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The Outline of Solar-B Mission Operation & Data Analysis

Version: 0.99C

The Solar-B MO&DA Working Group

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About the Document

The purpose of the document is to describe the plan for the mission operations and data analysis of Solar-B that has been developed in the Solar-B MO & DA working group and Science Working Group. Version 1.00 is signed by representatives of JAXA, NASA, and PPARC to indicate its acceptance by the Science Working Group.

Contents

1. Introduction

1.1 Overview of the Solar-B Mission

Solar-B is an international cooperative mission between JAXA/ISAS of Japan, NASA of the United States, and PPARC of the United Kingdom. It builds on the great success of the Yohkoh (or Solar-A) mission and is the second of NASA's Solar Terrestrial Probes (STP), which address fundamental science questions about the physics of space plasmas and flow of mass and energy through the solar system. It will perform coordinated, simultaneous measurements of the different layers of the solar atmosphere from a Sun-synchronous orbit around the Earth. Three instruments will perform these measurements, a Solar Optical Telescope (SOT), an Extreme Ultraviolet Imaging Spectrometer (EIS), and an X-Ray Telescope (XRT). The instruments will measure the Sun's magnetic field in the photosphere and the ultraviolet and X-ray radiation, emitted by the transition region/low corona, and the upper corona. Scientists will use the data obtained with the instruments to increase the scientific understanding of the sources and mechanisms of solar variability. The primary scientific goal of the Solar-B mission is to observe how changes in the photospheric magnetic field propagate through the different higher layers of the solar atmosphere. Achievement of this goal requires continuous, simultaneous observations, of specific solar features, by all three instruments.

The Solar-B mission contributes to NASA's strategic objective "to explore the Sun-Earth system to understand the Sun and its effects on Earth" and to two of three objectives in the STP Program:

- To describe the system behavior of the magnetic variable star, our Sun, and its interaction with the entire solar system; and,
- To understand the critical physics that link the Sun, Earth, and the interstellar medium.

The SOT and its focal plane instruments provide quantitative measurements of the Sun's full vector magnetic field on spatial scales of 200 to 300 km over a field of view large enough to contain small active regions. The instrument fields of view, sensitivities, and cadence allow changes in the Sun's magnetic energy to be related to both steady state (coronal heating) and transient (flares, coronal mass ejections) changes in the solar atmosphere.

The SOT is a diffraction-limited Gregorian telescope with a 0.5 meter aperture. The distance between the primary and secondary vertices is 1.5 meters. The field of view is greater than 400 arcsec in diameter. The wavelength band observed is between 380 nanometers (nm) and 660 nm.

SOT's instrument package, referred to as the Focal Plane Package (FPP), collects high resolution spectra and images of the photosphere and chromosphere, some with full polarization analysis. Processing on-board and on the ground makes magnetograms, Dopplergrams, and accurate vector magnetic measurements from these data products.

The FPP contains four distinct sub-systems:

- A broadband filter imager (BFI)
- A narrowband filter imager (NFI)
- A spectro-polarimeter (SP)
- A Correlation Tracker (CT)

EIS records extreme ultraviolet (EUV) spectra and images of the multi-thermal (10^5 to 10^7 K) plasmas in the quiet Sun, active regions, and flares at high spectral, spatial, and temporal scales characteristic of these processes

The EIS instrument incorporates two major optical components:

- A multi-layer coated normal incidence off-axis telescope with high spatial resolution; and,
- A multi-layer coated, normal-incidence, toroidal grating, stigmatic spectrometer covering two diagnostically important EUV wavelength bands centered on 19.50 nm and 27.00 nm.

XRT provides quantitative measurements of the emissions from the high temperature (10^6 – 10^7 K) component of the solar corona as a function of time and position. It is a Wolter I grazing incidence telescope similar to that used on Yohkoh, with a large format back-illuminated CCD. Pixels are 1 arcsecond and field of view is slightly larger than the full solar disk when pointed at disk center. With 9 analysis filters, the telescope covers a broad range of temperatures, with low temperature response enhanced compared with Yohkoh/SXT. It can also take visible G-band images for coalignment with SOT and EIS.

ISAS provides the overall mission management, mission operations, the spacecraft, the launch vehicle, and the SOT. In addition, the ISAS provides the tip-tilt mirror assembly, which is an integral part of the SOT Image Stabilization System. The ISAS also provides the charge-coupled device (CCD) and its associated electronics for the XRT camera.

NASA is providing all of the FPP and the polarization modulator wheel located between the SOT and the FPP. NASA will provide the opto-mechanical elements of the XRT components including the X-ray and visible light optics, filter wheel and filters, front door, camera focus mechanism, shutter, telescope structure, and integration of the instrument components into the XRT. NASA will provide the optical components for the EIS including the primary mirror assembly, the diffraction grating and grating slit sub-assemblies, and the front filters, spectrograph entrance filter, and the mechanism driver electronics. In addition, NASA supports participation in systems-level integration, mission operations preparations, mission operations, and data analysis.

PPARC is providing the major elements of the EIS including the spectrometer structure and thermal control system, the CCD detector system and radiator, the instrument control unit electronics, and the front filter enclosure. PPARC will integrate the NASA provided EIS components into the EIS instrument.

The spacecraft, designed and built by ISAS, provides structural interfaces, power, attitude control and pointing, data storage and transmission capability, and environmental protection services to the science instruments. It is designed for a three-year baseline mission, with a goal of an extended mission for many years beyond this.

The spacecraft provides an offset pointing capability that allows the optical axis of the SOT to be pointed at any point on the Sun, solar limb, and/or at any point less than or equal to 1 arc-minute above the solar limb.

Data storage and transmission/downlink are managed centrally by the spacecraft. The Mission Data Processor computer controls the science observing functions of the FPP and XRT and passes commands and data to EIS, which has its own internal Instrument Control Unit.

The Solar-B spacecraft will be delivered to orbit by a Japanese launch vehicle from the

Kagoshima Space Center, Japan. The planned launch date is September 2006. The Solar-B orbit is an approximately 600 km circular Sun-synchronous orbit with a nominal 97 degree inclination.

Spacecraft control, data collection, and tracking are under the control of the ISAS and will be conducted from the ISAS facility in Sagamihara, Japan. NASA will provide resources and/or NASA assets to assist in early launch operations tracking and science data downlink support. The European Space Agency will provide 15 additional downlinks per day using a ground station at Svalbard, Norway. This, support will dramatically increase the scientific return from Solar-B, helping to ensure that the Solar-B scientific goals can be achieved.

1.2 Purpose of this Document

The purpose of this document is to provide the outline of Mission Operation and Data Analysis for Solar-B. The following three topics are described in the document.

- Science operations of the Solar-B satellite and its instruments
- Scheduling and submission of observation plans
- Data policy, archiving, distribution and analysis of Solar-B data

The document is based on the following documents and presentations.

- Mission Operations and Data Analysis (@FPP-CDR [Tarbell])
- Science Implementation
  (XRT: SAO Solar-B Homepage "http://hea-www.harvard.edu/solarb/")
- Data Products of the XRT (@3rd Solar-B science meeting [DeLuca])
- EIS Ground Based Software Requirements (MSSL/SLB-EIS/SP/022.01)
- EIS Science Data Products (@3rd Solar-B science meeting [Harra])
- EIS Operation Planning (16/7/01) (EIS:MSSLHomepage "http://www/mssl/ucl/ac.uk/Solar-B/eis_planning.htm)
- Methods for Visualizing Solar Data (@3rd Solar-B science meeting [Berger])
- Minutes/résumés of the 1st Solar-B MO&DA Meeting @ Lockheed 2002/02/20-21
- Minutes/résumés of the 2nd Solar-B MO&DA Meeting @ SAO 2002/02/17-19
- Etc…do we really need these? It would be better to list living documents with some relevance, such as the ISAS Interim Reports, EICA's, etc.

2. Operations of the Solar-B Satellite and its Instruments

Principles of Solar-B Science Operations

Basic principles of the operation of the Solar-B satellite and its instruments are summarized as follows. The Solar-B team consists of the individual instrument teams, the Project Scientists, and their collaborators participating in science operations.

A) The Solar-B team shall coordinate observation plans among the three instruments aboard Solar-B for maximizing the scientific results from Solar-B observations. Items to be coordinated are
   - □ Target of the observation
   - □ Usage of the data recorder

B) In order to maximize the scientific returns from Solar-B observations, the Solar-B team, when appropriate, shall cooperate with other satellites and ground-based observatories.

C) The "observation plan" (i.e., observation tables and commands) of each instrument should be prepared independently, once the coordination is agreed.

D) To ensure effective operations, initially all operations will be conducted from ISAS and KSC. After operations become routine, team members will have the option to participate from remote sites. Certain operations may be performed effectively from remote sites, allowing team members located in Japan, US, UK, and Norway to devote a greater part of their time to scientific collaborations.

Along with the basic principles, the following scheme of Solar-B science operations will be implemented:

I. Duties and contributions to the Solar-B science operation are equally shared among Japan, US, and UK scientists in the Solar-B team

II. Chief observers (SOT_CO, XRT_CO, EIS_CO) are assigned for scientific operation planning and health-check of the instruments. In the early phases of the mission, chief observers will work at the ISAS/SAGAMIHARA campus, Japan.

III. Initially there will be a separate Chief Planner dedicated to coordination among the instruments and satellite science operations planning. The instrument teams are responsible for providing a Chief Planner on a rotating basis.

IV. Scientists are involved in the daily real-time operations of Solar-B. Since the real-time operations team (engineers of the contractors) at KSC cannot speak English, Japanese-speaking scientists are assigned for the persons in charge of the real-time operation. It is assumed that one of the chief observers is a Japanese speaking scientist.

1. The operation system of Solar-B

2.1.1. The personnel of Solar-B daily operation

The following positions are needed for the daily Solar-B operations.

□ Chief Observers (3)

SOT Chief Observer [SOT_CO]
XRT Chief Observer [XRT_CO]
EIS Chief Observer [EIS_CO]

- One person will be nominated for each instrument in shifts of at least one week.
- Each instrument team shall establish their staffing schedule.
- Initially COs will work at ISAS, but once operations have become routine may be located remotely.
- COs plan the observations, including preparation of the observation tables and command plans for the instrument.
- Check the instrument status at least daily.
- Contribute to collecting and analyzing calibration data.
- Review the contents (image quality etc) of the level-0 files generated by the reformatter (See also the roles of Solar-B database coordinator).
- Japan, US and UK scientists and/or graduate students (who have experience as the chief observer or the supporter) serve as chief observers. One of the three chief observers speaks Japanese.

□ Solar-B Chief Planner [CP] (1 or 0)

- Solar-B Chief Planner (CP) is a scientist provided by the instrument teams in shifts of at least a week. Initially, this person will be different from the chief observer of the instrument.

- CP works at ISAS Sagamihara campus.
- Main tasks of the CP are as follows:
  - To coordinate the observing plans among the telescopes and resolves conflicts when necessary,
  - To do routine works with automated software for making the sequence of satellite commands needed for nominal science observing, details of which are described later, and
  - To compile all the submitted commanding plans on the ISACS-PLN system and finalize the real-time command plan for USC operations and OP/OG (onboard command sequence).
- Coordination of observing plans (1)

  One of the important coordination is the usage of data recorder (DR) among three instruments. After the DR usage plan is defined in weekly and daily meetings, the CP will perform the following routine tasks:
  - To provide DR usage planning information to the COs,
  - To check whether the observations planned by the COs will not cause overflows in DR, and
  - To generate the sequence of commands for downlinks.
- Coordination of observing plans (2)

  Satellite pointing schedule (selection of targets for observing) is defined in weekly and daily meetings. The CP will operate AOCS[1]-team provided software and make commands for routine pointing to change the targets of interest.
- Routine works

  The CP performs routine works with AOCS-team provided software to prepare satellite commands needed for nominal science observing, including updating of orbital elements and parameters for AOCS-related timers and so on.
- Finalizing real-time commanding plan and OP/OG
  - After receiving the commands and observation tables from the COs, the CP complies all the received commands and tables and generates the real-time commanding plan for USC contacts and OP/OG plan. The ISACS-PLN system is used for this automated process.
  - The CP reviews the generated OP/OG and real-time commanding plan with graphical time-chart of major commands (pointing, downlink, eclipse,

[1] Attitude and Orbital Control System

etc).

- ✧ Finally, the CP submits the OP/OG and real-time commanding plan to real-time TOHBAN for approval.

- ◻ Persons responsible for the real-time operation [Real-Time TOHBAN] (3)
  - ➢ Real-Time TOHBAN are the conductors of the real-time operations
  - ➢ Stay at SAGAMIHARA campus after the initial phase.
  - ➢ Japan (ISAS/JAXA) basically takes responsible for real-time operations. However, due to limited human resource in Japan, ISAS/JAXA's latest baseline during nominal science observing period after initial phase is as follows. (See also Section 2.1.2):
    - ✧ The uploading of observation plans (OP/OG, observation tables) is performed in the evening passes, whereas the morning passes are basically used for data downlinks only.
    - ✧ One operation team works for the morning passes and another team for the evening passes. From the Solar-B project side, one person participates in the morning operations and two persons including at least one scientist or graduate student in the evening operations.
  - ➢ Real-time TOHBANs checks the status of the satellite and instruments in real time at AOS (acquisition of signal) and LOS (loss of signal).
    - ✧ If anomaly is found by the status check, the real-time TOHBAN can issue pre-determined commands to give the instrument a safe condition, by following operation manual.
    - ✧ The recovery operation of the instrument will be scheduled at evening operations, if it is not urgent.

- ◻ A supporter of the Solar-B Chief Planner [Supporter] (0 or 1)
  - ➢ Serves in shifts of one week, if necessary.
  - ➢ Supports the Solar-B chief planner and learns the Solar-B satellite and telescope operations.

In addition to the persons allocated for the daily operations, the following persons will support the daily operations and execute the following tasks. Since these tasks need continuity, a specific person will be assigned for a long period of time.

- ◻ The Ground-Base Contacts Coordinator [GCC] (1)

- Is an ISAS staff member or an engineer from a company.
- Schedules the ground-based contacts (KSC, ESA, and NASA ground stations) using the orbital elements supplied by NASDA.
- Checks the data transfer from the ground stations.
- ~~Calibrates the attitude data and makes the S/C attitude database.~~

□ Scientific Schedule Coordinators [SSC] (6 [TBD])

- Consist of senior scientists designated by each of the instrument PIs, who will reside at their home institutions.
- Coordinate the long-term (monthly) observation schedule and the proposals.
- Will be contact persons for proposal submission. If necessary, they will be also consultants for proposal preparation, and
- Will assign a member of the instrument teams consulted on the proposal.
- Manage the rotation of the chief planners among the instrument teams.

□ Solar-B Database Coordinator and his team [SDC] (1)

- SDC leads the data and analysis portion of the Solar-B project.
- SDC manages his team at ISAS/JAXA, which includes computer system administrator and some engineers for maintaining databases and checking the process of Level-0 reformatter.
- SDC and his team will take the following tasks:
  - □ To create and maintain the Solar-B database system
  - □ To maintain the data archive and analysis system of Solar-B at ISAS
  - □ To administrate the SOLAR-B computer system at ISAS
  - □ To check the progress of the Level-0 reformat process. Since he checks only whether the reformat process is running without anomalies, each CO shall review the contents (image quality) of the Level-0 files.
  - □ When he finds anomaly on the Level-0 reformatter process, he identifies the source of the anomaly and reports it to the reformatter's maker in instrument team if it is in the reformatter. The reformatter's maker in instrument team shall resolve the problem remotely.
  - □ To oversee the Level-0 file registration process to DARTS system.

During the initial phase of the Solar-B operation (until about 3 months after the Solar-B launch), a special setup of operation could be requested. In addition to the daily operation setup as described above, additional persons (satellite and instrument experts) might have to participate in the daily operations as described below.

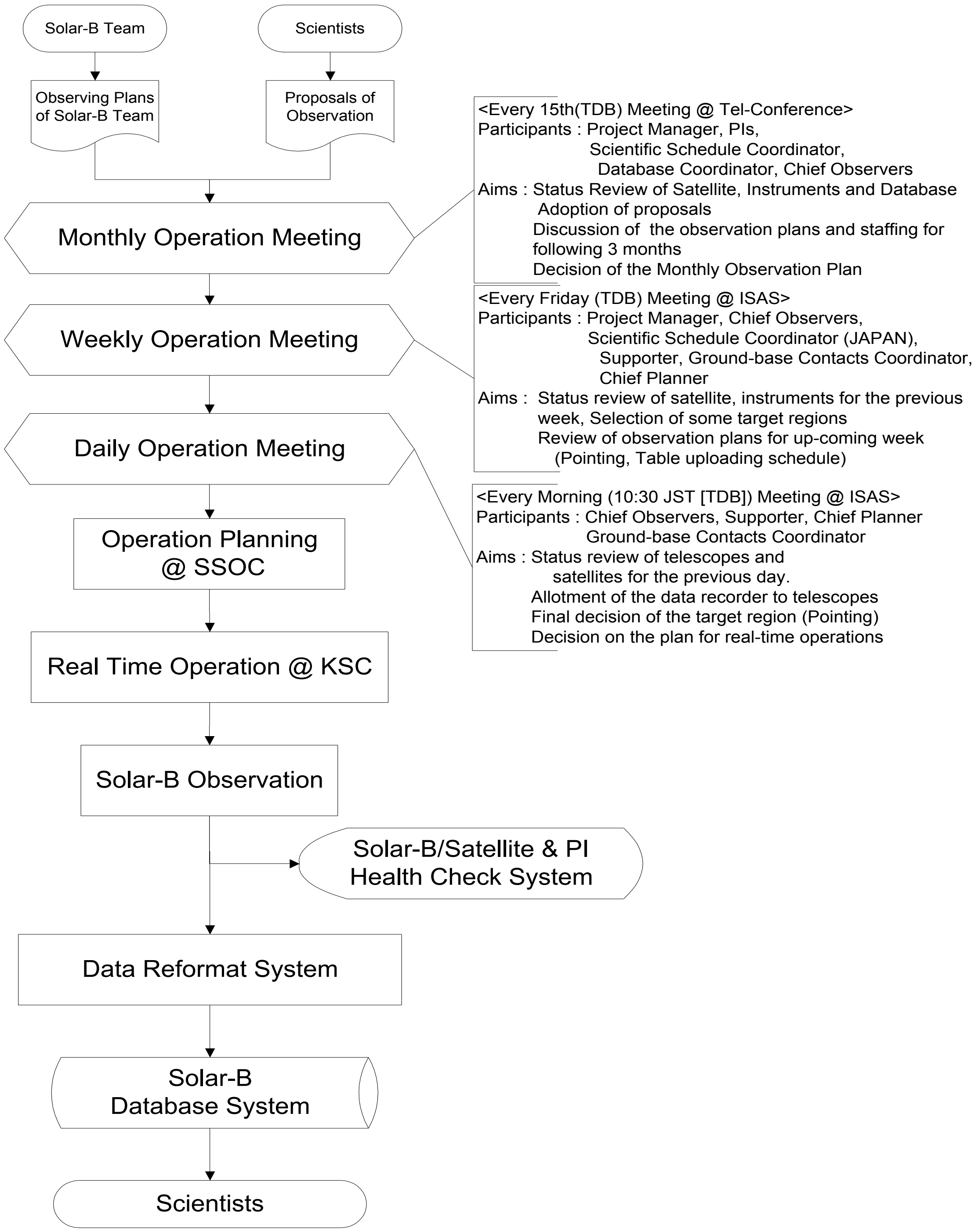
- SOT, XRT, EIS Engineering Advisors (3)
  - Will be assigned at minimum one person for each instrument, and
  - Will be staying at ISAS-SAGAMIHARA/Japan during the initial phase.
  - Will be responsible for power-up and functional checkout of the instrument, as well as:
    - Preparing the command plans for power up and functional checking
    - Monitoring the instrument status during real-time operations
    - Functional checkout and calibration of the instrument, and establishing standard procedures for instrument calibrations.

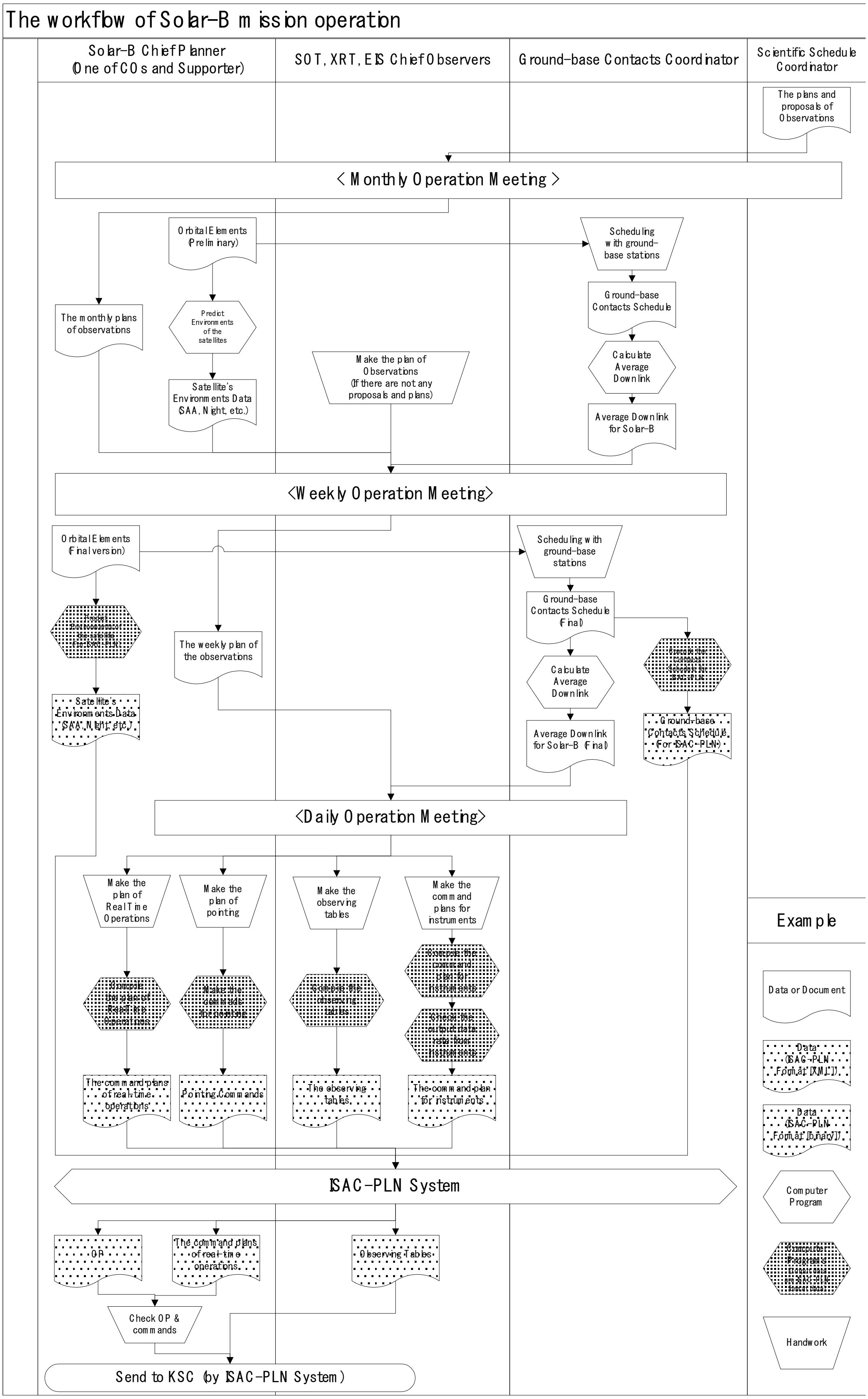
- SOT, XRT, EIS Software coordinators (3)
  - Will set up the system and environment for data archives and data analysis:
    - Installing and checking the instrument-specific database software
    - Making and installing the data analysis software

Throughout the mission, specialized engineering support for satellite operations will occasionally be needed to handle such things as orbital maneuvers and momentum management, thermal and power engineering during eclipse season, lunar occultions, safehold recoveries, and other spacecraft contingency responses. ISAS/JAXA and spacecraft contractors will be responsible for these activities.

2.1.2. The flowchart of the Solar-B operation

The Flowchart of Solar-B Operation




The workflow of Solar-B mission operation
Solar-B Chief Planner (One of COs and Supporter)
SOT, XRT, EIS Chief Observers
Ground-base Contacts Coordinator
Scientific Schedule Coordinator
The plans and proposals of Observations
< Monthly Operation Meeting >
Orbital Elements (Preliminary)
Scheduling with ground-base stations
Ground-base Contacts Schedule
The monthly plans of observations
Predict Environments of the satellites
Calculate Average Downlink
Make the plan of Observations (If there are not any proposals and plans)
Satellite's Environments Data (SAA, Night, etc.)
Average Downlink for Solar-B
<Weekly Operation Meeting>
Orbital Elements (Final version)
Scheduling with ground-base stations
Ground-base Contacts Schedule (Final)
The weekly plan of the observations
Calculate Average Downlink
Satellite's Environments Data (SAA, Night, etc.)
Average Downlink for Solar-B (Final)
Ground-base Contacts Schedule (For ISAC-PLN)
<Daily Operation Meeting>
Make the plan of Real Time Operations
Make the plan of pointing
Make the observing tables
Make the command plans for instruments
Example
Data or Document
The command plans of real-time operations
Pointing Commands
The observing tables
The command plan for instruments
Data (ISAC-PLN Format [XML])
Data (ISAC-PLN Format [binary])
ISAC-PLN System
Computer Program
OP
The command plans of real-time operations
Observing Tables
Check OP & commands
Handwork
Send to KSC (by ISAC-PLN System)

[The nominal time-line of SOLAR-B Daily Operation]

Time (JST)	Tasks for Day 1	Tasks for Day 2
Day 1		
10:30	**< Dead line of the observation tables and commanding plan for instruments of Day 1>**	
10:30	**<Daily Meeting>** •Review statuses of the satellite and instruments of the previous day of Day 1.	• CP provide DR usage planning information of Day 2 to the COs. • Confirm the observation plans, the allocation of DR, and the pointing schedule of Day 2
11:00	•The CP checks whether the observations planned by the COs will not cause overflows in DR. • The CP generates the sequence of commands for downlinks. •The CP complies all the received commands and tables and generates the real-time commanding plan for USC contacts and OP/OG plan of Day1. •The CP reviews the generated OP/OG and real-time commanding plan with graphical time-chart of major commands (pointing, downlink, eclipse, etc).	• COs start to create the observation tables and commanding plans for Day 2 •The CP operates AOCS-team provided software and makes commands for routine pointing to change the targets of interest. •The CP performs routine works with AOCS-team provided software to prepare satellite commands needed for nominal science observing, including updating of orbital elements and parameters for AOCS-related timers and so on.
15:00	• CP and Real-Time TOHBAN (Evening team) open the small meeting and discuss the operation of Day 1.	
15:30	• Rea-time TOHBAN (Evening team) start to prepare for the evening real-time operation.	
17:??	<Evening Passes at KSC> (2 or 1 passes) • Real-Time TOHBAN upload new OP and OG at first pass of Day 1. • Real-Time TOHBAN also upload the observing tables of Day 1. • Real-Time TOHBAN check the status of satellites and instruments, simply.	
Day 2		
05:??	<Morning Passes at KSC> (2 or 1 passes) • The morning passes are basically used for data downlinks, only. (They do not upload OP, OG and tables.) • If anomaly is found by the status check, the real-time TOHBAN can issue pre-determined commands to give the instrument a safe condition, by following operation manual.	
09:00	• CO and CP check the status of the instruments and the satellite using the data that are downlinked in the morning passes at USC.	
10:30		**< Dead line of the observation tables and commanding plan for instruments of Day 2>**

- Monthly Meeting [Tele-conference]
  - Participants: Project Manager, Principal Investigators, Science Scheduling Coordinators, Chief Observers, Database Coordinator

- Review status of the satellite, instruments and database
- Review of the proposals that have been received during the month
- Adoption of proposals
- Discussion of the observation plans and staffing for the following 3 months
- Coordinate staffing for the following (2nd) month
- Decisions on the next monthly plan.
- Prioritize the observations of the next month, and make the priority list of the observations.

● Weekly Meeting [@ISAS every Friday after the daily meeting]

- Participants: Project Manager, Chief Observers, Chief Planner, Supporter, Ground-base Contacts Coordinator, Science Scheduling Coordinator (at least one)
    - Remote participants by telecon
- Review of the satellite and instruments status in the next week, starting Monday
- Review of the schedule of ground-base contacts for the next week
- Review and decisions on the schedule of observation plans for next week (nearly final)
- Selection of some target regions and decisions on the pointing maneuver schedule of next week (nearly final)
- Allocation of the data recorder (DR) for each instrument (nearly final)

● Daily Meeting [@ISAS every weekday (Monday - Saturday) morning]

- Participants: Chief Planner, Supporter, Chief Observers, Ground-base Contacts

  Coordinator
    - Remote participants by telecon
- Confirm the target regions
- Confirm the allocation of the DR
- Confirm the pointing and the schedule of pointing maneuvers.
- Confirm the operation plans of the next-day real-time operations.
- If there are some changes in the schedule of the ground-base contacts, reallocate the data recorder for each instrument.

- The deadline for input to the next day's operation plan (commands, observation tables, etc.) to the Solar-B Chief Planner is 10:30 JST each day.

- The entire Solar-B operation plan for the next day, including the command plans during KSC real-time operations, the OP/OG, and the observation tables, is completed and sent to KSC for approval by the evening. The real-time TOHBANs make the final check of the operation plan in the evening. As a goal for operations after the initial phase, the plan might be uplinked during evening USC passes, to reduce the time delay between preparation and execution of the plan, to be more responsive to changing solar conditions.

- In nominal operations, the plans are approved on a daily basis. However, in case an urgent operation change is requested as the result of checking the data downlinked during the morning passes, the planners should make the revised plan for the evening real-time operations as soon as possible.

Scientists resident at ISAS from US and UK

For the first year of operations, the EIS team expects to provide three scientists at ISAS. NRL and MSSL will each provide one scientist who will reside in Japan. In addition, EIS team members from the UK, Norway, and the US will rotate to ISAS for roughly three weeks at a time to provide a third person to participate in EIS operations and data analysis. When foreign visitors are not available, Japanese EIS scientists will provide the additional manpower to keep the staffing at the desired level. Staffing at the 3 person-year/year level will make it possible for each person to participate effectively in both operations and data analysis.

The US FPP team intends to provide one scientist who will reside in Japan full-time (apart from occasional visits back to the US). This person will divide his/her time between mission operations and science data analysis approximately equally. In addition, the FPP team will always have one scientist visiting Japan on a rotating basis in shifts of approximately 2 weeks. During the first year, there will usually be a second scientist visiting Japan for operational training purposes. US FPP scientists will also visit Japan for purely scientific collaborations apart from mission operations, for periods of a few weeks to a few months at a time.

The US XRT team intends to provide the following persons in Japan to support Solar-B science operations during the first year of operations:

- Full time resident

An SAO scientist will be resident in Japan for the first year of operations. We will rotate this person back to SAO for 1 month periods every 3 months. The US XRT team will provide a scientist to cover each month that the resident scientist is away from Japan.

- Half time resident

The US XRT team will rotate scientists through Japan for periods of 3 week (or longer). The combined coverage of these scientists will be for 1/2 year during the first year of operations.

In the initial phase of the solar-B operation, additional scientists and/or engineers from each instrument team need to be available at ISAS for commissioning and contingency operations.

Software required for daily operations

In order to reduce the burden of operations and increase the time for scientific planning, all software for the operation is expected to provide simple, automated and user friendly tools for local and remote operation planning. In the following sections, we describe the software for the operation of the satellite and instruments.

2.1.3. ISACS-PLN

(TBS)

2.1.4. Software for the operation of Solar-B

Responsible parties for software development are indicated in the parentheses.

- □ Prediction of the satellite environments

  This software predicts the timing of ground station contacts, SAA, HLZ, and night periods of the satellite, calculating from the orbital elements. The software produces the graphical time chart and the list of events. These are very useful not only for planning of observations but also for troubleshooting of the spacecraft. In ISAS, the software is called "AOSLOS/DP-10".

- Japan team takes responsibility for the developments.
- USER : Chief Planner
- INPUT : Orbital Elements
- OUTPUT : SoE (SAA, HLZ, Night, Eclipse, etc.)

□ Estimating the downlink data size

After coordinating with the ground stations by Ground-base Contacts Coordinator, the information on the station contacts of Solar-B is provided with this software. The software estimates the volume of downlink data using the contacts schedule. The estimated data size is used for coordinating the usage of the data recorder (DR).

- Japan team takes responsibility for the developments.
- USER : Chief Planner
- INPUT : Orbital Elements
- OUTPUT : List of Ground-base Contacts
  SoE (Ground-base Contacts Schedule)
  List of the Average Downlink Rate

~~□ Support tools for creating OP, OG and the real-time commanding plans~~

~~In the Solar-B project, the ISAC-PLN software package is available for the management of the command plans, OP, OG, and the observing tables. The package can also create OP and the real-time operation plans based on the list of events, such as station contacts, SAA and satellite nights. The support software creates the event lists from the AOSLOS data and the plan of observations, and therefore, it has an interface to ISAC-PLN.~~

- ~~Japan team takes responsibility for the developments~~
- ~~USER : Chief Planner~~
- ~~INPUT : Observation Plans~~
- ~~OUTPUT : SoE and Macros for Special Operations~~

□ Supporting tool for checking OP and the real-time commanding plans

ISAC-PLN creates OP and the real-time command plans input from Chief Planner and Chief Observers. The software makes the graphical time-line charts, taking

OP, the real-time operation plans and the prediction of the data output rate from each instrument into account. The time-line also indicates the stored data volume of the data recorder.

- Japan team takes responsibility for the development
- USER : Chief Planner
- INPUT : OP (or SoE/Macros)
- OUTPUT : Graphical Time-chart of Operations

□ Making commands required for the satellite pointing

The chief observers for all 3 instruments can request the change of spacecraft pointing. The satellite, therefore, may be able to change the pointing several times a day. Since the parameters for commanding spacecraft maneuvers are complicated, and miss-commanding may lead to serious consequences, the software should calculate the parameters for S/C maneuvers from the solar coordinates of the target regions as inputs.

- Japan team and the contractor for AOCS (Attitude Orbital Control System) take responsibility for development
- USER : Chief Planner
- INPUT : Observation Plans
- OUTPUT : SoE and Macros for the pointing
  List of the pointing parameters

□ Checking the usage of DR and Making the commands for the limitation of telemetry

After making the commands and the observation tables by COs, CP checks the usage of DR based on the data output rates from all instruments and makes the MDP commands for the limitation of telemetry. The software supports the check and makes the commands for the limitation of telemetry.

- Japan team takes responsibility for the developments.
- USER : Chief Planner
- INPUT : List of Ground-base Contacts
  The data output rates calculated by COs.
- OUTPUT : SoE and/or Macros for the limitation of telemetry
  Graphical chart of the data size stored in DR

□ Health check reformat software

For the health check and monitoring system, the raw-telemetry data must be reformatted from CCSDS format to the IDL-readable format. The prototype of this reformatter software has already been developed during integration and test.

- Japan team take responsibility for the development
- USER : REAL-TIME TOHBAN, Chief Observer, etc.
- INPUT : raw-telemetry data (from SIRIUS)
- OUTPUT : Health Check data

□ Health check and monitoring system for the Satellite

During the real-time operations at USC, the REAL-TIME TOHBAN checks the health of Solar-B using the health check and monitoring systems. The system is used for checking the fundamental status of Solar-B, for example, battery voltages, temperatures, etc. The company that develops the telemetry system provides the software.

- Japan team and S/C contractor (MELCO) take responsibility for the developments
- USER : REAL-TIME TOHBAN
- INPUT : raw-telemetry data

2.1.5. Software for the operation of the instruments

Chief observers need tools for planning observations of the instruments. The tools assist chief observers in planning the command sequences and observing tables, which extract scientific returns as much as possible from the observations. Software must be available to choose instrument setup parameters and to simulate the observation. The user interface software must operate consistently from both ISAS and remote locations. A validation process will be in place to ensure that observation plans do not violate health and safety constraints of the instruments.

□ Solar-B planning and operations database

Observation plans used in the planned and/or performed observations must be archived by name, identification number or scientific objective, for ease of rerunning and/or modifying. Each instrument team will design and develop its own database.

- Instrument teams take responsibility for the databases
- USER : Chief Observer

- INPUT : Observation Plan
- OUTPUT : Database tables

□ Software for creating the observing tables

Chief Observers make the observing tables for each instrument based on the observation plans. This software creates the command sequence of the observing tables based on the observing plan of the chief observer. The software has interfaces with ISAC-PLN, and refers the database of Solar-B operation and observation, as well as with instrument-specific databases and/or software. The software also has an interface with the Solar-B database for collecting the ID, name and comments of the observing tables.

- Instrument teams take responsibility for the tool
- USER : Chief Observer
- INPUT : Observation Plan
- OUTPUT : Observing Table and Solar-B database

□ Instrument timeline command software

When an instrument needs to command the MDP (e.g., to stop the observation when the satellite changes the pointing), the command plans may include many real-time commands, coordinated with satellite activities such as pointing changes or telemetry downlinks. Hence, this software needs to refer the Chief Planner's command plans and the event lists. The software also has an interface with ISAC-PLN.

- Instrument teams take responsibility for the tool
- USER : Chief Observer
- INPUT : Observation Plan
- OUTPUT : SoE and/or Macros for Instrument Operation, Solar-B database

□ Observation simulation software for estimating the output data rate and size

This software simulates the observations from the observing tables and the instrument command timeline and estimates the data output between the ground-station contacts. The Chief Observer checks that the estimated data size does not exceed the allocated size of DR for the instrument.

- Instrument teams take responsibility for the tool
- USER : Chief Observer
- INPUT : Observing Table

- OUTPUT : Displays of data output rate and the ASCII text file

□ Health check and monitoring system for the instruments

During the real-time operations at USC, the REAL-TIME TOHBANs check the health of the instruments using this system. The system displays the status of the instruments and real-time images. The data distribution system at USC is as same as that at ISAS/SAGAMIHARA, which was used during the Proto-Model test, and will be during the Flight-Model test. We will use the same software developed in the PM and FM tests, and in the real-time operations at USC with minor revisions.

- Instruments team take responsibility for the tool
- USER : REAL-TIME TOHBANs, Chief Observer
- INPUT : Health Check data
- OUTPUT :real time display

□ Health and status monitoring for the instruments

The health and status of each instrument is also monitored frequently (though not in real time) by team members at ISAS, their home institutions or other remote sites. For this purpose, web displays of status information are automatically made from the reformatted status information. Sample images from the mission science data may also included in these displays as they become available.

- Instruments team take responsibility for the tool
- USER : Chief Observer, Instrument teams
- INPUT : Instrument Status data
- OUTPUT :web-based status reports

2.1.6. Special software for the instruments

□ Making MDP/SOT Doppler parameters

Since the wavelength setups of the spectropolarimeter and the narrowband tunable filter of SOT are affected by the orbital motion of the satellite. MDP accomMO&DAtes an on board software to calculate the Doppler velocity based on the spacecraft orbital elements uplinked in a regular time interval.

- SOT team take responsibility for the tool
- USER : Chief Observer of SOT
- INPUT : Observation Plan, Orbital Elements, etc.
- OUTPUT : Memory images of upload parameters

2.1.7. The summary table of the Solar-B operation tools

Tools	Maker	User	Input	Output
Prediction of satellite environments	ISAS	CP	Orb. Elem.	SoE
Estimating the downlink data size	ISAS	GCC	Orb. Elem.	SoE List
~~Support tool for creating OP/OG and real-time commanding plan~~	~~ISAS~~	~~CP~~	~~Obs. plan~~	~~SoE~~ ~~Macro~~
Support tool for checking OP and the real-time commanding plan	ISAS	CP RT	SoE OP	Graphical Time-chart
Making commands required for the satellite pointing	ISAS AOCS	CP	Obs. plan	SoE Macro
Checking DR and Making the TLM_LMT commands	ISAS	CP	data rates files	SoE/Macro Time-chart
Reformatter for Health Check Data (CCSDS > IDL-readable format)	ISAS	CO KSC	Raw-telem.	Health Check data
Health check system for spacecraft system	ISAS MELCO	KSC CP	Raw-telem.	(Display to monitor)
Creating the observation table	PI	CO	Obs. plan	Obs. table
Support tool for commanding plan for the instrument	PI	CO	Obs. plan	SoE Macro
Estimate the output data size from the prepared observing table	PI	CO	Obs. table	Time-chart ASCII file
Real time health check system for the instrument	PI	CO KSC	Health Check data	Display to monitor
Status Web Pages for remote checking	PI	Inst. Team	Status Data	Web Pages
Making SOT/MDP Doppler parameters	SOT	CO	Orb. Elem. Obs. plan	Parameter

3. Scheduling and Submission of Observation Plans and Data Policy

3.1. Principles of observation plans and data policy

- The Solar-B team recognizes the importance of rapid dissemination of the observatory's data sets to the worldwide solar physics community for both the success of the Solar-B mission and the benefit of solar physics. To this end, the Solar-B team will make all of its data available without restriction within six months from the date of observation. Scientists collaborating with the Solar-B team and Guest Investigators have unrestricted access to the data.

i. Solar-B will be operated according to a pre-determined plan during the initial phase of approximately the first 3 months of solar observations after commissioning. Each of the initial phase observation plans shall be reviewed and prioritized by the Solar-B SWG.

ii. Observations starting after the initial phase will consist of the PI baseline science programs and proposed observations from the wider community.

iii. Proposed observations will be submitted to the scientific scheduling coordinators (see 2.2.1).

iv. Data-use policy shall give a high priority to graduate students pursuing PhD research. Users accessing the data catalog or search engine shall be required to acknowledge a list of active PhD topics. Thesis advisors are responsible for ensuring that their students' PhD theses are represented on the list, and that these thesis topics are not unreasonably broad or extended. The list of PhD topics will be available from the homepage of Solar-B. Disputes or conflicts will be addressed by the SSCs.

3.2. Baseline programs and proposed observations

Observations after the initial phase will consist of baseline program and proposed observations that fall outside of the baseline. The baseline programs will be standard observations performed by the Solar-B team through its mission life. Baseline programs are designed to address the fundamental science goals of the Solar-B mission. Proposed observations will be executed based on the proposals submitted to the scientific scheduling coordinators. Joint observations with other satellites and ground-based observatories are encouraged.

3.2.1. Proposal requirements

- All proposals shall be in English.
- In order to receive proposals from scientists and students inside and outside the Solar-B team, the Scientific Schedule Coordinators will be assigned as contact points and also as consultants for the proposals.
- Proposals will not be treated as confidential information, since they may be discussed bby the entire Solar-B team.
- Proposals will be discussed at monthly operation meetings. Hence, a standard deadline for submission will be set before the monthly operation meeting in which the particular operation will be discussed for the first time, typically 3 months before the observations will take place.
- The Solar-B team will provide documents and software helpful for preparing proposals (for example, those of predicting the photon counts and of simulating observations).

3.2.2. Role of Scientific Schedule Coordinators

- The SSCs are the contact points and consultants for preparation of observation proposals. Using the received proposals and the baseline programs, they prepare a draft monthly schedule of observations presented in the Solar-B monthly operation meeting.
- Each instrument team shall have SSCs, one appointed by each PI, to whom proposals should be sent.
- SSCs will be authorized to select or reject proposal observations, and to draft the monthly observation schedules. Proposals may be rejected if, for example, the same observation plans are already proposed, the essential parts of the proposed plans overlap with a PhD thesis in progress, the science is not compelling, or the proposed observations exceed instrument capabilities or violate health and safety constraints..

- Every month the SSCs will designate targets of opportunity (if any) and set priorities for their observation.

3.2.3. Responses to solar activity and coordination with ground-based observatories

- Target of Opportunity campaigns can be inserted in the monthly planning.
- Proposals for these campaigns should be sent to Science Schedule Coordinators.
- Chief Observers and the Chief Planner choose the target in the daily meeting based on the priority list of observations [see 2.2.2]. They have the discretion to choose targets of opportunity, when they are included in the monthly plan.

4. Archiving, Distribution and Analysis of Solar-B Data

4.1. Fundamental views on Solar-B Data processing system

A) The Solar-B telemetry data processing system uses the ISAS satellite database system: the SIRIUS database for raw telemetry and the SDTP protocol for obtaining raw telemetry data.
B) The master archive of Solar-B data will be the DARTS system provided by ISAS.
C) Existing analysis tools, such as the SSW or SolarSoft package, will be also usable for Solar-B data analysis.
D) For health checks of the instruments, the health check system developed for ground integration and test will be used.
E) To ensure efficient data accessibility not only among the Solar-B science teams but also in the wider solar community, the Solar-B data providing system shall be designed to be compatible, if possible, with the Virtual Solar Observatory (VSO), European Grid for Solar Observations (EGSO),UK AstroGrid, CoSEC, or their successors.

4.2. Classification of Solar-B processed data

The Solar-B data are classified into the following categories based on the processing levels.

- Raw telemetry data
- Health check data
- Status data
- Level-0 data
- Calibration data
- Level-1 data
- Level-2 data
- Level-Q data

In addition to these levels of data, we will need

- Observing logs and data catalogues for archiving

In this section, we explain these data levels.

- □ **Raw telemetry data**
  - ➢ They are the data received at KSC and the other ground-based stations. The format is "CCSDS packet" format.
  - ➢ All raw telemetry data of Solar-B are archived on the "SIRIUS" database, the ISAS satellites database at the ISAS/SAGAMIHARA campus. ISAS maintain all the data of the ISAS satellites via this database on line.
  - ➢ The "SDTP" protocol (ISAS original protocol) is used to retrieve the data from the SIRIUS database.

- □ **Health check data**
  - ➢ The data will be reformatted from raw telemetry to IDL-readable. The data include not only observational data but also status data of the instruments.
  - ➢ These data are mainly used for the health check and monitoring systems of the instruments. They are also used for planning the next day's observations.
  - ➢ The data are decompressed, in case necessary, during the reformatting process.
  - ➢ One file per instrument is created for each downlink (real-time passes only)

  The health check data will be created temporarily and not stored in an archive.

- **Instrument status data**

Status data for each instrument will be retrieved from the SIRIUS database and reformatted from the raw telemetry into a file format chosen by each instrument. These status files will be permanently archived at ISAS along with the mission science data.

- □ **Level-0 data**
  - ➢ Reformatted raw telemetry data file.
  - ➢ The data format of Level-0 is FITS with binary table extension. The format of Level-0 data has two types.

    A. Standard FITS format (see Figure FITS-1)
    The uncompressed image data are written as standard, multi-image FITS files. The header information for each image are put the binary table after the primary HDU. The unit of the file is one observable as defined by each instrument. This is a single image for XRT. For SOT it

consists of all raw images obtained for a specific SOT data product; a single filter image, or a set of images obtained to create a single Doppler or magnetogram. SOT and XRT will use the format for Level-0 data.

B. SOHO/CDS like format (see Figure FITS-2)

The uncompressed data are put the binary table and there are no image data in primary HDU of FITS. The header information for each wavelength are put the header of the binary table. The unit of the file is one raster. EIS will be use the format for Level-0 data.

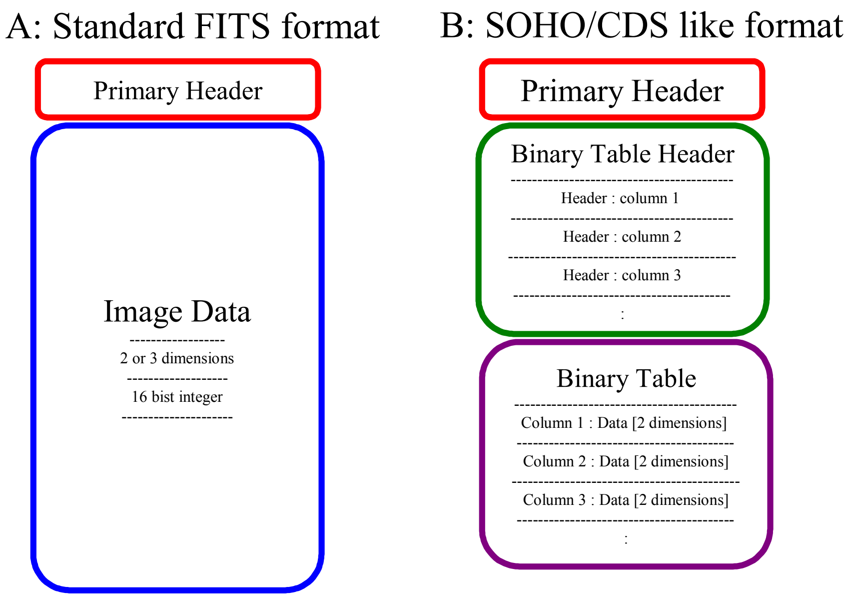


Figure FITS-1 Figure FITS-2

- The header is constructed from the telemetry data (e.g. observing time, exposure time, pixel size, coordinates on the CCD, etc.) and the Solar-B operation database (Table ID, Table name, Comments from Chief Observer, etc.).
- The Level-0 data may be recompressed using standard lossless compression schemes (e.g. gzip) to save the data storage volume and network bandwidth.
- Level-0 data are not calibrated.
- Raw data used for calibration (e.g., dark images), will be included in Level-0 data, when appropriate.
- Level-0 data are provided by the Solar-B data-providing system.

- **Calibration data**
  - Calibration data are made from Level-0 data, pointing data of Solar-B, pre-launch test data, appropriate spectrum synthesis models, etc.
  - The data are used to derive photon intensity, spectral line wavelength, etc., and for attitude determination.
  - The format of calibration data is the same as that of Level-0.
  - Calibration data are also provided by the Solar-B data-providing system.
  - When calibration data are revised, the instrument team should announce the revision using the homepage of Solar-B, e-mail, etc.

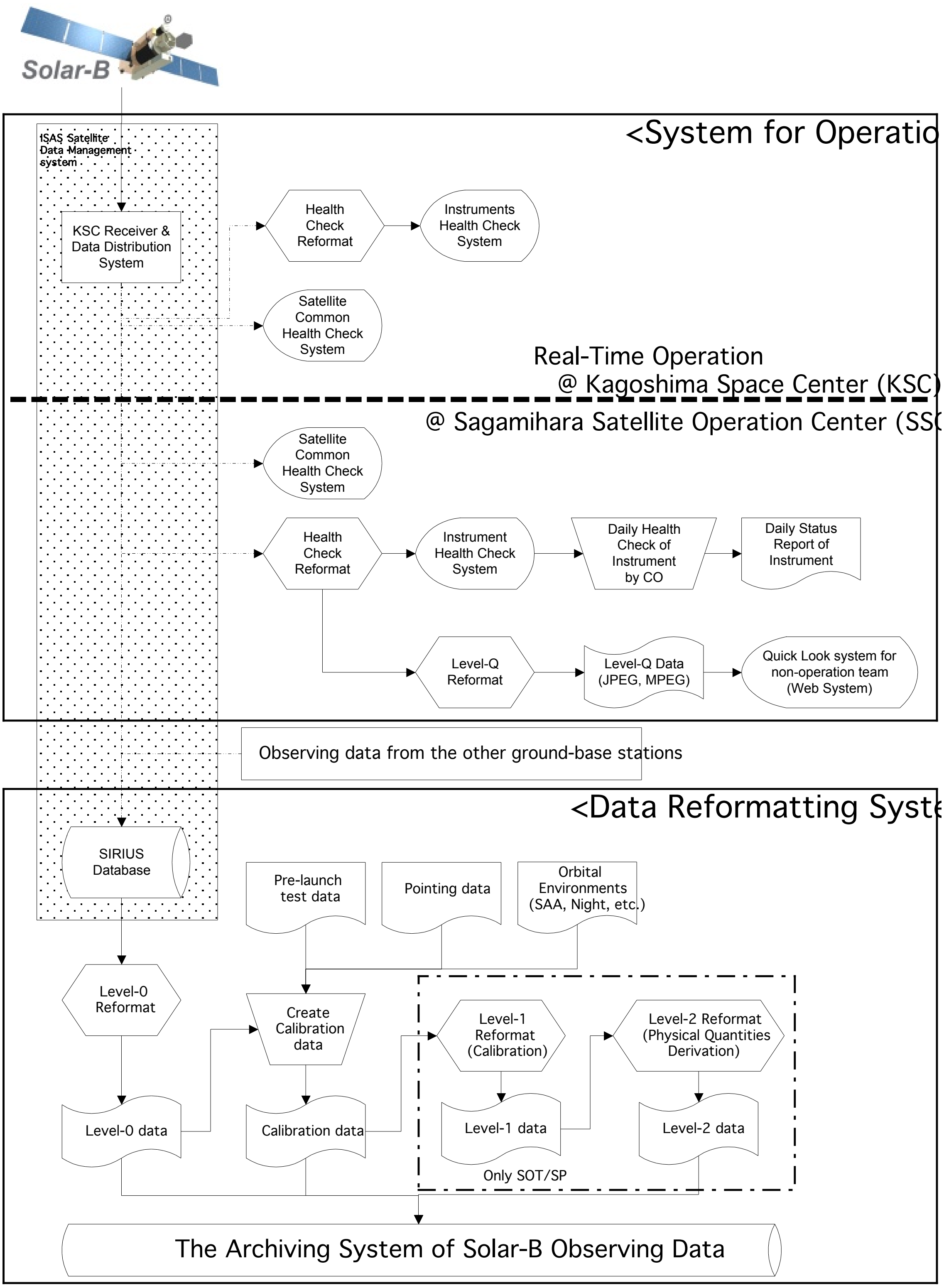
- **Level-1 data**
  - Level-1 data are made from Level-0 and Calibration data using software of the SSW/SOLAR-B package.
  - Level-1 data are fully calibrated and have the headers. The header of Level-1 includes the contents of Level-0 header, the coordinates on the sun, information of the calibration data, etc.
  - The format of level-1 data is standard FITS or the same as the Level-0.
  - Data users will calibrate the Level-0 data and generate Level-1 data by using the software provided by the Solar-B team. The Level-1 data generated by users will not be archived in the Solar-B data providing system.
  - Level-1 data are not provided by the Solar-B data-providing system.

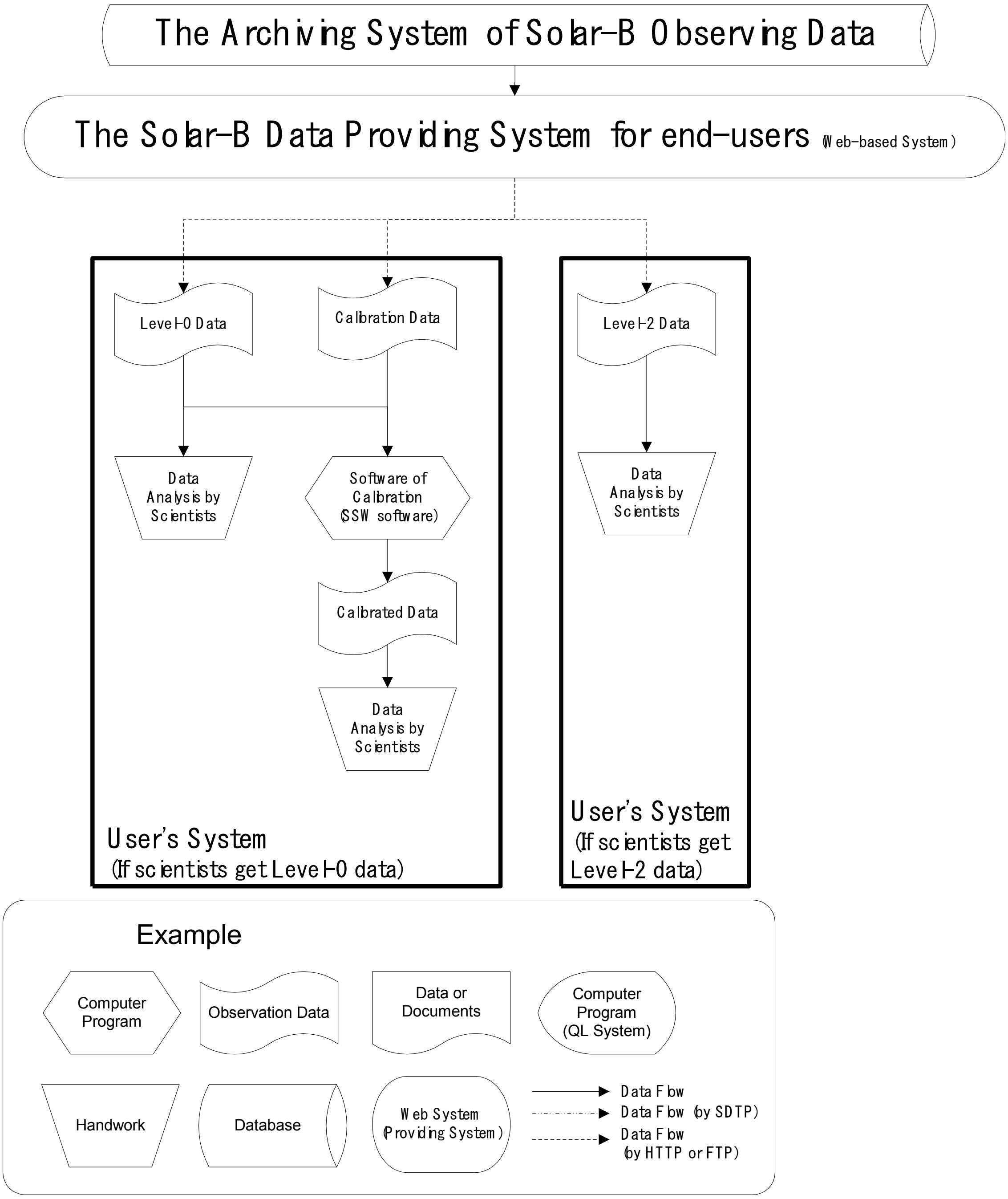
- **Level-2 Data**
  - Level-2 data are made from Level-1 data.
  - One category of Level-2 data is the data in physical units. In the other word the level-2 data consist of files such as longitudinal magnetogram, dopplergram, vector magnetogram, filling factor, B vector, etc.
  - The level-2 data have the headers that include the Level-1 headers and additional information about the derivation.
  - Level-2 data are compressed by loss-less compression methods.
  - Level-2 data that are standard data products made by the instrument teams.
  - Only SOT/SP Level-2 data are provided by the Solar-B data-providing system.
  - Additional Level-2 data volunteered by the team members and submitted to the archive may also be provided in the same way. For example, Combinations of Solar-B level - 1 data sets, mission objectives and external (e.g. GOES) data in

a variety of formats (data bases linked to data archive, html ...).

- **Level-Q data**
  - Level-Q data are made from Health check data or Level-0 data.
  - Level-Q data are made for monitoring the health and status of the instruments and for reporting the status of Solar-B observations to other satellites and ground-based observatories.
  - The data are accessible via the Solar-B homepage after every KSC contact, immediately and automatically.
  - Examples of Level-Q data are
    - ✓ Status data of S/C and the instruments (text and plots)
    - ✓ Snapshot images (and movies) observed with SOT filtergraph.
    - ✓ Magnetograms are made from the SOT filtergrams
    - ✓ Snapshot images (and movies) observed with XRT
    - ✓ Images observed with EIS (using several main lines)
    - ✓ Atlases of spectra observed with EIS.

4.3. The flowchart of the Solar-B data processing





4.4. The Archiving System of Solar-B data

- The master database, containing Level-0, 2[2], Q and Calibration data are constructed in ISAS.
- The Solar-B data archiving system use the resources of the ISAS-DARTS

[2] Only vector magnetograms made from SOT/SP data

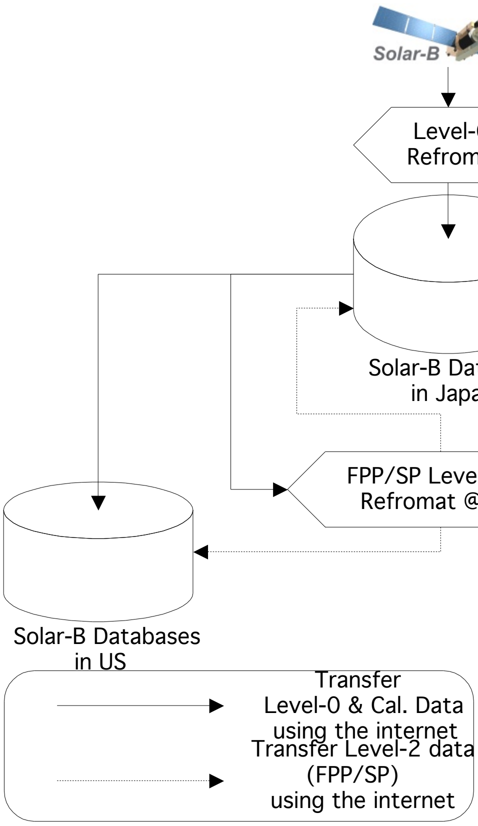
system (http://www.darts.isas.ac.jp/). The purpose of the DARTS system is to archive and distribute space science data obtained via ISAS spacecraft. The DARTS system is accessible everywhere through web browsers.

- The DARTS system provides only hardware (e.g., HD, Server) and some software (e.g., Oracle) for the archiving and providing systems. The mission specific system needs to be provided by the Solar-B team.

4.5. The Solar-B data-providing system for the main Solar-B sites at UK and US

We will make the copies of the Solar-B database at several institutes, for example, NAO in Japan, LMSAL, SAO, NRL, GSFC in US, RAL in UK and UoO in Norway. Level-0 data will be transferred via the internet using lossless compression and multi-stream transfers to achieve an acceptable transmission rate. We estimate a daily volume of approximately 20GB of uncompressed data for SOT and XRT images, thereby requiring a daily transfer of about 10GB/day of compressed files, or an average rate of ~100kB/s. Tests of the link between ISAS and LMSAL consistently display transmissions rates of 100kB/s for single ftp streams, thereby just satisfying the average requirement. Multiple ftp streams increase this rate proportionally and provide sufficient headroom to maintain the Level-0 data flow.

In the Solar-B project, level-1 data will be not archived or provided by the Solar-B providing system since the calibration data could be revised during initial phases. Hence, we transfer only level-0, Q data and Calibration data using the Internet from Japan to US and UK. The vector magnetograms and associated Level-2 data have to be provided by the Solar-B team from their home sites, since the calibration and Stokes parameter inversions are complicated and compute-intensive. These Level-2 data will be provided from LMSAL (the manufacturer of FPP) to Japan, UK and other US sites using the Internet since the size is less than 1/10 of that of original Level-0 spectropolarimeter data.



4.6. The Solar-B data-providing and searching system for end-users

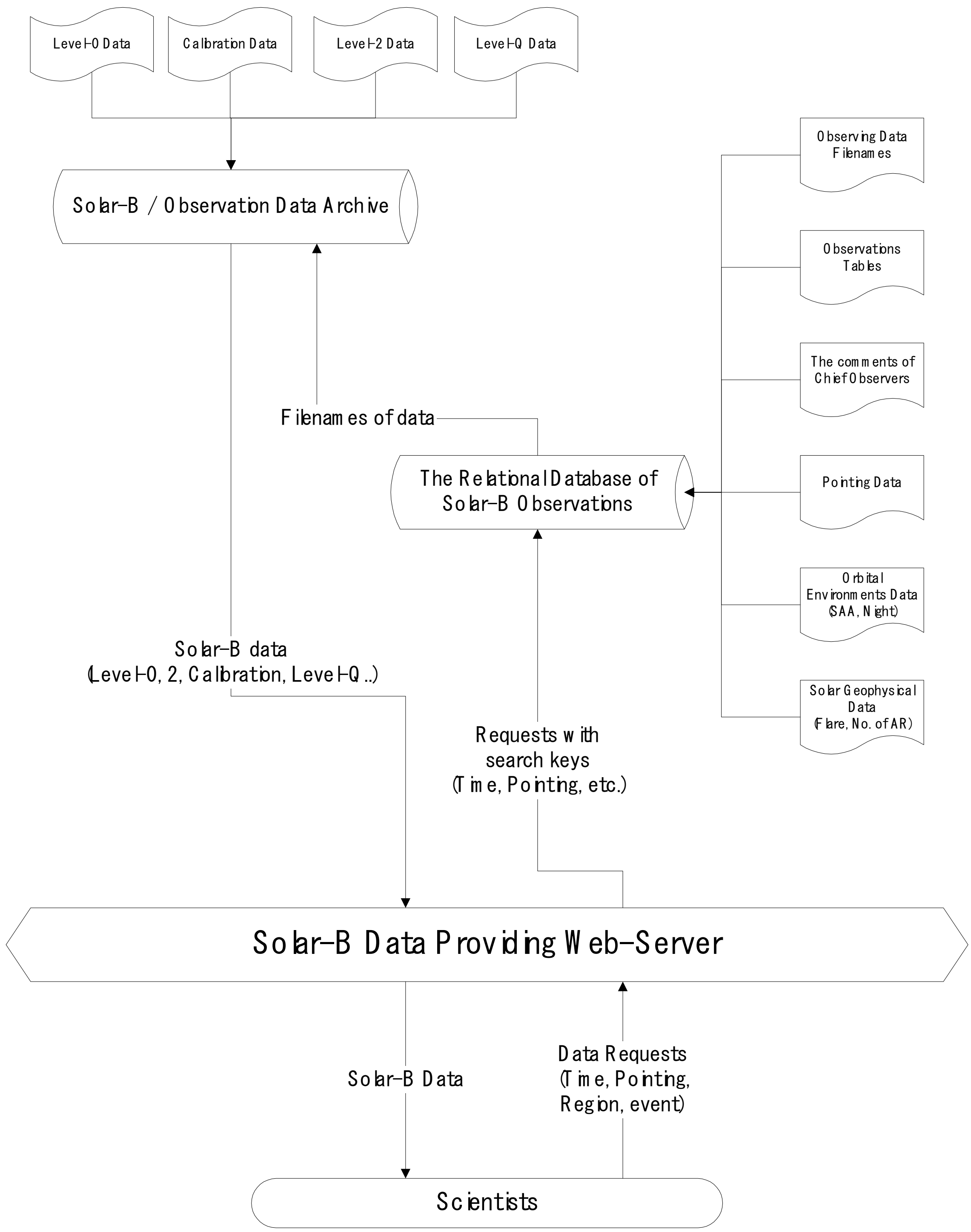
- A data-searching system is required for efficient data analysis. The system uses relational database software (ex. Oracle, PostgresSQL). The following figure is a plan of the Solar-B data-searching and providing system based on the relational database and the web system

  A. Open Item

  If we use the Oracle system, we need a full-time Oracle system administrator at least 1st year or two and a trained Oracle programmer.

- The software must support a GUI interface to the database for end-users. Users must be able to design queries to the database with the results viewable on screen and optionally printable. The user interface should access Level-Q data. [EIS team suggestion: The software support IDL GUI interfaces.]

Solar-B Data Searching and Providing System for end-users (Scientists)



- The data distribution and searching systems of Solar-B are located at several sites including ISAS, USA and UK. The catalogs of Solar-B observations and Level-0 data are mirrored daily.

4.7. Software required for Solar-B data processing

- ISAS will provide first stage of reformatting from raw telemetry to files sorted by instrument and data type.
- Each instrument team will provide secondary reformatters to make Level-0 data products for the science data.
- ISAS will provide secondary reformatters to make Level-0 data products for status data (based on Astro-F software)
- Level-1 reformat software (calibration)
  - Each instrument team provides the software for calibration.
- Level-2 software (derivation of physical quantities)
  - Each instrument team provides the software for derivations.
- Level-Q reformat software (Images and movies for Quick Look)
  - The instrument teams make the software
- Data-providing and searching system
    - Provided by TBD
  - The system is on the web server system and a relational database system.
  - Software packages for management of the relational database are available (e.g., Oracle, mySQL, PostgresSQL, IDL-DB [UIT]).
  - The web interfaces are convenient for users.
  - The search keys are based on the contents of FITS headers.
  - The system will be compatible with the Virtual Solar Observatory and European Grid for Solar Observations
- Data analysis software
    - Common parts of the data analysis software (ex. I/O of Level-0 and 1) are made by the Solar-B software developing team.
    - The SSW package is used for the development of the Solar-B data analysis software.
    - Software that is closely related to the instruments (calibration, inversion, line fitting, etc.) is provided by the instruments teams.
    - Solar-B data analysis software will become part of the SSW package, open to the public.

- The Solar-B team prepares the guidebook for Solar-B data analysis, which is similar to YAG (Yohkoh Analysis Guide).

5. Acronyms

CCD	Charge-Coupled Device
CCSDS	Consultative Comittee for Space Data System
CO	Chief Observer
CoSEC	Collaborative Sun Earth Connector
CP	Chief Planner of Solar-B
CT	Correlation Tracker
DARTS	Data Archive and Transmission System
DB	DataBase
DPCM	Differential Pulse Code Modulation
DR	Data Recorder
DVD	Digital Video Disk
EGSO	European Grid for Solar Observatories
EIS	Extreme Ultraviolet Imaging Spectrometer
EIS_CO	Chief Observer of EIS
ESA	European Space Agency
FITS	Flexible Image Transport System
FM	Flight Model
FPP	Focal Plane Package
GCC	Ground-Base Contact Coordinator
GSFC	Goddard Space Flight Center
GUI	Graphical User Interface
HD	Hard Disk
HDU	Header and Data Unit
HLZ	High Latitude Zone
I/O	Input/Output
IAP	Instrument (Input to the) Activity Plan
IDL	Interactive Data Language
ISAC-PLN	Intelligent Satellite Control Software - Plan
ISAS	Institute of Space and Astronautical Science
JAXA	Japanese Aerospace Exploration Agency
JPEG	Joint Photographic Experts Group
KSC	Kagoshima Space Center (Real-time Operation Center)
LMSAL	Lockheed Martin Solar & Astrophysics Lab
LOS	Loss of Signal
MDP	Mission Data Processor
MELCO	Mitsubishi Electric COrporation
MODA	Mission Operation and Data Analysis
MPEG	Moving Picture Experts Group
MSFC	Marshall Space Flight Center
MSSL	Mullard Space Science Lab
NAO (J)	National Astronomical Observatory (of Japan)
NASA	National Aeronautics and Space Agency