

Coordination of SOHO and Groundbased Observations

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Abstract. I present an overview of the preparations for joint solar observations between the SOHO spacecraft, ground based observatories, and other spacecraft. An extensive communications infra-structure will be needed to exploit the opportunity of coordinated, real-time target selection during campaigns. The cornerstones of this communication system are (1) fax and telephone, (2) network exchange of documents and data at several levels of network sophistication to include the widest possible community of solar physicist, (3) a uniform data format, and (4) a SOHO campaign data library. Equipment standards required to optimize joint observations with SOHO are described, and an overview is given of the SOHO science planning cycle in relation to the preparation for joint observations.

1. Profile of the SOHO Mission

An extensive description of the SOHO instruments and of the SOHO mission has been published in (1), and an updated version has been scheduled to appear in *Solar Physics* in the September 1995, two months before launch. For the context of this paper I will summarize those aspects of the SOHO mission relevant for joint observations of SOHO and groundbased and spacebased observatories (GBOs and SBOs).

SOHO will be launched in the fall of 1995, and after a transfer phase of 4 to 5 months will start orbiting the L1 Lagrangian point between Sun and Earth, which lies at a distance of 0.01 AU from the Earth on the Sun-Earth axis. This orbit allows for continuous monitoring of the sun without interruption by the day/night cycle. The nominal duration of the SOHO mission after reaching halo orbit is two years, but enough consumables are stored on-board for a four year mission extension.

The SOHO instruments can be divided in three categories. The first is that of the helioseismology instruments (GOLF, VIRGO, and MDI) whose primary aim is to study those parts of the solar oscillations spectrum that cannot be obtained from the ground. The required sensitivity for observing the very low modes ($l < 6$) and the very high modes ($l > 200$) 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.

The second category is that of the instruments for measuring "in situ" the elemental and isotopic abundances, the ionic charge states, and velocity distributions of ions originating in the solar atmosphere and carried outward by the solar wind (ERNE, CELIAS, and COSTEP).

Most important for joint operations with GBOs is the third category of instruments, high resolution imagers and spectrometers (EIT, LASCO, CDS, SUMER, SWAN, UVCS, and MDI in magnetogram mode), that remotely sense the solar atmosphere from the photosphere up to the outer corona.

During the nominal mission SOHO will have 8 hours a day real-time ground contact through NASA's Deep Space Network (DSN) with a 40 kbs^{-1} telemetry downlink for real-time data and 160 kbs^{-1} for data stored onboard during non-contact periods. For about 100 minutes per day the 160 kbs^{-1} link will be reserved for high rate helioseismology data. Two months a year SOHO will have complete (24 hours/day) DSN coverage, with 160 kbs^{-1} for high rate helioseismology data, and 40 kbs^{-1} telemetry for real-time data from the other instruments.

2. SOHO – A Coordinated Payload

A fascinating novel aspect of the SOHO mission is that during the real-time contacts the experimenters will be able to operate their instruments interactively. The uplink time for commands will be of the order of tens of seconds and the resulting images can be inspected immediately. This mode of operation creates a whole array of opportunities for joint and coordinated observations between the SOHO instruments and between SOHO and GBOs and other spacecraft.

Joint operation of the SOHO remote sensing instruments has been a design goal of the mission from the start. Just as coordinated campaigns between GBOs require advance planning on scientific goals, observing sequences, and targets, so will joint operations of SOHO instruments. To enable this coordination a SOHO Experiment Operations Facility (EOF) has been set up at NASA Goddard Space Flight Center that will serve as the focal point for SOHO mission science planning and instrument operations. At the EOF, instrument team 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. Most experiment teams will have both permanent and temporary representatives on a rotating schedule present at the EOF.

The EOF will be the prime center for the planning of inter-instrument observing programs and joint data analysis, and for the organization and implementation of observing campaigns in collaboration with other spacecraft and ground based observatories. Sophisticated "point-and-click" software programs exist to generate observing schedules and command loads for the remote sensing SOHO instruments in a matter of minutes, and to integrate these schedules into a joint SOHO observing time-line, with suggestions for conflict resolution, if required.

As the principal SOHO science center, the EOF will also be the location for scientific collaborations, SOHO science workshops and seminars. Selected SOHO Guest Investigators and other interested scientists will be welcome and encouraged to visit the EOF to analyze and/or acquire data in collaboration with the resident members of the SOHO PI teams.

3. An Infra-Structure for World-Wide Campaigns

While the existence of a SOHO EOF simplifies the joint operation of the SOHO instruments enormously, the joint operation of several spacecraft and GBOs during campaigns requires the coordination of efforts between groups of solar physicists spread all over the globe. Figure 1 provides an overview of Solar Terrestrial space missions that may operate

SOLAR TERRESTRIAL MISSIONS

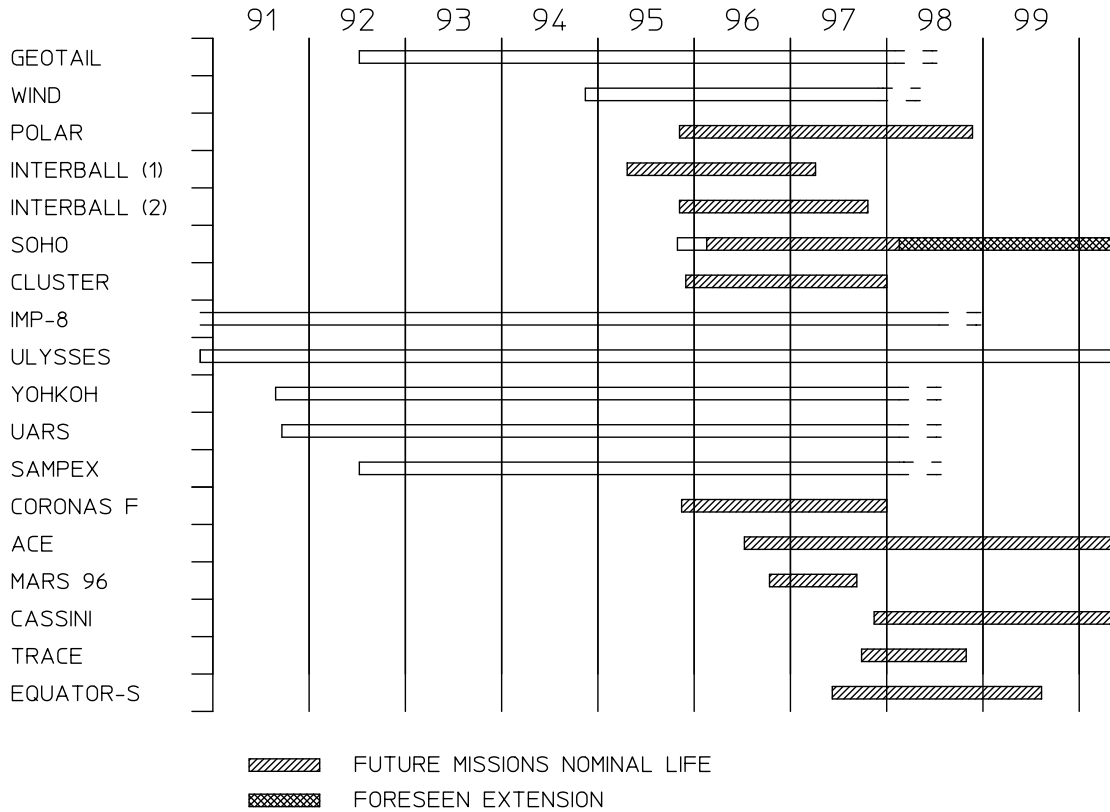


Figure 1: Solar Terrestrial Missions Simultaneous with SOHO

simultaneously with SOHO – an astounding number, indicating the great potential for joint observations.

We have taken our cue from Alan Kiplinger, coordinator of the successful Max '91 campaigns, that *“the primary key for successful coordination is clear communications”* (2). To achieve clear communications world-wide what is needed is a good communications infra-structure. Our prelaunch SOHO campaign preparations focus on providing this.

Setting up a communications infra-structure doesn't require us to reinvent the wheel; instead we rely in part upon the campaign system developed for the Max '91 campaigns, and being expanded for NOAA's Space Environment Laboratory (SEL), in particular for the SOONSPOT solar archival system (2). The cornerstones of the SOHO campaign system are telephone and fax, network exchange of information and data, a uniform data format, and a “live” SOHO data archive. These elements will be briefly described in the following.

1. Telephone and Fax

Telephones and faxes at the SOHO EOF will have a 24 hours per day world-wide direct dialing capability. Faxboards on several workstations at the EOF will enable us to send faxes (for example with the recent SOHO pointing data) to scores of solar observatories world-wide by a simple keystroke, and read incoming faxes on our screens. Through conference calls and exchange of live video images over digital phone lines,

observations at the EOF and GBOs can be coordinated in real time.

2. Network Exchange of Information and Data

The SEL system – which we intend to adopt – for making information electronically available to interested parties world-wide has a “layered” construction in order to serve users with widely different levels of network sophistication. The different levels and the user capabilities at each level are illustrated in figure 2.

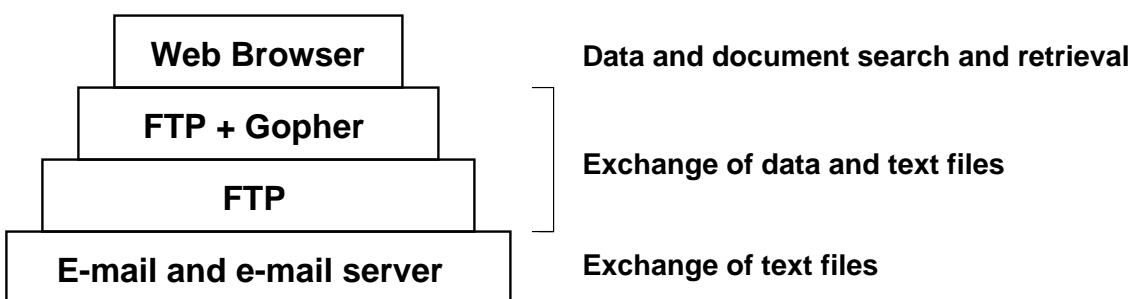


Figure 2. Exchange of SOHO documents and data at various levels of network sophistication.

At the lowest level, a user with a “dumb” terminal with e-mail capability, can receive observing plans, target regions, and advisory notes that are sent out regularly to a distribution list. An additional capability, being developed at SEL under the auspices of Dr. Kiplinger, allows users at this level to submit brief requests for specific information to an automatic e-mail answering system, “Major-domo”, that will return the requested information from the SOHO catalog or SOHO campaign register.

At the next two levels users with either ftp, or ftp and “Gopher” services at their disposal will be able to browse SOHO directories, and retrieve data and information available to the public via ftp. Finally, high end users will be able to peruse SOHO images and documents via the World Wide Web.

We find it important to provide communication channels at all these different levels, because it guarantees the inclusion of the widest possible group of scientists, independent of their available hardware.

3. Uniform Data Format

All SOHO scientific data will be stored and made available in the FITS format, a standard that has found widespread acceptance among solar observers. Keywords have been defined that are appropriate for the various instrument needs: a complete description will be available as part of the SOHO catalogue information on internet (and through email as well). Most solar GBOs also provide their data in FITS, but software will be available to import data in other formats (such as the Yohkoh format) and convert them to FITS.

4. SOHO Data System

To facilitate the intercomparison of SOHO experiment data, and of campaign data, an integrated SOHO data library (a “live” archive) for the catalogues and data from all experiments and from campaigns, and for data provided for planning purposes by other GBOs and SBOs, is currently being developed at the EOF. This library will store the

complete set of the telemetry received from the spacecraft and all the ‘science-processed’ data: the PI teams will calibrate the raw telemetry files into scientifically meaningful data and will deposit these at the library. These data will go into the public domain according to the terms specified by the SOHO Science Working Team. It is our goal to have all public domain SOHO data available on-line.

Together with the data this system will contain software for user-friendly access, data retrieval, and display. In particular a number of image processing tools will be provided, such as overlay displays, fine-pointing of solar targets, instrument field-of-view and coordinate transformations, solar rotation simulation, and solar ephemerides.

On-line detailed descriptions of all SOHO Joint Operation Programs (JOPs) and all campaigns with GBOs and other spacecraft, and an on-line user library with uniform documentation complete the system.

In addition to EOF archive, three European copies (in England, France and Italy) are under study to provide easy access for European users.

4. Collaborating with SOHO: Equipment Standards

Although is evident from the above that the SOHO scientists want to collaborate with widest possible community, there are certainly standards in hardware, software, and communications that will facilitate joint observations and exchange of data. We hope that our specification of these standards in this forum, can be of help for funding requests by solar observatories that want to upgrade their equipment in time for the SOHO launch.

From the description of the world-wide campaign system described above, we derive the following set of equipment requirements:

- Workstations
- Internet connections
- Digital data storage
- Fits-formatted data files
- IDL
- International Fax and telephone.

IDL, a commercial programming and visualization language, is listed above because all of the SOHO and Yohkoh software for image display and processing is written in IDL. However, since the FITS format does not require IDL, any other image processing system may be adequate as well, although it excludes the user from sharing the wealth of routines specifically developed for Yohkoh and SOHO data analysis.

Digital data storage in FITS format will allow an observatory to distribute its data immediately, so that SOHO, other spacecraft, and GBOs can use the data for science planning. Digital images are also much more amenable to quantitative analysis than are photographs or films, which greatly enhances their usefulness for analysis of campaign results.

After studying the FITS formatted images provided on-line by several solar GBOs, we recommend that observers include, if possible, the following information in the headers of their FITS-files: the direction of solar North and East (we found that few images

indicate the sun's rotation axis, and some have east-west reversal), the pixel coordinates of sun-center, and the radius of the disk in pixels. Knowledge of true North and East is indispensable for the software routines that produce overlays of images. Although interactive software exists to determine disk-center and radius, this still requires human effort every time the image is analyzed, so it would be preferable to provide this information once and for all in the image header.

5. Planning for Joint Observations with SOHO

Joint observations with SOHO can take place as part of world-wide observing campaigns, that are planned and announced long in advance. An example is the IACG (Inter-Agency Consultative Group, formed by ESA, NASA, ISAS, and IKI) campaign to observe CMEs originating from the sun's western hemisphere. This campaign will involve at least 14 (!) solar, interplanetary, and geospace spacecraft during the summer of 1996, and scores of GBOs. Planning started during a meeting in Japan in May 1994, more than two years in advance. A detailed description of this campaign can be found in (3), and will also be available on internet . GBOs that are interested in collaborating should contact the campaign leader, Dr. Richard Harrison, Principal Investigator of the CDS instrument onboard SOHO (rharrison@solar.stanford.edu).

While these campaigns are of major importance, SOHO scientists also anticipate joint observations with just a few, or one GBO, and with a much smaller lead time. It is important to note here that such collaborations can be initiated by either side: we ask ground based observers **to consider how they would like to involve the SOHO experiments in supporting investigations with their own instruments.**

Suppose now, that an observatory (or a group of observatories) would like to have supporting observations from one or several SOHO experiments: how would one go about setting up such a collaboration?

First, we would advise to send an e-mail message, briefly describing the plans (science goals, dates, observing plans, collaborating observatories) to the SOHO Science Operations Coordinator (SOC: *soc@soc2.nascom.nasa.gov*) as early in the preparations as possible. The SOC will forward copies of the message to the relevant SOHO experiment teams, but the authors of the message are welcome to contact key persons in the experiment teams directly if they feel more comfortable with that, as long as they keep the SOC informed as well. Messages by fax or ordinary mail are only recommended when no e-mail capability exists.

To determine how much advance notice is required, one needs to have some insight in the SOHO planning cycle, a summary of which is provided in Table 1. The initial notification, referred to above, is best done before the quarterly meeting of the SOHO Science Working Team (SWT), from 1 to 4 months prior to the joint observations. If the SWT decides to accept an invitation for joint observations then this decision will be carried out at the subsequent monthly meetings, unless there are exceptional circumstances. One sees that at the monthly meeting, for scheduling of the month starting in two weeks time, timeslots for joint observations are decided upon. This implies that fairly detailed plans for joint observations have to be submitted at least 3 to 7 weeks in advance of the planned date. Collaborations with less lead time are possible under exceptional circumstances, or for very brief observing periods.

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.
	Tomorrow	R/T instruments commands
	Day after tomorrow	Choice of pointing targets Changes to weekly plan S/C command load

Table 1: Schedule for SOHO planning meetings

Target selection is done on a daily basis, and can be coordinated through e-mail, phone, or fax, with either party taking the lead depending upon earlier agreements. Target selection can also be done in real time during SOHO DSN contact periods, with coordination through conference calls. As was mentioned above, live video images can now be transmitted over digital phone lines, so real time pointing verification is possible.

Finally let me point out that several SOHO experiments frequently make synoptic observations, which are often very useful as auxiliary data for campaigns by other observatories. Support of this type requires at most some coordination in timing, which can be done in the weekly meetings, 3 to 10 days prior to the observations.

In conclusion I want to emphasize that the coming years offer a unique opportunity for solar observing, by a whole starfleet of spacecraft in collaboration with scores of new and improved ground based solar observatories, that will very likely not be repeated during our lifetime. Let us welcome this opportunity and work together as much as we can.

References

- (1) "The SOHO Mission: Scientific and technical Aspects of the Instruments", 1988, ESA SP-1104, ESA Publications Division, Noordwijk.
- (2) Kiplinger, A.K. 1995, in "Proceedings of the Third SOHO Workshop", ESA Publications Division, Noordwijk, in press.
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