すばる望遠鏡の安定運用と機能向上:
「すばる２」から「すばる３」へ

Stable Operation and Upgrade of the Subaru Telescope:
From Subaru-2 to Subaru-3

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Presentation at NAOJ Future Symposium on 2024/12/03 JST

1. Summary of the Proposal

- Stable operation of Subaru Telescope
- Upgrade science capabilities of Subaru toward 2030s
- Respond community's demands (Subaru crucial for many other LoIs)
- Foster young generation in OIR astronomy

2. Science Goals

- Origin of the cosmic structures
- Formation and evolution of galaxies and blackholes
- Dark matter and dark energy
- Exoplanet, life in the universe

3. Scientific Objectives

- Understand the nature of dark matter and dark energy
- Understand the physical mechanisms of galaxy formation and evolution
- Contribute to multi-messenger astronomy
- Identify earth-like exoplanet

The main objective of this roadmap proposal is to maintain stable open-use observations of Subaru Telescope, and to continue support of development and acceptance of new instruments.

4. Scientific Investigations

5. Instruments and Data To Be Returned

- IRD SSP (2019-2025, 170 nights) [exoplanet, Subaru-2]
- PFS SSP (2025-2030, 360 nights) [cosmology, galaxies, Subaru-2]
- ULTIMATE SSP (2029-2034, >300 nights) [galaxies + MW, Subaru-2/3]

- These key surveys will be executed in parallel with semester-based normal open-use programs to respond to the wide variety of science demands from the community.
  - Open Use : SSP = 1 : 1
- Programs are *not* coordinated by the observatory *but* by the community leadership (SAC/TAC)
- Observatory goal: Continue stable operation of Subaru at Maunakea even beyond 2033.

6. Originality and International Competitiveness

- Upcoming wide-field facilities:
  - LSST/Rubin Observatory (optical)
  - ESA's Euclid, NASA's Roman Space Telescope (NIR)
- Subaru's originality and competitiveness:
  - Unique access to northern sky
  - Variety of photometric filters in (HSC & ULTIMATE)
  - Excellent wide-field + multi-object spectroscopic function (PFS)

7. Current Status

- "Subaru-2":
  - IRD: SSP until 2025A
  - PFS: science operation and large survey starting from 2025A
  - ULTIMATE: final design phase, to be completed in ~FY2028
- "Subaru-3":
  - Recently kicked off community discussion for Subaru-3 concept.
  - ULTIMATE: its survey will continue toward Subaru-3.

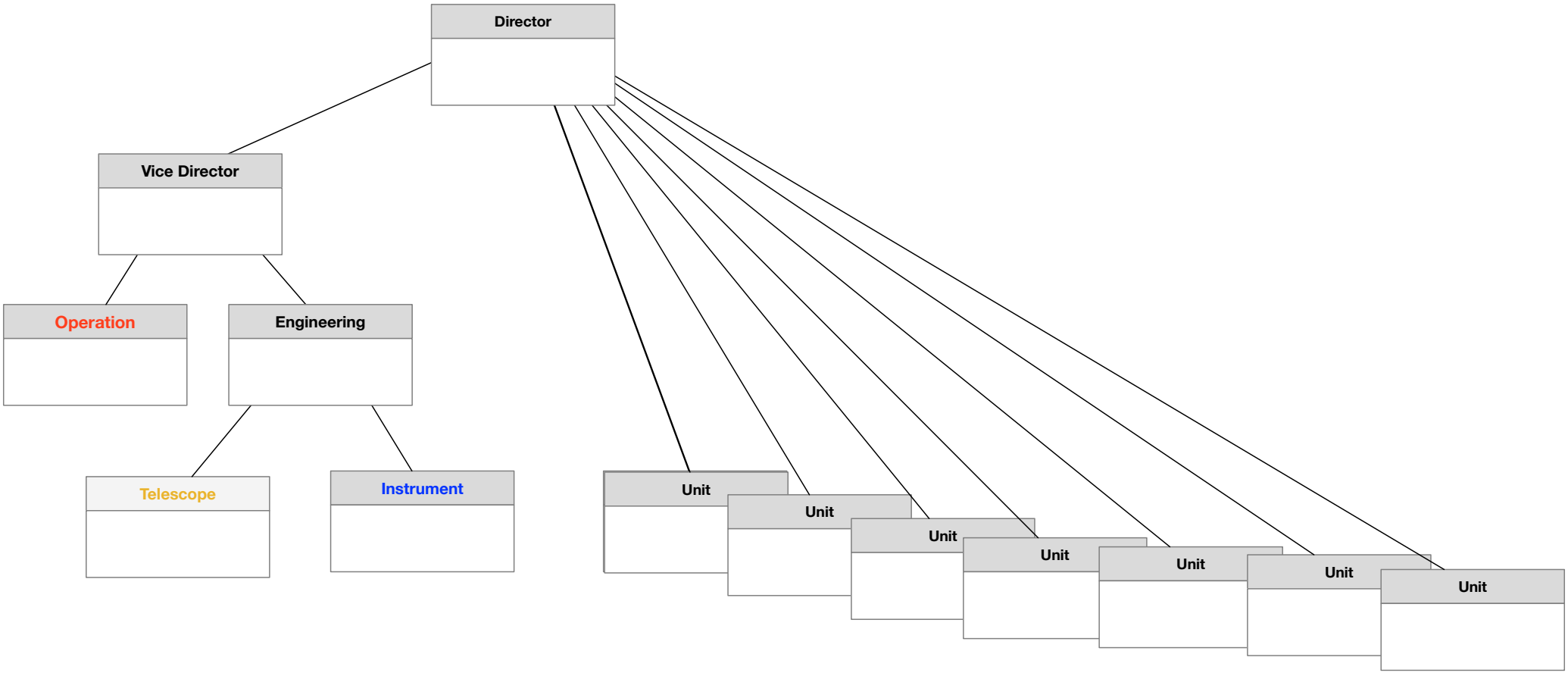
8. Cost Assessments, Budget Line and Status

- Expect continuous support from "Frontier budget" throughout Subaru-2 and Subaru-3.

- Considering all necessary costs required for normal operation and the development of Subaru-3 instruments (assuming similar scale to the Subaru-2 instruments), we need ~25億円/yr.

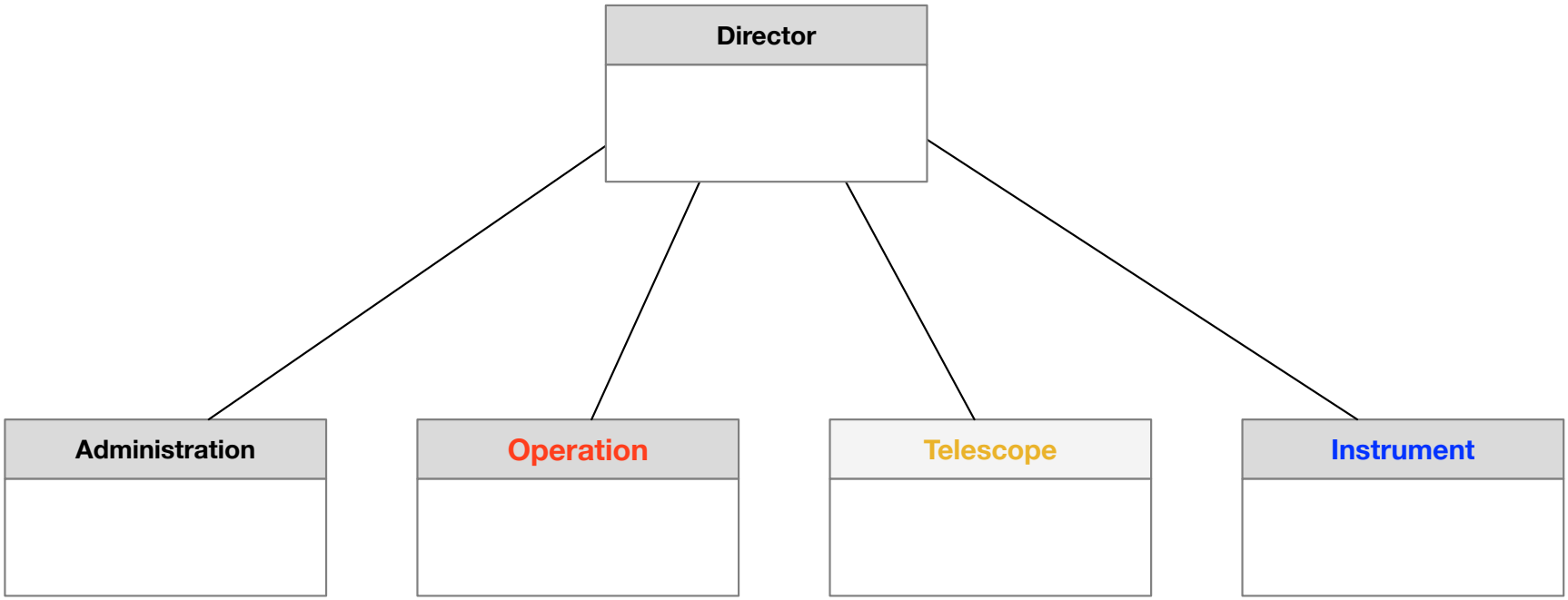
9. Project Organization

Before



9. Project Organization

After 2024/09/16



9. Project Organization

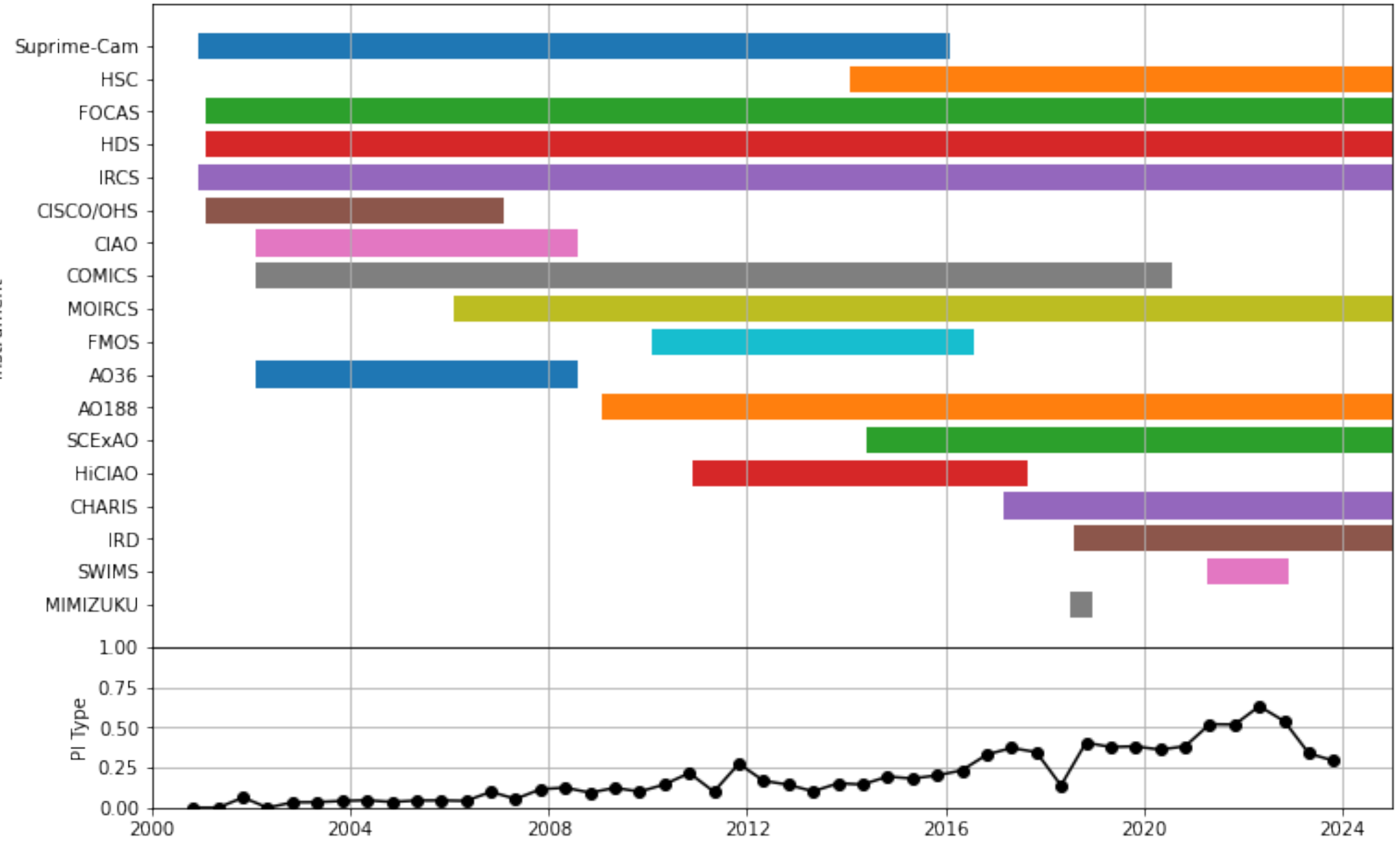
After 2024/09/16
Standing Committee

- Un-crewed Night Operation (OHia) Committee
- Archival Data Management Committee
- Nasmyth IR Management Committee
- Education Committee

10. Why NAOJ?

- NAOJ is obviously the only-one institution who can operate the large, complicated telescope facility like Subaru.
- With >25 years of experience and history in successful operation and community support since its construction.
- Excellent environment of surrounding centers - we need support of ATC to build new instruments (ongoing for ULTIMATE), and ADC for long-term data archive as well as the new-generation science platform for large datasets.

Subaru Instrument Suite so far



SWIMS: 2019/5/28 (Eng) - 2022/12/7

Subaru Instrument Suite so far

Name	Description	lambda	focus	GP	PI
Suprime-Cam	Imager (0.5deg)	VIS	P	○	
HSC	Imager (1.5 deg)	VIS	P	○	
FOCAS	Multi Object Spec. Img	VIS	Cs	○	
HDS	High Dispersion Spec.	VIS	Ns-OPT	○	
IRCS	Spec. Img.	NIR	Cs , Ns-IR	○	
CISCO/OHS	Spec. Img.	NIR	Ns-IR	○	
CIAO	Coronagraph Imager	NIR	Cs		
COMICS	Spec. Img.	MIR	Cs	○	
MOIRCS	Multi Object Spec. Img	NIR	Cs	○	
FMOS	Multi Object Spec.	NIR	P	○	
AO36	Adaptive Optics (36 ele.)	NIR	Cs	○	
AO188	Adaptive Optics (188 ele.)	NIR	Ns-IR	○	
SCExAO	Extreme AO	NIR	Ns-IR		○
HiCIAO	Coronagraph Imaging	NIR	Ns-IR		○
CHARIS	Spec. Img for SCExAO	NIR	Ns-IR		○
IRD	High Dispersion Spec.	NIR	Ns-IR		○
SWIMS	Multi Object Spec. Img	NIR	Cs	○	○
MIMIZUKU	Spec. Img.	MIR	Cs	○	○

Subaru Instrument Suite so far

- General Purpose Instruments have been popular quite for a long time
  - Suprime-Cam/HSC, FOCAS, HDS, IRCS, MOIRCS
- Special purpose instruments or instrument with sharp performance completed the science mission in 6 - 7 years, and were decommissioned after that.
- Fraction of nights spent for PI type instrument increased which is not healthy in the long run.
- Subaru as a test bench: MIMIZUKU and SWIMS
  - Good idea for community, but acceptors at the observatory occasionally became hectic because lots of exceptions tends to pop up. Returns should be clarified.

Coming Subaru Instruments

Name	Description	Wavelength	Focus	G.P.	PI	Operational
PFS	Multi Object Spec.	VIS NIR	P	○		2025/02 ~
GLAO	Ground Layer AO	NIR	Cs	○		2029 ~
WFI	Imager 0.3deg)	NIR	Cs	○		2029 ~

Subaru 3 Instruments

- Subaru 3 Workshop last August organized by Subaru Advisory Committee (Chair: M. Oguri)

Subaru 3 Workshop 2024

- Purpose: Speculate the future of Subaru in 2032 - 2041 !

Subaru 3 Workshop 2024

- Day 1

8/29 (木)

座長：大栗

11:00-11:25 (I) 小山佑世 すばるを取り巻く地上大型望遠鏡の今後の方向性

11:25-11:45 秋山正幸 すばる３とTMTの連携可能性

11:45-12:05 佐藤文衛 超高波長分解能分光観測による系外惑星探索と恒星活動現象の解明

Summary of rival projects

Working with TMT

座長：佐藤

13:30-13:55 (I) Olivier Guyon Exoplanets & Beyond with ExtremeAO-fed Instrumentation

13:55-14:20 (I) 小谷隆行 すばる３時代に望まれる系外惑星用の観測装置について

14:20-14:40 田村元秀 Ultra-Dopplerによる太陽系の双子の探査

Extreme AO prospects

Exoplanet search instruments

座長：川端

15:00-15:25 (I) 田中雅臣 すばる3とマルチメッセンジャー天文学

15:25-15:50 (I) 秋田谷洋 これからの地上からの近紫外線観測

15:50-16:10 海老塚昇 高分散・高帯域幅・高効率の新しい透過型回折格子

座長：宮崎

16:30-16:55 (I) 川端弘治 10-20年後のすばるによる偏光観測で目指すもの

16:55-17:15 西澤淳 Subaru HSC Medium band survey

17:15-17:40 (I) 宮武広直 すばる３で拓く高赤方偏移宇宙論

Polarimetry

Future Cosmological studies

Subaru 3 Workshop 2024

- Day 2

8/30 (金)
座長：小山
9:30-9:55 (I, R) 百瀬莉恵子 若手研究者のすばる3への参加機会
9:55-10:20 (I, R) 田村直之 PFS のアップグレードについて
10:20-10:40 平居悠 PFS高分散分光モードと銀河形成シミュレーションで探る銀河系形成

PFS upgrade

座長：小宮山
11:00-11:25 (I) 千葉柾司 すばる３時代のPFS：高分散分光機能の実装で世界最強へ
11:25-11:45 鈴木善久 すばる多天体高分散分光器を用いた銀河考古学のレガシーデータセット構築への展望
11:45-12:05 松野允郁 PFS HR で切り拓く2030年代の銀河考古学

座長：高田
13:30-13:50 小上樹 すばる望遠鏡/PFS HR modeで探る局所銀河群球状星団の性質
13:50-14:10 佐藤恭輔 すばる望遠鏡/PFS High-resolution modeで探る銀河系矮小銀河の形成史
14:10-14:35 (I) 小宮山裕 大フォーマットCMOSセンサーで展開する広視野高時間分解能観測

High speed CMOS camera

座長：諸隈
14:55-15:20 (I) 児玉忠恭 ULTIMATE survey of large scale structures and massive galaxies in the early Universe
15:20-15:45 (I, R) 美濃和陽典 すばる３時代のULTIMATEと補償光学観測の展望
15:45-16:00 宮崎聡 Habitable Worlds Observatory
16:00-16:30 議論

ULTIMATE Upgrade

Subaru 3 Workshop 2024

- Upgrade of Instruments
  - PFS
    - High resolution mode (re-route)
    - Integrated Field Unit mode (a swap of the fiber head unit)
  - HSC
    - Polarimetry
    - High speed readout (CMOS)
  - ULTIMATE
    - More powerful AO
    - Multi object spectrograph (inc. IFU)
  - SCExAO
    - Continuous upgrade (via AO 3K)
    - SCExAO as a test bench of new coronagraph systems for HWO

Subaru 3 Instruments

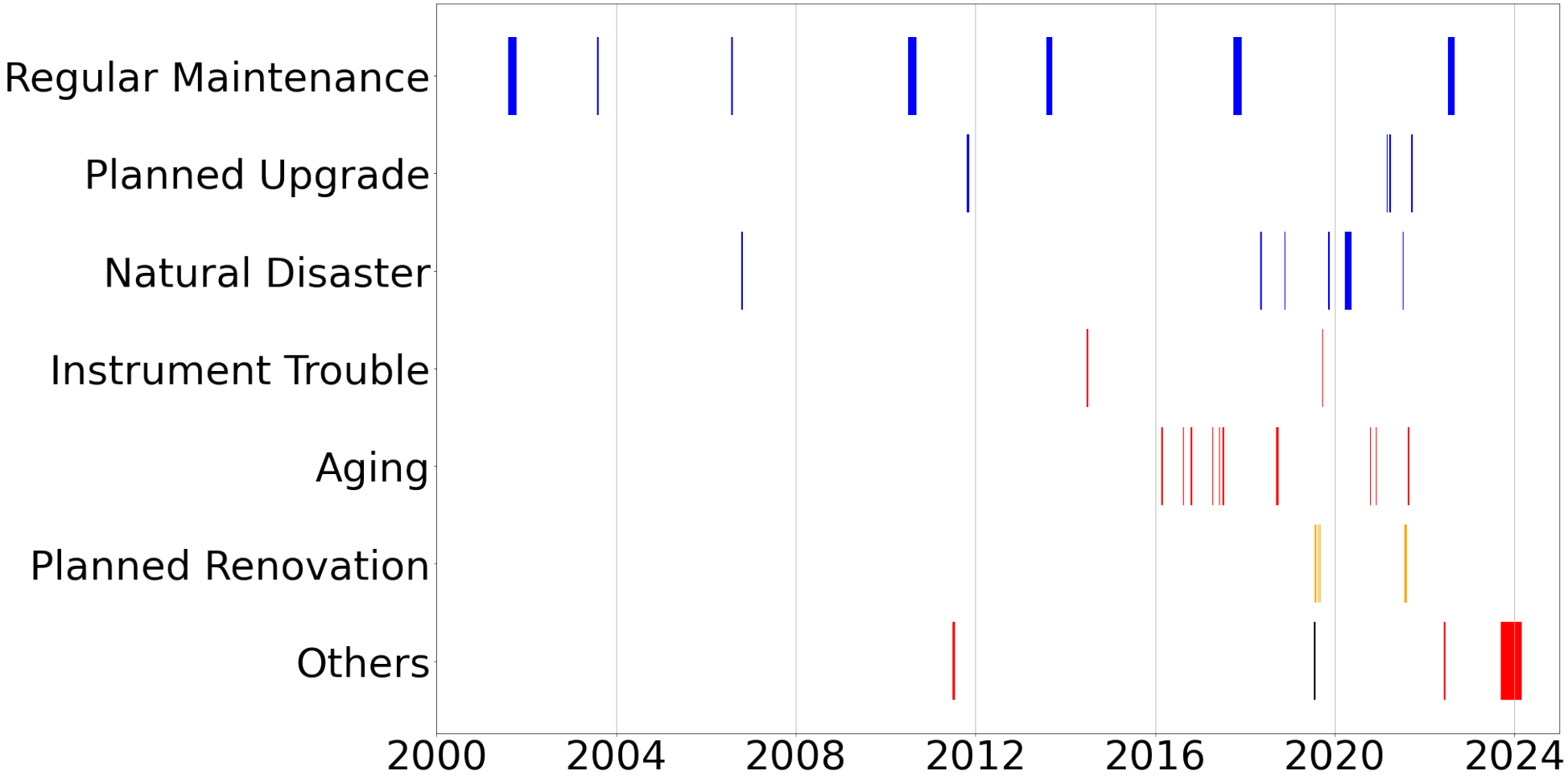
- Instruments should be proposed by well motivated groups of scientists from the bottom.
  - Top-down projects are usually boring, and short life with poor results.
- Budget has to be secured by the projects.
- Subaru and NAOJ are responsible for making necessary arrangements, and supporting selected projects as 黒子.

Observatory operation in the Subaru 3 era

Three Key Points:

- Counter measures against the aging facility
- Implementation of un-manned night operations
- Foster young generation in OIR astronomy

Observatory operation in the Subaru 3 era



Observatory operation in the Subaru 3 era

Observatory operation in the Subaru 3 era

Foster young generation in OIR astronomy

- On-site observation for student PIs,
- SOKENDAI program, Taiken-Kikaku (undergrad) program
- New OISTER student program