Overview of the Current Baseline of the Solar-C Spacecraft System

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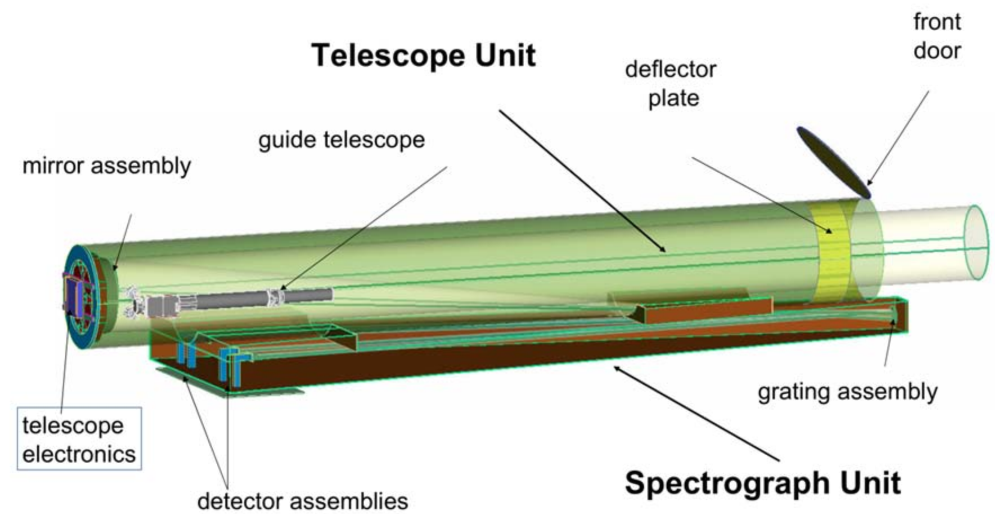
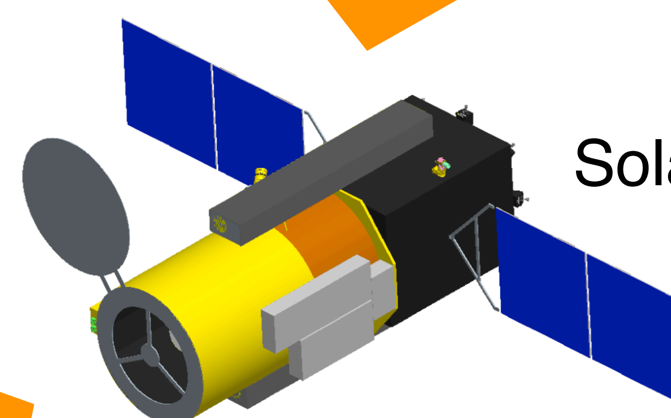
Solar-C Spacecraft System Overview

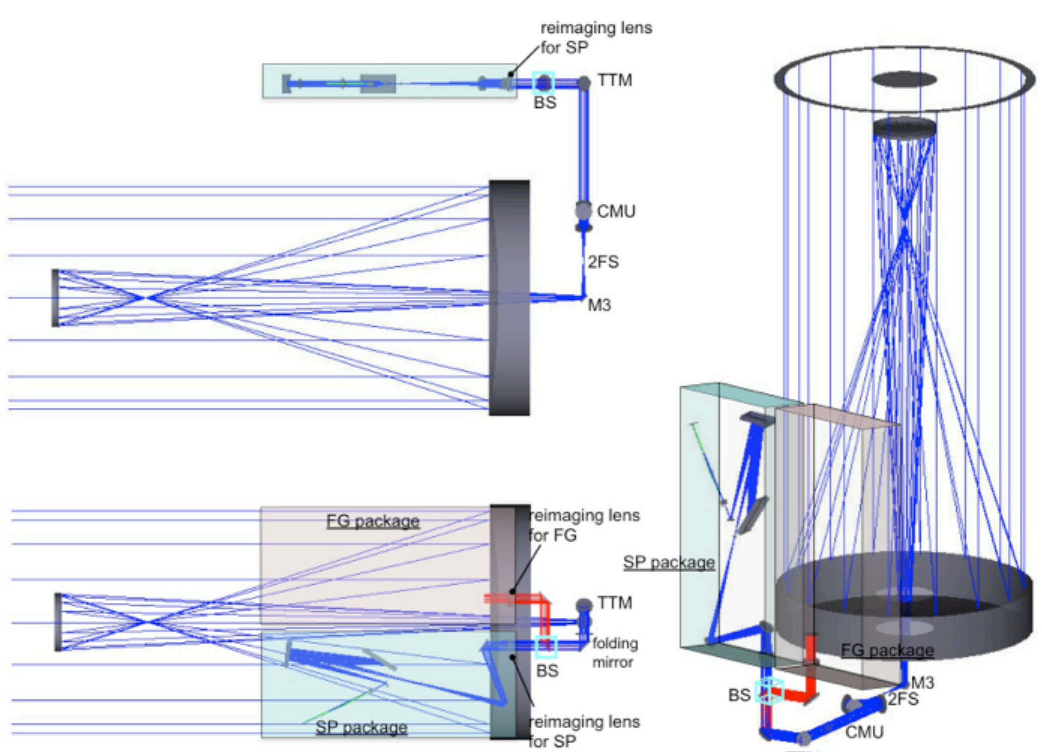
EUV/FUV High Throughput Spectroscopic Telescope (EUVST)

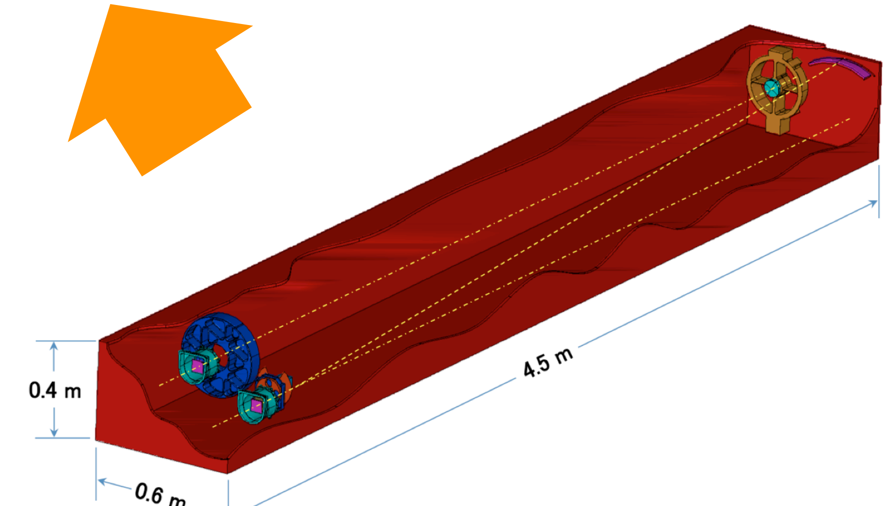




Solar-C S/C system

Solar UV-Visible-IR Telescope (SUVIT)





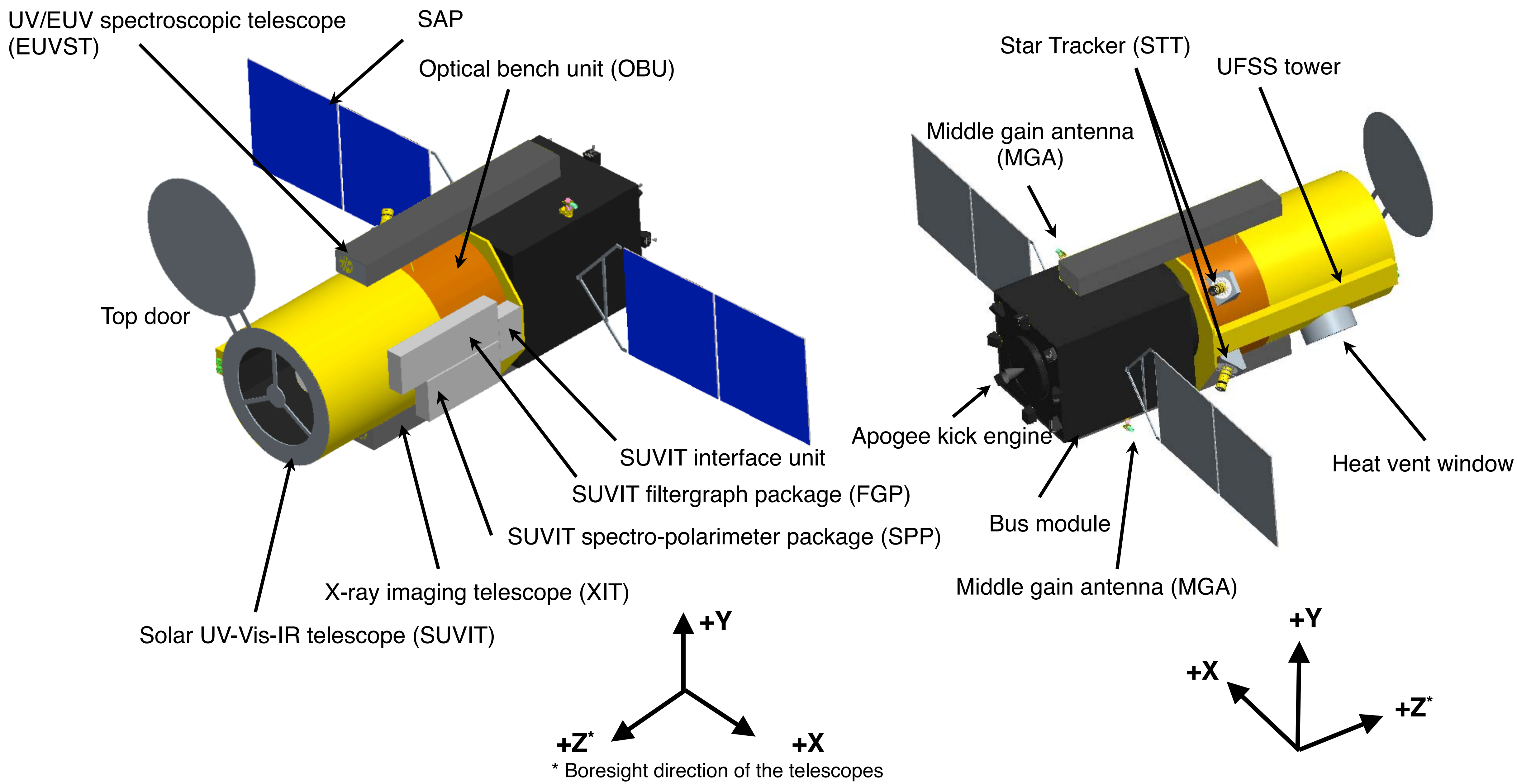
X-ray Imaging Telescope (XIT)

Current Baseline Spacecraft System

Model Specification of Spacecraft System

Size	3.7 m x 3.2 m x 7.1 m excluding solar array paddles
Weight	4.1 t (at liftoff), 2.3 t (dry weight)
Orbit	Geosynchronous orbit with a non-zero inclination (baseline)
Power	Power generation: 5kW @EOL Load: 1.5kW (average) + operational heaters
Communication	Mission data downlink: X-band 16-QAM, 24Mbps (baseline) Ka-band QPSK, 80Mbps (option) Uplink and housekeeping downlink: S-band
Data rate and volume	Average mission data rate: 8Mbps Data recorder storage: 100GB@EOL(3years)
Pointing stability and Attitude control	3-axis attitude control with very high Sun pointing accuracy Image stabilization system in each telescope
Science operation features	Includes close-to-real time access to the satellite and operation

Solar-C Spacecraft System Overview



Major concerns from the view point of system design

- **Total weight** (The weight of the mission instruments is increasing...)
- **Pointing stability performance** (Angular resolution of the telescopes are 2-5 times higher than the that of similar telescopes onboard Hinode)
- **Cost** (There is a very strict cost-cap for middle-size scientific satellite in JAXA)

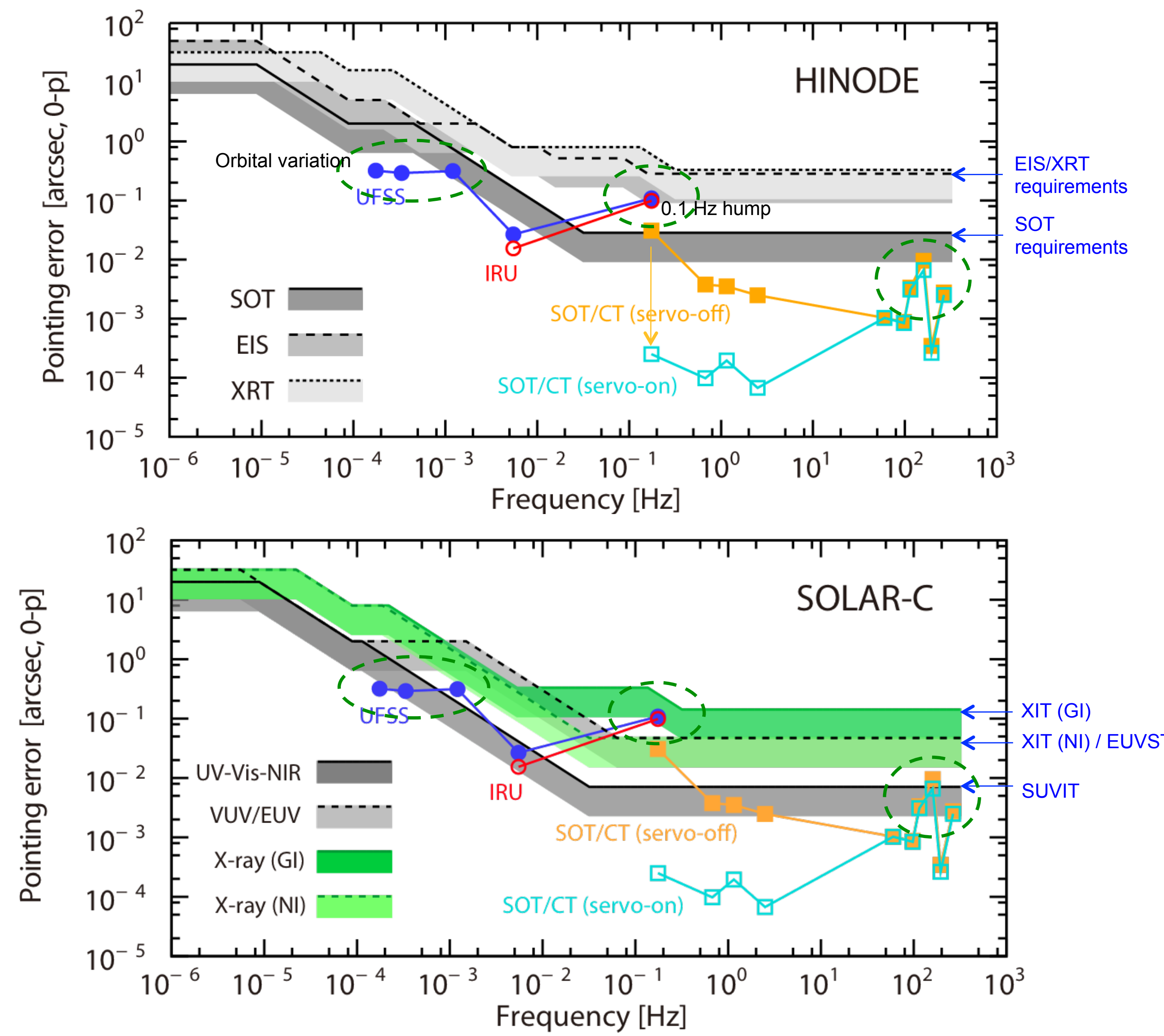
Technical Features of Solar-C Spacecraft #1

High Pointing Stability Requirement

Requirements on the pointing stability of Solar-C

Instruments		Time scale	Requirements (θx/θy)	Unit
SUVIT		1 sec	0.02	arcsec 3σ
		10 sec	0.02	arcsec 3σ
		1 hour	2	arcsec 0-p
		Mission life	20	arcsec 0-p
EUVST		0.5 sec	0.1	arcsec 3σ
		5 sec	0.1	arcsec 3σ
		1 hour	2	arcsec 0-p
		Mission life	32	arcsec 0-p
XIT	Normal incidence	1 sec	0.1	arcsec 3σ
		10 sec	0.1	arcsec 3σ
	Grazing incidence	1 sec	0.3	arcsec 3σ
		1 min	0.7	arcsec 3σ
		1 hour	8	arcsec 0-p
		Mission life	32	arcsec 0-p

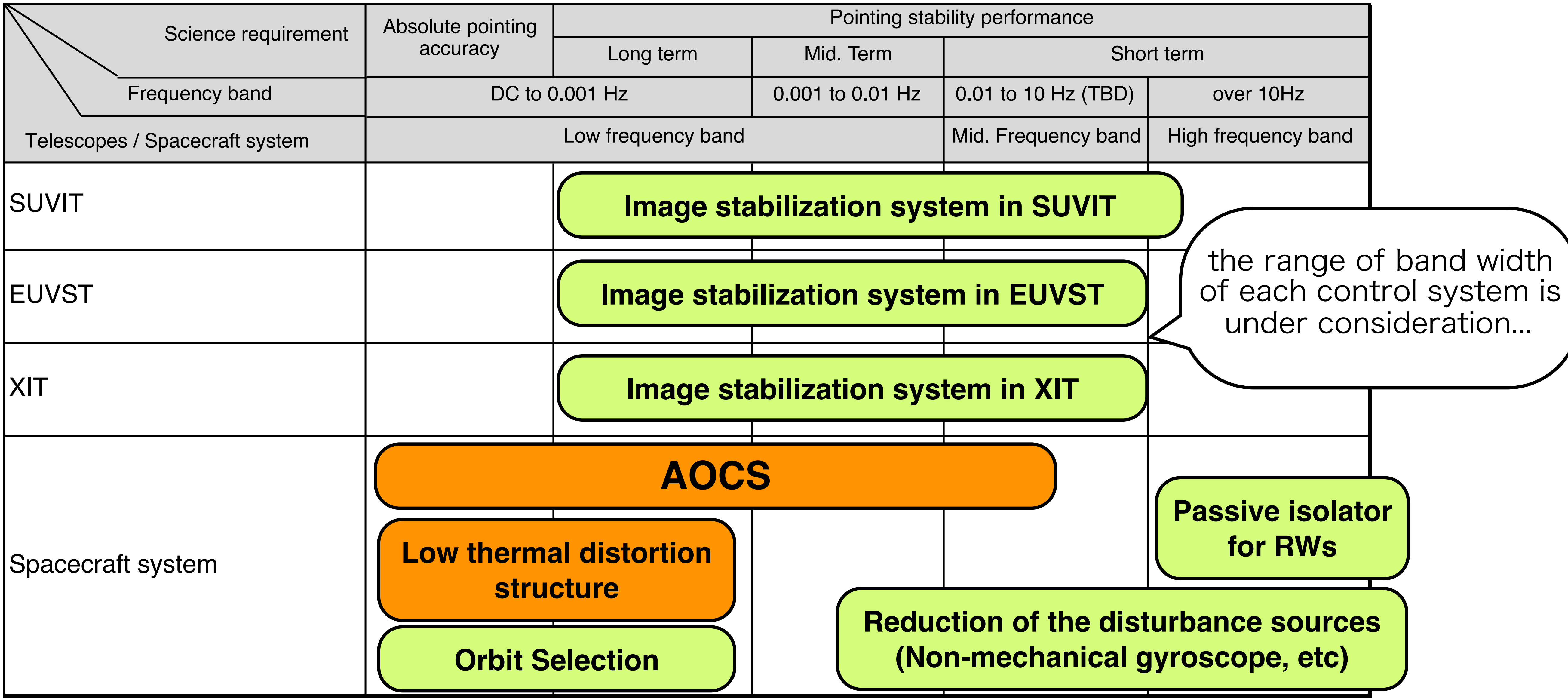
Instruments		Time scale	Requirements (θz)	Unit
SUVIT		1 hour	50	arcsec 0-p
EUVST		1 hour	100	arcsec 0-p
XIT	Normal incidence	1 hour	50	arcsec 0-p
	Grazing incidence	1 hour	100	arcsec 0-p



On-orbit performance of the pointing stability in Hinode in comparison with the requirements of Hinode (top) and Solar-C (bottom).

Required pointing stability is 2 - 5 times higher than the that of similar telescopes onboard Hinode.

Direction of system design for achieving the required pointing stability

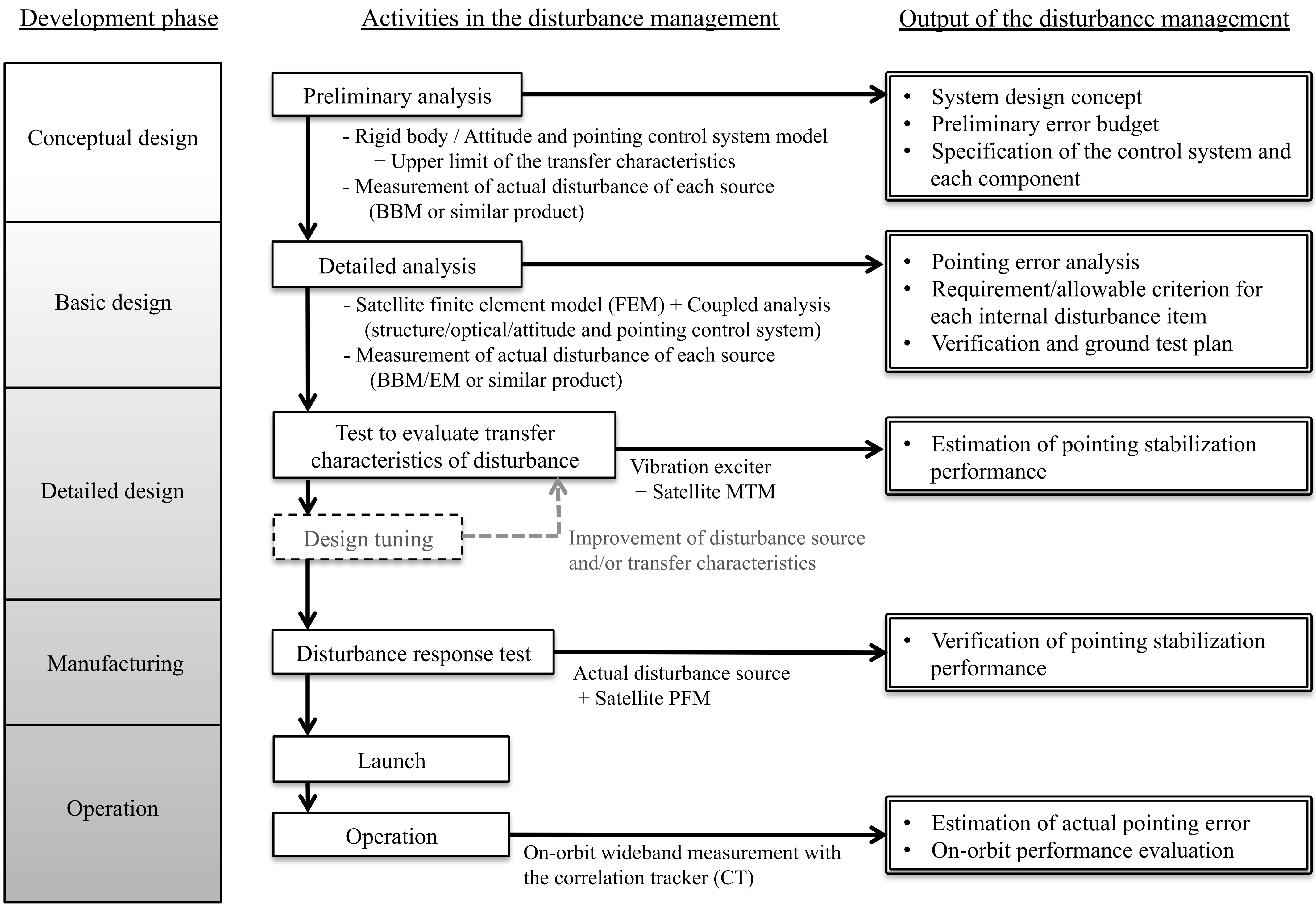


Ideas for the design improvements based on Hinode's experiences:

- to select an **orbit with less orbital variation and low disturbance environment.**
- to install **passive isolator system for RWs**.
- to adopt **non-mechanical gyroscopes** for IRU.
- to have dedicated **image stabilization system** inside each telescope.

Workflow of the disturbance management activities (concept)

Apply the methodology established in the development of the Hinode spacecraft with further improvements. Detailed verification scenario on the pointing stability performance is under consideration.....

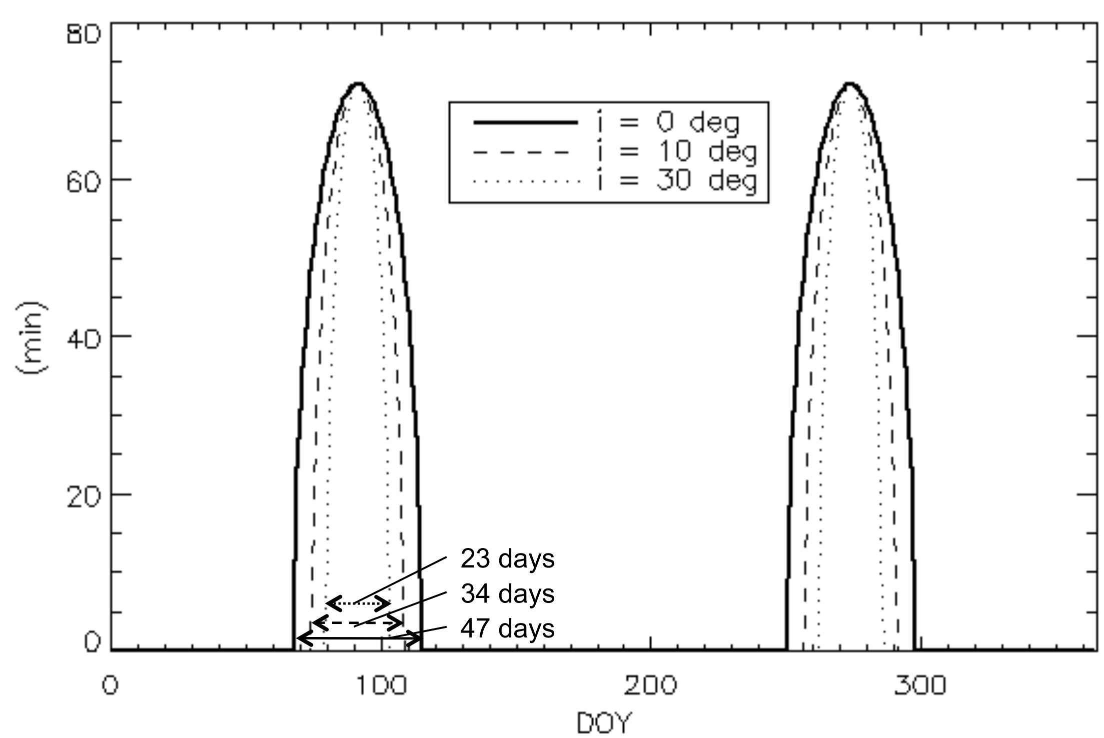


Technical Features of Solar-C Spacecraft #2
Operation in Geo-synchronous orbit

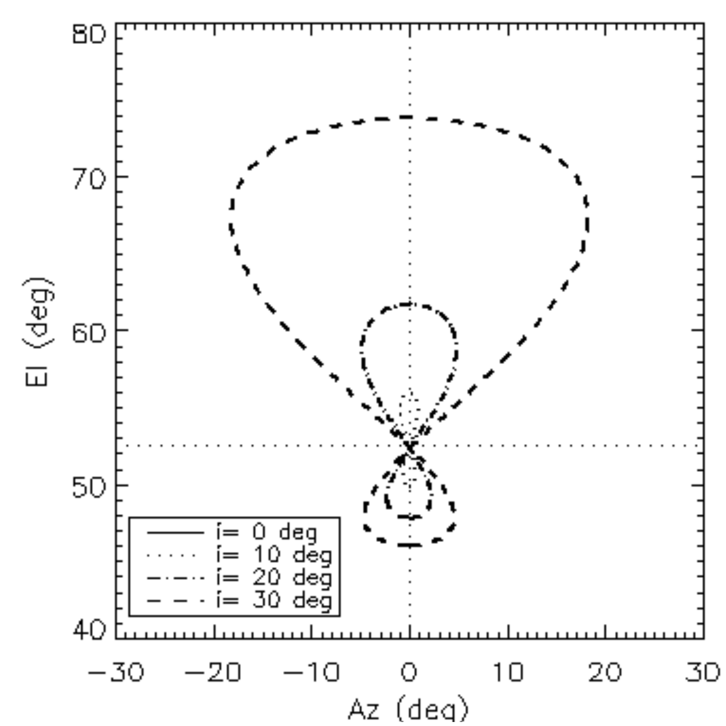
Trade-off studies on the operation orbit have been performed for several orbit candidates.
The viewpoints considered in the trade-off study;

- **High-rate science telemetry downlink** (100 Gbytes/day)
- **High pointing stability** (less orbital variation, low disturbance environment)
- **Thermal design** (especially the thermal design of the SUVIT telescope)
- **Continuity of observation** (shorter eclipse seasons)
- **Real-time science operation**
- **Feasibility of the launch** by H2A (type 202) or next generation launch vehicle

Baseline Orbit : Inclined geo-synchronous orbit (GSO)
- Similar to Solar Dynamic Observatory (NASA)
- Altitude: 36,000 km, inclination: 28.5 deg (baseline), period: 1 day



Eclipse duration in the case of GSO



Visibility of the spacecraft from USC, Japan

Concerns from orbit trade-off study

<table>
<tr><th></th><th>Sun-synchronous polar orbit (SSO)</th><th>Inclined geosynchronous orbit (GSO)</th><th>Geo-stationary earth orbit (GEO)</th><th>Halo orbit at the Lagrangian point L1</th></tr>
<tr><td>High-rate science telemetry downlink</td><td>Need to use Ka-band (~80Mbps, QPSK), which capability is newly required to ground station in polar region. 15 passes per day.
Need further survey on the ground station availability.</td><td colspan="2">X-band (16QAM) is recommended but required ~8hrs contact with USC 34m (24Mbps) or Katsuura (12Mbps max). Additional ESA and NASA stations are helpful to ensure the 8hr requirement.Ka-band (80Mbps, QPSK) requires only 3 hours contact, but concerns are rain attenuation due to humid climate in Japan and new development of station facility.</td><td>X-band (24Mbps, 16QAM) is possible with 30W transmitter and Ka-band possible with the rate higher than 24Mbps, but it needs ~8hr occupation of the 64m Usuda antenna. Severe time conflict with BepiColumbo MMO operations will make this option difficult. NASA DSN supports may be an option for Ka-band.</td></tr>
<tr><td>High pointing stability</td><td>The Ka-band antenna is quickly moved to direct to ground station (>100 deg/10min) every 98min, affecting the pointing stability.</td><td colspan="2">The motion speed of the antenna is slow (~30 deg/hr), but need to evaluate the micro-vibration level.</td><td>An angular motion of the antenna is very slow (~15 deg/month), but need to evaluate the micro-vibration level.</td></tr>
<tr><td>Thermal design</td><td>The orbital variation by the periodic infrared radiation from the earth is concerned on the high resolution performance of telescopes.
Earth albedo and infrared radiation enlarges the size of the radiators for cooling mirror and detectors.</td><td colspan="3">The orbital variation is very small and stable, providing a stable thermal environment.
Earth albedo and infrared radiation is very small, making the thermal design easier, especially for the SUVIT main telescope.</td></tr>
<tr><td>Continuity of observation</td><td>An eclipse season (for 3 months) with about 20 minutes (at maximum) duration every 98 minutes.</td><td>Eclipse seasons with about 70 minutes (at maximum) per day and it continues 20 days, twice every year. Related potential demerit is to need a large capacity of the battery.
Orbit maintenance maneuvers (twice a year) are needed every year.</td><td>Eclipse seasons with about 70 minutes (at maximum) per day and it continues 50 days, twice every year.
Same potential demerit as SGO exists.
Orbit maintenance maneuvers (twice a year) are needed every year.</td><td>No eclipse season.
Orbit maintenance maneuvers (several times a year) are needed every year.</td></tr>
<tr><td>Real-time science operation</td><td>Real-time access is possible but it is restricted to 10 minutes every 98 minutes for a polar ground station.</td><td colspan="3">Real-time access can be arranged in the duration of pass (8 hr maximum).</td></tr>
<tr><td>Feasibility of the launch by H2A 202 rocket</td><td>No critical issue.</td><td>The spacecraft mass constraint is a critical issue. In the preliminary study, the total mass of the spacecraft is about 4 tons and it is almost upper limitation of the H2A 202 rocket capability.</td><td>More propellant (about 200kg) compared with GSO is required.
Current mass estimation has negative margin for H2A 202 capability.</td><td>No critical issue on the mass limitation of the spacecraft.
Detailed study on the orbit design including transfer orbit will be needed.</td></tr>
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Technical Features of Solar-C Spacecraft #3
High-speed mission data downlink

Requirement on the data rate of the mission data from the mission instruments (after compression)

Instrument		Estimated data rate (Mbps)	
		Standard	Burst
SUVIT	Spectro-polarimeter (SP)	1.2	16.0
	Filtergraph (FG)	1.3	32.0
EUVST		1.7	5.1
XIT	XIT-NI	1.2	48.0
	XIT-GI	2.5	26.0
Total data rate (including XIT-PC)		7.9	127.1
Total data rate (no XIT-PC)		5.4	101.1
Data volume produced each day (GByte)		**～100**	

High speed dedicated telemetry channel is absolutely required for Solar-C Mission.

Baseline: X-band telemetry system
- up to **24Mbps** with **16QAM** modulation
- X-band/16QAM technology is used in several Japanese S/Cs
- **8 hours** telemetry downlink is required.

Option: Ka-band telemetry system
- up to **80Mbps** with **QPSK** modulation
- The usage of Ka-band downlink is **new exploration in Japan**. The installation of the Ka-band receiving systems at the ground stations is needed.
- Technical concern is the **attenuation of signals due to bad weather** in Japan.
- **International collaboration** on the ground station support should be beneficial.

Summary

- Current baseline of the Solar-C spacecraft system design is described. (Just 5 minutes overview! For detailed information, please refer to **MPD chapter 5**.)
- **The system requirements and the spacecraft design are NOT solid** in this phase (pre-phase A). There are still some flexibility and options in the system design (e.g. the frequency of the mission telemetry).
- **Any feedback is definitely helpful** for the definition of the system requirements.