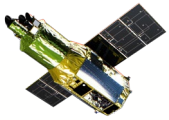
JAXA Saitama University



Ground and In-orbit Verifications of the XRISM Timing System

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a Saitama U., b JAXA, c Ehime U., d NEC coop., e Rikkyo U., f Hiroshima U., g Nara U. of Edu., h Nagoya U., i Nihon Fukushi U., j Fukuoka U., k Shibaura IT, l Nara Womens U., m Kagoshima U., n Chuo U., o Tokyo U. of Sci., p Shizuoka U., q RIKEN, r NASA GSFC, s U. of Maryland, t MIT, u Kyoto U., v Konan U.

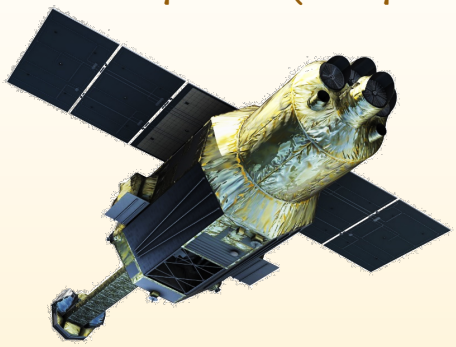
Timing Requirement and Timing System

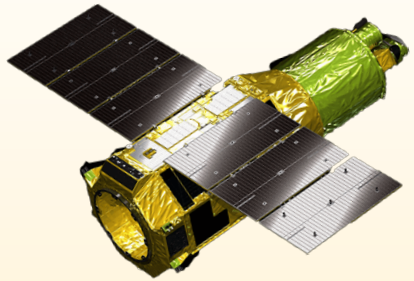
Kouzu et al 2014 IEEE, Terada et al 2018 JATIS
Terada et al 2024 SPIE proc in prep.

Science Requirement on Timing (absolute timing accuracy)

Hitomi: 350 μsec (50 μsec goal)

XRISM 1,000 μsec





Timing requirement value was relaxed.

Timing System

- ✓ Carry GPS receiver
- ✓ Timing distribution via SpW
- ✓ Time calculation on ground

Same system as Hitomi

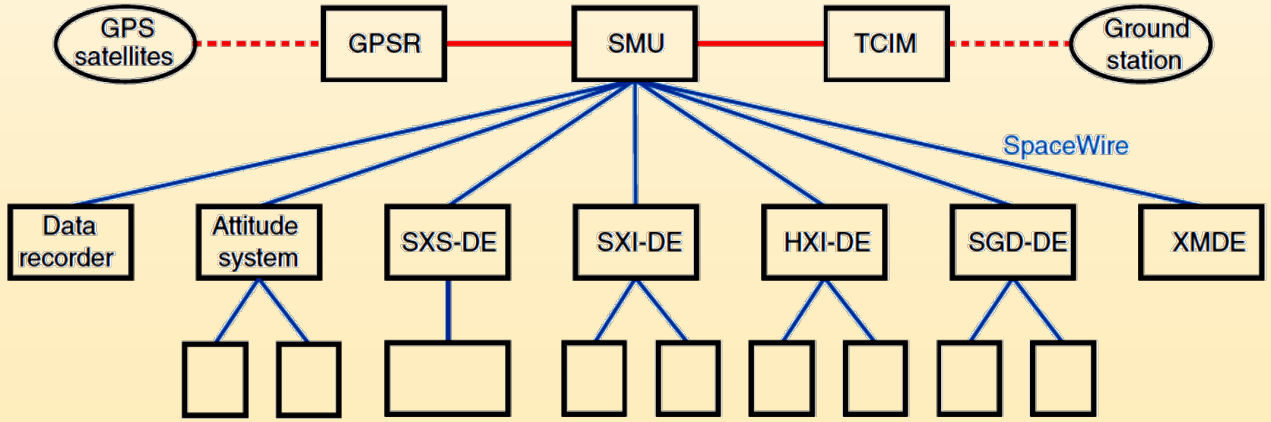
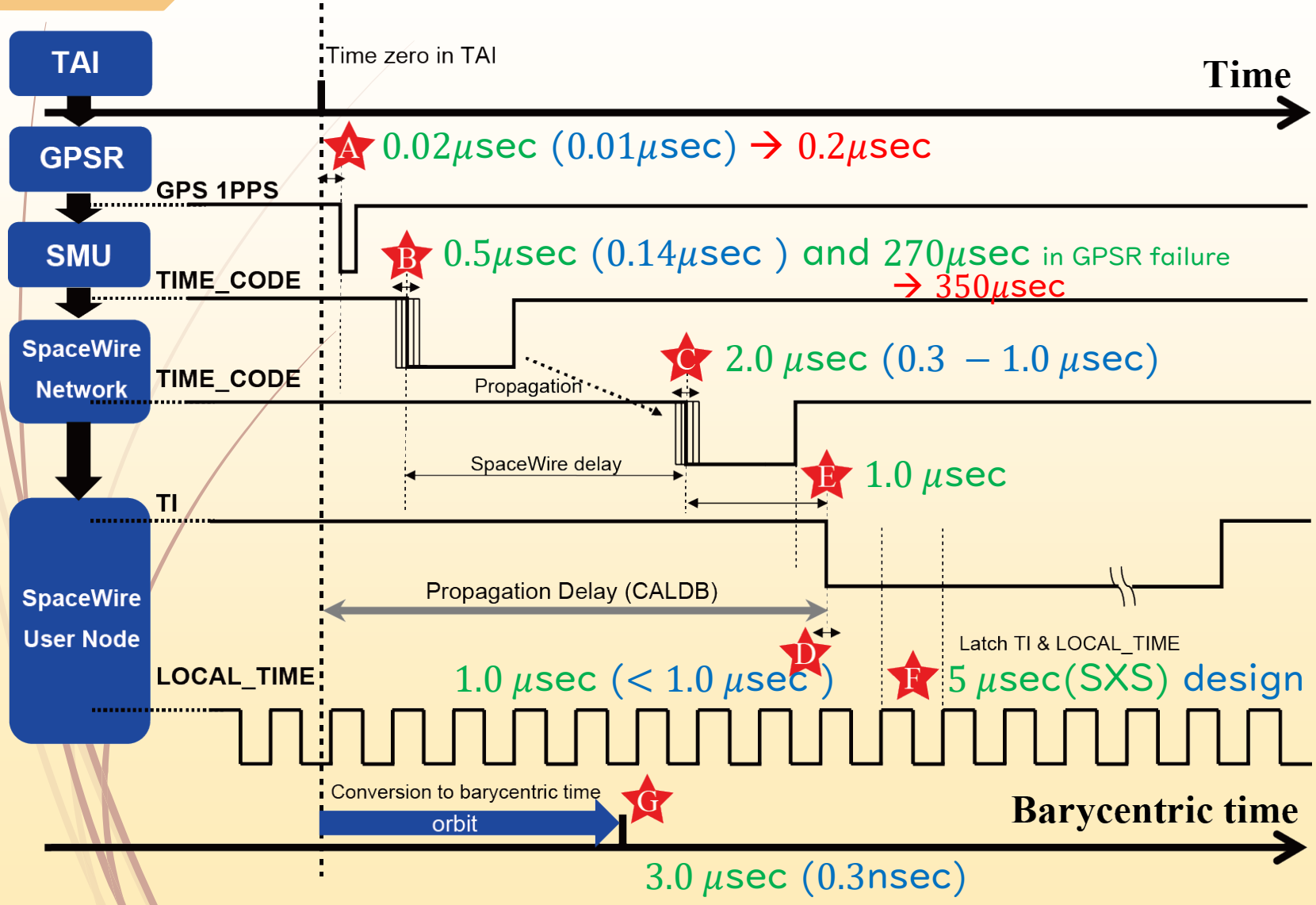


Fig. 1 A schematic diagram of the logical topology of the Hitomi network.[9] Boxes represent components onboard the spacecraft and ellipses are GPS satellites or the ground station. Communication lines (in blue) are realized by SpaceWire.

Error budget in timing accuracy

Terada et al 2018 JATIS



Distribution of Time info.

- ✓ TI is synchronized to TAI via GPSR
- ✓ Error budget was assigned by component and controlled.
- ✓ Hitomi design & performance are shown in green & blue.

- ✓ Updates for XRISM budget are shown in red.

Hitomi budget/performance, XRISM budget

Three steps in the development of Timing System

Step 1. Ground (before launch)

Component level development:

Design and verify the system by error items/components

Step 2. Commissioning phase (6 months after launch)

Total verification: Check "overall" timing performance

Step 3. PV + Calibration phase (now)

Parameter tuning: Tune timing parameters in CALDB

Calibration: Measure absolute timing accuracy

Step 0. Hitomi results

Table 6 Summary of performance by the timing error budgets.

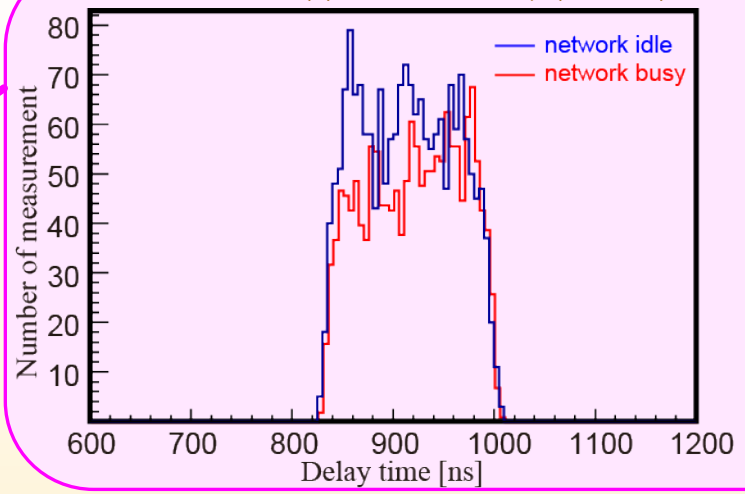
ID[a]	Component	Hitomi Performance
A	GPSR	0.01 μs
B	SMU	0.14 μs (GPS-ON)
C	SpaceWire network	0.3 to 1.0 μs (Table 4)
D	SpaceWire user node	<1.0 μs
E	Delay correction	<0.6 μs
F	Time resolution	5 or 25. 6 μs (Table 1)
G	Orbit	0.3 ns (GPS-ON), 0.5 μs (GPS-OFF)

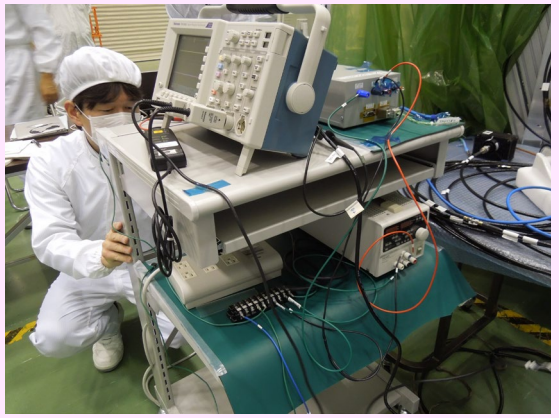
All OK ✓

Notes:
ID=A, E, F … design value
ID=G … orbital determination result

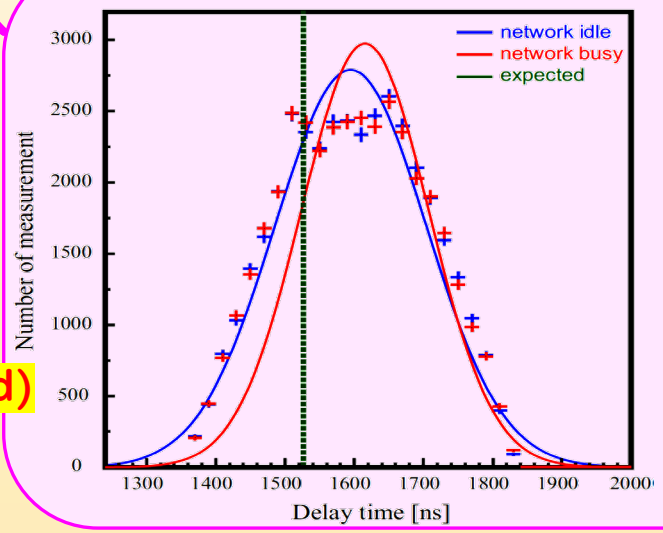
Note 2:
ID=B (GPSR failure mode) is not verified
→ See Shidatsu's talk (15 May Wed)

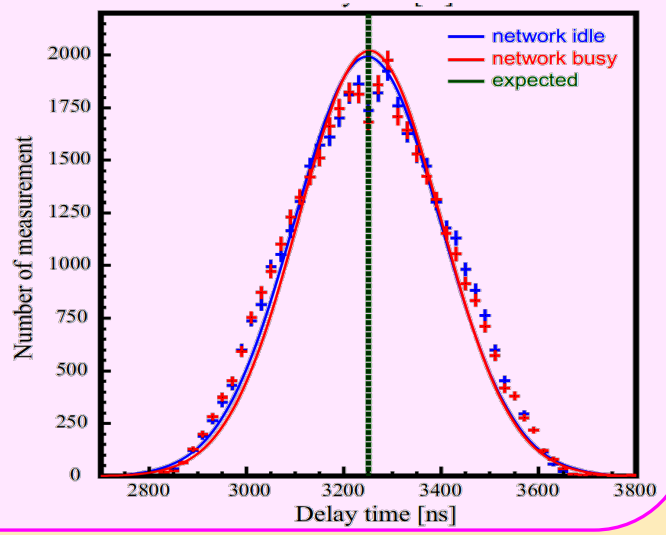
ID=B (*) Intrinsic delay (375 ns) is included





ID=C/D





XRISM uses the same timing system. Basically, all components satisfy the budget.

Step 1. Ground timing verification test

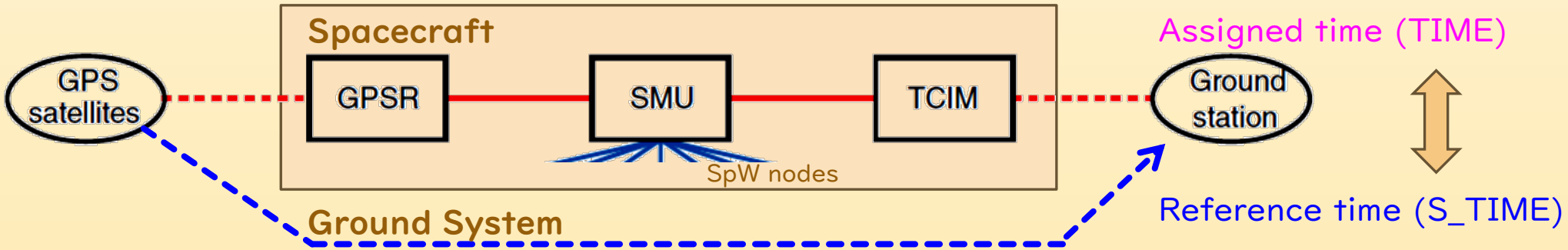
Goal: Pre-check of the overall timing performance before launch.
(i.e., check ID=A+B+C < 350 μsec)

Time, Place, and configuration:

- 26-28 Jan 2021 @ NEC Fuchu (bus system level)
- 13 Sep 2021 @JAXA TKSC (spacecraft bus system only, room temperature)
- 4 Aug - 1 Sep 2022 @ JAXA TKSC (flight configuration, thermal vacuum test)

Thermal Vacuum test 2022

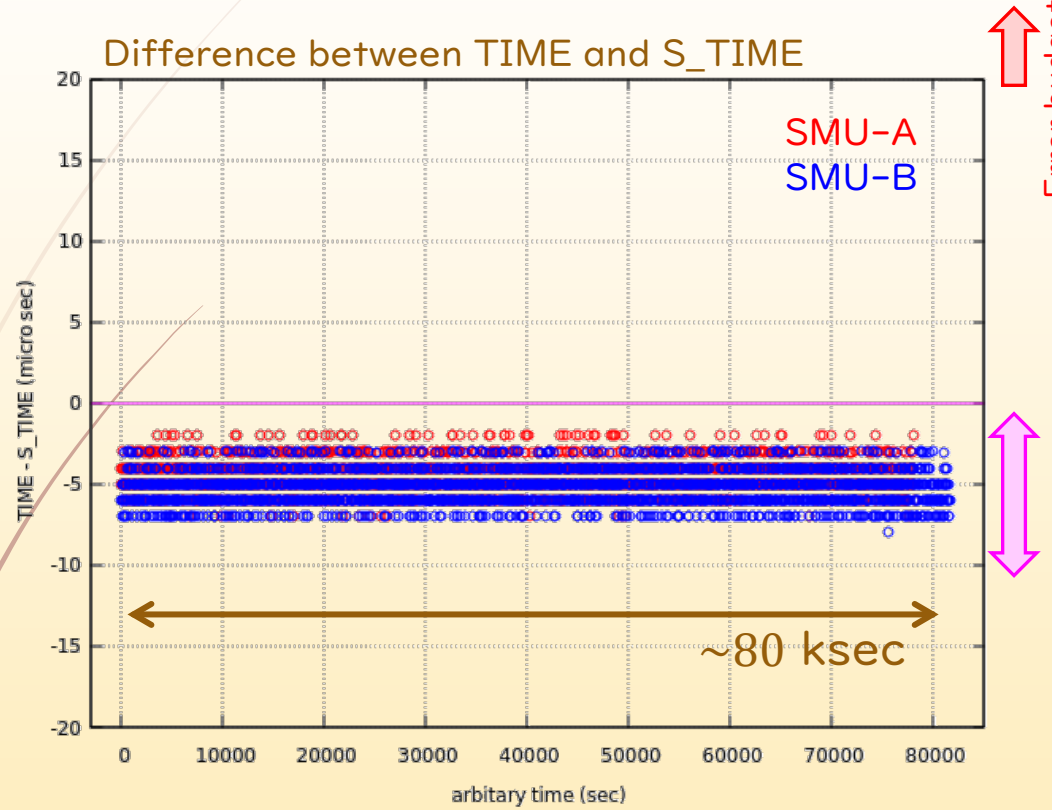
Setup: TIME is assigned in the pipeline process on ground using TI and look-up table in HK.
Ground system is synchronized with GPS time (TAI), which is used as a reference time.

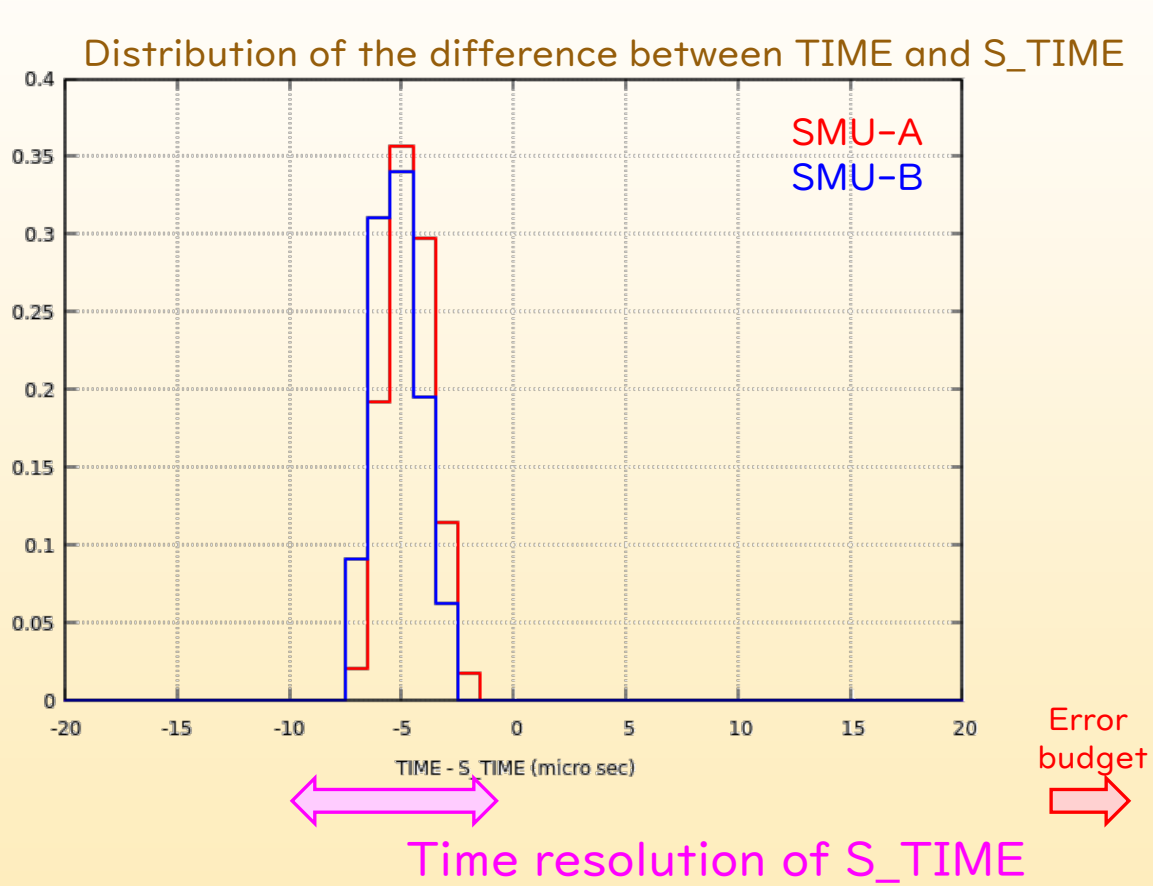


→ **TIME is tested by S_TIME**

Step 1. Ground timing verification test

Result: Time assignment of HK during GPS synchronized mode





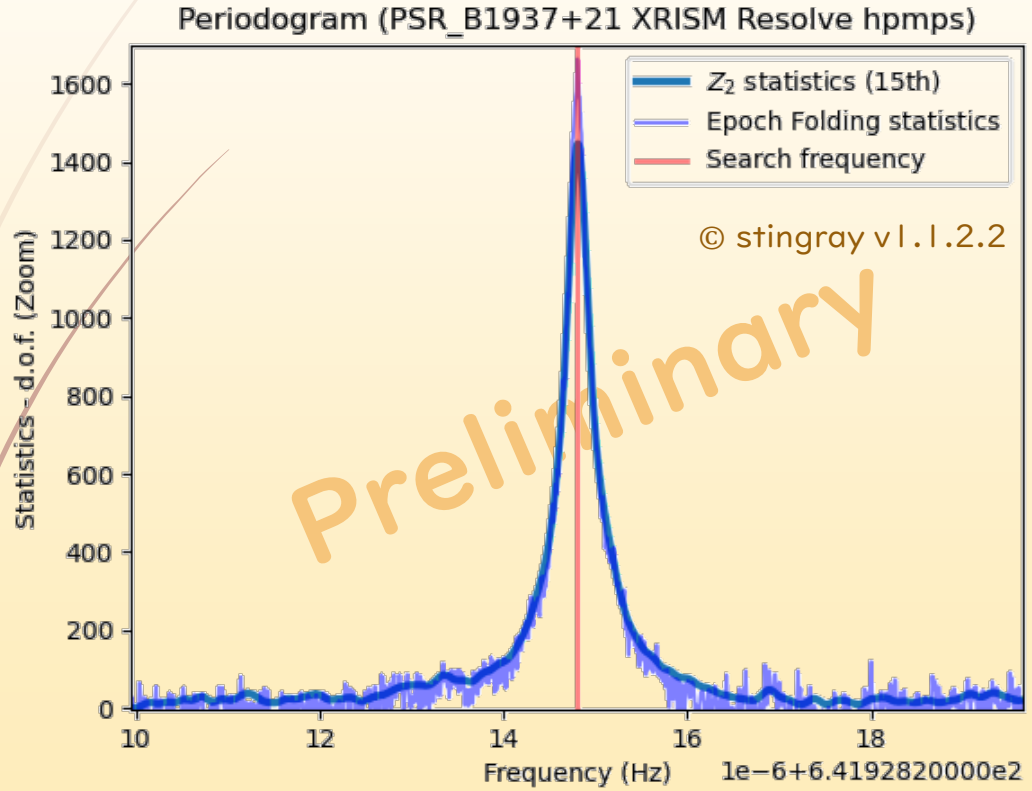
Accuracy of 'TIME' in the nominal mode is within the error budget (350μsec)

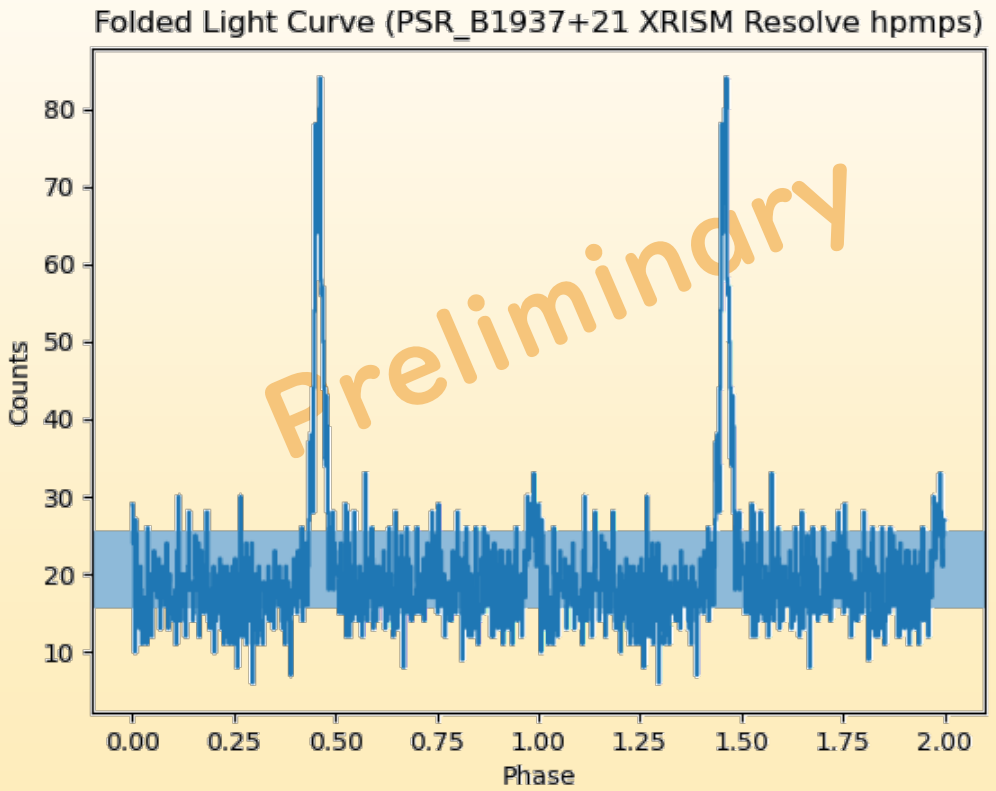
Step 2. Commissioning verification

Timing verification with mili-second pulsar, PSR B1937+21

- $P = 0.00155780656918537300$ sec
- $\dot{P} = -1.051003194988945 \times 10^{-19}$ sec/sec
- Exposure = 240 ksec

※ Nicer ephemeris in 2017-2022; H. Sun et al. 2023

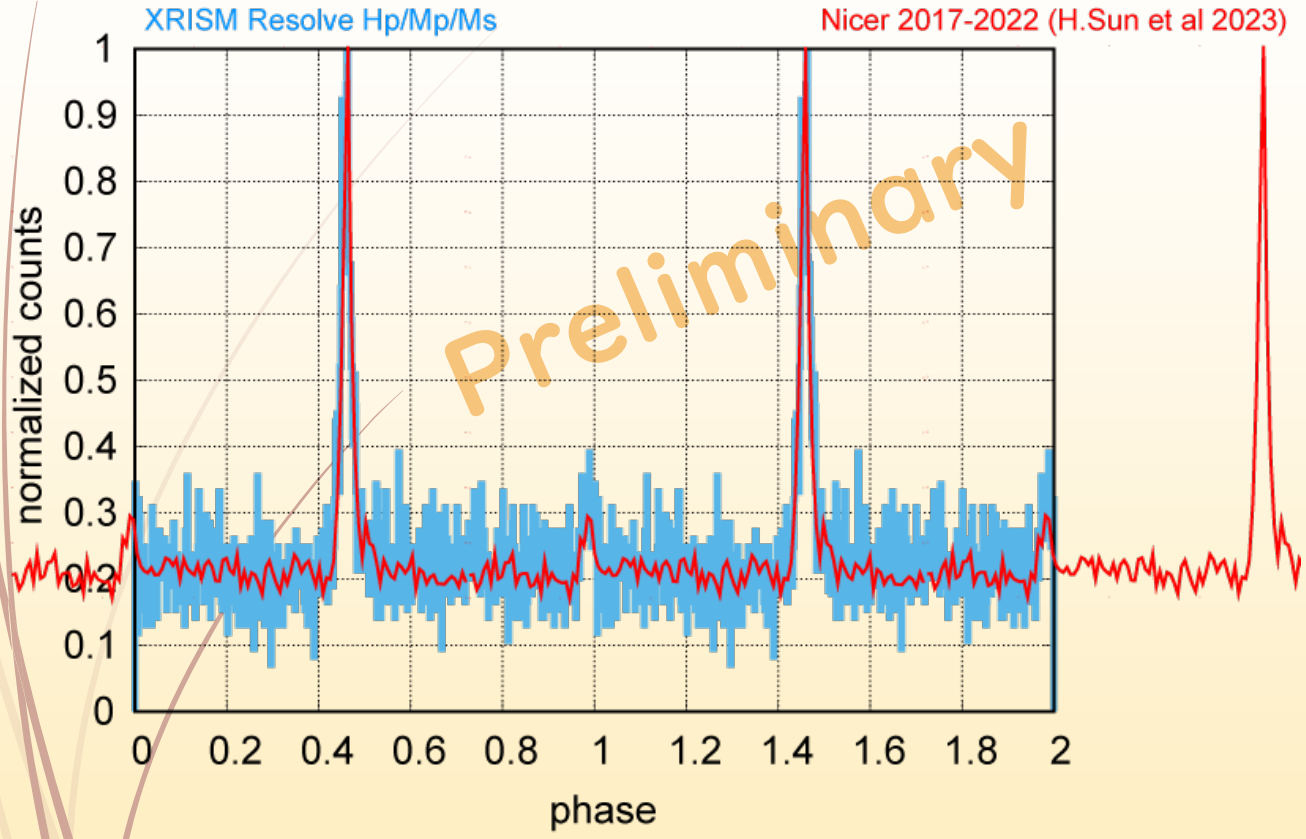


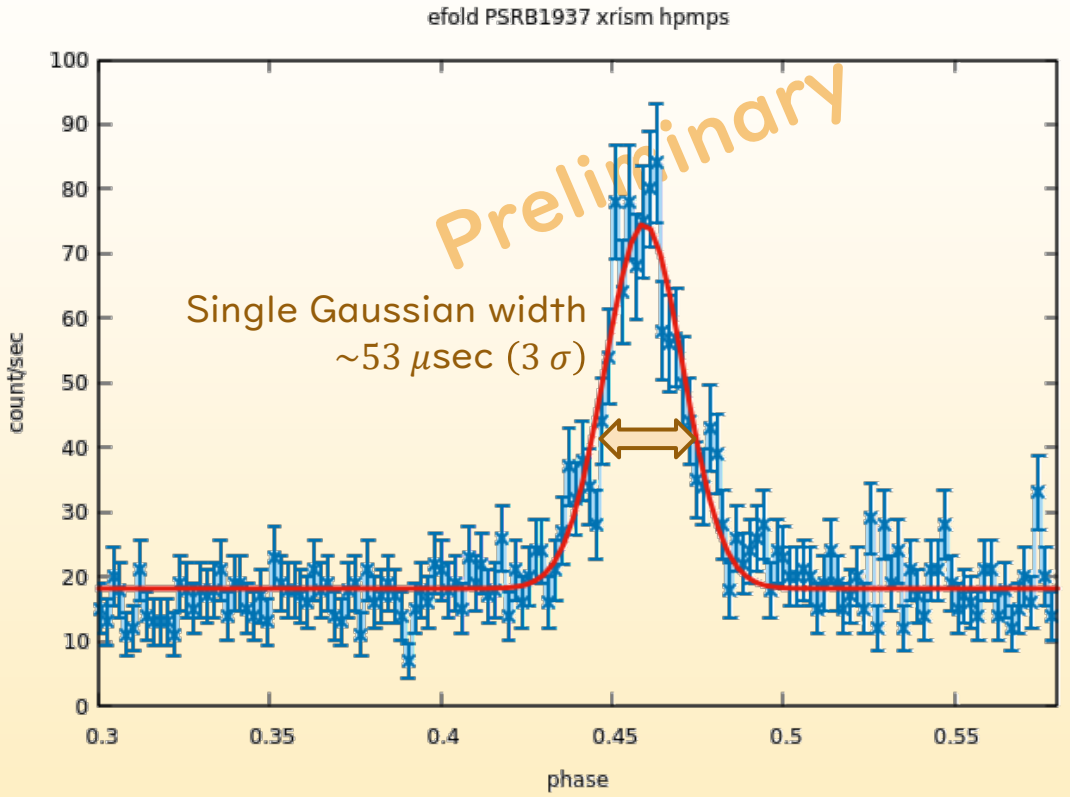


Note: Solar system ephemeris is different between NICER & XRISM

Periodic signal has been detected from ~700 events.

Step 2. Commissioning verification





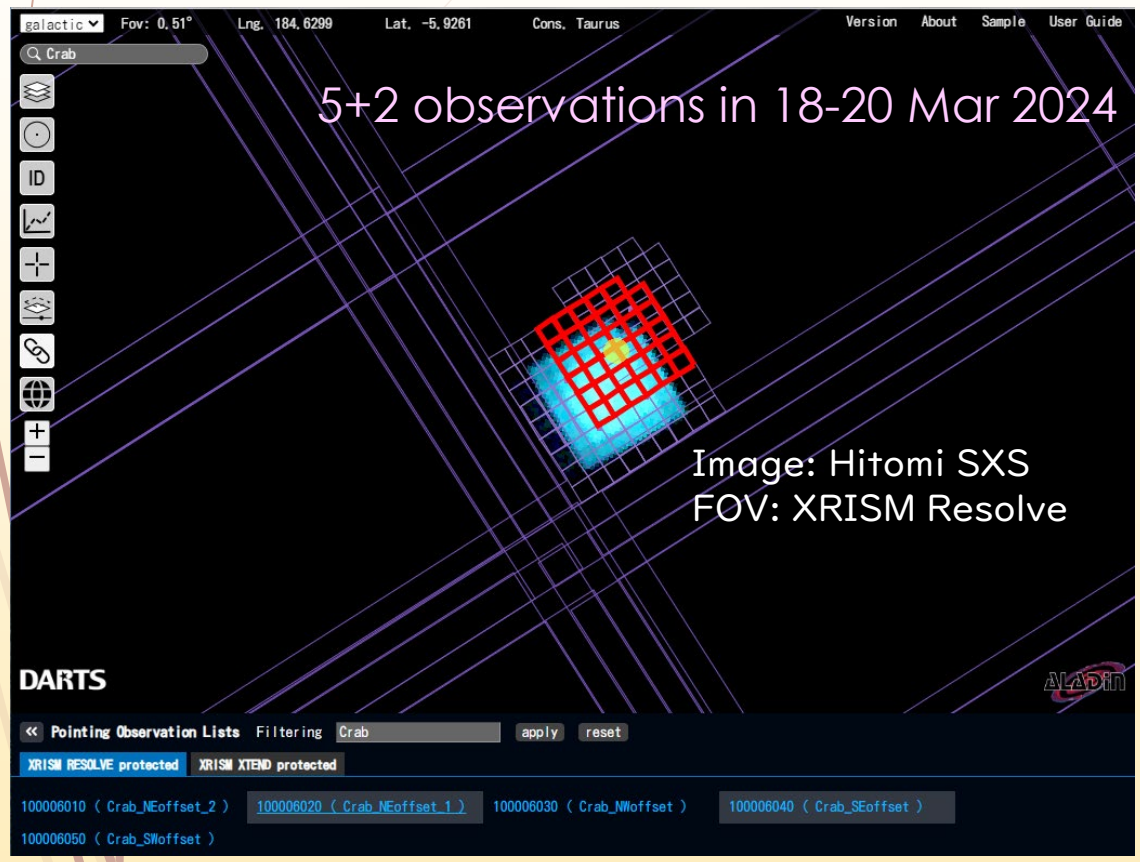
No major degradation of pulses from NICER profile

Degradation from NuSTAR (Gotthelf&Bogdanov 2017) $< 17\ \mu\mathrm{sec}\ (3\ \sigma)$

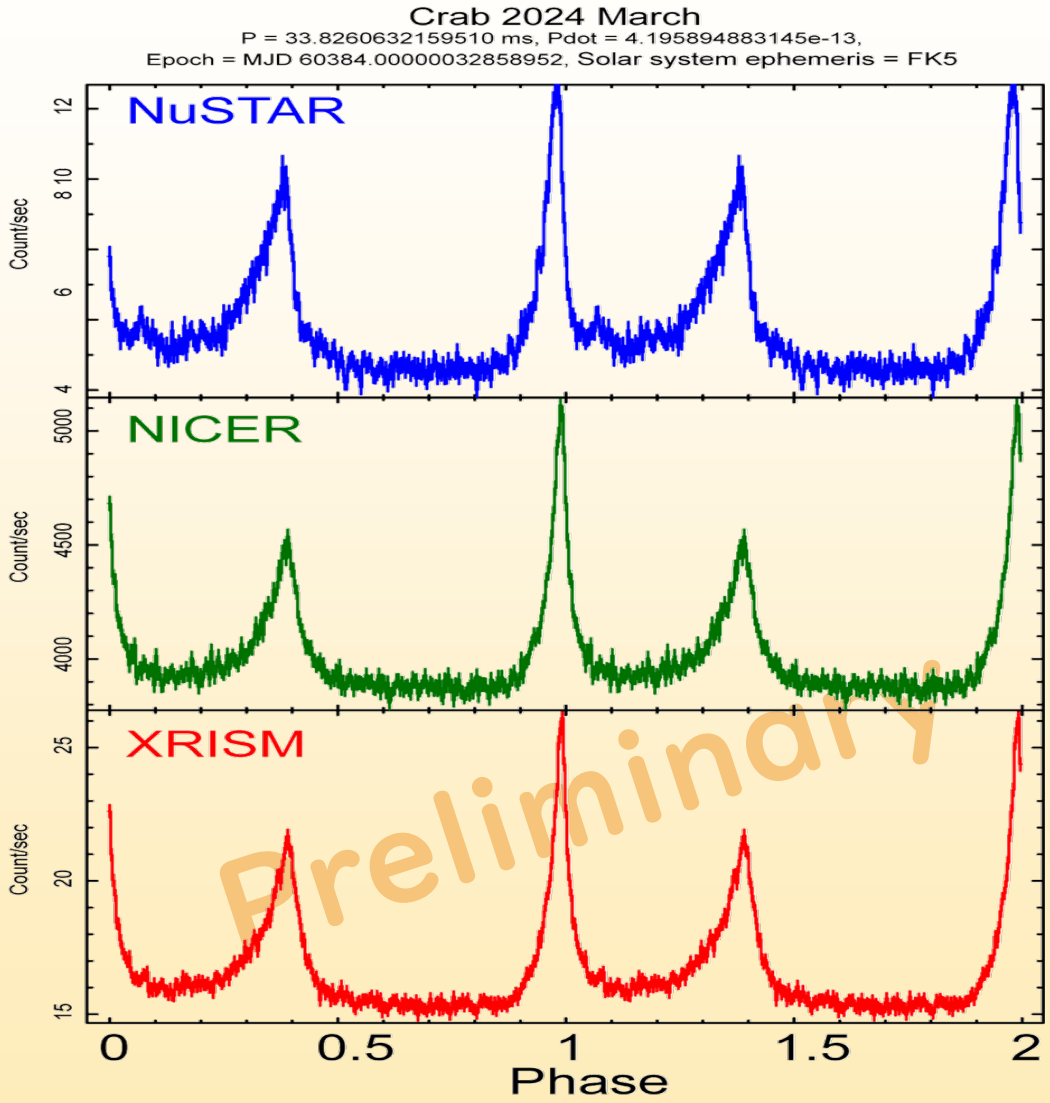
Commissioning: timing stability of the timing system has been verified.

Step 3. Timing calibration with Crab

Simultaneous observations with NICER/NuSTAR



https://app.darts.isas.jaxa.jp/judo2



Investigation on going → Come to Timing WG! (I 5 May Wed)

Summary

1. XRISM uses the same timing system as Hitomi, carrying GPS receiver.

2. In the design phase, timing accuracy of each component was verified.

3. On ground, we performed the ground timing calibration and concluded that the timing system satisfies the science requirement.

4. In the commissioning phase, we verified the performance of timing system using periodic signals from PSR B1937+21, and the test has been passed.

5. Now in the PV + calibration phase, we performed simultaneous observation of Crab with NICER and NuSTAR in Mar 2024, to tune the timing parameters and measure absolute timing accuracy.
   -- on going.