddatathatarestillinunitsproducedbyinstrument,but havetransformed(e.g.calibrated,rearranged)inareversible mannerandpackagedwithneededancillaryandauxiliarydata (e.g.radianceswithcalibrationequationsapplied).Referr edto intheMESSENGERProgramasCalibratedDataRecords(CDRs). Insomecasesthesealsoqualifyasderiveddataproducts (DDRs).CorrespondstoNASALevel1A.
4	Resampled data	Irreversiblytransformed(e.g.resampled,remapped,calibrated) valuesofth einstrumentmeasurements(e.g.radiances, magneticfieldstrength).ReferredtointheMESSENGER programaseitherderiveddataproducts(DDPs)orderived analysisproducts(DAPs).CorrespondstoNASALevel1B.
5	DerivedData	Derivedresultssuchasmaps ,reports,graphics,etc. CorrespondstoNASALevels2through5

CODMAC Level	Proc.Type	DataProcessingLevelDescription
6	Ancillary Data	Non-Sciencedataneededtogeneratecalibratedorresampled datasets.Consistsofinstrumentgains,offsets;pointing informationforscanplatforms,etc.
7	Corrective Data	Othersciencedataneededtointerpretspace -bornedatasets. Mayincludegroundbaseddataobservationssuchassoiltype oroceanbuoy measurementsof winddrift.
8	User Description	Descriptionofwhythedatawererequired,anypeculiarities associatedwiththedatasets,andenoughdocumentationto allowsecondaryusertoextractinformationfromthedata.

Theaboveisbasedonthenationalresearchcouncilcommitteeondatamanagementand computation(CODMAC)datalevels.

8.12 MESSENGER Glossary and Acronym List

ACT AppliedCoherentTechnologyCorporation

AMU AtomicMassUnit

APL TheJohnsHopkinsUniversityAppliedPhysicsLaboratory

ASCII AmericanStandardCodeforInformationInterchange

CDR CalibratedDataRecord

CK AttitudeC-Kernel(SPICE)

CODMAC CommitteeonDataManagementandComputation

DAP DerivedAnalysisProducts

DDP DerivedDataProducts

EDR ExperimentDataRecords

EPPS EnergeticParticleandPlasmaSpectrometer

EPS EnergeticParticleSpectrometer

ESA	ElectrostaticAnalyzer
FIFO	FirstIn,Firstout.Anelectroniccomponentthatstoresandretrieves informationfollowingafirst- in-first-outdiscipline.
FIPS	FastImagingPlasmaSpectrometer
FOV	Field- of-View
FSW	FlightSoftware
FTP	FileTransferprotocol
GEANT4	GEometryANdTrackingsoftwaretoolkit
GF	GeometricFactor
I2C	Inter-IntegratedCircuit
JPL	JetPropulsionLaboratory
IEM	IntegratedElectronicModule
LSB	LeastSignificantBit
LSK	LeapsecondsKernel(SPICE)
MCP	Micro-channelPlate
MESSENGER	MErcurySurface,SpaceENvironment,GEochemistry,andRanging
MET	MissionElapsedTime
MIDL	MissionIndependentDataLayer
MSO	Mercury-centricSolarOrbital
NAIF	NavigationandAncillaryInformationFacility
NASA	NationalAeronauticsandSpaceAdministration
PCK	PlanetaryConstantKernel(SPICE)
PDS	PlanetaryDataSystem
PHA	PulseHeightAnalysis
PPI	PlanetaryPlasmaInteractionsPDSNode

RDR	ReducedDataRecord
SCLK	SpaceClockKernel(SPICE)
SOC	ScienceOperationsCenter
SPICE	Spacecraft,Planet,Instrument,C-matrixEvents,referstothekernelfilesandNAIF softwareusedtogenerateviewinggeometry.
SPK	SpacecraftandPlanetsKernel(SPICE)
SSD	Solid-StateDetector
SSR	SpaceSciencesReview
TOF	TimeofFlight
UTC	CoordinatedUniversalTime