EISCAT_3Dレーダー計画の概要と日本の役割について

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極域データの保全・公開と利活用に関する研究集会-II
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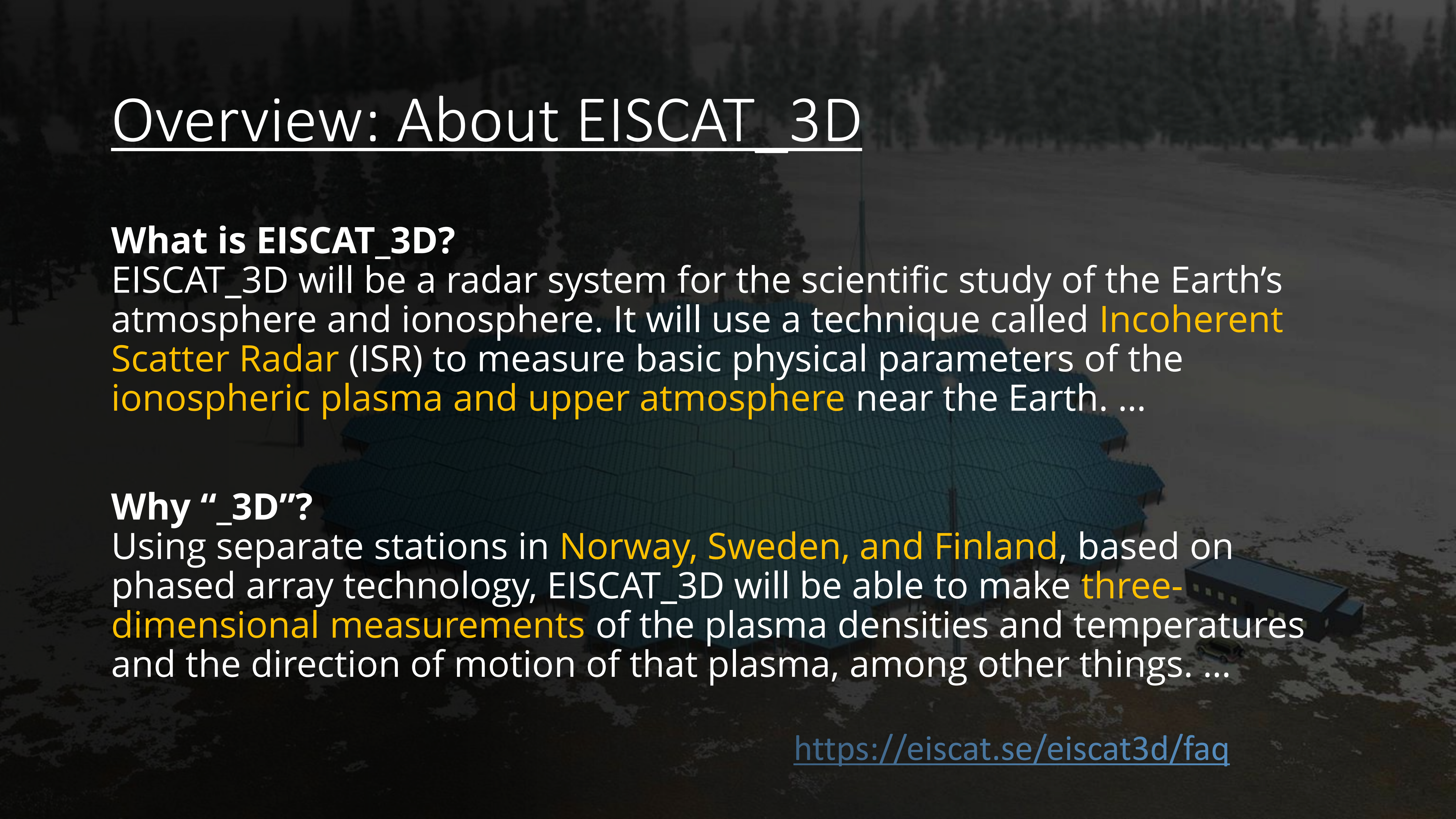


Overview: About EISCAT_3D

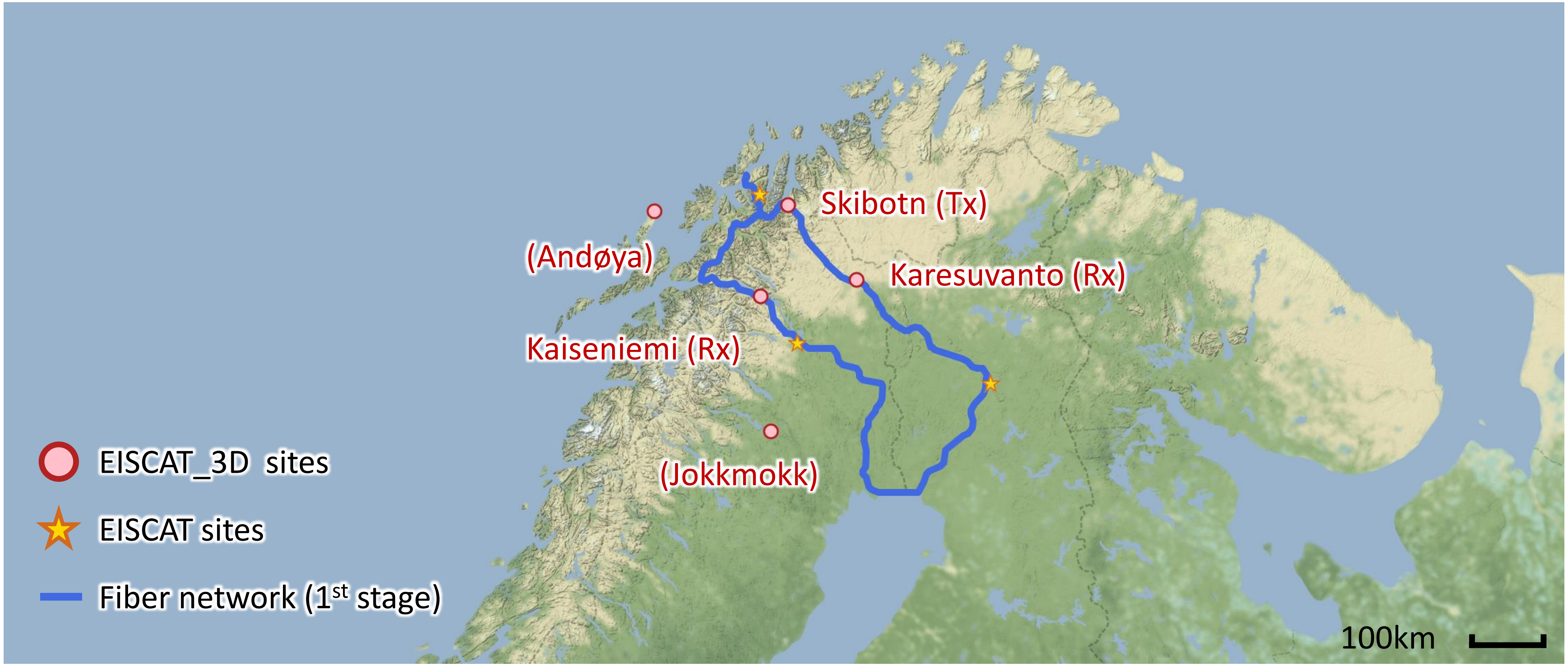
What is EISCAT_3D?
EISCAT_3D will be a radar system for the scientific study of the Earth's atmosphere and ionosphere. It will use a technique called Incoherent Scatter Radar (ISR) to measure basic physical parameters of the ionospheric plasma and upper atmosphere near the Earth. …

Why "_3D"?
Using separate stations in Norway, Sweden, and Finland, based on phased array technology, EISCAT_3D will be able to make three-dimensional measurements of the plasma densities and temperatures and the direction of motion of that plasma, among other things. …

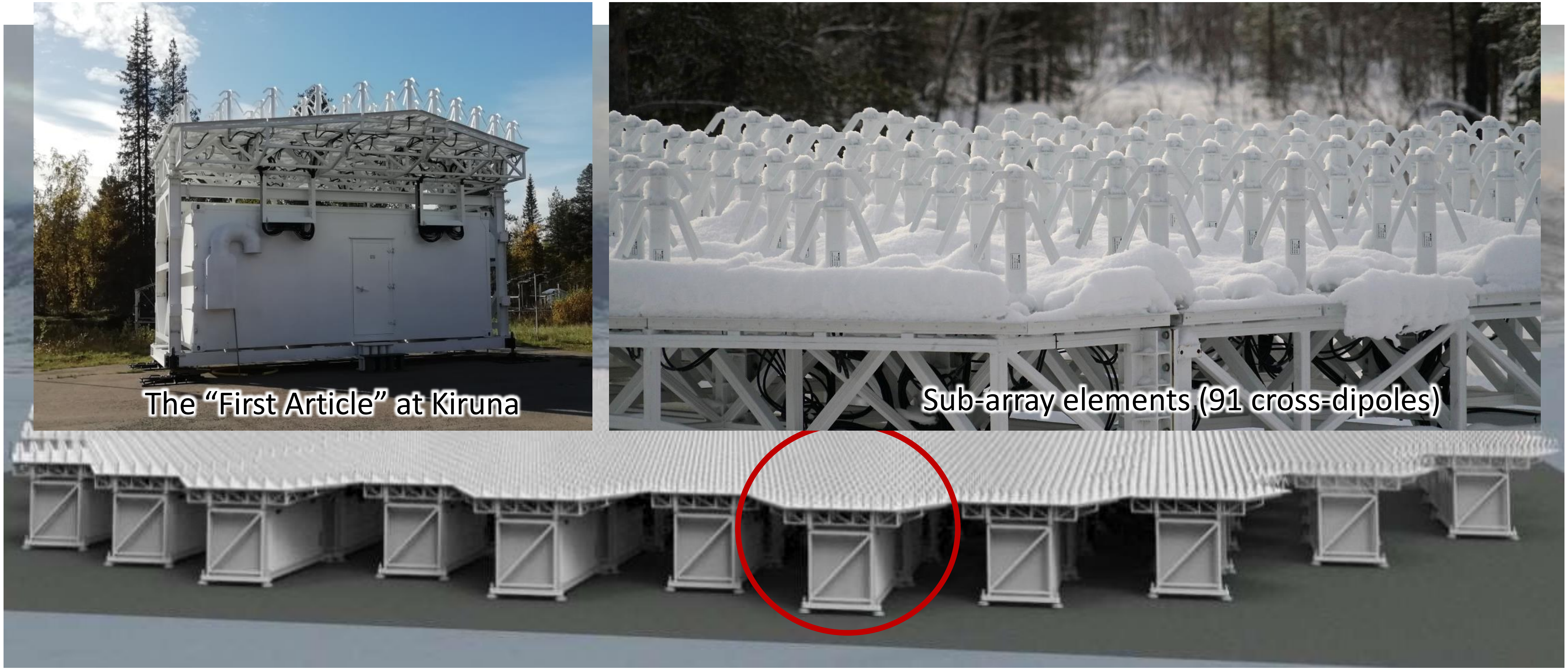
https://eiscat.se/eiscat3d/faq

各サイトの位置関係とネットワーク

- ✓ 各局は冗長性を持つ高速光ファイバネットワークリングにより接続
- ✓ NaaS（NORDUnetなど）＋自前のLast One Mileを想定



各サイト（アンテナアレイ）の外観



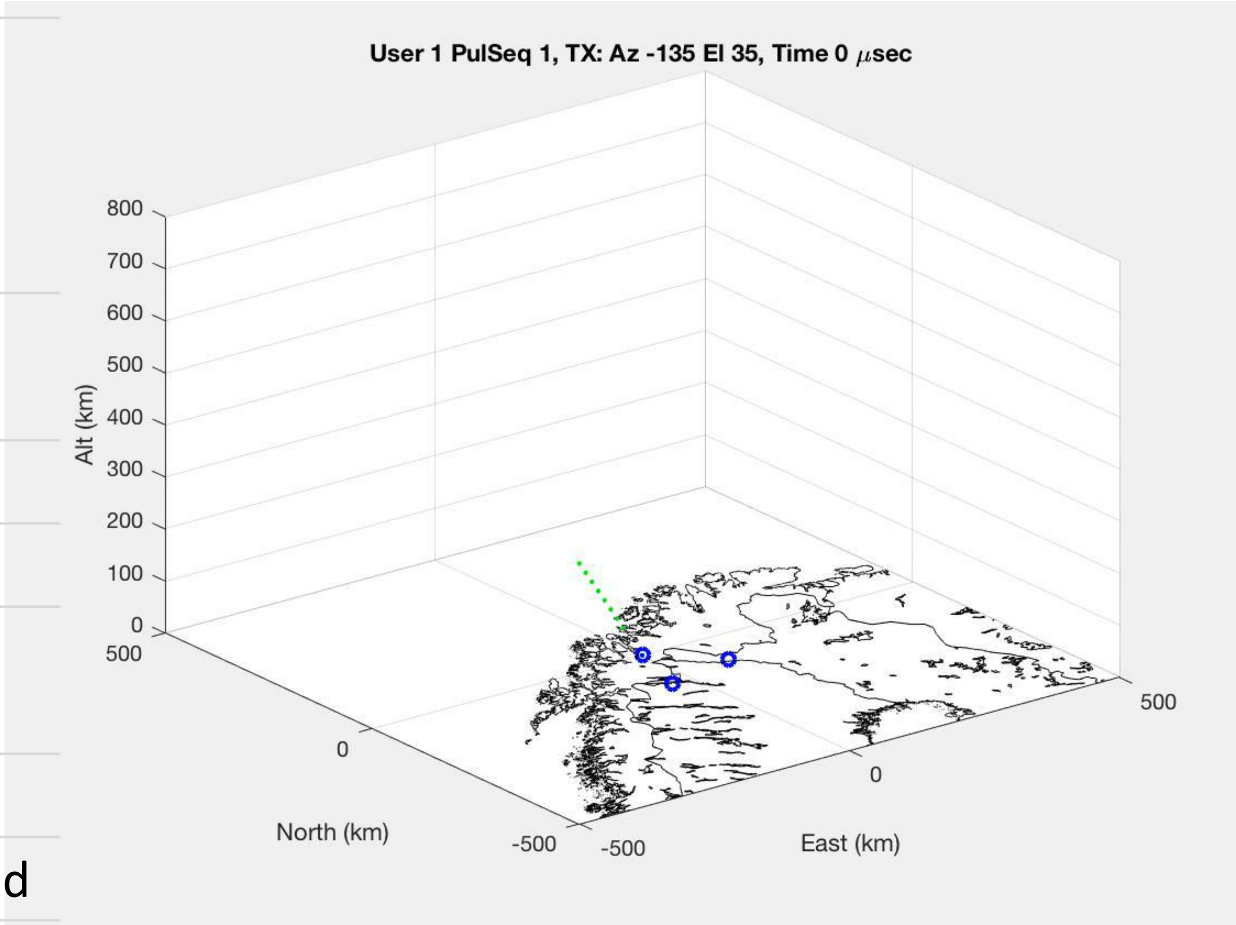
The “First Article” at Kiruna

Sub-array elements (91 cross-dipoles)

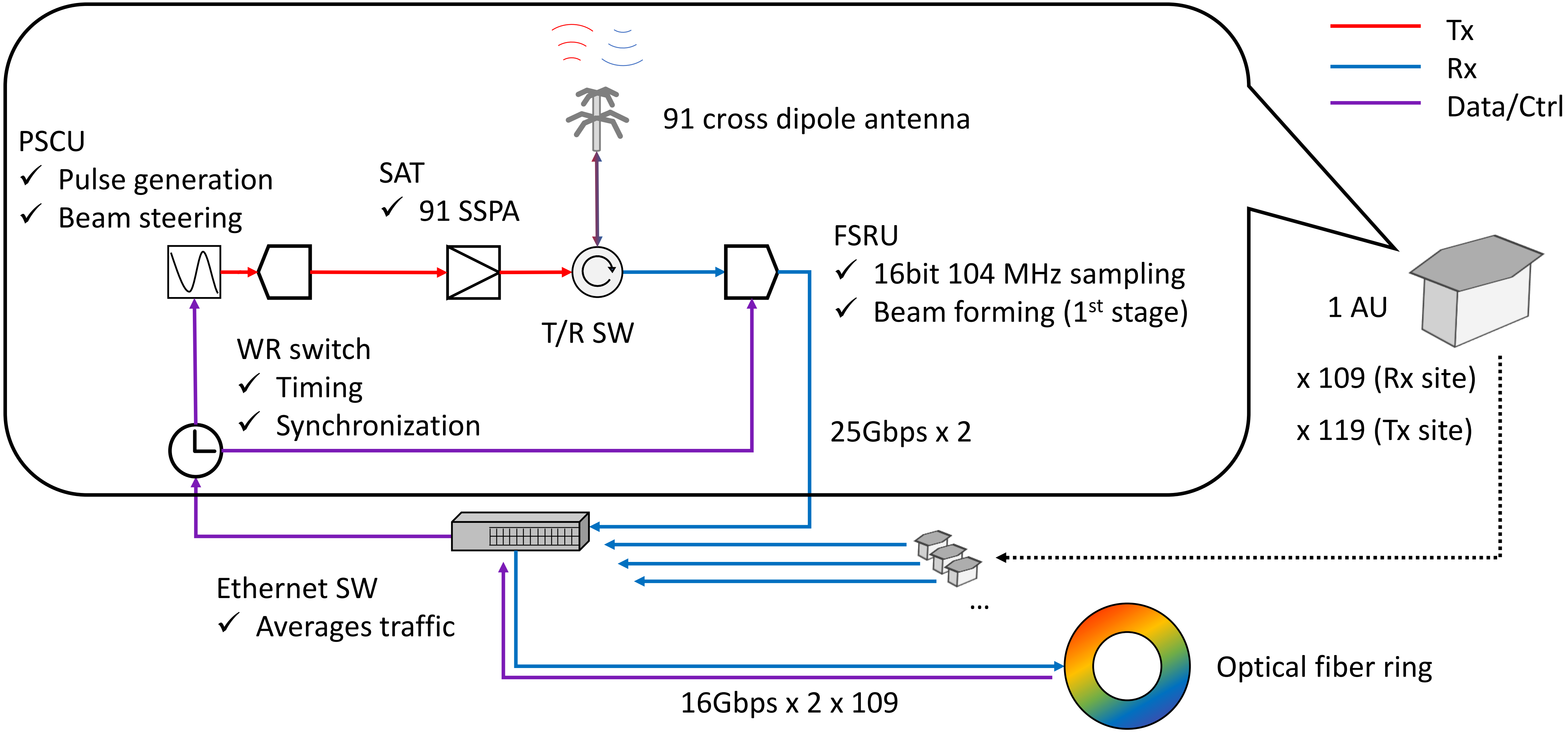
A site with 9919 antennas (109 antenna unit)

EISCAT_3Dレーダーの基本仕様

System	Multi-static / phased antenna array
Antennas	▸ 9919 cross dipole antennas at Tx and 4 Rx sites (80m diameter) ▸ 10 subarrays for interferometer at Tx (core at Skibotn) site
Range resolution	▸ Vertical 113m ▸ Horizontal 50m (finest)
ADC	16-bit 104MHz Sampling
Transmitter	9919 SSPA at Tx site (500W each)
Tx power	▸ 5MW (1st stage) ▸ 10MW (future)
Duty ratio	Max. 25%
Polarization	Two orthogonal pols. individually received
Zenith beam	0° – 60°



システム構成（各サイト）



Tx

Rx

Data/Ctrl

91 cross dipole antenna

PSCU

- ✓ Pulse generation
- ✓ Beam steering

SAT

- ✓ 91 SSPA

FSRU

- ✓ 16bit 104 MHz sampling
- ✓ Beam forming (1st stage)

T/R SW

WR switch

- ✓ Timing
- ✓ Synchronization

25Gbps x 2

1 AU

x 109 (Rx site)

x 119 (Tx site)

Ethernet SW

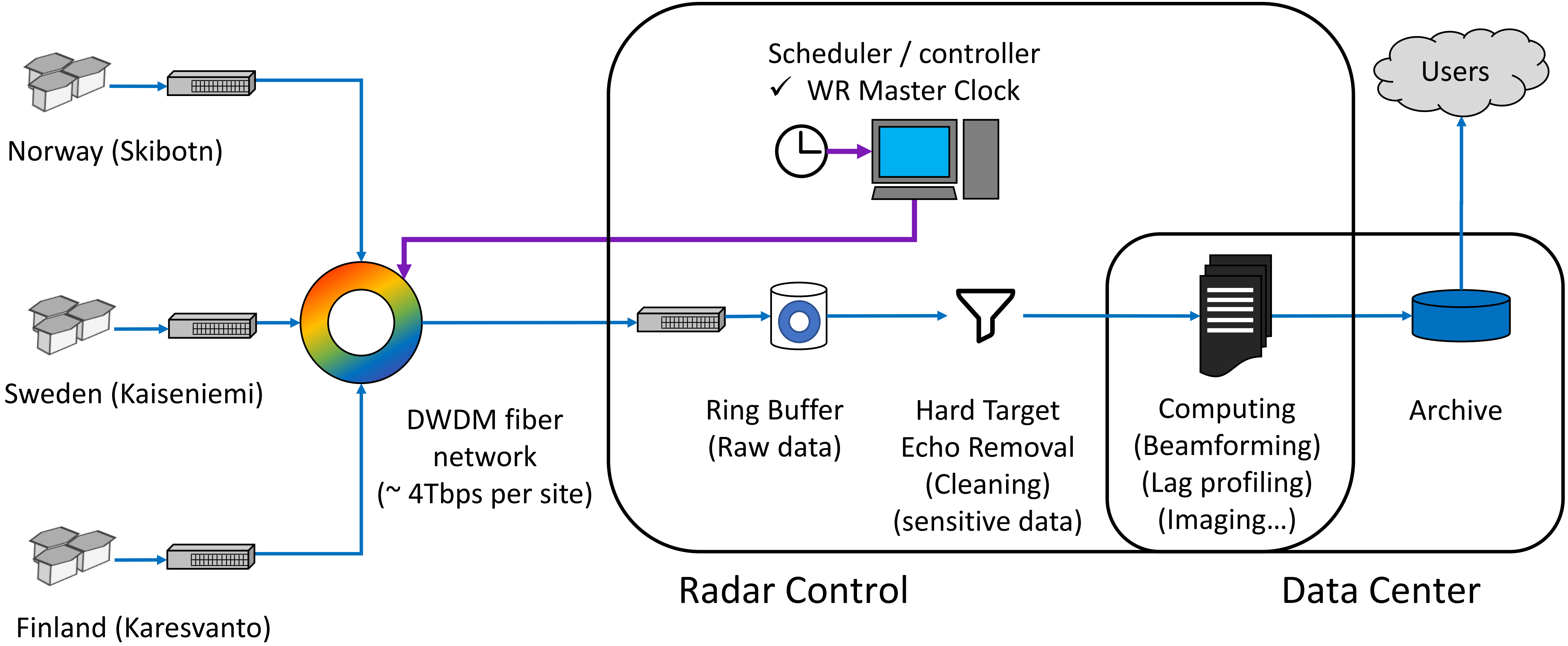
- ✓ Averages traffic

…

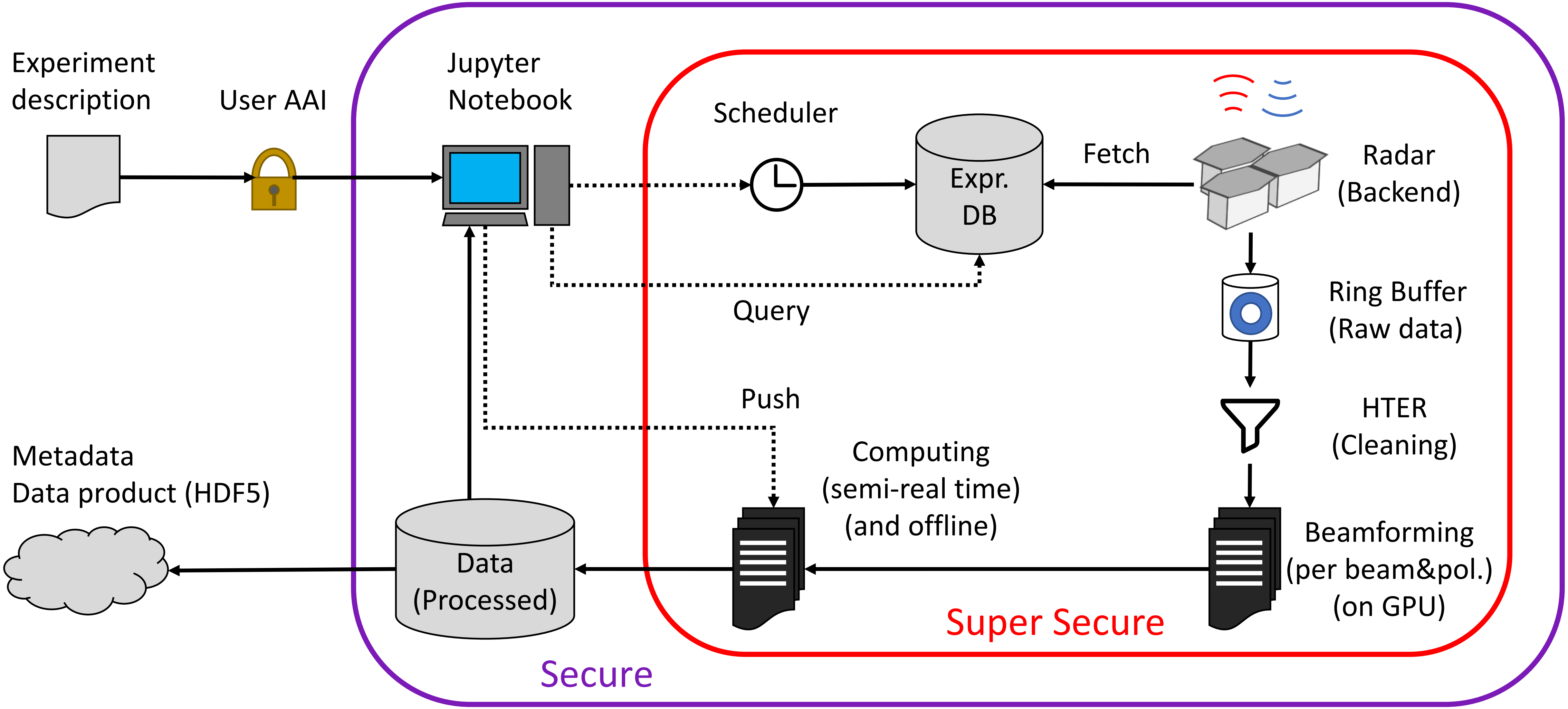
Optical fiber ring

16Gbps x 2 x 109

システム構成（ネットワーク）

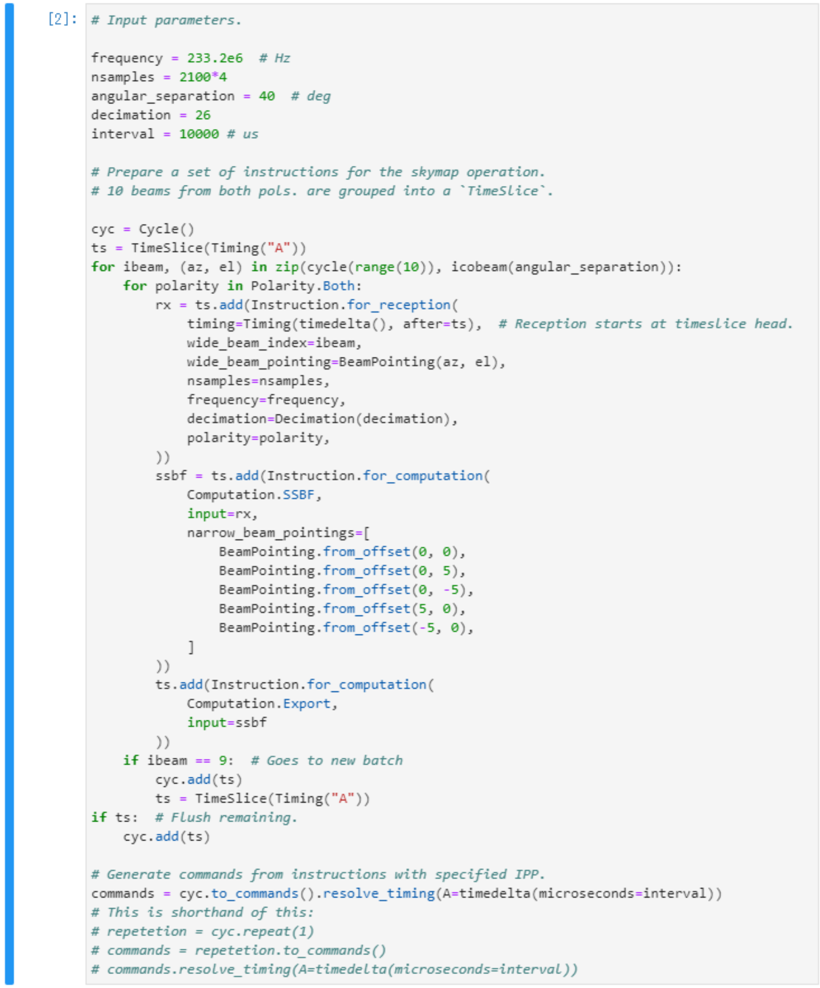


ユーザの実験フロー


Experiment
description
User AAI
Jupyter
Notebook
Scheduler
Expr.
DB
Fetch
Radar
(Backend)
Ring Buffer
(Raw data)
HTER
(Cleaning)
Query
Push
Computing
(semi-real time)
(and offline)
Beamforming
(per beam&pol.)
(on GPU)
Metadata
Data product (HDF5)
Data
(Processed)
Super Secure
Secure

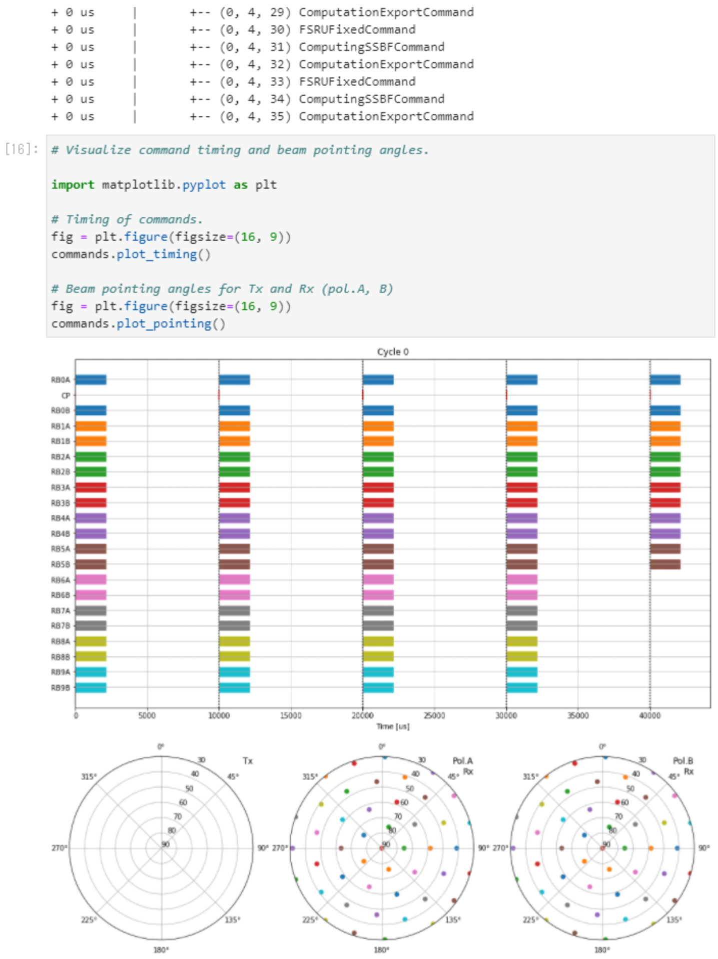
e3d.commanding Python package

Command design from scratch



```
[2]: # Input parameters.

     frequency = 233.2e6  # Hz
     nsamples = 2100*4
     angular_separation = 40  # deg
     decimation = 26
     interval = 10000 # us

     # Prepare a set of instructions for the skymap operation.
     # 10 beams from both pols. are grouped into a `TimeSlice`.

     cyc = Cycle()
     ts = TimeSlice(Timing("A"))
     for ibeam, (az, el) in zip(cycle(range(10)), icobeam(angular_separation)):
         for polarity in Polarity.Both:
             rx = ts.add(Instruction.for_reception(
                 timing=Timing(timedelta(), after=ts),  # Reception starts at timeslice head.
                 wide_beam_index=ibeam,
                 wide_beam_pointing=BeamPointing(az, el),
                 nsamples=nsamples,
                 frequency=frequency,
                 decimation=Decimation(decimation),
                 polarity=polarity,
             ))
             ssbf = ts.add(Instruction.for_computation(
                 Computation.SSBF,
                 input=rx,
                 narrow_beam_pointings=[
                     BeamPointing.from_offset(0, 0),
                     BeamPointing.from_offset(0, 5),
                     BeamPointing.from_offset(0, -5),
                     BeamPointing.from_offset(5, 0),
                     BeamPointing.from_offset(-5, 0),
                 ]
             ))
             ts.add(Instruction.for_computation(
                 Computation.Export,
                 input=ssbf
             ))
         if ibeam == 9:  # Goes to new batch
             cyc.add(ts)
             ts = TimeSlice(Timing("A"))
     if ts:  # Flush remaining.
         cyc.add(ts)

     # Generate commands from instructions with specified IPP.
     commands = cyc.to_commands().resolve_timing(A=timedelta(microseconds=interval))
     # This is shorthand of this:
     # repetetion = cyc.repeat(1)
     # commands = repetetion.to_commands()
     # commands.resolve_timing(A=timedelta(microseconds=interval))
```

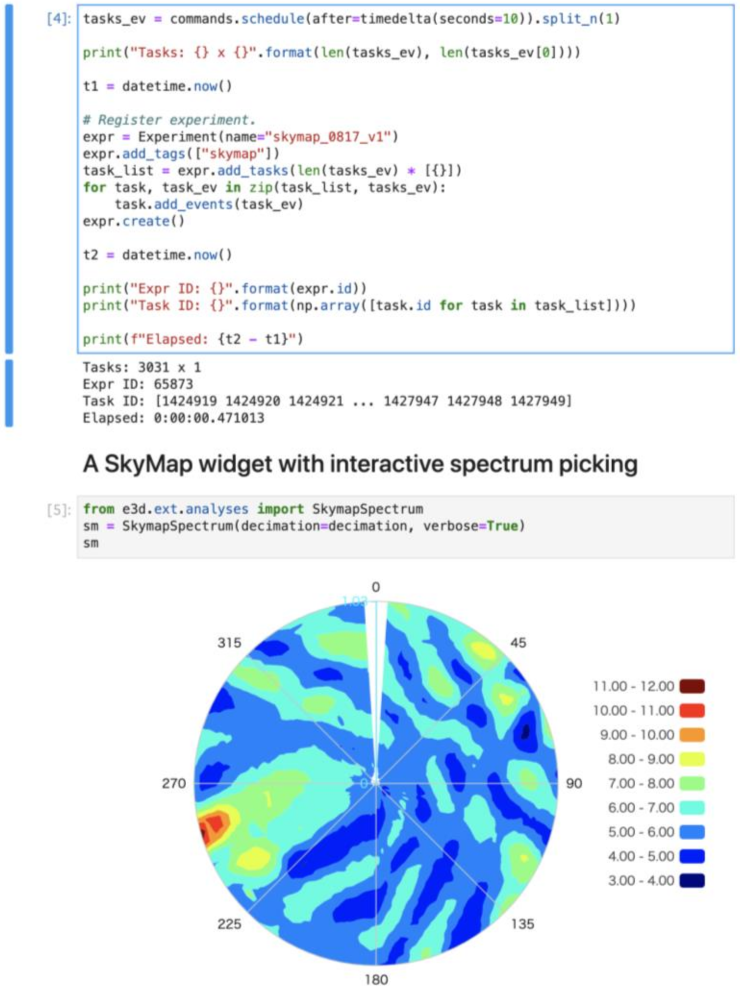
Timing visualization and validation



```
+ 0 us     |        +-- (0, 4, 29) ComputationExportCommand
+ 0 us     |        +-- (0, 4, 30) FSRUFixedCommand
+ 0 us     |        +-- (0, 4, 31) ComputingSSBFCommand
+ 0 us     |        +-- (0, 4, 32) ComputationExportCommand
+ 0 us     |        +-- (0, 4, 33) FSRUFixedCommand
+ 0 us     |        +-- (0, 4, 34) ComputingSSBFCommand
+ 0 us     |        +-- (0, 4, 35) ComputationExportCommand
```

```
[16]: # Visualize command timing and beam pointing angles.

      import matplotlib.pyplot as plt

      # Timing of commands.
      fig = plt.figure(figsize=(16, 9))
      commands.plot_timing()

      # Beam pointing angles for Tx and Rx (pol.A, B)
      fig = plt.figure(figsize=(16, 9))
      commands.plot_pointing()
```

Scheduling / Data quick look



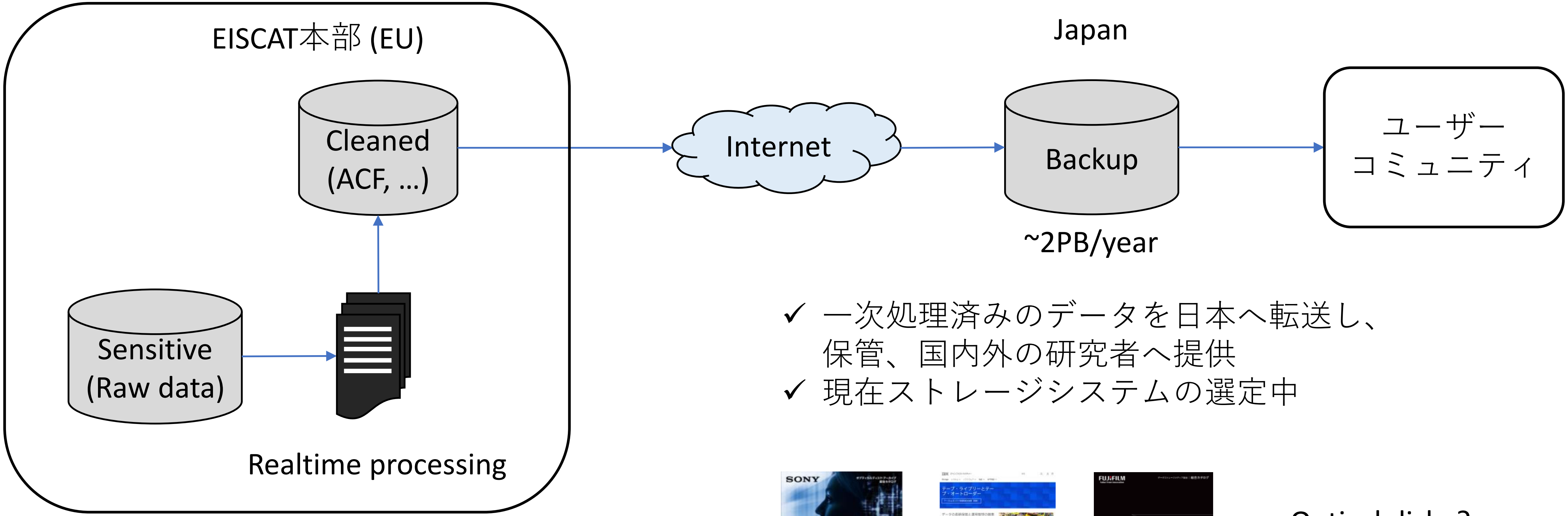
```
[4]: tasks_ev = commands.schedule(after=timedelta(seconds=10)).split_n(1)

     print("Tasks: {} x {}".format(len(tasks_ev), len(tasks_ev[0])))

     t1 = datetime.now()

     # Register experiment.
     expr = Experiment(name="skymap_0817_v1")
     expr.add_tags(["skymap"])
     task_list = expr.add_tasks(len(tasks_ev) * [{}])
     for task, task_ev in zip(task_list, tasks_ev):
         task.add_events(task_ev)
     expr.create()

     t2 = datetime.now()

     print("Expr ID: {}".format(expr.id))
     print("Task ID: {}".format(np.array([task.id for task in task_list])))

     print(f"Elapsed: {t2 - t1}")
```

```
Tasks: 3031 x 1
Expr ID: 65873
Task ID: [1424919 1424920 1424921 ... 1427947 1427948 1427949]
Elapsed: 0:00:00.471013
```

A SkyMap widget with interactive spectrum picking

```
[5]: from e3d.ext.analyses import SkymapSpectrum
     sm = SkymapSpectrum(decimation=decimation, verbose=True)
     sm
```

日本の役割：データのバックアップと公開



- ✓ 一次処理済みのデータを日本へ転送し、保管、国内外の研究者へ提供
- ✓ 現在ストレージシステムの選定中

SONY

オプティカルディスク・アーカイブ
総合カタログ

大切な資産を未来につなぐ

Optical Disc Archive

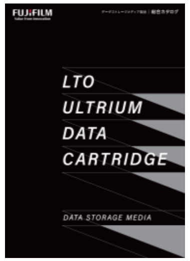
IBM

テープ・ライブラリーとテープ・オートローダー

データの長期保管と運用管理の簡素化

テープ・ライブラリーのメリット

テープ・ライブラリーとテープ・オートローダー


FUJIFILM

総合カタログ

LTO
ULTRIUM
DATA
CARTRIDGE

DATA STORAGE MEDIA

Optical disk..?

LTO (tape)..?

日本の役割：データ解析支援

- 付加価値を高めたデータベースの提供
  - 現行EISCATでも実施している追加の物理量導出
    参考：http://pc115.seg20.nipr.ac.jp/www/eiscatdata/
  - 4次元時空間のイメージング観測データを効率的に
    格納・抽出する階層型・ボクセル集合データベースの開発
  - 深層学習によるイベントの自動抽出
- EISCAT_3Dユーザーのためのツールの提供
  - 解析・可視化ツールの開発