SOHO
Science Operations Plan

Issue 2.1

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Contents

Preface

This document describes the concept and methodology of the SOHO science operations, including the organisation, dissemination, archiving and access mechanisms for the SOHO data products. It addresses the coordinated operation and data analysis of the SOHO investigations and will be a reference manual for that.

This issue 2.1 (March 1995) supersedes all previous issues. Changes with respect to draft issue 2.0 (May 1994) are marked with a margin bar.

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with inputs from the members of the SOHO Science Operations Working Group, both as individuals and as a group at their meetings.

Reference Documents

The SOHO Mission: ESA SP-1104
SOHO EID Part A
EID Part B of SOHO's experiments
Minutes of the SOWG meetings
Interface Control Document between SOHO, EOF, ECS and the SOHO instruments
GOLF Flight Operations Document
MDI/SOI technical facility doc.
Mission Operations Plan for the Wide-Angle White Light and Spectrometric Coronagraph: LASCO doc
SWAN Science Operations Plan
The Coronal Diagnostic Spectrometer for SOHO: Scientific Report
The SUMER Spectrometer for SOHO: Scientific Report
SOHO Inter-Instrument Flag Implementation and Utilisation Plan, Version 1.1, Dec. 1992
The SOHO Interdisciplinary Science Martix (R.A. Harrison & G. Schultz), ESA SP-348, p. 397

List of Acronyms

AIT	Atomic International Time
AIV	Assembly-Integration-Verification
AO	Announcement of Opportunity
CCSDS	Consultative Committee for Space Data Systems
CDDI	Copper Distributed Data Interface
CDF	Common Data Format (SFDU data format)
CDHF	Central Data Handling Facility
CDS	Coronal Diagnostic Spectrometer
CELIAS	Charge, ELement and Isotope Analysis
CEPAC	COSTEP – ERNE Particle Analyser Collaboration
CMS	Command Management System
Co-I	Co-Investigator
COSTEP	COmprehensive SupraThermal and Energetic Particle analyser
DDF	Data Distribution Facility
DSN	Deep Space Network
ECS	EOF Core System
ECS FRD	ECS Functional Requirements Document
EGSE	Electrical Ground Support Equipment
EIT	Extreme-ultraviolet Imaging Telescope
EOF	Experiment Operations Facility
ERNE	Energetic and Relativistic Nuclei and Electron experiment
ESA	European Space Agency
ESOC	European Space Operations Centre (ESA, Darmstadt)
Ethernet	local area network defined by ISO 802.3
FDDI	Fiber Distributed Data Interface
FDF	Flight Dynamics Facility
FITS	Flexible Image Transport System
FOT	Flight Operations Team
FTP	File Transfer Protocol
GCI	GeoCentric Inertial
GDCF/Pacor	ISTP Program Generic Data Capture Facility / Packet Processor
GGS	Global Geospace Science
GI	Guest Investigator
GISC	Guest Investigator Selection Committee
GOLF	Global Oscillations at Low Frequency
GSE	Geocentric Solar Ecliptic
GSFC	Goddard Space Flight Center
GSM	Geocentric Solar Magnetic
IDL	Interactive Data Language
IPD	Infomation Processing Division
ISTP	International Solar-Terrestrial Physics
IUE	International Ultraviolet Explorer
IWS	Instrumenter Workstation
LAN	Local Area Network
LASCO	Large Angle Spectroscopic COronagraph
MAR	Mission Analysis Room

MOR	Mission Operations Room
MDI/SOI	Michelson Doppler Imager/Solar Oscillations Imager
N/A	Not Applicable
NASA	National Aeronautics and Space Administration
NFS	Network File Services
NOAA	National Oceanic and Atmospheric Administration
NRT	Near Real-Time
NSI	NASA Science Internet
NSO	National Solar Observatory
NSSDC	National Space Science Data Center
OBT	On-Board Time
PACOR	Packet Processor
P/M	Payload Module
PI	Principal Investigator
POCC	Payload Operations Control Center
PS	Project Scientist
PSO	Project Scientist Office
PVL	Parameter Value Language
R/T	Real-Time
S/C	SpaceCraft
SDAC	Solar Data Analysis Center
SDC	Science Data Coordinator
SELDADS	Space Environment Laboratory Data Acquisition and Display System
SELSIS	Space Environment Laboratory Solar Imaging System
SFDU	Standard Formatted Data Unit
SMIP	SOHO Mission Implementation Plan
SMIRD	SOHO Mission Implementation Requirements Document
SMM	Solar Maximum Mission
SMOCC	SOHO Mission Operations Control Center
SOC	Science Operations Coordinator
SOHO	SOlar and Heliospheric Observatory
SOWG	SOHO Science Operations Working Team
SOL	Science Operations Leader
SOP	Science Operations Plan
SOT	Science Operations Team
SQL	Structured Query Language
SUMER	Solar Ultraviolet Measurements of Emitted Radiation
SWAN	Solar Wind ANisotropies
SWT	Science Working Team
TAI	Temps Atomique International
TBC	To Be Confirmed
TBD	To Be Defined
TC	TeleCommands
TCP/IP	Transmission Control Protocol / Internet Protocol
UTC	Universal Time Code
UVCS	UltraViolet Coronagraph Spectrometer
VIRGO	Variability of solar IRradiance and Gravity Oscillations
WS	Work-Station

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Chapter 1

Mission Overview

1.1 Scientific objectives

The SOHO satellite is a solar observatory to study: the structure, chemical composition, and dynamics of the solar interior, the structure (density, temperature and velocity fields), dynamics and composition of the outer solar atmosphere, and the solar wind and its relation to the solar atmosphere. To accomplish this, SOHO will carry a set of telescopes to study phenomena initiated by processes commencing below the photosphere, and propagating through the photosphere, chromosphere, and the transition region into the corona. The SOHO instruments are designed to investigate problems such as how the corona is heated and transformed into the solar wind that blows past the Earth at 400 km/s. To do so they will have spectrometers to study the emission and absorption lines produced by the ions present in the different regions of the solar atmosphere. From this information it will be possible to determine densities, temperatures and velocities in the changing structures. These measurements are complemented by the "in situ" study of the composition and energy distribution of the solar wind ions and energetic particles that emanate from the coronal structures observed by the telescopes. SOHO will thus greatly enhance our knowledge of the solar wind and its source region.

While the solar interior is the region that generates the kinetic and magnetic energy driving outer atmospheric processes, almost no direct information can be obtained about any region below the photosphere. The neutrinos generated by the nuclear reactions, taking place in the core, are the only direct radiation that reaches us from anything that is below the photosphere. A relatively new technique, helioseismology, has developed in the last two decades that allows us to study the stratification and the dynamical aspects of the solar interior. It uses the study of the acoustic and gravity waves that propagate through the interior of the Sun and can be observed as oscillatory motions of the photosphere. An analysis of these oscillations allows us to determine the characteristics of the resonant cavities in which they resonate, much in the same way as the Earth's seismic waves are used to determine the structure of the Earth interior.

To study the solar interior, SOHO will carry a complement of instruments whose aim is to study the oscillations at the solar surface by measuring the velocity (via the Doppler effect) and intensity changes produced by pressure and gravity waves. The study of such oscillations requires both high resolution imaging and long uninterrupted time series of observations. In addition, because it is paramount to understand the structure of the Sun in relation to the oscillation measurements, the total solar irradiance, or solar constant, and its variations will be measured.

Investigation	PI	Measurements	Technique	Bit rate (kb/s)
HELIOSEISMOLOGY				
GOLF	A.Gabriel, IAS, Orsay, F	Global Sun velocity oscillations (ℓ=0-3)	Na-vapour resonant scattering cell Doppler shift and circular polarization	0.160
VIRGO	C.Fröhlich, PMOD/WRC, Davos, CH	Low degree (ℓ=0-7) irradiance oscillations and solar constant	Global Sun and low resolution (12 pixels) imaging, active cavity radiometers	0.1
SOI/MDI	P.Scherrer, Stanford Univ., CA	Velocity oscillations with harmonic degree up to 4500	Doppler shift and magnetic field observed with Michelson Doppler Imager	5 (+160)
SOLAR ATMOSPHERE REMOTE SENSING				
SUMER	K.Wilhelm, MPAE, Lindau, D	Plasma flow characteristics: T, density, velocity in chrom. through corona	Normal incidence spectrometer: 50-160 nm spectral resolution 20000-40000, angular res.: 1.5"	10.5 (or 21)
CDS	R.Harrison, RAL, Chilton, UK	Temperature and density in transition region and corona	Normal and grazing incidence spectrom.: 15-80 nm, spectr. res. 1000-10000 angular res. 3"	12 (or 22.5)
EIT	J.P.Delaboudinière IAS, Orsay, F	Evolution of chromospheric and coronal structures	Images (1024 x 1024 pixels in 42' x 42') in the lines of He II, Fe IX, Fe XII, Fe XV	1 (or 26.2)
UVCS	J.Kohl, SAO, Cambridge, Mass.	Electron and ion temp. densities, velocities in corona (1.3-10 $R_\odot$)	Profiles and/or intensity of several EUV lines (Ly α, O VI, etc.) between 1.3 and 10 $R_\odot$	5
LASCO	G.Brueckner, NRL, Washington, DC	Evolution, mass, momentum and energy trans. in corona (1.1-30 $R_\odot$)	1 internal and 2 externally occulted coronagraphs, Fabry-Perot spectrometer for 1.1-3 $R_\odot$	4.2 (or 26.2)
SWAN	J.L.Bertaux, SA, Verrières-le-Buisson, F	Solar wind mass flux aniso-atropies + temporal var.	2 scanning telescopes with hydrogen absorption cell for Ly-α light	0.2
SOLAR WIND 'IN SITU'				
CELIAS	D.Hovestadt, MPE, Garching, D	Energy distribution and composition (mass, charge, ionic charge) of ions (0.1-1000 keV/e)	Electrostatic deflection system, Time-of-Flight measurements, solid state detectors	1.5
COSTEP	H.Kunow, Univ. of Kiel, D	Energy distribution of ions (p, He) 0.04-53 MeV/n and electrons 0.04-5 MeV	Solid state and plastic scintillator detector telescopes	0.3
ERNE	J.Torsti, Univ. of Turku, SF	Energy distribution and isotopic composition of ions (p - Ni) 1.4-540 MeV/n and electrons 5-60 MeV	Solid state and scintillator crystal detector telescopes	0.71

Table 1.1: SOHO payload

1.2 Instrumentation

The investigations on-board SOHO (Table 1.1) can be divided into three main groups, according to their area of research : helioseismology, solar atmospheric remote sensing, and "in situ" particle measurements.

Helioseismology
The helioseismology investigations primarily aim at the study of those parts of the solar oscillations spectrum that cannot be obtained from the ground. The required sensitivity for observing the very low modes ($l \leq 7$) and the high modes ($l \geq 300$) is difficult to achieve from the ground because of noise effects introduced by the Earth's diurnal rotation for the low modes, and the transparency and seeing fluctuations of the Earth's atmosphere for the high modes.

Solar atmospheric remote sensing
The solar atmosphere remote sensing investigations are carried out with a set of telescopes and spectrometers that will produce the data necessary to study the dynamic phenomena that take place in the solar atmosphere at and above the chromosphere. The plasma will be studied by spectroscopic measurements and high resolution images at different levels of the solar atmosphere. Plasma diagnos-

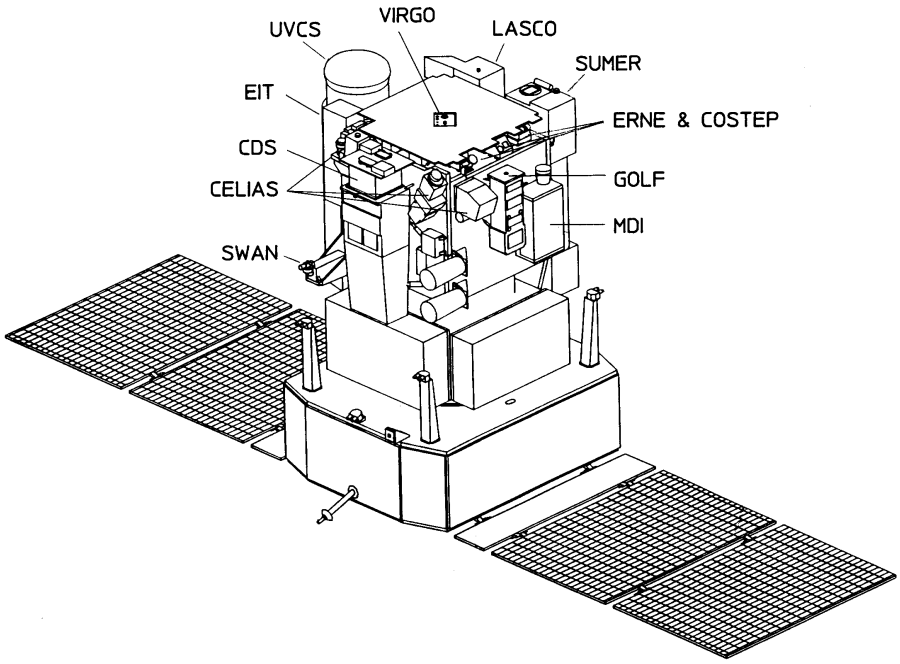

Figure 1.1: SOHO spacecraft schematic view

tics obtained with these instruments will provide temperature, density, and velocity measurements of the material in the outer solar atmosphere.

"In situ" measurements
The instruments to measure "in situ" the composition of the solar wind and energetic particles will determine the elemental and isotopic abundances, the ionic charge states and velocity distributions of ions originating in the solar atmosphere. The energy ranges covered will allow the study of the processes of ion acceleration and fractionation under the various conditions.

1.3 Spacecraft, Orbit, Attitude

The SOHO spacecraft (Fig. 1.1) will be three-axis stabilized and point to the Sun within an accuracy of 10 arc sec and have a pointing stability of 1 arcsec per 15 minutes interval. It will consist of a payload module which accommodates the instruments and a service module carrying the spacecraft subsystems and the solar arrays. The total mass will be about 1850 kg and 1150 W power will be provided by the solar panels. The payload will weigh about 640 kg and will consume 450 W in orbit.

SOHO is planned to be launched in July 1995 and will be injected in a halo orbit around the L1 Sun-Earth Lagrangian point, about 1.5×10^6 km sunward from the Earth. The halo orbit will have a period of 180 days and has been chosen because, 1) it provides a smooth Sun-spacecraft velocity change throughout the orbit, appropriate for helioseismology, 2) is permanently outside of the magnetosphere, appropriate for the "in situ" sampling of the solar wind and particles, and 3) allows permanent observation of the Sun, appropriate for all the investigations. The Sun-spacecraft velocity will be measured with an accuracy better than 0.5 cm/s.

SOHO is being designed for a lifetime of two years, but will be equipped with sufficient on-board consumables for an extra four years.

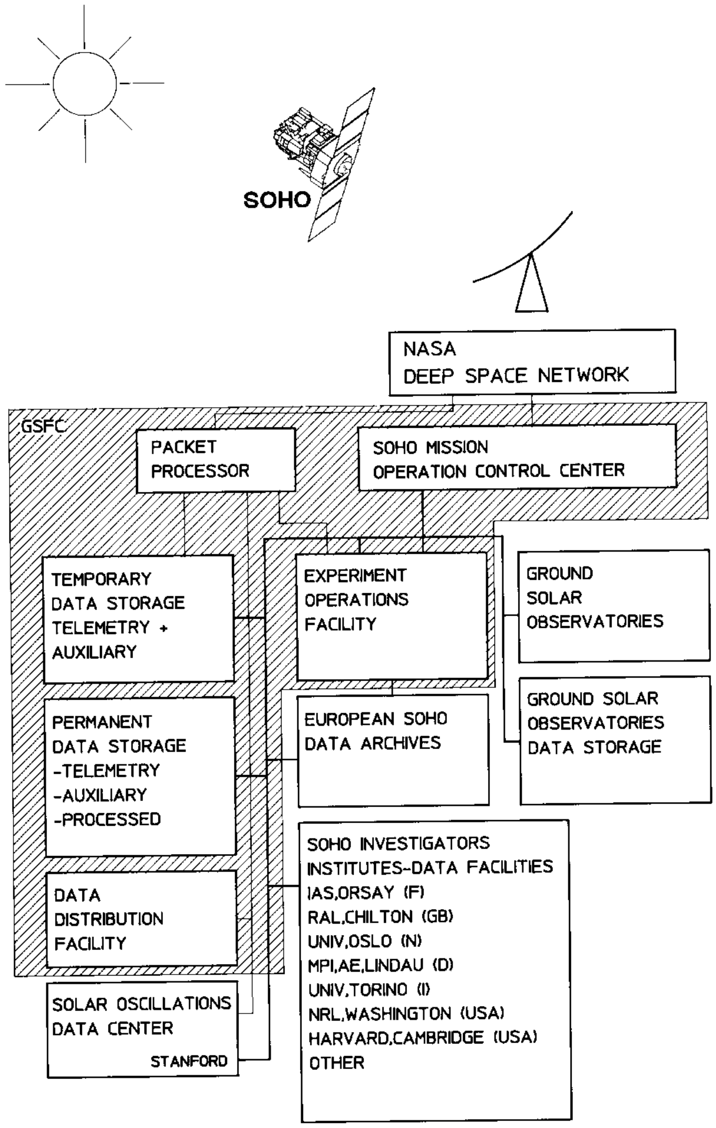

Figure 1.2: SOHO ground system: basic functions related to science operations

1.4 Operations

The diagram in Fig 1.2 shows the basic functions that will be present for the SOHO science operations. The SOHO Experiment Operations Facility (EOF), to be located at NASA Goddard Space Flight Center, will serve as the focal point for mission science planning and instrument operations. At the EOF, experiment PI representatives will receive real-time and playback flight telemetry data, process these data to determine instrument commands, and send commands to their instruments, both in near real-time and on a delayed execution basis. They will be able to perform data reduction and analysis, and have capabilities for data storage. To accomplish these ends, the appropriate experiment teams will use workstations (WS's) that will be connected to an EOF Local Area Network (LAN). Additional workstations and X-terminals will be used to support the Project Scientists (PS) and for SOHO planning and operations support staff in the EOF. There will be connections from the EOF to external facilities to allow transfer of incoming data from GSFC support elements, remote investigator institutes, other solar observatories, and ESA facilities. There will also be connections for the EOF to interact with the SOHO Mission Operations Control Center (SMOCC) and other required elements at GSFC for scheduling and commanding the SOHO flight experiments. Short term and long term data storage will be either within the EOF or at an external facility with electronic communication access from the EOF.

The Deep Space Network (DSN) will receive S/C telemetry during three short (1.6 hrs) and one long (8 hrs) station pass per day. Science data acquisition during non-station pass periods will be stored on-board and played back during the short station passes. The MDI high data rate stream will be transmitted only during the long station pass. For 2 consecutive months per year continuous data transmission, including MDI high data rate, will be supported by DSN. Whenever there is data transmission, the basic science data (40 kbits/s) and housekeepig data (15 kbit/s) will be available in near real-time at the EOF. From the EOF the SOHO investigators will control the operation of the instruments via the Payload Operations Control Center (POCC). The latter will verify and up-link the commands submitted by the experimenters.

Some SOHO instruments (CEPAC, CELIAS, VIRGO, GOLF, and SWAN) will generally operate automatically and will not need near real-time operational control except for surveillance of housekeeping data. Other instruments, those of the coronal imaging investigators, will be operated interactively every day in real (or near real-) time.

The EOF has the following functions:

a) Provides the means with which the PI teams participating in the SOHO programme can monitor and, via SMOCC, control their instruments on-board the spacecraft.

b) Is the center where the solar atmosphere investigators of SOHO will coordinate and plan the near real-time operation of their instruments, and will be the focal point on the one hand, for the overall SOHO science operations planning, and on the other, for coordinating science studies through the organisation of campaigns and data analysis workshops.

c) Provides electronic interfaces with the appropriate data bases and networks to support the WS's activities and to provide the necessary input from ground stations and other spacecraft data for the planning of the SOHO science operations.

d) Provides data storage for science, engineering and housekeeping data; common data (attitude, orbit and spacecraft housekeeping) are also stored there. Cataloging capabilities are also available.

A complete description of the EOF is found in chapter 4.

Chapter 2

SOHO Operations Policy and Requirements

2.1 Operations Plan

2.1.1 Overview

2.1.1.1 Routine operation

The SWT will set the overall science policy and direction for mission operations, set priorities, resolve conflicts and disputes, and consider Guest Investigator observing proposals. During SOHO science operations, the SWT will meet every three months to consider the quarter starting in one month's time and form a general scientific plan. If any non-standard DSN contacts are required, the requests must be formulated at this quarterly meeting. The three-month plan will then be refined during the monthly planning meetings (see 2.1.2) of the Science Operations Team (SOT), composed of those PIs or their team members with IWSs at the EOF, which will allocate observing sessions to specific programs. At weekly meetings of the SOT (2.1.3) , coordinated timelines will be produced for the instruments, together with detailed plans for spacecraft operations. Daily meetings of the SOT (2.1.4) will optimize fine pointing targets in response to solar conditions and adjust operations if DSN anomalies occur.

2.1.1.2 Responsibilities

While the Project Scientist (PS) will be responsible for the implementation of the scientific operations plan, execution of the plan will be carried out by the SOT. On a rotating basis, one of the PIs or their representatives at the EOF will serve as the Science Operations Leader (SOL). The SOL will serve for approximately 10 days, starting with the weekly planning meeting and continuing through the week of operations. The SOL will

- chair the weekly planning meeting and the daily meetings during the following week
- be responsible for the successful execution of the weekly plan.

To provide operational continuity over the course of the SOHO mission, and from one SOL's tenure to the next, a Science Operations Coordinator (SOC), who is not a member of any of the PI teams, will work daily with the SOL and SOT. The SOC's role is to

- produce and distribute an integrated science plan resulting from the daily meetings
- maintain the monthly scientific planning schedule

- insure coordination of inter-instrument operations and campaigns with other rocket, spacecraft, and ground based observatories
- advise the various planning meetings on the availability of ground- and space-based collaborations
- work daily with local PI teams to resolve inter-instrument conflicts and optimize scientific return
- coordinate commanding and problem resolution with Remote PI teams
- act as primary interface between experimenters and FOT to insure smooth planning and scheduling of all spacecraft activities
- inform the SOT of spacecraft status and DSN, SMOCC, and FDF (Flight Dynamics Facility) constraints on scheduling

There will be two full-time SOC's and two Science Data Coordinators (SDC). The SDC's role is to

- monitor data accountability of telemetry reception
- develop and maintain the SOHO archive at the EOF, i.e. update SOHO databases and catalogues with input from PI teams
- organize routine data handling activities:
  - Command History File.
  - SOHO Daily Activity Report.
  - Planning and scheduling information.
  - Time Correlation File information.
  - Predictive and Definitive Orbit File.
  - Definitive Attitude File.
  - Daily Summary Data.
  - Database/Catalogue information.
  - Images, particles and fields data.
- assemble and archive data from other observatories (both ground-based and other spacecraft) useful for planning purposes and scientific analysis
- assist users in the access and use of SOHO data and analysis software (this will start as a completely PI-team-based function, but gradually shift to a service role, reflecting experience gained during the operations phase in the use of archival data)

2.1.2 Monthly planning cycle

On a monthly time scale the SOT will meet to assess progress in achieving the scientific goals of their investigation and to discuss the objectives for operations starting in a month's time. This gives time for coordinated observations to be set up, arrangements for Guest Investigators to be made, and any deficiencies in observing sequences to be identified.

Approximately 2 weeks later a SOT meeting will discuss instrument health, solar activity and consider the operations for the month under consideration. SOL's will be appointed for each week and they will be responsible during the month for identifying any conflicts between the planned operations and the DSN schedule as they become available.

Inputs to the monthly meeting are made by each instrument team and common objectives are identified. The output of this meeting is a schedule showing when each instrument will be operating, whether

Meeting	Operational period being considered	Output
Quarterly SWT	Quarter starting in 1 month time	General plan
Monthly	Month starting in 2 weeks time	Observational priorities, schedule for month, time block allocated to specific programs, joint observations, supporting observations, guest investigators
Weekly	Week start in 3 days time	Detailed plan, time for sequences to be run, telemetry rates, flag-master/slaves, disturbances, calibrations.
	Week starting in 10 days time	Advance notice of changes to monthly schedule
Daily	Current day	Optimisation of current pointing targets. R/T instruments commands
	Tomorrow	Choice of pointing targets
	Day after tomorrow	Changes to weekly plan S/C command load

Table 2.1: Schedule for SOHO planning meetings

joint or individual observations are being made, the types of solar features being observed, ground observatory support and a backup plan if these conditions are not met. Requirements for telemetry rate switching should be identified together with any spacecraft operations which may affect the observations, for example momentum dumping and station keeping. Conflicts between instruments for resources are resolved and disturbances identified.

2.1.3 Weekly detailed planning

A weekly meeting considers the week starting in approximately three days time and this is when the detailed plans for all the SOHO instruments are synchronised. It will be convened by the SOL designated to lead that week. The intention is to lay out a definitive plan with timings, flag status, disturbances, etc., so that the daily meetings only consider deviations from the weekly plan. This meeting will have the conflict-free DSN schedule available.

The weekly meeting will also be the forum for instrument teams to give advance notice of any special operations or changes to the plan for future weeks. The DSN forecast schedule will be available for the week commencing in 10 days time and the strawman proposal will be available for the week following that.

2.1.4 Daily optimisation meeting

The daily meeting convenes to hear about the state of the Sun, discusses fine pointing targets and whether any changes are necessary in view of yesterday's operations. On the nominal timeline which follows, this meeting would take place early in the long real time contact, at approximately 10:00 GSFC local time, so that recent images from other SOHO instruments and ground observatories will be available and allow optimisation of observations, particularly pointing targets, for the current pass and also those planned for the next 24 hours. A "SOHO planning day" will start towards the end of the long real time pass, at approximately 15:00, so routine commands for the next 24 hours should

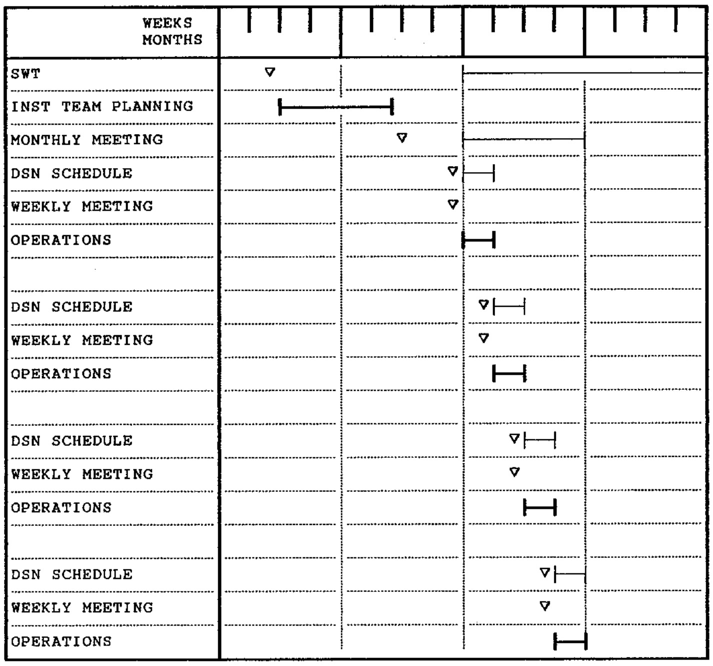

Figure 2.1: SOHO planning cycle

be uplinked by 15:00 to allow for checking and contingency. Figure 2.1 and 2.2 summarize the SOHO planning cycle activities.

2.1.5 S/C operations time line

Fig 2.2 shows the proposed overall time line of operations. The time of the long real-time operation (MDI high data rate) has been chosen to be day-light in GSFC and to overlap about half time with the Canary Islands observatories and with the USA western observatories. The 2-month continuous operation is arbitrary selected. It is expected that both the time of the day and the period of the year for the MDI high data rate will have to be adapted to DSN capabilities both for technical and scheduling reasons.

It is also expected that the Soho SWT will, on certain occasions, for correlative studies with particular ground observations or with other space missions, request modifications to the baseline operations schedule for limited periods of time.

2.1.6 Commanding schedule

During the real time operation periods the individual investigators will send their commands as needed from their workstations. It is required that the command processing time from WS to spacecraft be less than one minute. Real-time commanding rate will be typically less than 100 per hour, with peaks of about 10-20 per minute.

2.1.7 Instruments timeline: sample

This two day timeline is intended to show the degree of interaction and coordination between the instruments during a “typical” day (Fig. 2.3 and 2.4). At some times all of the instruments will be addressing a common objective, at other times joint science will be carried out by smaller number and

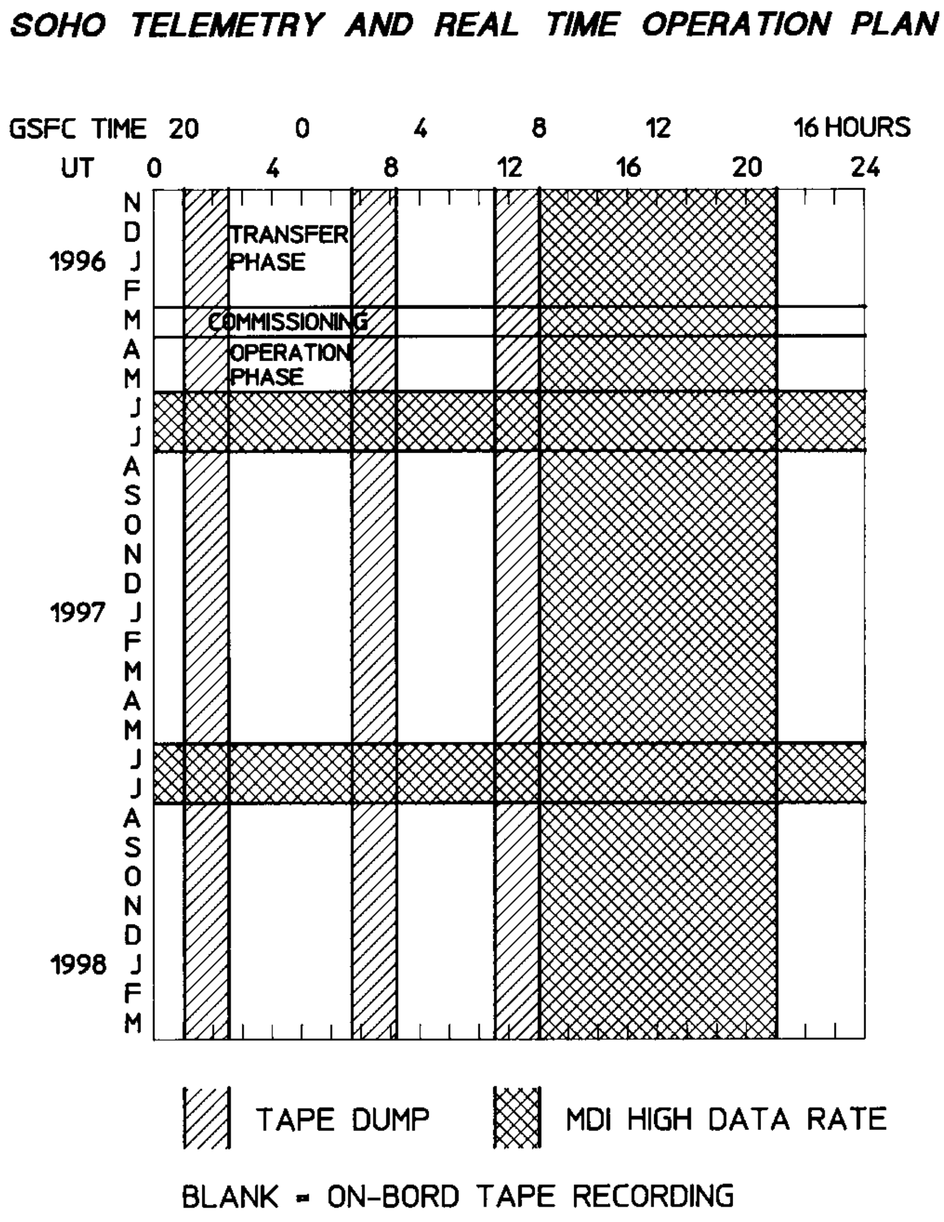

Figure 2.2: SOHO telemetry and real time operation plan

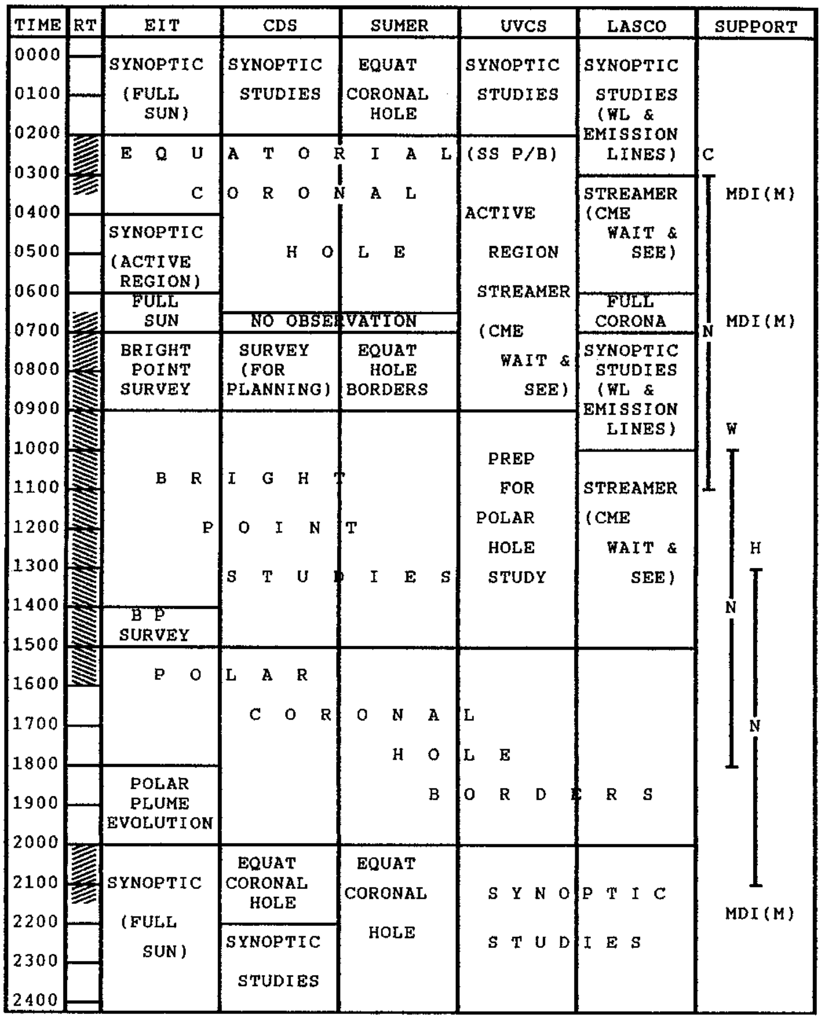

Figure 2.3: One day SOHO observing plan (Coronal instruments), Day D

there will be occasions when instruments will be working individually. Naturally there is a tremendous scope for variation.

Notes:

- TIME refers to local i.e. GSFC time. 07:00 is noon GMT.
- RT is when Real Time contact through the DSN is scheduled.
- SUPPORT: C denotes nominal observing time at the Canaries, W at the US West coast observatories and H at Hawaii. MDI (M) is when an MDI magnetogram is taken. This is scheduled for the end of the short real time passes to enable the tape recorder to be dumped first, but at the beginning of the low real time pass so that it is coincident with the EIT image.

02:00 CDS and SUMER check instrument performance and optimise observing programs (particularly pointing) for the next session. UVCS and LASCO observe a streamer which may give a CME.

03:25 MDI make a magnetogram.

07:00 Telemetry format 2 is used to enable EIT and LASCO to make full Sun images. MDI make magnetogram.

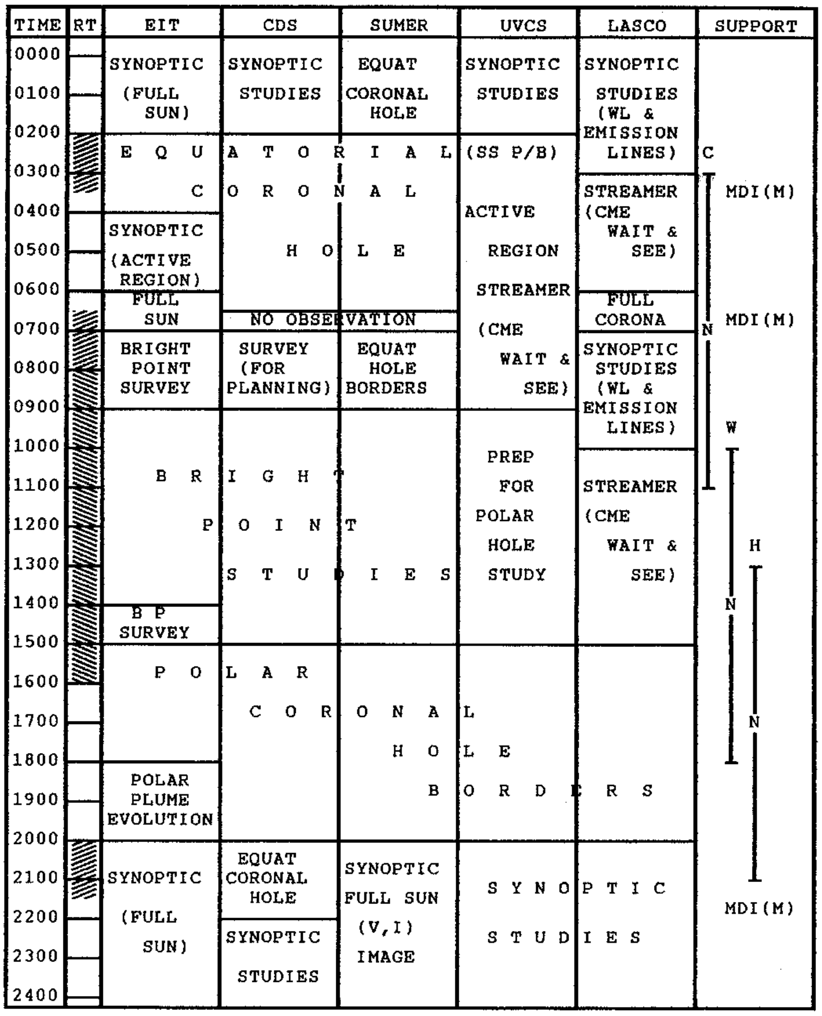

Figure 2.4: One day SOHO observing plan (Coronal instruments), Day D+1

07:30 - 09:00 CDS and SUMER make a series of short interactive observations to identify features to be studied during the rest of the real time pass and features to be studied collectively during the following SOHO day. EIT carry out a bright point survey. LASCO continue synoptic studies.

10:00 Daily SOHO meeting which optimises the plan for the day starting at 15:00 and considers the plan for the day after.

14:00 EIT repeat their bright point survey.

15:00 SOHO observing day starts. All instruments concentrating on the same area with the same objectives.

20:00 CDS and SUMER check instrument performance and optimise observing programs (particularly pointing) for the next session. Every 2 days SUMER will make a full Sun scan to give intensity and velocity maps. EIT, UVCS and LASCO start synoptic observations.

2.1.8 Coordinated campaigns

Within SOHO

During agreed periods one or several experiment teams and, if agreed, teams from other spacecraft or ground observatories will run, in collaboration, observation campaigns to address specific topics. The periods of two-months continuous near real-time observation will probably be the most convenient for campaigns that require continuous observation during more than 8 hours, or that require coordination with ground observations only feasible from particular observatories around the world. For each campaign a campaign leader will be responsible for the coordination.

Examples:

- LASCO, SWAN and SUMER
  Possible coordinated cometary observations (known or new). This should be organized on relatively short notice. Extension and magnitude of polar coronal holes. This can be done on a slower time schedule.
- LASCO, UVCS, EIT, SUMER, CDS and MDI
  A candidate structure emerges from the East limb, it is tracked by LASCO and UVCS, followed by EIT, SUMER, CDS, MDI when it transits the disk, and then LASCO and UVCS when it disappears beyond the West limb.

With ground-based observatories

If the ground-based observatory is one that has electronic links that allow near real-time imaging transmission to and from the EOF, the coordination will be no different than if the ground based observatory were one of the SOHO experiments.

If no real-time data transmission is needed or possible, the coordinated operation will be an agreed time of simultaneous observations.

Generally speaking the coordinated observations with ground observatories will need a longer time lead in their planning to insure availability of the facility and coincidence of the SOHO real-time coverage.

2.2 Conventions

The following conventions apply to facilitate the coordination of science planning, expedite the exchange of data between different instrument teams, and enhance the overall science activities.

2.2.1 Spacecraft time

The SOHO On Board Time (OBT) will use the CCSDS format, level 1 (TAI reference, 1958 January 1 epoch), as discussed in section 3.3.9 of the SOHO Experiment Interface Document Part A (Issue 1). The SOHO OBT is an unsegmented time code with a basic time equal to 1 second and a value representing the number of seconds from 1 January 1958 based on International Atomic Time. The OBT Pulse is adjusted to maintain the OBT within ± 20 ms of the ground TAI.

The SOHO OBT is used to time tag the data packets sent to the EOF and to the Data Distribution Facility (DDF). The time tags for the spacecraft and instrument housekeeping packets are generated by the spacecraft on-board data handling system. The time tags for the instrument science data packets are inserted by the instruments generating the science data. The time tags will be provided in 6 bytes; the first 4 bytes are TAI seconds (2^0 to 2^{31} seconds) and the last 2 bytes are fractions of a second with the resolution of the On Board Time Pulse (2^{-11} seconds).

The SOHO Daily Pulse is generated every 86,400 seconds, and is synchronized to the TAI with an accuracy better than ± 100 ms. The Daily Pulse will correspond to the beginning of a TAI "day", that is the Daily Pulse will occur at the zeros of TAI modulo 86,400. As of 1 January 1993, the difference between TAI midnight and 00:00 UTC was 27 seconds. Since July 1^{st} 1993 UTC - TAI = –28 sec (TBC).

The helioseismology experiments plan to center one minute observations on the TAI minute, that is where TAI modulo 60 is zero.

2.2.2 Ground time

Coordinated Universal Time (UTC) will be used as the operational time reference in the Experiment Operations Facility. The "SOHO operations day" is defined to begin at 00:00 UTC and the computer systems in the SMOCC and EOF will be synchronized to run on UTC.

2.2.3 Solar rotation axis

The solar rotation axis will be calculated using the Carrington ephemeris elements. These elements define the inclination of the solar equator to the ecliptic as 7.25 degrees, and the longitude of the ascending node of the solar equator on the ecliptic as $(75.76 + 0.01397 * T)^{\circ}$, where T is the time in years from J2000.0.

The solar rotation axis used for alignment of the SOHO spacecraft will be determined from the Carrington ephemeris elements. The Experiment Interface Document Part A (Issue 1, Rev 3) lists the longitude of the ascending node of the solar equator as 75.62° and the position of the pole of the solar equator in celestial coordinates as 286.11° right ascension and 63.85° declination. This definition is consistent with a solar rotation axis determined from the Carrington elements for a date of 1 January 1990. As mentioned in the EID Part A, this information must be updated for the actual launch date.

Heliographic longitudes on the surface of the Sun are measured from the ascending node of the solar equator on the ecliptic on 1 January 1854, Greenwich mean noon, and are reckoned from 0 to 360° in the direction of rotation. Carrington rotations are reckoned from 9 November 1853, 00:00 UT with a mean sidereal period of 25.38 days, and are designated as CR_{1903} etc..

2.2.4 Inter-instrument flag reference coordinates

The spacecraft optical axes are defined with respect to the optical alignment cube of the Fine Pointing Sun Sensor, with the optical X axis (X_0) nominally perpendicular to the spacecraft launcher separation plane and pointing from the separation ring through the spacecraft. The spacecraft optical Y axis (Y_0) is along the direction of the solar panel extension with positive Y_0 pointing from the interior of the spacecraft towards the UVCS instrument.

The orientation of the SOHO spacecraft is planned to have the spacecraft optical X axis (X_0) pointing towards the photometric center of the Sun, and the spacecraft optical Z axis (Z_0) oriented towards the north ecliptic hemisphere such that the (X_0,Z_0) plane contains the Sun axis of rotation. As such the Y_0 axis will be parallel to the solar equatorial plane pointing towards the east (opposite to the solar rotation direction). ESA will be responsible for achieving this orientation with the misalignment margins defined in the EID-A.

A standard coordinate system is required for joint observations between instruments on the ground (for test purposes) and in space. This system, designated (X_{ii},Y_{ii}), will be defined as follows: On the ground, the Y_{ii} axis is parallel to the spacecraft Z_0 axis and the X_{ii} axis is anti-parallel to the spacecraft Y_0 axis. In space, the (Y_0,Z_0) system is however no longer accessible. We will therefore define a virtual system (Y_0^*,Z_0^*), which is nominally coincident with (Y_0,Z_0) and where Y_0^* is perfectly aligned with the solar equator and its origin is at the Sun centre, and define (X_{ii},Y_{ii}) in space as above using the virtual system (Y_0^*,Z_0^*).

The inter-instrument flag system (X_{ii},Y_{ii}) thus has its origin at the Sun centre, its Y_{ii} axis is in the plane containing the solar rotation axis pointing north, and its X_{ii} axis positive towards the west limb.

Each instrument participating in the flag exchange is reponsible for determining its orientation with respect to the (X_{ii},Y_{ii}) system and report the coordinates of their observations in (X_{ii},Y_{ii}) coordinates in units of 2 arcsec. Off-limb observations need special treatment if X_{ii}, $Y_{ii} > 1022$".

2.2.5 Spacecraft orbit coordinates

The Orbit data will describe the position and motion of the spacecraft, and it will be available in several coordinate systems including: geocentric inertial (GCI) coordinates for the J2000 system; geocentric solar ecliptic (GSE); geocentric solar magnetospheric (GSM) coordinates; and Heliocentric Ecliptic coordinate system.

The GSE coordinate system is defined as follows: The origin is Earth centered, with the X axis pointing from the center of the Earth to the center of the Sun; the Y axis lies in the ecliptic plane and points in the opposite direction of the Earth's orbital motion; the Z axis completes a right-handed orthogonal coordinate system and is parallel to the ecliptic pole. The Sun position is the true "instantaneous" position rather than the "apparent" (light-time delayed or aberrated) position. The ecliptic is the true ecliptic of date.

The Heliocentric Ecliptic coordinate system is defined as follows: the origin is Sun centered, with the Z axis parallel to the ecliptic pole with positive north of the ecliptic plane; the X-Y plane lies in the ecliptic plane and the X axis points towards the first point of Aries; the Y axis completes a right-handed orthogonal coordinate system.

The GCI coordinate system is defined as follows: Earth centered, where the X axis points from the Earth towards the first point of Aries (the position of the Sun at the vernal equinox). This direction is the intersection of the Earth's equatorial plane and the ecliptic plane — thus the X axis lies in both planes. The Z axis is parallel to the rotation axis of the Earth and the Y axis completes a right-handed orthogonal coordinate system. As mentioned above, the X axis is the direction of the mean vernal equinox of J2000. The Z axis is also defined as being normal to the mean Earth equator of J2000.

The GSM coordinate system is defined as follows: again this system is Earth centered and has its X axis pointing from the Earth towards the Sun. The positive Z axis is perpendicular to the X axis and paralle to the projection of the negative dipole moment on a plane perpendicular to the X axis (the northern magnetic pole is in the same hemisphere as the tail of the magnetic moment vector). Again this is a right-handed orthogonal coordinate system.

2.3 Inter-instrument flags

In crude terms, a flag is a message sent by an instrument to another instrument, which enables the latter one to respond by operating in a more efficient manner. The implication is that the data/command loop for responses via the ground would be far too long to be of use for the flagged event.

The coronal extreme ultraviolet and ultraviolet instrumentation on-board SOHO will have limited fields of view and limited telemetry streams. For this reason, one has to examine ways of increasing the efficiency of the available system. Short time scale events may best be detected by one SOHO instrument which may relay information to the others to generate operating mode changes or more precise pointing.

With SOHO we are considering a range of flags which will enable an efficient programme for observing a range of features. The inputs to this study from the various experiment teams have resulted in the list of flags given in Tables 2.2 and 2.3. For each entry we list the event-type, the time-scale needed for a response, the instrument which generates the flag, and the instruments which may wish to respond

Event type	Response time	Identified activity
Jets/Turbulent events	<Minute	Pocket of Doppler shifts
Micro/Subflares	Seconds	Brightening
Bright points Activated prominences	<Minutes Tens of minutes	Brightening Increased Doppler shifts
Eruptive prominences	Minutes	Transverse motion or detection of prominence in corona
Coronal Mass Ejection	Minutes	"Precursor" brightenings or Ejection in corona
Flares	Seconds	Extreme brightenings

Table 2.2: Transient events to be studied by the use of flags

to such a flag. Since the features being studied are not necessarily as easy to identify as a flare, we also define the nature of the activity which can be monitored in order to generate the flag.

Event type	Originator	Receiver
Jets/Turbulent events	SUMER / CDS	CDS / SUMER
Micro/Subflares	SUMER / CDS	CDS / SUMER
Bright points	EIT CDS	SUMER / CDS SUMER
Activated prominences	SUMER	CDS / LASCO / UVCS
Eruptive prominences	CDS / SUMER LASCO	LASCO / UVCS CDS / SUMER
Coronal Mass Ejection	CDS LASCO	LASCO / UVCS UVCS/ CDS / SUMER
Flares	EIT / CDS / SUMER	EIT / CDS / SUMER / UVCS / LASCO / MDI

Table 2.3: Flag generating and receiving instruments on SOHO

Timing (for flag to be read by receiving instrument):	within 16 seconds of being detected by generator.
Form of flag words:	2 x 10 bit words (X, Y location on Sun) 1 x 4 bit word (Identifier)
Notes:	all flags sent to all receiving instruments one flag generating instrument enabled at a time planned from EOF

The rules and conventions adopted in the generation and reception of flags are described in Annex C.

Chapter 3

Data

3.1 Data sets

The purpose of this section is to describe the data sets available in the EOF and at the different SOHO facilities.

3.1.1 Science data

NASA will forward real-time level 0 (=packetized) science data from the GDCF/Pacor (Generic Data Capture Facility/Packet Processor) to the EOF Core System, which will distribute it to the PI Workstations. There is no additional front-end processing performed on these data by NASA to assess the quality prior to its routing to the EOF. Playback data will be sent to the EOF in the same manner with transmission delays from DSN (approximately 3 hours) and processing delays to turn the data around (approximately 2 hours).

3.1.2 Housekeeping data

NASA will provide the level 0 housekeeping data packets obtained from the raw telemetry stream. These data are treated the same way as the science data. The SMOCC will provide the EOF with access to the SMOCC displays. The displayed data will be available in both raw counts and engineering units, and will include housekeeping parameters defined in the Project Data Base.

3.1.3 Ancillary data

Various parameters relating to the spacecraft condition will be collected together into a data set called ancillary data. Table 3.1 provides a list of the parameters that are to be included in the ancillary data set. The data set may be accessed electronically from the EOF and will be maintained for the entire SOHO mission. Some of the ancillary data parameters will be transmitted to the DDF for distribution on hard media to the PIs.

All the parameters, except for the verified attitude, will be generated by SMOCC or FDF. The verified attitude will be the responsibility of the PI teams, and will be generated from a comparison of the definitive attitude with science data. The verification process is anticipated to be a long-term process and will therefore not be included with the ancillary data set distributed by the DDF.

The Definitive Attitude file now consists of two products, (a) the Definitive Attitude File and (b) the Full Time Resolution Attitude File.

Ancillary Data Parameter	Where available EOF (On-line)	DDF
Orbit predictions	X	
Orbit definitive	X	X
Attitude definitive	X	X
Attitude verified (PI responsibility)	X	
Time corrections ($\Delta t > 0.1$ sec)	X	X
DSN Schedule real-time periods	X	
Command history	X	X
SOHO Daily Report	X	X

Table 3.1: Ancillary data parameter

It is anticipated that the on-board clock may occasionally jump. Therefore corrections to the on-board clock must be accommodated and the list of "glitches" be maintained on-line and distributed by the DDF. The frequency corrections to keep the clock within 20 ms will be logged, too.

3.1.4 Summary data

The Summary Data will be used both to plan observations at the EOF and to provide an overview of the observations that have been obtained from the SOHO. Tables 3.2, 3.3, and 3.4 provide a list of the contributions from each PI team. The Summary Data will consist of three classes. The first two classes will consist of a representative image from each of the imaging experiments, and key parameters from the non-imaging experiments. The third class will be a list of observing programs and start/stop times of data sequences. Together these data will provide a synopsis of solar conditions and the science programs that have been carried out by the observatory.

The Summary Data will be available on-line from the EOF for 28 days and will be transmitted to the DDF for distribution on hard media to the PIs. Tables 3.2, 3.3, and 3.4 also include an estimate of the daily storage requirement. The total requirement is determined essentially by the number and size of the images, and is 20 Mbyte/day. If it is necessary to reduce this requirement, smaller and/or 1 Mbyte images can be considered.

The Summary Data will be the responsibility of the PI teams, and are to be generated as quickly as possible after receipt at the EOF. The data will be generated from quick-look science data and will have only preliminary calibrations performed on them. The Summary Data will therefore NOT be citable. The individual PI summaries will be transmitted by the PI to the Science Operations Coordinator's workstation (or other appropriate disk file system) either by file transfer (e.g. ftp) or by electronic mail.

An event log will be maintained in the summary data file and will be distributed by the DDF. However, the contents of the log at the EOF will be allowed to change, and will therefore be different than the one distributed by the DDF. The event log will provide a registry of events that may be of general interest. The log may also include events identified by observatories other than SOHO, but which might be relevant to the SOHO observations.

1. Each of the instruments will have an observation program summary data file even if they have only a few entries.

MDI	Full disk magnetogram, 1024 x 1024 x 2 byte (2MB) Full disk continuum, 1024 x 1024 x 2 byte (2MB)
EIT	Full disk Fe IX, 1024 x 1024 x 2 byte (2MB) Full disk Fe XII, 1024 x 1024 x 2 byte (2MB) Full disk Fe XV, 1024 x 1024 x 2 byte (2MB) Full disk He II, 1024 x 1024 x 2 byte (2MB)
UVCS	1.2-10 $R_\odot$ Corona Ly α, 256 x 256 x 1 byte (0.25 MB) 1.2-10 $R_\odot$ Coronal Temperature, 256 x 256 x 1 byte (0.25 MB)
LASCO	1.1-30 $R_\odot$ Corona White Light, 1024 x 1024 x 2 byte (2 MB) 1.1-3 $R_\odot$ Corona Fe XIV, 1024 x 1024 x 1 byte (1 MB) 1.1-3 $R_\odot$ Corona Fe X, 1024 x 1024 x 1 byte (1 MB) 1.1-3 $R_\odot$ Corona Ca XV, 1024 x 1024 x 1 byte (1 MB)

Table 3.2: Summary Data File I: Images (size per day)

VIRGO	Solar constant, SPM, LOI for each pixel (1 value/day) (0.1 kB)
SWAN	Observations sensor 1 and 2 (1.5 kB)
CELIAS	Solar wind speed, heavy ion flux (5 minutes averages) (1.5 kB)
CEPAC	17 particles flux every 5 min or 15 min (12 kB)

Table 3.3: Summary Data File II: Parameters (size per day)

SUMER	Operation modes, time, heliographic area covered (16 kB)
CDS	Operation modes, time, heliographic area covered (16 kB)
SWAN	Operation modes, area observed, start/stop time (5 kB) Operation modes, time, heliographic area covered (5 kB)
UVCS	Operation modes, sequence number, FOV, start/stop time (10 kB)
LASCO	Operation Modes, time, events (10 kB)

Table 3.4: Summary Data File III: Observation programmes (size per day)

GOLF	Time series of global velocity field
VIRGO	Times series of irradiance
MDI	Time series of full disk velocity, intensity and magnetograms images Time series of high resolution velocity, intensity and magnetograms images Time series of mode amplitudes, low resolution velocity, intensity images
SUMER	UV spectra, images (scans) and time series
CDS	EUV spectra, images (scans) and time series
EIT	Full disk EUV images, time series of selected regions
UVCS	UV spectra (Ly-α, O VI) and images of the solar corona out to 10 $R_{\odot}$
LASCO	Time series of coronal images (white light brightness, pB, line ratios)
SWAN	Antisolar Lyman-α intensity, Lyman-α maps of the sky
CELIAS	Composition (mass, charge, ionic charge) and energies of solar wind and suprathermal particles
CEPAC	Count rates, energy spectra, and isotopic composition of energetic particles (e, p, He – Ni)

Table 3.5: Processed science data

2. The observation program will have both a planned and an executed data file. Ideally the formats of the planned and executed files should be identical. In addition, it would speed up generation of the executed data file if it could be extracted entirely from the command history log (instead of from the instrument data streams).
3. A standard format for the observation program file will be defined for all the instruments in order to make it easier to correlate observations. The format could include Operation Mode, Start Time, Stop Time, and Observing Parameters. The Operation Mode would include instrument name, detector, and observing sequence identification. The Start and Stop Times would be in a well defined format (for example, yymmdd hh:mm.ss). The Observing Parameters could include heliographic area covered, field of view, sequence number, events, etc. and might have the format of parameter=value.
4. The observation program might be better as a database apart form the summary data. In addition, it would be a good place to start with the definition of a catalog and keywords. The disadvantage of having the observation program as a stand-alone database would be the difficulty of updating the information. This would be less of a problem if the observation program database could be generated automatically from the command history log.

3.1.5 Processed science data

Each investigation group will convert the level-0 Science data and other related data into more elaborate data files (or have the necessary software) for scientific analysis. Any processed data must have a level greater than 0 (i.e. level 1,2, etc...). Details of the archived files are to be found in the individual experiment Operations Manual. Table 3.5 gives an indication of the files to be generated.

3.1.6 Synoptic information and predictive information

The following data sets will be available at the EOF by electronic means either from SELDADS or directly from solar ground-based observatories. Among the "core support observatories" are Mitaka, Nobeyama, Norikura (all Japan), Huairou (China), Ondrejov (Czech Republic), Pic du Midi (France), Izana (Tenerife), Huntsville, SEL (Boulder), Sac Peak, Kitt Peak, Big Bear, Mt. Wilson, Mees, and Mauna Loa (all USA).

Provided data from ground stations are:

- H-α images
- Ca K images
- Full disk magnetograms
- Helium 10830 Å images
- Radio images
- Sun map with coronal holes
- Coronagraph pictures
- Solar flares monitoring
- Zurich Sunspot number
- 10.7 cm Ottawa radio flux

Provided data from other S/C:

- X-ray images from Yohkoh (and other S/C, if available)
- GOES full Sun X-ray profiles
- Key parameters from Ulysses, WIND, CLUSTER

Provision to other projects from SOHO:

- Summary Data

3.2 Dissemination and archiving

3.2.1 Data availability

Table 3.6 indicates where and when the various data sets are to be available. The exchange of data between SOHO experimenters will facilitate the successful implementation of joint observing programs to achieve common science objectives. Electronic access to data sets remote to an individual PIs computer system provides a quick and reliable mechanism for the collaborative exchange of data. The following plan for data availability requires a submission of data from the PI teams as soon as possible after receipt, and hopefully within 24 hours. Therefore most of the inputs to the summary data should be generated by automated procedures. For example, the planned observing schedule should be generated from the planned command load.

In Table 3.6, an X indicates data availability at that facility. If a time is indicated, then the data set will be available within the time specified. The MDI High Data Rate Data will be delivered directly to Stanford University and will not go through the EOF. However the MDI magnetogram data occurring at the end of every tape recorder playback will be delivered to the EOF.

The spacecraft housekeeping shall be archived for electronic access from the EOF for 28 days after data collection. The data may be kept as digital counts, but conversion to engineering units would be preferable.

The maintenance of quick look science data is the responsibility of the PI teams. While it is desirable that the most recent 30 days be kept on-line or near on-line, it is recognized that each experiment team will have different requirements and different capabilities and no fixed requirement for on-line data retention can be imposed on the PI teams.

	Where available		
	PI WS	EOF (On-line)	DDF
Catalogs			
Ancillary Data		X	X
Summary Data		X	X
S/C Level 0 Data		X	X
Instrument Quick Look Data	X	X	
Instrument Final Data	X	X	
Ancillary Data		X	X
Definitive Orbit		1 week	1 week
Definitive Attitude		1 week	1 week
Command History		1 week	1 week
Summary Data			
Images	1 day	1 day	1 week
Parameters	1 day	1 day	1 week
Planned observations	1 day	1 day	
Executed observations	1 day	1 day	1 week
S/C Level 0 Data			
Housekeeping - real-time	<1 minute	<1 minute	
Housekeeping - playback	3.5-5 hour	3.5-5 hour	
Housekeeping - combined		4 days	X
Instrument Quick Look Data			
Housekeeping - real-time	<1 minute	<1 minute	
Housekeeping - playback	3.5-5 hour	3.5-5 hour	
Housekeeping - combined		4 days	X
Science - real-time	<1 minute	<1 minute	
Science - playback	3.5-5 hour	3.5-5 hour	
Science - combined		4 days	X
MDI			
Magnetogram	<1 minute	<1 minute	
High Data Rate (to Stanford)		1 week	X

Table 3.6: Data availability

3.2.2 Data Distribution Facility

The DDF will mail a hard copy (currently, in CD-ROM) of the respective level–0 science/housekeeping and ancilliary data to each PI within 30 days of receipt at GSFC. The PI is then responsible for further distribution to Co-Is and support institutions. In addition, such telemetry data will be available in the form of "snapshots" for limited call up to approved participating organisations. Those data, available electronically from the Central Data Handling Facility (CDHF), will represent the most recent 8 days of information.

Each PI will receive a copy of his own investigation data set, and of any other if so agreed, after 30 days of reception by DDF.

CDHF will process the key parameters for CELIAS and CEPAC to be included in the Summary Data. The Summary Data and the As-Run Plan, created and maintained on line at the EOF, is sent to CDHF for hard copy (CD-ROM) distribution. Both CDHF and EOF will keep these data online.

3.2.3 EOF

A number of SOHO participating institutes (PIs and others) will hold archives of the Science and processed science data corresponding to the experiment of their responsibility.

The central archiving facility for processed data is being developed at the EOF. This archive will hold the complete set of SOHO data with the only exception of the high data rate MDI helioseimology data set.

The following data sets will be generated for SOHO and available from the EOF archive:

- Telemetry Science Data (final level–0 distribution).
- Housekeeping Data (final level–0 distribution).
- Ancilliary Data
- Summary Data (including the As Run Plan).
- Event file
- Synoptic data (from ground-based and space-based observatories).
- Processed Data (files that are ready for scientific data analysis). Most of the data exchange between scientists and groups will be done with these data sets. The processed data will be generated at the EOF or/and the PI or collaborating institutes or observatories.

3.2.4 Databases

The various database catalogs may be accessed electronically over the EOF LAN. The catalogs will be data base tables that are linked together using standard relational data base techniques. A standard query language (SQL) is used to access the databases, but an interface program has been developed in order to use more user-friendly front ends to the EOF archive. The first interface is World-Wide-Web based and its available to anyone with Internet access. The second one is based on IDL and will be used mainly within the EOF for data analysis purposes.

The type of information stored into these database files will fall into several categories. The first category will consist of information about observing programs. For this category, a standard set of data field names and their definition has been prepared to provide uniformity in developing the individual experiment databases. Not all fields names may apply to a particular instrument, in which case that field will simply be blank for that instrument. The type of information stored in these databases will include information like identification of what type of observing program was followed, the purpose or target of the observing program, the time range of the observing program, and the heliographic area of the sun covered. Users will be able to simultaneously sample this information not only at the EOF, but worldwide. This will be accomplished maintaining a combined database incorporating this information from all the instruments on a central file server system using updates supplied by the PI teams. There will be two main datasets: the As Plan File, describing the upcoming observing plans of the instruments (will reside at ECS), and the As Run File detailing what was actually observed. This last file will be part of the Summary Data set.

The second category of database files will contain information about events that may be relevant to more than one instrument. Exactly what information will be stored in this catalog is yet TBD, but most likely it will contain the same information as found in the Observatory Log (section 3.1.4). This could consist of information about such things as spacecraft rolls, as well as information about solar events and features. Information for this file will be received from several sources: CMS (spacecraft events), ECS (global planning related events) and PI workstations. This database will also contain information about events registered by other observatories, that may be relevant to the SOHO observations. Related into this events catalog will be additional database files which will serve to logically relate the events to the individual SOHO observations, and to store information about what effect a given event had on a given observation, if any.

The third category of database will contain information about scientific data. Several tables will describe science processed, summary and synoptic observations. Access to this data sets will be unrestricted unless otherwise specified in the SOHO Science Working Team data rights agreements. Ancillary, summary, event and synoptic data will be in the public domain immediately after acquisition. The science processed data will be public after an initial period of restricted access.

There will be a way for users to attach comments to the individual entries in each of the database files. The procedure used to control this process is as yet TBD.

3.3 Standard formats

3.3.1 Overview

The specification and use of a standard format or set of formats enables data to be exchanged easily between investigators. SOHO will use the Standard Formatted Data Unit (SFDU) which is becoming more common in data archives. For example, all data in the ISTP CDHF at NASA/GSFC must be SFDU conforming data objects. Documents describing formatting standards may be obtained from:

NASA/OSSA Office of Standards and Technology
Code 933
NASA Goddard Space Flight Center
Greenbelt MD 20771
USA

3.3.2 SFDU

SFDU is an international standard that facilitates the exchange of information between users. The SFDU formalism enables a description of the data to be specified in a standard way and in a way that anyone, possibly years later, can obtain from the appropriate international agency. Such agencies are called Control Authorities, two of which are the NASA/NSSDC and ESA/ESOC. A data description that is registered with such a Control Authority is given a unique identifier that is included with the data as an SFDU label (either as a separate file or included with the data at the beginning of the data).

Thus any user of the data who is unfamiliar with the data can obtain a description by contacting a Control Authority. A FORTRAN procedure is available to generate SFDU labels.

The SOHO Science Operations Working Group has adopted the SFDU formalism for any product that is going to be distributed to the community. For example the summary data will have SFDU labels (detached) as will the orbit and attitude files.

The SFDU is described in the following documents:

- "Draft Recommendation for Space Data System Standards: Standard Formatted Data Units — Control Authority Procedures", CCSDS 630.0-R-0.2, Consultative Committee For Space Data Systems.
- "Draft Recommendation for Space Data System Standards: Standard Formatted Data Units — Structure and Construction Rules", CCSDS 620.0-R1.1, Consultative Committee for Space Data Systems.
- "Report Concerning Space Data System Standards: Space Data Systems Operations with Standard Formatted Data Units — System and Implementation Aspects", CCSDS 610.0-G-5, Consultative Committee for Space Data Systems.
- "Draft Report for Space Data System Standards: Standard Formatted Data Units — A Tutorial", CCSDS 621.0-G-1, Consultative Committee for Space Data Systems. Distillations of these documents have been included in minutes of SOWG or splinter group meetings.

The SFDU does not in itself specify the format of the data. It permits any format, either registered or not to be used. If a non-registered format is used, then the format specification needs to be included with the data. Three data formats that are registered are the Parameter Value Language (PVL), Flexible Image Transport System (FITS), and the Common Data Format (CDF), all of which will be used in SOHO files.

3.3.3 PVL

The SFDU uses PVL to specify required information. It is a generalization of the format in the header of FITS files, and is of the form "Parameter = Value". It is an international standard also and is described in the following documents:

- "Report Concerning Space Data System Standards: Parameter Value Language — A Tutorial", CCSDS 641.0 - G-1, Consultative Committee for Space Data Systems.
- "Recommendation Concerning Space Data System Standards: Parameter Value Language Specification (CCSD0006)", CCSDS 641.0-B-1, Consultative Committee for Space Data Systems.

The catalogs that will be generated by SOHO experimenters will use PVL/FITS concepts. In order to ensure that everyone is using the keywords (parameters) in a consistent way, the keywords and their definitions will be registered with a Control Authority. A draft document of the keywords has been circulated (see Annex 6 in the minutes of the 8^{th} SOWG meeting).

3.3.4 FITS

All scientific data files generated by the PI teams will be in FITS format. In particular, this applies to the summary data, and to level-1 (and higher) data files. An exception are the summary data files of the three particles experiments CELIAS, COSTEP, and ERNE which will be in CDF.

A formal description of the FITS standard can be found in "Implementation of the Flexible Image Transport System (FITS)", available as publication NOST 100-0.3b from the Office of Standards and Technology, or by anonymous ftp from nssdca.gsfc.nasa.gov (128.183.36.23), or via DECnet from NSSDCA::ANON_DIR:[FITS] (15548::).

FITS files facilitate interoperability by using a specified binary standard for encoding data values independent of the computer platform. In other words, FITS files look the same regardless of what computer the file is sitting on, and can be copied from computer to computer without modification. FITS files are also used in a wide range of astronomical applications, and are directly supported in such astronomical software packages as IRAF, and indirectly supported in some broader data analysis packages such as IDL.

Some standardized software for reading and writing FITS files are available in the public domain. The FITSIO package by William Pence is a set of FORTRAN subroutines available by anonymous ftp from tetra.gsfc.nasa.gov (128.183.8.77). There are also IDL routines available for reading and writing FITS files, as part of the IDL Astronomy User's Library. These are available via anonymous ftp from idlastro.gsfc.nasa.gov (128.183.84.71), or by DECnet copy from uit::1DUA5:[IDLUSER] (15384::).

3.3.4.1 Primary FITS files

The simplest form of FITS file consists of a single FITS header and data unit. FITS headers are a series of eighty-character card images of the form keyword=value. The keywords are restricted to a maximum of eight characters, and include a standard set of predefined keywords, some of which are required, and whatever additional keywords the experimenter wishes to define.

The data unit consists of an N-dimensional data array. The size, dimensions, and datatype of the array are described by standard FITS keywords in the header. IEEE standards are used for the binary representation of the data.

The primary FITS header and data unit can be followed by one or more FITS extensions. In that case it is not required that there be a primary data array; the number of elements can be given as zero. There are a number of different kinds of standard extension types, and there is also the possibility of defining new kinds of extensions.

3.3.4.2 ASCII tables

One standard extension type, the "TABLE" extension, allows the experimenter to store an ASCII encoded table. The format of each column in the table is defined individually. This extension could be used to store catalog-type information.

3.3.4.3 Binary tables

Similar to the "TABLE" extension, the "BINTABLE" extension allows the storage of data organized into a table with rows and columns. However, the data are stored with a binary representation (although ASCII fields are allowed), and individual items in the table can be arrays rather than scalar values.

At the moment there is no formal standard for describing the dimensions of an array. This is principally because there is no one "right' way to do this. However, there is a proposal for one way to do this, the "Multidimensional Array Facility", which is given as an Appendix in the NOST FITS document, and uses TDIMn keywords in the header to describe the dimensions. This TDIM approach should meet the needs of any SOHO instrument team that wants to use binary tables to store their data.

Binary tables represent a powerful and efficient way of associating together a number of different data variables in a single FITS file.

3.3.4.4 The IMAGE extension

The "IMAGE" extension has been proposed by the IUE (International Ultraviolet Explorer) team as a standard for storing multiple arrays in a single FITS file. Each IMAGE extension is basically of the same format as the primary FITS header and data unit.

IMAGE extensions are appropriate when the number of data arrays, and hence the number of extensions, to store together in a single FITS file is small. If the number of non-scalar variables is large, or the data structure is complex, then binary tables are more appropriate.

3.3.5 CDF

The GGS/ISTP (Global Geospace Science / International Solar-Terrestrial Physics) project has adopted the NSSDC (National Space Science Center) CDF for use in key parameters and some other data products maintained at the CDHF. The exact role of the CDHF in storing and distributing SOHO summary data still needs to be worked out, but at the very least key parameters from certain SOHO instruments will be incorporated into the CDHF database. Since that database uses CDF, and SOHO uses FITS, some conversion will be necessary.

CDF has some properties in common with FITS, in that it is self-describing, and that it allows the association of information about the data, (units, description of data axes, etc.) together with the data arrays. The underlying physical representation, and the basic data model, are different however.

The NSSDC supplies a set of standard FORTRAN and C libraries for reading and writing CDF files on VMS and Unix computers. These are available via anonymous ftp for VMS from nssdca.gsfc.nasa.gov (128.183.36.23), or by DECnet copy from NSSDCA::ANON_DIR:[CDF.CDF21- DIST] (15548::). Software for various Unix workstations are available using anonymous ftp from ncgl.gsfc.nasa.gov (128.183.10.238).

The CDHF also supplies software to aid in the generation of key parameter software in ISTP/CDF format. This software is available via DECnet from ISTP::SYS$PUBLIC:[SFDU_TOOLS.BLD_SFDU]- (15461::) or by anonymous ftp from either istp1.gsfc.nasa.gov (128.183.92.58) or from istp2.gsfc.nasa. gov (128.183.92.59) in the directory SYS$PUBLIC:[SFDU_TOOLS.BLD_SFDU].

The format used by the ISTP/CDHF is a subset of the complete CDF specification, and further specifies the format to promote uniformity between the different ISTP data sets. This uniformity extends such things as the binary representation of data (e.g. IEEE format for floating point numbers, the same as FITS), and the representation of times.

Both FITS and CDF are supported in IDL.

3.4 Use of SOHO data — data rights

3.4.1 Introduction

The objective of a coherent policy on these aspects should be to ensure the maximum exploitation of the SOHO data in order to extract the best scientific output from the mission. For this purpose, it is necessary to find a just equilibrium between the two conflicting strategies. These are :

a) to open up free access to the widest possible community, thereby making available special capabilities and expertise from outside the SOHO teams, and

b) to protect the interests of the PI teams who have invested so much personal effort, and through rewards for this effort to motivate them to continue to work for the collective scientific interest.

Leadership in applying such a policy rests with the PIs, who have a moral responsibility for maximising the science from the mission, as well as the structure and authority within their teams for applying a well-defined strategy. However, since the joint exploitation of combined data sets is a key objective of SOHO, it is important to have joint PI or SWT agreements on this policy. This section summarizes the policy that the SOHO PIs have agreed to abide by with respect to the utilization of the data generated by their instruments.

3.4.2 Definitions

3.4.2.1 Data access rights

Two types of data access rights can be envisaged:

1. **Data access for planning purposes**

   All SOHO PIs have the right to access all other SOHO data for the purpose of operations planning during the mission. They also have the right to have access to the data to survey them to evaluate their possible use for cooperative research, but *not* to carry out data analysis with a view to publication.

   Access rights defined in the above manner may serve many other useful functions, e.g. to allow potential guest investigators to verify the availability of the required data sets before finalising their proposal.

2. **Data access for analysis and research**

   This is regulated by the data rights policy of the SOHO SWT as described in this document. Specific data rights policies are defined for the SOHO Guest Investigators (GI) (see 3.4.5) and for SWT approved campaigns.

3.4.2.2 SOHO science projects

A proposed project must consist of a clear scientific objective, together with the proposed means for its accomplishment. It might or might not include the need for new observations, the definition of new observing sequences, cooperation between several SOHO instruments or with non-SOHO space or ground-based observations. It can be based upon analysis of synoptic data over long periods, recorded primarily for completely different objectives. It can involve the use of a new analysis or theoretical techniques to analyse existing data. In spite of flexibility in the form, science projects must be closely defined. Otherwise, approval to follow one research aspect could be interpreted to cover a very wide range of activities.

3.4.2.3 Responsibilities

PI individual responsibilities include :

a) To manage, in the broadest sense the attribution of science projects amongst their team scientists and CoI's.

b) To advise on the selection of Guest Investigator (GI) proposals which concern their instrument.

c) To consider how wider access with appropriate controls could help in stimulating outside (GI) participation.

d) To define, and announce publicly a Publication Policy. This should include a policy for initial publications; i.e. a declared number of early papers, formally authored, which can also give rewards for those involved in technical or engineering effort. An on-going publications policy should indicate the approval or vetting procedure (if any), authorship policy, etc.

SWT agreements and responsibilities include:

a) Data access policy, as suggested above.

b) Joint Public Relations activities

c) The establishment and managing of joint science projects.

d) Advice on the selection of GI joint science proposals.

e) To encourage a common strategy for the PI (Individual) policy.

3.4.2.4 Data levels

The SOHO data are distributed to the PIs by two channels.

1. A general line of SOHO data originates at the Data Distribution Facility (DDF):

   - **Level 0 or unprocessed data** are the data distributed by the DDF to the PIs (raw data)
   - **Level 1 or basic data** are corrected for a priori known effects such as flat fields of CCD's and other instrument inherent effects, as well as the Sun-instrument geometry (distance, radial velocity, solar disk coordinates, etc.) and they are evaluated to physical units. Level 1 data are still raw data in the sense that they do not contain corrections for e.g. degradation, which cannot be calculated right away. Level 1 data may be useful for some limited scientific analysis.
   - **Level 2 or processed (or calibrated) data** will be corrected for long term degradation and calibration changes and will contain derived parameters that will be useful for scientific evaluation in general.

2. Another line of data originates at the EOF:

   - The **real time** and the **tape dump play back** data received at the EOF by the PIs are in the same format as the level 0 data described above.
   - Out of it will be produced the **summary data** for the Summary Data File and the
   - **quick look processed** data to be used at the EOF for science operations planning.

3.4.3 SOHO science data access policy

> *The intent of the SOHO data access policy is to provide data to as wide a community as possible and as soon as possible. From the beginning of the operational mission, the scientific community is welcomed and encouraged to participate in the analysis of the SOHO data in collaboration with the PI teams. The goal is to make fully callibrated data available for public use through ESA and NASA archives one year after reception by the PIs.*

In addition to this general policy, the following rules apply:

- For each PI team the data distribution, data rights and publication policy is defined in their Science Book.
- All the PIs have the right to access the data of the other SOHO experimenters for planning purposes in the terms defined in section 3.4.2.1.
- For this purpose, each PI will make the data available according to a mutually agreed schedule.
- The SWT will establish rules to be applied to data obtained during agreed observation campaigns.
- Exchange of data acquired during internally coordinated SOHO observations will be regulated by the cooperating teams themselves.

3.4.4 Archiving

A SOHO data archive is being developed at the EOF at GSFC for operation during the mission and for more than 10 years after nominal operations. This SOHO archive will contain copies of all the data sets referred to in section 3.1. The level 0 science, housekeeping, ancillary, summary and synoptic data will be gathered automatically. The PIs will provide the level 2 data according to an agreed schedule. It is understood that the data archived will have to be updated when improved versions of the processed data are generated. Three European institutions (IAS, Orsay, France; RAL, Chilton, England; Univ. of Torino, Italy) will host a copy of the SOHO archive at GSFC. The European and NASA archives will provide the necessary security and infrastructure facilities to ensure that access is limited according to the criteria agreed upon by the PIs.

3.4.5 Guest Investigators

3.4.5.1 General

A SOHO Guest Investigator Programme has been envisaged from the onset of the SOHO programme. To ensure the maximum exploitation of the SOHO data in order to extract the best scientific output from the mission, and to attract special capabilities and expertise from outside the SOHO teams, selected Guest Investigators (GI's) will have the opportunity to acquire and/or analyze specific data sets, or, for some experiments, to become part of the PI teams.

3.4.5.2 Nature of participation

Two types of GI participation in SOHO PI teams are foreseen, depending upon the nature of the SOHO experiment involved. For the coronal experiments (CDS, EIT, LASCO, SUMER, SWAN, and UVCS), GI participation will be of a traditional nature (like for SMM or Yohkoh): GIs will be attached to an experiment team and within that team have priority rights for the analysis of certain datasets (either newly acquired, or from the archive), or priority rights for a certain type of analysis of datasets otherwise available for study to the whole experiment team. An example of the first is the study of a specific event, for example a CME, and an example of the latter is a statistical study, say a study of the magnitude of redshifts as a function of position on the solar disc.

The data from the helioseismology (GOLF, VIRGO, MDI), and from the particle experiments (CELIAS, COSTEP, ERNE) are of a totally different nature; they do not lend themselves to being split up into 'events', observing sequences, or time intervals, each of which could be studied by different investigators. Hence the mode of participation of GIs attached to these instruments will be different. It is envisaged that, possibly for a limited period of time, approved GIs will be included as members of the PI teams and share the rights and obligations of the team members, according to the team-specific rules. Approval of proposals for these SOHO experiments will depend on whether the proposed work adds to the expertise existing within the SOHO experiment team – an example could be the implementation of a statistically superior method of analyzing time series for a helioseismology instrument.

3.4.5.3 Mechanics of selection

The first cooperative ESA/NASA Announcement of Opportunity (AO) will be issued on 1 Dec 1995, about 1 month after SOHO launch, and prospective GI's are required to react with a letter of intent by 1 Feb 1996. Proposals will be due on 1 May 1996. Proposals received at the due date by the Project Scientist Office (PSO) will be forwarded to the SOHO PI teams proposed for attachment. These PIs will comment on the proposals in writing, and forward their comments to the for consideration in the Guest Investigator Selection Committee (GISC). PIs can object to proposals that

- duplicate their declared major objectives
- demand excessive PI group resources
- interfere with other PI programmes for technical reasons

A Guest Investigator Selection Committee (GISC) will be nominated by ESA and NASA after recommendation by the SOHO SWT, ESA's SSWG, and its NASA equivalent. The GISC will rate the GI proposals according to the evaluation criteria, and rank them in order. Those proposals will be selected that meet an absolute quality standard t.b.d. by the GISC, and rank within the cutoff defined by 30% cumulative observing time for the coronal instruments, or the maximum number of GIs for the particle and helioseismology instruments, set in advance by the PI teams.

The GISC will produce a referee report for each proposal. The referee report, the absolute rating of the proposal according to the criteria, and the notification of selection or rejection, will be forwarded to the GIs approximately 1 Sep 1996. For US proposals, the same will be forwarded to NASA for consideration for funding.

Selected GIs from other countries can forward their proposals and their GISC evaluations to their national, or to international agencies for funding. The 6 month time span between the announcement of the GI selection (1 Sep 1996) and the start of the GI investigations (1 Jan 1997) leaves time for the selected GIs to secure this funding.

3.4.5.4 Implementation

After selection of their proposal, approved GIs will be assigned a point of contact within the relevant SOHO PI team, who will work with the GI until completion of the investigation.

Initial scheduling of the new observations from accepted GI proposals will take place at the last quarterly SWT meeting before the start of the GI investigations (1 Jan 1997). Selected GIs approach their point of contact before this meeting (i.e. at least three months before the start of the GI investigations) to discuss the need for their presence during their observations, and the times of their availability. GIs that are required to assist with obtaining their observations, and that do not show up at the mutually agreed scheduled time, may lose their rights, at the determination of the SWT.

Approved GIs who have requested data from the SOHO archive should contact the Project Scientist at the EOF at least two weeks before the start of their guest investigation. They will be given network access to the approved data only in the SOHO data archive, and to the general SOHO software for visualisation and data analysis. If necessary, data can also be forwarded on tape, or by other media, but network transfer is the preferred means.

In case of accepted Guest Investigations which do not require new SOHO observations, or have to secure additional funding, the starting date of the investigation can be moved forward in consultation with the Project Scientist and the relevant SOHO PI Teams.

Selected GIs for the coronal instruments will have a priority right to carry out the research described in their proposal, and/or the data identified in their proposal, for 12 months after the receipt of the data in usable form, or from access to the archive. After this time the relevant SOHO PI team in consultation with the GI will decide on how to proceed. Approved SOHO GIs will have access to data from other SOHO experiments, in the same manner as SOHO Co-I's for the subject for which they have been selected.

Approved GIs for the helioseismology and particle experiments will become members of the relevant SOHO PI team. They may have to attend PI team scientific meetings, and otherwise will have to comply with the team rules on division of tasks, reporting, and authorship of publications. In general they will be the lead authors on publications of the direct results from the specific new research identified in their proposals.

The guest investigation ends 12 months after access to the data, or, in case of theoretical investigations, 12 months after the formal start of the guest investigation (on 31 Dec 1997). However, this period can be extended in mutual agreement with the SOHO PI team that the GI is attached to. A final report on the guest investigation is due within one month after the end of the investigation period. The final report shall briefly summarize the main results and list all publications resulting, or partially resulting, from the guest investigation, and have copies of these publications attached. After the final report has been submitted, the GI will provide the relevant SOHO PIs and the PS with copies of any further publications resulting from the guest investigation.

It is intended that the AO for the SOHO GI programme will be renewed every year, until several years after the end of the mission, with a similar review cycle each time.

Chapter 4

EOF Functional Requirements

This chapter is intended to provide a framework for the configuration of the SOHO Experiment Operations Facility (EOF). A more complete description of requirements for the NASA-supplied elements of the EOF can be found in the SOHO EOF Core System Functional Requirements Document (ECS FRD; edition of April 1992 and subsequent revisions). Data exchange and command interfaces are described in detail in the ECS-Experimenter Interface Control Document (January 1994 and subsequent revisions).

4.1 EOF/EAF Overview

The requirement for NASA to provide suitable space for the SOHO experimenters is being implemented by two separate facilities at Goddard Space Flight Center - –the Experiment Operations Facility (EOF) and the Experiment Analysis Facility (EAF).

The operations area (EOF) will consist of approximately 3200 square feet of space in Building 3. This space is contiguous to the SoHO Mission Operations Control Center where the Flight Operations Team works. The EOF is composed of a large Common Area with conference table where planning meetings and joint operations can occur, and individual office space for the following groups: Project Scientists, Science Operations Coordinator and ECS hardware, EIT, LASCO, UVCS, SUMER, CDS, and MDI-GOLF.

The EOF is the location for:

- Daily Planning Meetings
- Monitoring telemetry from the instruments
- Real-time commanding (individual or joint)
- Campaign coordination

Because there is insufficient space in the EOF to house all of the personnel for the resident experiment teams, additional space in Building 26 has been provided to SOHO. Modular workspace will be available for resident PI team members and for visiting scientists and engineers. The Building 26 space will be shared with the Solar Data Analysis Center (SDAC) and with other elements of the ISTP program, and it will include a conference area. A high capacity data communications link between the EOF and the EAF is being implemented, but real-time experiment operations will not take place from the EAF.

The EAF is the location for:

- Weekly and Monthly Planning Meetings

- Data analysis and reformatting activities
- Scientific interchange

4.2 Workstation requirements

Three types of workstations are envisioned at the EOF: the workstations of resident, and in some cases nonresident, PI teams (Instrumenter Workstation or IWS), the Project Scientists' workstation, and the Science Operations Coordinator's workstation.

The Science Operations Coordinator's workstation is an EOF-resident workstation for use by SOHO science operations personnel, under the direction of the Science Operations Coordinator. This workstation will be used to receive and display data used in planning (e.g. from ground-based observatories), to resolve conflicts in instrument operations so as to produce weekly science operations schedules, and maintain various databases (such as the key parameters) to be transmitted to DDF and ISTP CDHF.

The Project Scientists' workstation is an EOF-resident workstation specifically for the use of the Project Scientists, but can also be used as a temporary backup to the Science Operations Coordinator's workstation in the event of unavailability. A PI team that has made arrangements with the Project Scientists to implement IWS software on the Project Scientists' workstation will have a similar backup capability in case of IWS failure. Non-resident investigators will coordinate their operational commanding activities via one of the EOF resident workstations, normally the Science Operations Coordinator's workstation. Commands from remote sites are to be submitted in a format ready for verification and validation before they are relayed to the SMOCC. Software to perform such functions on the EOF-resident workstation is to be furnished by each PI team requiring this capability.

All EOF workstations will support agreed upon standard software (Motif or Motif-compatible implementations of the OpenLook toolkit, IDL, SQL) and formats (FITS) to facilitate the exchange of catalog, scientific, engineering, and planning data. The only exceptions can be specific platforms which are not capable of supporting a subset of the agreed standards (e.g. certain PC Unix implementations for which IDL is not available, but which can open Motif windows on other EOF systems with IDL).

Each EOF resident investigation team will provide a sufficient number of dedicated workstations to acquire incoming data, process and/or monitor those data as required, and prepare schedules and command sequences for submission to the SMOCC.

Each EOF workstation will provide its own capabilities for interfacing with the GSFC EOF Local Area Network (LAN), including provisions for any special additional data interfaces.

Each EOF workstation will provide its own capability for storage of instrument data and resident databases, and for data display and hardcopy, unless specifically stated otherwise herein or in the ECS FRD.

Each EOF workstation will provide its own capability to obtain data from a variety of databases, with elements on a common file server as well as on individual teams' workstations. The individual instrument databases should be accessible to other SOHO users at the EOF. Each PI team will develop and maintain a catalog of accessible files for that instrument. This catalog will also be readable through the EOF LAN interface.

Security provisions to ensure that command transmissions from remote sites over public networks do in fact originate with the authorized PI team and have been received intact are to be installed on the remote and EOF resident workstations.

All EOF workstations will be compatible with standard U.S. power (60 Hz, 110 V) and receptacles.

4.3 LAN requirements

The EOF LAN will provide a high speed (e.g. FDDI or copper FDDI) connection between resident systems to allow the exchange of catalogs, scientific data (including large-format images), engineering data, and planning data among the instrument and flight operations teams. All EOF resident workstations will use the EOF LAN to communicate with the Core System and other resident workstations.

The EOF LAN is a collection of Ethernet sub-segments, joined together in a high speed router. The ECS sub-LAN is to be CDDI.

The EOF LAN will provide a secure interface (e.g. a multiprotocol-filtering bridge or router) that will protect the secure elements of the LAN (the IWSs used for commanding, the ECS elements used for connecting those workstation with the SMOCC, and the interface with the SMOCC) from unauthorized access from the public elements of the LAN (i.e., those elements connected to public networks). This interface will nonetheless allow data transfers from public LAN elements to secure IWSs when initiated by the latter, as required for planning, particularly in near real-time.

The EOF LAN will support all protocols required to interface the EOF to GSFC support facilities and remote investigator institutions.

The EOF LAN will be compatible with the LAN used to conduct SOHO spacecraft AIV (Assembly-Integration-Verification) tests at the spacecraft integrations contractor's facility. The EOF LAN will have the capability to receive SOHO real-time telemetry (formats VC0, VC1, VC2). The ECS does not accept VC4 (tape recorder playback) telemetry. Those data come from the GSFC Information Processing Division (IPD) as a quicklook file.

The EOF LAN will have the capability to interface with the SMOCC for instrument command loads, real-time instrument commands, DSN schedules, and command history files.

The EOF LAN will interface with the GSFC Centerwide LAN, through which the EOF resident workstations will be able to access and utilize existing GSFC facilities such as the ISTP CDHF, supercomputing facilities, and mass storage facilities.

The EOF LAN will be capable of network access to the following:

- The online SOHO predictive and definitive orbit and attitude files updated weekly by the FDF.
- The SELDADS computer network for data regarding current solar activity.
- Ground-based observatories' computer systems for the coordination of observing programs.
- PI-specific communications links to remote PI institutions.
- NSI/DECnet (SPAN) and NSI/Internet for communication with remote investigator institutions, other research institutes, and other sources of solar data such as NOAA SELSIS.

4.4 Incoming data requirements

Realtime data captured by Pacor, including normal scientific data, MDI magnetogram data, and spacecraft housekeeping data, will be routed to the EOF with minimum processing delay following receipt at the ground station, and transferred to the Investigator workstations.

Playback data will be captured by the GSFC Pacor data processing facility and routed to the EOF within two hours of their receipt by that facility. These data will include both scientific data packets and spacecraft housekeeping packets, but will not include all of the preprocessing and quality checking operations performed by the DDF in producing Level-0 distribution data products.

The real-time data and playback data will be stored for up to 7 days after their time of origin. A map of received data packets will be maintained to allow IWS to determine whether to initiate downloads of recently arrived data.

Retransmissions will be arranged for playback data lost due to problems with the network, Pacor, or ECS elements; the resulting delay will be determined by the location and severity of the problem, as well as the availability of network bandwidth.

Experiment data files including the Level-0 scientific and housekeeping data packets from both real-time and playback telemetry, definitive orbit and attitude data files, command history files, and summary data of daily key parameters will be available to the EOF as distribution data. The DDF-produced data products will be distributed to each Project-approved Investigator and Institution on a regular basis (frequency to be determined).

POCC page displays will be provided to the EOF via dedicated display systems. In order for PI teams to be able to monitor instrument performance in near real-time, these remote displays will include all POCC housekeeping display pages and a display of the POCC command buffer page. In addition, a message window facility will allow error-free communication of command requests between the EOF and the FOT in the POCC.

Data from other observatories, both ground-based and space-based, will be received by the EOF and subsequently stored for access by the Investigators.

4.5 Commanding requirements

The EOF will establish an interface with the SMOCC that supports both near real-time commanding, the scheduled uplink of commands for the following day, and the "background" uplink of long memory loads sent to the EOF from remote PI institutions. Delayed loading capability will include the ability to specify an earliest and latest time of uplink.

A prioritization scheme will be established for uplinking commands.

In cases of instrument anomalies, the SMOCC will support emergency reloads with best available turnaround.

The PI groups will develop procedures for the verification and validation of their own processor loads.

To produce daily and weekly schedules of observations and other spacecraft activities, the Science Operations Coordinator and his/her staff will resolve scheduling conflicts, with the aid of rule-based software if such proves feasible by the time of the SOHO launch.

During real-time contact with the spacecraft, Investigator teams may issue commands for near real-time initiation of command sequences and/or the reconfiguration of instrument operational modes. Issuance of critical or so-called "spacecraft" commands will have to be coordinated with the FOT. Any IWS used for commanding will be provided with the status of each command group being handled by the ECS and SMOCC.

The ECS will implement special provisions for accepting command requests from remote institutions, verifying and validating the requests, and then relaying the requests to the SMOCC.

4.6 Data storage requirements

Online storage in the EOF will be provided for the real-time and playback housekeeping and science telemetry data for 7 days. Then the data are stored off-line for an additional 21 days, the nominal turnaround time for DDF to produce the Distribution data.

Summary Data will be stored for real-time access for the most recent 28 days. These data will be provided daily by the investigator teams to the SOC, who will assemble and transmit them daily to the CDHF.

4.7 Support requirements

EOF staff will normally support a 10-hour operating day, during both regular and campaign (i.e. 24-hour real-time contact) periods. Normal operations will be synchronized with local daytime at NASA Goddard. Sufficient staff should be available to support 7-day-a-week operations.

Four classes of support staff are required for the operation of the EOF: science operations, SMOCC coordination, computer administration, and EOF administration.

The SOC who is not a member of any instrument team will be responsible for ensuring the success of the scientific operation of the SOHO mission by executing the decisions of the PS, the SWT, and the regular SOT planning meetings chaired by the SOL.

A system administration team will ensure around-the-clock operation of ECS systems, including interfaces with the IWSs, SMOCC, Pacor, DDF, etc.; telecommanding and telemetry capabilities for the PI teams; EOF-wide e-mail facilities; and EOF-wide time service. In addition, the system administration team will ensure the operation of the PS's and SOC's WS; maintain the various databases and catalogs on the ECS file server; manage any other common ECS hardware elements (e.g. shared hardcopy capability); be responsible for maintenance calls on all ECS hardware and software elements, routine backup and recovery, and system configuration documentation.

An administrative assistant to the PS will aid the personnel working at the EOF in clerical support, access to GSFC resources, security (especially for international visitors), travel arrangements, and interfacing with Project, GSFC, and NASA administration.

Sufficient office support facilities are required to support the EOF. This includes a dedicated voice/data line to the SMOCC, data communications links with external networks, telephone and fax support with international direct dialing capability at all times, copying machine, and dedicated conference room with projection equipment.

Appendix A

Institutions involved in data processing and analysis

GOLF

Primary data processing and distribution:	
Institut d'Astrophysique Spatiale Orsay	Alan Gabriel (PI), Patrick Boumier
Initial science analysis:	
Institut d'Astrophysique Spatiale Orsay	Patrick Boumier
Universite de Nice	Gerard Grec
Service d'Astrophysique, CE-Saclay	Sylvaine Turck-Chieze
Instituto de Astrofisica de Canarias, Tenerife	Teo Roca Cortes
University of Southern California, Los Angeles	Roger Ulrich

VIRGO

Primary data processing and distribution:	
IAC, La Laguna, Tenerife	T. Roca Cortes, A. Jimenez, F. Gomez
Science analysis (PI, Co-I's, AS):	
PMOD/WRC, Davos	Claus Fröhlich (PI), J. Romero, C. Wehrli
IRMB, Bruxelles	Dominique Crommelynck
ESA Space Science Department	T. Appourchaux, V. Domingo, T. Toutain
Observatoire de la Cote d'Azur Nice	P. Delache, G. Berthomieu, J. Provost
Norwegian Space Center	Bo Andersen
University of Cambridge, England	Douglas Gough
National Solar Observatory, Tucson	Andrew Jones
Stanford University, CA	Todd Hoeksema
University of Southern California, Los Angeles	Werner Däppen
Jet Propulsion Laboratory	J. Pap, R. Willson

SOI/MDI

Primary data processing and distribution:	
Stanford University	Philip Scherrer (PI)
Co-Investigators – science analysis:	
Lockheed Palo Alto Research Labs	Alan Title
Lockheed Palo Alto Research Labs	Theodore Tarbell
NCAR High Altitude Observatory	Timothy Brown
Aarhus Universitet, Denmark	Joergen Christensen-Dalsgaard
Institute of Astronomy, Cambridge, England	Douglas Gough
Michigan State University	Jeffrey R. Kuhn
National Solar Observatory, Tucson	John Leibacher
California Institute of Technology	Kenneth Libbrecht
Smithsonian Astrophysical Observatory	Robert Noyes
University of Southern California	Edward Rhodes, Jr.
JILA University of Colorado	Juri Toomre
University of California at Los Angeles	Roger Ulrich
University of Colorado	Ellen Zweibel

SUMER

Primary data processing and distribution:	
IAS Orsay	Philippe Lemaire
Science Analysis:	
MPAe Lindau	K. Wilhelm (PI), E. Marsch, U. Schühle
IAS Orsay	P. Lemaire, J.-C. Vial, A. Gabriel
GSFC	S. Jordan, A.I. Poland, R.J. Thomas
HAO Boulder	D. Hassler
Astronomishes Institut Tübingen	M. Grewing
ESA Space Science Department	M. Huber

CDS

Primary data processing and distribution:	
Rutherford Appleton Laboratory	Richard Harrison (PI)
	Jeff Payne (Ground System Eng.)
	David Pike (Software Leader)
Science Analysis:	
Rutherford Appleton Laboratory	Richard Harrison
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Appendix B

Data formats and software

	Data formats				Software packages	
	SFDU	FITS	CDF	Others	IDL	Others
GOLF	Yes	Yes	No	-	No	Fortran
VIRGO	Yes	Yes	No	-	Yes	-
MDI	Yes	Yes	Yes	-	Yes	-
SUMER	Yes	Yes	No	-	Yes	-
CDS	Yes	Yes	No	-	Yes	-
EIT	Yes	Yes	No	Yohkoh	Yes	-
UVCS	-	Yes	No	-	Yes	-
LASCO	Yes	Yes	No	-	Yes	-
SWAN	To be defined				Yes	-
CELIAS	Yes	No	Yes	-	Yes	-
CEPAC	Yes	Yes	Yes	ASCII	Yes	-

Appendix C

Inter-Instrument Flags

Flags are used to transfer information from one instrument to another, on the same platform, to enable immediate modifications to be made to operations, in a pre-programmed manner. The exchange of information on board is much faster than the sum of the downlink, manual decision and uplink times, and thus the use of a flag system can allow the efficient observation of a whole class of transient solar phenomena.

The operation of the coronal payload on SOHO will be performed in three layers. Standard operations will involve planning sessions at the EOF with targets and operating sequences fixed one or more days prior to the operation. This is adequate for most solar targets. The second layer involves developments in solar activity that may demand changes in operation overriding previous planning, and this can be done by commanding from the ground during real time passes. For the shortest time-scale transient activity, such as the build-up of a bright point, the onset of a flare or eruption, the EOF real-time interruption is not quick enough. Therefore, the third layer of operation requires the use of an inter-instrument flag.

Multiple Flag Policy

The operation of the SOHO scientific payload is extremely flexible and the likely solar targets are many. This demands the use of multiple flags. Such a system dictates a great need for care in planning, operation and responses to flags as the potential for error is great. We avoid much complexity and potential clashes by enabling only one flag at a time. Thus, at any one time, only one pre-defined instrument may flag an event in response to a specified observation, and this will only have one potential reaction by the receiving instruments. The "flag enabled" instrument will be known as the Master and the receiving instruments known as the Receivers. Not all experiments will want to receive a particular flag. Thus, for each flag-type there will be a differing number of Receivers. The contents of the flag message will include the co-ordinates of the solar event and some identification data. The Master and Receivers are assigned from the ground, an individual experiment cannot define its own role.

On receiving a flag, an instrument in a Receiver status will terminate the current operating sequence and run a new, pre-defined sequence centred on the co-ordinates given. An instrument may choose to ignore the flag if the co-ordinates are inappropriate (e.g., require significant re-pointing).

One issue that must be addressed is the flexibility of the order of the flag receivers. It is useful to have differing orders for different flags since particular flags will be of greater interest to different experiments.

The Inter-Instrument Process

The Inter-Instrument Data Exchange Protocol is described in Section 3 of the SOHO EID A (Page 92, 25 March 1991). The flag data exchange will be controlled in a cyclic manner by a COBS software task running in the On Board Data Handling (OBDH). Two 16 bit words will be sampled every 16 seconds from the Master. The words contain a validity bit which, if set to 0, dictates that the X,Y solar co-ordinates of the solar event be sent by block command to each Receiver. From the acquisition of the flag from the Master, it takes 2 seconds to be relayed to the first Receiver, another 2 seconds to the next and so on.

The OBDH block header 16 bit word is defined as follows. Bits 2-5 are the destination address as defined in the table below. Bits 6-10 are the command identifier where 00100 corresponds to Master/Receiver Selection, and 00110 corresponds to Inter-Instrument Data Exchange. If the command identifier is 00100 the block length, given as bits 11-15, is 00010 since the data field will only contain the mode selection word and the checksum dat word (defined in the EID A). The mode selection word is 0000 0000 0000 0000 for Standy by, 1111 1111 1111 1111 for Master mode, and 1010 1010 1010 1010 for Receiver mode.

Instrument Identification Codes

CDS	0100
EIT	0111
LASCO	1001
SUMER	1011
UVCS	1101
MDI	1010

If the command identifier is 00110 the block length is 00011. This is followed with the two 16 bit words from the Master and the checksum data word from the OBDH. In the first word, bits 1-4 are the instrument ID, bit 5 is set to 0, and bits 6 to 15 are the X co-ordinate of the solar event. For the second word, bits 1-4 are the solar event ID, bit 5 is set to 1, and bits 6-15 are the Y co-ordinate of the solar event. Bit 0 is the validity bit for both words, set to 0 for a valid message and 1 for an invalid message.

The inter-instrument communication process can be in an active or disabled state. In the latter, all instruments are set to the stand-by flag state.

Event Identification

The first problem is the identification of a solar event to be flagged. Such an event would presumably be identified by a change of circumstances, be it a significant rise or fall in brightness at a specific wavelength or a Doppler shift. A Doppler shift can be thought of as a brightening if one is monitoring intensities just off line-centre from a specific spectral line. A further event-type would be transverse motion which would have to be identified through differencing of successive images.

An example of a flag is given below, along with a method of identification, the Master and Receiver instruments and event ID for use in the flag word (see above).

Solar Event: Flare
Event ID: 0001
Master(s): EIT/CDS/SUMER

Receivers: CDS/SUMER/UVCS/LASCO/MDI
Method for Event Recognition: Identify excessive brightenings either in the EIT image or in a hot CDS(NIS)/SUMER spectral line (e.g. Fe XVI 335.40Å, 360.76Åor Si XII 520.67Å) during a large raster scan over an active region. The intensity threshold must be set to a relatively high level.

Other potentially useful flags are, e.g., Bright Point, Microflare, High Velocity Events, Tranverse Velocity Events, Activated Prominence, Eruptive Prominence, Coronal Mass Ejection, and Precursor Activity.

Many flags can only be set through experience. For example, the setting of thresholds must remain flexible since we do not have an accurate feeling for expected intensities for some events. Furthermore, while the crossing of intensity thresholds is clear cut, the idenitication of transverse motions through image comparisons, on board, is not straightforward and may require much development and tuning. As a result, we cannot expect to have a complete, finely tuned system from day one.

Schedule

The mechanism for the flag generation and processing should be set up as the OBDH and instrument CDHS systems are developed. That is, the instruments should adhere to the instructions in the EID-A as described above.

Specific codes should be written into the instrument CDHS for each potential Master and Receiver to generate and respond to flags 0001 and 0010 as described above. These are the simplest flags. Threshold figures should be estimated.

The flag system will not be among the highest priority operations at the start of the mission and will most likely not be used for some weeks after arriving at the L1 point. Initial scientific operations will include the onset of basic synoptic programmes and "look and see" spectral scans and rasters. However, it is recommended that the flag system be brought into operation within a month of the start of scientific operations at the L1 point.

Once the go ahead is given to initiate the flag campaigns, the experience gained will be used to adjust the flag thresholds and to fine tune the responses to the flags. And later, more complex flags will be implemented.

Appendix D

The SOHO Interdisciplinary Science Matrix

The goals of SOHO require comparison and analysis of data-sets from very different experiments. Such interdisciplinary studies require careful planning, prior to the observations, and involve complex analysis procedures. In recognition of this, the SOHO Coronal and Particle Working Group (SCPWG, now merged to the Science Planning Working Group, SPWG) initiated a study to provide an overview of the nature of such activities.

The underlying goal of the ESA Solar Terrestrial Science Programme (STSP) is to develop an understanding of the activity of the Sun and its influence on the Earth. SOHO and the Cluster spacecraft fleet were designed to provide the backbone of such a study. Even with such a co-ordinated effort, it is difficult to correlate solar and space plasma events and structures. Complexites arise because of time delays and the uncertainty of propagation paths, as well as the linking of observations made with fundamentally different instruments, such as spectrometers and particle detectors.

At the SCPWG meeting in the Spring of 1991, attempts were made to bring the scientific discussion to focus on operations. As part of this an overall picture of interdisciplinary operations was developed by constructing a matrix which describes each experiment's activities during certain campaigns.

Studies

Several scientific studies or campaigns which involve inter-experiment operations on SOHO are presented in matrix form. The entries are limited to those schemes suggested by people who responded to the call for input. Most are derived from detailed schemes, with specific operations for each instrument.

Included here are only studies which involve many instruments, and especially those involving instruments belonging to more than one of the experiment groups (see Table 1.1 in Chapter 1). For the present, we are concentrating on the interdisciplinary aspects of the solar atmospheric and space plasma observations and will not consider the operations of the GOLF, VIRGO and MDI experiments.

The studies fall into three categories:

• E = Event driven study. For this, a specific feature may be tracked through different regimes by the experiments, e.g. tracking a mass ejection from the Sun to 1AU.

- C = Campaign.
- R = Regular or periodic observation.

The participation of an instrument in each study is noted by the letters x, w or d. Non-participation is denoted by a '-'. An x entry simply denotes that the experiment is participating. A w entry means that the instrument is waiting for an event, probably operating in a "sit and stare" mode until a flag is triggered. A d denotes some time delay during an event driven study (E) from the onset of the event observation in the first instruments. For example, a flare seen in CDS, which was operating in a w mode, might generate a stream of particles seen in ERNE some 10 min later.

Each study is denoted by a three letter identifier:

FIL = Filament eruption study.
CME = Coronal mass ejection study.
HOL = Coronal hole study.
ION = Ion abundance study.
ELE = Element abundance study.
FIN = Fine scale structure study.
STR = Streamer study.
FLA = Flare study.
COR = Coronal evolution study.
SCT = Sector boundary study.
SHK = Development and propagation of shocks.
BRT = Bright point study.

Most of the studies are of a campaign nature. This will probably be the most productive interdisciplinary approach. These will be relatively easy to operate since they do not attempt to make direct links between observed features, the observations can be easily defined and plans may be made well ahead of the campaign.

The event driven studies involve some of the coronal instruments "waiting" in a pre-event "sit and stare mode". This may be wasteful. Once an event has occurred, we are very dependent on it's path of propagation to receive signals in the high coronal or in situ devices.

Most of the studies require specific ground-based input, and will, most likely require supporting satellite data. Good information exchange and communication between SOHO and ground based and other satellite instrument groups is essential.

One way ahead is for the SPWG to extend the Matrix by filling in the detailed operation for each instrument for each entry in the Matrix. From that point one may input a schematic event, such as a simple mass ejection, to produce dummy data. Methods for comparing the different signatures may be discussed, then, for a known input.

The Flare Study

SOHO is not a flare mission, but discussion of how we would hunt a flare provides one extreme in potential operations. The sequence of events could be as follows:

(i) Some weeks prior to the observation, at the EOF planning meetings, the details of a FLA campaign is discussed. The plan is to observe a flare within a region 30-60 degrees from the western limb, so we may observe low coronal structure with CDS and SUMER, and the high coronal response with LASCO and UVCS. EIT and MDI would be involved. The particle instruments are informed, in case flare generated particles arrive at the spacecraft.

(ii) Having identified a candidate active region crossing the eastern hemisphere, in the preceding week, contacts are made to ground based observatories to ensure good Hα monitoring, vector magnetogram data on the relevant region, and to the receipt of coronameter data. Similarly, approaches are made to relevant spacecraft teams.

(iii) CDS is chosen to be the inter-instrument flag Master. An intensity threshold in a particular hot line is chosen as the flag generation mechanism. Flags will be used by SUMER, to home in on the flare region, and by UVCS and LASCO to change mode to scan the overlying corona. The other instruments will not change mode during the operation.

(iv) At the specified time CDS points to the identified active region. The other instruments may continue other observations or also view the active region or overlying corona.

(v) A flare occurs and a flag is sent. Automatic repointing and mode changing is immediately performed by the other instruments, as specified during the planning, to enhance the observation. There is no time for control by ground contact; this is flag driven. The operation continues for a specified time.

(vi) A team has been appointed to co-ordinate the analysis of the data-set. In practice, this should be individuals from the involved experiment groups and would include someone from each of the other non-SOHO instruments. The SOHO data-sets should be processed and forwarded to the team, as should other space-based and ground-based data. An initial report on the success of the campaign (i.e. the operational aspects such as the performance of the flag, the delay in getting data, the loss of any data due to weather, drop outs etc.) should be reported to the SPWG within a month of the campaign. This provides the experience for improving future campaigns. The analysis of the data-set and the publications should be co-ordinated by the team over the following months.

The Matrix

The columns 2-10 represent the SOHO instruments and column denoted G-B includes comments on ground-based support.

Study	SUM	CDS	EIT	UVC	LAS	SWA	CEL	COS	ERN	G-B
FIL/E	w	w	w	d(30m)	d(30m)	d(1hr)	d(1d)	d(10m)	d(1hr)	1,2,3
CME/E	w	w	w	w	w	d(1hr)	d(1d)	d(10m)	d(1hr)	1,2,3
HOL/R	x	x	x	x	x	x	x	x	x	4
ION/C	x	x	-	-	-	-	x	x	x	-
ELE/C	x	x	-	-	-	-	x	x	x	-
FIN/C	x	x	x	-	-	-	x	x	x	-
STR/R	x	x	x	x	x	x	-	-	-	2
FLA/E	w	w	w	-	-	-	d(1d)	d(10m)	d(1hr)	3
COR/C	-	-	x	x	x	x	-	-	-	2
SCT/C	-	-	x	x	x	-	x	x	x	1
SHK/E	w	w	w	d(m)	d(m)	d(hr)	d(1d)	d(10m)	d(1hr)	5
BRT/C	x	x	x	x	-	-	x	x	x	1,3

The suggested ground-based support is taken from the following list:
1 - Magnetograph (e.g. Marshall Space Flight Cente)
2 - Mauna Loa Solar Observatory (coronagraph and Hα limb monitor)
3 - Hα (e.g. Big Bear Solar Observatory)
4 - He I 10830Å (e.g. Kitt Peak).
5 - Metric radio observations (Type II)