The Solar-B Mission

Tetsuya Watanabe

National Astronomical Observatory, Japan

National Institutes for Natural Sciences

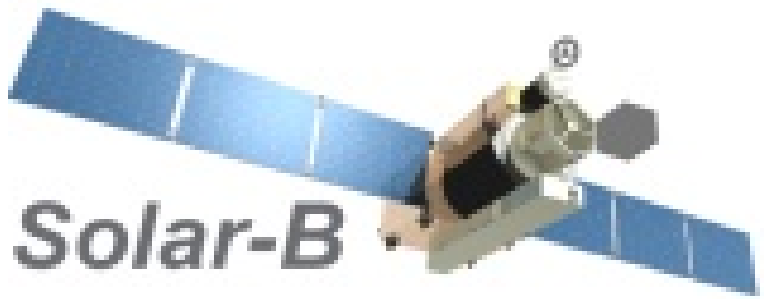
The Solar-B Mission

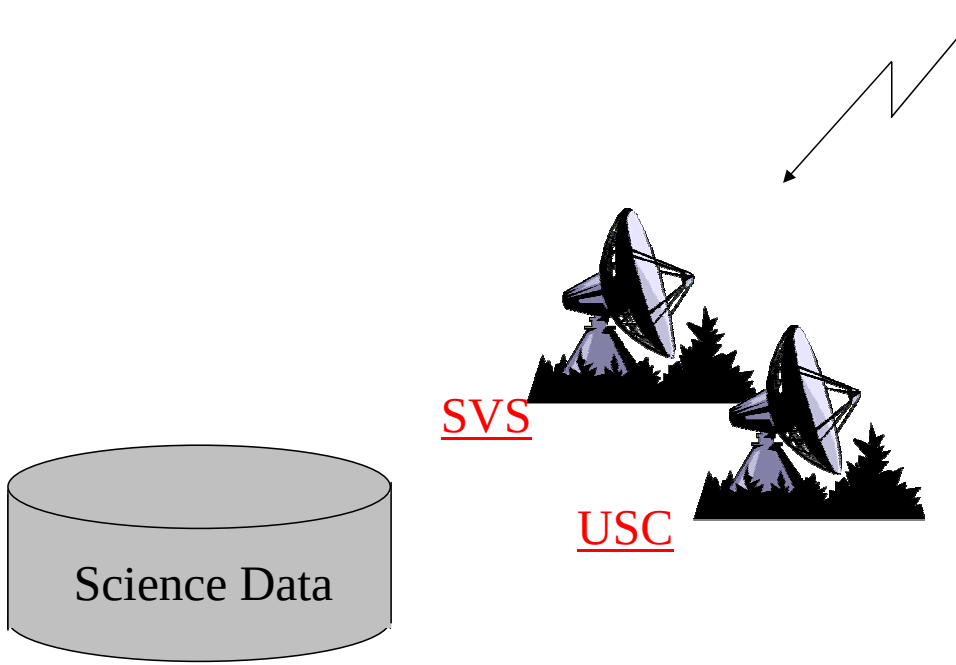
Mission & Scientific Instruments

AOCS （FOVs and Pointing）

MDP-DHU capabilities

(Data Recorder, Data Rates, Flare detection)





Mission Scientific Operation

Operaton planning & operation

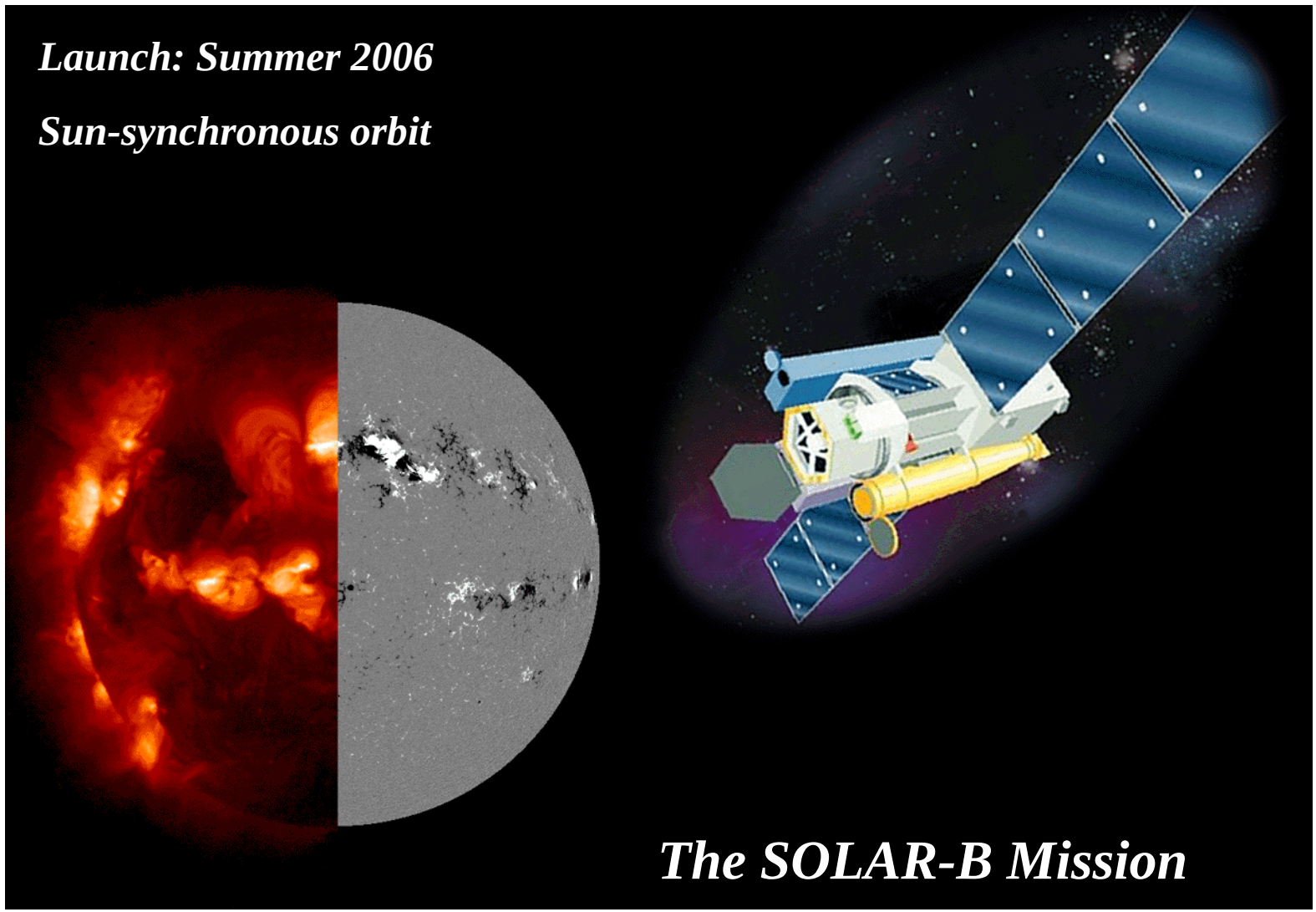
Command Uplink

Data Downlink

Data distribution

Tetsuya Watanabe (NAOJ)

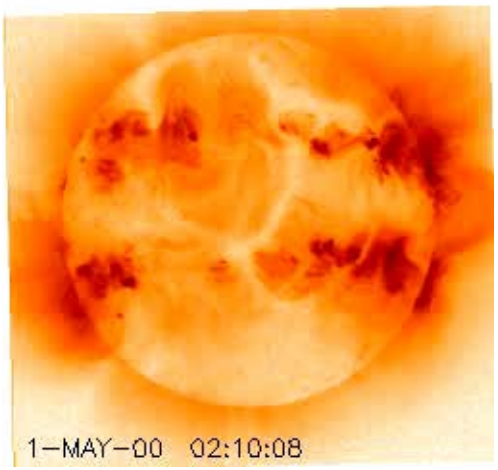
The Solar-B Mission



Tetsuya Watanabe (NAOJ)

The Solar-B Mission

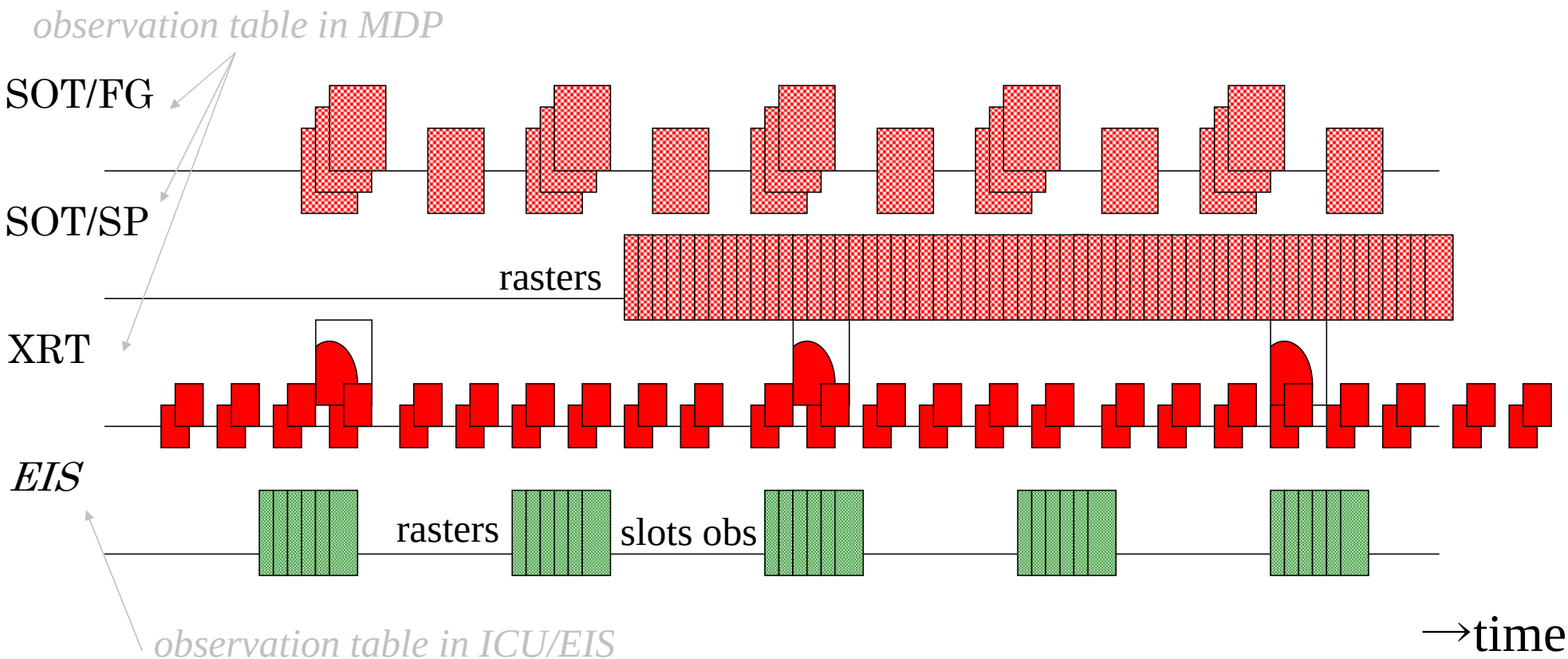
Science Objectives of the *Solar-B* Mission



- **Coronal heating**
  chromospheric heating, spicule,,,
- **Coronal dynamics and structures**
  jets, prominence, CME, solar wind, wave/shock,,,
- **Elementary processes such as reconnection**
  reconnection jet, inflow, slow/fast shocks,,,
- **Emerging flux and dynamo**
  flux tube, sunspot, convection,,,,

The Solar-B Mission

Data control at MDP
SOT & XRT via Observation Table



Tetsuya Watanabe (NAOJ)

The Solar-B Mission

Solar-B instrument specification (=Scientific requirements):

	SOT		EIS	XRT
	FG	SP		
Spatial resolution	0.08/pix	0.16”/pix	1”/pix	1”/pix
FOV	320x160”	0.16x160”	1x512”	2048“^{2}
Spectral resolution	100mA	20mA/pix	22mA/pix	-
# of wavelength	~20	~240	~2000	~10
Time resolution	~10sec	~3sec	~2sec	~2sec
Continuous time coverage	2weeks	“	“	“
Accuracy	16bits	16bits	12bits	12bits
Polarization	I,Q,U,V	I,Q,U,V	-	-
Data amount(bits/2weeks)	1.3×10^{15}	6.3×10^{12}	7.4×10^{12}	3.0×10^{14}

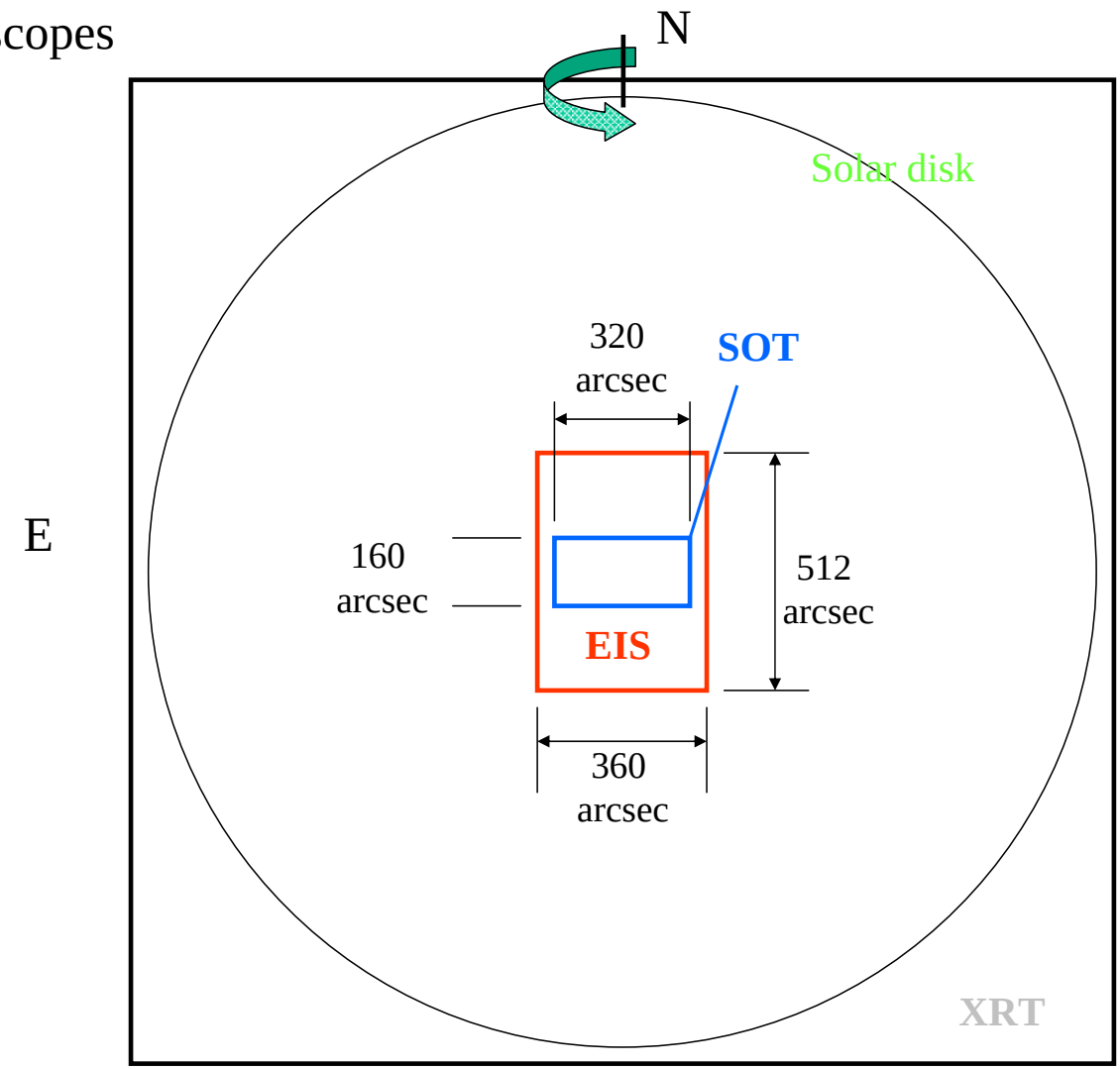
The Solar-B Mission

Field of View and Pixel Sizes of the Mission Instruments

Instrument	FOV	Pixel Size
SOT: Solar Optical Telescope		
NFI: Narrowband Filter Instrument	328”×164”	0.08”
BFI: Broadband Filter Instrument	205”×102"	0.05”
SP: Spectro Polarimeter	328”×164”	0.16”
XRT: X-Ray Telescope	2048”×2048”	1.0”
EIS : EUV Imaging Spectrometer	360”×512”	1.0”

The Solar-B Mission

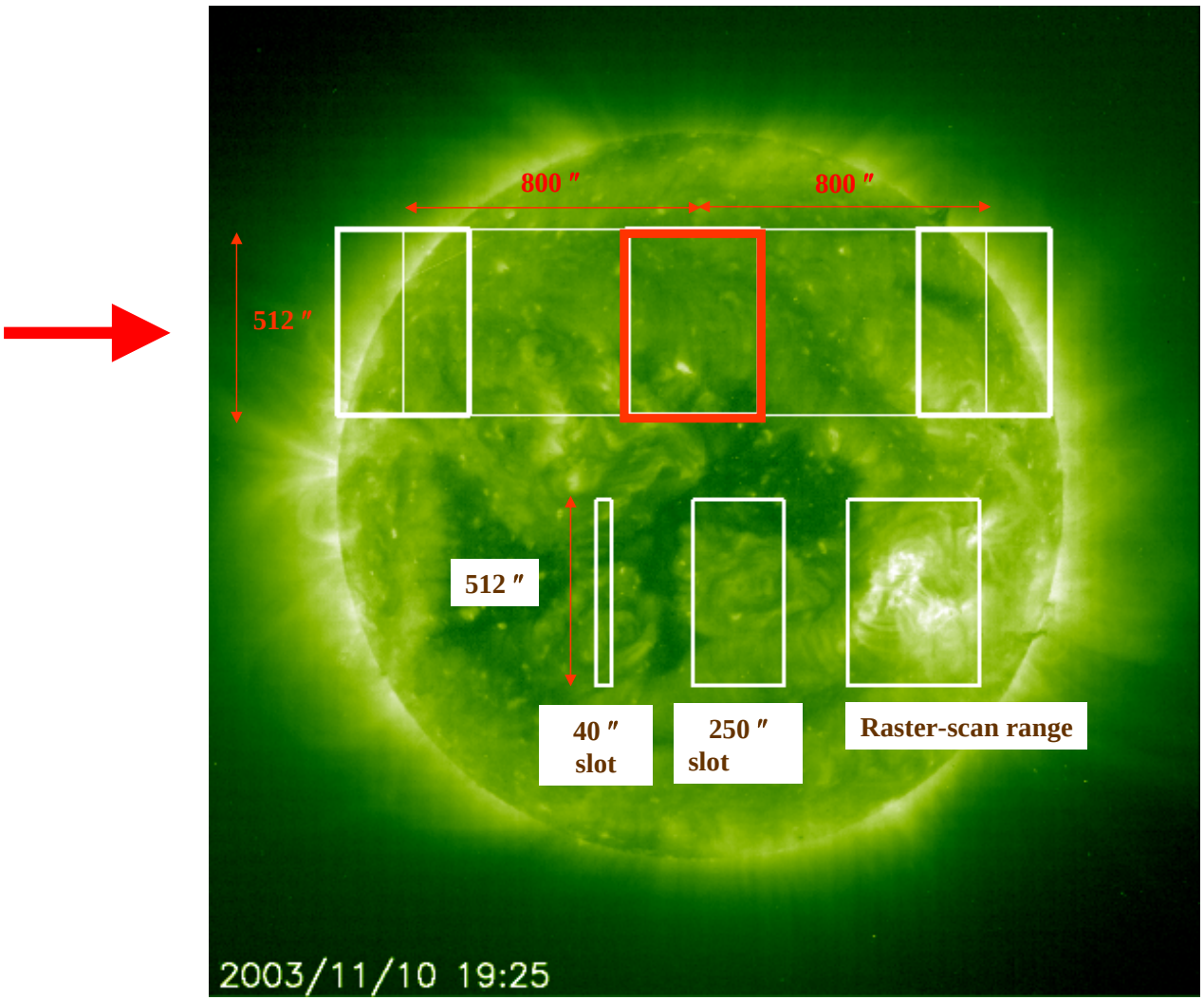
FOV of the Telescopes



Tetsuya Watanabe (NAOJ)

The Solar-B Mission

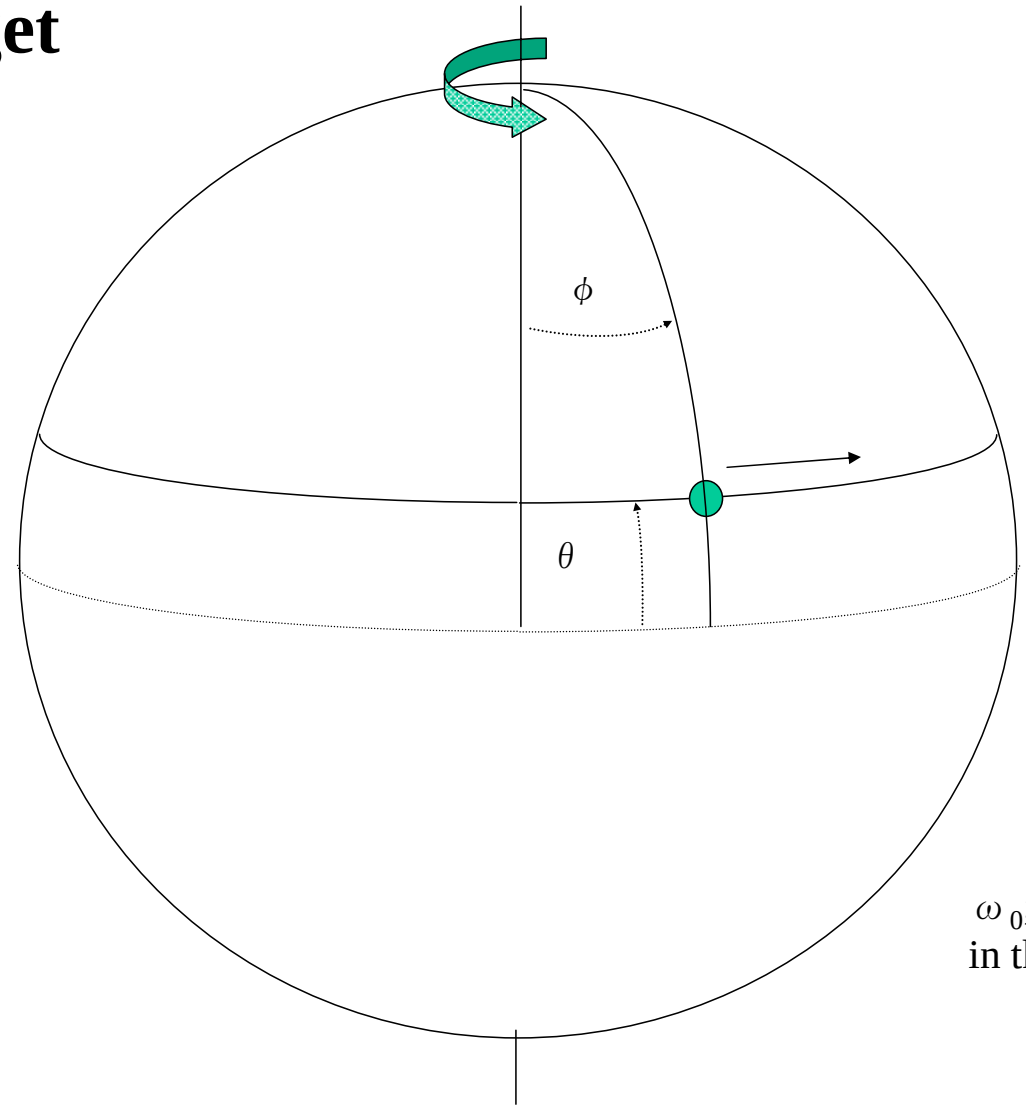
EIS Shift of FOV center with *coarse-mirror* motion



Tetsuya Watanabe (NAOJ)

The Solar-B Mission

pointing target



ω_0; commandable from the ground in the range of 0.15 – 0.26 rad/day.

Tetsuya Watanabe (NAOJ)

The Solar-B Mission

Pointing target of the spacecraft

$$\theta(t) = \theta(t_0) \quad \& \quad \phi(t) = \phi(t_0) + \omega t,$$

where θ and ϕ are heliospheric latitude and longitude, t is time, and t_0 is an epoch, ω is the anglular velocity seen from the earth. As the sun rotates differentially, ω depends on the heliospheric latitude, and is expressed as follows, using ω_0, the angular velocity in the inertia frame.

$$\omega = \omega_0 - \Omega_e; \qquad \omega_0 = a - b \sin^2(\theta)$$

a = 14.44 deg/day

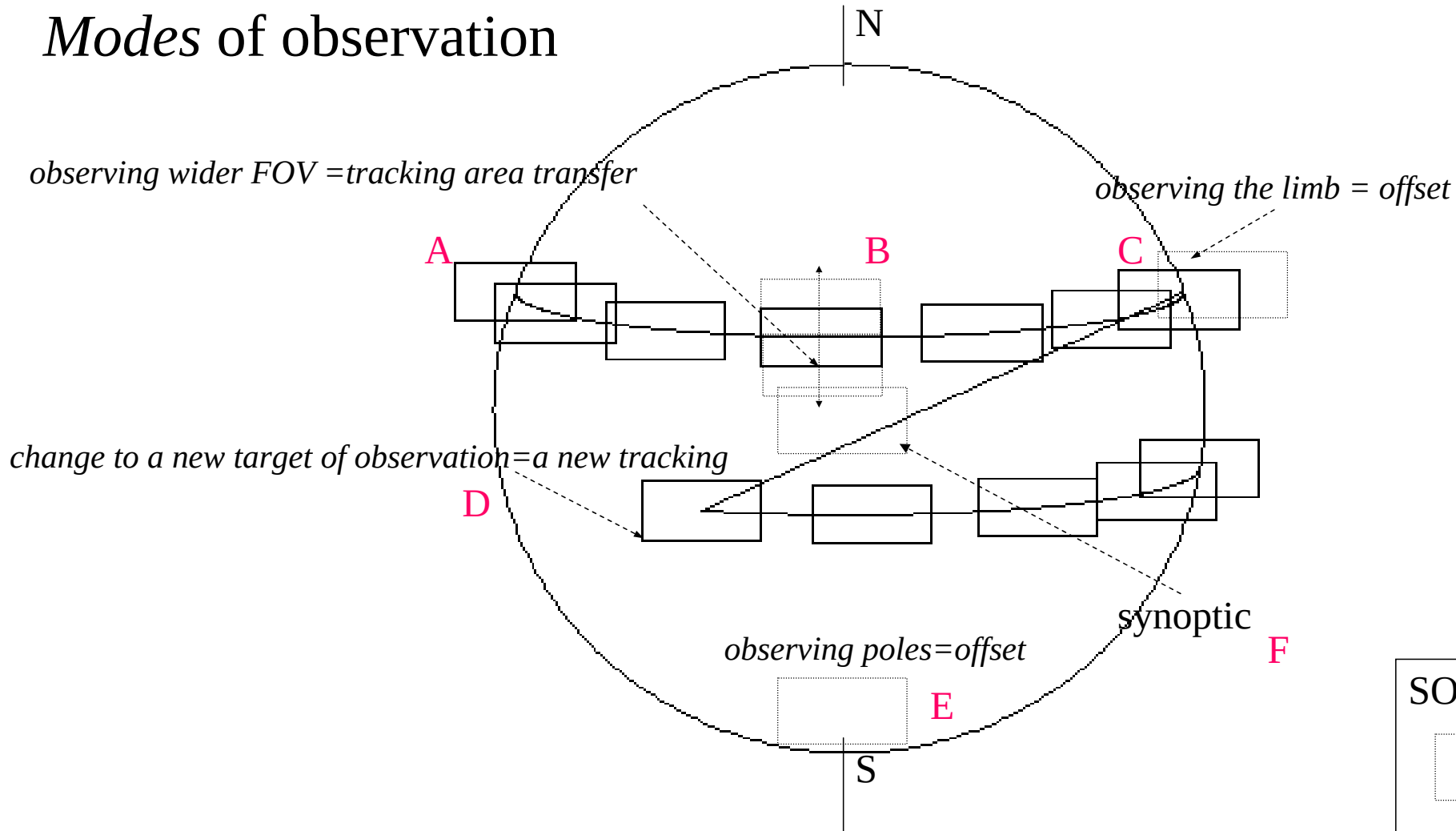
b = 3.0”

(Allen, 1973, ‘Astrophysical Quantities’)

where Ω_e is the angular velocity of revolution of the earth.

The Solar-B Mission

Modes of observation



Tetsuya Watanabe (NAOJ)

The Solar-B Mission

Image stability

Table Items to be considered for image stability requirements

Item	Remarks	Unit considered	Time Scale	Specification
1. Ensure Spatial Resolutions	Images should be stabilized in a pixel during the exposure	Pixel size	Exposure time 1 - 60 sec	3 σ
2. Minimize Image Distortions	Distortions of images constructed after raster scanning should be minimized within allowance.	Pixel size or Time scale of target structural change	Scanning Time 5 – 60 min	0－p or average
3. Areal Tracking	Structurally changing phenomena should be within the observing FOV	Minimum FOV /a factor	Tracking Time ~1 hour	0－p
4. Avoid Image Rotaion	Orientation adjustment of images should be avoided for co-aligning the time series of images	Pixel size /FOV	＞Tracking Time	0－p

Remark: Specifying with 3 σ in Item 1 is adopted because it has good correlation with image contrast.

The Solar-B Mission

Table Pointing Stability (Ver.4.2)： *All numbers are in unit of arcseconds *AR: Active Region、QR: Quiet Region, CH: Corona Hole

		Time Scale		X/ Y (arcsec)		z (Addition conditions, arcsec)		Unit
SOT	FLT	10sec	Integ-Ration	0.06* (T; 0.04)	Strehl～0.973, Time scale of observing targets.	--		3σ
		1hr	Continuos Obs.	2+	Narrow FOV obs: min FOV (10") /5	200	1pix @edge of 2kx2k FOV	0－p
	SP	10sec	Integrat.	0.12*	Twice of FLT	--		3σ
		1hr	Raster Scan	2+	Raster distortion~granular flow (ave ~0.4km/s)	--		0－p
		Mission life		20	FOV(164")/8	--		0－p
XRT		1sec	Std. Exp	0.7	1pixel int = 85%	--		3σ
		1min	Longest Exposure	1.7	1pixel int (2x2pix) = 90% (Coronal Hole)	--		3σ
		1hr	Cont Obs	16	FOV(256")/16	400	1pix@512"-off(good image QT)	0－p
		Mission life		32	FOV(256")/8	--		0－p
EIS		2sec	AR* exp	0.6	Strehl～0.92	--		3σ
		20sec	QR* exp	1.1 (T; 0.6)	Strehl～0.78	--		3σ
		1min	CH* exp	1.7	Strehl～0.62	--		3σ
		10min	Raster	2.0	Raster distortion	--		0－p
		1hr	Cont obs	5.0	FOV (256")/50	800	1pix@slit edge	0－p
		Mission Life		50	Max FOV (512")/10	--		0－p

Tetsuya Watanabe (NAOJ)

The Solar-B Mission

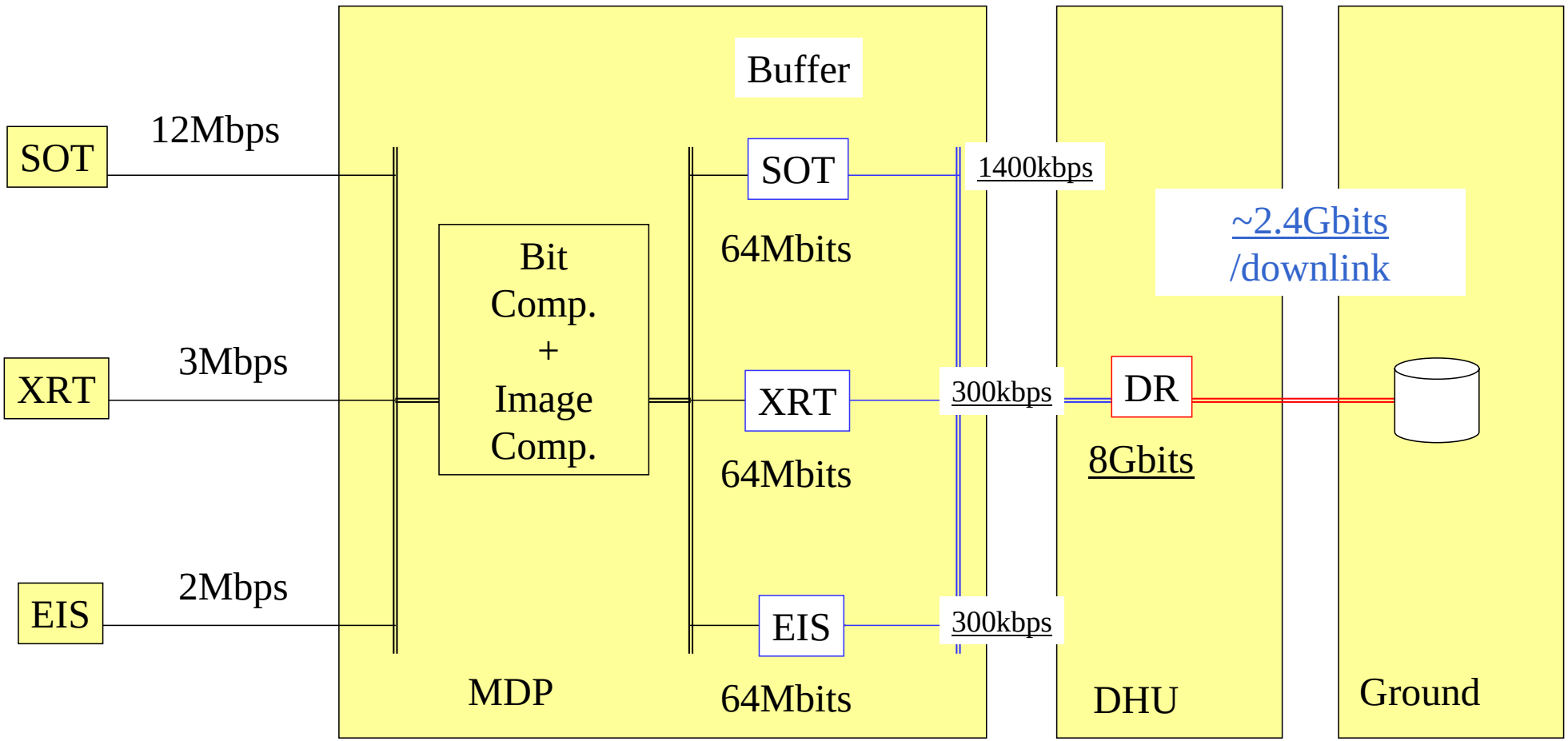
Pointing Stability of the spacecraft

Short term:	0.7 arcsec/1 sec
	{0.06arcsec/10sec}
	1.1 arcsecs/20 sec
Medium term:	1.7 arcsecs/1 min
	2 arcesec/20 min
Long term:	5 arcsecs/1 hour
	{2arcsecs/1hour}
Mission long:	20 arcsecs

achieved by *AOCS* (body) {+ *CTM/TTM* (ctm/ttm)}

The Solar-B Mission

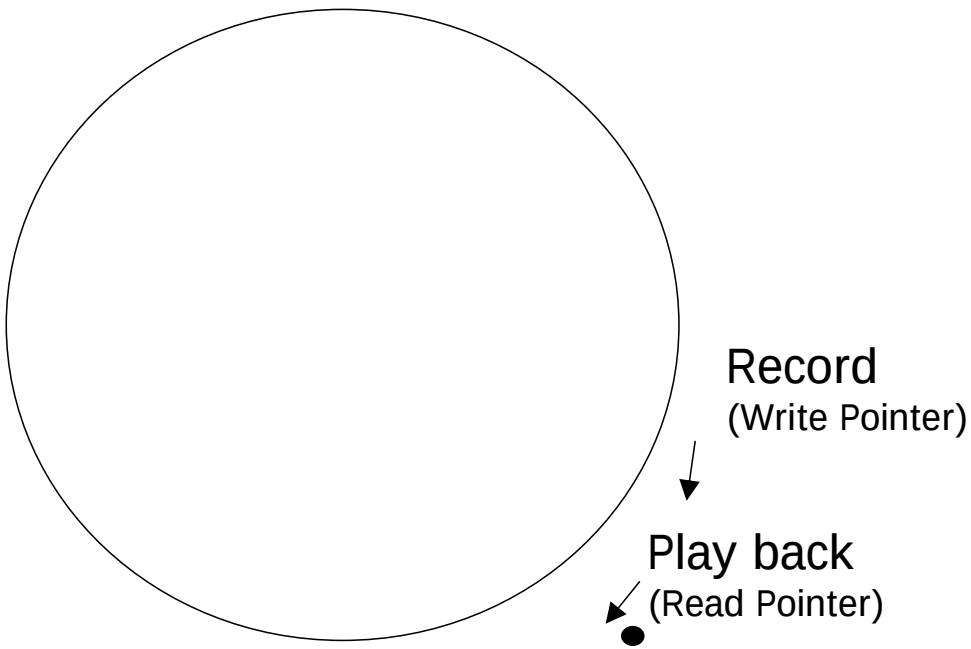
Data Recorder (DR)



Tetsuya Watanabe (NAOJ)

The Solar-B Mission

- Simple ring buffers (size～8Gbits)
  - One partition for SOT, XRT & EIS (+MDP)
  - One partition for S/C
- No priority control
  - Stop or overwrite @ full (selectable)

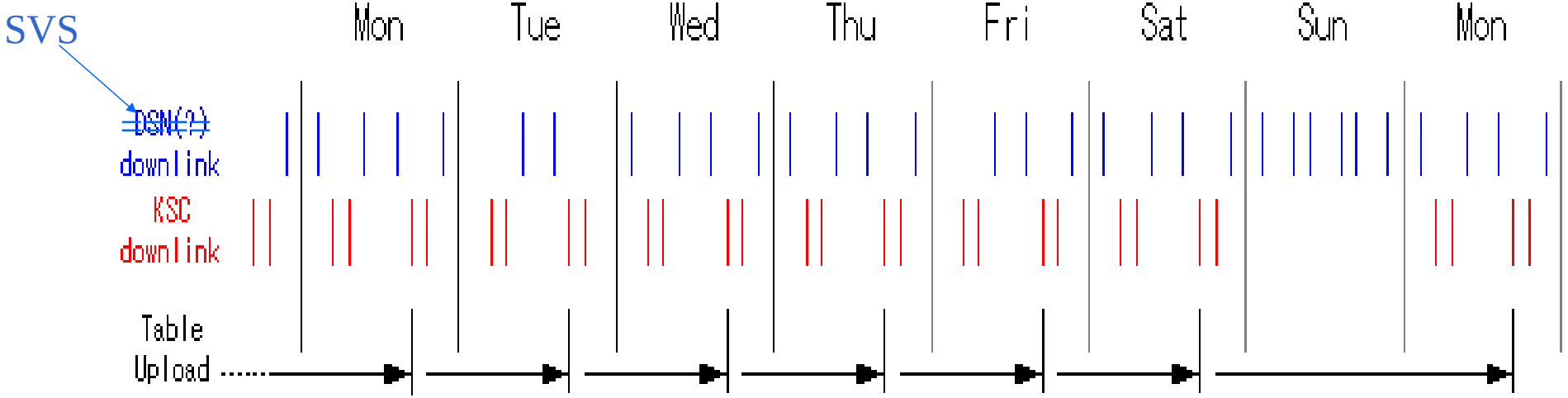


The Solar-B Mission

Down link

- 4Mbps (X-band)
  - *Bottle neck for total amount of data*

    32kbps(S-band) - For S/C
- 200 minutes of down-link / day
  - 4 KSC + 15 SVS / day



2.4G×(#downlinks)

Tetsuya Watanabe (NAOJ)

The Solar-B Mission

Sharing of Telemetry (per downlink)

SOT	1400Mbits (70%)	FG	1100Mbits (55%)
		SP	300Mbits (15%)
XRT	300Mbits (15%)	Partial Frame	225Mbits (11.25%)
		Full Frame	75Mbits (3.75%)
EIS	300Mbits (15%)		

- Ratio can be changed

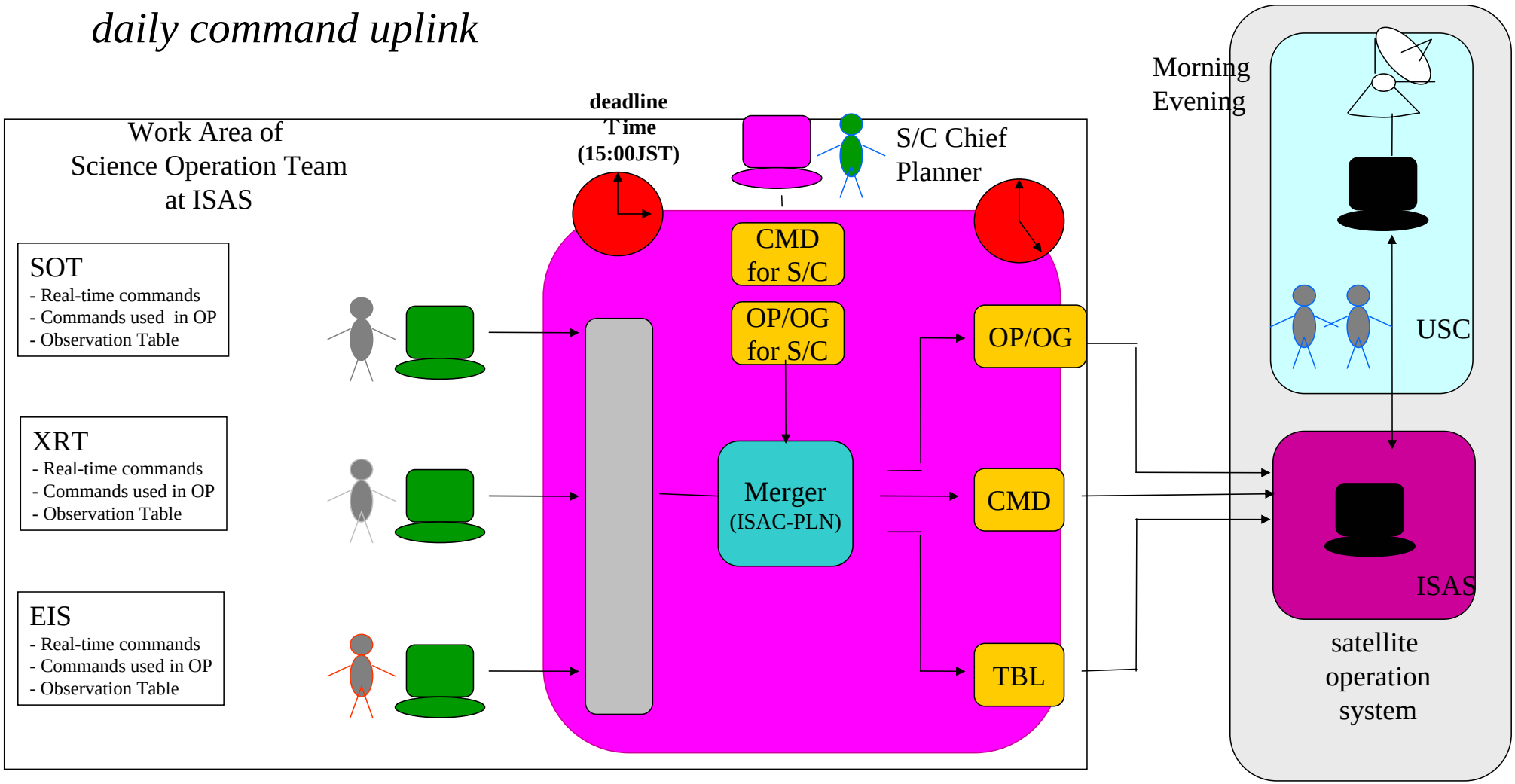
The Solar-B Mission

FLare Detection (FLD)

- FLD is the function to detect flare occurrence and radiation belts (SAA, HLZ).
  - Detection of Flare occurrence
  - Detection of Radiation Belts
  - *Set FL flag and notify FL location to EIS and SOT*
- FLD with flare patrol images in *soft X-rays*
  - Time resolution : 10 sec – 640 sec
  - Spatial Resolution : 8”
    (8x8 binning on CCD = 256x256)

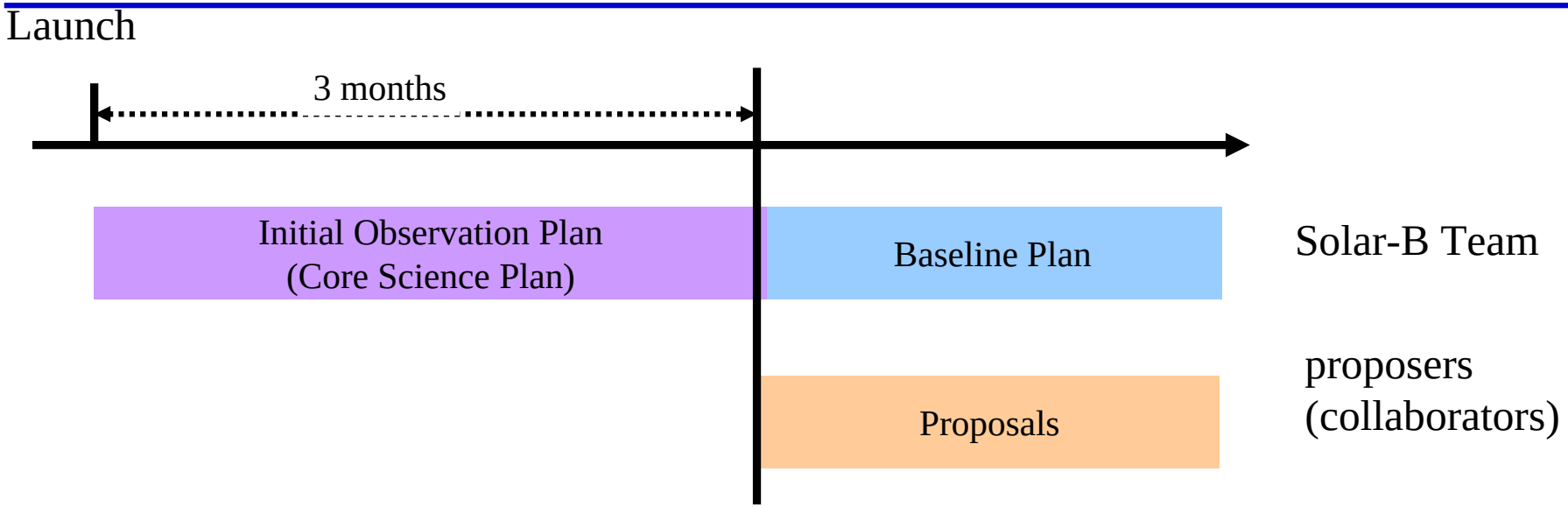
The Solar-B Mission

Mission Operation
daily command uplink



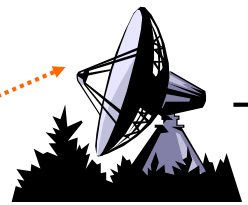
Tetsuya Watanabe (NAOJ)

The Solar-B Mission



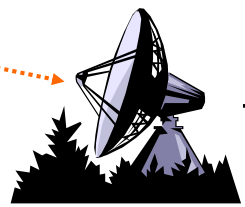
- "Initial 3-month Observation Plan" during initial three (TBD) months: "*Solar-B Core Science Programme*"
- After the initial three (TBD) months, the initial plans will constitute "*baseline*" observation plans. Observation plans will be widely proposed and inserted in the "baseline" observation plans.

The Solar-B Mission



KSC
Kagoshima, Japan

Database
at ISAS



SVS Station

Data conv tool

Data flow from Solar-B to
Level-0 Data: I

Example

Software

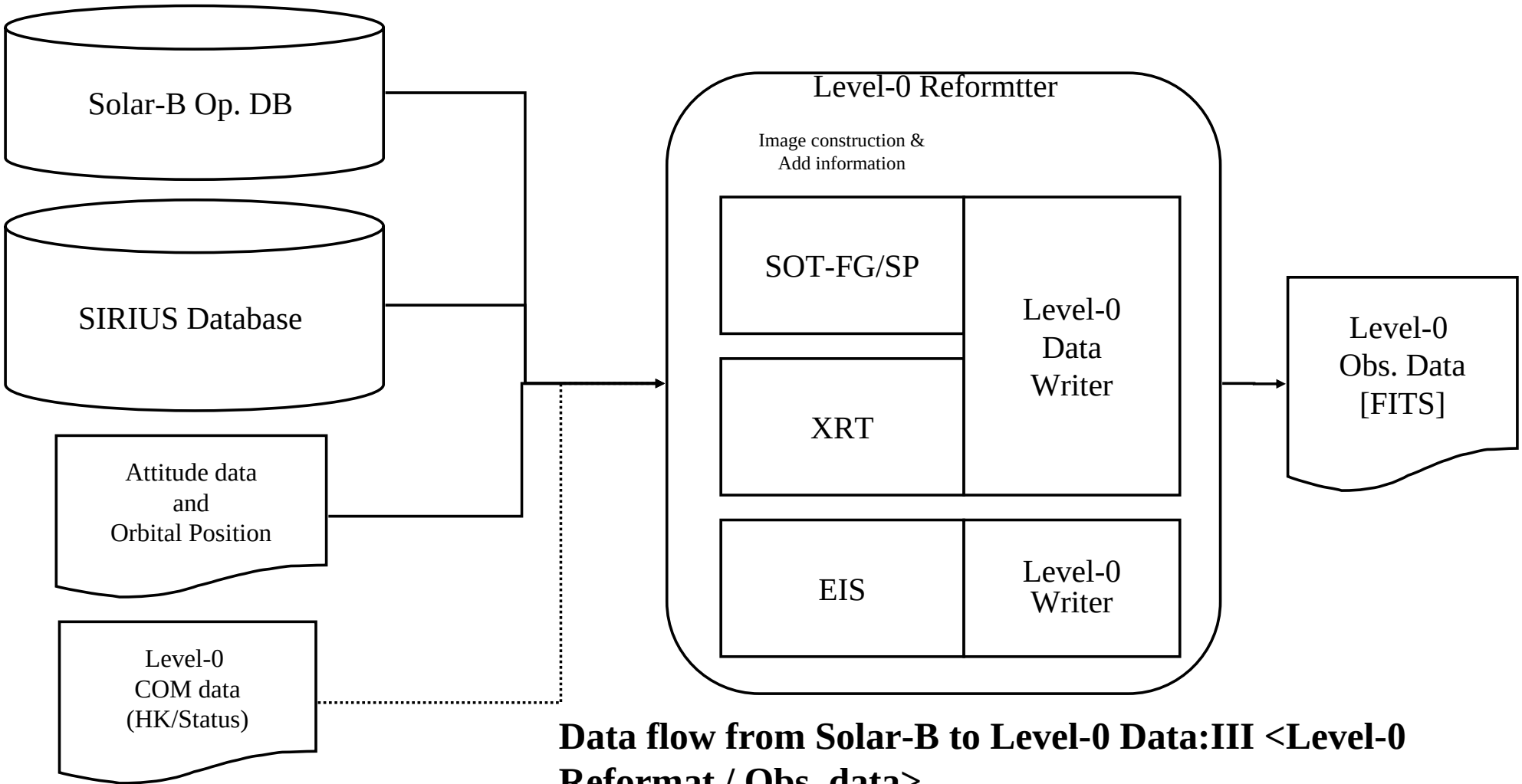
Data

Database

Hand work
W/ software

Tetsuya Watanabe (NAOJ)

The Solar-B Mission

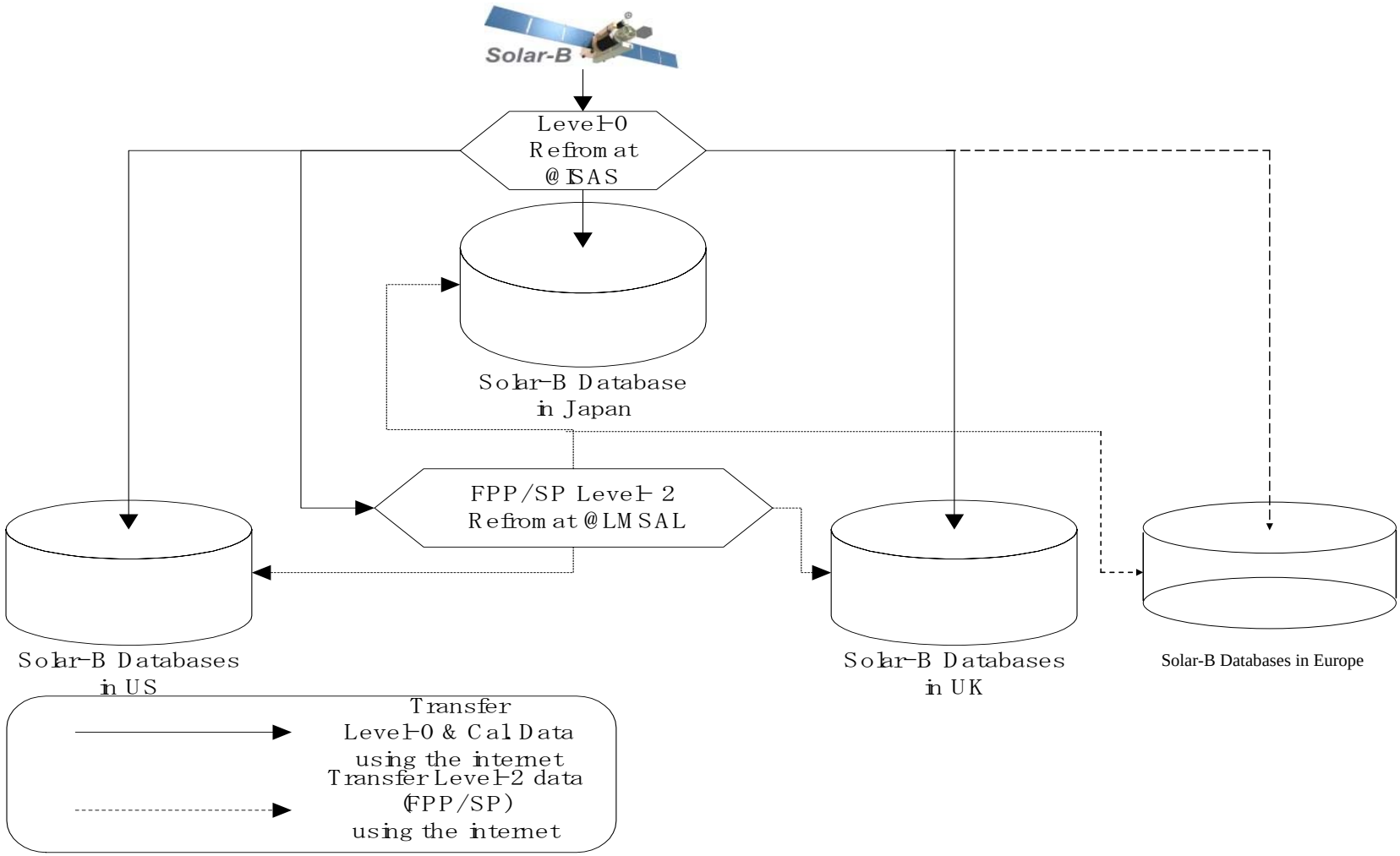


Data flow from Solar-B to Level-0 Data:III <Level-0 Reformat / Obs. data>

Tetsuya Watanabe (NAOJ)

The Solar-B Mission

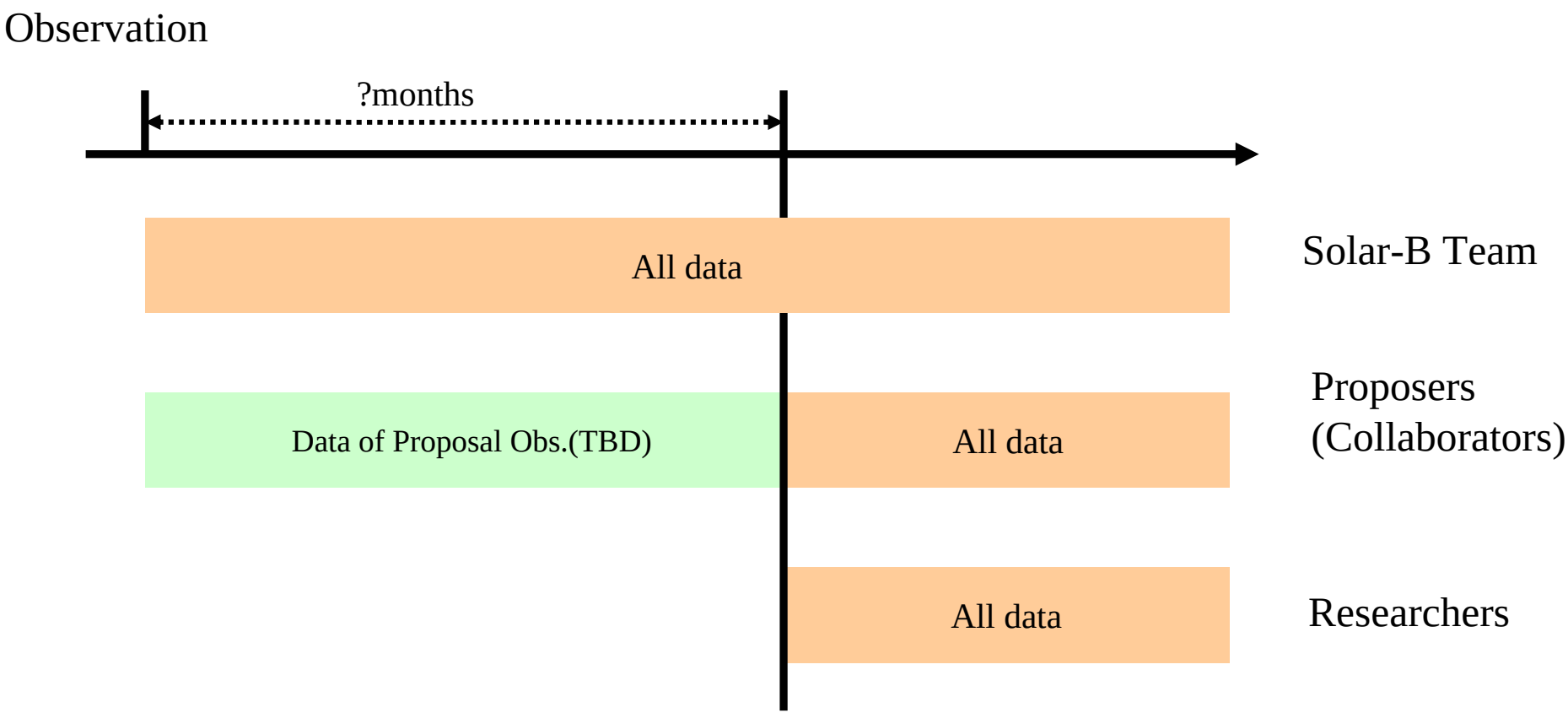
Data flow after downlink



Tetsuya Watanabe (NAOJ)

The Solar-B Mission

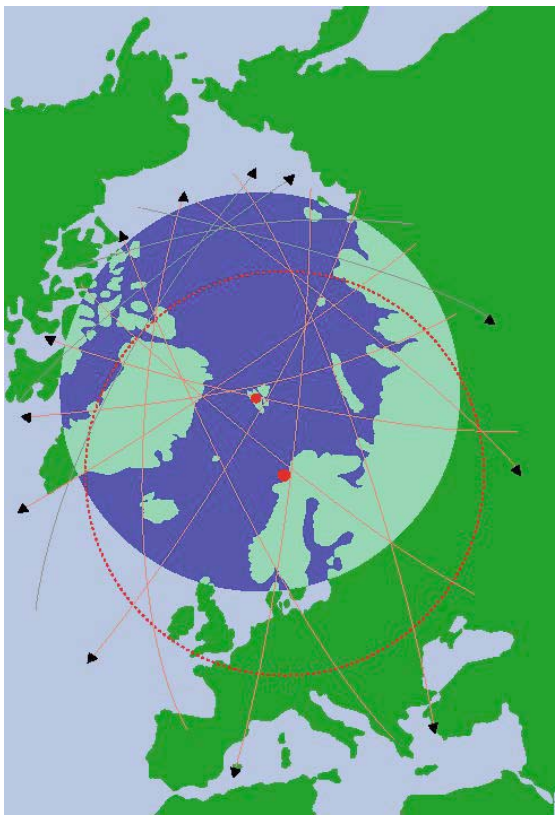
Solar-B data should be open to the public as early as possible (… months after data collection).



The Solar-B Mission

USC

SVS



KSC34m antenna

Tetsuya Watanabe (NAOJ)

The Solar-B Mission

* Why do we need study the Sun?

1. **"The Sun as a Star" (A Classical Field of Astrophysics)**
   - **Stellar Structure / Evolution**
   - **Dynamo Mechanism (Cosmic Magnetism)**

2. **Corona: a Prototype for Superhot Astrophysical Plasma**
   - **Why is the corona so hot?**
   - **Coronal Structure / Dynamics**
   - **Sudden Energy Release and Particle Acceleration**

   *** Key Word: Magnetic Reconnection**

3. **Factors Controlling the Space Weather and Climate**
   - **Solar Wind**
   - **Flares and CMEs as a Cause of IP Disturbances**

Tetsuya Watanabe (NAOJ)

The Solar-B Mission

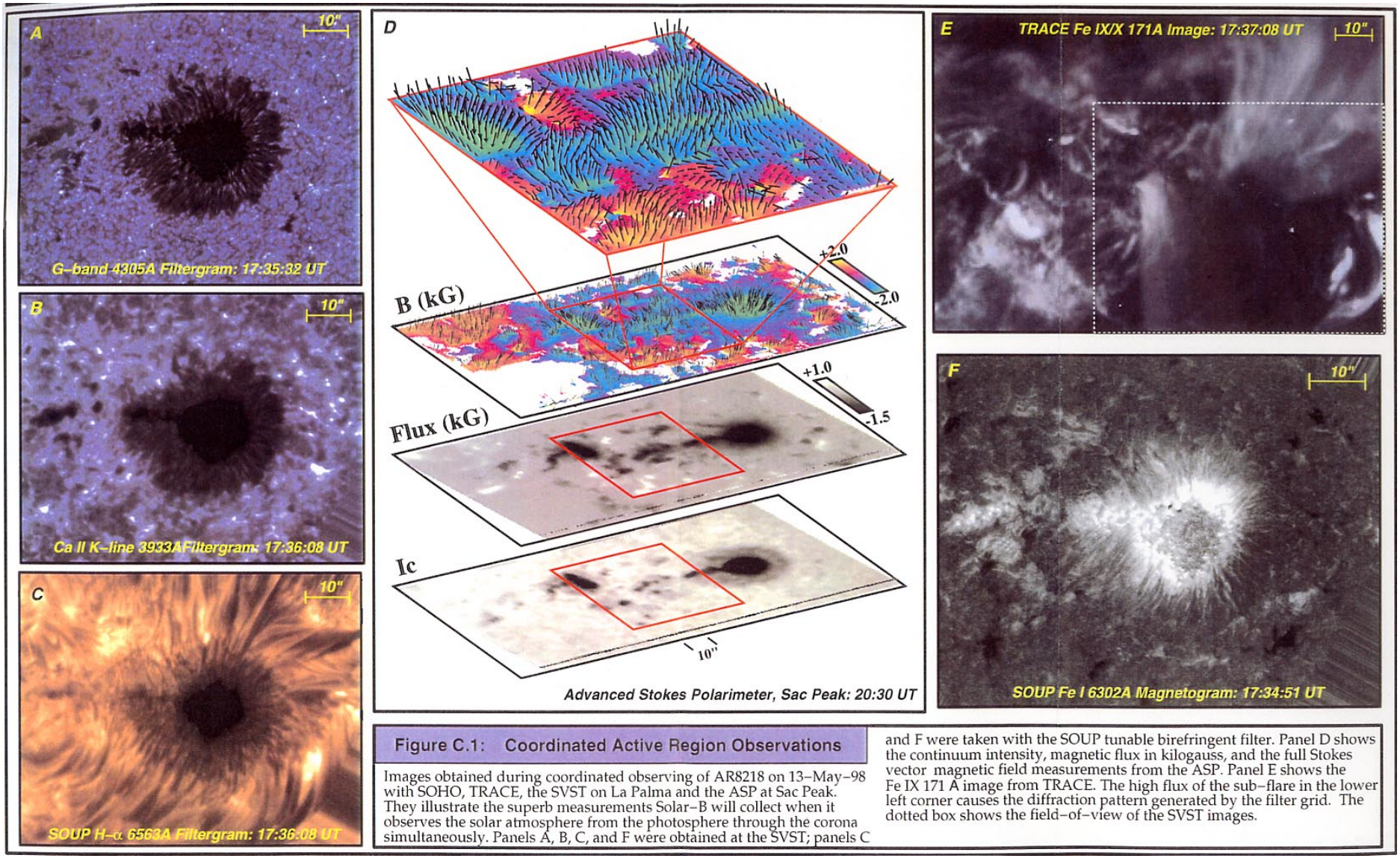


Figure C.1: Coordinated Active Region Observations

Images obtained during coordinated observing of AR8218 on 13–May–98 with SOHO, TRACE, the SVST on La Palma and the ASP at Sac Peak. They illustrate the superb measurements Solar–B will collect when it observes the solar atmosphere from the photosphere through the corona simultaneously. Panels A, B, C, and F were obtained at the SVST; panels C and F were taken with the SOUP tunable birefringent filter. Panel D shows the continuum intensity, magnetic flux in kilogauss, and the full Stokes vector magnetic field measurements from the ASP. Panel E shows the Fe IX 171 A image from TRACE. The high flux of the sub–flare in the lower left corner causes the diffraction pattern generated by the filter grid. The dotted box shows the field–of–view of the SVST images.

Tetsuya Watanabe (NAOJ)

The Solar-B Mission

- **Solar Optical Telescope (SOT)**

  Largest optical telescope ever to observe the Sun from space

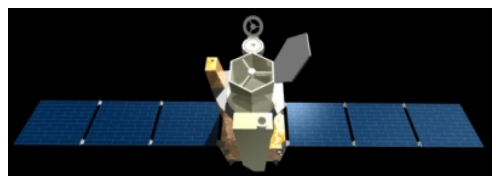
  Diffraction-limited (0.2 – 0.3 arcsec) imaging in 388 – 668 nm

  Vector magnetic field measurement at the photosphere

- **X-Ray Telescope (XRT)**

  Highest angular resolution imaging at > 3 MK corona

  Wide temperature coverage from below 1 MK to above 10 MK



- **EUV Imaging Spectrometer (EIS)**

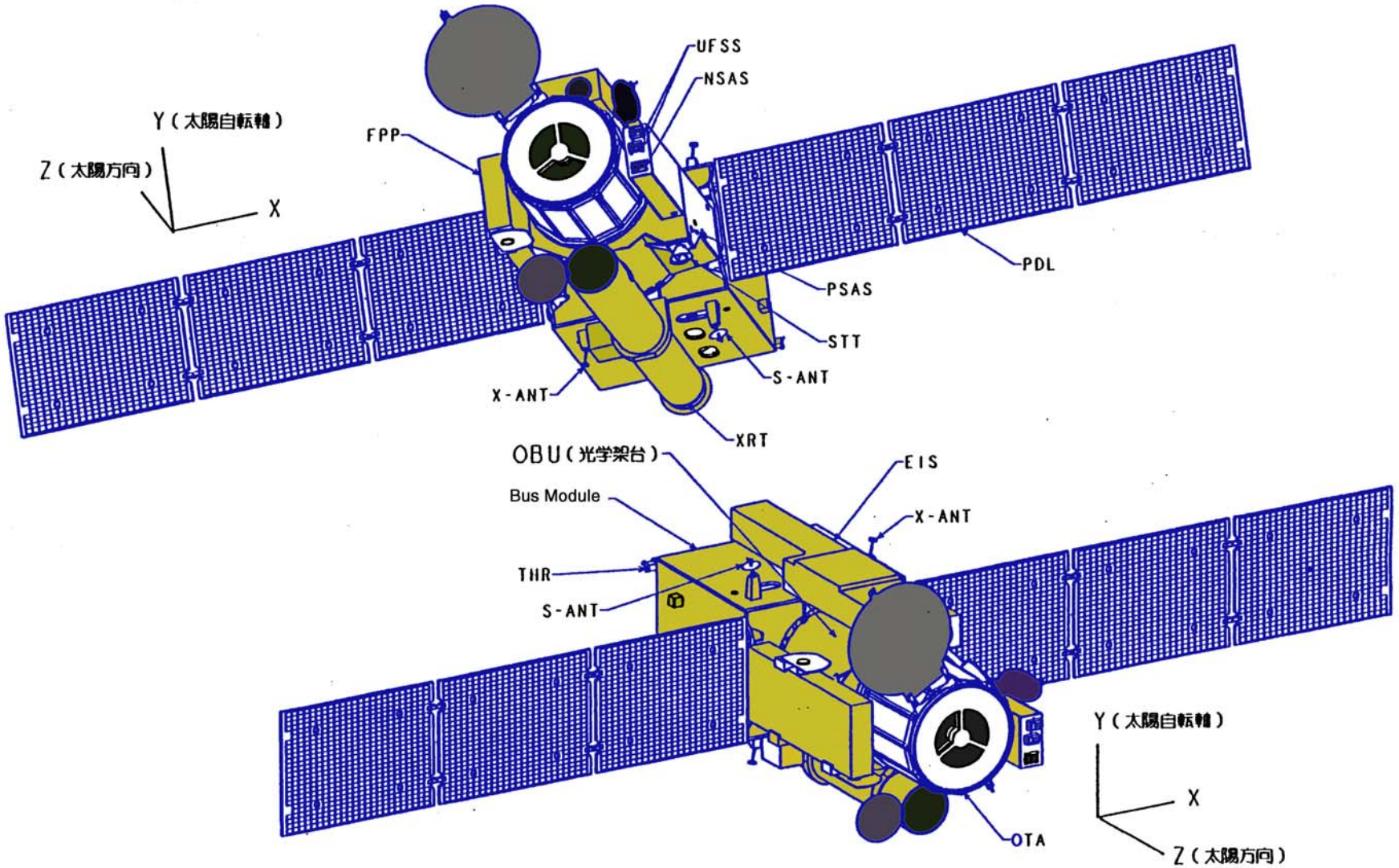
  Precise plasma diagnostics in the 17 – 21 nm & 25 – 29 nm ranges

Continuous observation without interruption for 8 months a year

Coordinated observation among the three telescopes

Tetsuya Watanabe (NAOJ)

The Solar-B Mission



Tetsuya Watanabe (NAOJ)

The Solar-B Mission

Mechanical Test Model (2002 May)

Tetsuya Watanabe (NAOJ)

The Solar-B Mission

International Collaboration

Joint Operations and Data Analysis

ISAS (Japan): Integration of S/C; Launch & Operation

Mission Instruments:

SOT (optics), XRT (camera), EIS (I/f to S/C)

NASA (US):

SOT (focal plane package), XRT (optics / mech.),

EIS (optics components), NASA polar station(s)

PPARC (UK): EIS (structure, detectors & electronics)

ESA: Polar station(s) for data downlink

Tetsuya Watanabe (NAOJ)

EIS SOLAR-B

The Solar-B Mission

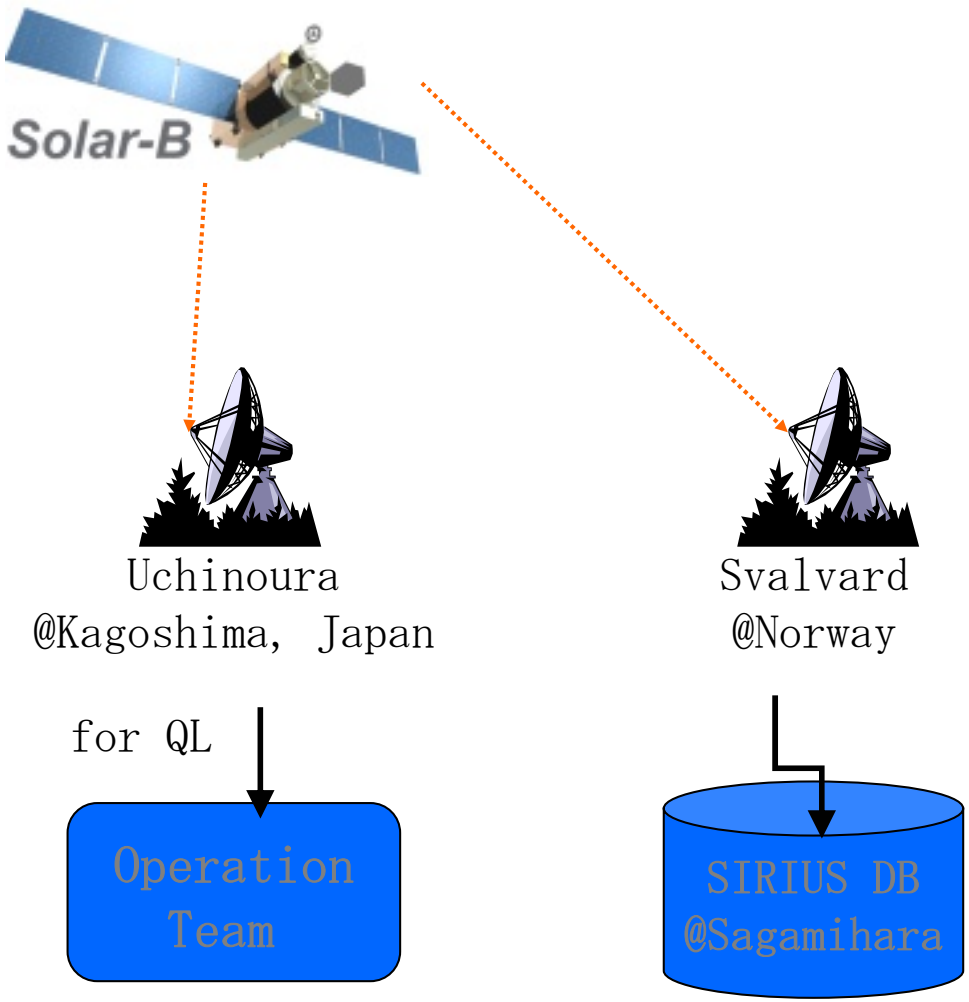
Solar-B data, together with analysis software tools, will be opened to the world solar physics (and related) communities as quickly as possible. *(hopefully in a few months after data acquisition)*

We welcome proposals for observation plans from outside the Solar-B team. *(Details TBD)*

Collaborative observations with other space- and ground-based observatories are encouraged. Any collaborations with, or suggestions/advices from, theoreticians are most welcome.

Tetsuya Watanabe (NAOJ)

Data Flow from SOLAR-B to Scientists: 1

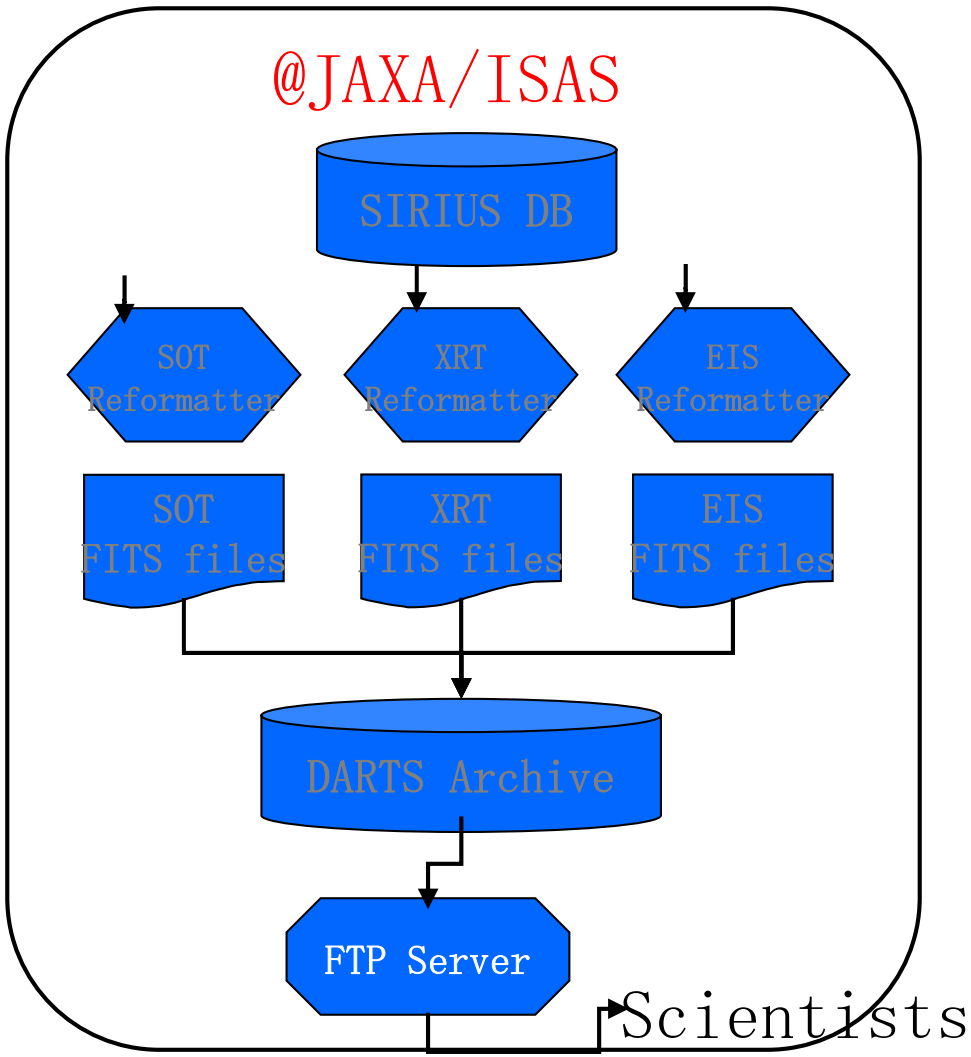


- In nominal operations, all data of SOLAR-B are downloaded at Uchinoura (Japan) and Svalvard (Norway).
- All data are transferred from USC and Svalvard to the SIRIUS database of JAXA/ISAS using Internet.
- We predict that it takes a few weeks till we get the complete set of SOLAR-B data from **SIRIUS** database.
- In order to check the status of instruments and make the operation plan, the operation team uses the data from Uchinoura.

Tetsuya Watanabe (NAOJ)

The Solar-B Mission

Data Flow from SOLAR-B to Scientists: 2

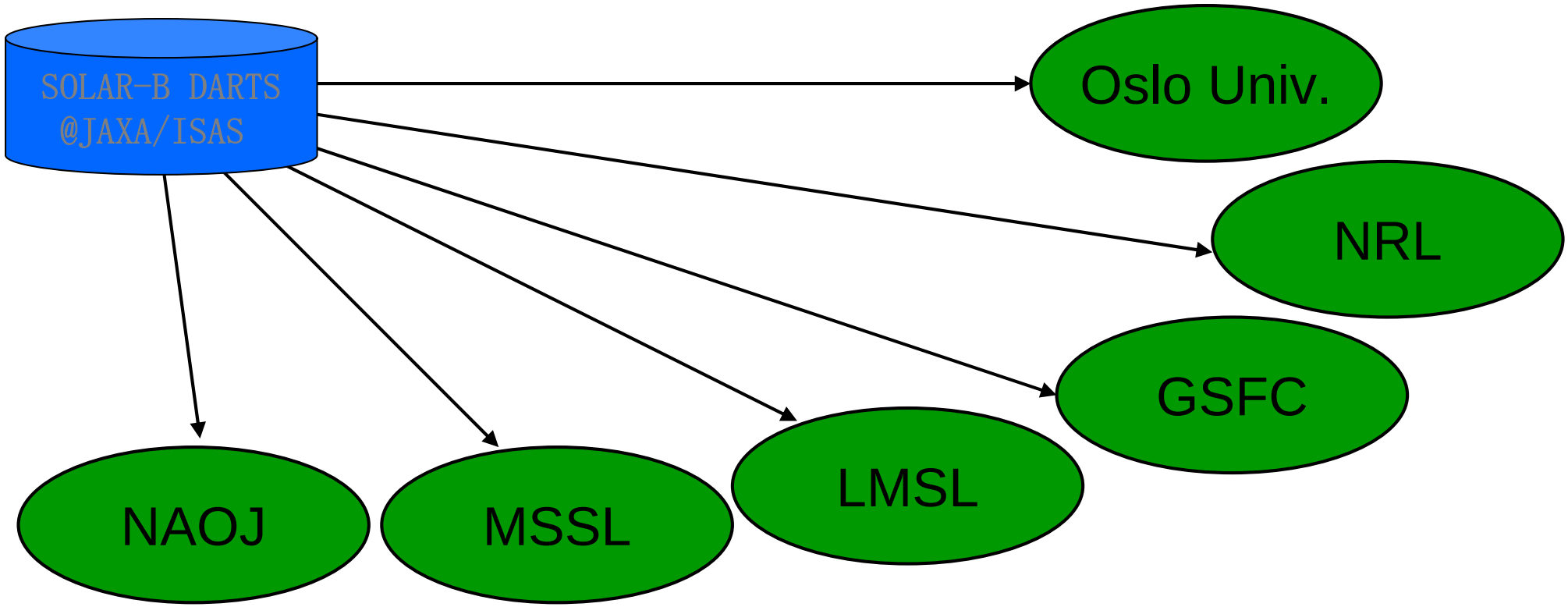


- All scientific data are reformatted to Level-0 FITS files by each instrument team at JAXA/ISAS.
- "Level-0" means that the data are not calibrated.
- All FITS files of SOLAR-B are archived in DARTS (the Data ARchive and Transmission System) at ISAS/JAXA.
- Scientists can get the SOLAR-B data using the ftp server of DARTS.

Tetsuya Watanabe (NAOJ)

The Solar-B Mission

Data Flow from SOLAR-B to Scientists: 3



- The SOLAR-B FITS files are mirrored by the SOLAR-B project team around the world.
- Scientists may get the SOLAR-B FITS files from these sites.

EIS SOLAR-B

The Solar-B Mission

FM Synthetic Electrical Testing Completed

(29-Sep-2005)

Tetsuya Watanabe (NAOJ)