

PFS: Status of hardware commissioning at Subaru

The commissioning of the various PFS hardware subsystems started in 2018, with the metrology camera installed on the Cassegrain focus.

Since then, 2 science fiber cables, 2 spectrograph modules (with 2 visible cameras each), and the Prime Focus Instrument were successfully installed and tested at the summit.

Commissioning of these systems continues with regular improvement of design, stability and operation procedures.

We expect the last PFS hardware to be installed and commissioned during FY2023, with the installation of the 2 remaining science fiber cables, the third and fourth spectrograph modules and all four NIR cameras.

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Spectrograph Modules System (SpS)

PFS ~2400 science fibers will be connected to 4 identical spectrograph modules (SM), each receiving ~600 fibers. Every spectrograph module will host 3 cameras, covering the blue (380-650 nm), red (630-970 nm) and near-infrared (940-1260 nm) wavelengths [1].

The spectrograph modules are located on the top floor of the telescope dome, in a dedicated clean room, which temperature is precisely controlled ($4 \pm 0.25^\circ\text{C}$).

Currently, the clean room is hosting the first 2 spectrograph modules (SM1 and SM3) with 2 visible cameras (blue and red) on each of them (see Fig. 1).

SM1 have been stable since its installation in 2019, and performing as expected.

The only major maintenance being the replacement of SM1 red shutter, which belt broke due to manufacturing error.

The installation of the second SM (SM3) was completed in Nov. 2022 with the assistance of our colleagues from LAM (France) and commissioning is still ongoing (see Fig. 2).

Both spectrograph modules are now in use during the PFS engineering runs, while being connected to ~1200 science fibers.

During 2023, we expect to complete PFS spectrographs, with the delivery and installation of the first 2 NIR cameras on SM1 and SM3 (in Mar./Apr.) and the remaining spectrograph modules, SM2 and SM4 (in Jun./Jul.).

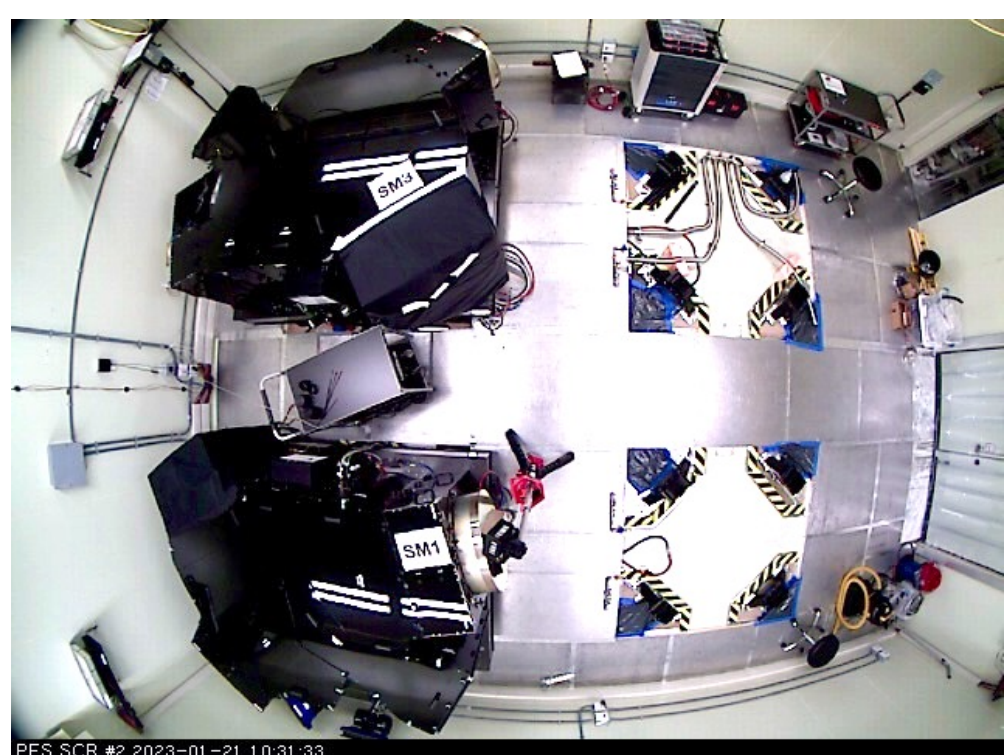
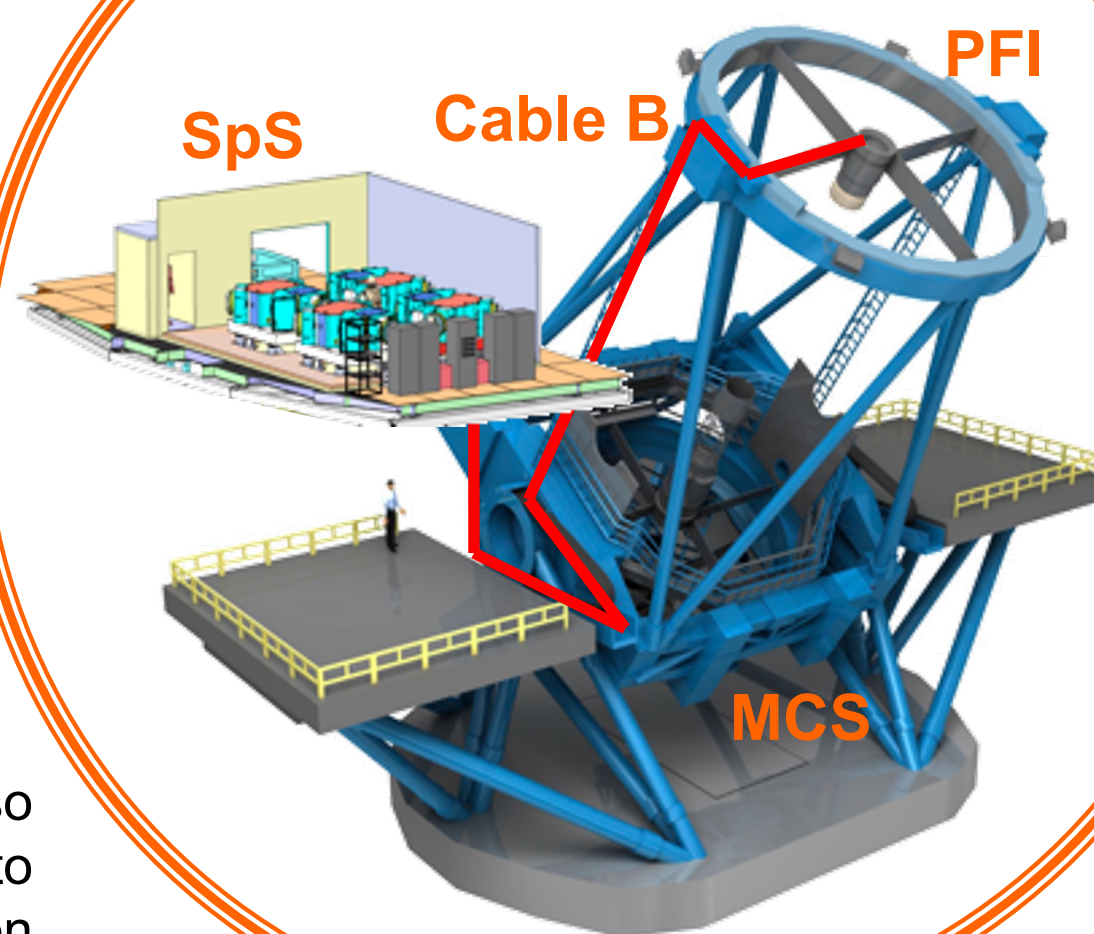


Fig. 1: Top view of the spectrograph clean room, with SM1 (bottom left) and SM3 (Top left)



Fig. 2: SM3 (right) during integration at Subaru.



Prime Focus Instrument (PFI)

The Prime Focus Instrument hosts PFS focal plane with all ~2400 science fibers on their individual cobra positioners, and 6 auto-guiding cameras. During observation, PFI is installed inside POpt2 (the prime focus unit), behind the wide field corrector, at Subaru prime focus, similarly to HSC (see Fig. 4). While not in use, PFI is stored on the unit selector with the other prime focus instruments and secondary mirrors (see Fig. 3).

PFI was delivered to Subaru in June 2021, from our colleagues at ASIAA, and subsequently commissioned on the telescope during various engineering runs [2/6]. Since then, various maintenance and corrective actions have been performed on PFI, including the modification of the rotator limit switches,

the repair of a leak sensor and the stabilization of its auxiliary electronics.

The operation of the auto-guiding cameras was successfully confirmed during previous engineering runs, but they still need to be integrated to the telescope tracking system, with assistance from MELCO. This work is scheduled for Apr. 2023.

In Feb. 2023, small windows will also be installed in front of the auto-guiding cameras to correct a focus offset (~0.6mm) between the science fibers and the auto-guiding cameras.

Work is also ongoing to optimize the PFI installation process, from the unit selector to the telescope prime focus (see Fig. 4).



Fig. 3: PFI stored on the unit-selector



Fig. 4: PFI being installed on the telescope prime focus

Science fiber Cables (Cable B)

The ~2400 science fibers are spread amongst 4 pairs of fiber cables, ~55m long, connecting PFI on the telescope prime focus (see Fig. 5) to the spectrographs on the top floor of the dome (see Fig. 6).

Each pair of cable includes 2 strain relief boxes and a monitoring system to confirm the fiber connection on PFI [3].

As of today, all 4 science fiber cables were delivered to Subaru, while 2 of them were installed on the telescope in Feb. 2021 (see Fig. 7) and Apr. 2022. These 2 science fiber cables are now connected to the spectrograph modules SM1 and SM3. Performance measurements of the science fiber cable were performed just before and after installation, including focal-ratio degradation, uniformity, and throughput. The results were consistent with previous measurements at LNA in Brazil and PFS requirements.



Fig. 5: Inside view of the tower connector (~600 fibers), interfacing with PFI

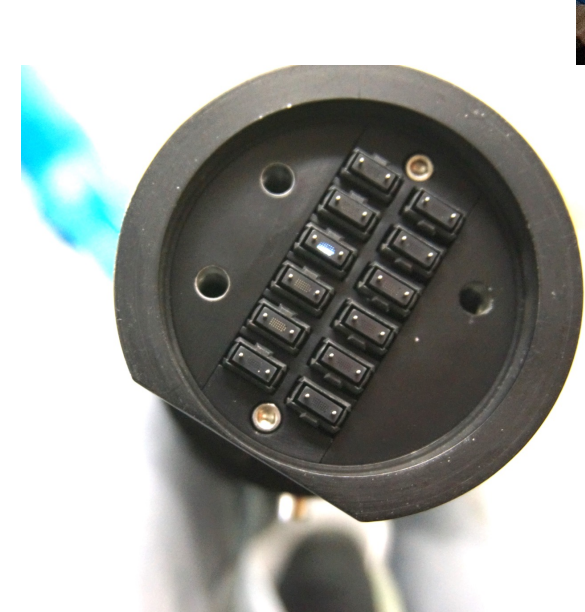


Fig. 6: One of two gang connector (~300 fibers), interfacing with a spectrograph module

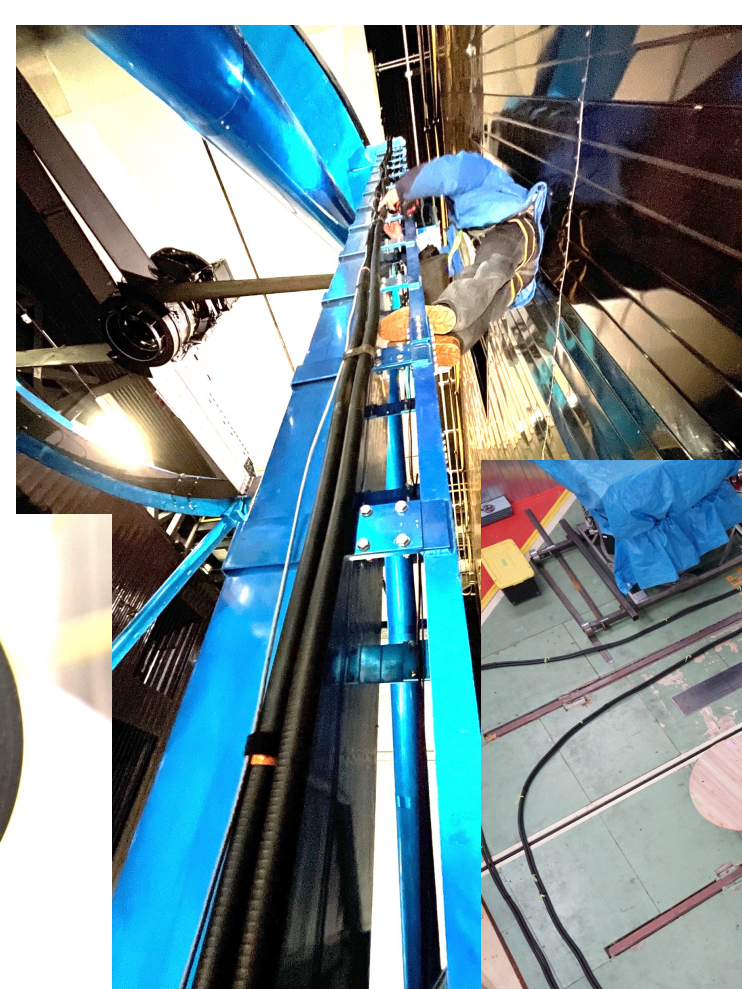


Fig. 7: Installing Cable B#1 along the side of the telescope

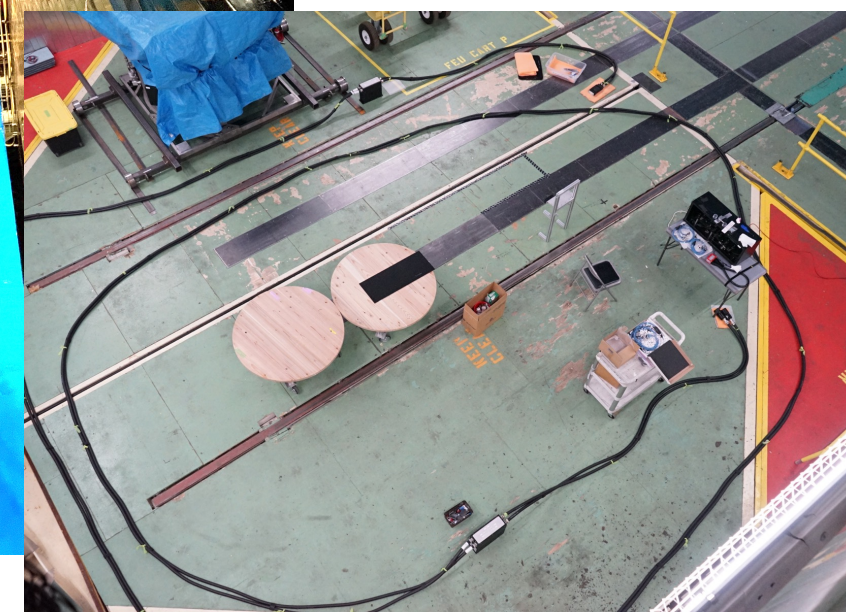


Fig. 8: Cable B#3 laying down on the observation floor during testing, prior to installation

Metrology Camera System on Cassegrain focus (Cs-MCS)

The metrology camera (Cs-MCS) is a 380mm Schmidt telescope located at the Subaru Cassegrain focus, equipped with a 50M pixel camera. It is used to take images and measure the positions of the back-illuminated science fiber on the focal plane [4].

Cs-MCS was installed and commissioned in 2018 (see Fig. 9), using a back-illuminated pinhole mask on the focal plane. The only major repair made on Cs-MCS was the modification of its primary mirror support structure in 2019, to reduce stress on the mirror and improve Cs-MCS image quality.

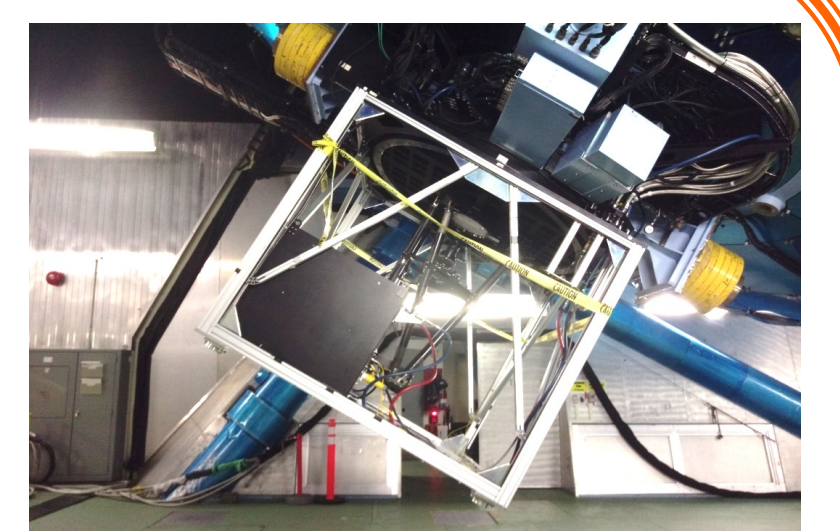


Fig. 9: Cs-MCS on Cassegrain focus

Metrology Camera on the Unit-Selector (US-MCS)

A smaller version of the metrology camera was recently installed below PFI on the unit selector, where PFI is stored when not in use (see Fig. 10). This camera is currently being tested and will be used to continue the commissioning of PFI while in standby, and perform functionality tests before observation.

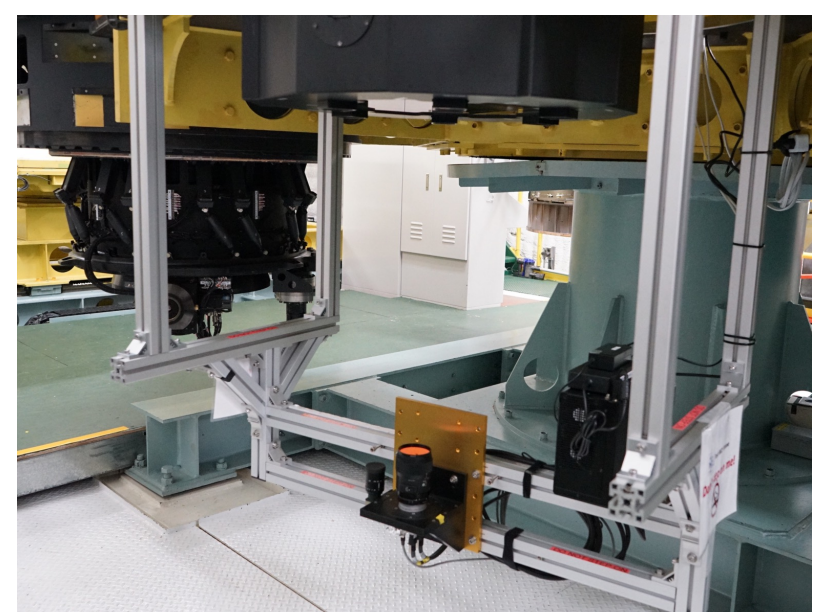


Fig. 10: US-MCS below PFI on the unit-selector

Subaru Night Sky Spectrograph (SuNSS)

The Subaru Night Sky Spectrograph (SuNSS) is a dedicated instrument used to measure the spatial and temporal variation of the night-sky background emissions, in order to improve the accuracy of sky subtraction on PFS spectra [5].

SuNSS is composed of 2 small aperture (~36mm) telescopes permanently attached to Subaru spider arm (see Fig. 11). One has a clear lens, while the other uses a diffuser. Each of them feed the sky emission to 127 fibers, connected to one of PFS science fiber cable, and one of PFS spectrographs, while PFI is not used

SuNSS was installed in 2021, and since then several hundreds of hours of data was taken, including data for the stability test of the first spectrograph (SM1) and the first science fiber cable (CableB#1).

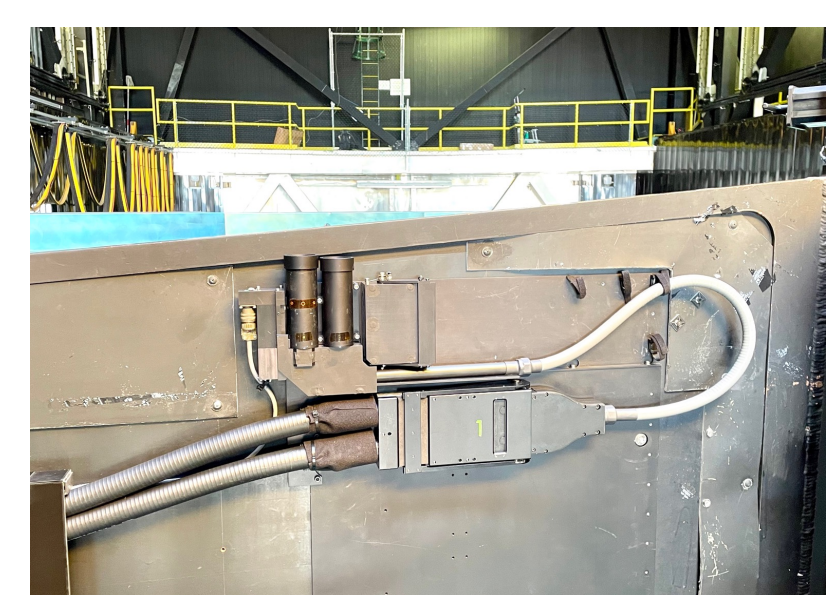
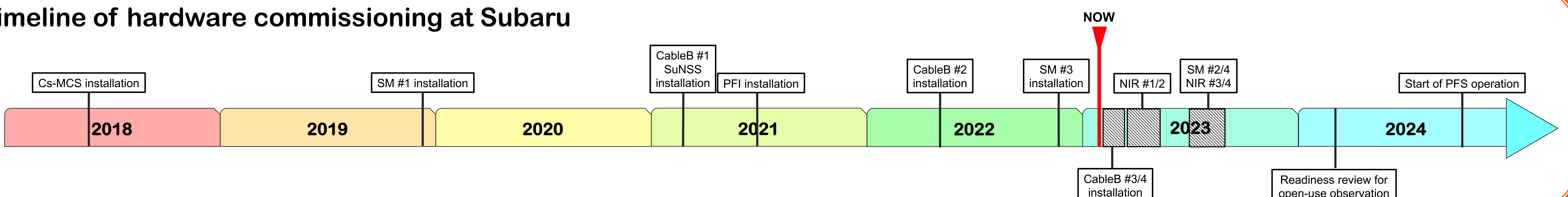


Fig. 11: SuNSS on telescope spider arm, connected to Cable B#1

Timeline of hardware commissioning at Subaru



- [1] Prime Focus Spectrograph (PFS) for the Subaru Telescope: its start of the last development phase, Naoyuki Tamura et al., SPIE 2022
 [2] Prime focus spectrograph (PFS) for the Subaru Telescope: the prime focus instrument, Shiang-Yu Wang et al., SPIE 2022
 [3] Prime Focus Spectrograph (PFS): fiber optical cable and connector system (FOCCoS) – integration, Antonio Cesar de Oliveira et al., SPIE 2022
 [4] Prime Focus Spectrograph (PFS): the metrology camera system, Shiang-Yu Wang et al., SPIE 2020
 [5] Subaru Night-Sky Spectrograph (SuNSS): fiber cable construction, Antonio Cesar de Oliveira et al., SPIE 2022
 [6] Subaru FY2022 User Meeting poster "Summary of PFS Engineering Observations in FY 2022", Shintaro Koshida