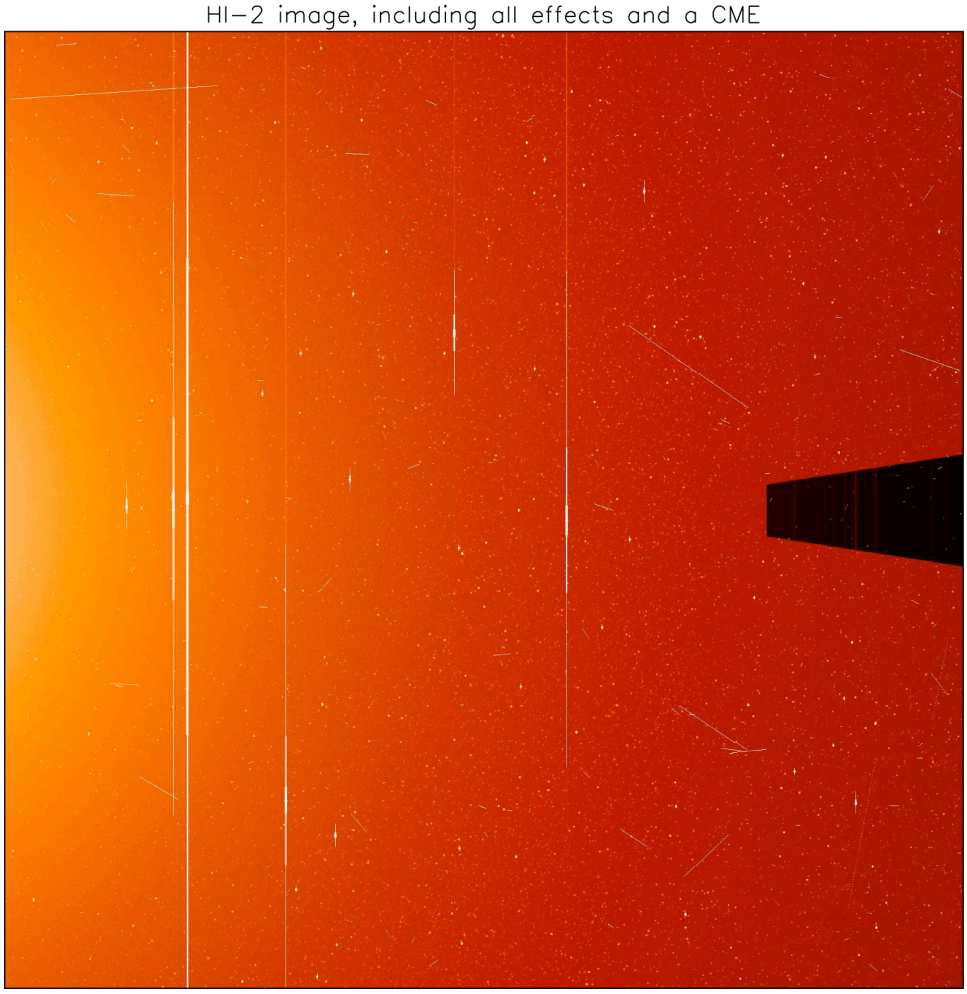
SECCHI/Heliospheric Imager Science Studies

HI−2 image, including all effects and a CME



Sarah Matthews
Mullard Space Science Laboratory
University College London
Holmbury St. Mary, Dorking
Surrey RH5 6NT
sam@mssl.ucl.ac.uk

Version 2, 12 December 2003

1. Introduction

This document is intended to provide a focus for the scientific operation of the Heliospheric Imager camera systems that form part of the SECCHI instrument payload on STEREO. Its purpose is to provide a brief introduction to the instruments and their capabilities, within the context of the SECCHI instrumentation as a whole, and to outline a series of proposed science studies whose primary focus requires the HI1 and/or HI2, although this does not preclude the inclusion of studies whose main focus is another of the SECCHI instruments. In addition to defining the science goals for the HI these science studies also provide operational constraints that as far as possible will be fed into the on-board software requirements. In order to obtain a detailed view of the instruments, the science goals and operations, it is recommended that this document should be used together with the Heliospheric Imager Operations Document written by Richard Harrison and the Image Simulation document written by Chris Davis & Richard Harrison.

2. SECCHI and the Heliospheric Imager

SECCHI is a set of remote sensing instruments designed to follow Coronal Mass Ejections (CMEs) from their origins on the Sun, out through the corona and the interplanetary medium and to possible impact with the Earth.

The instrument package comprises 3 telescopes:

- EUV Imaging Telescope (EUVI) - a full Sun instrument which images the chromosphere and corona in 4 emission lines: He II 304 A, Fe IX/X 171 A, Fe XII 195 A and Fe XV 284 A.
- COR 1 and COR 2 - two white-light coronagraphs to observe the inner (1.1-3 solar radii) and outer (2-15 solar radii) corona at high temporal and spatial resolution, and provide polarization information.
- Heliospheric Imager (HI1 and HI2) - these are externally occulted coronagraphs that image the inner heliosphere between the Sun and the Earth between 12-215 solar radii.

STEREO is the first mission dedicated to understanding the physics of CMEs and their effects on the Earth's environment. The mission's overall science objectives are as follows:

- Understand the causes and mechanisms of CME inititation
- Characterize the propagation of CMEs through the Heliosphere
- Discover the mechanisms and sites of energetic particle acceleration in the low corona and the interplanetary medium
- Improve determination of the structure of the ambient solar wind

Within these objectives SECCHI has its own primary science goals to:

- Determine the 3D structure of coronal loops, coronal streamers and large-scale coronal structures
- Determine the 3D properties of CMEs
- Determine the timing of physical properties involved in CME initiation
- Determine the critical forces controlling propagation of CMEs in the corona and interplanetary medium.

The HI instruments, with their unique FOV, will provide the first direct imaging observations of CMEs in the inner heliosphere. As such they will directly address the issue of the forces that control CME evolution and propagation in the corona inner heliopshere, as well as providing insights into the mechanisms and sites of particle acceleration in this region and space weather alerts.

3. Heliospheric Imager characteristics

A detailed description of the design of the Heliospheric Imager can be found in the operations document and in Socker et al., 2000. The basic concept uses occultation and a baffle system to achieve the light rejection levels necessary to provide wide-angle views of the heliosphere. The two cameras are centred on the Earth-Sun line with two circular fields of view of 20^{o} (HI-1) and 70^{o} (HI-2), offset from the Sun at 13.65^{o} and 53.35^{o}, respectively. This allows us to view the whole Sun-Earth line from 12 solar radii to near Earth orbit.

The detectors are CCDs of 2048x2048 13.5 micron pixels which are usually binned on board to give images of size 1024x1024 pixels, with a resolution of 70 arcsec (HI-1) and 4 arc mins (HI-2). Nominal exposure times are in the range 12-20 s for HI-1 and 60-90s for HI-2. Note that the nominal cadence for each camera is 60 min (HI-1) and 120 min (HI-2). The driver behind these numbers is the need to accumulate sufficient signal to noise and to remove cosmic rays from each exposure prior to summing to produce the image. These characteristics are summarised in Table 1 of the operations document, which we reproduce below for convenience.

	HI-1	HI-2
Instrument Type	Externally occulted coronagraph	Externally occulted coronagraph
Centre of Field-of-view Direction	Along Sun-Earth line □ = 13.65 degrees	Along Sun-Earth line □ = 53.35 degrees
Angular field-of-view	20 degrees	70 degrees
Coronal coverage	12-84 R_{sun}	66-318 R_{sun}
Overlap with COR-2	12-15 R_{sun}	N/A
Overlap with HI-1	N/A	66-84 R_{sun}
Baseline image (2x2 binning)	1024x1024	1024x1024
Image pixel scale	70 arcsec	4 arc min

(binned)		
Spectral bandpass	630 – 730 nm	400 – 1000 nm
Exposure time	12 –20 s	60 – 90 s
Nominal images per sequence	70	60
Required cadence	60 min	120 min
Brightness sensitivity	3×10^{-15} B_{sun}	3×10^{-16} B_{sun}
Straylight rejection	3×10^{-13} B_{sun}	10^{-14} B_{sun}
Brightness accuracy	10%	10%

Table 1:Characteristics of the Heliospheric Imager

4. Science scenarios

The default mode of operation of STEREO is a synoptic one , with the synoptic operation of the HI based on the values given in Table 1. However, SECCHI, and the HI in particular, can be used to answer a wide range of scientific questions, some of which will fall outside of the scope of the synoptic operational mode. In order to assess the range of operational requirements that may be needed, from an HI perspective in particular, the UK SECCHI/STEREO science team has considered a range of different scientific problems and the instrumental and operational caveats associated with them. To ensure a degree of uniformity a schema was provided for people that outlined the basic instrumental choices and the synoptic fields of view, exposure times, cadences etc. In addition people were asked to consider whether co-ordination with other instruments on STEREO was required, or with other spacecraft and ground-based facilities, since these clearly raise more complicated planning issues. The resulting 15 science questions are listed below in Table 2 along with their authors and institutes. The scientific justification and detailed observational requirements can be found in section 5 of this document.

Study	***Author***
1. Impact of CME on the Earth	Richard Harrison (RAL)
2. CMEs in interplanetary space	Peter Cargill (IC)
3. Understanding how observations at L1 & SECCHI are related	Peter Cargill (IC)
4. 3-D structure of interplanetary CMEs	Lucie Green (Cardiff)
5. CME onset	Sarah Matthews (MSSL)
6. The relationship between CMEs and magnetic clouds	Sarah Matthews (MSSL)
7. Particle acceleration at CME shocks	Sarah Matthews (MSSL)
8. Synoptic CME programme	Richard Harrison (RAL)

9. Solar wind microstructure	Andy Breen (Aberystwyth)
10. Development of co-rotating interaction regions	Andy Breen (Aberystwyth)
11. Differential drift velocities in the fast & slow solar winds	Andy Breen (Aberystwyth)
12. Boundary regions between fast & slow streams in the solar wind	Andy Breen (Aberystwyth)
13. Remote solar wind speed & direction measurements from 3-D observations of cometary ion tails	Geraint Jones (IC)
14. Interplanetary acceleration of ICMEs	Mathew Owens (IC)
15. Beacon mode	Sarah Matthews (MSSL), Richard Harrison & Chris Davis (RAL)

Table 2: list of science scenarios

5. Science scenarios

Observation Title: *Impact of CME on the Earth*

Name: *Richard Harrison*
Institute: *RAL*
E-mail: *r.harrison@rl.ac.uk*

Version Date: *1 May 2002*

Brief Scientific Objective and Observation Overview:

One of the principal aims of STEREO is to enable a better understanding of the arrival and impact of CMEs on the Earth. Thus, a major goal is the direct observation of a CME event arriving at Earth. For this, the prime instrument here is HI2, which has the Earth and CME within its field of view. However, the support of HI1, COR1 and COR2 is required to provide the most complete understanding of the CME structure and evolution as it propagates from the Sun.

Sequence Details

EUVI: [Bands - He II 304, Fe IX 171, Fe XII 195, Fe XV 284 Å; Resolution - 1.6 arcsec/pixel; FOV - 0.9 deg Sun-centred; Nominal cadence 30 s]

- Required (yes/no) - No
- Which bands? - n/a
- Image cadence? - n/a
- FOV (full Sun, partial Sun (define area and pointing)) - n/a
- Other details - n/a

COR1: [Bandpass - 650-660 nm (brightness and pB); Resolution - 7.5 arcsec/pixel; FOV - 1.3-4.0 R (full revolution; Sun centred); Nominal cadence 20 s (3 images/min in different polarisation angles)]

- Required (yes/no) - Yes
- Image cadence? nominal
- FOV (full or partial field (define area and pointing)) - full
- Other details

COR2: [Bandpass - 650-750 nm (brightness and pB); Resolution - 15 arcsec/pixel; FOV - 2-15 R (full revolution; Sun centred); Nominal cadence 100 s]

- Required (yes/no) - Yes
- Image cadence? - nominal
- FOV (full or partial field (define area and pointing)) - full
- Other details

HI1: [Bandpass - 650-750 nm (brightness); Resolution - 35 arcsec/pixel; FOV - 20^{o} circle centred at 13.28^{o} to Sun centre (3.28-23.28^{o} along ecliptic); Nominal cadence 1 hr]

- Required (yes/no) - Yes
- Image cadence? - nominal
- FOV (full or partial field (define area and pointing)) - full
- Other details

HI2: [Bandpass - 400-1000 nm (brightness); Resolution - 240 arcsec/pixel;
FOV - 70^{o} circle centred at 53.36^{o} to Sun centre (18.36-88.36^{o} along ecliptic); Nominal cadence 2 hr]

- Required (yes/no) - Yes
- Image cadence? - 2 hr
- FOV (full or partial field (define area and pointing)) - see details

Other details

Cadence sized for fast (1000 km/s) CME travelling from 73 to 212 solar radii, i.e. 27 hours to cross from inner limit to Earth. Want minimum of 10 images for fast CME.

FOV could be full field. Alternatively, for better cadence/telemetry capability, could return field only on the Sun-ward side of Earth.

Other Spacecraft/Instruments Required (give details of observation)?

In-situ observations from L1 (ACE) and Earth Orbit (Cluster, Polar, Wind).

Other relevant details?

HI2 is the key instrument here. The COR1, COR2 and HI1 instruments are asked to operate in their nominal modes; this will support the observation.

Special Operational/Software Requirements? (i.e. requirements to feed into operations planning and software during mission development)

Must be able to vary the HI cadence and have a capability to return partial fields from HI.

Observation Title: CMEs in interplanetary space

Name: Peter Cargill
Institute: Imperial College
E-mail: p.cargill@ic.ac.uk

Version Date: 26 May 2002

Brief Scientific Objective and Observation Overview:
To study the deformation of an ICME between 20 – 30 solar radii and 1 AU.

Sequence Details

EUVI: [Bands - He II 304, Fe IX 171, Fe XII 195, Fe XV 284 Å; Resolution - 1.6 arcsec/pixel; FOV - 0.9 deg Sun-centred; Nominal cadence 30 s]

- Required (yes/no) NO
- Which bands? N/A
- Image cadence? N/A
- FOV (full Sun, partial Sun (define area and pointing)) N/A
- Other details

COR1: [Bandpass - 650-660 nm (brightness and pB); Resolution - 7.5 arcsec/pixel; FOV - 1.3-4.0 R (full revolution; Sun centred); Nominal cadence 20 s (3 images/min in different polarisation angles)]

- Required (yes/no) NO
- Image cadence? N/A
- FOV (full or partial field (define area and pointing)) N/A
- Other details

COR2: [Bandpass - 650-750 nm (brightness and pB); Resolution - 15 arcsec/pixel; FOV - 2-15 R (full revolution; Sun centred); Nominal cadence 100 s]

- Required (yes/no) YES
- Image cadence? Nominal
- FOV (full or partial field (define area and pointing)) FULL
- Other details: Required for initial ICME state at 15 Rs

HI1: [Bandpass - 650-750 nm (brightness); Resolution - 35 arcsec/pixel; FOV - 20^{o} circle centred at 13.28^{o} to Sun centre (3.28-23.28^{o} along ecliptic); Nominal cadence 1 hr]

- Required (yes/no) YES
- Image cadence? 20 minutes
- FOV (full or partial field (define area and pointing)) Full

- Other details. Need high resolution to track evolution of fast ICME (>1000 km/s at Sun so will pass through HI1 FOV in few hours) Also expect evolution to be fastest near Sun.

HI2: [Bandpass - 400-1000 nm (brightness); Resolution - 240 arcsec/pixel;
FOV - 70^{o} circle centred at 53.36^{o} to Sun centre (18.36-88.36^{o} along ecliptic); Nominal cadence 2 hr]

- Required (yes/no) YES
- Image cadence? 1 hour
- FOV (full or partial field (define area and pointing)) Full

Other details; Cadence: see HI1 for reason for fact cadence.

Other Spacecraft/Instruments Required (give details of observation)?

Other relevant details?

Special Operational/Software Requirements? (i.e. requirements to feed into operations planning and software during mission development)

High cadence is essential at all locations in order to track fast CMEs.

Observation Title: Understanding how L1 and SECCHI observations are related.

Name: Peter Cargill
Institute: Imperial College
E-mail: p.cargill@ic.ac.uk

Version Date: 26 May 2002

Brief Scientific Objective and Observation Overview:
To understand how HI observations relate to in-situ ones at L1. HI measures plasma properties, whereas for space weather one is interested in magnetic field. How do HI plasma measurements relate to field structure of ICME?

Sequence Details

EUVI: [Bands - He II 304, Fe IX 171, Fe XII 195, Fe XV 284 Å; Resolution - 1.6 arcsec/pixel; FOV - 0.9 deg Sun-centred; Nominal cadence 30 s]

- Required (yes/no) NO
- Which bands? N/A
- Image cadence? N/A
- FOV (full Sun, partial Sun (define area and pointing)) N/A
- Other details

COR1: [Bandpass - 650-660 nm (brightness and pB); Resolution - 7.5 arcsec/pixel; FOV - 1.3-4.0 R (full revolution; Sun centred); Nominal cadence 20 s (3 images/min in different polarisation angles)]

- Required (yes/no) NO
- Image cadence? N/A
- FOV (full or partial field (define area and pointing)) N/A
- Other details

COR2: [Bandpass - 650-750 nm (brightness and pB); Resolution - 15 arcsec/pixel; FOV - 2-15 R (full revolution; Sun centred); Nominal cadence 100 s]

- Required (yes/no) NO
- Image cadence? N/A
- FOV (full or partial field (define area and pointing)) N/A
- Other details:

HI1: [Bandpass - 650-750 nm (brightness); Resolution - 35 arcsec/pixel; FOV - 20^{o} circle centred at 13.28^{o} to Sun centre (3.28-23.28^{o} along ecliptic); Nominal cadence 1 hr]

- Required (yes/no) NO
- Image cadence? N/A
- FOV (full or partial field (define area and pointing)) N/A
- Other details:

HI2: [Bandpass - 400-1000 nm (brightness); Resolution - 240 arcsec/pixel;
FOV - 70^{o} circle centred at 53.36^{o} to Sun centre (18.36-88.36^{o} along ecliptic); Nominal cadence 2 hr]

- Required (yes/no) YES
- Image cadence? 3 hour / 1 hour
- FOV (full or partial field (define area and pointing)) Partial. Need to look at 150 – 220 Rs at Earth with full angular view.

Other details;

Other Spacecraft/Instruments Required (give details of observation)?
ACE (MAG and SWEPAM). Any other s/c in vicinity of Earth.

Other relevant details?

Special Operational/Software Requirements? (i.e. requirements to feed into operations planning and software during mission development)

One wants to take snapshots of ICME as it passes over ACE (say). This can take up to a day. In first instance use nominal cadence, then try shorter. Partial field will optimize telemetry requirements.

Observation Title:3-D structure of interplanetary CMEs

Name: Lucie Green
Institute: University of Cardiff
E-mail: lmg@mssl.ucl.ac.uk

Version Date: 7 June , 2002

Brief Scientific Objective and Observation Overview:

The helicity content of interplanetary CMEs is currently computed using in-situ data taken from one spacecraft crossing, under the assumption that the structure can be well modeled by a single, twisted flux rope. A more accurate helicity computation requires knowledge of the true 3 dimensional structure of the interplanetary CME. For this, coronagraph observations from more than one view point need to be combined with theoretical models.

Sequence Details

EUVI: [Bands - He II 304, Fe IX 171, Fe XII 195, Fe XV 284 Å; Resolution - 1.6 arcsec/pixel; FOV - 0.9 deg Sun-centred; Nominal cadence 30 s]

- Required (yes/no) No
- Which bands?
- Image cadence?
- FOV (full Sun, partial Sun (define area and pointing))
- Other details

COR1: [Bandpass - 650-660 nm (brightness and pB); Resolution - 7.5 arcsec/pixel; FOV - 1.3-4.0 R (full revolution; Sun centred); Nominal cadence 20 s (3 images/min in different polarisation angles)]

- Required (yes/no) Yes
- Image cadence? Few minutes

- FOV (full or partial field (define area and pointing)) Full
- Other details

Possibility to trigger high cadence CME mode for passage of ejecta through COR1 and COR2?

COR2: [Bandpass - 650-750 nm (brightness and pB); Resolution - 15 arcsec/pixel; FOV - 2-15 R (full revolution; Sun centred); Nominal cadence 100 s]

- Required (yes/no) Yes
- Image cadence? Few minutes
- FOV (full or partial field (define area and pointing)) Full
- Other details

HI1: [Bandpass - 650-750 nm (brightness); Resolution - 35 arcsec/pixel; FOV - 20^{o} circle centred at 13.28^{o} to Sun centre ($3.28\text{-}23.28^{o}$ along ecliptic); Nominal cadence 1 hr]

- Required (yes/no) yes
- Image cadence? 10's of minutes
- FOV (full or partial field (define area and pointing)) Full
- Other details

HI2: [Bandpass - 400-1000 nm (brightness); Resolution - 240 arcsec/pixel;
FOV - 70^{o} circle centred at 53.36^{o} to Sun centre ($18.36\text{-}88.36^{o}$ along ecliptic); Nominal cadence 2 hr]

- Required (yes/no) Yes
- Image cadence? 10's of minutes
- FOV (full or partial field (define area and pointing))
- Other details:

Other Spacecraft/Instruments Required (give details of observation)?

In-situ measurements of the magnetic field are required for the helicity computation. In-situ particle fluxes are needed to look for signatures of field lines which remain attached to the Sun. This will help to obtain a good understanding of the CME structure and also give an indication of the upper limit of the CME length to complement the model. Radius of interplanetary CME also needs to be found from the in-situ data to complement that predicted from the CME model.

Other relevant details?

Special Operational/Software Requirements? (i.e. requirements to feed into operations planning and software during mission development): Ability to automatically change cadence of observations upon CME detection.

Observation Title: CME onset

Name: Sarah Matthews
Institute: MSSL
E-mail: sam@mssl.ucl.ac.uk

Version Date: 31 May 2002

Brief Scientific Objective and Observation Overview: While on-disk signatures in association with CME onset are now often observed in the X-ray and EUV, the actual trigger for these events remains elusive. The 3-D view from STEREO will provide a much less ambiguous view of pre-CME structures in the corona, which combined with magnetic field information from Solar-B and STEREO should provide clues to this process.

Sequence Details

EUVI: [Bands - He II 304, Fe IX 171, Fe XII 195, Fe XV 284 Å; Resolution - 1.6 arcsec/pixel; FOV - 0.9 deg Sun-centred; Nominal cadence 30 s]

- Required (yes/no) Yes
- Which bands? All
- Image cadence? 30s
- FOV (full Sun, partial Sun (define area and pointing)) Full
- Other details

COR1: [Bandpass - 650-660 nm (brightness and pB); Resolution - 7.5 arcsec/pixel; FOV - 1.3-4.0 R (full revolution; Sun centred); Nominal cadence 20 s (3 images/min in different polarisation angles)]

- Required (yes/no) Yes
- Image cadence? Nominal
- FOV (full or partial field (define area and pointing)) Full
- Other details

COR2: [Bandpass - 650-750 nm (brightness and pB); Resolution - 15 arcsec/pixel; FOV - 2-15 R (full revolution; Sun centred); Nominal cadence 100 s]

- Required (yes/no) Yes
- Image cadence? Nominal
- FOV (full or partial field (define area and pointing)) Full
- Other details:

HI1: [Bandpass - 650-750 nm (brightness); Resolution - 35 arcsec/pixel; FOV - 20^{o} circle centred at 13.28^{o} to Sun centre (3.28-23.28^{o} along ecliptic); Nominal cadence 1 hr]

- Required (yes/no) No
- Image cadence?
- FOV (full or partial field (define area and pointing))
- Other details

HI2: [Bandpass - 400-1000 nm (brightness); Resolution - 240 arcsec/pixel;
FOV - 70^{o} circle centred at 53.36^{o} to Sun centre (18.36-88.36^{o} along ecliptic); Nominal cadence 2 hr]

- Required (yes/no) No
- Image cadence?
- FOV (full or partial field (define area and pointing))
- Other details:

Other Spacecraft/Instruments Required (give details of observation)?
Solar – B : SOT, XRT and EIS to provide high resolution magnetic field, high cadence EUV/X-ray imaging and spectroscopic measurements of plasma parameters e.g. velocity. Since EIS and SOT are not full Sun instruments pointing would have to be defined in this case, in which a partial field could also be used in SECCHI. Sacrificing the spectral observations and using SOHO-MDI would give a whole Sun view and greater probability of observing the region where onset occurs.

Other relevant details?

Special Operational/Software Requirements? (i.e. requirements to feed into operations planning and software during mission development) This one really needs to be done early in the mission to make use of the complementary information from Solar-B. A co-ordinated campaign tracking an active region during its disk passage with both STEREO and Solar-B would be the ideal case.

Observation Title: Relationship between CMEs and magnetic clouds

Name: Sarah Matthews
Institute: MSSL
E-mail: sam@mssl.ucl.ac.uk

Version Date: 31 May 2002

Brief Scientific Objective and Observation Overview:
While magnetic clouds are known to have a high probability of producing enhanced geomagnetic activity only ~ 1/3 of CMEs can be confidently

associated with magnetic clouds. In order to assess the potential geo-effectiveness of a CME it is thus important to assess whether there are particular characteristics that lead to the production of a magnetic cloud. The observation would involve combining all of the SECCHI instruments with in-situ measurements from other IMPACT and ACE to ensure a complete description of the CME parameters and their evolution.

Sequence Details

EUVI: [Bands - He II 304, Fe IX 171, Fe XII 195, Fe XV 284 Å; Resolution - 1.6 arcsec/pixel; FOV - 0.9 deg Sun-centred; Nominal cadence 30 s]

- Required (yes/no) Yes
- Which bands? Fe XII 195, He II 304
- Image cadence? 30s
- FOV (full Sun, partial Sun (define area and pointing)) Full Sun
- Other details Fe XII and He II should give a good indication of the initial field configuration of the CME site and also onset time information to compare with coronagraph signatures.

COR1: [Bandpass - 650-660 nm (brightness and pB); Resolution - 7.5 arcsec/pixel; FOV - 1.3-4.0 R (full revolution; Sun centred); Nominal cadence 20 s (3 images/min in different polarisation angles)]

- Required (yes/no) Yes
- Image cadence? Nominal
- FOV (full or partial field (define area and pointing)) Full
- Other details

COR2: [Bandpass - 650-750 nm (brightness and pB); Resolution - 15 arcsec/pixel; FOV - 2-15 R (full revolution; Sun centred); Nominal cadence 100 s]

- Required (yes/no) Yes
- Image cadence? Nominal
- FOV (full or partial field (define area and pointing)) Full
- Other details

HI1: [Bandpass - 650-750 nm (brightness); Resolution - 35 arcsec/pixel; FOV - 20^{o} circle centred at 13.28^{o} to Sun centre (3.28-23.28^{o} along ecliptic); Nominal cadence 1 hr]

- Required (yes/no) Yes
- Image cadence? Nominal
- FOV (full or partial field (define area and pointing)) Full
- Other details

HI2: [Bandpass - 400-1000 nm (brightness); Resolution - 240 arcsec/pixel;
FOV - 70^{o} circle centred at 53.36^{o} to Sun centre (18.36-88.36^{o} along ecliptic); Nominal cadence 2 hr]

- Required (yes/no) Yes
- Image cadence? 2hr
- FOV (full or partial field (define area and pointing)) Ideally a partial field from the Sun-ward side of the Earth to provide better cadence for slower CMEs.

Other details

Other Spacecraft/Instruments Required (give details of observation)?
IMPACT – magnetic field, speed profile, electron and proton temperatures. Similar from ACE.
Other relevant details?

Special Operational/Software Requirements? (i.e. requirements to feed into operations planning and software during mission development) Since we would like to determine whether specific CME parameters are more likely to produce magnetic clouds than others it is important to be able to study CMEs with a range of speeds. Therefore being able to vary the cadence in HI-2 would be extremely useful to provide good coverage of the slow ones.

Observation Title: Particle acceleration at CME shocks

Name: Sarah Matthews
Institute: MSSL
E-mail: sam@mssl.ucl.ac.uk

Version Date: 31 May 2002

Brief Scientific Objective and Observation Overview: SEP events are now thought to fall into 2 classes: impulsive and gradual. Impulsive events are thought to be flare-related, while the gradual events are thought to CME driven. However, the distinction is not always a clear one and hybrid events are often seen. The prolonged decay of the gradual events is also not well understood. The combination of 3-D coronagraph and in-situ observations from STEREO can be used to address these hybrid events and the role of particle acceleration at the CME shock.

Sequence Details

EUVI: [Bands - He II 304, Fe IX 171, Fe XII 195, Fe XV 284 Å; Resolution - 1.6 arcsec/pixel; FOV - 0.9 deg Sun-centred; Nominal cadence 30 s]

- Required (yes/no) Yes
- Which bands? Fe XII 195, Fe XV 284
- Image cadence? Nominal
- FOV (full Sun, partial Sun (define area and pointing)) Full sun
- Other details EUVI will provide information on the CME onset and any associated flaring activity that would accelerate particles.

COR1: [Bandpass - 650-660 nm (brightness and pB); Resolution - 7.5 arcsec/pixel; FOV - 1.3-4.0 R (full revolution; Sun centred); Nominal cadence 20 s (3 images/min in different polarisation angles)]

- Required (yes/no) Yes
- Image cadence? Nominal
- FOV (full or partial field (define area and pointing)) Full
- Other details

COR2: [Bandpass - 650-750 nm (brightness and pB); Resolution - 15 arcsec/pixel; FOV - 2-15 R (full revolution; Sun centred); Nominal cadence 100 s]

- Required (yes/no) Yes
- Image cadence? Nominal
- FOV (full or partial field (define area and pointing)) Full
- Other details

HI1: [Bandpass - 650-750 nm (brightness); Resolution - 35 arcsec/pixel; FOV - 20^{o} circle centred at 13.28^{o} to Sun centre (3.28-23.28^{o} along ecliptic); Nominal cadence 1 hr]

- Required (yes/no) Yes
- Image cadence? Nominal
- FOV (full or partial field (define area and pointing)) Full
- Other details

HI2: [Bandpass - 400-1000 nm (brightness); Resolution - 240 arcsec/pixel;
FOV - 70^{o} circle centred at 53.36^{o} to Sun centre (18.36-88.36^{o} along ecliptic); Nominal cadence 2 hr]

- Required (yes/no) Yes
- Image cadence? < 2hr
- FOV (full or partial field (define area and pointing)) Partial, sun-ward side
- Other details

Other Spacecraft/Instruments Required (give details of observation)?
IMPACT – shock speed, magnetic field, particle flux/distribution
RHESSI – Flare –related particle information
ACE – similar to IMPACT at 1AU

Other relevant details?

Special Operational/Software Requirements? (i.e. requirements to feed into operations planning and software during mission development)
Although slower CMEs are less likely to drive shocks it would still be useful to have as many images as possible in the HI-2 as the CME propagates to help determine whether it undergoes any acceleration/deceleration, so variable cadence and partial FOV would be useful here.

Observation Title: Synoptic CME Programme

Name: Richard A. Harrison
Institute: RAL
E-mail: r.harrison@rl.ac.uk

Version Date: 6 June 2002

Brief Scientific Objective and Observation Overview:

One of the major objectives of the STEREO effort is the routine monitoring and identification of CMEs which are Earth-directed. Thus, we require a standard synoptic observation programme, which is described here.

Sequence Details

EUVI: [Bands - He II 304, Fe IX 171, Fe XII 195, Fe XV 284 Å; Resolution - 1.6 arcsec/pixel; FOV - 0.9 deg Sun-centred; Nominal cadence 30 s]

- Required (yes/no) - Yes
- Which bands? - All
- Image cadence? - 20 min
- FOV (full Sun, partial Sun (define area and pointing)) - Full field
- Other details - Standard synoptic cadence

COR1: [Bandpass - 650-660 nm (brightness and pB); Resolution - 7.5 arcsec/pixel; FOV - 1.3-4.0 R (full revolution; Sun centred); Nominal cadence 20 s (3 images/min in different polarisation angles)]

- Required (yes/no) - Yes
- Image cadence? - 8 min

- FOV (full or partial field (define area and pointing)) - Full field
- Other details - Standard synoptic cadence

COR2: [Bandpass - 650-750 nm (brightness and pB); Resolution - 15 arcsec/pixel; FOV - 2-15 R (full revolution; Sun centred); Nominal cadence 100 s]

- Required (yes/no) - Yes
- Image cadence? - 20 min
- FOV (full or partial field (define area and pointing)) - Full field
- Other details - Standard synoptic cadence

HI1: [Bandpass - 650-750 nm (brightness); Resolution - 35 arcsec/pixel; FOV - 20^{o} circle centred at 13.28^{o} to Sun centre (3.28-23.28^{o} along ecliptic); Nominal cadence 1 hr]

- Required (yes/no) - Yes
- Image cadence? - 1 hour
- FOV (full or partial field (define area and pointing)) - Full field
- Other details - Standard synoptic cadence

HI2: [Bandpass - 400-1000 nm (brightness); Resolution - 240 arcsec/pixel;
FOV - 70^{o} circle centred at 53.36^{o} to Sun centre (18.36-88.36^{o} along ecliptic); Nominal cadence 2 hr]

- Required (yes/no) - Yes
- Image cadence? - 2 hours
- FOV (full or partial field (define area and pointing)) - Full field

Other details - Standard synoptic cadence

Other Spacecraft/Instruments Required (give details of observation)?
Standard monitoring of STEREO particle, field and radio data would be advantageous as would coincident space weather monitoring programmes. Little planning is required as these would be standard operations.

Other relevant details? None

Special Operational/Software Requirements? (i.e. requirements to feed into operations planning and software during mission development)
None

Observation Title: Boundary regions between fast and slow streams in the solar wind

Name: Andy Breen
Institute: University of Wales, Aberystwyth
E-mail: azb@aber.ac.uk

Version Date: 2003/11/17

Brief Scientific Objective and Observation Overview:
The programme is intended to study velocity and density gradients above the boundary regions between regions dominated by fast and slow wind and to investigate the large-scale structure of fast and slow streams. Measurements of interplanetary scintillation (IPS) from EISCAT (covering 15-80 R_{Sun}) and Toyokawa (covering 40-200 R_{Sun}) provide velocity information, while COR2 and HI1 provide density information (which is also used to constrain the fitting of IPS velocities). EUV1 measurements provide information on the source regions of fast and slow streams, so the programme gives full coverage of the evolution of velocity and density structure from the corona to interplanetary distances, allowing study of the evolution of boundary layers and the relationship between different regions of the corona (EUV coronal holes, quiet Sun, streamers) and the fast and slow solar winds.

Sequence Details

EUVI: [Bands - He II 304, Fe IX 171, Fe XII 195, Fe XV 284 Å; Resolution - 1.6 arcsec/pixel; FOV - 0.9 deg Sun-centred; Nominal cadence 30 s]

- Required (yes/no) Yes
- Which bands? Fe XII 195
- Image cadence? 5 minutes
- FOV (full Sun, partial Sun (define area and pointing)) Partial Sun, pointing determined by position of IPS sources (or could use full Sun, depending on telemetry limits)
- Other details

COR1: [Bandpass - 650-660 nm (brightness and pB); Resolution - 7.5 arcsec/pixel; FOV - 1.3-4.0 R (full revolution; Sun centred); Nominal cadence 20 s (3 images/min in different polarisation angles)]

- Required (yes/no) Yes
- Image cadence? Nominal
- FOV (full or partial field (define area and pointing)) Partial Sun, pointing determined by position of IPS sources
- Other details

COR2: [Bandpass - 650-750 nm (brightness and pB); Resolution - 15 arcsec/pixel; FOV - 2-15 R (full revolution; Sun centred); Nominal cadence 100 s]

- Required (yes/no) Yes
- Image cadence? Nominal
- FOV (full or partial field (define area and pointing)) Partial Sun, pointing determined by position of IPS sources
- Other details

HI1: [Bandpass - 650-750 nm (brightness); Resolution - 35 arcsec/pixel; FOV - 20^{o} circle centred at 13.28^{o} to Sun centre (3.28-23.28^{o} along ecliptic); Nominal cadence 1 hr]

- Required (yes/no) Yes
- Image cadence? Nominal
- FOV (full or partial field (define area and pointing)) Partial Sun, pointing determined by position of IPS sources
- Other details Most important STEREO instrument for this programme – needed to provide electron density profile information for interpreting IPS observations.

HI2: [Bandpass - 400-1000 nm (brightness); Resolution - 240 arcsec/pixel;
FOV - 70^{o} circle centred at 53.36^{o} to Sun centre (18.36-88.36^{o} along ecliptic); Nominal cadence 2 hr]

- Required (yes/no) Yes
- Image cadence? Nominal
- FOV (full or partial field (define area and pointing)) Partial Sun, pointing determined by position of IPS sources
- Other details

Other Spacecraft/Instruments Required (give details of observation)?
IPS observations from EISCAT, Toyokawa – times of observations will vary with date programme runs

Other relevant details?
HI1 is the key instrument on STEREO for this programme, but especially high cadences are not required from any intrument.

Special Operational/Software Requirements? (i.e. requirements to feed into operations planning and software during mission development)

Need to be able to change partial field pointing for COR1, COR2, HI1, HI2 during programme run.

Observation Title: Development of co-rotating interaction regions

Name: Andy Breen
Institute: University of Wales, Aberystwyth
E-mail: azb@aber.ac.uk

Version Date: 2003/11/17

Brief Scientific Objective and Observation Overview:
Co-rotating interaction regions (CIRs) are the driving terms for recurrent geomagnetic disturbances, but the early stages of their evolution are still not well understood. This programme combines C2 and HI observations of white-light intensities on stream boundaries with measurements of radio scintillation (from EISCAT and MERLIN) to study the development of compression regions on boundaries between fast and slow flow from inside 10 R_{sun} out to 80-100 R_{sun}. The differing sensitivities of the white-light and radio observations to variations in electron density will provide information on the development of compression regions, with the radio measurements providing additional information on the turbulent-scale structure of the solar wind in these interaction regions.

Sequence Details

EUVI: [Bands - He II 304, Fe IX 171, Fe XII 195, Fe XV 284 Å; Resolution - 1.6 arcsec/pixel; FOV - 0.9 deg Sun-centred; Nominal cadence 30 s]

- Required (yes/no) No
- Which bands?
- Image cadence?
- FOV (full Sun, partial Sun (define area and pointing))
- Other details

COR1: [Bandpass - 650-660 nm (brightness and pB); Resolution - 7.5 arcsec/pixel; FOV - 1.3-4.0 R (full revolution; Sun centred); Nominal cadence 20 s (3 images/min in different polarisation angles)]

- Required (yes/no) No
- Image cadence?
- FOV (full or partial field (define area and pointing))
- Other details

COR2: [Bandpass - 650-750 nm (brightness and pB); Resolution - 15 arcsec/pixel; FOV - 2-15 R (full revolution; Sun centred); Nominal cadence 100 s]

- Required (yes/no) Yes
- Image cadence? 30 minutes

- FOV (full or partial field (define area and pointing)) Partial Sun –determined by position of radio source off solar limb
- Other details

HI1: [Bandpass - 650-750 nm (brightness); Resolution - 35 arcsec/pixel; FOV - 20^{o} circle centred at 13.28^{o} to Sun centre (3.28-23.28^{o} along ecliptic); Nominal cadence 1 hr]

- Required (yes/no) Yes
- Image cadence? 1 hour
- FOV (full or partial field (define area and pointing)) Partial Sun, pointing determined by position of radio source off solar limb
- Other details

HI2: [Bandpass - 400-1000 nm (brightness); Resolution - 240 arcsec/pixel;
FOV - 70^{o} circle centred at 53.36^{o} to Sun centre (18.36-88.36^{o} along ecliptic); Nominal cadence 2 hr]

- Required (yes/no) Yes
- Image cadence? 2hours
- FOV (full or partial field (define area and pointing)) Partial Sun, pointing determined by position of radio source off solar limb
- Other details

Other Spacecraft/Instruments Required (give details of observation)?
Measurements of Interplanetary Scintillation (IPS) from EISCAT, MERLIN (and Toyokawa?). Times of observation and sources used depend on dates when programme is run.

Other relevant details?
HI1 is the most important part of the STEREO side of these observations. Higher cadence than nominal would be useful if it allowed velocity estimates to be obtained from HI1 in the inner part of its field of view.

Special Operational/Software Requirements? (i.e. requirements to feed into operations planning and software during mission development)

Must be able to change from one partial field to another in HI during observations.

Observation Title: Solar wind microstructure

Name: Andy Breen
Institute: University of Wales, Aberystwyth
E-mail: azb@aber.ac.uk

Version Date: 2003/11/17

Brief Scientific Objective and Observation Overview:
Measurements of interplanetary scintillation (IPS) use the modulation of radio signals from compact astronomical sources by turbulent-scale irregularities in the solar wind as a source of information on the velocity and density structure of the solar wind. The relationship between scintillation level, average electron density and level of turbulence is, however, still imperfectly understood. STEREO HI measurements, providing profiles of electron density along the IPS ray-paths, should make it possible to determine the contributions due to variations in electron density and so allow the variation of turbulence with heliocentric distance to be determined for both the fast and slow solar winds, as well as for stream/stream interaction regions. IPS is the only technique available for probing solar wind microstructure at distances of 15-100 R_{sun}, but it requires STEREO/HI measurements to do so unambiguously.

Sequence Details

EUVI: [Bands - He II 304, Fe IX 171, Fe XII 195, Fe XV 284 Å; Resolution - 1.6 arcsec/pixel; FOV - 0.9 deg Sun-centred; Nominal cadence 30 s]

- Required (yes/no) No
- Which bands? N/A
- Image cadence? N/A
- FOV (full Sun, partial Sun (define area and pointing)) N/A
- Other details N/A

COR1: [Bandpass - 650-660 nm (brightness and pB); Resolution - 7.5 arcsec/pixel; FOV - 1.3-4.0 R (full revolution; Sun centred); Nominal cadence 20 s (3 images/min in different polarisation angles)]

- Required (yes/no) No
- Image cadence?
- FOV (full or partial field (define area and pointing))
- Other details

COR2: [Bandpass - 650-750 nm (brightness and pB); Resolution - 15 arcsec/pixel; FOV - 2-15 R (full revolution; Sun centred); Nominal cadence 100 s]

- Required (yes/no) Yes
- Image cadence? 1 hour or same as HI1
- FOV (full or partial field (define area and pointing)) Partial field, covering region below HI1 FOV
- Other details

HI1: [Bandpass - 650-750 nm (brightness); Resolution - 35 arcsec/pixel; FOV - 20^{o} circle centred at 13.28^{o} to Sun centre (3.28-23.28^{o} along ecliptic); Nominal cadence 1 hr]

- Required (yes/no) Yes
- Image cadence? Best obtainable
- FOV (full or partial field (define area and pointing)) Full field
- Other details

HI2: [Bandpass - 400-1000 nm (brightness); Resolution - 240 arcsec/pixel;
FOV - 70^{o} circle centred at 53.36^{o} to Sun centre (18.36-88.36^{o} along ecliptic); Nominal cadence 2 hr]

- Required (yes/no) Yes
- Image cadence? Best obtainable without impacting on HI1 cadence
- FOV (full or partial field (define area and pointing)) Full field
- Other details

Other Spacecraft/Instruments Required (give details of observation)?
EISCAT IPS measurements - times of observation depend on dates when programme is run.

Other relevant details?

Special Operational/Software Requirements? (i.e. requirements to feed into operations planning and software during mission development)

Observation Title: Differential drift velocities in the fast and slow solar winds

Name: Andy Breen
Institute: University of Wales, Aberystwyth
E-mail: azb@aber.ac.uk

Version Date: 2003/11/17

Brief Scientific Objective and Observation Overview:
The acceleration of the solar wind is still one of the outstanding problems of solar physics. One difficulty is the uncertainty in remote-sensing observations of solar wind outflow speeds – when using proxies for solar wind velocity such as the drift velocity of large-scale features seen in white-light data or of turbulent-scale structures observed via measurements of interplanetary scintillation (IPS) it is not always obvious how these drift speeds relate to that of t he background solar wind. In particular, there is evidence that the turbulent –scale structures may be boosted above the wind speed by wave action in the fast wind close to the sun.
The proposed observational programme combines overlapping C1 and C2 coronal observations, IPS measurements from MERLIN and EISCAT (covering 6-60 R_{sun}) and HI1 measurements. The C1 and C2 instruments will provide drift speeds for large-scale structures (~1000 km scale) which might be expected to be drifting with the solar wind and, together with HI1, give information on density structure in the solar wind. The IPS measurements will provide velocities for turbulent-scale features (~50-100 km) – the accuracy of these velocities being greatly improved by inclusion of C2/HI1 electron densities in the analysis – and on other parameters such as wave flux. The programmer should provide information on the relationship between the velocities of small-scale features in the fast and slow solar winds and the background wind speed and on the evolution of the Alfven wave flux in the fast and slow winds, including the origin of inwards-propagating Alfven waves in the slow wind.

Sequence Details

EUVI: [Bands - He II 304, Fe IX 171, Fe XII 195, Fe XV 284 Å; Resolution - 1.6 arcsec/pixel; FOV - 0.9 deg Sun-centred; Nominal cadence 30 s]

- Required (yes/no) Possible – need to discuss
- Which bands?
- Image cadence?
- FOV (full Sun, partial Sun (define area and pointing))
- Other details

COR1: [Bandpass - 650-660 nm (brightness and pB); Resolution - 7.5 arcsec/pixel; FOV - 1.3-4.0 R (full revolution; Sun centred); Nominal cadence 20 s (3 images/min in different polarisation angles)]

- Required (yes/no) Yes
- Image cadence? 20s
- FOV (full or partial field (define area and pointing)) Partial field, determined by position of IPS sources
- Other details

COR2: [Bandpass - 650-750 nm (brightness and pB); Resolution - 15 arcsec/pixel; FOV - 2-15 R (full revolution; Sun centred); Nominal cadence 100 s]

- Required (yes/no) Yes
- Image cadence? As high as possible
- FOV (full or partial field (define area and pointing)) Partial field, determined by position of IPS sources
- Other details Main STEREO instrument for programme

HI1: [Bandpass - 650-750 nm (brightness); Resolution - 35 arcsec/pixel; FOV - 20^{o} circle centred at 13.28^{o} to Sun centre (3.28-23.28^{o} along ecliptic); Nominal cadence 1 hr]

- Required (yes/no) Yes
- Image cadence? As high as possible
- FOV (full or partial field (define area and pointing)) Partial field, determined by position of IPS sources
- Other details

HI2: [Bandpass - 400-1000 nm (brightness); Resolution - 240 arcsec/pixel;
FOV - 70^{o} circle centred at 53.36^{o} to Sun centre (18.36-88.36^{o} along ecliptic); Nominal cadence 2 hr]

- Required (yes/no) No
- Image cadence?
- FOV (full or partial field (define area and pointing))
- Other details

Other Spacecraft/Instruments Required (give details of observation)? Measurements of interplanetary scintillation (IPS) from EISCAT and MERLIN. Possibly also VLBI measurements of phase scintillation. Times of observation and sources used depend on dates when programme is run.

Other relevant details?

COR2 is the key instrument on STEREO here. Cadence needs to be high enough to get good velocity estimates in slow and fast solar winds.

Special Operational/Software Requirements? (i.e. requirements to feed into operations planning and software during mission development)

Must be able to change partial field pointing of C2, HI1 during programme. Need highest possible cadence COR2 for velocity estimates. Will HI1 be capable of a high enough cadence to get "Sheeley blob" velocities in the inner part of its field of view? Being able to vary cadence

during a run – to increase or decrease COR2 and HI1 cadence to get slow or fast wind velocities – would be very useful.

Observation Title: Remote solar wind speed and direction measurements from 3D observations of cometary ion tails

Name: Geraint Jones
Institute: Imperial College London
E-mail: g.h.jones@imperial.ac.uk

Version Date: 28th March 2003

Brief Scientific Objective and Observation Overview:
The three-dimensional orientation of cometary ion tails would be inferred from combined observations by the two STEREO spacecraft, or from one STEREO spacecraft and ground-based telescopes. From this information, the solar wind speed and direction would be inferred for the vicinity of the observed comet. Solar wind speed measurements from comet ion tail observations currently rely on assuming the solar wind flow to be purely radial, which is not the case.
As well as providing information on ambient solar wind conditions, interactions of comets with CMEs would provide valuable ejecta flow direction information.
Heliospheric current sheet crossings could be detected remotely from disconnection events in the cometary ion tails.
STEREO will provide solar wind data from comets at low elongations that are often unobservable from Earth.

Sequence Details

EUVI: [Bands - He II 304, Fe IX 171, Fe XII 195, Fe XV 284 Å; Resolution - 1.6 arcsec/pixel; FOV - 0.9 deg Sun-centred; Nominal cadence 30 s]

- Required (yes/no) No
- Which bands?
- Image cadence?
- FOV (full Sun, partial Sun (define area and pointing))
- Other details

COR1: [Bandpass - 650-660 nm (brightness and pB); Resolution - 7.5 arcsec/pixel; FOV - 1.3-4.0 R (full revolution; Sun centred); Nominal cadence 20 s (3 images/min in different polarisation angles)]

- Required (yes/no) Only if comet is in field of view.

- Image cadence? Synoptic observations would be sufficient. For very bright comets, short exposure frames would be beneficial to minimize blooming in images.
- FOV (full or partial field (define area and pointing)) Synoptic set-up would be sufficient.
- Other details

COR2: [Bandpass - 650-750 nm (brightness and pB); Resolution - 15 arcsec/pixel; FOV - 2-15 R (full revolution; Sun centred); Nominal cadence 100 s]

- Required (yes/no) Only if comet is in field of view.
- Image cadence? FOV (full or partial field (define area and pointing)) See comments for COR1.
- Other details

HI1: [Bandpass - 650-750 nm (brightness); Resolution - 35 arcsec/pixel; FOV - 20^{o} circle centred at 13.28^{o} to Sun centre (3.28-23.28^{o} along ecliptic); Nominal cadence 1 hr]

- Required (yes/no) Only if comet is in field of view.
- Image cadence? As for COR 1 and 2, synoptic observations should be sufficient in most cases. For comets in high-inclination orbits, which would provide additional information on the latitudinal structure of the solar wind, increased cadence would be beneficial due to rapid cometary motion near perihelion. For very bright comets, short exposure frames would be highly beneficial to minimize blooming in images, at least some of the time.
- FOV (full or partial field (define area and pointing)) Partial field frames could be beneficial for some comets, to increase cadence.
- Other details

HI2: [Bandpass - 400-1000 nm (brightness); Resolution - 240 arcsec/pixel;
FOV - 70^{o} circle centred at 53.36^{o} to Sun centre (18.36-88.36^{o} along ecliptic); Nominal cadence 2 hr]

- Required (yes/no) Only if comet is in field of view.
- Image cadence? See response for HI1
- FOV (full or partial field (define area and pointing)) See response for HI1
- Other details

Other Spacecraft/Instruments Required (give details of observation)?

For comets only observable by one STEREO spacecraft, ground-based observations would be required, where feasible, to produce three-dimensional images. Routine amateur observations should be of sufficiently high quality to allow successful combination with STEREO data.

Other relevant details?

Special Operational/Software Requirements? (i.e. requirements to feed into operations planning and software during mission development)

It should be possible to plan well beforehand for expected apparitions of periodic comets. Newly-discovered comets may provide the most useful solar wind data, due to their often higher production rates and high inclination orbits. The possibility of planning observations of these objects at short notice (within days or weeks) should be allowed if possible.

Observation Title: Interplanetary acceleration of ICMEs.

Name: Mathew Owens
Institute: Imperial College London
E-mail: mathew.owens@ic.ac.uk

Version Date: 27/11/03

Brief Scientific Objective and Observation Overview:

To construct the acceleration profile of a fast moving ICME over a large heliocentric range, so as to better understand the dominant forces acting on ejecta in interplanetary space. This should enable better prediction of the arrival times of ICMEs at Earth.

Multipoint observations of the heliocentric distance of the leading edge (or dense sheath region ahead of) a fast ICME are required. Enhanced cadence of the HI1 and HI2 instruments will benefit this study.

Sequence Details

EUVI: [Bands - He II 304, Fe IX 171, Fe XII 195, Fe XV 284 Å; Resolution - 1.6 arcsec/pixel; FOV - 0.9 deg Sun-centred; Nominal cadence 30 s]

- Required (yes/no) No.
- Which bands?
- Image cadence?
- FOV (full Sun, partial Sun (define area and pointing))
- Other details

COR1: [Bandpass - 650-660 nm (brightness and pB); Resolution - 7.5 arcsec/pixel; FOV - 1.3-4.0 R (full revolution; Sun centred); Nominal cadence 20 s (3 images/min in different polarisation angles)]

- Required (yes/no) no

- Image cadence?
- FOV (full or partial field (define area and pointing))
- Other details

COR2: [Bandpass - 650-750 nm (brightness and pB); Resolution - 15 arcsec/pixel; FOV - 2-15 R (full revolution; Sun centred); Nominal cadence 100 s]

- Required (yes/no) yes
- Image cadence? nominal
- FOV (full or partial field (define area and pointing)) full
- Other details required for the identification of CMEs and measurement of their initial speed.

HI1: [Bandpass - 650-750 nm (brightness); Resolution - 35 arcsec/pixel; FOV - 20^{o} circle centred at 13.28^{o} to Sun centre (3.28-23.28^{o} along ecliptic); Nominal cadence 1 hr]

- Required (yes/no) yes
- Image cadence? ~ 30 mins
- FOV (full or partial field (define area and pointing)) full
- Other details: Multi-point measurements of the heliocentric distance of the sheath region associated with a fast ICME are required.

HI2: [Bandpass - 400-1000 nm (brightness); Resolution - 240 arcsec/pixel;
FOV - 70^{o} circle centred at 53.36^{o} to Sun centre (18.36-88.36^{o} along ecliptic); Nominal cadence 2 hr]

- Required (yes/no) yes
- Image cadence? ~ 1 hour
- FOV (full or partial field (define area and pointing)) full
- Other details

Other Spacecraft/Instruments Required (give details of observation)?

Other relevant details?

Special Operational/Software Requirements? (i.e. requirements to feed into operations planning and software during mission development)

Observation Title: HI Beacon mode

Name: Sarah Matthews, Richard Harrison & Chris Davis
Institute: RAL/MSSL
E-mail: sam@mssl.ucl.ac.uk

Version Date: 2003/12/10

Brief Scientific Objective and Observation Overview:
This observation scenario addresses the optimum HI data product required for space weather purposes returned via the STEREO beacon mode. The HI is a unique instrument for space weather, providing the first opportunity to observe CMEs along the sun-Earth line with the Earth in the field of view (in practice we will have to occult the Earth due to its brightness), it is therefore vital to ensure that we exploit this valuable resource fully. Our baseline sequence provides HI1 and HI2 images binned to 256x256 pixels on an alternating hourly basis.

Sequence Details

EUVI: [Bands - He II 304, Fe IX 171, Fe XII 195, Fe XV 284 Å; Resolution - 1.6 arcsec/pixel; FOV - 0.9 deg Sun-centred; Nominal cadence 30 s]

- Required (yes/no) No
- Which bands?
- Image cadence?
- FOV (full Sun, partial Sun (define area and pointing))
- Other details

COR1: [Bandpass - 650-660 nm (brightness and pB); Resolution - 7.5 arcsec/pixel; FOV - 1.3-4.0 R (full revolution; Sun centred); Nominal cadence 20 s (3 images/min in different polarisation angles)]

- Required (yes/no) No
- Image cadence?
- FOV (full or partial field (define area and pointing))
- Other details

COR2: [Bandpass - 650-750 nm (brightness and pB); Resolution - 15 arcsec/pixel; FOV - 2-15 R (full revolution; Sun centred); Nominal cadence 100 s]

- Required (yes/no) No
- Image cadence?
- FOV (full or partial field (define area and pointing))
- Other details

HI1: [Bandpass - 650-750 nm (brightness); Resolution - 35 arcsec/pixel;

FOV - 20^{o} circle centred at 13.28^{o} to Sun centre (3.28-23.28^{o} along ecliptic); Nominal cadence 1 hr]

- Required (yes/no) Yes
- Image cadence? 1 hour
- FOV (full or partial field (define area and pointing)) Full
- Other details Needs to be binned to 256x256 pixels after summing

HI2: [Bandpass - 400-1000 nm (brightness); Resolution - 240 arcsec/pixel;
FOV - 70^{o} circle centred at 53.36^{o} to Sun centre (18.36-88.36^{o} along ecliptic); Nominal cadence 2 hr]

- Required (yes/no) Yes
- Image cadence? 1 hour
- FOV (full or partial field (define area and pointing)) Full
- Other details: Needs to be binned to 256x256 after summing

Other Spacecraft/Instruments Required (give details of observation)?

Other relevant details?

Special Operational/Software Requirements? (i.e. requirements to feed into operations planning and software during mission development)

The beacon mode has a separate telemetry stream that allows approximately 7 256x256 images to be down-linked each hour from SECCHI as a whole. The HI minimum requirement is for the inclusion of alternate 256x256 images from HI1 and HI2 to be included each hour.

6. Issues and requirements for consideration

The UK community has considered an inexhaustive, but representative, sample of science questions that may be addressed with SECCHI in combination with other instruments on STEREO and from other platforms. For several of these the science goal can be achieved using SECCHI's synoptic mode of operation. Studies that fall into this category include numbers 1, 3, 5, 6, 7, 8, 10 and 12. However, of these 8 studies 5 (1, 3, 10, 12 and 13) ask for the option of returning partial FOVs and would like higher cadences than nominal if possible. Several studies, while not always quantifying the actual values, ask for cadences higher than the nominal case. These include studies 2, 4, 9, 11 and 14. In addition, more than half of the studies proposed require co-ordination with either other instruments on STEREO (e.g. IMPACT) and/or instruments on other spacecraft or at ground-based facilities. These clearly represent challenges

from a planning perspective. To summarise some of the key points raised are:

1. The synoptic mode of operation of EUVI and COR 1 & 2 satisfies most of the science questions raised here. Synoptic operation of the HI instruments satisfies approximately half of the scenarios, but may well be adequate for a number of others.
2. Several of the scenarios listed here use only part of the SECCHI instrument package and so the ability to operate only part of the payload for specific campaigns should be considered, particularly if the subsequent re-distribution of telemetry allows some of the higher cadence requirements to be satisfied.
3. There are a number of studies that require partial fields, both in HI and other instruments. In particular, the studies involving co-ordination with IPS measurements (9,10,11,12) require pointing defined on the basis of the location of the IPS sources and the ability to change this pointing during the programme run, for HI in particular. In addition those studies involving co-ordination with remote sensing instruments either on the ground or on other platforms present challenges in terms of determining pointing.
4. There is a strong desire to be able to vary exposure times and cadences within HI. This is clearly has to be balanced against the requirement to achieve a reasonable signal-to-noise and to scrub the cosmic rays.
5. Expanding on point 2, there is a requirement to return data from only one of the HI instruments or to vary the order of the images. This requirement also applies to the HI beacon mode data.
6. There are clear planning issues arising from the desire to co-ordinate both with other STEREO instruments and other instruments on different spacecraft or ground-based facilities. This is most pronounced for those instruments with restricted fields of view (e.g. Solar-B EIS/FPP, SOHO-CDS) and where partial fields are required for the SECCHI instruments on the basis of IPS sources. The separation of the spacecraft is clearly an issue for some studies and so if these studies are to be run, substantial planning needs to be done prior to launch.
7. There was one request for COR1 to provide a CME trigger that would allow cadences in COR2 and HI1 and 2 to be varied, or to switch to a partial FOV. The benefit of such a trigger clearly depends on the ability to vary and improve cadences either by re-distributing telemetry or reading parts of the CCD.

7. Questions

1. Image cadences for HI

In principle the range of exposure times is limited only by the requirement that the on-board processor times the exposure. The instrument tick is planned to be 10-15ms, thus a 100 ms exposure will have an associated error of this order. Since there is no shutter it should be borne in mind that the time taken to clock out the CCD (2048□s for line transfers) means

that the final measured intensity will include a contribution from every pixel in the CCD column.

The factors which limit the instrument cadence include telemetry restrictions, cosmic ray scrubbing, CCD readout times etc. Methods that might be used to improve the cadence include using smaller FOVs and telemetry re-distribution – e.g. it is possible to have continuous coverage in HI1 with no HI2 coverage and vice versa. Partial FOVs are also possible – what is the maximum improvement in cadence that we obtain by limiting the FOV? The images are cleaned on-board and this cosmic ray scrubbing is one of the main limitations as far as cadence is concerned, without additional CPU power on-board. Is it possible, or desirable, to consider the option of disabling this feature where very high cadence observations are required and cleaning cosmic rays on the ground?

Other suggestions might include on-board differencing. Pixel summing is available on-board, both on-chip and in software – could we consider transmitting image differences, or would the additional processing cancel out any gains made in down-linking the data?

2. Planning Considerations

There will be a limited command uplink and so very complicated daily schedules which involve several different observations requiring different variations on any of the above methods to improve cadence, will be difficult to execute. We might want to consider, in agreement with the rest of the SECCHI team, the possibility of campaigns which last for as long as a few days in order to address specific science objectives that have requirements outside of the nominal instrument parameters. This would lead to a much simpler schedule.

Other planning issues to consider are co-ordinations with other instruments, both in space and on the ground. Those studies which rely heavily on complementary data-sets from remote-sensing instruments will be most easily achieved early in the mission when the spacecraft separation is small.

8. Appendix – study form template

Observation Title:

Name: Institute: E-mail:

Version Date:

Brief Scientific Objective and Observation Overview:

Sequence Details

EUVI: [Bands - He II 304, Fe IX 171, Fe XII 195, Fe XV 284 Å; Resolution - 1.6 arcsec/pixel; FOV - 0.9 deg Sun-centred; Nominal cadence 30 s]

- Required (yes/no)
- Which bands?
- Image cadence?
- FOV (full Sun, partial Sun (define area and pointing))
- Other details

COR1: [Bandpass - 650-660 nm (brightness and pB); Resolution - 7.5 arcsec/pixel; FOV - 1.3-4.0 R (full revolution; Sun centred); Nominal cadence 20 s (3 images/min in different polarisation angles)]

- Required (yes/no)
- Image cadence?
- FOV (full or partial field (define area and pointing))
- Other details

COR2: [Bandpass - 650-750 nm (brightness and pB); Resolution - 15 arcsec/pixel; FOV - 2-15 R (full revolution; Sun centred); Nominal cadence 100 s]

- Required (yes/no)
- Image cadence?
- FOV (full or partial field (define area and pointing))
- Other details

HI1: [Bandpass - 650-750 nm (brightness); Resolution - 35 arcsec/pixel; FOV - 20^{o} circle centred at 13.28^{o} to Sun centre (3.28-23.28^{o} along ecliptic); Nominal cadence 1 hr]

- Required (yes/no)
- Image cadence?
- FOV (full or partial field (define area and pointing))
- Other details

HI2: [Bandpass - 400-1000 nm (brightness); Resolution - 240 arcsec/pixel;
FOV - 70^{o} circle centred at 53.36^{o} to Sun centre (18.36-88.36^{o} along ecliptic); Nominal cadence 3 hr]

- Required (yes/no)
- Image cadence?

- FOV (full or partial field (define area and pointing))
- Other details

Other Spacecraft/Instruments Required (give details of observation)?

Other relevant details?

Special Operational/Software Requirements? (i.e. requirements to feed into operations planning and software during mission development)