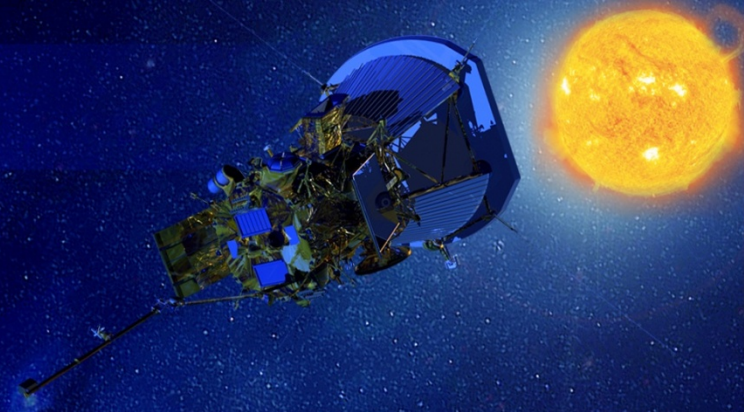
Solar Probe Plus

A NASA Mission to Touch the Sun



Solar Probe Plus Payload Requirements Document Peer Review

APL
The Johns Hopkins University
APPLIED PHYSICS LABORATORY

WISPR Measurements

PAY-70: Measurement: Visible Broadband Intensity 0.046 AU to 0.07 AU

WISPR shall be capable of providing Full Frame Images of visible broadband intensity over solar orbital distances of 0.046 AU to 0.07 AU as follows:

-- capturing the radial scene from elongations of 14 degrees to 90 degrees from sun center;

-- capturing the transverse scene from 20 degrees (at 14 degrees elongation) to 44 degrees (at 90 degrees elongation);

-- with image spatial resolution across the FOV of ≤ 6.4 arcmin (for elongations 14 degrees to 53 degrees) and ≤ 9.3 arcmin (for elongations 53 degrees to 90 degrees);

-- with SNR for a binned pixel ≥ 20 (for elongations of 14 degrees to 20 degrees), ≥ 10 (for elongations of 20 degrees to 26 degrees) and ≥ 5 (for elongations of 26 degrees to 90 degrees);

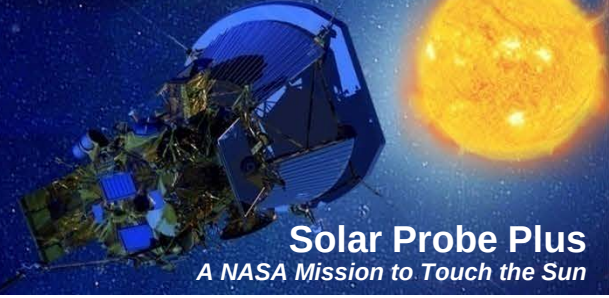
-- with nominal cadence of ≤ 10 min.

Description/Clarification

L2 Spatial resolution and photometric accuracy at the required spatial resolution and cadence are only required to be satisfied in the inner FOV of the image. L2 Cadence is an average cadence requirement over the orbit. The cadence requirement will be faster inside 0.11 AU. Since instrument cadence for the same effective aperture will vary as a function of the signal to noise ratio in the scene based on the spacecraft distance to the sun and elongation, the increase in the instrument cadence inside 0.11 AU is not driving the WISPR instrument design.

Rationale	**Requirement Allocation**
This requirement meets Level 2 Mission Science Requirements.	WISPR
Parent Traceability	**Functional Allocation**
MRD-95 : The Mission shall measure visible broadband intensity, as follows: -- Cadence: <= 16.5 min -- Field of view: >= 76 degrees radial x >= 20 degrees transverse at 14 degrees elongation to >= 44 degrees transverse at 90 degrees elongation -- Inner FOV boundary: <= 14 degrees -- Spatial Resolution: <= 6.4 arcmin -- Photometric sensitivity (SNR per pixel): >= 20.	

WISPR Measurements



PAY-71: Measurement: Visible Broadband Intensity 0.07 AU to 0.11 AU

WISPR shall be capable of providing Full Frame Images of visible broadband intensity over solar orbital distances of 0.07 AU to 0.11 AU as follows:

-- capturing the radial scene from elongations of 14 degrees to 90 degrees from sun center;

-- capturing the transverse scene from 20 degrees (at 14 degrees elongation) to 44 degrees (at 90 degrees elongation);

-- with image spatial resolution across the FOV of ≤ 6.4 arcmin (for elongations 14 degrees to 53 degrees) and ≤ 9.3 arcmin (for elongations 53 degrees to 90 degrees);

-- with SNR for a binned pixel ≥ 20 (for elongations of 14 degrees to 20 degrees), ≥ 10 (for elongations of 20 degrees to 26 degrees) and ≥ 5 (for elongations of 26 degrees to 90 degrees);

-- with nominal cadence of ≤ 15 min.

Description/Clarification

L2 Spatial resolution and photometric accuracy at the required spatial resolution and cadence are only required to be satisfied in the inner FOV of the image. L2 Cadence is an average cadence requirement over the orbit. The cadence requirement will be faster inside 0.11 AU and slower outside 0.174 AU.

Rationale	**Requirement Allocation**
This requirement meets Level 2 Mission Science Requirements.	WISPR
Parent Traceability	**Functional Allocation**
MRD-95 : The Mission shall measure visible broadband intensity, as follows: -- Cadence: <= 16.5 min -- Field of view: >= 76 degrees radial x >= 20 degrees transverse at 14 degrees elongation to >= 44 degrees transverse at 90 degrees elongation -- Inner FOV boundary: <= 14 degrees -- Spatial Resolution: <= 6.4 arcmin -- Photometric sensitivity (SNR per pixel): >= 20.	

WISPR Measurements

PAY-72: Measurement: Visible Broadband Intensity 0.11 AU to 0.174 AU

WISPR shall be capable of providing Full Frame Images of visible broadband intensity over solar orbital distances of 0.11 AU to 0.174 AU as follows:

-- capturing the radial scene from elongations of 14 degrees to 90 degrees from sun center;

-- capturing the transverse scene from 20 degrees (at 14 degrees elongation) to 44 degrees (at 90 degrees elongation);

-- with image spatial resolution across the FOV of ≤ 6.4 arcmin (for elongations 14 degrees to 53 degrees) and ≤ 9.3 arcmin (for elongations 53 degrees to 90 degrees);

-- with SNR for a binned pixel ≥ 20 (for elongations of 14 degrees to 20 degrees), ≥ 10 (for elongations of 20 degrees to 26 degrees), ≥ 5 (for elongations of 26 degrees to 40 degrees), ≥ 3.33 (for elongations of 40 degrees to 53 degrees), and ≥ 5 (for elongations of 53 degrees to 90 degrees);

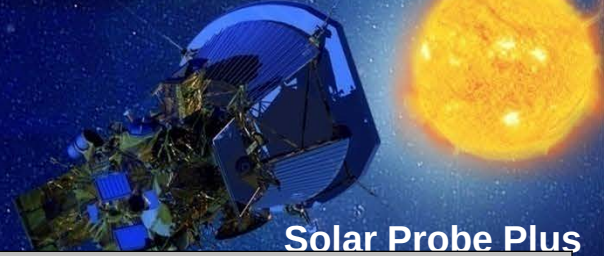
-- with nominal cadence of ≤ 16.5 min (for elongations 14 degrees to 26 degrees) and ≤ 36 min (for elongations 26 degrees to 90 degrees).

Description/Clarification

L2 Spatial resolution and photometric accuracy at the required spatial resolution and cadence are only required to be satisfied in the inner FOV of the image. L2 Cadence is only required to be satisfied in the inner FOV of the image.

Rationale	**Requirement Allocation**
This requirement meets Level 2 Mission Science Requirements.	WISPR
Parent Traceability MRD-95 : The Mission shall measure visible broadband intensity, as follows: -- Cadence: <= 16.5 min -- Field of view: >= 76 degrees radial x >= 20 degrees transverse at 14 degrees elongation to >= 44 degrees transverse at 90 degrees elongation -- Inner FOV boundary: <= 14 degrees -- Spatial Resolution: <= 6.4 arcmin -- Photometric sensitivity (SNR per pixel): >= 20.	**Functional Allocation**

WISPR Measurements



PAY-73: Measurement: Visible Broadband Intensity 0.174 AU to 0.25 AU

WISPR shall be capable of providing Full Frame Images of visible broadband intensity over solar orbital distances of 0.174 AU to 0.25 AU as follows:

-- capturing the radial scene from elongations of 14 degrees to 90 degrees from sun center;

-- capturing the transverse scene from 20 degrees (at 14 degrees elongation) to 44 degrees (at 90 degrees elongation);

-- with image spatial resolution across the FOV of ≤ 6.4 arcmin (for elongations 14 degrees to 33.5 degrees), ≤ 10.25 arcmin (for elongations 33.5 degrees to 53 degrees), ≤ 9.3 arcmin (for elongations 53 degrees to 78 degrees), and ≤ 14.2 arcmin (for elongations 78 degrees to 90 degrees);

-- with SNR for a binned pixel ≥ 10 (for elongations of 14 degrees to 20 degrees), ≥ 5 (for elongations of 20 degrees to 40 degrees), ≥ 3.33 (for elongations of 40 degrees to 53 degrees), and ≥ 5 (for elongations of 53 degrees to 90 degrees);

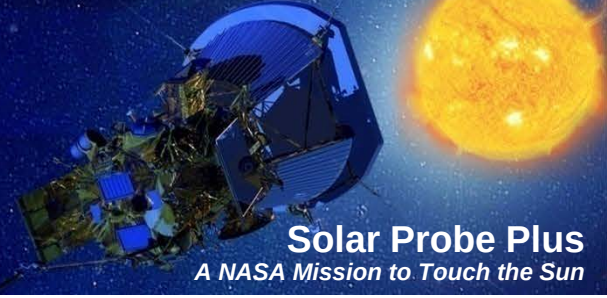
-- with nominal cadence of ≤ 24 min (for elongations 14 degrees to 26 degrees) and ≤ 45 min (for elongations 26 degrees to 90 degrees).

Description/Clarification

L2 Spatial resolution and photometric accuracy at the required spatial resolution and cadence are only required to be satisfied in the inner FOV of the image. L2 Cadence is an average cadence requirement over the orbit. The cadence requirement will be slower outside 0.174 AU across the entire FOV.

Rationale	**Requirement Allocation**
This requirement meets Level 2 Mission Science Requirements.	WISPR
Parent Traceability	**Functional Allocation**
MRD-95 : The Mission shall measure visible broadband intensity, as follows: -- Cadence: <= 16.5 min -- Field of view: >= 76 degrees radial x >= 20 degrees transverse at 14 degrees elongation to >= 44 degrees transverse at 90 degrees elongation -- Inner FOV boundary: <= 14 degrees -- Spatial Resolution: <= 6.4 arcmin -- Photometric sensitivity (SNR per pixel): >= 20.	

WISPR Measurements



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PAY-74: Measurement: Visible Broadband Inner Field of View Subframe

WISPR shall be capable of providing Inner Field of View (FOV) Subframe images over solar orbital distances of 0.046 AU to 0.07 AU as follows:

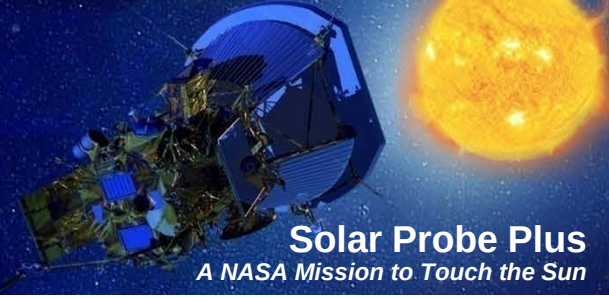
-- capturing the radial scene from elongations of 14 degrees to 20 degrees from sun center;
-- capturing the transverse scene over 12 degrees;
-- with image spatial resolution across the Inner FOV of ≤ 3.4 arcmin;
-- with SNR for a binned pixel ≥ 10;
-- with nominal cadence of ≤ 6 sec.

Description/Clarification

Inner FOV Subframe images do not drive the WISPR Instrument design, based on the fact that the photometric accuracy at higher cadence and smaller spatial resolution in the inner FOV where there is a high SNR is equivalent to the photometric accuracy for the low cadence and spatial resolution in PAY-70 above.

Rationale	**Requirement Allocation**
Wave Turbulance images at the inner FOV at a reduced photometric accuracy with higher spatial resolution and cadence directly address the SPP science questions, but was not included in the L2 science measurement requirements.	WISPR
Parent Traceability MRD-95 : The Mission shall measure visible broadband intensity, as follows: -- Cadence: <= 16.5 min -- Field of view: >= 76 degrees radial x >= 20 degrees transverse at 14 degrees elongation to >= 44 degrees transverse at 90 degrees elongation -- Inner FOV boundary: <= 14 degrees -- Spatial Resolution: <= 6.4 arcmin -- Photometric sensitivity (SNR per pixel): >= 20.	**Functional Allocation**

ISIS Measurements



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PAY-76: Measurement: Energetic Electrons Energy Range (EPI-Lo)

EPI-Lo shall be capable of measuring energetic electrons over solar orbital distances of 9.86 Rs to 0.25 AU with an energy range of ≤ 0.05 MeV to 0.5 MeV (TBR).

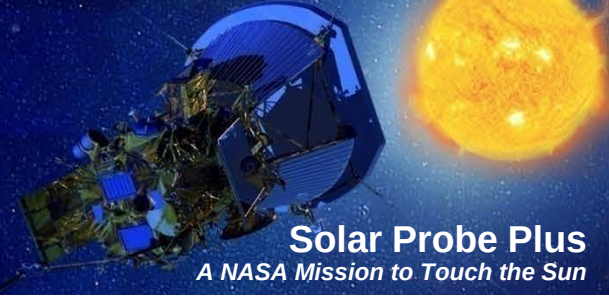
Description/Clarification

It is presently thought that there will be no gap between the EPI-Lo and EPI-Hi energy coverages for electrons, but a factor of 2 energy gap is allowed to take into account the possibility that the energy ranges actually achieved may differ slightly from those presently planned. If there were a gap it would be located near an energy of 0.5 MeV.

Rationale	**Requirement Allocation**
This requirement meets Level 2 Mission Science Requirements. The electron energy range should extend from the suprathermal tail of the solar wind up to highly relativistic energies to allow studies of electron acceleration, to trace connectivity of the magnetic field back to structures on the Sun, and to determine release times of energetic particles from the Sun.	ISIS
Parent Traceability	**Functional Allocation**
MRD-96 : The Mission shall measure energetic electrons, as follows: -- Energy range[1]: <= 0.05 to >= 3 MeV -- Highest cadence[2]: <=1s for selected rates -- Field of view[3]: >= π/2 sr in sunward and anti-sunward hemispheres -- Angular sectoring: <= 45 degree sectors -- Composition[4]: n/a Notes: [1] Combined energy range of all sensors; small gaps in energy coverage are acceptable [2] Additional rates at lower cadences, as appropriate, for expected statistics and bit rate allocation [3] Combined sky coverage of all sensors, some regions densely sampled rather than 100% covered [4] Measured species; not all measured under all conditions	

APL

ISIS Measurements



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PAY-200: Measurement: Energetic Electrons Energy Range (EPI-Hi)

EPI-Hi shall be capable of measuring energetic electrons over solar orbital distances of 9.86 Rs to 0.25 AU with an energy range of 0.5 MeV (TBR) to ≥ 3 MeV.

Description/Clarification

It is presently thought that there will be no gap between the EPI-Lo and EPI-Hi energy coverages for electrons, but a factor of 2 energy gap is allowed to take into account the possibility that the energy ranges actually achieved may differ slightly from those presently planned. If there were a gap it would be located near an energy of 0.5 MeV. The lower bound on the EPI-Hi energy range might be changed later to maybe as high as 1.0 MeV (?), but the intent is to be as close to 0.5 MeV as possible].

Rationale

This requirement meets Level 2 Mission Science Requirements. The electron energy range should extend from the suprathermal tail of the solar wind up to highly relativistic energies to allow studies of electron acceleration, to trace connectivity of the magnetic field back to structures on the Sun, and to determine release times of energetic particles from the Sun.

Requirement Allocation

ISIS

Parent Traceability

MRD-96 : The Mission shall measure energetic electrons, as follows:

-- Energy range[1]: <= 0.05 to >= 3 MeV
-- Highest cadence[2]: <=1s for selected rates
-- Field of view[3]: >= π/2 sr in sunward and anti-sunward hemispheres
-- Angular sectoring: <= 45 degree sectors
-- Composition[4]: n/a

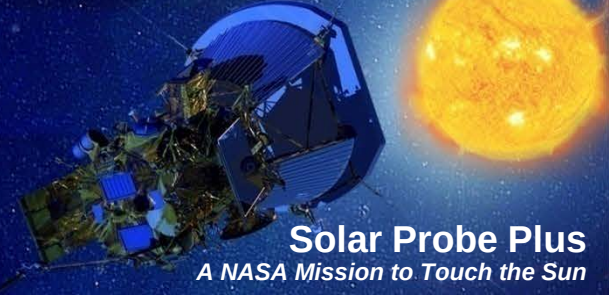
Notes:

[1] Combined energy range of all sensors; small gaps in energy coverage are acceptable
[2] Additional rates at lower cadences, as appropriate, for expected statistics and bit rate allocation
[3] Combined sky coverage of all sensors, some regions densely sampled rather than 100% covered
[4] Measured species; not all measured under all conditions

Functional Allocation

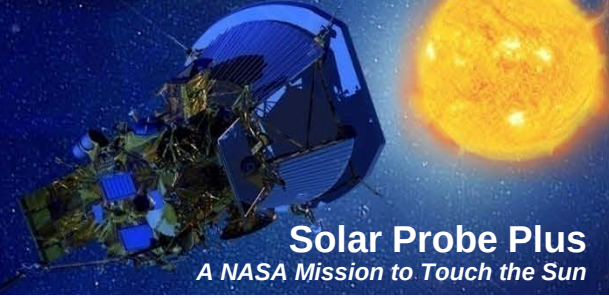
APL

ISIS Measurements



PAY-77: Measurement: Energetic Electrons Bins (EPI-Lo) EPI-Lo shall be capable of measuring electron intensities with at least 6 energy bins per decade.	
Rationale The energy binning should be fine enough to investigate spectral features (e.g., high-energy cutoffs) that occur over an energy width smaller than a decade.	**Requirement Allocation** ISIS
Parent Traceability MRD-96 : The Mission shall measure energetic electrons, as follows: -- Energy range[1]: <= 0.05 to >= 3 MeV -- Highest cadence[2]: <=1s for selected rates -- Field of view[3]: >= π/2 sr in sunward and anti-sunward hemispheres -- Angular sectoring: <= 45 degree sectors -- Composition[4]: n/a Notes: [1] Combined energy range of all sensors; small gaps in energy coverage are acceptable [2] Additional rates at lower cadences, as appropriate, for expected statistics and bit rate allocation [3] Combined sky coverage of all sensors, some regions densely sampled rather than 100% covered [4] Measured species; not all measured under all conditions	**Functional Allocation**

ISIS Measurements



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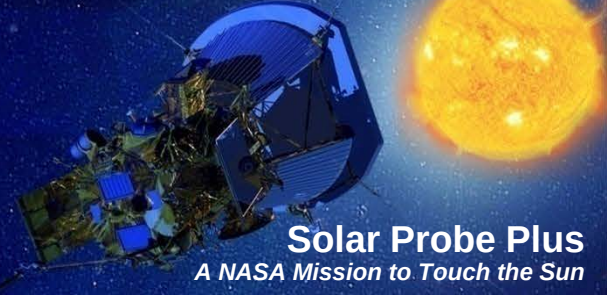
PAY-201: Measurement: Energetic Electrons Bins (EPI-Hi)	
EPI-Hi shall be capable of measuring electron intensities with at least 6 energy bins per decade.	
Rationale The energy binning should be fine enough to investigate spectral features (e.g., high-energy cutoffs) that occur over an energy width smaller than a decade.	**Requirement Allocation** ISIS
Parent Traceability MRD-96 : The Mission shall measure energetic electrons, as follows: -- Energy range[1]: <= 0.05 to >= 3 MeV -- Highest cadence[2]: <=1s for selected rates -- Field of view[3]: >= π/2 sr in sunward and anti-sunward hemispheres -- Angular sectoring: <= 45 degree sectors -- Composition[4]: n/a Notes: [1] Combined energy range of all sensors; small gaps in energy coverage are acceptable [2] Additional rates at lower cadences, as appropriate, for expected statistics and bit rate allocation [3] Combined sky coverage of all sensors, some regions densely sampled rather than 100% covered [4] Measured species; not all measured under all conditions	**Functional Allocation**

APL

ISIS Measurements



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PAY-78: Measurement: Energetic Electrons Cadence (EPI-Lo)

EPI-Lo shall be capable of measuring electron count rate in at least one energy range over solar orbital distances of 9.86 Rs to 0.25 AU below 0.5 MeV (TBR) with a time resolution of 1 s or faster.

Description/Clarification

Electrons from a broad range of energies and incidence angles can be combined in order to increase statistical accuracy. Additional electron rates, subdivided according to energy and incidence angle, will be measurable at various time cadences, ≤ 1 s to ≥ 1 hr, as appropriate to expected counting statistics.

Rationale

This requirement meets Level 2 Mission Science Requirements. Electron rates at high cadence are needed to look for fast time structure in the energetic particle intensities as might be caused, for example, by rapid changes in the magnetic field direction. Electron rates with good statistical accuracy at slower cadences but higher energy and angular resolution are needed to measure energy spectra, to use velocity dispersion for timing studies, and to investigate the time evolution of energetic electron flows over the course of an event.

Requirement Allocation

ISIS

Parent Traceability

MRD-96 : The Mission shall measure energetic electrons, as follows:

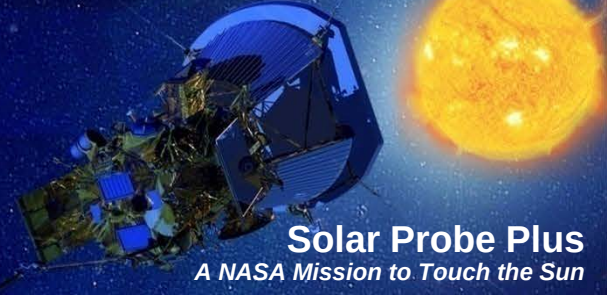
-- Energy range[1]: <= 0.05 to >= 3 MeV
-- Highest cadence[2]: <=1s for selected rates
-- Field of view[3]: >= π/2 sr in sunward and anti-sunward hemispheres
-- Angular sectoring: <= 45 degree sectors
-- Composition[4]: n/a

Notes:

[1] Combined energy range of all sensors; small gaps in energy coverage are acceptable
[2] Additional rates at lower cadences, as appropriate, for expected statistics and bit rate allocation
[3] Combined sky coverage of all sensors, some regions densely sampled rather than 100% covered
[4] Measured species; not all measured under all conditions

Functional Allocation

ISIS Measurements



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PAY-202: Measurement: Energetic Electrons Cadence (EPI-Hi)

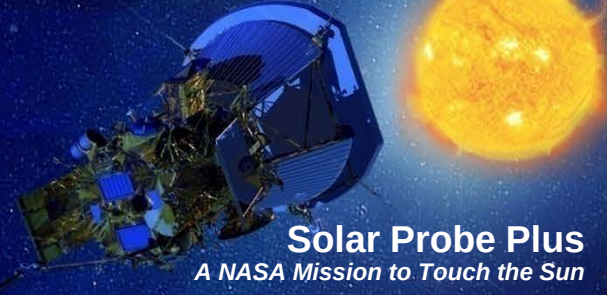
EPI-Hi shall be capable of measuring electron count rate in at least one energy range over solar orbital distances of 9.86 Rs to 0.25 AU above 0.5 MeV (TBR) with a time resolution of 1 s or faster.

Description/Clarification

Electrons from a broad range of energies and incidence angles can be combined in order to increase statistical accuracy. Additional electron rates, subdivided according to energy and incidence angle, will be measurable at various time cadences, ≤ 1 s to ≥ 1 hr, as appropriate to expected counting statistics.

Rationale	**Requirement Allocation**
This requirement meets Level 2 Mission Science Requirements. Electron rates at high cadence are needed to look for fast time structure in the energetic particle intensities as might be caused, for example, by rapid changes in the magnetic field direction. Electron rates with good statistical accuracy at slower cadences but higher energy and angular resolution are needed to measure energy spectra, to use velocity dispersion for timing studies, and to investigate the time evolution of energetic electron flows over the course of an event.	ISIS
Parent Traceability MRD-96 : The Mission shall measure energetic electrons, as follows: -- Energy range[1]: <= 0.05 to >= 3 MeV -- Highest cadence[2]: <=1s for selected rates -- Field of view[3]: >= π/2 sr in sunward and anti-sunward hemispheres -- Angular sectoring: <= 45 degree sectors -- Composition[4]: n/a Notes: [1] Combined energy range of all sensors; small gaps in energy coverage are acceptable [2] Additional rates at lower cadences, as appropriate, for expected statistics and bit rate allocation [3] Combined sky coverage of all sensors, some regions densely sampled rather than 100% covered [4] Measured species; not all measured under all conditions	**Functional Allocation**

ISIS Measurements



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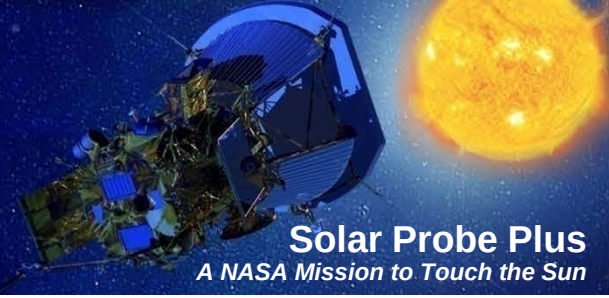
PAY-79: Measurement: Energetic Electrons Angular Sectoring (EPI-Lo)

EPI-Lo shall be capable of measuring energetic electron angular distributions over solar orbital distances of 9.86 Rs to 0.25 AU using sectors of width ≤ 45°.

Rationale	**Requirement Allocation**
This requirement meets Level 2 Mission Science Requirements. Sectoring of electron intensity measurements is required for deriving pitch angle distributions (in conjunction with measurements of the magnetic field direction), for observing the time evolution of these distributions, and for estimating the fractions of the distributions that are unmeasured due to field of view limitations.	ISIS
Parent Traceability	**Functional Allocation**
MRD-96 : The Mission shall measure energetic electrons, as follows: -- Energy range[1]: <= 0.05 to >= 3 MeV -- Highest cadence[2]: <=1s for selected rates -- Field of view[3]: >= π/2 sr in sunward and anti-sunward hemispheres -- Angular sectoring: <= 45 degree sectors -- Composition[4]: n/a Notes: [1] Combined energy range of all sensors; small gaps in energy coverage are acceptable [2] Additional rates at lower cadences, as appropriate, for expected statistics and bit rate allocation [3] Combined sky coverage of all sensors, some regions densely sampled rather than 100% covered [4] Measured species; not all measured under all conditions	

ISIS Measurements



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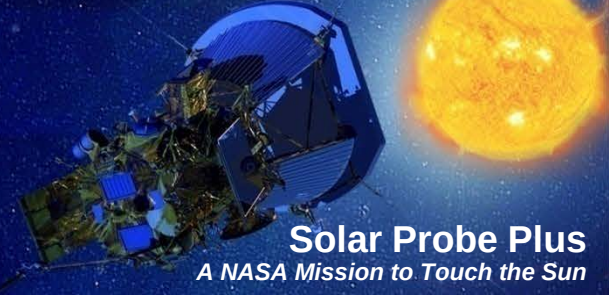
PAY-266: Measurement: Energetic Electrons Angular Sectoring (EPI-Hi)

EPI-Hi shall be capable of measuring energetic electron angular distributions over solar orbital distances of 9.86 Rs to 0.25 AU using sectors of width ≤ 45° over at least 1 steradian in both the sunward and anti-sunward hemisphere.

Rationale	**Requirement Allocation**
This requirement meets Level 2 Mission Science Requirements. Sectoring of electron intensity measurements is required for deriving pitch angle distributions (in conjunction with measurements of the magnetic field direction), for observing the time evolution of these distributions, and for estimating the fractions of the distributions that are unmeasured due to field of view limitations.	ISIS
Parent Traceability	**Functional Allocation**
MRD-96 : The Mission shall measure energetic electrons, as follows: -- Energy range[1]: <= 0.05 to >= 3 MeV -- Highest cadence[2]: <=1s for selected rates -- Field of view[3]: >= π/2 sr in sunward and anti-sunward hemispheres -- Angular sectoring: <= 45 degree sectors -- Composition[4]: n/a Notes: [1] Combined energy range of all sensors; small gaps in energy coverage are acceptable [2] Additional rates at lower cadences, as appropriate, for expected statistics and bit rate allocation [3] Combined sky coverage of all sensors, some regions densely sampled rather than 100% covered [4] Measured species; not all measured under all conditions	

ISIS Measurements



PAY-80: Measurement: Protons/Heavy Ions Energy Range (EPI-Lo)

EPI-Lo shall be capable of measuring protons and heavy ions (Z ≥ 2) over solar orbital distances of 9.86 Rs to 0.25 AU with an energy range of ≤ 0.05 MeV/nuc to 1 MeV/nuc (TBR).

Description/Clarification

Minimizing the gap in energy coverage between EPI-Lo and EPI-Hi is important for a good intercalibration of the two instruments and for investigating spectral features (e.g., high energy spectral cutoffs) when they occur near the boundary between the energy coverage of the two instruments. Because of the different techniques used for species identification (ToF vs E for EPI-Lo, dE/dx vs E for EPI-Hi), the size of the gap increases with increasing atomic number. A gap may exist near 1 MeV/nuc where the EPI-Lo and EPI-Hi energy ranges do not converge. This gap will not exceed a factor of 10 (TBR) in energy per nucleon for any given element between H and Si. For Fe the gap may be up to a factor of 20.

Rationale

This requirement meets Level 2 Mission Science Requirements. The energy range needs to go from the suprathermal tail of the solar wind at low energies up to the high energies of importance for space weather studies.

Requirement Allocation

ISIS

Parent Traceability

MRD-97 : The Mission shall measure energetic protons and heavy ions, as follows:

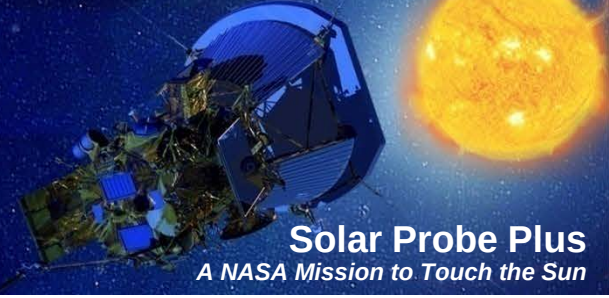
-- Energy range[1]: <= 0.05 to >= 50 MeV/nucleon
-- Highest cadence[2]: <= 5s for selected rates
-- Field of view[3]: >= π/2 sr in sunward and anti-sunward hemispheres
-- Angular sectoring: <= 30 degree sectors
-- Composition[4]: at least H, He, 3He, C, O, Ne, Mg, Si, Fe

Notes:

[1] Combined energy range of all sensors; small gaps in energy coverage are acceptable
[2] Additional rates at lower cadences, as appropriate, for expected statistics and bit rate allocation
[3] Combined sky coverage of all sensors, some regions densely sampled rather than 100% covered
[4] Measured species; not all measured under all conditions

Functional Allocation

ISIS Measurements



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PAY-203: Measurement: Protons/Heavy Ions Energy Range (EPI-Hi)

EPI-Hi shall be capable of measuring protons and heavy ions (Z ≥ 2) over solar orbital distances of 9.86 Rs to 0.25 AU with an energy range of 1 MeV/nuc (TBR) to ≥ 50 MeV/nuc.

Description/Clarification

Minimizing the gap in energy coverage between EPI-Lo and EPI-Hi is important for a good intercalibration of the two instruments and for investigating spectral features (e.g., high energy spectral cutoffs) when they occur near the boundary between the energy coverage of the two instruments. Because of the different techniques used for species identification (ToF vs E for EPI-Lo, dE/dx vs E for EPI-Hi), the size of the gap increases with increasing atomic number. A gap may exist near 1 MeV/nuc where the EPI-Lo and EPI-Hi energy ranges do not converge. This gap will not exceed a factor of 10 (TBR) in energy per nucleon for any given element between H and Si. For Fe the gap may be up to a factor of 20.

Rationale

This requirement meets Level 2 Mission Science Requirements. The energy range needs to go from the suprathermal tail of the solar wind at low energies up to the high energies of importance for space weather studies.

Requirement Allocation

ISIS

Parent Traceability

MRD-97 : The Mission shall measure energetic protons and heavy ions, as follows:

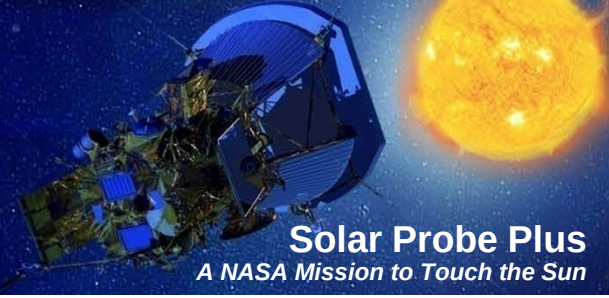
-- Energy range[1]: <= 0.05 to >= 50 MeV/nucleon
-- Highest cadence[2]: <= 5s for selected rates
-- Field of view[3]: >= π/2 sr in sunward and anti-sunward hemispheres
-- Angular sectoring: <= 30 degree sectors
-- Composition[4]: at least H, He, 3He, C, O, Ne, Mg, Si, Fe

Notes:

[1] Combined energy range of all sensors; small gaps in energy coverage are acceptable
[2] Additional rates at lower cadences, as appropriate, for expected statistics and bit rate allocation
[3] Combined sky coverage of all sensors, some regions densely sampled rather than 100% covered
[4] Measured species; not all measured under all conditions

Functional Allocation

ISIS Measurements



Solar Probe Plus
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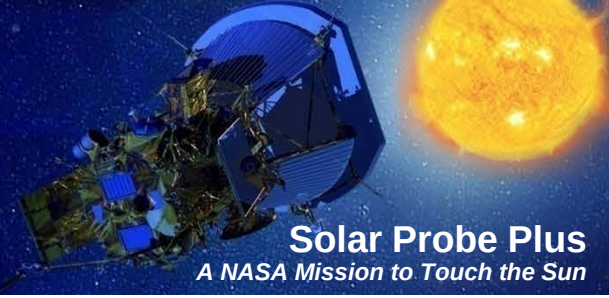
PAY-81: Measurement: Protons/Heavy Ions Bins (EPI-Lo)	
EPI-Lo shall be capable of measuring proton and heavy ion intensities with at least 6 energy bins per decade.	
Rationale The energy binning should be fine enough to investigate spectral features (e.g., high-energy cutoffs) that occur over an energy width smaller than a decade.	**Requirement Allocation** ISIS
Parent Traceability MRD-97 : The Mission shall measure energetic protons and heavy ions, as follows: -- Energy range[1]: <= 0.05 to >= 50 MeV/nucleon -- Highest cadence[2]: <= 5s for selected rates -- Field of view[3]: >= π/2 sr in sunward and anti-sunward hemispheres -- Angular sectoring: <= 30 degree sectors -- Composition[4]: at least H, He, 3He, C, O, Ne, Mg, Si, Fe Notes: [1] Combined energy range of all sensors; small gaps in energy coverage are acceptable [2] Additional rates at lower cadences, as appropriate, for expected statistics and bit rate allocation [3] Combined sky coverage of all sensors, some regions densely sampled rather than 100% covered [4] Measured species; not all measured under all conditions	**Functional Allocation**

ISIS Measurements



Solar Probe Plus
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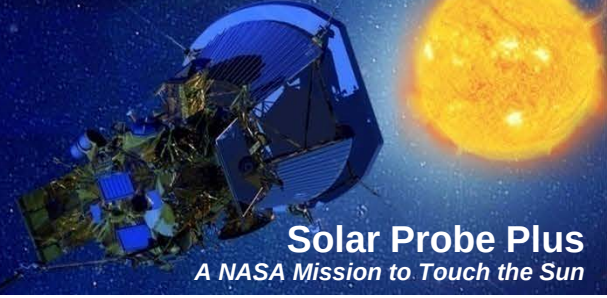
PAY-205: Measurement: Protons/Heavy Ions Bins (EPI-Hi)	
EPI-Hi shall be capable of measuring proton and heavy ion intensities with at least 6 energy bins per decade.	
Rationale The energy binning should be fine enough to investigate spectral features (e.g., high-energy cutoffs) that occur over an energy width smaller than a decade.	**Requirement Allocation** ISIS
Parent Traceability MRD-97 : The Mission shall measure energetic protons and heavy ions, as follows: -- Energy range[1]: <= 0.05 to >= 50 MeV/nucleon -- Highest cadence[2]: <= 5s for selected rates -- Field of view[3]: >= π/2 sr in sunward and anti-sunward hemispheres -- Angular sectoring: <= 30 degree sectors -- Composition[4]: at least H, He, 3He, C, O, Ne, Mg, Si, Fe Notes: [1] Combined energy range of all sensors; small gaps in energy coverage are acceptable [2] Additional rates at lower cadences, as appropriate, for expected statistics and bit rate allocation [3] Combined sky coverage of all sensors, some regions densely sampled rather than 100% covered [4] Measured species; not all measured under all conditions	**Functional Allocation**

ISIS Measurements



Solar Probe Plus
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PAY-82: Measurement: Protons/Heavy Ions Cadence (EPI-Lo)

EPI-Lo shall be capable of measuring proton count rate in at least one energy range over solar orbital distances of 9.86 Rs to 0.25 AU below 1 MeV with a time resolution of 5 s or faster.

Description/Clarification

Electrons from a broad range of energies and incidence angles can be combined in order to increase statistical accuracy. Additional proton and heavy-ion rates, subdivided according to species, energy, and incidence angle, will be measurable at various time cadences, ≤ 5 s to ≥ 1 hr, as appropriate to expected counting statistics.

Rationale

This requirement meets Level 2 Mission Science Requirements. Proton rates at high cadence are needed to look for fast time structure in the energetic particle intensities as might be caused, for example, by a rapid changes in the magnetic field direction or by the passage of a shock. Proton and heavy-ion rates with good statistical accuracy at slower cadences but higher energy and angular resolution are needed to measure energy spectra and angular distributions and to trace their evolution over the course of an event.

Requirement Allocation

ISIS

Parent Traceability

MRD-97 : The Mission shall measure energetic protons and heavy ions, as follows:

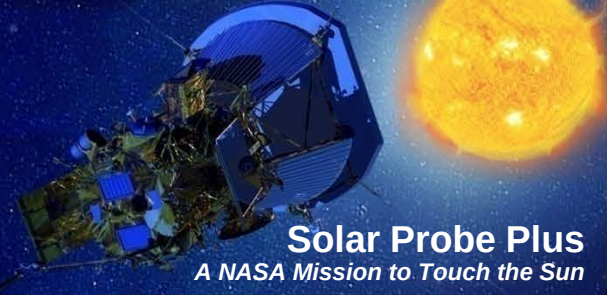
-- Energy range[1]: <= 0.05 to >= 50 MeV/nucleon
-- Highest cadence[2]: <= 5s for selected rates
-- Field of view[3]: >= π/2 sr in sunward and anti-sunward hemispheres
-- Angular sectoring: <= 30 degree sectors
-- Composition[4]: at least H, He, 3He, C, O, Ne, Mg, Si, Fe

Notes:

[1] Combined energy range of all sensors; small gaps in energy coverage are acceptable
[2] Additional rates at lower cadences, as appropriate, for expected statistics and bit rate allocation
[3] Combined sky coverage of all sensors, some regions densely sampled rather than 100% covered
[4] Measured species; not all measured under all conditions

Functional Allocation

ISIS Measurements



Solar Probe Plus
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PAY-267: Measurement: Protons/Heavy Ions Cadence (EPI-Hi)

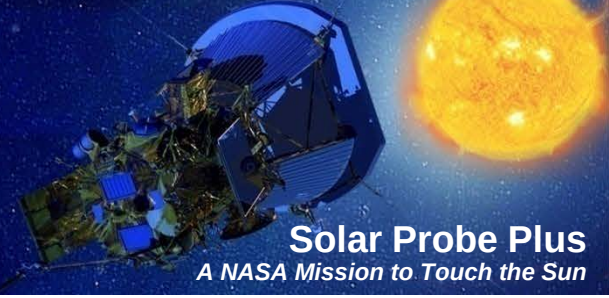
EPI-Hi shall be capable of measuring proton count rate in at least one energy range over solar orbital distances of 9.86 Rs to 0.25 AU above 1 MeV with a time resolution of 5 s or faster.

Description/Clarification

Electrons from a broad range of energies and incidence angles can be combined in order to increase statistical accuracy. Additional proton and heavy-ion rates, subdivided according to species, energy, and incidence angle, will be measurable at various time cadences, ≤ 5 s to ≥ 1 hr, as appropriate to expected counting statistics.

Rationale	**Requirement Allocation**
This requirement meets Level 2 Mission Science Requirements. Proton rates at high cadence are needed to look for fast time structure in the energetic particle intensities as might be caused, for example, by a rapid changes in the magnetic field direction or by the passage of a shock. Proton and heavy-ion rates with good statistical accuracy at slower cadences but higher energy and angular resolution are needed to measure energy spectra and angular distributions and to trace their evolution over the course of an event.	ISIS
Parent Traceability	**Functional Allocation**
MRD-97 : The Mission shall measure energetic protons and heavy ions, as follows: -- Energy range[1]: <= 0.05 to >= 50 MeV/nucleon -- Highest cadence[2]: <= 5s for selected rates -- Field of view[3]: >= π/2 sr in sunward and anti-sunward hemispheres -- Angular sectoring: <= 30 degree sectors -- Composition[4]: at least H, He, 3He, C, O, Ne, Mg, Si, Fe Notes: [1] Combined energy range of all sensors; small gaps in energy coverage are acceptable [2] Additional rates at lower cadences, as appropriate, for expected statistics and bit rate allocation [3] Combined sky coverage of all sensors, some regions densely sampled rather than 100% covered [4] Measured species; not all measured under all conditions	

ISIS Measurements



Solar Probe Plus
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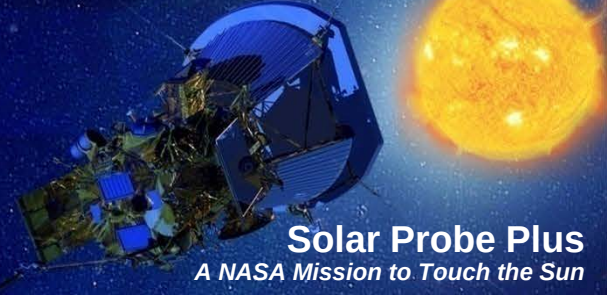
PAY-83: Measurement: Protons/Heavy Ions Angular Sectoring (EPI-Lo)

EPI-Lo shall be capable of measuring proton and heavy ion angular distributions over solar orbital distances of 9.86 Rs to 0.25 AU using sectors of width ≤ 30° (TBR).

Rationale	**Requirement Allocation**
This requirement meets Level 2 Mission Science Requirements. Sectoring of proton and heavy-ion intensity measurements is required for deriving pitch angle distributions (in conjunction with measurements of the magnetic field direction), for observing the time evolution of these distributions, and for estimating the fractions of the distributions that are unmeasured due to field-of-view limitations.	ISIS
Parent Traceability	**Functional Allocation**
MRD-97 : The Mission shall measure energetic protons and heavy ions, as follows: -- Energy range[1]: <= 0.05 to >= 50 MeV/nucleon -- Highest cadence[2]: <= 5s for selected rates -- Field of view[3]: >= π/2 sr in sunward and anti-sunward hemispheres -- Angular sectoring: <= 30 degree sectors -- Composition[4]: at least H, He, 3He, C, O, Ne, Mg, Si, Fe Notes: [1] Combined energy range of all sensors; small gaps in energy coverage are acceptable [2] Additional rates at lower cadences, as appropriate, for expected statistics and bit rate allocation [3] Combined sky coverage of all sensors, some regions densely sampled rather than 100% covered [4] Measured species; not all measured under all conditions	

ISIS Measurements



PAY-206: Measurement: Protons/Heavy Ions Angular Sectoring (EPI-Hi)

EPI-Hi shall be capable of measuring proton and heavy ion angular distributions over solar orbital distances of 9.86 Rs to 0.25 AU using sectors of width ≤ 30° (TBR).

Rationale

This requirement meets Level 2 Mission Science Requirements. Sectoring of proton and heavy-ion intensity measurements is required for deriving pitch angle distributions (in conjunction with measurements of the magnetic field direction), for observing the time evolution of these distributions, and for estimating the fractions of the distributions that are unmeasured due to field-of-view limitations.

Requirement Allocation

ISIS

Parent Traceability

MRD-97 : The Mission shall measure energetic protons and heavy ions, as follows:

-- Energy range[1]: <= 0.05 to >= 50 MeV/nucleon
-- Highest cadence[2]: <= 5s for selected rates
-- Field of view[3]: >= π/2 sr in sunward and anti-sunward hemispheres
-- Angular sectoring: <= 30 degree sectors
-- Composition[4]: at least H, He, 3He, C, O, Ne, Mg, Si, Fe

Notes:

[1] Combined energy range of all sensors; small gaps in energy coverage are acceptable

[2] Additional rates at lower cadences, as appropriate, for expected statistics and bit rate allocation

[3] Combined sky coverage of all sensors, some regions densely sampled rather than 100% covered

[4] Measured species; not all measured under all conditions

Functional Allocation

ISIS Measurements

PAY-84: Measurement: Protons/Heavy Ions Composition (EPI-Lo)

EPI-Lo shall be capable of resolving at least the elements H, He, C, O, Ne, Mg, Si, and Fe, each with a FWHM charge (Z) resolution ≤ 0.5 times the charge separation from the nearest neighbor element in the list.

Rationale

This requirement meets Level 2 Mission Science Requirements. These elements, which are the most abundant in solar energetic particle events, can sample a wide range in the ratio M/Q (mass to ionic charge) and provide important diagnostics of the acceleration mechanism. A FWHM resolution of half the spacing to the nearest adjacent major element (or isotope in the case of He isotope studies) will allow measurements of abundances ratios up to at least as great as 10:1.

Requirement Allocation

ISIS

Parent Traceability

MRD-97 : The Mission shall measure energetic protons and heavy ions, as follows:

-- Energy range[1]: <= 0.05 to >= 50 MeV/nucleon
-- Highest cadence[2]: <= 5s for selected rates
-- Field of view[3]: >= π/2 sr in sunward and anti-sunward hemispheres
-- Angular sectoring: <= 30 degree sectors
-- Composition[4]: at least H, He, 3He, C, O, Ne, Mg, Si, Fe

Notes:

[1] Combined energy range of all sensors; small gaps in energy coverage are acceptable

[2] Additional rates at lower cadences, as appropriate, for expected statistics and bit rate allocation

[3] Combined sky coverage of all sensors, some regions densely sampled rather than 100% covered

[4] Measured species; not all measured under all conditions

Functional Allocation

ISIS Measurements

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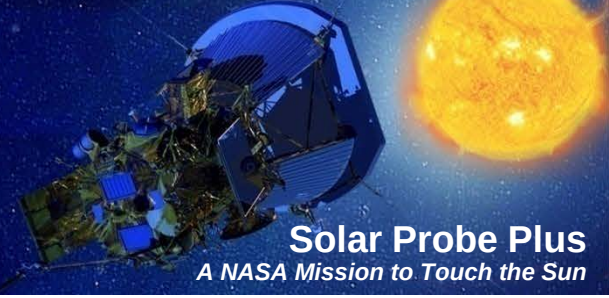
PAY-268: Measurement: Protons/Heavy Ions Composition (EPI-Hi)

EPI-Hi shall be capable of resolving at least the elements H, He, C, O, Ne, Mg, Si, and Fe, each with a FWHM charge (Z) resolution ≤ 0.5 times the charge separation from the nearest neighbor element in the list.

Rationale	**Requirement Allocation**
This requirement meets Level 2 Mission Science Requirements. These elements, which are the most abundant in solar energetic particle events, can sample a wide range in the ratio M/Q (mass to ionic charge) and provide important diagnostics of the acceleration mechanism. A FWHM resolution of half the spacing to the nearest adjacent major element (or isotope in the case of He isotope studies) will allow measurements of abundances ratios up to at least as great as 10:1.	ISIS
Parent Traceability	**Functional Allocation**
MRD-97 : The Mission shall measure energetic protons and heavy ions, as follows: -- Energy range[1]: <= 0.05 to >= 50 MeV/nucleon -- Highest cadence[2]: <= 5s for selected rates -- Field of view[3]: >= π/2 sr in sunward and anti-sunward hemispheres -- Angular sectoring: <= 30 degree sectors -- Composition[4]: at least H, He, 3He, C, O, Ne, Mg, Si, Fe Notes: [1] Combined energy range of all sensors; small gaps in energy coverage are acceptable [2] Additional rates at lower cadences, as appropriate, for expected statistics and bit rate allocation [3] Combined sky coverage of all sensors, some regions densely sampled rather than 100% covered [4] Measured species; not all measured under all conditions	

ISIS Measurements



Solar Probe Plus
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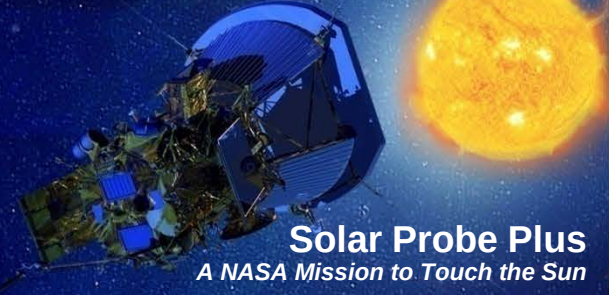
PAY-223: Measurement: Protons/Heavy Ions Element Ratio & mass resolution (EPI-Lo)	
EPI-Lo shall be capable of measuring the 3He/4He ratio over at least TBD decades in energy below 1 MeV/nuc and resolving 4He with a FWHM mass resolution ≤ 0.5 AMU (TBR).	
Rationale This requirement supports Level 2 Mission Science Requirements.	**Requirement Allocation** ISIS
Parent Traceability MRD-97 : The Mission shall measure energetic protons and heavy ions, as follows: -- Energy range[1]: <= 0.05 to >= 50 MeV/nucleon -- Highest cadence[2]: <= 5s for selected rates -- Field of view[3]: >= π/2 sr in sunward and anti-sunward hemispheres -- Angular sectoring: <= 30 degree sectors -- Composition[4]: at least H, He, 3He, C, O, Ne, Mg, Si, Fe Notes: [1] Combined energy range of all sensors; small gaps in energy coverage are acceptable [2] Additional rates at lower cadences, as appropriate, for expected statistics and bit rate allocation [3] Combined sky coverage of all sensors, some regions densely sampled rather than 100% covered [4] Measured species; not all measured under all conditions	**Functional Allocation**

APL

ISIS Measurements



Solar Probe Plus
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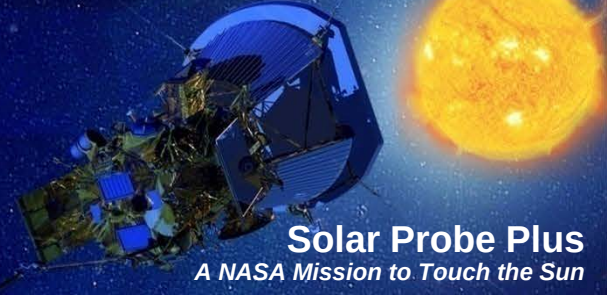
PAY-224: Measurement: Protons/Heavy Ions Element Ratio & mass resolution (EPI-Hi)	
EPI-Hi shall be capable of measuring the 3He/4He ratio over at least one decade in energy above 1 MeV/nuc (TBR) and resolving 4He with a FWHM mass resolution ≤ 0.5 AMU (TBR).	
Rationale This requirement supports Level 2 Mission Science Requirements.	**Requirement Allocation** ISIS
Parent Traceability MRD-97 : The Mission shall measure energetic protons and heavy ions, as follows: -- Energy range[1]: <= 0.05 to >= 50 MeV/nucleon -- Highest cadence[2]: <= 5s for selected rates -- Field of view[3]: >= π/2 sr in sunward and anti-sunward hemispheres -- Angular sectoring: <= 30 degree sectors -- Composition[4]: at least H, He, 3He, C, O, Ne, Mg, Si, Fe Notes: [1] Combined energy range of all sensors; small gaps in energy coverage are acceptable [2] Additional rates at lower cadences, as appropriate, for expected statistics and bit rate allocation [3] Combined sky coverage of all sensors, some regions densely sampled rather than 100% covered [4] Measured species; not all measured under all conditions	**Functional Allocation**

APL

ISIS Measurements



Solar Probe Plus
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PAY-85: Measurement: SEP Event Energetic Electrons (EPI-Lo)	
EPI-Lo shall be capable of measuring energy spectra and angular distributions for energetic electrons from 0.05 MeV to 0.5 MeV (TBR) for solar energetic particle event intensities up to at least 10^6 particles/cm2-sr-s (TBR).	
Rationale Capability for making good measurements, without excessive saturation or background, during times of high particle intensity is important for assuring that high quality data can be obtained even in solar energetic particle events that occur when the spacecraft is close to the Sun. Intensities are expected to increase at least as fast as 1/r2 going in toward the Sun.	**Requirement Allocation** ISIS
Parent Traceability MRD-96 : The Mission shall measure energetic electrons, as follows: -- Energy range[1]: <= 0.05 to >= 3 MeV -- Highest cadence[2]: <=1s for selected rates -- Field of view[3]: >= π/2 sr in sunward and anti-sunward hemispheres -- Angular sectoring: <= 45 degree sectors -- Composition[4]: n/a Notes: [1] Combined energy range of all sensors; small gaps in energy coverage are acceptable [2] Additional rates at lower cadences, as appropriate, for expected statistics and bit rate allocation [3] Combined sky coverage of all sensors, some regions densely sampled rather than 100% covered [4] Measured species; not all measured under all conditions	**Functional Allocation**

ISIS Measurements

Solar Probe Plus
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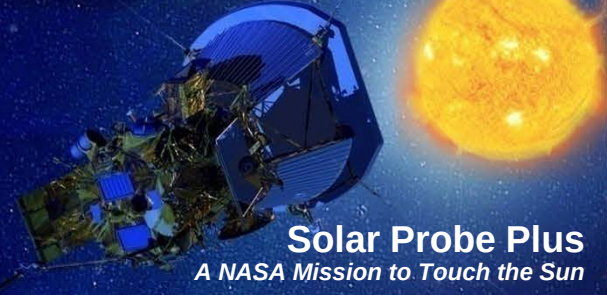
PAY-226: Measurement: SEP Event Ions (EPI-Lo)

EPI-Lo shall be capable of measuring energy spectra, composition, and angular distributions for ions from ≤ 0.05 MeV/nuc to ≥ 5 MeV/nuc to a maximum energy of 15 MeV for solar energetic particle event intensities up to at least 10^6 particles/cm2-sr-s.

Rationale	**Requirement Allocation**
Capability for making good measurements, without excessive saturation or background, during times of high particle intensity is important for assuring that high quality data can be obtained even in solar energetic particle events that occur when the spacecraft is close to the Sun. Intensities are expected to increase at least as fast as 1/r2 going in toward the Sun.	ISIS
Parent Traceability	**Functional Allocation**
MRD-97 : The Mission shall measure energetic protons and heavy ions, as follows: -- Energy range[1]: <= 0.05 to >= 50 MeV/nucleon -- Highest cadence[2]: <= 5s for selected rates -- Field of view[3]: >= π/2 sr in sunward and anti-sunward hemispheres -- Angular sectoring: <= 30 degree sectors -- Composition[4]: at least H, He, 3He, C, O, Ne, Mg, Si, Fe Notes: [1] Combined energy range of all sensors; small gaps in energy coverage are acceptable [2] Additional rates at lower cadences, as appropriate, for expected statistics and bit rate allocation [3] Combined sky coverage of all sensors, some regions densely sampled rather than 100% covered [4] Measured species; not all measured under all conditions	

ISIS Measurements



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PAY-228: Measurement: SEP Event Energetic Electrons (EPI-Hi)

EPI-Hi shall be capable of measuring energy spectra and angular distributions for energetic electrons from 0.5 MeV (TBR) to ≥3 MeV up to 10% (TBR) of an upper-limit spectrum of electron intensities specified in the SPP Environmental Design and Test Requirements Document, 7434-9039.

Rationale	**Requirement Allocation**
n the case of the rare occurrence of an extreme solar energetic particle event close to perihelion, some saturation of the instrument is likely to occur when operated in its normal mode. The instrument will be designed to allow a graceful degradation of performance as intensities increase above the specified levels and maximize the achievable scientific return up to the full level given by the upper-limit spectrum.	ISIS
Parent Traceability	**Functional Allocation**
MRD-96 : The Mission shall measure energetic electrons, as follows: -- Energy range[1]: <= 0.05 to >= 3 MeV -- Highest cadence[2]: <=1s for selected rates -- Field of view[3]: >= π/2 sr in sunward and anti-sunward hemispheres -- Angular sectoring: <= 45 degree sectors -- Composition[4]: n/a Notes: [1] Combined energy range of all sensors; small gaps in energy coverage are acceptable [2] Additional rates at lower cadences, as appropriate, for expected statistics and bit rate allocation [3] Combined sky coverage of all sensors, some regions densely sampled rather than 100% covered [4] Measured species; not all measured under all conditions	

ISIS Measurements

Solar Probe Plus
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PAY-230: Measurement: SEP Event Ions (EPI-Hi)

EPI-Hi shall be capable of measuring energy spectra, composition, and angular distributions for energetic ions from 1 MeV/nuc (TBR) to ≥ 50 MeV/nuc up to 10% (TBR) of an upper-limit spectrum of proton intensities specified in the SPP Environmental Design and Test Requirements Document, 7434-9039.

Rationale

In the case of the rare occurrence of an extreme solar energetic particle event close to perihelion, some saturation of the instrument is likely to occur when operated in its normal mode. The instrument will be designed to allow a graceful degradation of performance as intensities increase above the specified levels and maximize the achievable scientific return up to the full level given by the upper-limit spectrum.

Requirement Allocation

ISIS

Parent Traceability

MRD-97 : The Mission shall measure energetic protons and heavy ions, as follows:

-- Energy range[1]: <= 0.05 to >= 50 MeV/nucleon
-- Highest cadence[2]: <= 5s for selected rates
-- Field of view[3]: >= π/2 sr in sunward and anti-sunward hemispheres
-- Angular sectoring: <= 30 degree sectors
-- Composition[4]: at least H, He, 3He, C, O, Ne, Mg, Si, Fe

Notes:

[1] Combined energy range of all sensors; small gaps in energy coverage are acceptable

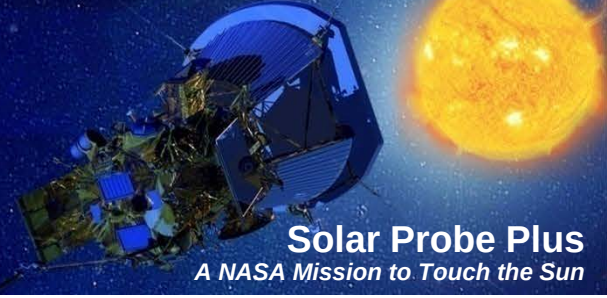
[2] Additional rates at lower cadences, as appropriate, for expected statistics and bit rate allocation

[3] Combined sky coverage of all sensors, some regions densely sampled rather than 100% covered

[4] Measured species; not all measured under all conditions

Functional Allocation

ISIS Measurements



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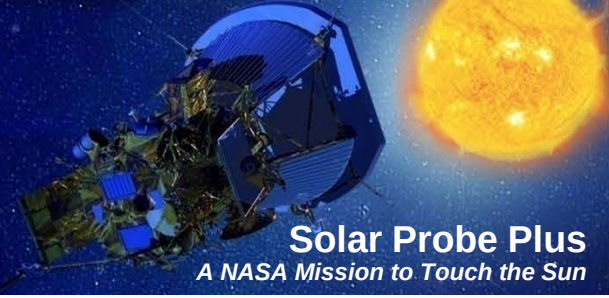
PAY-87: Measurement: Energetic Electrons Field-of-View (EPI-Lo)

EPI-Lo shall be capable of measuring energetic electrons over solar orbital distances of 9.86 Rs to 0.25 AU with a ≥ π/2 steradians FOV in the sunward hemisphere and a ≥ π/2 steradians FOV in the anti-sunward hemisphere including coverage within 10° of the Spacecraft-Sun line, subject to the constraints and FOV obstructions defined in the ISIS-to-Spacecraft ICD (7434-9058).

Rationale	**Requirement Allocation**
This requirement meets Level 2 Mission Science Requirements. The FOV should cover as much as the sky as possible in order to allow accurate particle intensity measurements even when the angular distribution is highly anisotropic or the magnetic field deviates strongly from the nominal Parker spiral. The minimum FOV requirement allows measurement of particles with pitch angles out to ~40° from the nominal field direction in both the forward and backward directions and enables good determinations of first order anisotropies. Additional measurements closer to 90° pitch angle are important for investigating the time evolution of particle pitch angle distributions and for measuring higher order anisotropies.	ISIS
Parent Traceability	**Functional Allocation**
MRD-96 : The Mission shall measure energetic electrons, as follows: -- Energy range[1]: <= 0.05 to >= 3 MeV -- Highest cadence[2]: <=1s for selected rates -- Field of view[3]: >= π/2 sr in sunward and anti-sunward hemispheres -- Angular sectoring: <= 45 degree sectors -- Composition[4]: n/a Notes: [1] Combined energy range of all sensors; small gaps in energy coverage are acceptable [2] Additional rates at lower cadences, as appropriate, for expected statistics and bit rate allocation [3] Combined sky coverage of all sensors, some regions densely sampled rather than 100% covered [4] Measured species; not all measured under all conditions	

APL

ISIS Measurements



Solar Probe Plus
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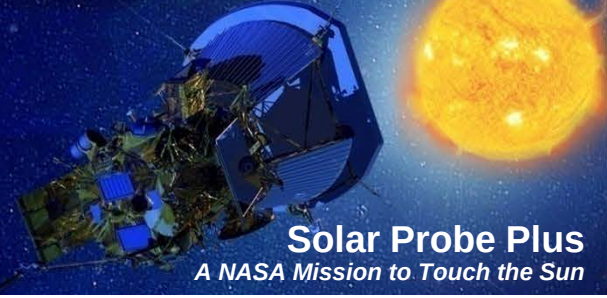
PAY-208: Measurement: Energetic Electrons Field-of-View (EPI-Hi)

EPI-Hi shall be capable of measuring energetic electrons over solar orbital distances of 9.86 Rs to 0.25 AU with a ≥ π/2 steradians FOV in the sunward hemisphere and a ≥ π/2 steradians FOV in the anti-sunward hemisphere including coverage within 10° of the Spacecraft-Sun line, subject to the constraints and FOV obstructions defined in the ISIS-to-Spacecraft ICD (7434-9058).

Rationale	**Requirement Allocation**
This requirement meets Level 2 Mission Science Requirements. The FOV should cover as much as the sky as possible in order to allow accurate particle intensity measurements even when the angular distribution is highly anisotropic or the magnetic field deviates strongly from the nominal Parker spiral. The minimum FOV requirement allows measurement of particles with pitch angles out to ~40° from the nominal field direction in both the forward and backward directions and enables good determinations of first order anisotropies. Additional measurements closer to 90° pitch angle are important for investigating the time evolution of particle pitch angle distributions and for measuring higher order anisotropies.	ISIS
Parent Traceability	**Functional Allocation**
MRD-96 : The Mission shall measure energetic electrons, as follows: -- Energy range[1]: <= 0.05 to >= 3 MeV -- Highest cadence[2]: <=1s for selected rates -- Field of view[3]: >= π/2 sr in sunward and anti-sunward hemispheres -- Angular sectoring: <= 45 degree sectors -- Composition[4]: n/a Notes: [1] Combined energy range of all sensors; small gaps in energy coverage are acceptable [2] Additional rates at lower cadences, as appropriate, for expected statistics and bit rate allocation [3] Combined sky coverage of all sensors, some regions densely sampled rather than 100% covered [4] Measured species; not all measured under all conditions	

APL

ISIS Measurements

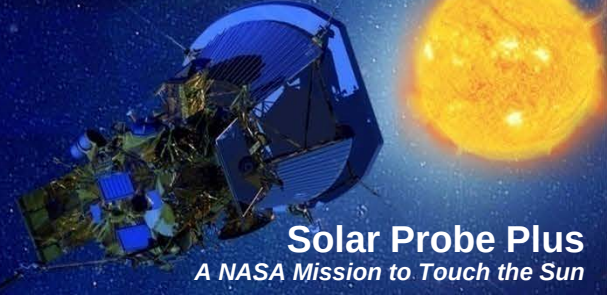


Solar Probe Plus
A NASA Mission to Touch the Sun

PAY-270: Measurement: Energetic Protons/Heavy Ions Field-of-View (EPI-Lo)	
EPI-Lo shall be capable of measuring protons and heavy ions over solar orbital distances of 9.86 Rs to 0.25 AU with a ≥ π/2 steradians FOV in the sunward hemisphere and a ≥ π/2 steradians FOV in the anti-sunward hemisphere including coverage within 10° of the Spacecraft-Sun line, subject to the constraints and FOV obstructions defined in the ISIS-to-Spacecraft ICD (7434-9058).	
Rationale This requirement meets Level 2 Mission Science Requirements. The FOV should cover as much as the sky as possible in order to allow accurate particle intensity measurements even when the angular distribution is highly anisotropic or the magnetic field deviates strongly from the nominal Parker spiral. The minimum FOV requirement allows measurement of particles with pitch angles out to ~40° from the nominal field direction in both the forward and backward directions and enables good determinations of first order anisotropies. Additional measurements closer to 90° pitch angle are important for investigating the time evolution of particle pitch angle distributions and for measuring higher order anisotropies.	**Requirement Allocation** ISIS
Parent Traceability MRD-97 : The Mission shall measure energetic protons and heavy ions, as follows: -- Energy range[1]: <= 0.05 to >= 50 MeV/nucleon -- Highest cadence[2]: <= 5s for selected rates -- Field of view[3]: >= π/2 sr in sunward and anti-sunward hemispheres -- Angular sectoring: <= 30 degree sectors -- Composition[4]: at least H, He, 3He, C, O, Ne, Mg, Si, Fe Notes: [1] Combined energy range of all sensors; small gaps in energy coverage are acceptable [2] Additional rates at lower cadences, as appropriate, for expected statistics and bit rate allocation [3] Combined sky coverage of all sensors, some regions densely sampled rather than 100% covered [4] Measured species; not all measured under all conditions	**Functional Allocation**

APL

ISIS Measurements



Solar Probe Plus
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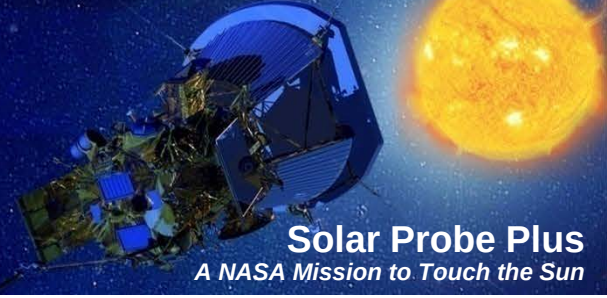
PAY-271: Measurement: Energetic Protons/Heavy Ions Field-of-View (EPI-Hi)

EPI-Hi shall be capable of measuring protons and heavy ions over solar orbital distances of 9.86 Rs to 0.25 AU with a ≥ π/2 steradians FOV in the sunward hemisphere and a ≥ π/2 steradians FOV in the anti-sunward hemisphere including coverage within 10° of the Spacecraft-Sun line, subject to the constraints and FOV obstructions defined in the ISIS-to-Spacecraft ICD (7434-9058).

Rationale	**Requirement Allocation**
This requirement meets Level 2 Mission Science Requirements. The FOV should cover as much as the sky as possible in order to allow accurate particle intensity measurements even when the angular distribution is highly anisotropic or the magnetic field deviates strongly from the nominal Parker spiral. The minimum FOV requirement allows measurement of particles with pitch angles out to ~40° from the nominal field direction in both the forward and backward directions and enables good determinations of first order anisotropies. Additional measurements closer to 90° pitch angle are important for investigating the time evolution of particle pitch angle distributions and for measuring higher order anisotropies.	ISIS
Parent Traceability	**Functional Allocation**
MRD-97 : The Mission shall measure energetic protons and heavy ions, as follows: -- Energy range[1]: <= 0.05 to >= 50 MeV/nucleon -- Highest cadence[2]: <= 5s for selected rates -- Field of view[3]: >= π/2 sr in sunward and anti-sunward hemispheres -- Angular sectoring: <= 30 degree sectors -- Composition[4]: at least H, He, 3He, C, O, Ne, Mg, Si, Fe Notes: [1] Combined energy range of all sensors; small gaps in energy coverage are acceptable [2] Additional rates at lower cadences, as appropriate, for expected statistics and bit rate allocation [3] Combined sky coverage of all sensors, some regions densely sampled rather than 100% covered [4] Measured species; not all measured under all conditions	

APL

SWEAP Measurements



Solar Probe Plus
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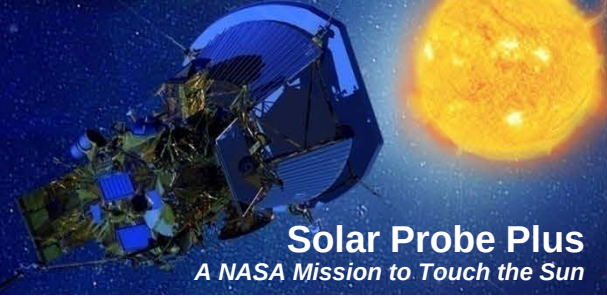
PAY-56: Measurement: Thermal Ions Field-of-View (nadir-direction)	
SPC shall be capable of measuring thermal ions in the nadir direction over solar orbital distances of 9.86 Rs to 0.25 AU with a ≥ 28 degree half-angle (≥ 56 degree full-angle) cone FOV oriented within 10 degrees of the Spacecraft z-axis, subject to the FOV obstructions defined in the SWEAP to Spacecraft ICD 7434-9056.	
Rationale This requirement meets Level 2 Mission Science Requirements. SWEAP must be able to determine certain bulk properties of the solar wind, such as the p core and e- strahl. This implies i+ and e- fields of view that cover a large fraction of the sky.	**Requirement Allocation** SWEAP
Parent Traceability MRD-93 : The Mission shall measure thermal ions, as follows: -- Energy range[1]: 10 eV – 20 keV -- Energy resolution: < 20% -- FOV: nadir and ram directions -- Angular resolution[2]: 10 deg x 25 deg -- VDF cadence: 1 Hz -- Mass resolution[3]: d(m/q)/(m/q) < 25% Notes: [1] Energy range not required in all directions [2] Angular resolution not required in all directions [3] Mass resolution not required in all directions	**Functional Allocation**

APL

SWEAP Measurements



Solar Probe Plus
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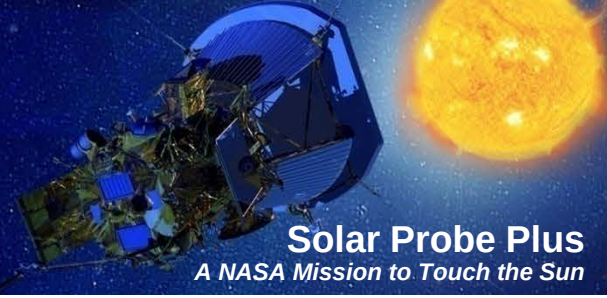
PAY-182: Measurement: Thermal Ions Field-of-View (ram-direction)

SPAN-A+ shall be capable of measuring thermal ions in the ram direction over solar orbital distances of 9.86 Rs to 0.25 AU with a FOV of ≥ 180 degrees about the Spacecraft y-axis and ≥ 30 degrees out of the Spacecraft X-Z plane for ions with energy/charge ≤ 4 keV/q, subject to the FOV obstructions defined in the SWEAP to Spacecraft ICD 7434-9056.

Rationale	**Requirement Allocation**
This requirement meets Level 2 Mission Science Requirements. SWEAP must be able to determine certain bulk properties of the solar wind, such as the p core and e- strahl. This implies i+ and e- fields of view that cover a large fraction of the sky.	SWEAP
Parent Traceability MRD-93 : The Mission shall measure thermal ions, as follows: -- Energy range[1]: 10 eV – 20 keV -- Energy resolution: < 20% -- FOV: nadir and ram directions -- Angular resolution[2]: 10 deg x 25 deg -- VDF cadence: 1 Hz -- Mass resolution[3]: d(m/q)/(m/q) < 25% Notes: [1] Energy range not required in all directions [2] Angular resolution not required in all directions [3] Mass resolution not required in all directions	**Functional Allocation**

APL

SWEAP Measurements



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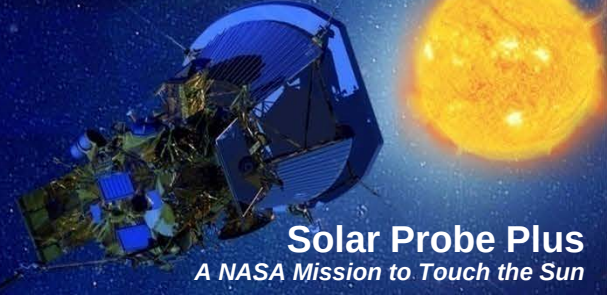
PAY-57: Measurement: Thermal Ions Minimum Ion Energy (nadir-direction)	
SPC shall be capable of measuring thermal ions in the nadir direction over solar orbital distances of 9.86 Rs to 0.25 AU with a minimum energy/charge of ≤ 150 eV/q, except when the Spacecraft potential is > + TBD V. ***Description/Clarification*** SWEAP is not required to meet L2 minimum energy requirement in all directions.	
Rationale This requirement meets Level 2 Mission Science Requirements.	**Requirement Allocation** SWEAP
Parent Traceability MRD-93 : The Mission shall measure thermal ions, as follows: -- Energy range[1]: 10 eV – 20 keV -- Energy resolution: < 20% -- FOV: nadir and ram directions -- Angular resolution[2]: 10 deg x 25 deg -- VDF cadence: 1 Hz -- Mass resolution[3]: d(m/q)/(m/q) < 25% Notes: [1] Energy range not required in all directions [2] Angular resolution not required in all directions [3] Mass resolution not required in all directions	**Functional Allocation**

APL

SWEAP Measurements



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PAY-183: Measurement: Thermal Ions Minimum Ion Energy (ram-direction)

SPAN-A+ shall be capable of measuring thermal ions in the ram direction over solar orbital distances of 9.86 Rs to 0.25 AU with a minimum energy/charge of ≤ 10 eV/q, except when the Spacecraft potential is > + TBD V.

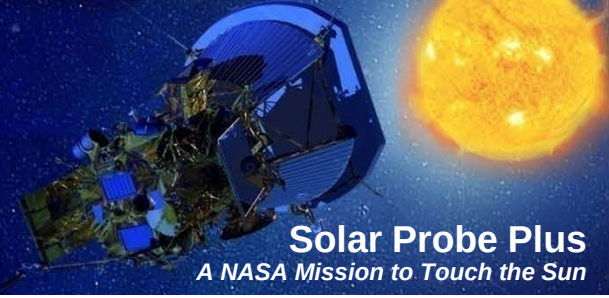
Description/Clarification

SWEAP is not required to meet L2 minimum energy requirement in all directions.

Rationale	**Requirement Allocation**
This requirement meets Level 2 Mission Science Requirements.	SWEAP
Parent Traceability MRD-93 : The Mission shall measure thermal ions, as follows: -- Energy range[1]: 10 eV – 20 keV -- Energy resolution: < 20% -- FOV: nadir and ram directions -- Angular resolution[2]: 10 deg x 25 deg -- VDF cadence: 1 Hz -- Mass resolution[3]: d(m/q)/(m/q) < 25% Notes: [1] Energy range not required in all directions [2] Angular resolution not required in all directions [3] Mass resolution not required in all directions	**Functional Allocation**

APL

SWEAP Measurements



Solar Probe Plus
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PAY-58: Measurement: Thermal Ions Maximum Ion Energy (nadir-direction, close range)

SPC shall be capable of measuring thermal ions in the nadir direction over solar orbital distances of 9.86 Rs to 20 Rs with a maximum energy/charge of > 4 keV/q.

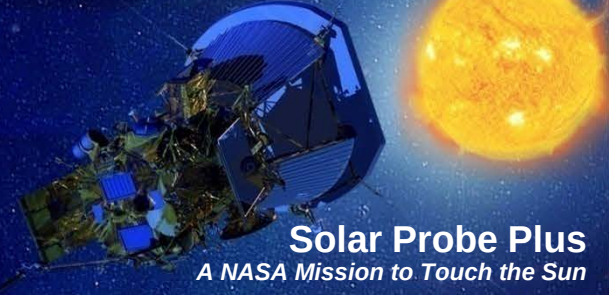
Description/Clarification

SWEAP is not required to meet L2 maximum energy requirement in all directions and distances.

Rationale	**Requirement Allocation**
This requirement meets Level 2 Mission Science Requirements.	SWEAP
Parent Traceability	**Functional Allocation**
MRD-93 : The Mission shall measure thermal ions, as follows: -- Energy range[1]: 10 eV – 20 keV -- Energy resolution: < 20% -- FOV: nadir and ram directions -- Angular resolution[2]: 10 deg x 25 deg -- VDF cadence: 1 Hz -- Mass resolution[3]: d(m/q)/(m/q) < 25% Notes: [1] Energy range not required in all directions [2] Angular resolution not required in all directions [3] Mass resolution not required in all directions	

APL

SWEAP Measurements



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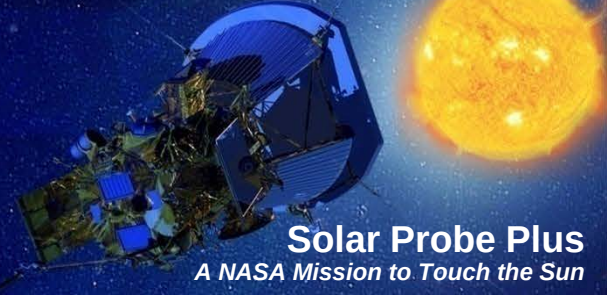
PAY-269: Measurement: Thermal Ions Maximum Ion Energy (nadir-direction, far range)	
SPC shall be capable of measuring thermal ions in the nadir direction over solar orbital distances of 20 Rs to 0.25 AU with a maximum energy/charge of > 6 keV/q. ***Description/Clarification*** SWEAP is not required to meet L2 maximum energy requirement in all directions and distances.	
Rationale This requirement meets Level 2 Mission Science Requirements.	**Requirement Allocation** SWEAP
Parent Traceability MRD-93 : The Mission shall measure thermal ions, as follows: -- Energy range[1]: 10 eV – 20 keV -- Energy resolution: < 20% -- FOV: nadir and ram directions -- Angular resolution[2]: 10 deg x 25 deg -- VDF cadence: 1 Hz -- Mass resolution[3]: d(m/q)/(m/q) < 25% Notes: [1] Energy range not required in all directions [2] Angular resolution not required in all directions [3] Mass resolution not required in all directions	**Functional Allocation**

APL

SWEAP Measurements



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PAY-184: Measurement: Thermal Ions Maximum Ion Energy (ram-direction)

SPAN-A+ shall be capable of measuring thermal ions in the ram direction over solar orbital distances of 9.86 Rs to 0.25 AU with a maximum energy/charge of > 20 keV/q (TBR).

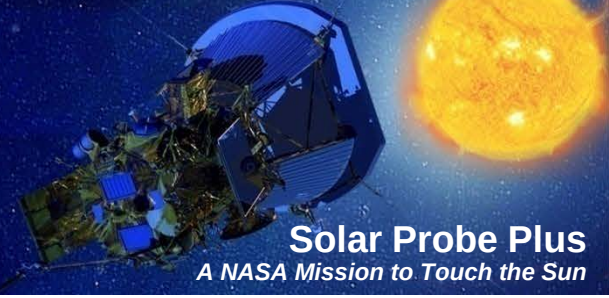
Description/Clarification

SWEAP is not required to meet L2 maximum energy requirement in all directions and distances.

Rationale	**Requirement Allocation**
This requirement meets Level 2 Mission Science Requirements.	SWEAP
Parent Traceability MRD-93 : The Mission shall measure thermal ions, as follows: -- Energy range[1]: 10 eV – 20 keV -- Energy resolution: < 20% -- FOV: nadir and ram directions -- Angular resolution[2]: 10 deg x 25 deg -- VDF cadence: 1 Hz -- Mass resolution[3]: d(m/q)/(m/q) < 25% Notes: [1] Energy range not required in all directions [2] Angular resolution not required in all directions [3] Mass resolution not required in all directions	**Functional Allocation**

APL

SWEAP Measurements



Solar Probe Plus
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PAY-59: Measurement: Thermal Ions Energy Resolution (nadir-facing)

SPC shall be capable of measuring thermal ions in the nadir direction over solar orbital distances of 9.86 Rs to 0.25 AU with an energy/charge (E/q) resolution of d(E/q)/(E/q) ≤ 20%.

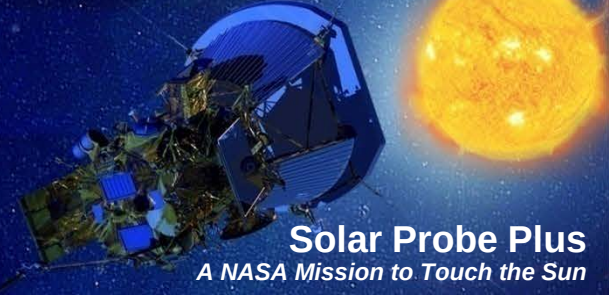
Description/Clarification

Energy resolution is needed to determine ion temperatures.

Rationale	**Requirement Allocation**
This requirement meets Level 2 Mission Science Requirements.	SWEAP
Parent Traceability	**Functional Allocation**
MRD-93 : The Mission shall measure thermal ions, as follows: -- Energy range[1]: 10 eV – 20 keV -- Energy resolution: < 20% -- FOV: nadir and ram directions -- Angular resolution[2]: 10 deg x 25 deg -- VDF cadence: 1 Hz -- Mass resolution[3]: d(m/q)/(m/q) < 25% Notes: [1] Energy range not required in all directions [2] Angular resolution not required in all directions [3] Mass resolution not required in all directions	

APL

SWEAP Measurements

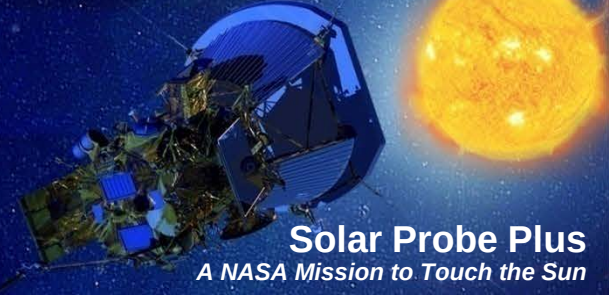


Solar Probe Plus
A NASA Mission to Touch the Sun

PAY-185: Measurement: Thermal Ions Energy Resolution (ram-facing) SPAN-A+ shall be capable of measuring thermal ions in the ram direction over solar orbital distances of 9.86 Rs to 0.25 AU with an energy/charge (E/q) resolution of d(E/q)/(E/q) ≤ 20%. ***Description/Clarification*** Energy resolution is needed to determine ion temperatures.	
Rationale This requirement meets Level 2 Mission Science Requirements.	**Requirement Allocation** SWEAP
Parent Traceability MRD-93 : The Mission shall measure thermal ions, as follows: -- Energy range[1]: 10 eV – 20 keV -- Energy resolution: < 20% -- FOV: nadir and ram directions -- Angular resolution[2]: 10 deg x 25 deg -- VDF cadence: 1 Hz -- Mass resolution[3]: d(m/q)/(m/q) < 25% Notes: [1] Energy range not required in all directions [2] Angular resolution not required in all directions [3] Mass resolution not required in all directions	**Functional Allocation**

APL

SWEAP Measurements



Solar Probe Plus
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PAY-60: Measurement: Thermal Ions Angular Resolution (nadir-facing)

SPC shall be capable of measuring thermal ion flow angles in the nadir direction over solar orbital distances of 9.86 Rs to 0.25 AU with an angular resolution of ≤ 10 degrees, except when Spacecraft potential is > + TBD V.

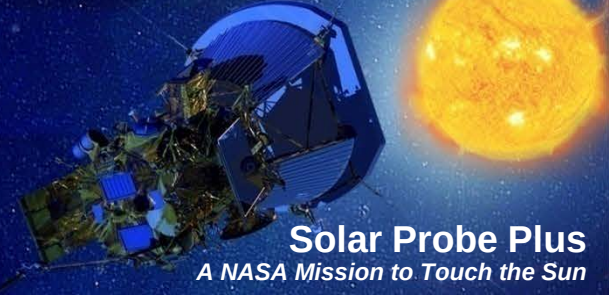
Description/Clarification

SWEAP is not required to meet L2 angular resolution requirement in all directions.

Rationale	**Requirement Allocation**
This requirement meets Level 2 Mission Science Requirements.	SWEAP
Parent Traceability MRD-93 : The Mission shall measure thermal ions, as follows: -- Energy range[1]: 10 eV – 20 keV -- Energy resolution: < 20% -- FOV: nadir and ram directions -- Angular resolution[2]: 10 deg x 25 deg -- VDF cadence: 1 Hz -- Mass resolution[3]: d(m/q)/(m/q) < 25% Notes: [1] Energy range not required in all directions [2] Angular resolution not required in all directions [3] Mass resolution not required in all directions	**Functional Allocation**

APL

SWEAP Measurements



Solar Probe Plus
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PAY-186: Measurement: Thermal Ions Angular Resolution (ram-facing)

SPAN-A+ shall be capable of measuring thermal ions in the ram direction over solar orbital distances of 9.86 Rs to 0.25 AU with an angular resolution of ≤ 25 degrees about the Spacecraft y-axis and ≤ 10 degrees in the Spacecraft X-Z plane, except when Spacecraft potential is > + TBD V.

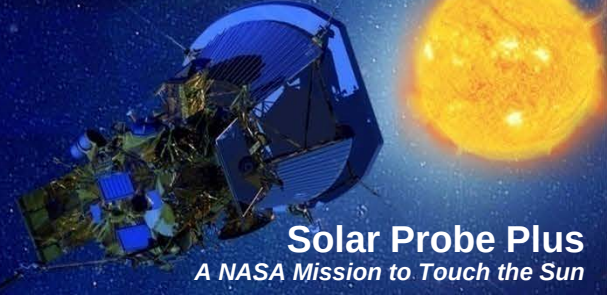
Description/Clarification

SWEAP is not required to meet L2 angular resolution requirement in all directions.

Rationale	**Requirement Allocation**
This requirement meets Level 2 Mission Science Requirements.	SWEAP
Parent Traceability MRD-93 : The Mission shall measure thermal ions, as follows: -- Energy range[1]: 10 eV – 20 keV -- Energy resolution: < 20% -- FOV: nadir and ram directions -- Angular resolution[2]: 10 deg x 25 deg -- VDF cadence: 1 Hz -- Mass resolution[3]: d(m/q)/(m/q) < 25% Notes: [1] Energy range not required in all directions [2] Angular resolution not required in all directions [3] Mass resolution not required in all directions	**Functional Allocation**

APL

SWEAP Measurements



Solar Probe Plus
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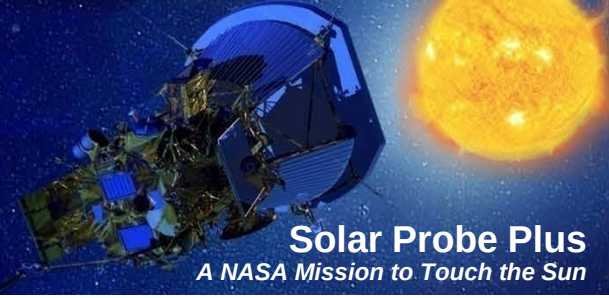
PAY-61: Measurement: Thermal Ions Velocity Distribution Function (nadir-facing)	
SPC shall be capable of measuring thermal ions in the nadir direction over solar orbital distances of 9.86 Rs to 0.25 AU with a VDF measurement cadence of ≥ 1 Hz.	
Rationale This requirement meets Level 2 Mission Science Requirements.	**Requirement Allocation** SWEAP
Parent Traceability MRD-93 : The Mission shall measure thermal ions, as follows: -- Energy range[1]: 10 eV – 20 keV -- Energy resolution: < 20% -- FOV: nadir and ram directions -- Angular resolution[2]: 10 deg x 25 deg -- VDF cadence: 1 Hz -- Mass resolution[3]: d(m/q)/(m/q) < 25% Notes: [1] Energy range not required in all directions [2] Angular resolution not required in all directions [3] Mass resolution not required in all directions	**Functional Allocation**

SWEAP Measurements

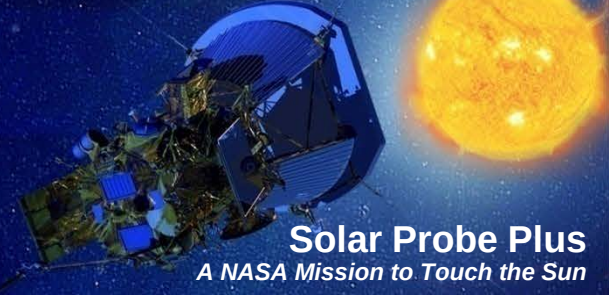


Solar Probe Plus
A NASA Mission to Touch the Sun

PAY-187: Measurement: Thermal Ions Velocity Distribution Function (ram-facing)	
SPAN-A+ shall be capable of measuring thermal ions in the ram direction over solar orbital distances of 9.86 Rs to 0.25 AU with a VDF measurement cadence of ≥ 1 Hz.	
Rationale This requirement meets Level 2 Mission Science Requirements.	**Requirement Allocation** SWEAP
Parent Traceability MRD-93 : The Mission shall measure thermal ions, as follows: -- Energy range[1]: 10 eV – 20 keV -- Energy resolution: < 20% -- FOV: nadir and ram directions -- Angular resolution[2]: 10 deg x 25 deg -- VDF cadence: 1 Hz -- Mass resolution[3]: d(m/q)/(m/q) < 25% Notes: [1] Energy range not required in all directions [2] Angular resolution not required in all directions [3] Mass resolution not required in all directions	**Functional Allocation**

APL

SWEAP Measurements



Solar Probe Plus
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PAY-62: Measurement: Thermal Ions Mass Resolution

SPAN-A+ shall be capable of measuring thermal ions in the ram direction over solar orbital distances of 9.86 Rs to 0.25 AU with a mass/charge resolution d(m/q)/(m/q) of ≤ 25%.

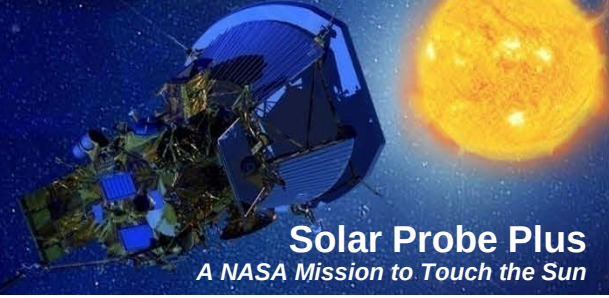
Description/Clarification

Distinguish between proton & alpha particles with the same energy per charge by also measuring their mass/charge ratio. SWEAP is not required to meet L2 mass resolution in all directions.

Rationale	**Requirement Allocation**
This requirement meets Level 2 Mission Science Requirements.	SWEAP
Parent Traceability	**Functional Allocation**
MRD-93 : The Mission shall measure thermal ions, as follows: -- Energy range[1]: 10 eV – 20 keV -- Energy resolution: < 20% -- FOV: nadir and ram directions -- Angular resolution[2]: 10 deg x 25 deg -- VDF cadence: 1 Hz -- Mass resolution[3]: d(m/q)/(m/q) < 25% Notes: [1] Energy range not required in all directions [2] Angular resolution not required in all directions [3] Mass resolution not required in all directions	

APL

SWEAP Measurements



Solar Probe Plus
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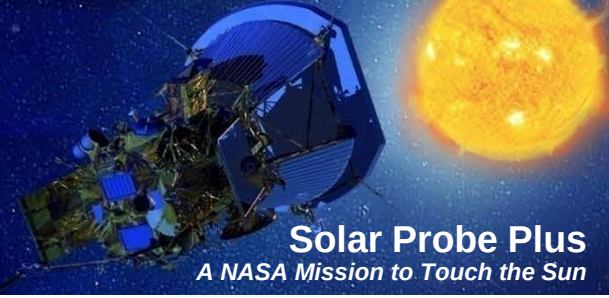
PAY-63: Measurement: Thermal Electrons Field-of-View (nadir-facing)	
SPC shall be capable of measuring thermal electrons in the nadir direction over solar orbital distances of 9.86 Rs to 0.25 AU with a ≥ 28 degree half-angle (≥ 56 degree full-angle) cone FOV oriented within 10 degrees of the Spacecraft z-axis, subject to the FOV obstructions defined in the SWEAP to Spacecraft ICD 7434-9056.	
Rationale This requirement meets Level 2 Mission Science Requirements. Electron flux is needed to determine electron properties because the thermal electron distribution is subsonic, and needed to detect bi-directional electron flow along magnetic fields.	**Requirement Allocation** SWEAP
Parent Traceability MRD-94 : The Mission shall measure thermal electrons, as follows: -- Energy range[1]: 5 eV – 20 keV -- Energy resolution: < 20% -- FOV: > 75% of the sky -- Angular resolution[2]: 10 deg x 10 deg -- VDF cadence: 1 Hz -- Mass resolution[3]: n/a Notes: [1] Energy range not required in all directions [2] Angular resolution not required in all directions [3] Mass resolution not required in all directions	**Functional Allocation**

APL

SWEAP Measurements



Solar Probe Plus
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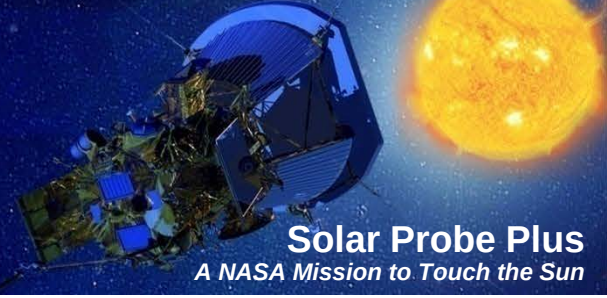
PAY-188: Measurement: Thermal Electrons Field-of-View (ram-facing)

SPAN-A+ shall be capable of measuring thermal electrons in the ram direction over solar orbital distances of 9.86 Rs to 0.25 AU with a FOV of ≥ 180 degrees about the Spacecraft y-axis (TBR) and ≥ 30 degrees out of Spacecraft X-Z plane (TBR) for electrons with energy ≤ 4 keV, subject to the FOV obstructions defined in the SWEAP to Spacecraft ICD 7434-9056.

Rationale	**Requirement Allocation**
This requirement meets Level 2 Mission Science Requirements. Electron flux is needed to determine electron properties because the thermal electron distribution is subsonic, and needed to detect bi-directional electron flow along magnetic fields.	SWEAP
Parent Traceability	**Functional Allocation**
MRD-94 : The Mission shall measure thermal electrons, as follows: -- Energy range[1]: 5 eV – 20 keV -- Energy resolution: < 20% -- FOV: > 75% of the sky -- Angular resolution[2]: 10 deg x 10 deg -- VDF cadence: 1 Hz -- Mass resolution[3]: n/a Notes: [1] Energy range not required in all directions [2] Angular resolution not required in all directions [3] Mass resolution not required in all directions	

APL

SWEAP Measurements



Solar Probe Plus
A NASA Mission to Touch the Sun

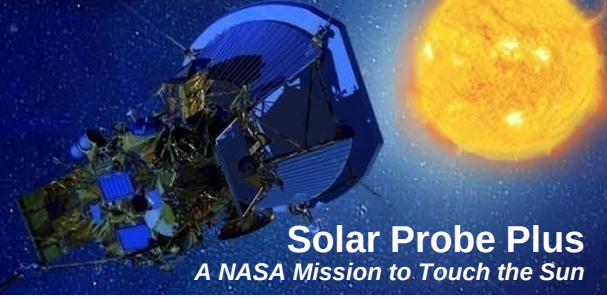
PAY-189: Measurement: Thermal Electrons Field-of-View (anti-ram-facing)

SPAN-B shall be capable of measuring thermal electrons in the anti-ram direction over solar orbital distances of 9.86 Rs to 0.25 AU with a FOV of ≥ 180 degrees about the Spacecraft z-axis (TBR) and ≥ 30 degrees out of Spacecraft X-Y plane (TBR) for electrons with energy ≤ 4 keV, subject to the FOV obstructions defined in the SWEAP to Spacecraft ICD 7434-9056.

Rationale	**Requirement Allocation**
This requirement meets Level 2 Mission Science Requirements. Electron flux is needed to determine electron properties because the thermal electron distribution is subsonic, and needed to detect bi-directional electron flow along magnetic fields.	SWEAP
Parent Traceability	**Functional Allocation**
MRD-94 : The Mission shall measure thermal electrons, as follows: -- Energy range[1]: 5 eV – 20 keV -- Energy resolution: < 20% -- FOV: > 75% of the sky -- Angular resolution[2]: 10 deg x 10 deg -- VDF cadence: 1 Hz -- Mass resolution[3]: n/a Notes: [1] Energy range not required in all directions [2] Angular resolution not required in all directions [3] Mass resolution not required in all directions	

APL

SWEAP Measurements



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PAY-64: Measurement: Thermal Electrons Minimum Electron Energy (nadir-facing)

SPC shall be capable of measuring thermal electrons in the nadir direction over solar orbital distances of 9.86 Rs to 0.25 AU with a minimum energy of ≤ 100 eV (TBR), except when the Spacecraft potential is ≤ - TBD V.

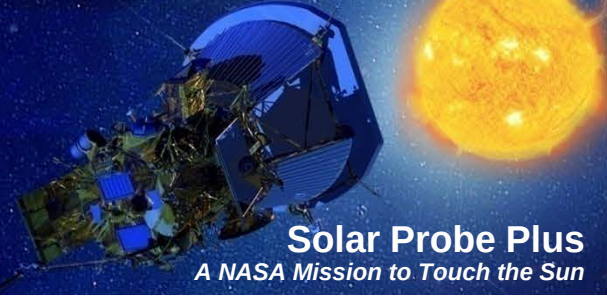
Description/Clarification

SWEAP is not required to meet L2 minimum energy requirement in all directions.

Rationale	**Requirement Allocation**
This requirement meets Level 2 Mission Science Requirements. This energy range is needed to observe the thermal electron population & the suprathermal electron population that dominates the heat flux of the solar wind.	SWEAP
Parent Traceability MRD-94 : The Mission shall measure thermal electrons, as follows: -- Energy range[1]: 5 eV – 20 keV -- Energy resolution: < 20% -- FOV: > 75% of the sky -- Angular resolution[2]: 10 deg x 10 deg -- VDF cadence: 1 Hz -- Mass resolution[3]: n/a Notes: [1] Energy range not required in all directions [2] Angular resolution not required in all directions [3] Mass resolution not required in all directions	**Functional Allocation**

APL

SWEAP Measurements



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PAY-190: Measurement: Thermal Electrons Minimum Electron Energy (ram-facing)

SPAN-A+ shall be capable of measuring thermal electrons in the ram direction over solar orbital distances of 9.86 Rs to 0.25 AU with a minimum energy of ≤ 5 eV, except when the Spacecraft potential is ≤ - TBD V.

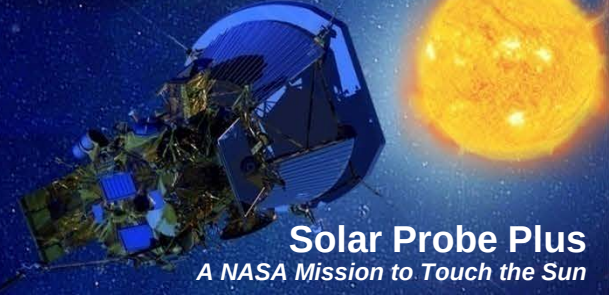
Description/Clarification

SWEAP is not required to meet L2 minimum energy requirement in all directions.

Rationale	**Requirement Allocation**
This requirement meets Level 2 Mission Science Requirements. This energy range is needed to observe the thermal electron population & the suprathermal electron population that dominates the heat flux of the solar wind.	SWEAP
Parent Traceability	**Functional Allocation**
MRD-94 : The Mission shall measure thermal electrons, as follows: -- Energy range[1]: 5 eV – 20 keV -- Energy resolution: < 20% -- FOV: > 75% of the sky -- Angular resolution[2]: 10 deg x 10 deg -- VDF cadence: 1 Hz -- Mass resolution[3]: n/a Notes: [1] Energy range not required in all directions [2] Angular resolution not required in all directions [3] Mass resolution not required in all directions	

APL

SWEAP Measurements



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PAY-191: Measurement: Thermal Electrons Minimum Electron Energy (anti-ram-facing)

SPAN-B shall be capable of measuring thermal electrons in the anti-ram direction over solar orbital distances of 9.86 Rs to 0.25 AU with a minimum energy of ≤ 5 eV, except when the Spacecraft potential is ≤ - TBD V.

Description/Clarification

SWEAP is not required to meet L2 minimum energy requirement in all directions.

Rationale

This requirement meets Level 2 Mission Science Requirements. This energy range is needed to observe the thermal electron population & the suprathermal electron population that dominates the heat flux of the solar wind.

Requirement Allocation

SWEAP

Parent Traceability

MRD-94 : The Mission shall measure thermal electrons, as follows:

-- Energy range[1]: 5 eV – 20 keV
-- Energy resolution: < 20%
-- FOV: > 75% of the sky
-- Angular resolution[2]: 10 deg x 10 deg
-- VDF cadence: 1 Hz
-- Mass resolution[3]: n/a

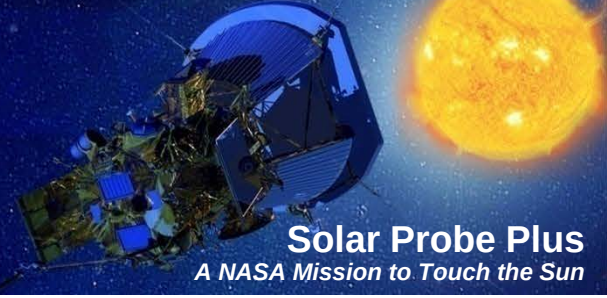
Notes:

[1] Energy range not required in all directions
[2] Angular resolution not required in all directions
[3] Mass resolution not required in all directions

Functional Allocation

APL

SWEAP Measurements



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PAY-65: Measurement: Thermal Electrons Maximum Electron Energy (nadir-facing)

SPC shall be capable of measuring thermal electrons in the nadir direction over solar orbital distances of 9.86 Rs to 0.25 AU with a maximum energy of ≥ 1.5 keV.

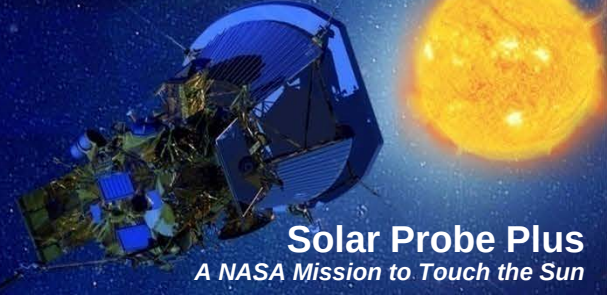
Description/Clarification

SWEAP is not required to meet L2 maximum energy requirement in all directions.

Rationale	**Requirement Allocation**
This requirement meets Level 2 Mission Science Requirements. This energy range is needed to observe the thermal electron population & the suprathermal electron population that dominates the heat flux of the solar wind.	SWEAP
Parent Traceability MRD-94 : The Mission shall measure thermal electrons, as follows: -- Energy range[1]: 5 eV – 20 keV -- Energy resolution: < 20% -- FOV: > 75% of the sky -- Angular resolution[2]: 10 deg x 10 deg -- VDF cadence: 1 Hz -- Mass resolution[3]: n/a Notes: [1] Energy range not required in all directions [2] Angular resolution not required in all directions [3] Mass resolution not required in all directions	**Functional Allocation**

APL

SWEAP Measurements



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PAY-192: Measurement: Thermal Electrons Maximum Electron Energy (ram-facing)

SPAN-A+ shall be capable of measuring thermal electrons in the ram direction over solar orbital distances of 9.86 Rs to 0.25 AU with a maximum energy of ≥ 20 keV.

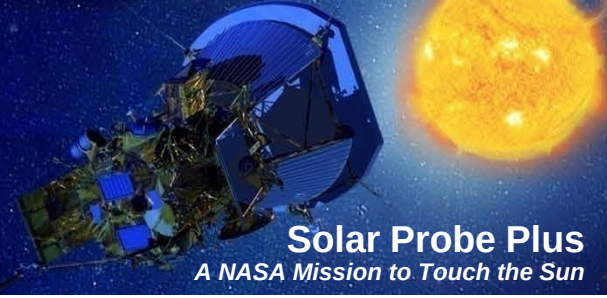
Description/Clarification

SWEAP is not required to meet L2 maximum energy requirement in all directions.

Rationale	**Requirement Allocation**
This requirement meets Level 2 Mission Science Requirements. This energy range is needed to observe the thermal electron population & the suprathermal electron population that dominates the heat flux of the solar wind.	SWEAP
Parent Traceability	**Functional Allocation**
MRD-94 : The Mission shall measure thermal electrons, as follows: -- Energy range[1]: 5 eV – 20 keV -- Energy resolution: < 20% -- FOV: > 75% of the sky -- Angular resolution[2]: 10 deg x 10 deg -- VDF cadence: 1 Hz -- Mass resolution[3]: n/a Notes: [1] Energy range not required in all directions [2] Angular resolution not required in all directions [3] Mass resolution not required in all directions	

APL

SWEAP Measurements



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PAY-196: Measurement: Thermal Electrons Maximum Electron Energy (anti-ram-facing)

SPAN-B shall be capable of measuring thermal electrons in the anti-ram direction over solar orbital distances of 9.86 Rs to 0.25 AU with a maximum energy of ≥ 20 keV.

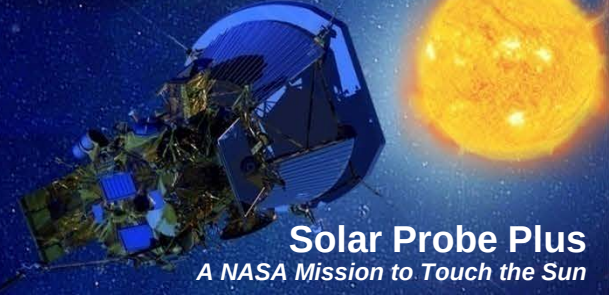
Description/Clarification

SWEAP is not required to meet L2 maximum energy requirement in all directions.

Rationale	**Requirement Allocation**
This requirement meets Level 2 Mission Science Requirements. This energy range is needed to observe the thermal electron population & the suprathermal electron population that dominates the heat flux of the solar wind.	SWEAP
Parent Traceability	**Functional Allocation**
MRD-94 : The Mission shall measure thermal electrons, as follows: -- Energy range[1]: 5 eV – 20 keV -- Energy resolution: < 20% -- FOV: > 75% of the sky -- Angular resolution[2]: 10 deg x 10 deg -- VDF cadence: 1 Hz -- Mass resolution[3]: n/a Notes: [1] Energy range not required in all directions [2] Angular resolution not required in all directions [3] Mass resolution not required in all directions	

APL

SWEAP Measurements



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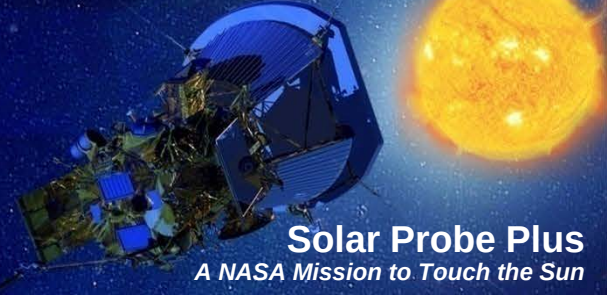
PAY-66: Measurement: Thermal Electrons Energy Resolution (nadir-facing)	
SPC shall be capable of measuring thermal electrons in the nadir direction over solar orbital distances of 9.86 Rs to 0.25 AU with an energy resolution dE/E of < 20%.	
Rationale This requirement meets Level 2 Mission Science Requirements. Energy resolution is needed to determine electron temperature.	**Requirement Allocation** SWEAP
Parent Traceability MRD-94 : The Mission shall measure thermal electrons, as follows: -- Energy range[1]: 5 eV – 20 keV -- Energy resolution: < 20% -- FOV: > 75% of the sky -- Angular resolution[2]: 10 deg x 10 deg -- VDF cadence: 1 Hz -- Mass resolution[3]: n/a Notes: [1] Energy range not required in all directions [2] Angular resolution not required in all directions [3] Mass resolution not required in all directions	**Functional Allocation**

SWEAP Measurements



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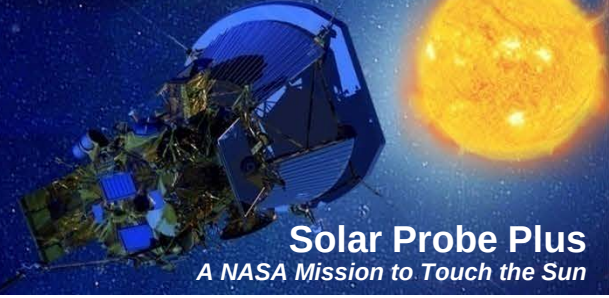
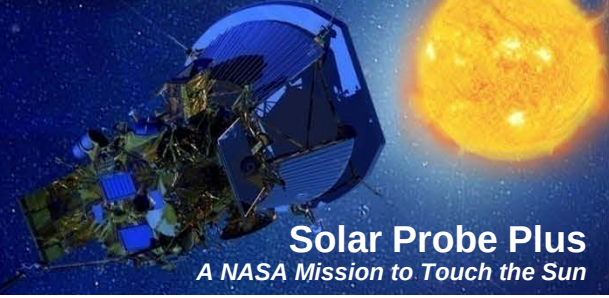
PAY-193: Measurement: Thermal Electrons Energy Resolution (ram-facing)	
SPAN-A+ shall be capable of measuring thermal electrons in the ram direction over solar orbital distances of 9.86 Rs to 0.25 AU with an energy resolution dE/E of < 20%.	
Rationale This requirement meets Level 2 Mission Science Requirements. Energy resolution is needed to determine electron temperature.	**Requirement Allocation** SWEAP
Parent Traceability MRD-94 : The Mission shall measure thermal electrons, as follows: -- Energy range[1]: 5 eV – 20 keV -- Energy resolution: < 20% -- FOV: > 75% of the sky -- Angular resolution[2]: 10 deg x 10 deg -- VDF cadence: 1 Hz -- Mass resolution[3]: n/a Notes: [1] Energy range not required in all directions [2] Angular resolution not required in all directions [3] Mass resolution not required in all directions	**Functional Allocation**

SWEAP Measurements



PAY-197: Measurement: Thermal Electrons Energy Resolution (anti-ram-facing)	
SPAN-B shall be capable of measuring thermal electrons in the anti-ram direction over solar orbital distances of 9.86 Rs to 0.25 AU with an energy resolution dE/E of < 20%.	
Rationale This requirement meets Level 2 Mission Science Requirements. Energy resolution is needed to determine electron temperature.	**Requirement Allocation** SWEAP
Parent Traceability MRD-94 : The Mission shall measure thermal electrons, as follows: -- Energy range[1]: 5 eV – 20 keV -- Energy resolution: < 20% -- FOV: > 75% of the sky -- Angular resolution[2]: 10 deg x 10 deg -- VDF cadence: 1 Hz -- Mass resolution[3]: n/a Notes: [1] Energy range not required in all directions [2] Angular resolution not required in all directions [3] Mass resolution not required in all directions	**Functional Allocation**

SWEAP Measurements



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PAY-194: Measurement: Thermal Electrons Angular Resolution (ram-facing)

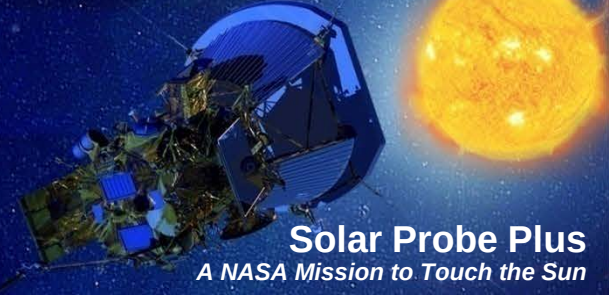
SPAN-A+ shall be capable of measuring thermal electrons in the ram direction over solar orbital distances of 9.86 Rs to 0.25 AU with an angular resolution of ≤ 25 degrees about the Spacecraft y-axis and ≤ 10 degrees about the Spacecraft X-Z plane, except when Spacecraft potential is ≤ - TBD V.

Description/Clarification

SWEAP is not required to meet L2 angular resolution requirement in all directions.

Rationale	**Requirement Allocation**
This requirement meets Level 2 Mission Science Requirements. Angular resolution is needed to determine electron temperature anisotropy and to characterize electron beams.	SWEAP
Parent Traceability	**Functional Allocation**
MRD-94 : The Mission shall measure thermal electrons, as follows: -- Energy range[1]: 5 eV – 20 keV -- Energy resolution: < 20% -- FOV: > 75% of the sky -- Angular resolution[2]: 10 deg x 10 deg -- VDF cadence: 1 Hz -- Mass resolution[3]: n/a Notes: [1] Energy range not required in all directions [2] Angular resolution not required in all directions [3] Mass resolution not required in all directions	

SWEAP Measurements



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PAY-198: Measurement: Thermal Electrons Angular Resolution (anti-ram-facing)

SPAN-B shall be capable of measuring thermal electrons in the anti-ram direction over solar orbital distances of 9.86 Rs to 0.25 AU with an angular resolution of ≤ 25 degrees about the Spacecraft y-axis and ≤ 10 degrees about the Spacecraft X-Z plane, except when Spacecraft potential is ≤ - TBD V.

Description/Clarification

SWEAP is not required to meet L2 angular resolution requirement in all directions.

Rationale

This requirement meets Level 2 Mission Science Requirements. Angular resolution is needed to determine electron temperature anisotropy and to characterize electron beams.

Requirement Allocation

SWEAP

Parent Traceability

MRD-94 : The Mission shall measure thermal electrons, as follows:

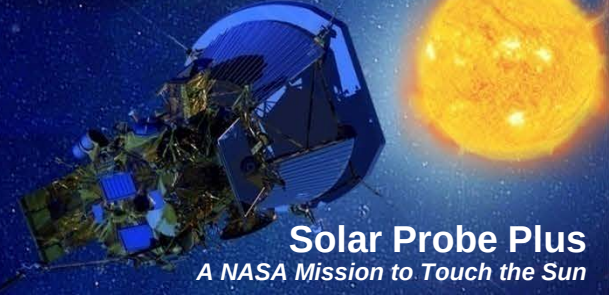
-- Energy range[1]: 5 eV – 20 keV
-- Energy resolution: < 20%
-- FOV: > 75% of the sky
-- Angular resolution[2]: 10 deg x 10 deg
-- VDF cadence: 1 Hz
-- Mass resolution[3]: n/a

Notes:

[1] Energy range not required in all directions
[2] Angular resolution not required in all directions
[3] Mass resolution not required in all directions

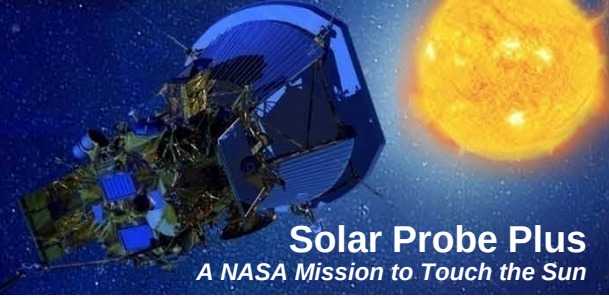
Functional Allocation

SWEAP Measurements



PAY-68: Measurement: Thermal Electrons Velocity Distribution Function (nadir-facing)	
SPC shall be capable of measuring thermal electrons in the nadir direction over solar orbital distances of 9.86 Rs to 0.25 AU with a VDF measurement cadence of ≥ 1 Hz.	
Rationale This requirement meets Level 2 Mission Science Requirements. Velocity Distribution Function is needed to resolve structures.	**Requirement Allocation** SWEAP
Parent Traceability MRD-94 : The Mission shall measure thermal electrons, as follows: -- Energy range[1]: 5 eV – 20 keV -- Energy resolution: < 20% -- FOV: > 75% of the sky -- Angular resolution[2]: 10 deg x 10 deg -- VDF cadence: 1 Hz -- Mass resolution[3]: n/a Notes: [1] Energy range not required in all directions [2] Angular resolution not required in all directions [3] Mass resolution not required in all directions	**Functional Allocation**

SWEAP Measurements



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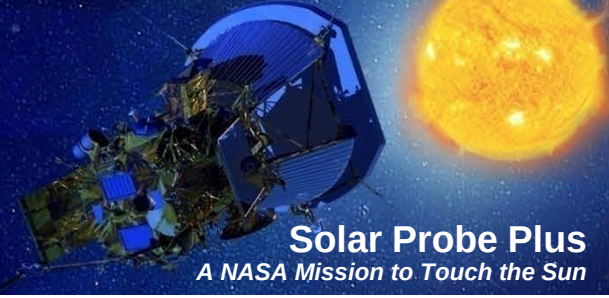
PAY-195: Measurement: Thermal Electrons Velocity Distribution Function (ram-facing)	
SPAN-A+ shall be capable of measuring thermal electrons in the ram direction over solar orbital distances of 9.86 Rs to 0.25 AU with a VDF measurement cadence of ≥ 1 Hz.	
Rationale This requirement meets Level 2 Mission Science Requirements. Velocity Distribution Function is needed to resolve structures.	**Requirement Allocation** SWEAP
Parent Traceability MRD-94 : The Mission shall measure thermal electrons, as follows: -- Energy range[1]: 5 eV – 20 keV -- Energy resolution: < 20% -- FOV: > 75% of the sky -- Angular resolution[2]: 10 deg x 10 deg -- VDF cadence: 1 Hz -- Mass resolution[3]: n/a Notes: [1] Energy range not required in all directions [2] Angular resolution not required in all directions [3] Mass resolution not required in all directions	**Functional Allocation**

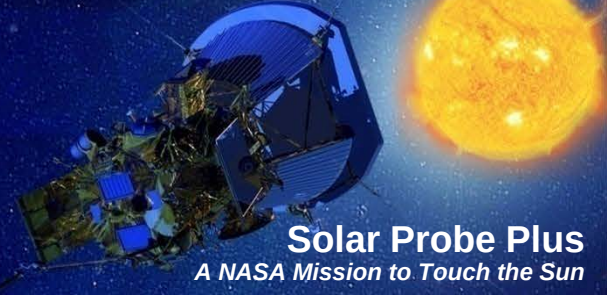
APL

SWEAP Measurements



PAY-199: Measurement: Thermal Electrons Velocity Distribution Function (anti-ram-facing)	
SPAN-B shall be capable of measuring thermal electrons in the anti-ram direction over solar orbital distances of 9.86 Rs to 0.25 AU with a VDF measurement cadence of ≥ 1 Hz.	
Rationale This requirement meets Level 2 Mission Science Requirements. Velocity Distribution Function is needed to resolve structures.	**Requirement Allocation** SWEAP
Parent Traceability MRD-94 : The Mission shall measure thermal electrons, as follows: -- Energy range[1]: 5 eV – 20 keV -- Energy resolution: < 20% -- FOV: > 75% of the sky -- Angular resolution[2]: 10 deg x 10 deg -- VDF cadence: 1 Hz -- Mass resolution[3]: n/a Notes: [1] Energy range not required in all directions [2] Angular resolution not required in all directions [3] Mass resolution not required in all directions	**Functional Allocation**

FIELDS Measurements



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PAY-37: Measurement: Magnetic Field MAG

MAG shall be capable of measuring 3D vector magnetic fields over solar orbital distances of 9.86 Rs to 0.25 AU as follows:

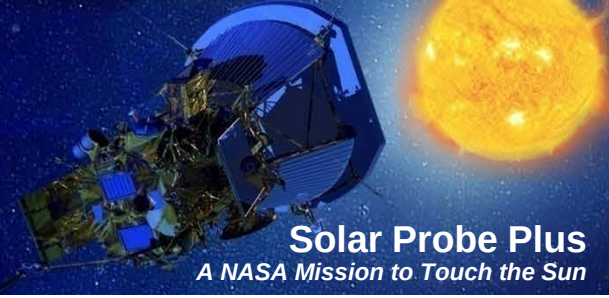
-- frequency range: DC to greater than 100 Hz;
-- maximum field intensity: -65000 to +65000 nT;
-- cadence: up to 2x the highest frequency in vectors/sec;
-- minimum sensitivity (excluding external noise sources) better than:
    4 nT in 65000 nT range;
    0.1 nT in 1000 nT range;
-- accuracy: 5 nT;
-- in three orthogonal components.

Description/Clarification

Maximum field intensity is the maximum expected value, based on HELIOS data, and extrapolating inward for solar orbital distances of 10Rs to 0.25AU. MAG will have multiple ranges to accommodate the dynamic range of expected measurements. Highest sensitivity is available in the lowest range. Sensitivity at higher ranges is limited by 16-bit ADC performance. Cadence is expressed as a peak value, average cadence in data stream will be lower.

Rationale	**Requirement Allocation**
This requirement meets Level 2 Mission Science Requirements. Frequency range must include DC, and provide at least a decade overlap with SCM.	FIELDS
Parent Traceability	**Functional Allocation**
MRD-89 : The Mission shall measure the magnetic field, as follows: -- dynamic range: 140 dB, -- cadence: 100k vectors/sec, -- bandwidth: DC – 50 kHz	

FIELDS Measurements



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PAY-38: Measurement: Magnetic Field SCM

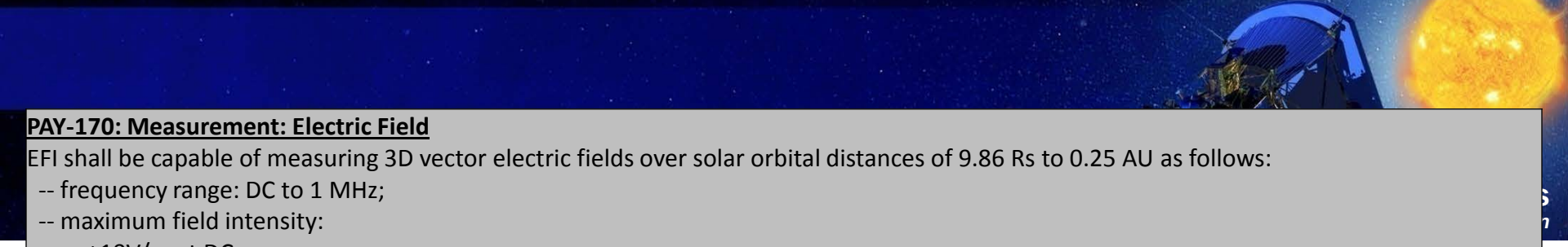
SCM shall be capable of measuring 3D vector magnetic fields over solar orbital distances of 9.86 Rs to 0.25 AU as follows:
-- frequency range: 10 Hz to greater than 50 KHz;
-- maximum field intensity: 3000nT above noise floor at 3.5kHz;
-- cadence: up to 2x the highst frequency in vectors/sec;
-- minimum sensitivity (excluding external noise sources) better than:
1 x 10^(-3) nT/sqrt(Hz) at 100 Hz;
1 x 10^(-4) nT/sqrt(Hz) at 3.5 kHz;
-- in three orthogonal components.

Description/Clarification

This is one of two identical requirements that address different Level 2 Mission Science Requirements. This requirement addresses the DC Magnetic Field measurement requirement. Maximum field intensity is the maximum expected value, based on HELIOS data, and extrapolating inward for solar orbital distances of 10Rs to 0.25AU. Minimum sensitivity is 10x the expected noise floor of the sensor, and provides margin for signal processing. Cadence is expressed as a peak value, average cadence in data stream will be lower. Dynamic range, across the spectrum of magnetic field measurements, is greater than 140dB, as required by MRD-89, and demonstrated by this example:
SCM rms noise, Ns = sqrt(3500)*1E-4nT = 5.9E-3nT.
MAG peak signal, Sm = 2*65000nT
Dynamic range = 20*log(Sm/Ns) ≥ 140dB

Rationale	**Requirement Allocation**
This requirement meets Level 2 Mission Science Requirements. The frequency range spans a decade in common with MAG, and extends up to 50kHz as required in Level 2.	FIELDS
Parent Traceability	**Functional Allocation**
MRD-89 : The Mission shall measure the magnetic field, as follows: -- dynamic range: 140 dB, -- cadence: 100k vectors/sec, -- bandwidth: DC – 50 kHz	

APL



PAY-170: Measurement: Electric Field

EFI shall be capable of measuring 3D vector electric fields over solar orbital distances of 9.86 Rs to 0.25 AU as follows:

-- frequency range: DC to 1 MHz;

-- maximum field intensity:

±10V/m at DC;

±5V/m at 20kHz;

±1V/m at 1MHz;

-- cadence: up to 2x the highest frequency in vectors/sec;

-- sensitivity (excluding power converter frequencies and external noise sources) better than:

300 µV/m (TBR) in 10V/m range at DC;

30 µV/m (TBR) in 1V/m range at DC;

1x10^(-7) V/m/sqrt(Hz) at 100kHz;

6x10^(-8) V/m/sqrt(Hz) (TBR) at 1MHz;

-- in three orthogonal components in the frequency range 100 kHz – 500 kHz.

Description/Clarification

This is one of two identical requirements that address different Level 2 Mission Science Requirements. This requirement addresses the DC Electric Field measurement requirement. Maximum field intensity is the maximum expected value, based on extrapolation of HELIOS and 1AU measurements to solar orbital distances of 10Rs to 0.25AU. EFI will have multiple ranges to accommodate the dynamic range of expected measurements. Sensitivity at the higher frequencies is set by requirement to observe shot noise of antennas and galactic thermal noise background. Sensitivity at lower frequencies limited by 16-bit ADC performance. Cadence is expressed as a peak value, average cadence in data stream will be lower. Dynamic range, across the spectrum of electric field measurements, is greater than 140dB, as required in MRD-99, and demonstrated by this example:

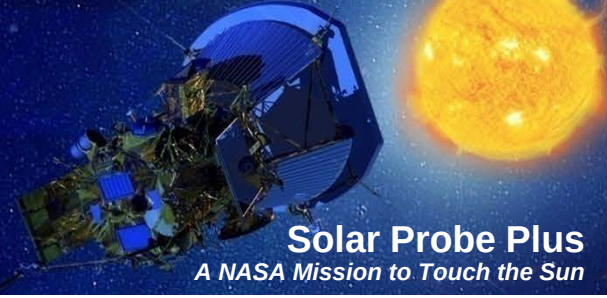
EFI rms noise in 1kHz measurement BW, Ne = sqrt(1000)*6E-8V/m = 1.9E-6V/m

EFI peak signal, Se = 2*10V/m

Dynamic range = 20*log(Se/Ne) ≥ 140dB

Rationale	**Requirement Allocation**
This requirement meets Level 2 Mission Science Requirements. Frequency range derives directly from Level 2 requirement.	FIELDS
Parent Traceability	**Functional Allocation**
MRD-99 : The Mission shall measure the electric field, as follows: -- dynamic range: 140 dB, -- cadence: 2M vectors/sec, -- bandwidth: DC – 1 MHz	

FIELDS Measurements



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PAY-171: Measurement: Plasma Waves (Magnetic Field SCM)

SCM shall be capable of measuring 3D vector magnetic fields over solar orbital distances of 9.86 Rs to 0.25 AU as follows:

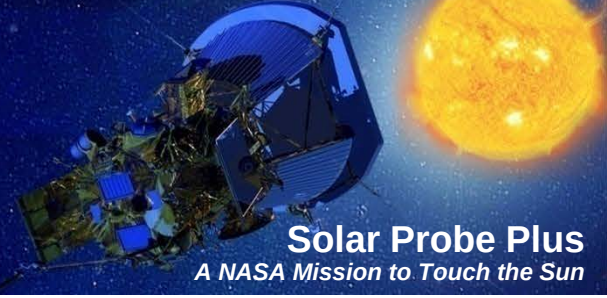
-- frequency range: 10 Hz to greater than 50 KHz;
-- maximum field intensity: 3000nT above noise floor at 3.5kHz;
-- cadence: up to 2x the highest frequency in vectors/sec;
-- minimum sensitivity (excluding external noise sources) better than :
    1 x 10^(-3) nT/sqrt(Hz) at 100 Hz;
    1 x 10^(-4) nT/sqrt(Hz) at 3.5 kHz;
-- in three orthogonal components.

Description/Clarification

This is one of two identical requirements that address different Level 2 Mission Science Requirements. This requirement addresses the Plasma Waves requirement. Cadence is expressed as a peak value, average cadence in data stream will be lower.

Rationale	**Requirement Allocation**
This requirement meets Level 2 Mission Science Requirements.	FIELDS
Parent Traceability	**Functional Allocation**
MRD-103 : The Mission shall measure the plasma waves, as follows: -- dynamic range: 140 dB, -- cadence: 1 spectrum/sec, -- bandwidth: 5 Hz – 1 MHz	

FIELDS Measurements



Solar Probe Plus
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PAY-172: Measurement: Plasma Waves (AC Magnetic Field)

SCM shall be capable of measuring AC magnetic field amplitude over solar orbital distances of 9.86 Rs to 0.25 AU as follows:

-- frequency range: 1 kHz – 1 MHz;
-- maximum field intensity: 6 nT above noise floor at 100 kHz;
-- cadence: up to 2M vectors/second;
-- sensitivity (excluding power converter frequencies and external noise sources) better than:
1 x 10^(-4) nT/sqrt(Hz) at 10 kHz;
3 x 10^(-5) nT/sqrt(Hz) at 100 kHz;
-- one component aligned with one axis of SCM-LF.

Description/Clarification

The frequency range covers the span of plasma frequencies expected for solar orbital distances of 10Rs to 0.25AU. Cadence is expressed as a peak value, average cadence in data stream will be lower.

Rationale	**Requirement Allocation**
This requirement meets Level 2 Mission Science Requirements. For plasma wave observation, at least one axis of AC magnetic field measurement is necessary to distinguish waves as electrostatic or electromagnetic.	FIELDS
Parent Traceability	**Functional Allocation**
MRD-103 : The Mission shall measure the plasma waves, as follows: -- dynamic range: 140 dB, -- cadence: 1 spectrum/sec, -- bandwidth: 5 Hz – 1 MHz	

APL

FIELDS Measurements

PAY-173: Measurement: Plasma Waves (Electric Field)

EFI shall be capable of measuring 3D vector electric fields over solar orbital distances of 9.86 Rs to 0.25 AU as follows:

-- frequency range: DC to 1 MHz;

-- maximum field intensity:

±10V/m at DC;

±5V/m at 20kHz;

±1V/m at 1MHz;

-- cadence: up to 2x the highest frequency in vectors/sec;

-- sensitivity (excluding power converter frequencies an dexternal noise sources) better than:

300 µV/m (TBR) in 10V/m range at DC;

30 µV/m (TBR) in 1V/m range at DC;

1x10^(-7) V/m/sqrt(Hz) at 100kHz;

6x10^(-8) V/m/sqrt(Hz) (TBR) at 1MHz;

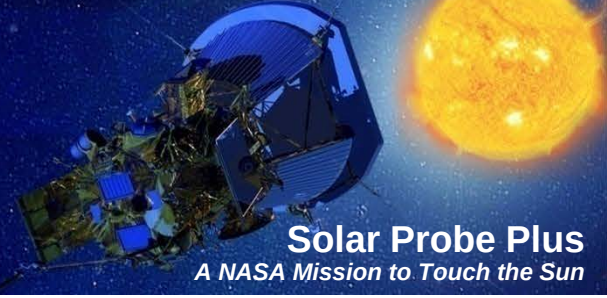
-- in three orthogonal components in the frequency range 100 kHz – 500 kHz.

Description/Clarification

This is one of two identical requirements that address different Level 2 Mission Science Requirements. This requirement addresses the Plasma Waves requirement. Cadence is expressed as a peak value, average cadence in data stream will be lower.

Rationale	**Requirement Allocation**
This requirement meets Level 2 Mission Science Requirements.	FIELDS
Parent Traceability	**Functional Allocation**
MRD-103 : The Mission shall measure the plasma waves, as follows: -- dynamic range: 140 dB, -- cadence: 1 spectrum/sec, -- bandwidth: 5 Hz – 1 MHz	

FIELDS Measurements



PAY-174: Measurement: Plasma Waves (Magnetic Field Power Spectra)

SCM shall be capable of measuring power spectra of AC magnetic fields over solar orbital distances of 9.86 Rs to 0.25 AU as follows:

-- frequency range: 10 Hz – 1 MHz;

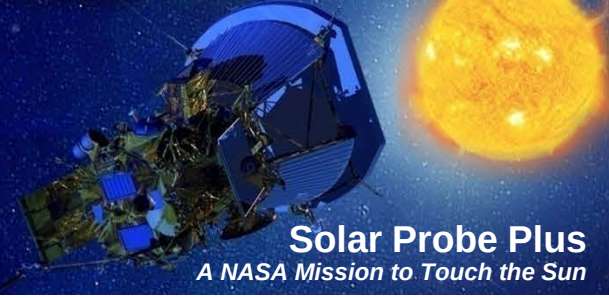
-- cadence: up to 1 spectrum/second.

Description/Clarification

Cadence is expressed as a peak value, average cadence in data stream will be lower.

Rationale	**Requirement Allocation**
This requirement meets Level 2 Mission Science Requirements. Frequency range derives directly from Level 2 requirement. At frequencies above 50kHz, the spectra can be limited to one axis.	FIELDS
Parent Traceability	**Functional Allocation**
MRD-103 : The Mission shall measure the plasma waves, as follows: -- dynamic range: 140 dB, -- cadence: 1 spectrum/sec, -- bandwidth: 5 Hz – 1 MHz	

FIELDS Measurements



PAY-272: Measurement: Plasma Waves (Electric Field Power Spectra)	
EFI shall be capable of measuring power spectra of AC electric fields from SPP over solar orbital distances of 9.86 Rs to 0.25 AU as follows: -- frequency range: 5 Hz – 1 MHz; -- cadence: up to 1 spectrum/second. ***Description/Clarification*** Cadence is expressed as a peak value, average cadence in data stream will be lower.	
Rationale This requirement meets Level 2 Mission Science Requirements. Frequency range derives directly from Level 2 requirement.	**Requirement Allocation** FIELDS
Parent Traceability MRD-103 : The Mission shall measure the plasma waves, as follows: -- dynamic range: 140 dB, -- cadence: 1 spectrum/sec, -- bandwidth: 5 Hz – 1 MHz	**Functional Allocation**

PAY-175: Measurement: Electric Field QTN Spectroscopy

EFI shall be capable of measuring QTN Spectroscopy (TNR/HFR Survey Mode) over solar orbital distances of 9.86 Rs to 0.25 AU as follows:

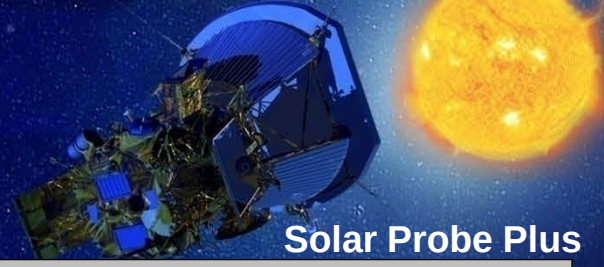
-- frequency range: 10 kHz - 2500 kHz;
-- dynamic range: 100 dB;
-- maximum field intensity: ±200mV/m at 100kHz
-- cadence: up to 1 spectrum / 4 seconds;
-- sensitivity (excluding power converter frequencies and external noise sources) better than:
    1 x 10^(-7) V/m/sqrt(Hz) at 100 kHz;
    2 x 10^(-8) V/m/sqrt(Hz) at 2 MHz;
-- in one direction.

Description/Clarification

Maximum field is derived from scaling Type III radio burst intensity inward to SPP solar orbital distances. Sensitivity is derived from requirement to observe shot noise of antennas and galactic thermal noise background. Cadence is expressed as a peak value, average cadence in data stream will be lower. Dynamic range, across the spectrum of QTN measurements, is greater than 100dB, as required in MRD-107, and demonstrated by this example:
EFI rms noise in 2kHz measurement BW, Ne = sqrt(2000)*2E-8V/m = 9E-7V/m
EFI peak signal, Se = 2*0.2V/m
Dynamic range = 20*log(Se/Ne) ≥ 100dB

Rationale	**Requirement Allocation**
This requirement meets Level 2 Mission Science Requirements. Frequency range is derived from expected variation of plasma density for solar orbital distances of 10Rs to 0.25 AU.	FIELDS
Parent Traceability	**Functional Allocation**
MRD-107 : The Mission shall measure the quasi-thermal noise, as follows: -- dynamic range: 100 dB, -- cadence: 1 spectrum / 4 sec, -- bandwidth: 10 - 2500 kHz	

FIELDS Measurements



PAY-176: Measurement: Electric Field Radio Emissions

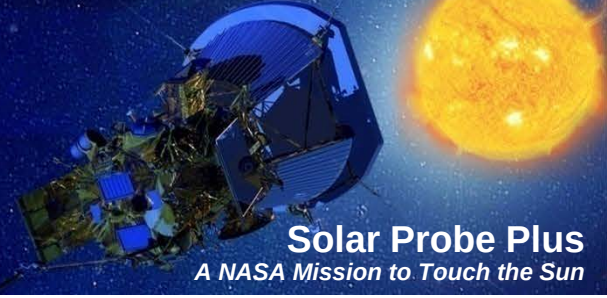
EFI shall be capable of measuring Radio Emissions over solar orbital distances of 9.86 Rs to 0.25 AU as follows:
-- frequency range: 1 MHz - 16 MHz;
-- dynamic range: 80 dB;
-- maximum field intensity: ±100mV/m at 2 MHz
-- cadence: up to 1 spectrum/16 sec;
-- sensitivity (excluding power converter frequencies and external noise sources) better than:
2 x 10^(-8) V/m/sqrt(Hz) at 2 MHz and above;
-- in two orthogonal components.

Description/Clarification

Maximum field is derived from scaling Type III radio burst intensity for solar orbital distances of 10Rs to 0.25AU.
Sensitivity is derived from requirement to observe shot noise of antennas and galactic thermal noise background.
Cadence is expressed as a peak value, average cadence in data stream will be lower. Dynamic range, across the spectrum of Radio Emissions measurement, is greater than 80dB, as required in MRD-108, and demonstrated by this example:
EFI rms noise in 20kHz BW, Ne = sqrt(20000)*2E-8V/m = 2.8E-6V/m
EFI peak signal, Se = 2*0.1V/m
Dynamic range = 20*log(Se/Ne) ≥ 100dB

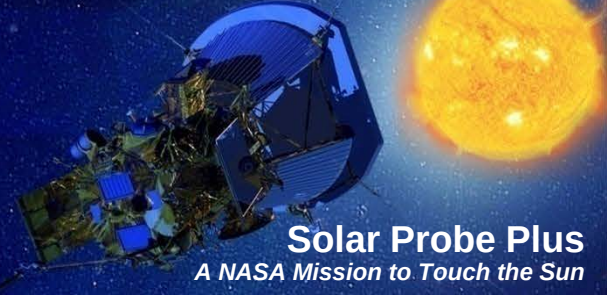
Rationale	**Requirement Allocation**
This requirement meets Level 2 Mission Science Requirements. Frequency range is derived directly from Level 2 requirement.	FIELDS
Parent Traceability	**Functional Allocation**
MRD-108 : The Mission shall measure radio emissions, as follows: -- dynamic range: 80 dB, -- cadence: 1 spectrum / 16 sec, -- bandwidth: 1 – 16 MHz	

System Operability



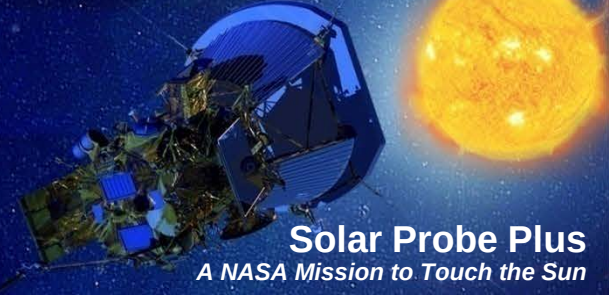
PAY-99: Payload: Minimum Perihelion	
All instruments shall be designed to provide science measurements over at least three solar encounter periods with perihelion distance of 9.86 Rs +TBD/-0 Rs from the center of the Sun.	
Rationale This requirement meets Level 2 Requirements.	**Requirement Allocation** FIELDS SWEAP WISPR ISIS
Parent Traceability MRD-20 : The Mission shall complete at least three orbits with perihelion distance of 9.5 Rs +TBD/-0 Rs from the center of the Sun.	**Functional Allocation**

System Operability



PAY-100: Payload: Minimum Perihelion Hours All instruments shall be designed to provide science measurements for at least 920 hours below 20 Rs, with at least 14 hours below 10 Rs.	
Rationale This requirement meets Level 2 Requirements, which meets baseline science requirements.	**Requirement Allocation** FIELDS SWEAP WISPR ISIS
Parent Traceability MRD-134 : The Mission shall spend 920 hours below 20 Rs, with no less than 14 hours below 10 Rs.	**Functional Allocation**

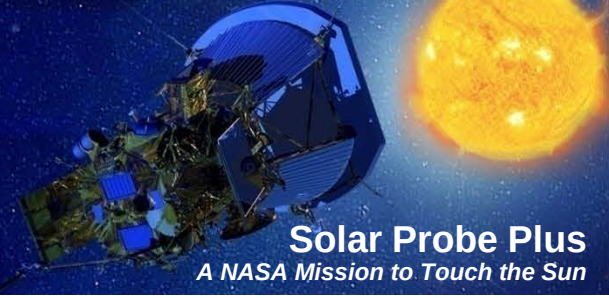
System Operability



Solar Probe Plus
A NASA Mission to Touch the Sun

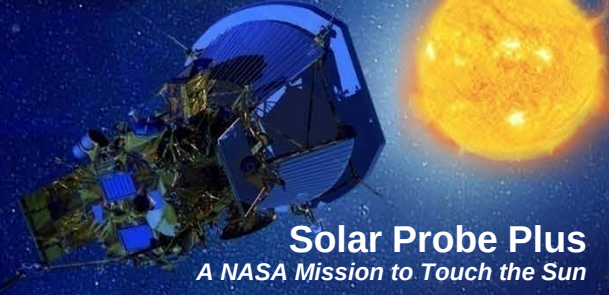
PAY-101: Payload: Mission Length All instruments shall be designed to acheive an operational lifetime of at least 7 years after launch.	
Rationale This requirement meets Level 2 Requirements. The mission is being designed for a lifetime of 7 years for spacecraft, payload, and ground system longevity purposes. This requirement meets a design decision.	**Requirement Allocation** FIELDS SWEAP WISPR ISIS
Parent Traceability MRD-22 : The Mission shall achieve minimum perihelion passes within 7 years of launch.	**Functional Allocation**

System Operability



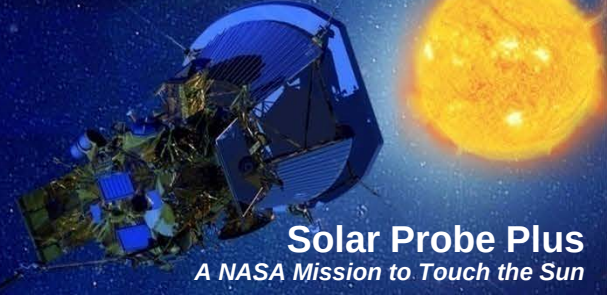
PAY-102: Payload: Launch Readiness Calibration All instruments shall be calibrated to meet instrument performance requirements prior to launch.	
Rationale This requirement meets a Level 2 Launch Readiness Date Requirement.	**Requirement Allocation** FIELDS SWEAP WISPR ISIS
Parent Traceability MRD-23 : The Mission shall be ready to launch in July, 2018.	**Functional Allocation**

System Operability



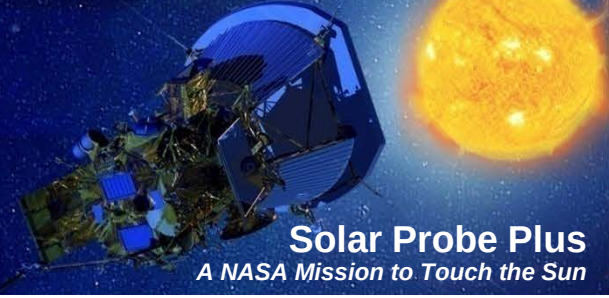
PAY-231: Payload: In-Flight Calibration All instruments shall be designed to accommodate instrument check-out/in-flight calibration. ***Description/Clarification*** The term "calibration" is used to refer to in-flight operations so instruments may best prepare for measurement modes during the science campaign.	
Rationale Instruments require check-out and in-flight calibration to acheive baseline science requirements.	**Requirement Allocation** FIELDS SWEAP WISPR ISIS
Parent Traceability	**Functional Allocation**

System Operability



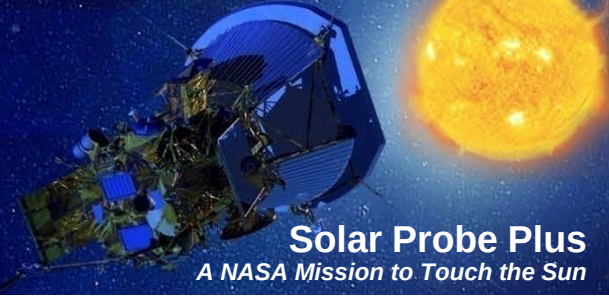
PAY-104: Payload: Risk Category FIELDS shall be single fault tolerant.	
Rationale	**Requirement Allocation** FIELDS
Parent Traceability MRD-28 : The Mission shall be designed as a Mission Category 1, per NPR 7120.5D, and Risk Category B mission, as defined in NPR 8705.4	**Functional Allocation**

System Operability



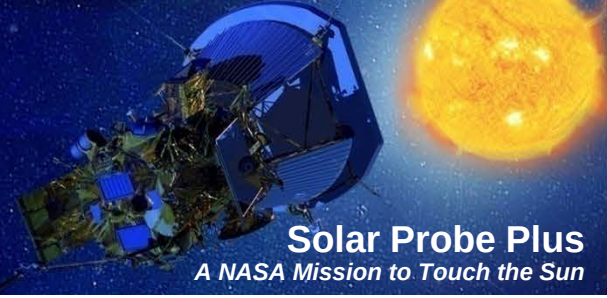
PAY-109: Payload: Burst Mode Management FIELDS shall be responsible for management of its internal burst data buffer.	
Rationale This requirement supports Level 2 Burst Mode Requirements. Internal burst data buffer management meets a design desision.	**Requirement Allocation** FIELDS
Parent Traceability MRD-29 : The Mission shall be capable of sharing a limited amount of instrument messaging information sufficient for the purposes of coordinating concentrated or focused measurement (burst mode) periods.	**Functional Allocation**

System Operability



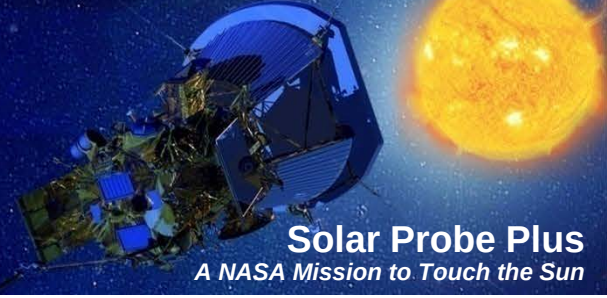
PAY-110: Payload: Burst Mode Management SWEAP shall be responsible for management of its internal burst data buffer.	
Rationale This requirement supports Level 2 Burst Mode Requirements. Internal burst data buffer management meets a design desision.	**Requirement Allocation** SWEAP
Parent Traceability MRD-29 : The Mission shall be capable of sharing a limited amount of instrument messaging information sufficient for the purposes of coordinating concentrated or focused measurement (burst mode) periods.	**Functional Allocation**

System Operability



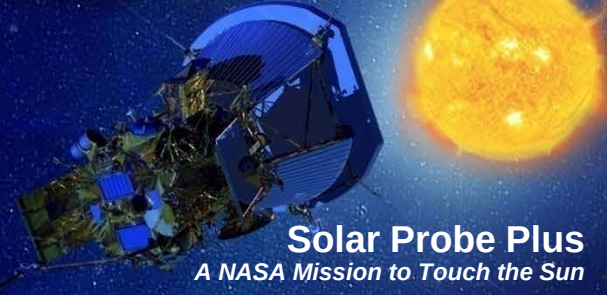
PAY-112: Payload: Flight Software Modification All instruments shall be capable of modifying operational flight software and/or change calibration coefficients or tables in response to respective SOC instrument commands.	
Rationale This capability is required for anomaly investigations.	**Requirement Allocation** FIELDS SWEAP WISPR ISIS
Parent Traceability	**Functional Allocation**

Timekeeping



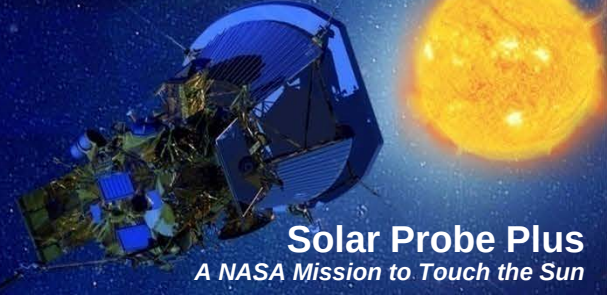
PAY-113: Timekeeping: FIELDS Time Knowledge Accuracy	
FIELDS shall limit internal instrument timing uncertainty to +/- 2 msec (3-sigma) (TBR) relative to the most recently received Spacecraft time reference.	
Rationale This requirement meets Level 2 Requirements.	**Requirement Allocation** FIELDS
Parent Traceability MRD-34 : The Mission shall ensure that the absolute time knowledge accuracy for measurements made by the FIELDS instruments is to within +/- 1 second (3-sigma) after post-processing on the ground when the spacecraft is within 0.25 AU of the Sun.	**Functional Allocation**

Timekeeping



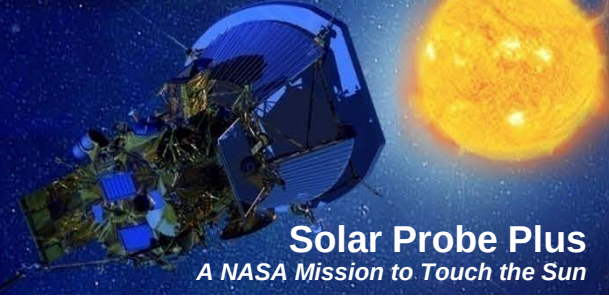
PAY-115: Timekeeping: SWEAP Time Knowledge Accuracy SWEAP shall limit internal instrument timing uncertainty to +/- 2 msec (3-sigma) (TBR) relative to the most recently received Spacecraft time reference.	
Rationale This requirement meets Level 2 Requirements.	**Requirement Allocation** SWEAP
Parent Traceability MRD-36 : The Mission shall ensure that the absolute time knowledge accuracy for measurements made by the SWEAP instruments is to within +/- 1 second (3-sigma) after post-processing on the ground when the spacecraft is within 0.25 AU of the Sun.	**Functional Allocation**

Timekeeping



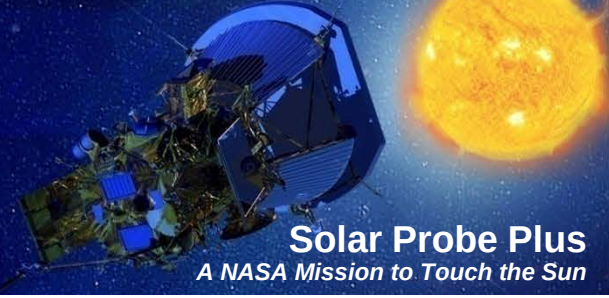
PAY-116: Timekeeping: WISPR Time Knowledge Accuracy WISPR shall limit internal instrument timing uncertainty to +/- 2 msec (3-sigma) (TBR) relative to the most recently received Spacecraft time reference.	
Rationale This requirement meets Level 2 Requirements.	**Requirement Allocation** WISPR
Parent Traceability MRD-37 : The Mission shall ensure that the absolute time knowledge accuracy for measurements made by the WISPR instruments is to within +/- 1 second (3-sigma) after post-processing on the ground when the spacecraft is within 0.25 AU of the Sun.	**Functional Allocation**

Timekeeping



PAY-114: Timekeeping: ISIS Time Knowledge Accuracy ISIS shall limit internal instrument timing uncertainty to +/- 2 msec (3-sigma) (TBR) relative to the most recently received Spacecraft time reference.	
Rationale This requirement meets Level 2 Requirements.	**Requirement Allocation** ISIS
Parent Traceability MRD-35 : The Mission shall ensure that the absolute time knowledge accuracy for measurements made by the ISIS instruments is to within +/- 1 second (3-sigma) after post-processing on the ground when the spacecraft is within 0.25 AU of the Sun.	**Functional Allocation**

Timekeeping



PAY-117: Timekeeping: Support for Accuracy Verification All instruments shall include provisions to support verification during Observatory I&T that the absolute time accuracy requirements are satisfied.	
Rationale This requirement meets Level 2 Requirements.	**Requirement Allocation** FIELDS SWEAP WISPR ISIS
Parent Traceability MRD-157 : The Mission shall include provisions to support verification during Observatory I&T that the absolute time accuracy requirements are satisfied.	**Functional Allocation**

Data Post-Processing & Delivery

PAY-132: CDH Data Delivery: SDMP

All Science Operations Centers shall provide inputs to a NASA Headquarters-approved Science Data Management Plan, as defined in [each instrument's CDRL's, TBR].

Description/Clarification

This information is further detailed in the Science Data Management Plan. The verifiable requirement is carried in this document.

Rationale	**Requirement Allocation**
This requirement meets Level 2 Requirements.	FIELDS SWEAP WISPR ISIS
Parent Traceability	**Functional Allocation**
MRD-66 : The Mission shall create, update and adhere to a NASA Headquarters-approved Science Data Management Plan that specifies file contents, metadata, formats, standards, schedule and pathways for public data access, and the destination of the data upon mission termination.	

Data Post-Processing & Delivery

PAY-133: CDH Data Delivery: Quick-Look Data	
All Science Operations Centers shall provide for public dissemination a quick-look processed version of science data (e.g. thumbnails) within 6 months (TBR) of downlink for the first three orbits after launch and 60 days (TBR) of downlink thereafter. ***Description/Clarification*** This information is further detailed in the Science Data Management Plan. The verifiable requirement is carried in this document.	
Rationale This requirement meets Level 2 Requirements.	**Requirement Allocation** FIELDS SWEAP WISPR ISIS
Parent Traceability MRD-58 : The Mission shall ensure that each SOC provides for public dissemination a quick-look processed version of science data (e.g. thumbnails) within 60 days (TBR) of downlink.	**Functional Allocation**

Data Post-Processing & Delivery

PAY-134: CDH Data: Data Sharing All Science Operations Centers shall be capable of sharing data with other SPP instrument teams to support data analysis as specified in the Science Data Management Plan (7434-9101). ***Description/Clarification*** This information is further detailed in the Science Data Management Plan. The verifiable requirement is carried in this document.	
Rationale This requirement meets Level 2 Requirements.	**Requirement Allocation** FIELDS SWEAP WISPR ISIS
Parent Traceability MRD-59 : The Mission shall be capable of sharing data between instrument teams to support data analysis as specified in the Science Data Management Plan (7434-9101).	**Functional Allocation**

Data Post-Processing & Delivery

PAY-135: CDH Data: Engineering Data Sharing

All Science Operations Centers shall be capable of sharing ancillary engineering information necessary to validate and calibrate science data sets with all investigation teams prior to depositing them in a NASA approved data repository.

Description/Clarification

This information is further detailed in the Science Data Management Plan. The verifiable requirement is carried in this document.

Rationale	**Requirement Allocation**
This requirement meets Level 2 Requirements.	FIELDS SWEAP WISPR ISIS
Parent Traceability	**Functional Allocation**
MRD-60 : The Mission shall be capable of sharing ancillary engineering information necessary to validate and calibrate science data sets to all investigation teams prior to depositing them in a NASA approved data repository.	

Data Post-Processing & Delivery

PAY-136: CDH Data: Public Dissemination

All Science Operations Centers shall provide processed science data obtained as part of the SPP mission to the public no later than 6 months (TBR) from downlink of all a given encounter's data.

Description/Clarification

This information is further detailed in the Science Data Management Plan. The verifiable requirement is carried in this document.

Rationale	**Requirement Allocation**
This requirement meets Level 2 Requirements.	FIELDS SWEAP WISPR ISIS
Parent Traceability	**Functional Allocation**
MRD-61 : The Mission shall ensure that each SPP science investigation provides processed science data obtained as part of the SPP mission to the public no later than 6 months (TBR) from downlink of all a given encounter's data.	

Data Post-Processing & Delivery

PAY-137: CDH Data Delivery: Data Retention at MOC

All Science Operations Centers shall maintain all instrument telemetry & all associated data products throughout the duration of the operational phase of the mission plus one year (TBR).

Description/Clarification

This information is further detailed in the Science Data Management Plan. The verifiable requirement is carried in this document.

Rationale	**Requirement Allocation**
This requirement meets Level 2 Requirements.	FIELDS SWEAP WISPR ISIS
Parent Traceability	**Functional Allocation**
MRD-63 : The Mission shall ensure that all instrument telemetry received by the MOC, all associated ancillary data products generated by the ground system, and any processed science data products received by the MOC at any point in the mission life cycle are retained at the MOC throughout the duration of the operational phase of the mission plus one year (TBR).	

Data Post-Processing & Delivery

PAY-138: CDH Data Delivery: Data Retention at SOCs All Science Operations Centers shall maintain a data archive of its instrument science, documentation, software and science data products for the life of the mission plus one year (TBR). ***Description/Clarification*** This information is further detailed in the Science Data Management Plan. The verifiable requirement is carried in this document.	
Rationale This requirement meets Level 2 Requirements.	**Requirement Allocation** FIELDS SWEAP WISPR ISIS
Parent Traceability MRD-64 : The Mission shall ensure that each SOC maintains a data archive of its instrument science, documentation, software and science data products for the life of the mission plus one year (TBR).	**Functional Allocation**

Data Post-Processing & Delivery

PAY-139: CDH Data Delivery: Data Delivery to NASA

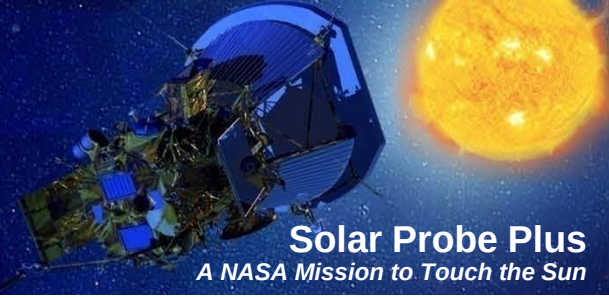
All Science Operations Centers shall deliver its data archive from the operational phase of the mission to a NASA-designated location for a deep data archive within 12 months (TBR) of completion of the operational phase of the mission.

Description/Clarification

This information is further detailed in the Science Data Management Plan. The verifiable requirement is carried in this document.

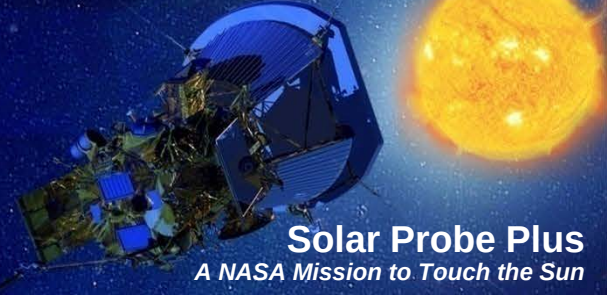
Rationale	**Requirement Allocation**
This requirement meets Level 2 Requirements.	FIELDS SWEAP WISPR ISIS
Parent Traceability	**Functional Allocation**
MRD-65 : The Mission shall ensure that each science investigation team delivers their respective data archive from the operational phase of the mission to a NASA-designated location for a deep data archive within 12 months (TBR) of completion of the operational phase of the mission.	

Environment



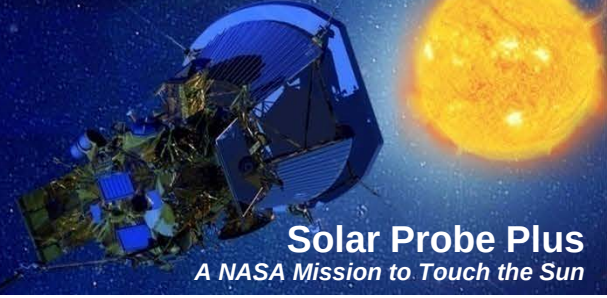
PAY-142: TSA: SPC Thermal Load SPC shall be designed such that the thermal load to the TSA is no more than 25 W and no less than 0 W, including 30% margin.	
Rationale This requirement meets thermal constraints on the Spacecraft subsystems.	**Requirement Allocation** SWEAP
Parent Traceability	**Functional Allocation**

Environment



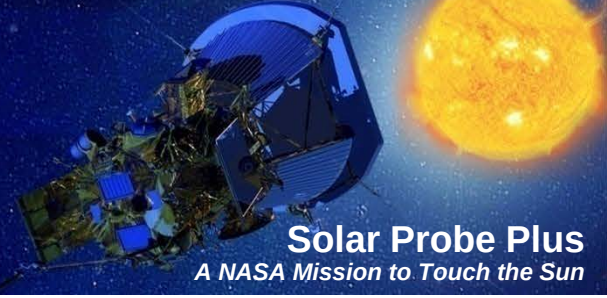
PAY-143: Cooling System: SPC Thermal Load SPC shall be designed such that the thermal load to the Cooling System is no more than 65 W, including 30% margin.	
Rationale This requirement meets thermal constraints on the Spacecraft subsystems.	**Requirement Allocation** SWEAP
Parent Traceability	**Functional Allocation**

Environment



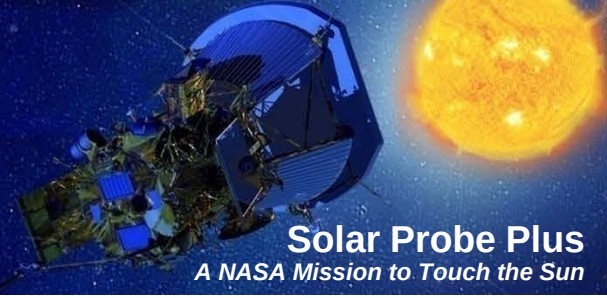
PAY-144: Spacecraft: SPC Thermal Load SPC shall be designed such that the thermal load to the Spacecraft bus is no more than 0W and no less than 0 W, ±1 W.	
Rationale This requirement meets thermal constraints on the Spacecraft subsystems.	**Requirement Allocation** SWEAP
Parent Traceability	**Functional Allocation**

Environment



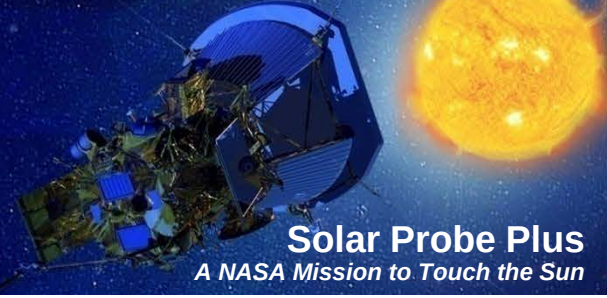
PAY-145: TSA: Antennas Thermal Load FIELDS shall be designed such that the thermal load from the antennas to the TSA is no more than 25 W and no less than 0W, including 30% margin (total for all 4 instruments).	
Rationale This requirement meets thermal constraints on the Spacecraft subsystems.	**Requirement Allocation** FIELDS
Parent Traceability	**Functional Allocation**

Environment



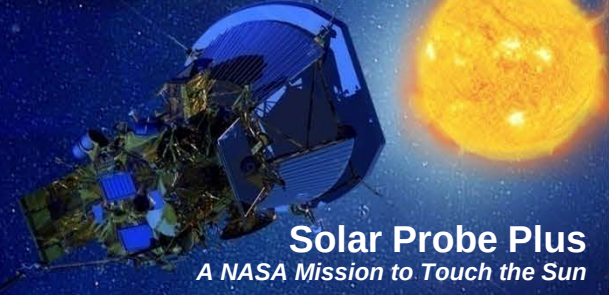
PAY-146: Cooling System: Antennas Thermal Load FIELDS shall be designed such that the thermal load from the antennas to the Cooling System is no more than 35 W, including 30% margin (total for all 4 instruments).	
Rationale This requirement meets thermal constraints on the Spacecraft subsystems.	**Requirement Allocation** FIELDS
Parent Traceability	**Functional Allocation**

Environment



PAY-147: Spacecraft: Antennas Thermal Load	
FIELDS shall be designed such that the thermal load from the antennas to the Spacecraft bus is no more than 6W and no less than 1W, including 30% margin (total for all 4 instruments).	
Rationale This requirement meets thermal constraints on the Spacecraft subsystems.	**Requirement Allocation** FIELDS
Parent Traceability	**Functional Allocation**

Environment



PAY-292: Solar Storm Event Operability

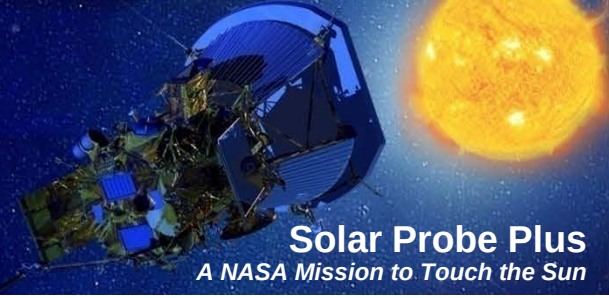
All instruments shall be capable of continuing to acquire science data during solar storm events, as defined by Cases TBR in Sections TBR of the EDTRD.

Description/Clarification

It is understood that the instrument may lose the ability to function during the solar storm, depending on storm intensity, saturation, etc. It is not required that instruments always continue to meet performance requirements (such as signal-to-noise ratio) during these larger storm events. The expected verification activity is Analysis.

Rationale	**Requirement Allocation** FIELDS SWEAP WISPR ISIS
Parent Traceability	**Functional Allocation**

Compliance



PAY-274: Compliance: SPP Instrument Shared Data Document

All instruments shall comply with the requirements and constraints imposed by the SPP Instrument Shared Data Document 7434-XXXX.

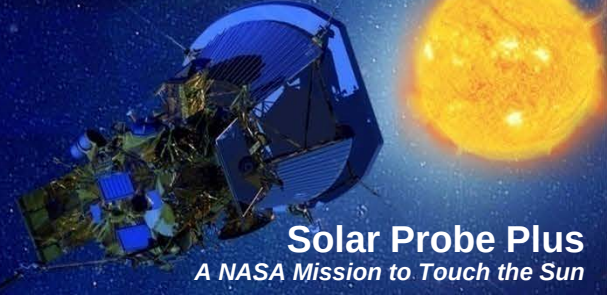
Description/Clarification

The SPP Project Office and the science investigations will collaborate to define these requirements. The requirements will be approved per SCS-SPP-005. This requirement will only be verified once relevant requirements in the referenced document are verified. Relevant requirements include (but are not limited to):

- the capability to share instrument messaging information;
- the capability to generate and send Instrument Status Packets to the Spacecraft.

Rationale	**Requirement Allocation**
The referenced document contains verifiable requirements that are relevant to instruments.	FIELDS SWEAP WISPR ISIS
Parent Traceability	**Functional Allocation**
MRD-29 : The Mission shall be capable of sharing a limited amount of instrument messaging information sufficient for the purposes of coordinating concentrated or focused measurement (burst mode) periods.	

Compliance



PAY-276: Compliance: General Instrument Specification

All instruments shall comply with the requirements and constraints imposed by the General Instrument ICD 7434-XXXX.

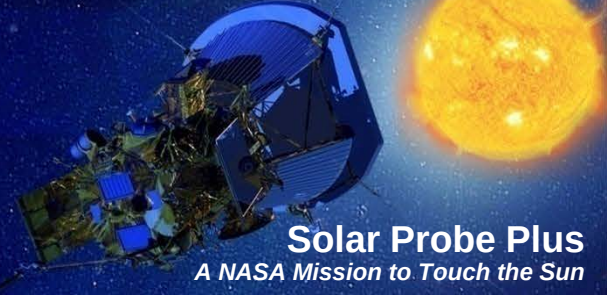
Description/Clarification

The SPP Project Office and the science investigations will collaborate to define these requirements. The requirements will be approved per SCS-SPP-005. This requirement will only be verified once relevant requirements in the referenced document are verified. Relevant requirements include (but are not limited to):

- a design in accordance with the Spacecraft coordinate system;
- the capability to receive and react to Spacecraft time & status packets;
- a design that accommodates real-time communications during instrument commissioning.

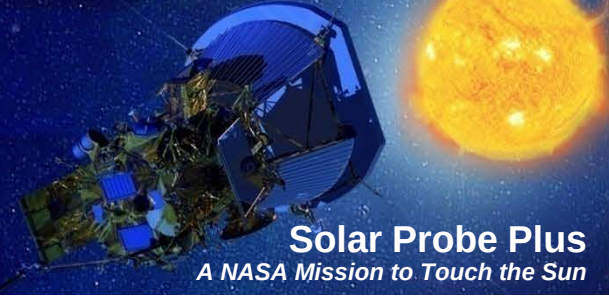
Rationale	**Requirement Allocation**
The referenced document contains verifiable requirements that are relevant to instruments.	FIELDS SWEAP WISPR ISIS
Parent Traceability	**Functional Allocation**
MRD-53 : The Mission shall provide real-time communication during instrument commissioning. MRD-75 : The Mission shall provide a means to recover to an operational state from critical faults. MRD-115 : The Mission shall provide an indicator to instruments prior to firing a thruster.	

Compliance



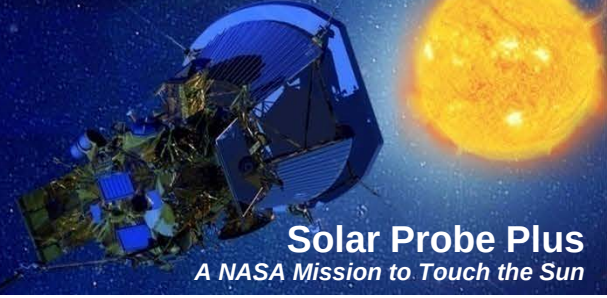
PAY-277: Compliance: FIELDS to SWEAP ICD (FIELDS)	
FIELDS shall comply with the requirements and constraints imposed by the FIELDS to SWEAP ICD #XXXX. ***Description/Clarification*** This requirement will only be verified once relevant requirements in the referenced document are verified. Relevant requirements include (but are not limited to): • responsibility for the exchange of synchronized real time data with the SWEAP instrument.	
Rationale The referenced document contains verifiable requirements that are relevant to instruments.	**Requirement Allocation** FIELDS
Parent Traceability MRD-29 : The Mission shall be capable of sharing a limited amount of instrument messaging information sufficient for the purposes of coordinating concentrated or focused measurement (burst mode) periods.	**Functional Allocation**

Compliance



PAY-278: Compliance: FIELDS to SWEAP ICD (SWEAP)	
SWEAP shall comply with the requirements and constraints imposed by the FIELDS to SWEAP ICD #XXXX. ***Description/Clarification*** This requirement will only be verified once relevant requirements in the referenced document are verified. Relevant requirements include (but are not limited to): • responsibility for the exchange of synchronized real time data with the FIELDS instrument.	
Rationale The referenced document contains verifiable requirements that are relevant to instruments.	**Requirement Allocation** SWEAP
Parent Traceability MRD-29 : The Mission shall be capable of sharing a limited amount of instrument messaging information sufficient for the purposes of coordinating concentrated or focused measurement (burst mode) periods.	**Functional Allocation**

Compliance



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PAY-279: Compliance: FIELDS to Spacecraft ICD

FIELDS shall comply with the requirements and constraints imposed by the FIELDS to Spacecraft ICD 7434-9055.

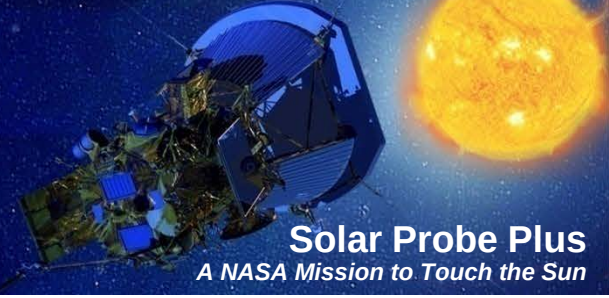
Description/Clarification

The SPP Project Office and the science investigations will collaborate to define these requirements. The requirements will be approved per SCS-SPP-005. This requirement will only be verified once relevant requirements in the referenced document are verified. Relevant requirements include (but are not limited to):

- a design with a total internal alignment error as described;
- the capability to provide real-time instrument health and status data in telemetry formats as described;
- the capability to provide data to the Spacecraft for downlink in volumes as described;
- the capability to provide data to the Spacecraft in CCSDS-compliant packets;
- compliance with maximum mass and power constraints;
- a design that imparts a torque as described;
- a design that accommodates FOV obstructions as described;
- a design that compensates for possible shifts of the Spacecraft TPS prior to launch.

Rationale	**Requirement Allocation**
The referenced document contains verifiable requirements that are relevant to instruments.	FIELDS
Parent Traceability MRD-49 : The Mission shall be capable of supporting real-time commands. MRD-52 : The Mission shall provide an average of 85 (TBR) Gbits of science data per orbit to the ground. MRD-112 : The Mission shall be capable of pointing the spacecraft +z axis to within 3 degrees (TBR) (3-sigma) to the Sun, for FIELDS accuracy, during science measurements, within solar distances less than 0.25 AU. MRD-158 : The Mission shall be capable of determining spacecraft pointing knowledge relative to the Sun center to within 1 degree (TBR) (3-sigma) during FIELDS science data collection, within solar distances less than 0.25 AU.	**Functional Allocation**

Compliance



PAY-280: Compliance: SWEAP to Spacecraft ICD

SWEAP shall comply with the requirements and constraints imposed by the SWEAP to Spacecraft ICD 7434-9056.

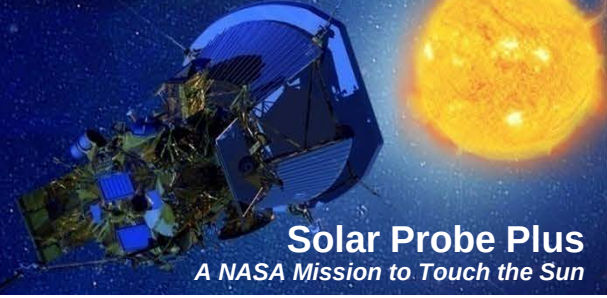
Description/Clarification

The SPP Project Office and the science investigations will collaborate to define these requirements. The requirements will be approved per SCS-SPP-005. This requirement will only be verified once relevant requirements in the referenced document are verified. Relevant requirements include (but are not limited to):

- a design with a total internal alignment error as described;
- the capability to provide real-time instrument health and status data in telemetry formats as described;
- the capability to provide data to the Spacecraft for downlink in volumes as described;
- the capability to provide data to the Spacecraft in CCSDS-compliant packets;
- compliance with maximum mass and power constraints;
- a design that imparts a torque as described;
- a design that accommodates FOV obstructions as described;
- a design that compensates for possible shifts of the Spacecraft TPS prior to launch.

Rationale	**Requirement Allocation**
The referenced document contains verifiable requirements that are relevant to instruments.	SWEAP
Parent Traceability MRD-49 : The Mission shall be capable of supporting real-time commands. MRD-52 : The Mission shall provide an average of 85 (TBR) Gbits of science data per orbit to the ground. MRD-114 : The Mission shall be capable of determining spacecraft pointing knowledge relative to the Sun center to within 1 degree (TBR) (3-sigma) during SWEAP science data collection, within solar distances less than 0.25 AU.	**Functional Allocation**

Compliance



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PAY-281: Compliance: WISPR to Spacecraft ICD

WISPR shall comply with the requirements and constraints imposed by the WISPR to Spacecraft ICD 7434-9057.

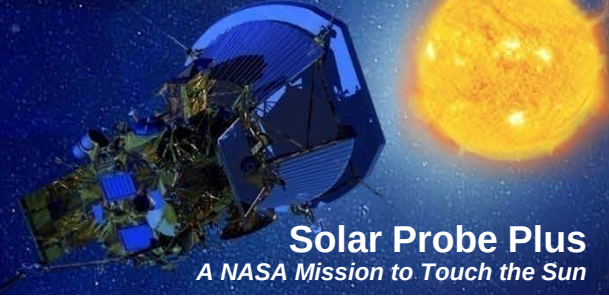
Description/Clarification

The SPP Project Office and the science investigations will collaborate to define these requirements. The requirements will be approved per SCS-SPP-005. This requirement will only be verified once relevant requirements in the referenced document are verified. Relevant requirements include (but are not limited to):

- a design with a total internal alignment error as described;
- the capability to provide real-time instrument health and status data in telemetry formats as described;
- the capability to provide data to the Spacecraft for downlink in volumes as described;
- the capability to provide data to the Spacecraft in CCSDS-compliant packets;
- a design that accommodates FOV obstructions as described;
- compliance with maximum mass and power constraints.

Rationale	**Requirement Allocation**
The referenced document contains verifiable requirements that are relevant to instruments.	WISPR
Parent Traceability MRD-43 : The Mission shall be capable of pointing the WISPR instrument to an accuracy of 6 arcmin (TBR) (3-sigma) relative to WISPR optical z axis and 60 arcmin (TBR) (3-sigma) about the WISPR optical z axis for a spacecraft solar distance <= 0.25 AU. MRD-49 : The Mission shall be capable of supporting real-time commands. MRD-52 : The Mission shall provide an average of 85 (TBR) Gbits of science data per orbit to the ground. MRD-140 : The Mission shall be capable of determining spacecraft pointing knowledge relative to the Sun center to within 1.2 arcmin (TBR) (3-sigma) relative to the WISPR optical z axis and 3.4 arcmin (TBR) (3-sigma) about the WISPR optical z axis. The following image displays the WISPR instrument as defined in Document 7434-XXXX (TBD). In the case of a conflict, Document 7434-XXXX shall take precedence.	**Functional Allocation**

Compliance



PAY-282: Compliance: ISIS to Spacecraft ICD

ISIS shall comply with the requirements and constraints imposed by the ISIS to Spacecraft ICD 7434-9058.

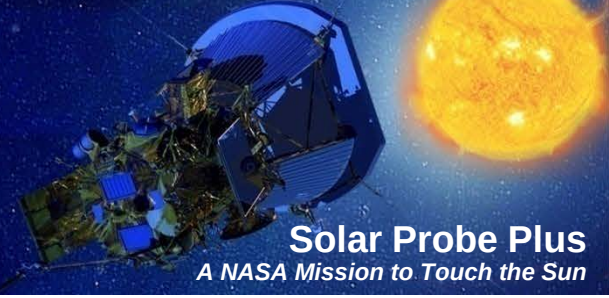
Description/Clarification

The SPP Project Office and the science investigations will collaborate to define these requirements. The requirements will be approved per SCS-SPP-005. This requirement will only be verified once relevant requirements in the referenced document are verified. Relevant requirements include (but are not limited to):

- a design with a total internal alignment error as described;
- the capability to provide real-time instrument health and status data in telemetry formats as described;
- the capability to provide data to the Spacecraft for downlink in volumes as described;
- the capability to provide data to the Spacecraft in CCSDS-compliant packets;
- a design that accommodates FOV obstructions as described;
- compliance with maximum mass and power constraints.

Rationale	**Requirement Allocation**
The referenced document contains verifiable requirements that are relevant to instruments.	ISIS
Parent Traceability MRD-49 : The Mission shall be capable of supporting real-time commands. MRD-52 : The Mission shall provide an average of 85 (TBR) Gbits of science data per orbit to the ground. MRD-113 : The Mission shall be capable of pointing the spacecraft +z axis to within 2 degrees (TBR) (3-sigma) to the Sun, for ISIS accuracy, during science measurements, within solar distances less than 0.25 AU. MRD-159 : The Mission shall be capable of determining spacecraft pointing knowledge relative to the Sun center to within 1 degree (TBR) (3-sigma) during ISIS science data collection, within solar distances less than 0.25 AU.	**Functional Allocation**

Compliance



PAY-283: Compliance: MOC to SOC ICD

All instruments shall comply with the requirements and constraints imposed by the MOC to SOC ICD 7434-9078.

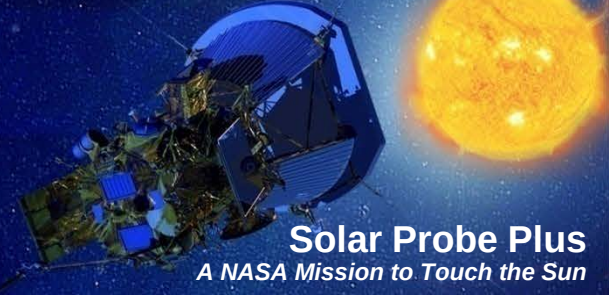
Description/Clarification

The SPP Project Office and the science investigations will collaborate to define these requirements. The requirements will be approved per SCS-SPP-005. This requirement will only be verified once relevant requirements in the referenced document are verified. Relevant requirements include (but are not limited to):

- the capability to implement real-time commands via CCSDS packets in files uplinked via CFDP;
- operations in accordance with described procedures for science operations.

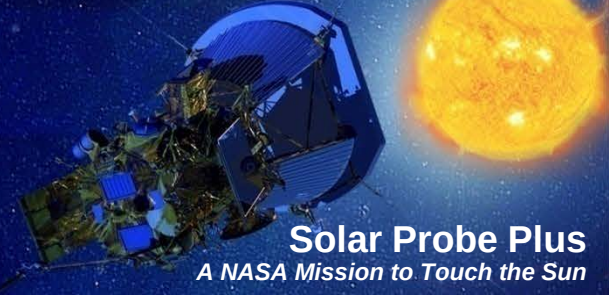
Rationale	**Requirement Allocation**
The referenced document contains verifiable requirements that are relevant to instruments.	FIELDS SWEAP WISPR ISIS
Parent Traceability	**Functional Allocation**
MRD-49 : The Mission shall be capable of supporting real-time commands.	

Compliance



PAY-140: Compliance: EMECP All instruments shall comply with the requirements and constraints imposed by the SPP Electromagnetic Environment Control Plan, 7434-9040. ***Description/Clarification*** The SPP Project Office and the science investigations will collaborate to define these requirements. The requirements will be approved per SCS-SPP-005.	
Rationale The referenced document contains verifiable requirements that are relevant to instruments.	**Requirement Allocation** FIELDS SWEAP WISPR ISIS
Parent Traceability MRD-67 : The Mission shall comply with the requirements and constraints imposed by the SPP Electromagnetic Environment Control Plan, 7434-9040.	**Functional Allocation**

Compliance



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PAY-141: Compliance: EDTRD

All instruments shall comply with the requirements and constraints imposed by the SPP Environmental Design and Test Requirements Document, 7434-9039.

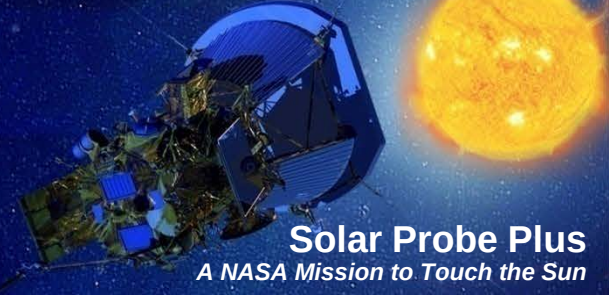
Description/Clarification

The SPP Project Office and the science investigations will collaborate to define these requirements. The requirements will be approved per SCS-SPP-005. This requirement will only be verified once relevant requirements in the referenced document are verified. Relevant requirements include (but are not limited to):

- tolerance to Spacecraft reorientation;
- compliance with solar environment conditions;

Rationale	**Requirement Allocation**
The referenced document contains verifiable requirements that are relevant to instruments.	FIELDS SWEAP WISPR ISIS
Parent Traceability	**Functional Allocation**
MRD-47 : The Mission shall be capable of supporting instrument and spacecraft component calibration and commissioning activities within sun safety and other operational constraints (TBD). MRD-68 : The Mission shall comply with the requirements and constraints imposed by the SPP Environmental Design and Test Requirements Document, 7434-9039.	

Compliance



PAY-148: Compliance: CCP All instruments shall comply with the requirements and constraints imposed by the SPP Contamination Control Plan, 7434-9011. ***Description/Clarification*** The SPP Project Office and the science investigations will collaborate to define these requirements. The requirements will be approved per SCS-SPP-005.	
Rationale The referenced document contains verifiable requirements that are relevant to instruments.	**Requirement Allocation** FIELDS SWEAP WISPR ISIS
Parent Traceability MRD-69 : The Mission shall comply with the requirements and constraints imposed by the SPP Contamination Control Plan, 7434-9011.	**Functional Allocation**

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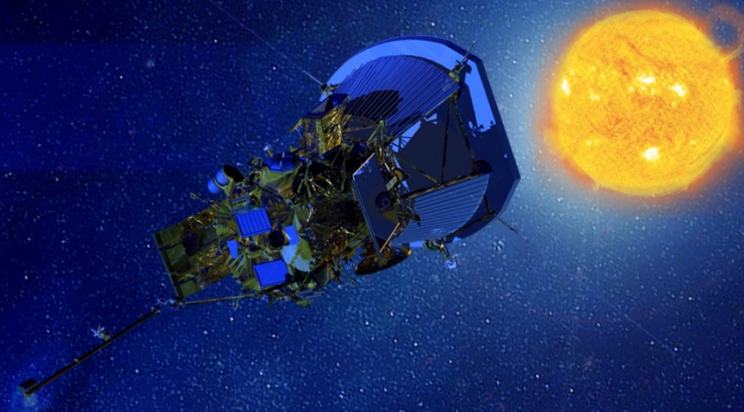
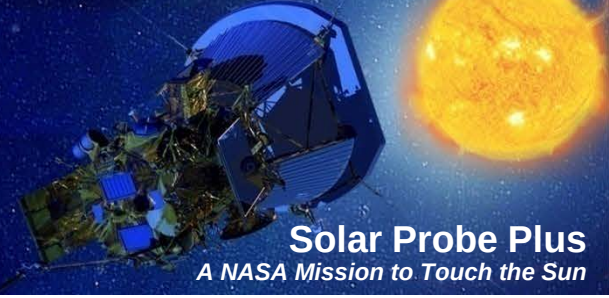


Backup

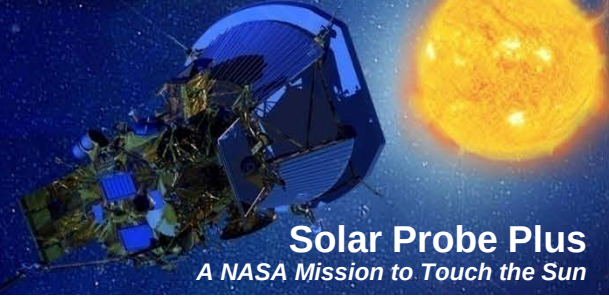
The Johns Hopkins University
APPLIED PHYSICS LABORATORY

Instrument Data Sharing



PAY-105: Payload: FIELDS Burst Mode	
FIELDS shall be capable of sharing a limited amount of instrument messaging information sufficient for the purposes of coordinating concentrated or focused measurement (burst mode) periods, as defined in the SPP Instrument Shared Data Document 7434-XXXX (TBR). *Description/Clarification* This is a placeholder requirement. It will likely be kept in the SPP Instrument Shared Data Plan. It is being held here currently.	
Rationale This requirement meets Level 2 Requirements. FIELDS will be participating in Burst Mode data sharing.	**Requirement Allocation** FIELDS
Parent Traceability	**Functional Allocation**

Instrument Data Sharing



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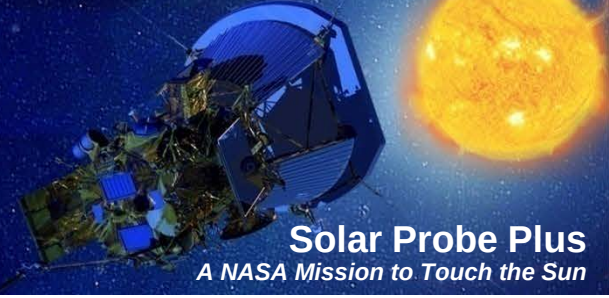
PAY-211: Payload: SWEAP Burst Mode	
SWEAP shall be capable of sharing a limited amount of instrument messaging information sufficient for the purposes of coordinating concentrated or focused measurement (burst mode) periods, as defined in the SPP Instrument Shared Data Document 7434-XXXX (TBR). *Description/Clarification* This is a placeholder requirement. It will likely be kept in the SPP Instrument Shared Data Plan. It is being held here currently.	
Rationale This requirement meets Level 2 Requirements. SWEAP will be participating in Burst Mode data sharing.	**Requirement Allocation** SWEAP
Parent Traceability	**Functional Allocation**

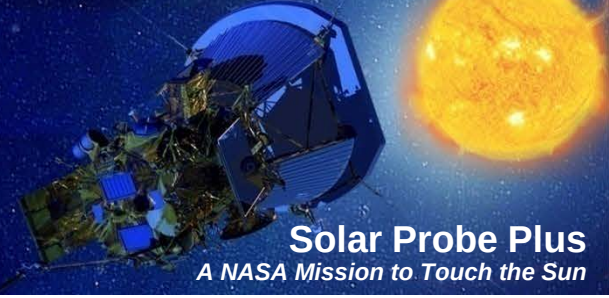
APL

Instrument Data Sharing



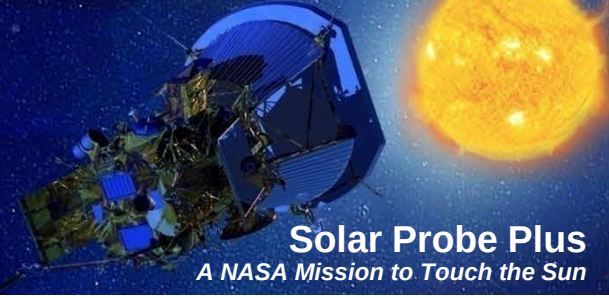
PAY-215: Payload: ISIS Burst Mode	
ISIS shall be capable of sharing a limited amount of instrument messaging information sufficient for the purposes of coordinating concentrated or focused measurement (burst mode) periods, as defined in the SPP Instrument Shared Data Document 7434-XXXX (TBR). *Description/Clarification* This is a placeholder requirement. It will likely be kept in the SPP Instrument Shared Data Plan. It is being held here currently.	
Rationale This requirement meets Level 2 Requirements. ISIS will be participating in Burst Mode data sharing.	**Requirement Allocation** ISIS
Parent Traceability	**Functional Allocation**

Instrument Data Sharing



PAY-106: Payload: FIELDS Status Packets	
FIELDS shall be capable of generating and sending CCSDS Instrument Status Packets to the Spacecraft at a rate of 1 packet per second that includes instrument status and shared burst data, as defined in the SPP Instrument Shared Data Document 7434-XXXX (TBR). *Description/Clarification* This is a placeholder requirement. It will likely be kept in the SPP Instrument Shared Data Plan. It is being held here currently.	
Rationale This requirement meets Level 2 Requirements. CCSDS is the protocol by which status packets are sent.	**Requirement Allocation** FIELDS
Parent Traceability	**Functional Allocation**

Instrument Data Sharing



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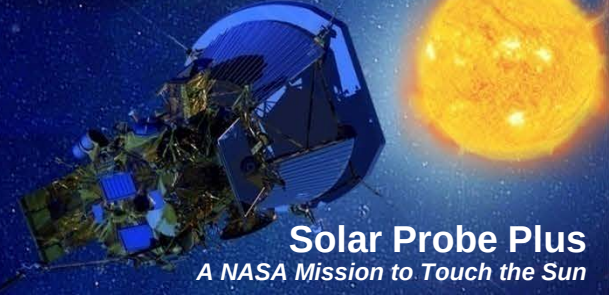
PAY-213: Payload: SWEAP Status Packets	
SWEAP shall be capable of generating and sending CCSDS Instrument Status Packets to the Spacecraft at a rate of 1 packet per second that includes instrument status and shared burst data, as defined in the SPP Instrument Shared Data Document 7434-XXXX (TBR). *Description/Clarification* This is a placeholder requirement. It will likely be kept in the SPP Instrument Shared Data Plan. It is being held here currently.	
Rationale This requirement meets Level 2 Requirements. CCSDS is the protocol by which status packets are sent.	**Requirement Allocation** SWEAP
Parent Traceability	**Functional Allocation**

APL

Instrument Data Sharing



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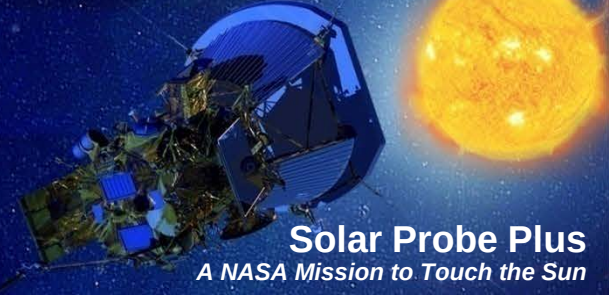
PAY-216: Payload: ISIS Status Packets	
ISIS shall be capable of generating and sending CCSDS Instrument Status Packets to the Spacecraft at a rate of 1 packet per second that includes instrument status and shared burst data, as defined in the SPP Instrument Shared Data Document 7434-XXXX (TBR). *Description/Clarification* This is a placeholder requirement. It will likely be kept in the SPP Instrument Shared Data Plan. It is being held here currently.	
Rationale This requirement meets Level 2 Requirements. CCSDS is the protocol by which status packets are sent.	**Requirement Allocation** ISIS
Parent Traceability	**Functional Allocation**

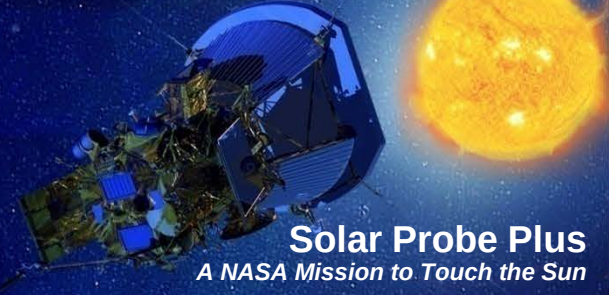
APL

System Operability



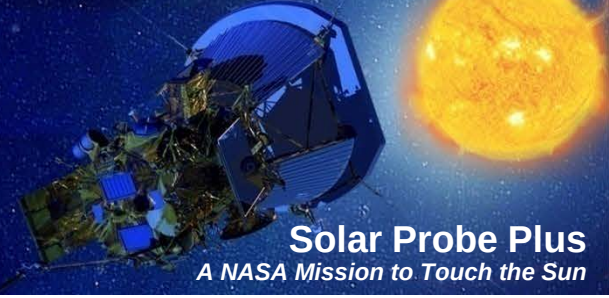
PAY-153: Payload: Maximum Mass & Power All instruments shall comply with maximum mass and power constraints as defined in each individual instrument to spacecraft ICD. *Description/Clarification* This is a placeholder requirement. It will likely be kept in each specific Instrument to Spacecraft ICD. It is being held here currently.	
Rationale Compliance with the mass and power NTEs will allow the Spacecraft to acheive launch wet mass capability.	**Requirement Allocation** FIELDS SWEAP WISPR ISIS
Parent Traceability	**Functional Allocation**

Alignment & Pointing



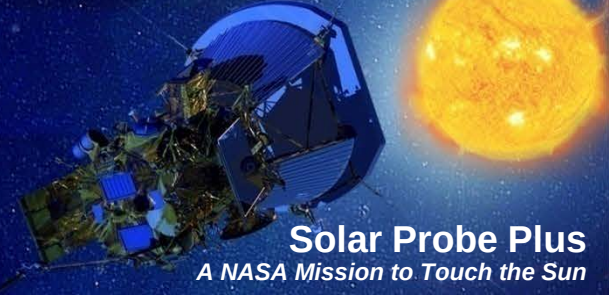
PAY-118: ADC: Spacecraft Coordinate Frame Definition	
All instruments shall be designed in accordance with the spacecraft coordinate system as defined in the Solar Probe Plus Spacecraft ICD 7434-0011. The following images display the spacecraft coordinate system as defined in Document 7434-0011. In the case of a conflict, Document 7434-0011 will take precedence. *Description/Clarification* This is a placeholder requirement. It will likely be kept in each specific Instrument to Spacecraft ICD or in the General Instrument ICD. It is being held here currently until the best reference source is determined.	
Rationale This requirement meets Level 2 Requirements.	**Requirement Allocation** FIELDS SWEAP WISPR ISIS
Parent Traceability MRD-138 : The Mission shall be designed such that the observatory has a spacecraft coordinate system as defined in Document 7434-0011 Solar Probe Plus Spacecraft ICD. The following images display the spacecraft coordinate system as defined in Document 7434-0011. In the case of a conflict, Document 7434-0011 will take precedence.	**Functional Allocation**

Alignment & Pointing



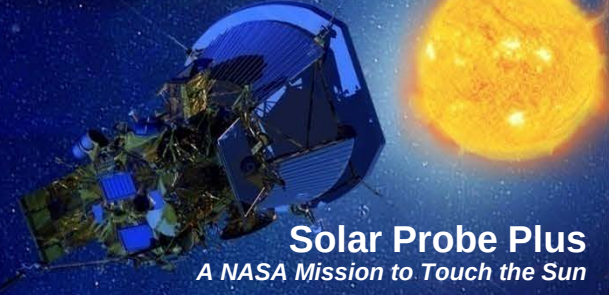
PAY-121: ADC: FIELDS Alignment FIELDS shall be designed such that its total internal alignment error (including contributions for static & dynamic errors) is ≤ TBR, as described in the FIELDS to Spacecraft ICD 7434-9055. *Description/Clarification* This is a placeholder requirement. It will likely be kept in the specific Instrument to Spacecraft ICD. It is being held here currently.	
Rationale	**Requirement Allocation** FIELDS
Parent Traceability	**Functional Allocation**

Alignment & Pointing



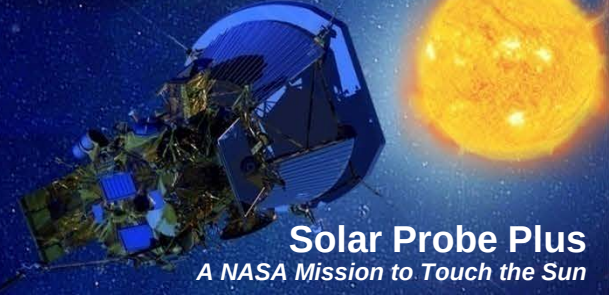
PAY-125: ADC: SWEAP Alignment SWEAP shall be designed such that its total internal alignment error (including contributions for static & dynamic errors) is ≤ TBR, as described in the SWEAP to Spacecraft ICD 7434-9056. *Description/Clarification* This is a placeholder requirement. It will likely be kept in the specific Instrument to Spacecraft ICD. It is being held here currently.	
Rationale	**Requirement Allocation** SWEAP
Parent Traceability	**Functional Allocation**

Alignment & Pointing



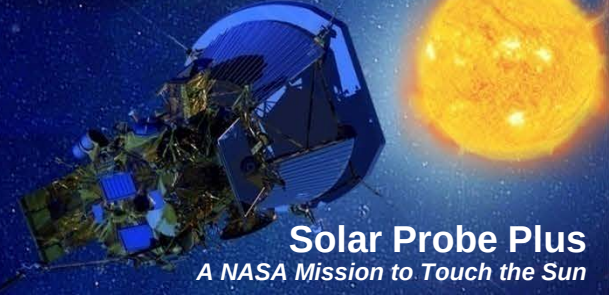
PAY-120: ADC: WISPR Alignment WISPR shall be designed such that its total internal alignment error (including contributions for static & dynamic errors) is ≤ TBR, as described in the WISPR to Spacecraft ICD 7434-9057. *Description/Clarification* This is a placeholder requirement. It will likely be kept in the specific Instrument to Spacecraft ICD. It is being held here currently.	
Rationale	**Requirement Allocation** WISPR
Parent Traceability	**Functional Allocation**

Alignment & Pointing



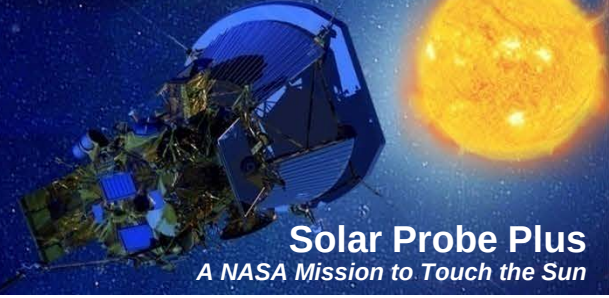
PAY-123: ADC: ISIS Alignment ISIS shall be designed such that its total internal alignment error (including contributions for static & dynamic errors) is ≤ TBR, as described in the ISIS to Spacecraft ICD 7434-9058. *Description/Clarification* This is a placeholder requirement. It will likely be kept in the specific Instrument to Spacecraft ICD. It is being held here currently.	
Rationale	**Requirement Allocation** ISIS
Parent Traceability	**Functional Allocation**

Alignment & Pointing



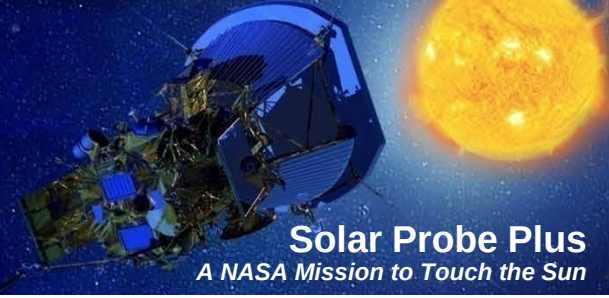
PAY-156: ADC: FIELDS torque	
FIELDS shall impart antenna-derived torques to the Spacecraft associated with antenna geometry and optical properties of TBD +/- TBD, 3-sigma (TBR) to support control of spacecraft Cp-Cg balance, assuming nominal antenna deployments. *Description/Clarification* This is a placeholder requirement. It will likely be kept in the specific Instrument to Spacecraft ICD. It is being held here currently.	
Rationale	**Requirement Allocation** FIELDS
Parent Traceability	**Functional Allocation**

Alignment & Pointing



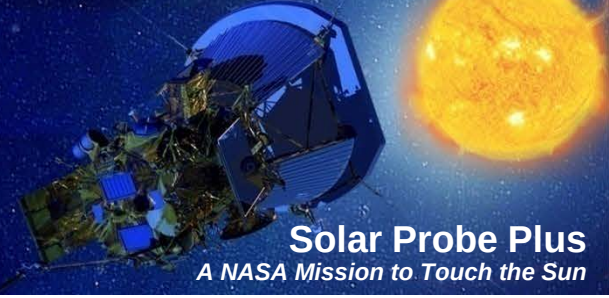
PAY-154: ADC: SPC torque SPC shall impart a torque to the spacecraft associated with SPC geometry and optical properties of TBD +/- TBD, 3-sigma (TBR) to support control of spacecraft Cp-Cg balance. *Description/Clarification* This is a placeholder requirement. It will likely be kept in the specific Instrument to Spacecraft ICD. It is being held here currently.	
Rationale	**Requirement Allocation** SWEAP
Parent Traceability	**Functional Allocation**

Alignment & Pointing



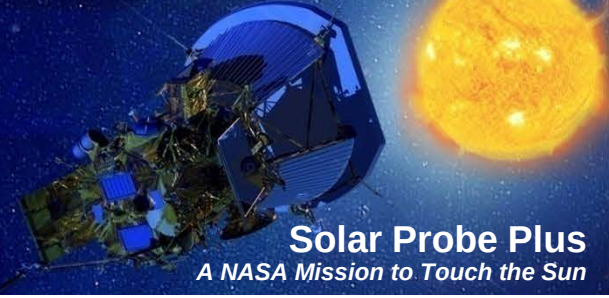
PAY-155: ADC: SPC compensation of TPS shift SPC shall include design features (including adjustable bracket length) to compensate for possible shifts of the spacecraft TPS prior to launch, as defined in the SWEAP to Spacecraft ICD. *Description/Clarification* This is a placeholder requirement. It will likely be kept in the specific Instrument to Spacecraft ICD. It is being held here currently.	
Rationale	**Requirement Allocation** SWEAP
Parent Traceability	**Functional Allocation**

Commanding & Uplink



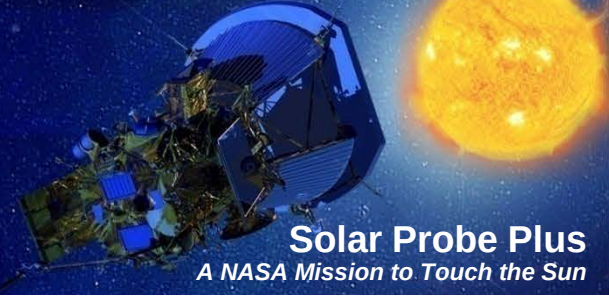
PAY-127: CDH: Real-time Commands	
All instruments shall be capable of implementing real-time commands via CCSDS packets in files uplinked via CFDP, as defined in the MOC-to-SOC ICD 7434-9078. *Description/Clarification* This is a placeholder requirement. It will likely be kept in the MOC-to-SOC ICD. It is being held here currently.	
Rationale This requirement supports the capability to utilize real-time commands during instrument commissioning and off-nominal situations where necessary.	**Requirement Allocation** FIELDS SWEAP WISPR ISIS
Parent Traceability	**Functional Allocation**

Commanding & Uplink



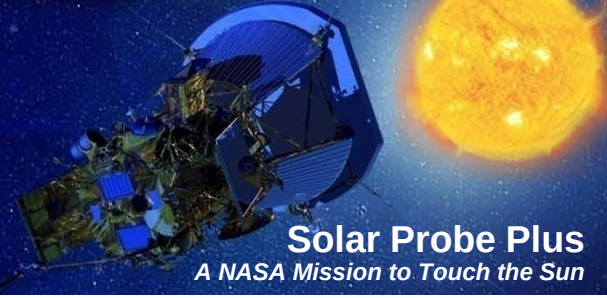
PAY-128: CDH: MOC Interface	
All instruments shall operate in accordance with procedures for science operations described in the MOC-to-SOC ICD 7434-9078. *Description/Clarification* This is a placeholder requirement. It will likely be kept in the MOC-to-SOC ICD. It is being held here currently.	
Rationale	**Requirement Allocation** FIELDS SWEAP WISPR ISIS
Parent Traceability	**Functional Allocation**

Data Return & Downlink



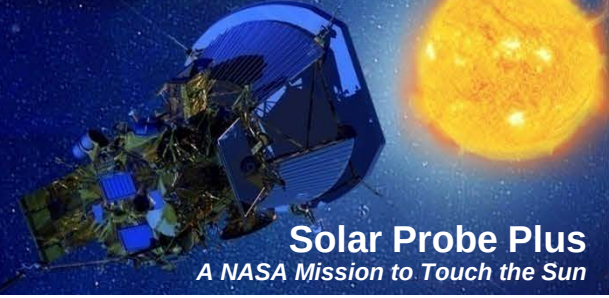
PAY-129: CDH: Data Return All instruments shall provide data to the spacecraft for downlink in volumes that are defined by TBD and at transfer rates defined by each individual payload ICD. *Description/Clarification* This is a placeholder requirement. It will likely be kept in the specific Instrument to Spacecraft ICD. It is being held here currently.	
Rationale	**Requirement Allocation** FIELDS SWEAP WISPR ISIS
Parent Traceability	**Functional Allocation**

Data Return & Downlink



PAY-131: CDH: Housekeeping All instruments shall be capable of providing real-time instrument health and status data in telemetry formats specified by each individual payload to spacecraft ICD, when required by mission operations for routine monitoring of housekeeping data and status. *Description/Clarification* This is a placeholder requirement. It will likely be kept in the specific Instrument to Spacecraft ICD. It is being held here currently.	
Rationale	**Requirement Allocation** FIELDS SWEAP WISPR ISIS
Parent Traceability	**Functional Allocation**

Fault Management



PAY-149: FP: Instrument Fault Protection

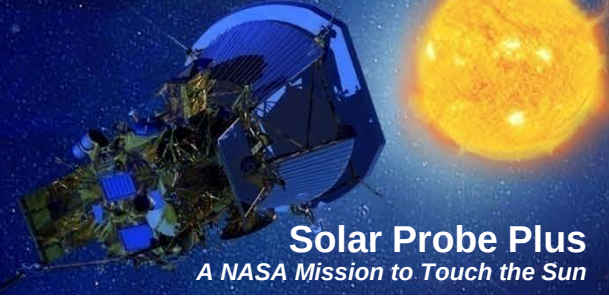
All instruments shall provide data to support instrument fault protection (including ground system monitoring of selected instrument health data, remote SOC notifications of critical fault conditions, and autonomous onboard instrument power-downs in response to instrument request, detection of stale instrument heartbeat, or overcurrent).

Description/Clarification

This is a placeholder requirement. It will likely be kept in each specific Instrument to Spacecraft ICD or in the General Instrument ICD. It is being held here currently.

Rationale	**Requirement Allocation**
This requirement meets Level 2 Requirements.	FIELDS SWEAP WISPR ISIS
Parent Traceability	**Functional Allocation**
MRD-72 : The Mission shall provide instrument fault protection to include ground system monitoring of selected instrument health data, remote SOC notifications of critical fault conditions, and autonomous onboard instrument power-downs in response to instrument request and critical telemetry.	

Fault Management



PAY-150: FP: Instrument Power-Down Safe State

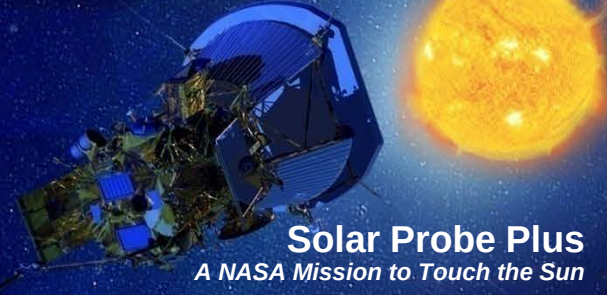
All instruments shall be capable of entering a safe state of powering down upon receipt of a spacecraft-provided bit in the spacecraft status message to request an instrument put itself in a safe state for power down.

Description/Clarification

This is a placeholder requirement. It will likely be kept in each specific Instrument to Spacecraft ICD or in the General Instrument ICD. It is being held here currently.

Rationale	**Requirement Allocation**
	FIELDS SWEAP WISPR ISIS
Parent Traceability MRD-72 : The Mission shall provide instrument fault protection to include ground system monitoring of selected instrument health data, remote SOC notifications of critical fault conditions, and autonomous onboard instrument power-downs in response to instrument request and critical telemetry.	**Functional Allocation**

Fault Management



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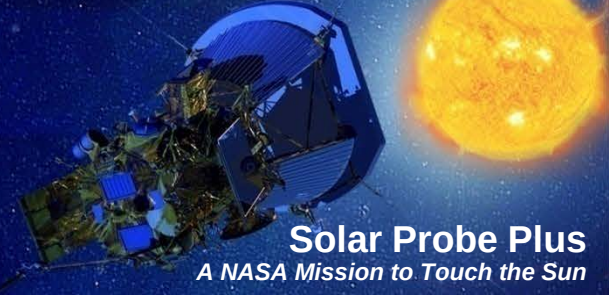
PAY-151: FP: Instrument Power-Down Time All instruments shall be capable of safely powering down within TBD s upon receipt of a status message with a bit indicating power-down command. *Description/Clarification* This is a placeholder requirement. It will likely be kept in each specific Instrument to Spacecraft ICD or in the General Instrument ICD. It is being held here currently.	
Rationale This requirement meets Level 2 Requirements.	**Requirement Allocation** FIELDS SWEAP WISPR ISIS
Parent Traceability MRD-72 : The Mission shall provide instrument fault protection to include ground system monitoring of selected instrument health data, remote SOC notifications of critical fault conditions, and autonomous onboard instrument power-downs in response to instrument request and critical telemetry.	**Functional Allocation**

Fault Management



PAY-152: FP: Instrument Power-Down Preparedness	
All instruments shall be designed to accommodate immediate loss of power (without warning) without damage to the instrument. *Description/Clarification* This is a placeholder requirement. It will likely be kept in each specific Instrument to Spacecraft ICD or in the General Instrument ICD. It is being held here currently.	
Rationale This requirement meets Level 2 Requirements.	**Requirement Allocation** FIELDS SWEAP WISPR ISIS
Parent Traceability MRD-72 : The Mission shall provide instrument fault protection to include ground system monitoring of selected instrument health data, remote SOC notifications of critical fault conditions, and autonomous onboard instrument power-downs in response to instrument request and critical telemetry.	**Functional Allocation**