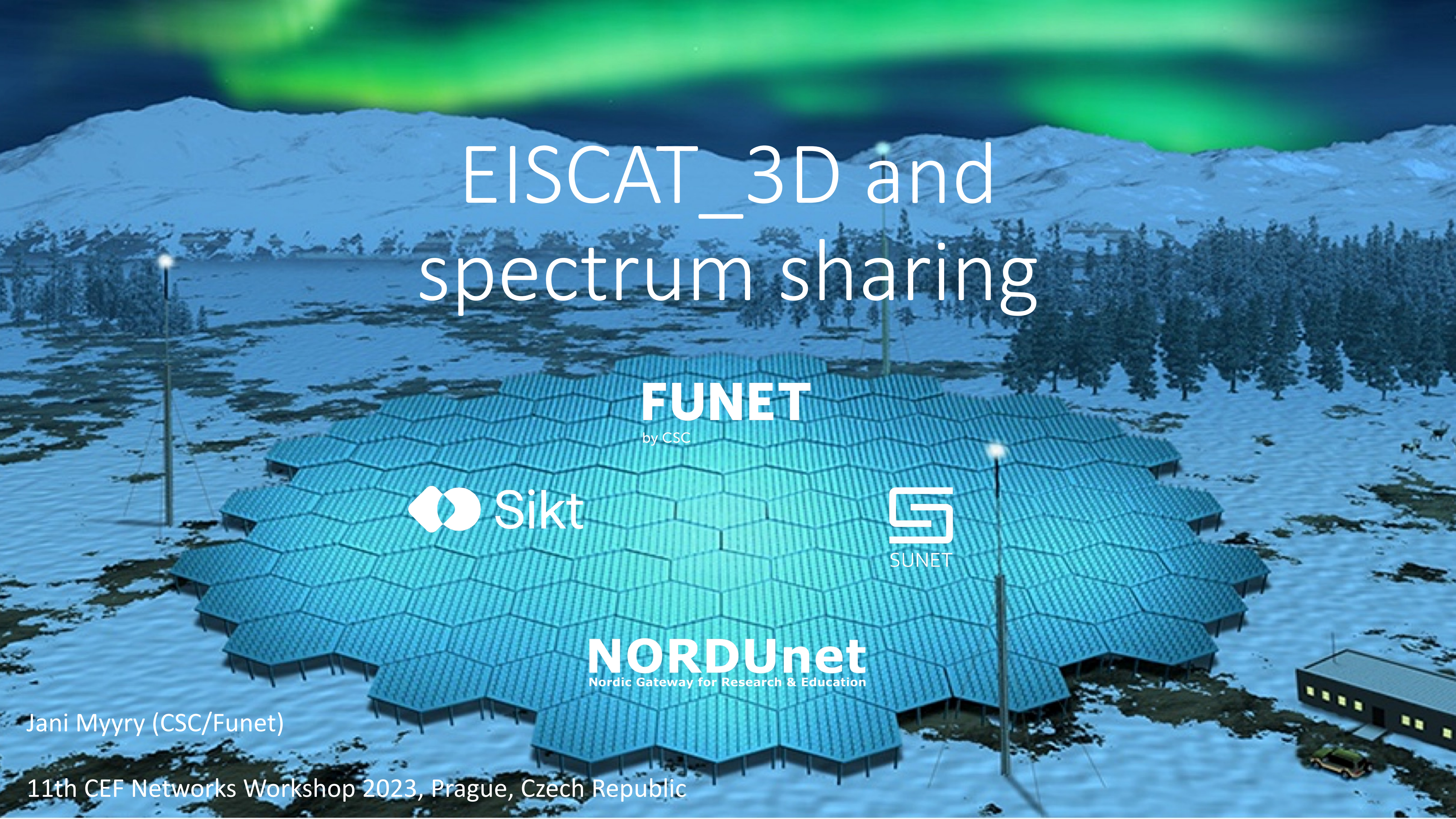


EISCAT_3D and spectrum sharing

FUNET
by CSC

Sikt

SUNET

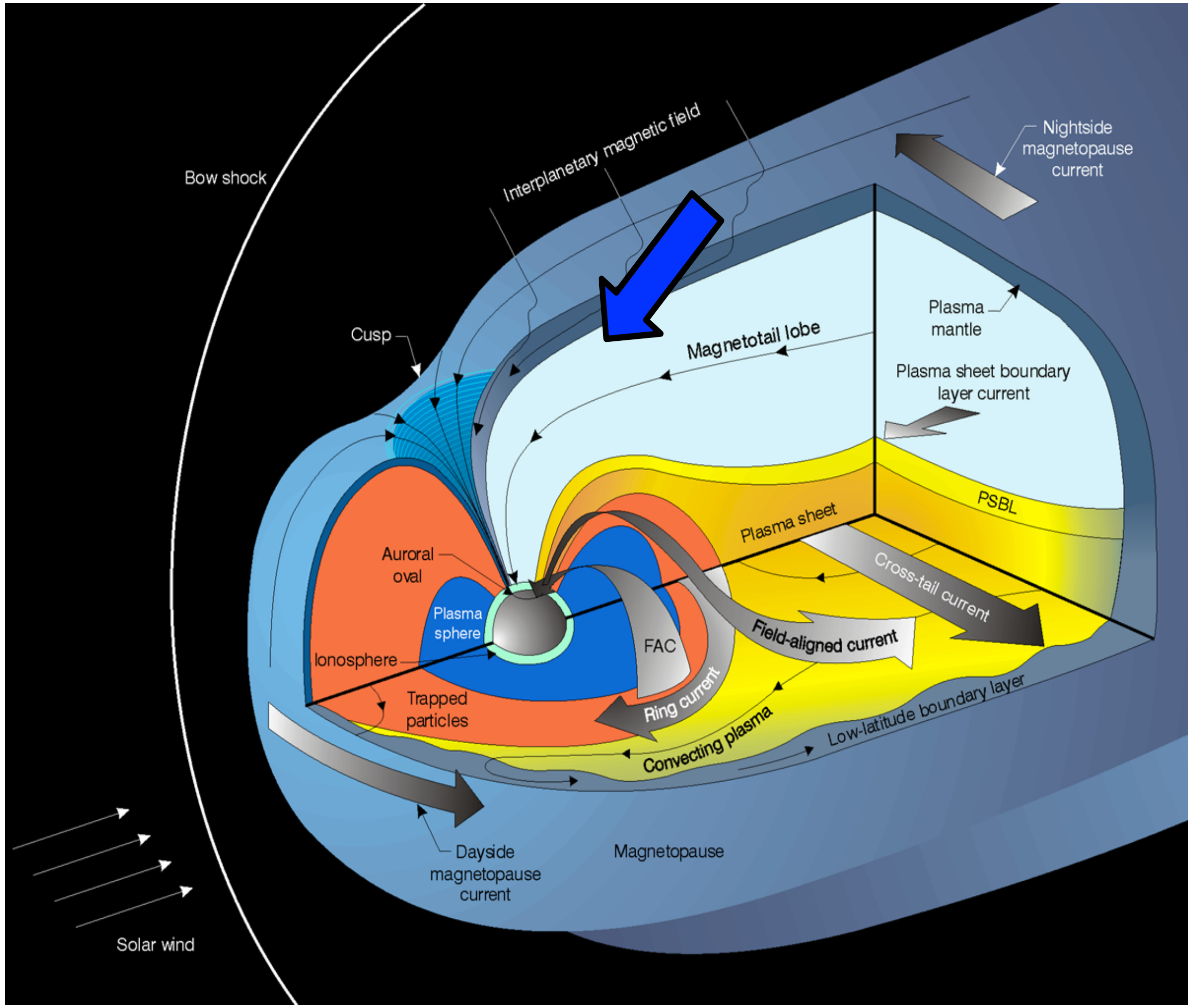
NORDUnet
Nordic Gateway for Research & Education

Jani Myyry (CSC/Funet)

11th CEF Networks Workshop 2023, Prague, Czech Republic

EISCAT

studies polar ionosphere



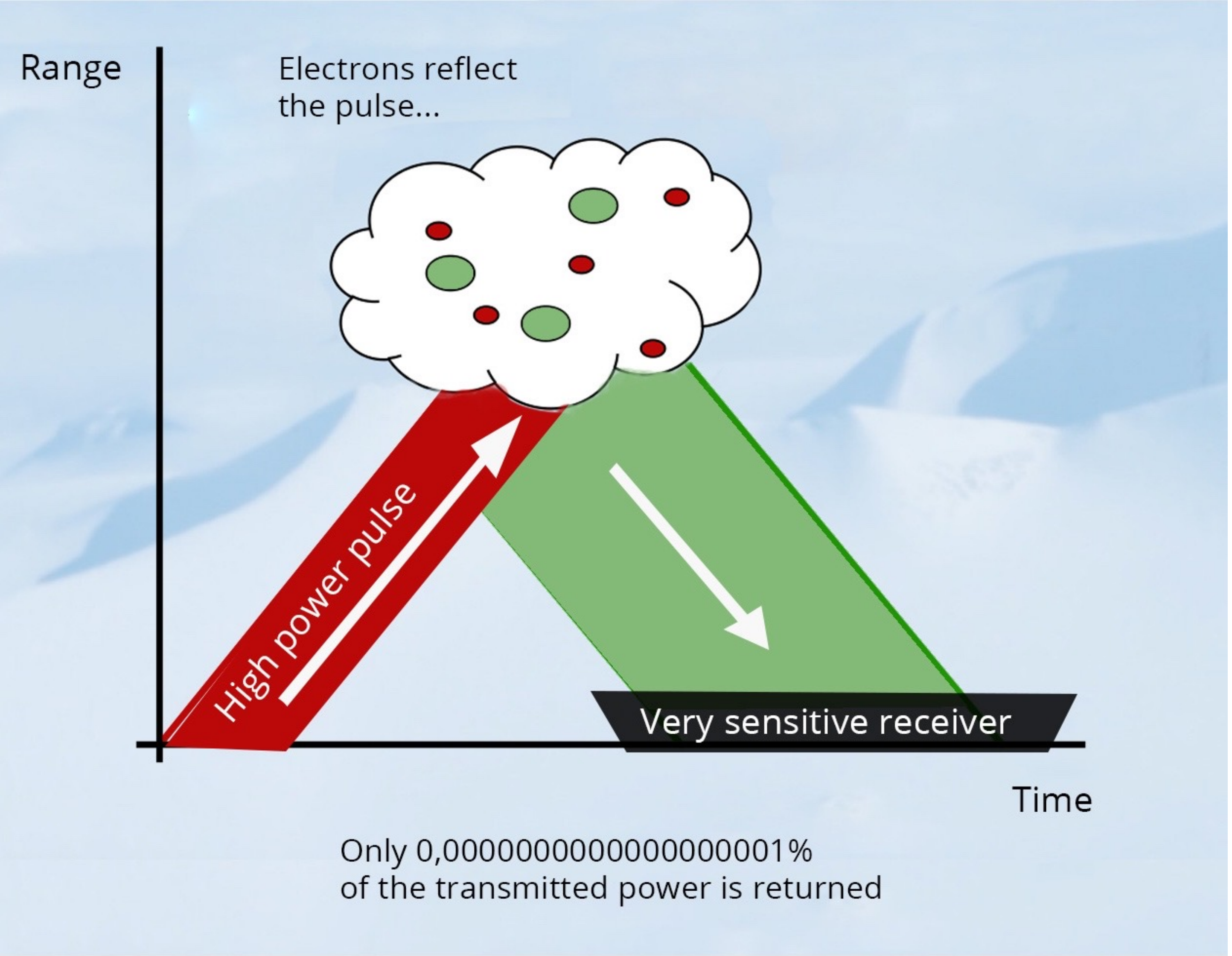
Space

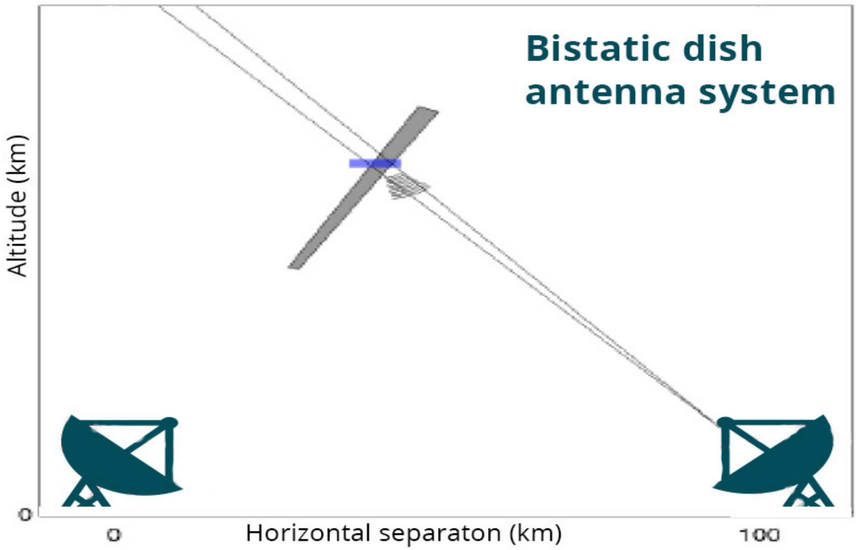
EISCAT
studies **polar** ionosphere
≈ 60 – 1200 km

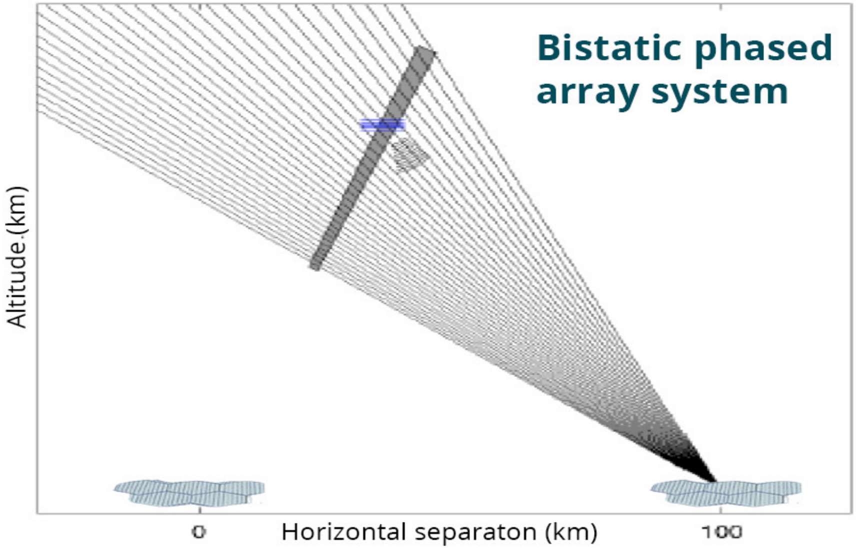
Neutral Atmosphere

altitude

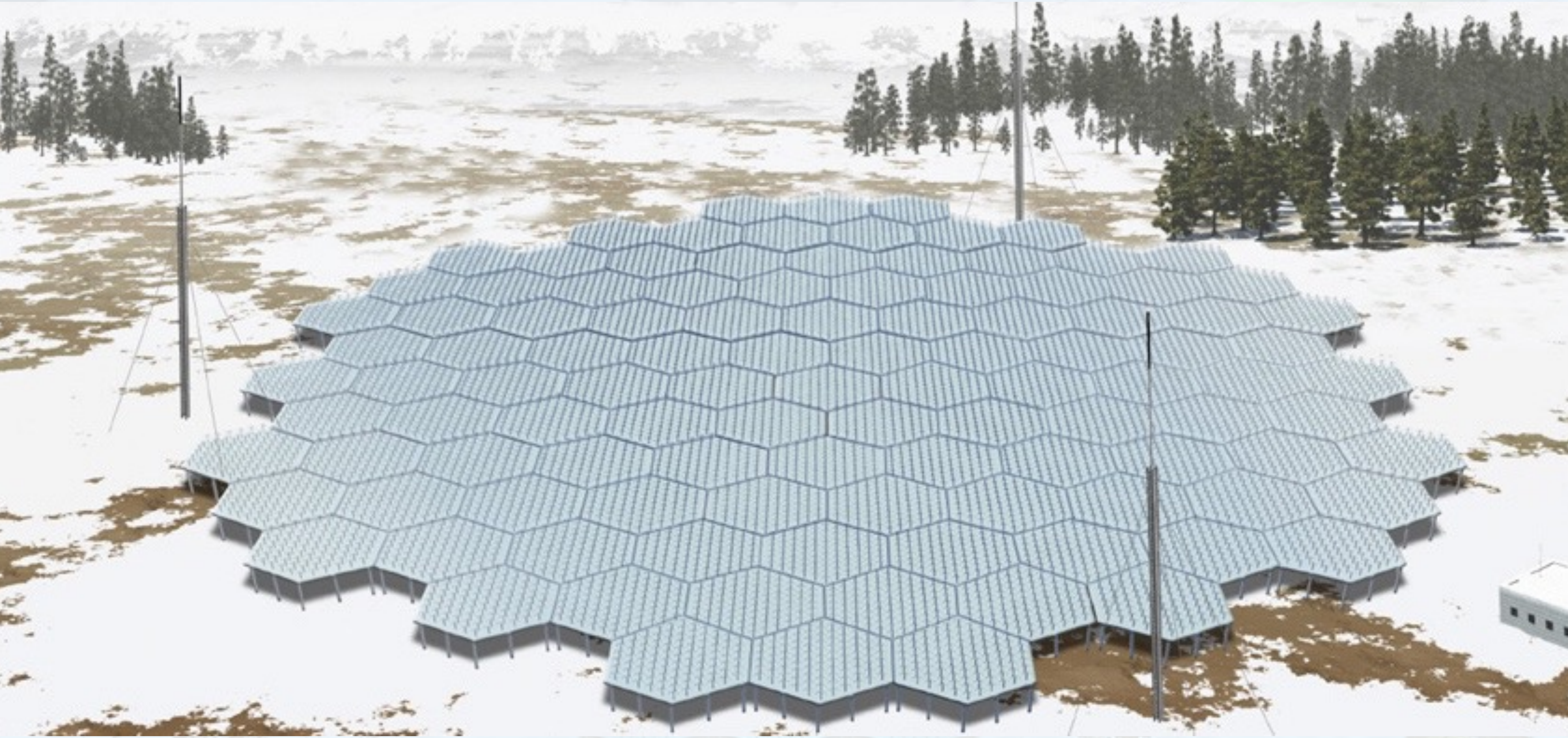
with incoherent scatter radars







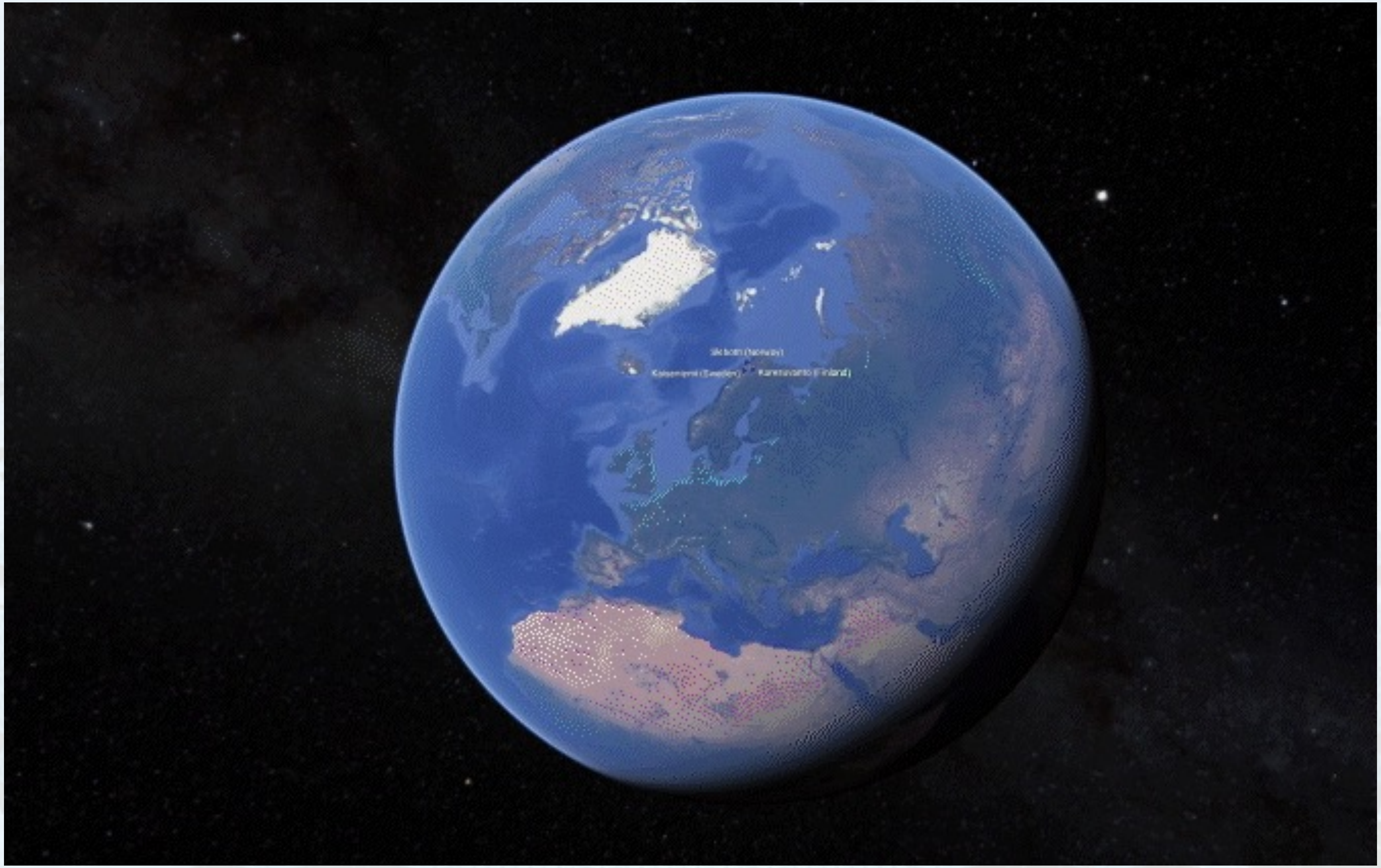
by using the new EISCAT_3D stations



Applications

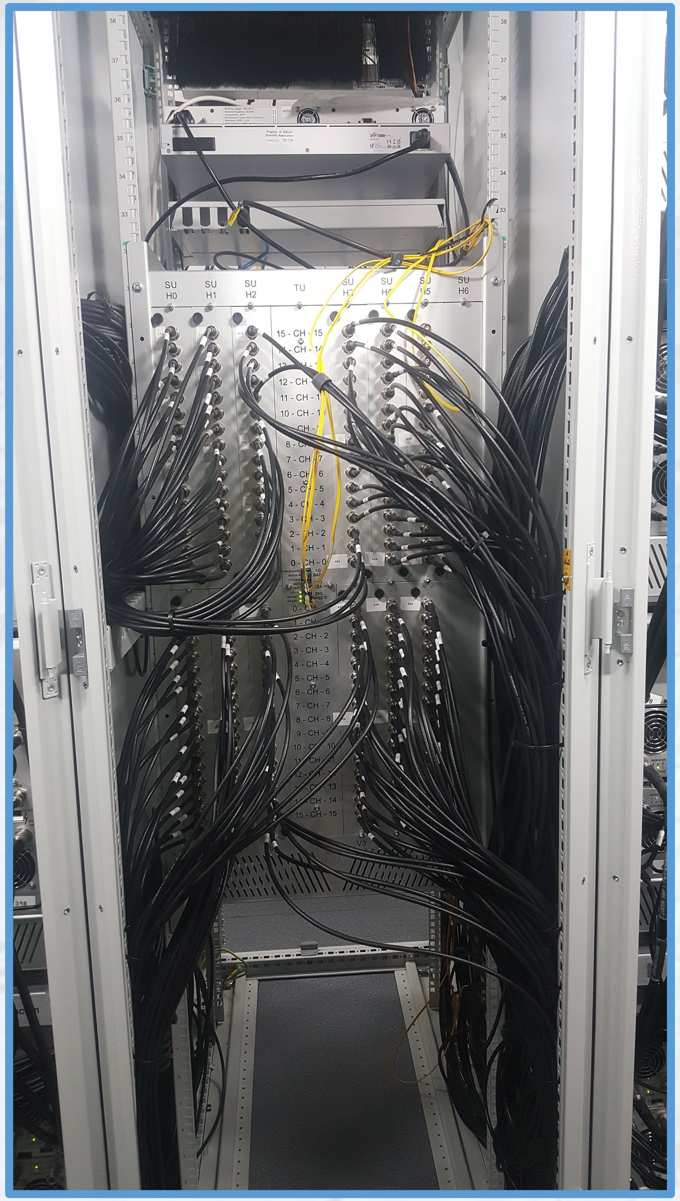
- Ionosphere studies
- Space weather studies, forecasting
- Space debris tracking
- Auroral observation
- Meteor studies
- And other stuff

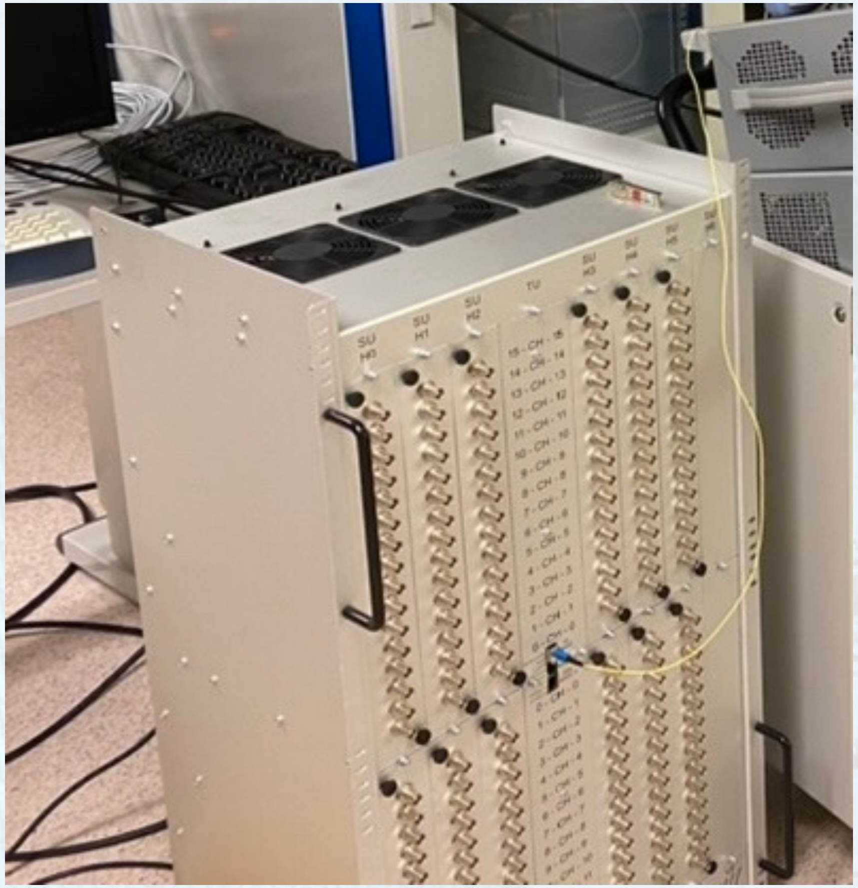
Stations in the arctic region



EISCAT_3D test container and antenna

EISCAT_3D antenna test equipment

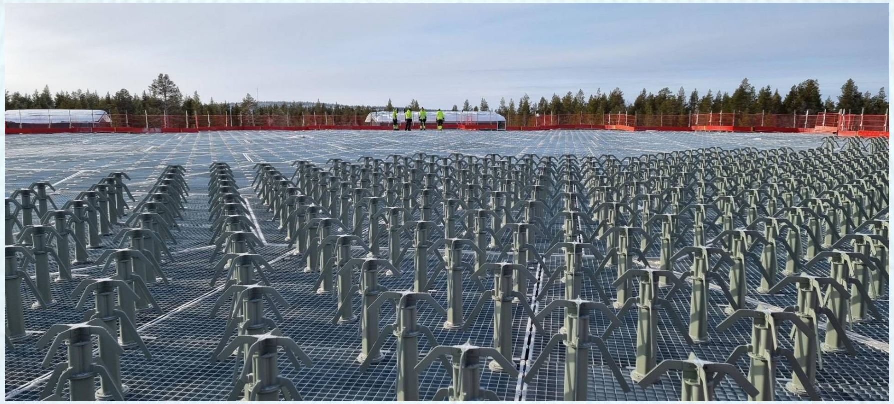




EISCAT_3D sites (2/2023)

Skibotn, Norway

Kaaresuvanto, Finland

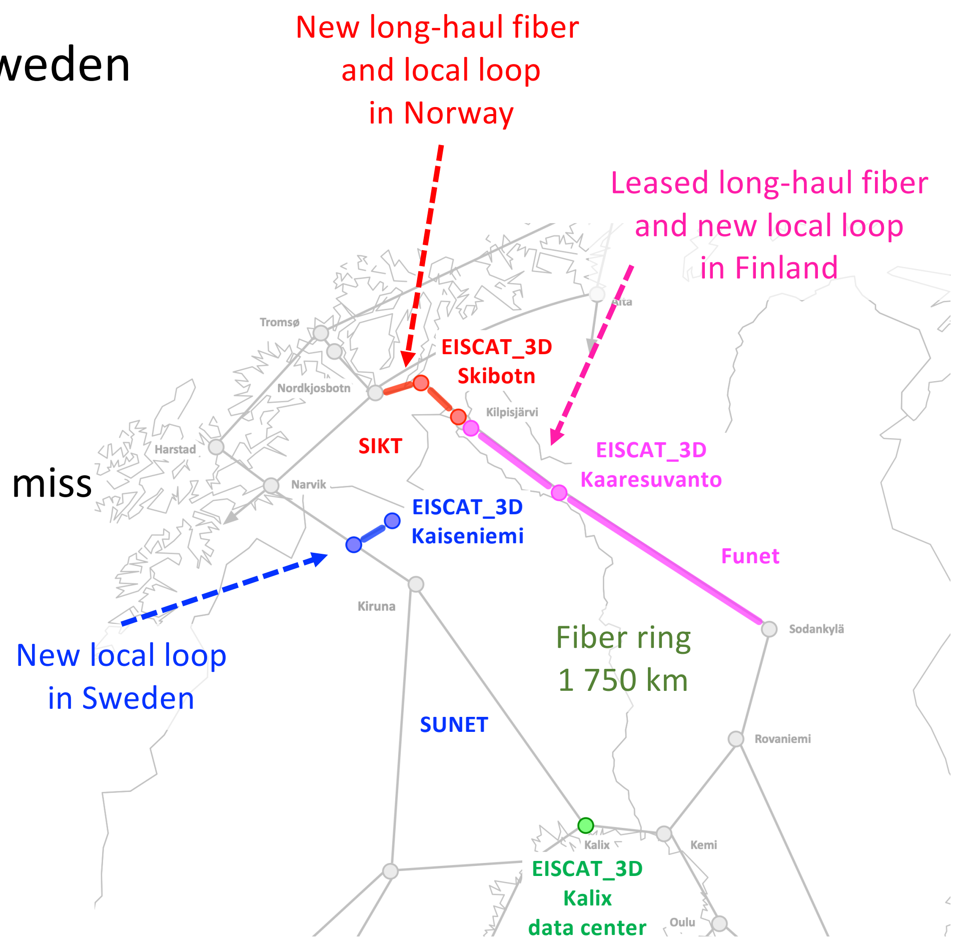


Partially installed antenna arrays (Kaaresuvanto, Finland)

Images: EISCAT Scientific Association

EISCAT_3D and fiber networks in the arctic region

- Joint project between EISCAT, NORDUnet and the Nordic NRENs in Finland (Funet), Norway (SIKT) and Sweden (SUNET)
- Three antenna sites with 2 optional locations in Norway and Sweden
  - Skibotn, Norway, **transmitter** and **receiver** site
  - Kaiseniemi, Sweden, **receiver** site
  - Kaaresuvanto, Finland, **receiver** site
- Separate data center location somewhere within the region
  - Kalix, Sweden (2023: moved from Kiruna)
- None of the antenna sites had fibers available
  - Required building new local loops and building or leasing fibers for the miss haul routes
- Fiber ring to avoid extensive service breaks
  - Difficult to fix issues in winter times due to harsh weather
  - Reuse existing fiber topologies where available
  - Flexibility to serve multiple potential data center locations



Network architecture – the beginning

- Network planning started in 2015 together with the NRENs and EISCAT
  - Original EISCAT_3D architecture based on computing at the sites
  - Bandwidth requirements up to **53 Gbps** per site after local process computing
- Services to be offered with IP/MPLS networks
  - Traditional design with router-to-router connections at the border locations
  - Router connectivity to each antenna site
  - Extensive use of backbone links which need to be upgraded as well
- NRENs were using optical line systems from 2000s
  - Designed for 10G with dispersion compensation but 100G possible
  - Fixed-grid and on some spans very limited spectrum available
  - Vendor lock-in with capacity licencing

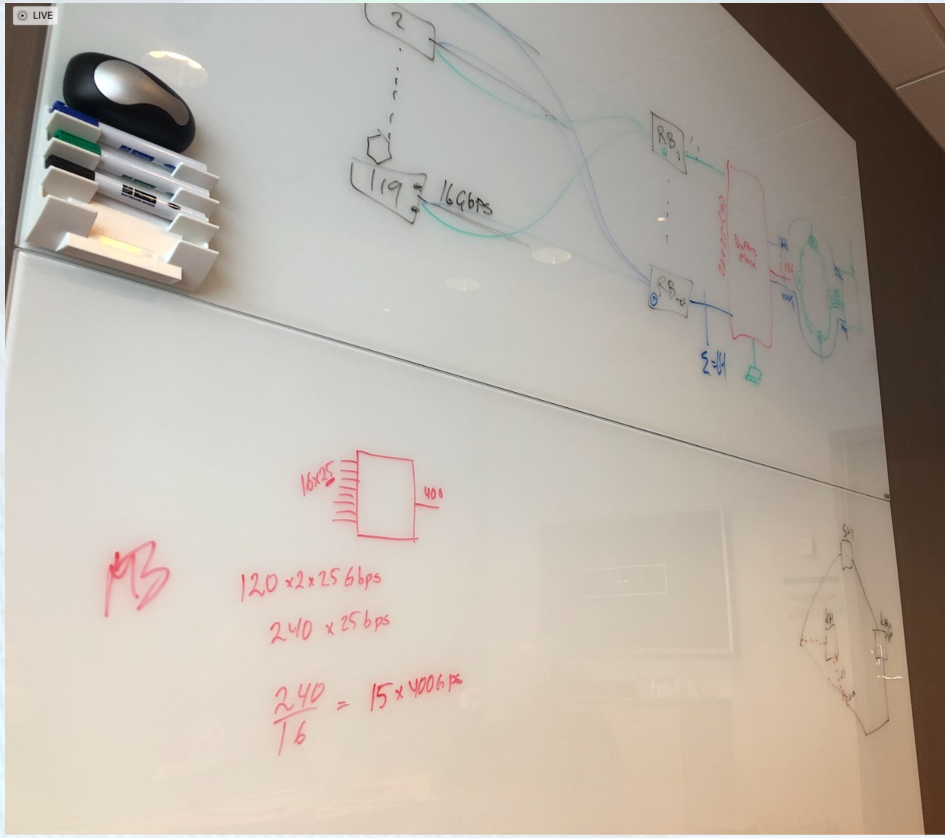
Network architecture – open optical line systems

- During the project existing optical systems started to reach end-of-life
  - Need for new optical line systems to replace the older systems
- SUNET began with their renewal in 2016
  - **Very high OSNR** with hybrid EDFA/Raman amplification
  - **Gridless** spectrum
  - **Open** line system with **licensing-free** spectrum
- Later other NRENs decided to follow the model
  - Economical and technical limitations were practically gone
- Huge development with transponders driven by cloud giants
  - Disaggregated DCIs, up to 600+G line interfaces
  - Significant cost reduction

Without all NRENs supporting all of these requirements the networking model would have been very different

Network architecture – "Terabit to the Tundra" model

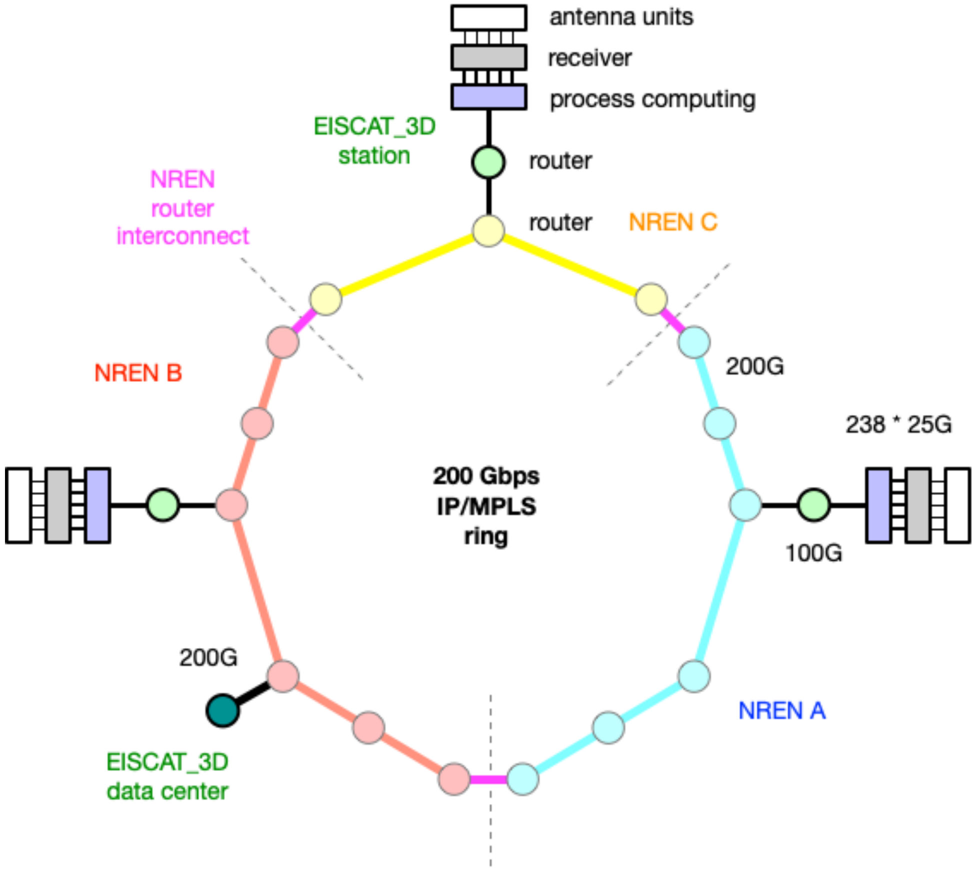
- First proposals to change the original IP/MPLS model
  1. Separate Ethernet ring between the sites and the data center with domain-specific waves
     - No need to upgrade backbone IP routers and links
  2. End-to-end Ethernet connectivity to the data center with alienwaves across the borders
     - Even less waves needed
     - Possibility for optical protection
- But terabit-era was closing, could we refresh the model altogether?
  - Data received directly from the receivers to a single computing location would give big benefits for analysing stage
  - Receivers have Ethernet interfaces and could be transported
  - Increases transmission costs but decreases operational and equipment costs on sites
- EISCAT_3D project scientists were interested about the idea
  - TCO estimates were calculated based on existing DCIs available
  - And eventually it was accepted and chosen



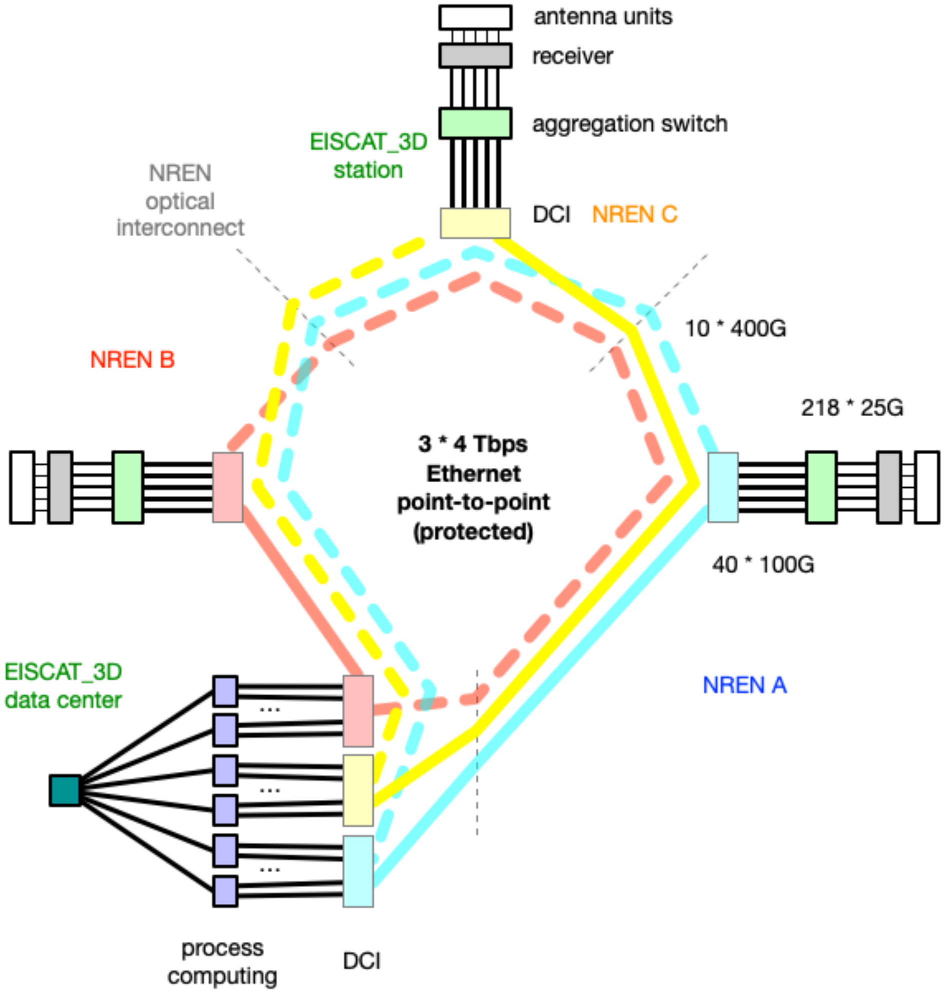
Technical meeting between NRENs and EISCAT in Arlanda, Sweden (30.9.2019)

Earliest recorded sketch for terabit transport (more detailed technical & budgetary proposal presented two weeks later…)

Network architecture – evolution towards terabit



2015 2023

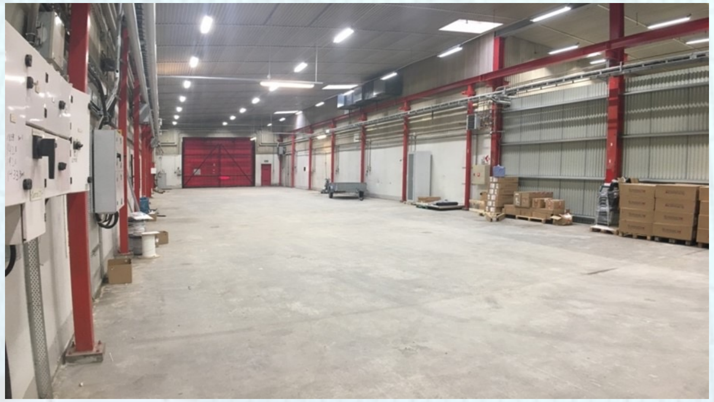


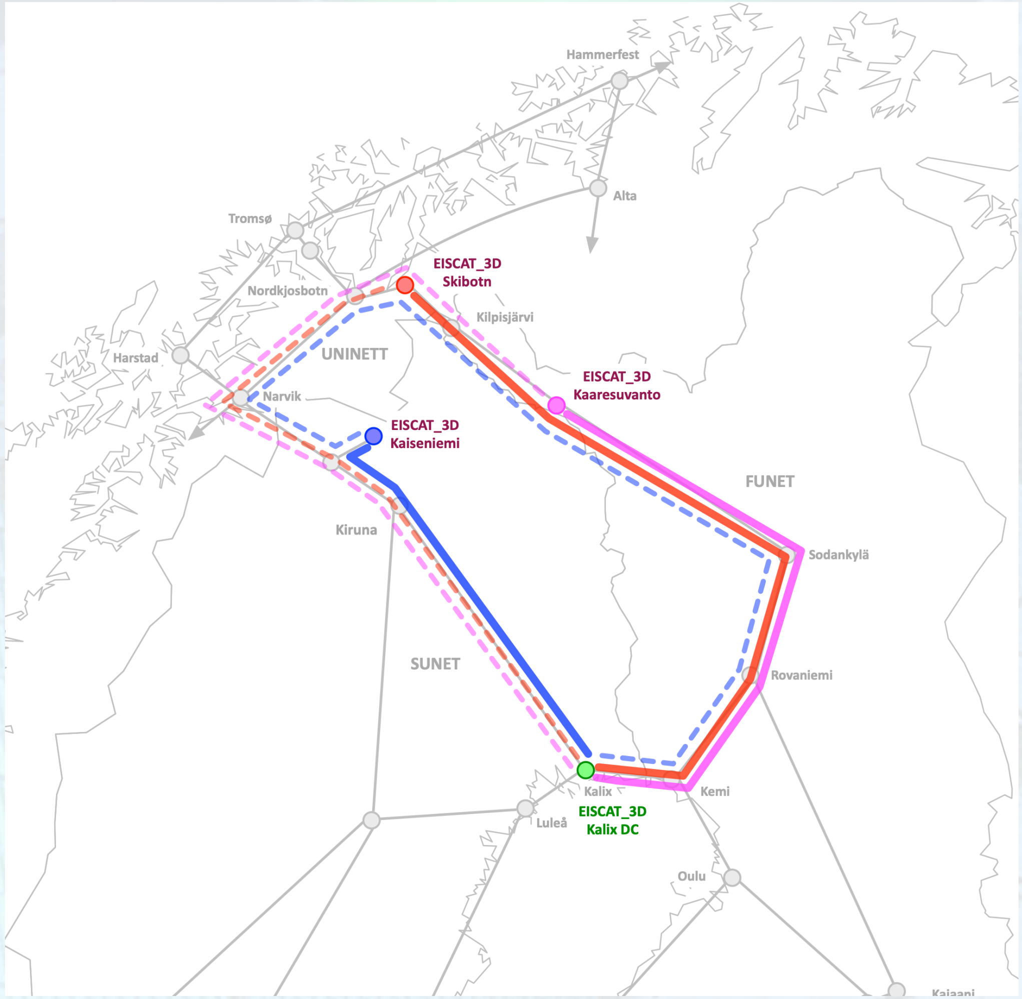
Current status (implementation)

- Antenna containers have arrived and installed at all sites
  - First measurements planned in April/May in Skibotn (without network)
  - Antennas, receivers, intra-site cabling etc. to be installed next
- Buildings still under construction
  - NRENs waiting for official handover to start installing OLS and transport
  - Remaining fibers and power lines after snow/ground has melted
- DC site under preparation
  - Recent site relocation should not cause big changes to schedules
  - Facilities available for the networking equipment installations soon
  - Facilities for computing planned 2H/2023

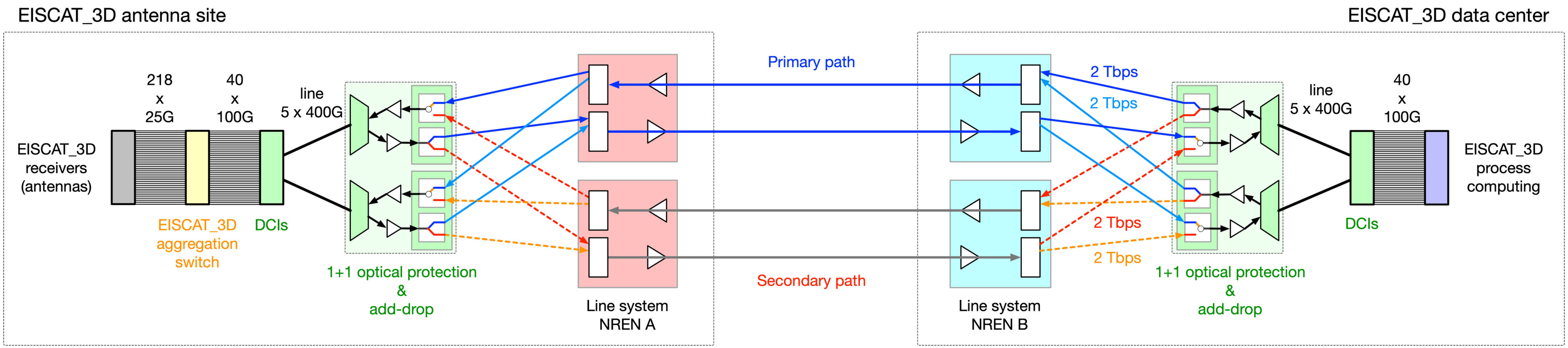
Kalix (”SUNET Orion DC” computing location)

- 2 x 4 Tbps + 1 x 3,2 Tbps (2,1 THz)
  - 400G line signals
- Max primary path: 820 km
- Max secondary path: 1250 km

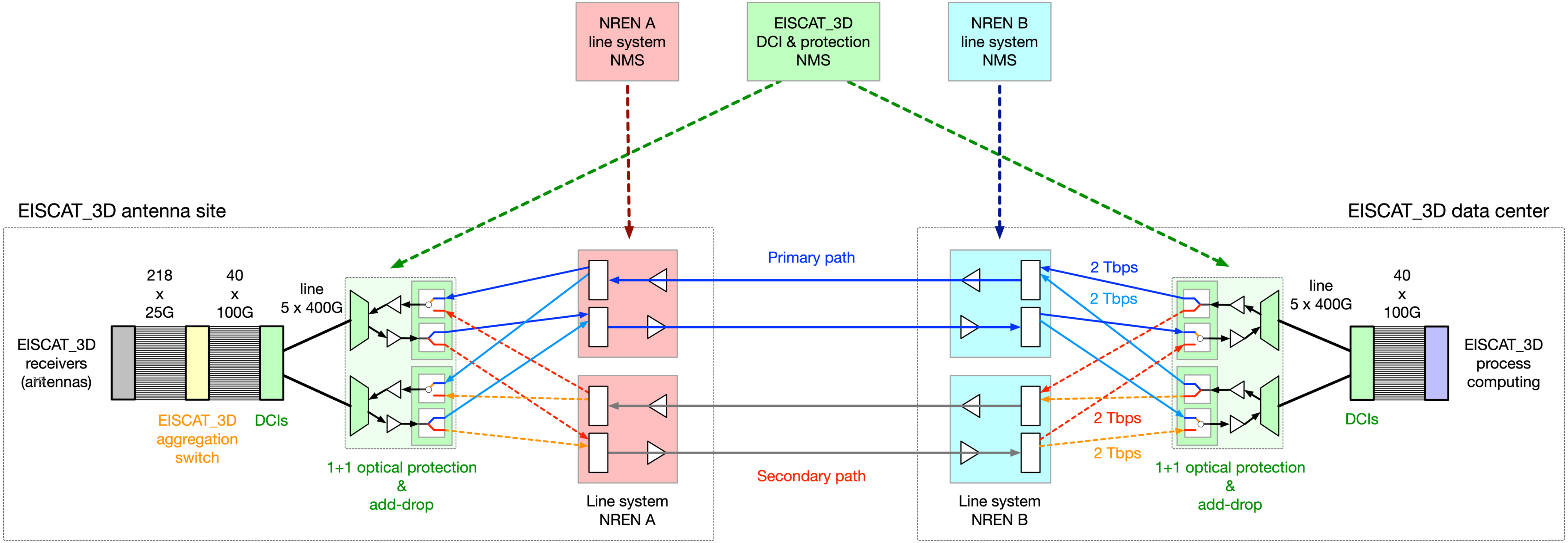




EISCAT_3D site-to-site transport (400G protected)



EISCAT_3D site-to-site transport (management)



FSP 3000 chassis options

T-SH1R-2 "TeraFlex" - 1RU compact HD-shelf

Used for high-speed transponder modules

Depth 485 mm (19.1 in.)
Width 448 mm (17.6 in.)
Height 43.8 mm (1.7 in.)

550mm depth supporting 600mm+ racks

- T-SH1R-2 shelf with 3x hot swappable traffic units
- Rear 1+1 hot swappable power supplies (AC 105-230V, DC +/-48V) T-PSM-AC(-DC) w/ separate fans
- Rear side field replaceable controller: T-ECM
  - Non-service affecting replacement
  - Easy access to non-volatile memory

1RU platform supporting 3.6Tb/s

ADVA

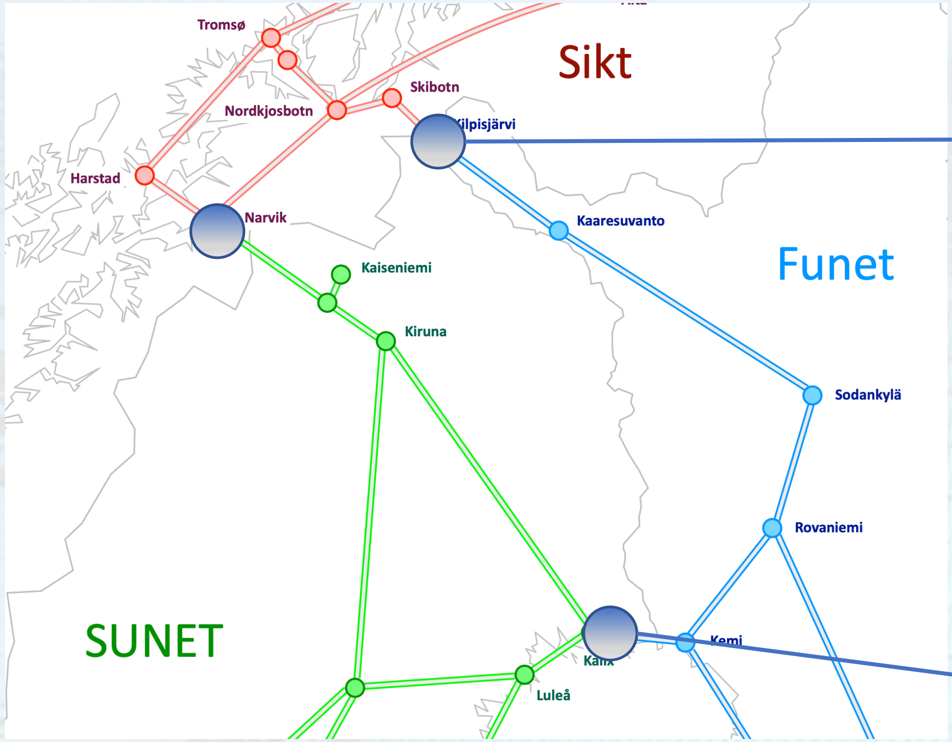
Spectrum planning

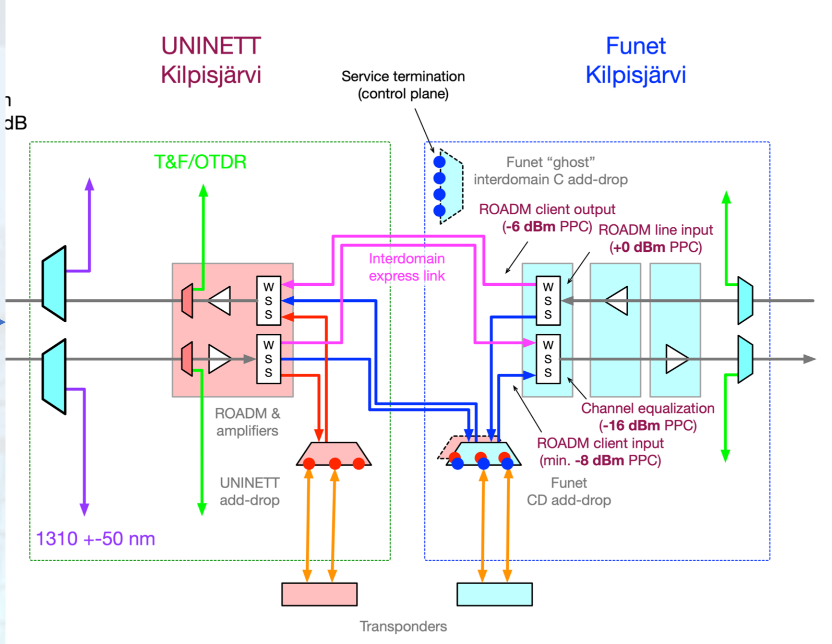
- Original topology with 2 sites using the ring
  - 20 * 100 GHz channels -> 2,0 THz spectrum
  - 20 * 75 GHz channels -> 1,5 THz spectrum
- New topology with 3 sites using the ring
  - 28 * 75 GHz channels -> 2,1 THz spectrum
- Real life implementation pending testing
  - 2 * 400G per media channel (150 GHz?)
  - Adjacent media channels will decrease filtering effect in flex-grid ROADMs
- Avoid spectrum fragmentation
  - Reuse and extend same slices already provided for GÉANT (2 * 600 GHz)
- SIKT shares OLS with another partner
  - No unlimited resources

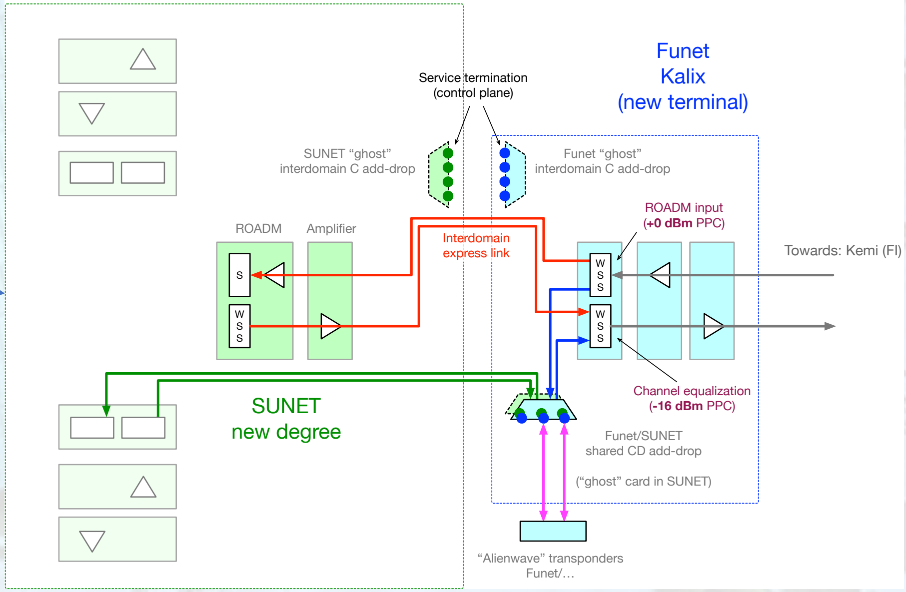
Spectrum sharing and operations

- We all already provide spectrum for external users
  - But not in the scale of EISCAT_3D 😅
- Multi-domain/vendor environment will be challenging
  - Potential signal power fluctuations (fiber cuts, power outages, OLS power equalisation algorithms)
  - Interdomain spectrum exchange is relatively simple
    - In principle: NREN1 ROADM client <-> NREN2 ROADM client
    - No equipment balancing unexpected power changes with extremely fast feedback loop
- Any change and maintenance would need careful planning and coordination

Optical interconnects, three optical domains







Management and monitoring

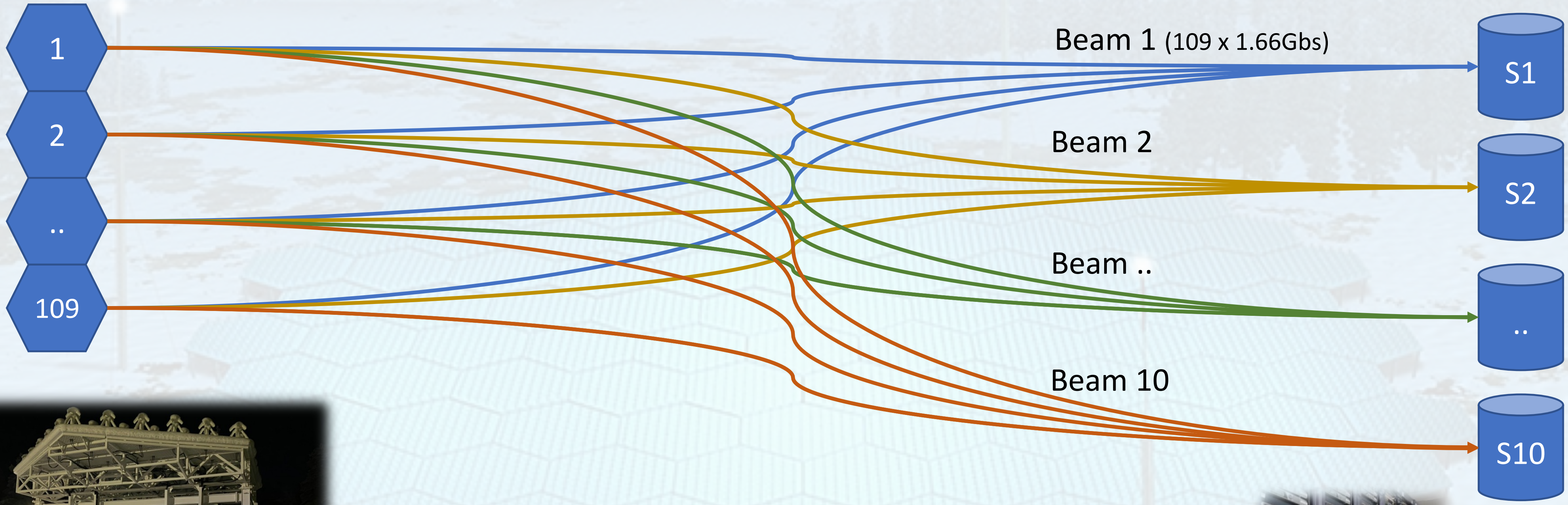
- Totally isolated DCN and NMS for EISCAT_3D transport
  - Support shared operations and engineering
  - OLS domains remain separate per NREN
- Multi-domain monitoring
  - Separate on-going initiative to develop cross-domain monitoring between the Nordic NRENs
    - Multiple applications for spectrum sharing like NORDUnet-NG, GÉANT, EISCAT_3D
  - Define models to share normalised critical metrics
    - NREN OLS systems (ADVA, Nokia, Ciena, Infinera, Ribbon, …)
    - Transport (DCIs, coherent pluggables)
    - Packet networks
  - Multi-layer visualisations and trends

EISCAT_3D packet layer

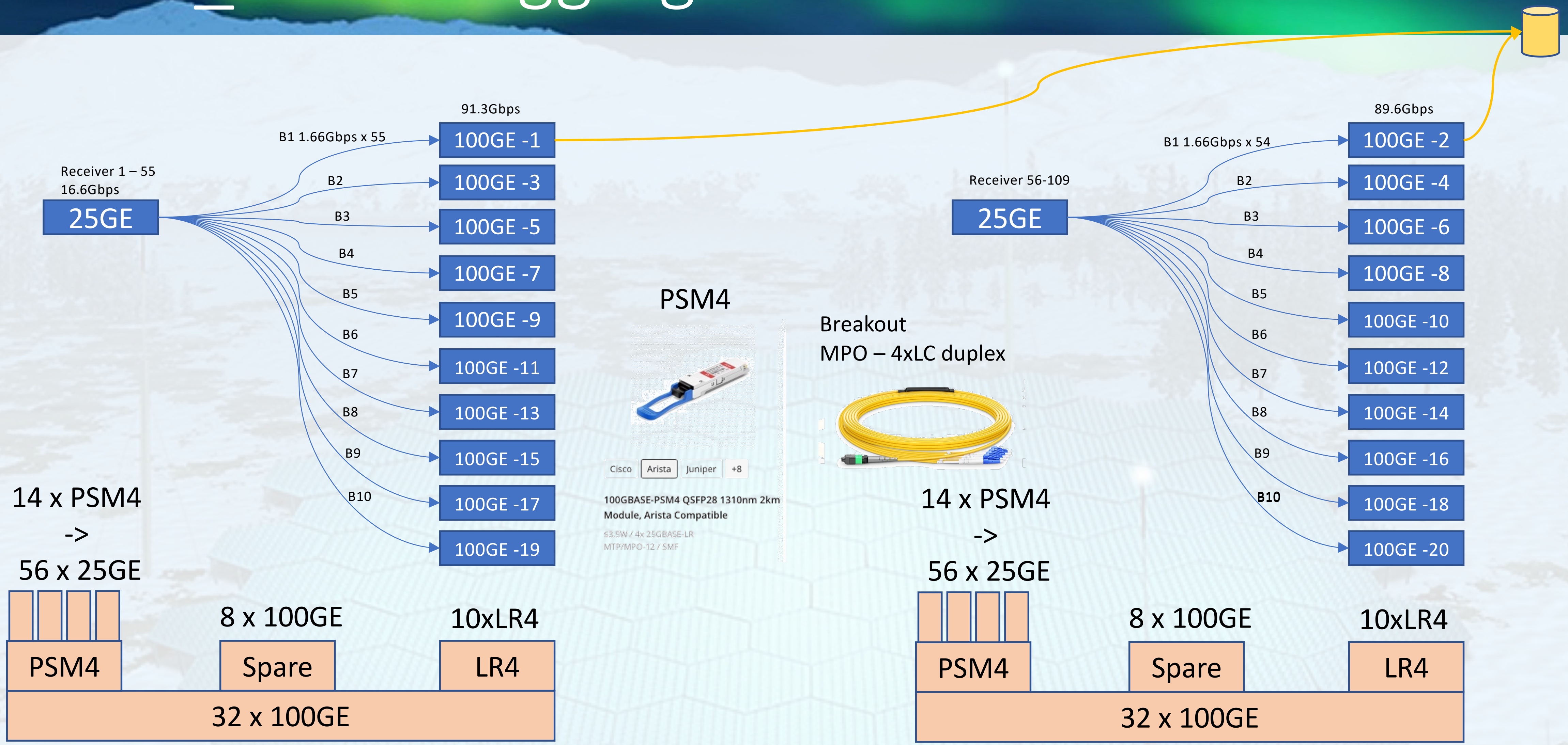
- A very simple L2 switching model chosen
  - Base on static MAC addresses etc.
  - No datacenter switches needed between the transport and servers
  - 4 * 32 port 100G switches will cover full topology needs
    - 54 or 55 * 25 GbE interfaces from branch-out optics in each switch
    - 10 * 100 GbE interfaces towards transport in each switch
  - Will also support Skibotn 119 receivers

Traffic pattern

Each Antenna container generates data streams for ten beams.
A beam has an X and Y polarisation.
Data from all containers are computed per beam on dedicated Servers.



EISCAT_3D: 4 x Aggregation switch



Switch 1: X-pol Rec 1-55

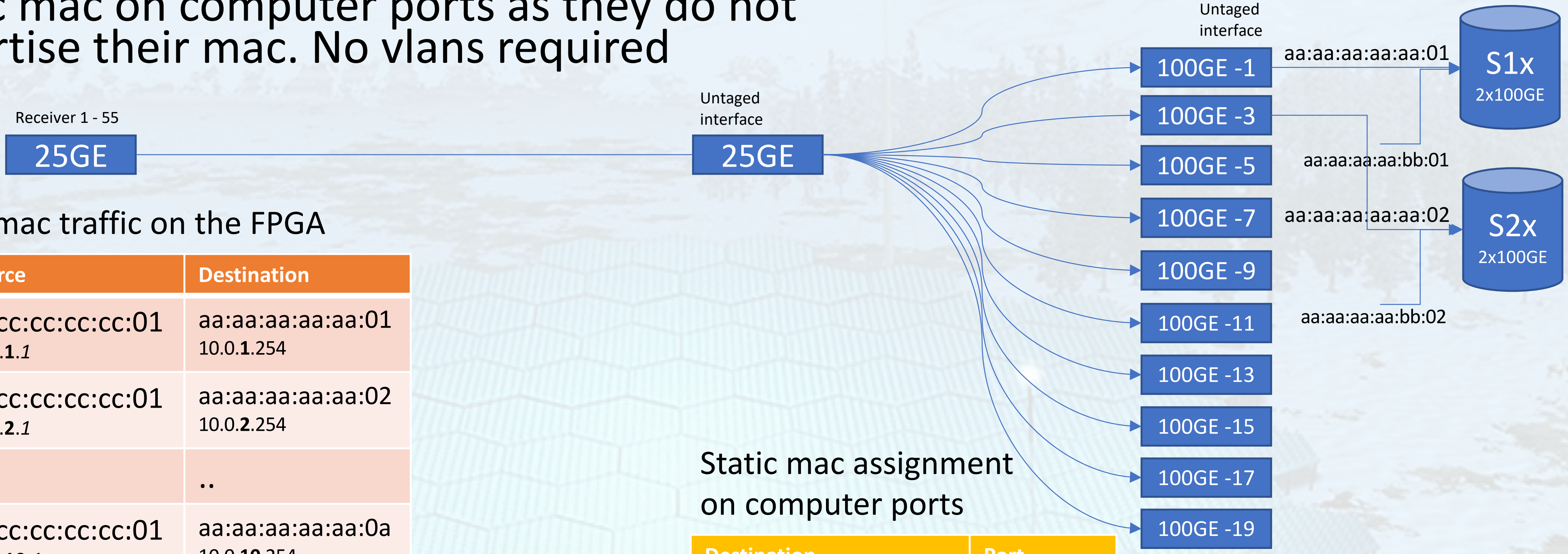
Switch 2: X-pol Rec 56-109 (119)

Switch 3: Y-pol Rec 1-55

Switch 4: Y-pol Rec 56-109 (119)

Traffic steering using mac-addresses

- Unidirectional traffic
- Static mac on computer ports as they do not advertise their mac. No vlans required



Programmed mac traffic on the FPGA

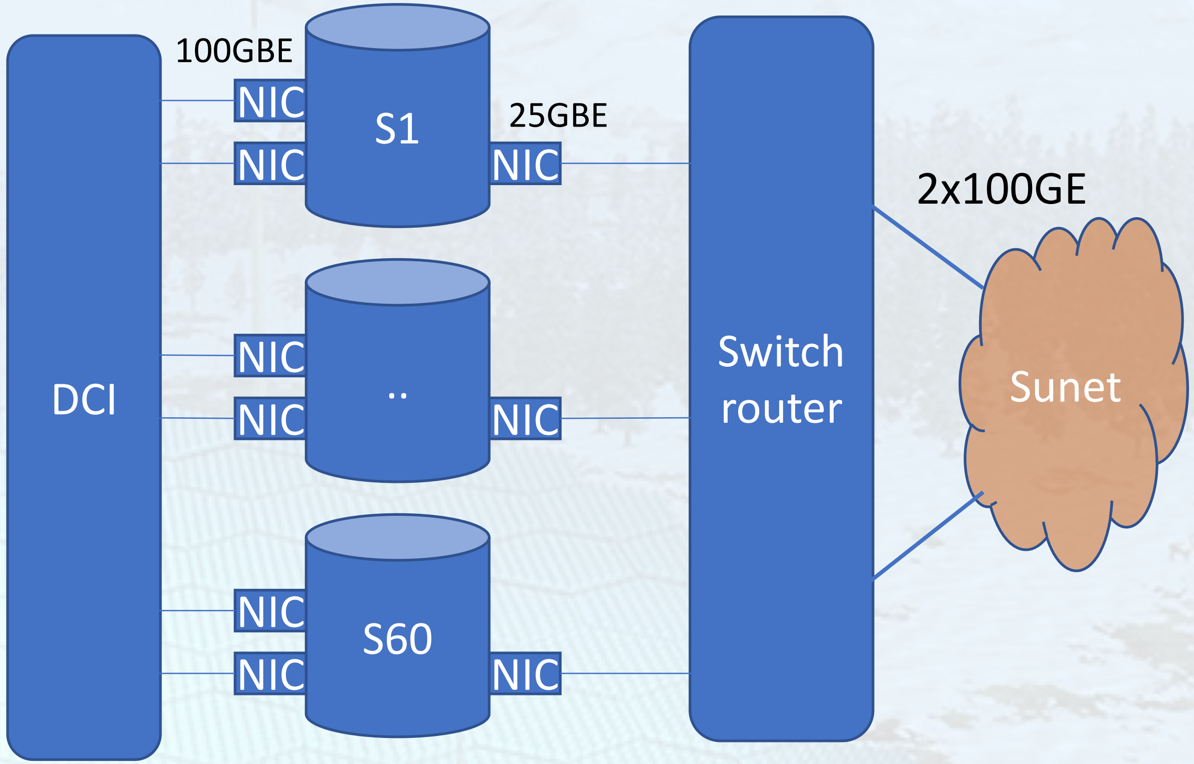
Rec	Beam	Source	Destination
1	**1**	cc:cc:cc:cc:cc:01 10.0.**1**.*1*	aa:aa:aa:aa:aa:01 10.0.**1**.254
1	**2**	cc:cc:cc:cc:cc:01 10.0.**2**.*1*	aa:aa:aa:aa:aa:02 10.0.**2**.254
..	..	..	..
1	10	cc:cc:cc:cc:cc:01 10.0.**10**.*1*	aa:aa:aa:aa:aa:0a 10.0.**10**.254
2	1	cc:cc:cc:cc:cc:02 10.0.**1**.*2*	aa:aa:aa:aa:aa:01 10.0.**1**.254
2	2	cc:cc:cc:cc:cc:02 10.0.**2**.*2*	aa:aa:aa:aa:aa:02 10.0.**2**.254
..	..	..	...

Static mac assignment on computer ports

Destination	Port
aa:aa:aa:aa:aa:01	Port 1
aa:aa:aa:aa:aa:02	Port 3
..	
aa:aa:aa:aa:aa:0a	Port 19

DC site

- Servers at DC site
  - 2 x 100GE for the antennas connected directly to the DCI optical system
  - 1 x 25GE for communication of processed data and communication to the “Internet”
    - The 25GE interface needs to be connected to a switch infrastructure at the DC.



Thank you!

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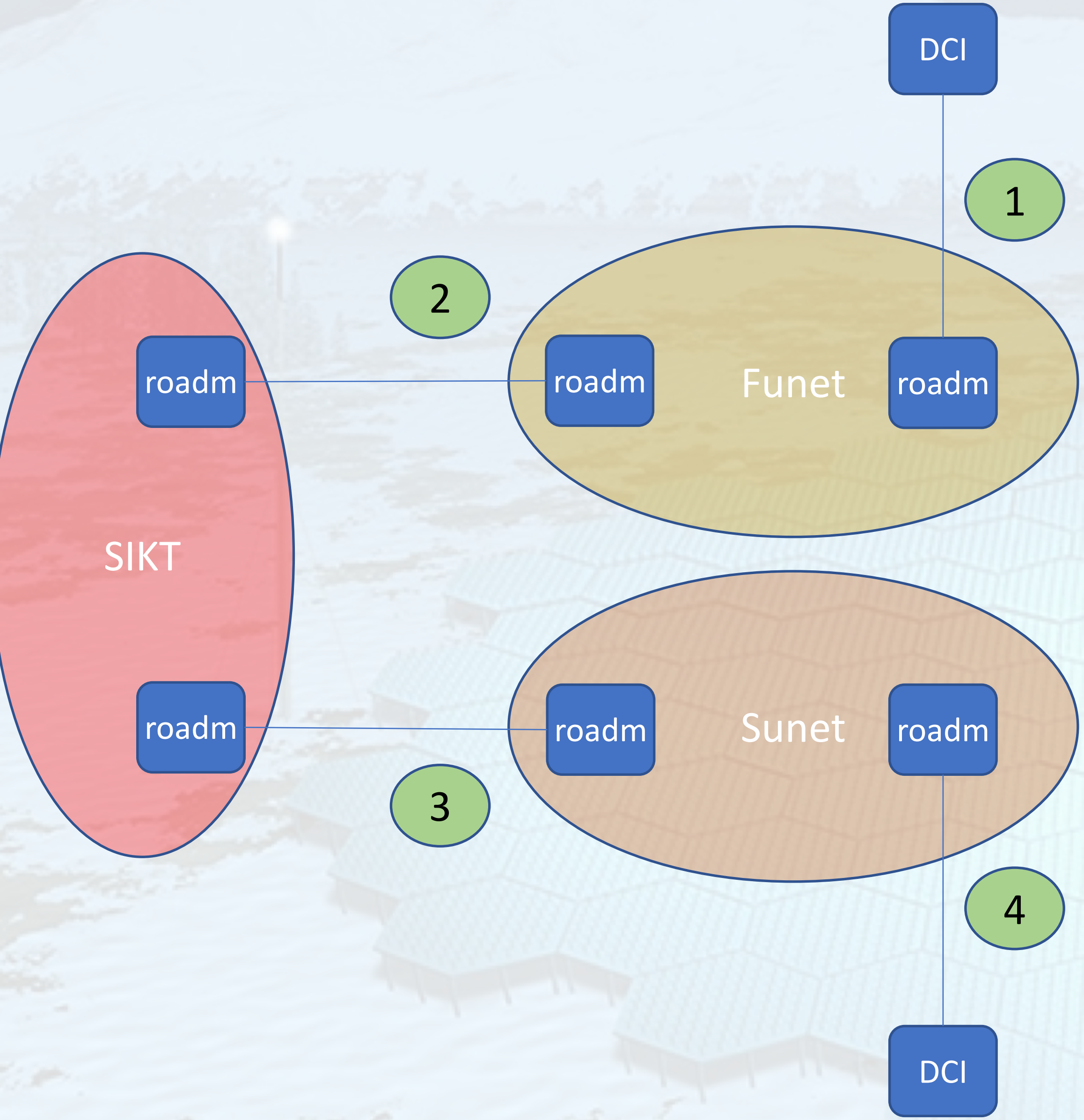
NORDUnet
Nordic Gateway for Research & Education

Jani Myyry (CSC/Funet)

together with
Magnus Bergroth, Dennis Wallberg (SUNET)
Kurosh Bozorgebrahimi (SIKT)

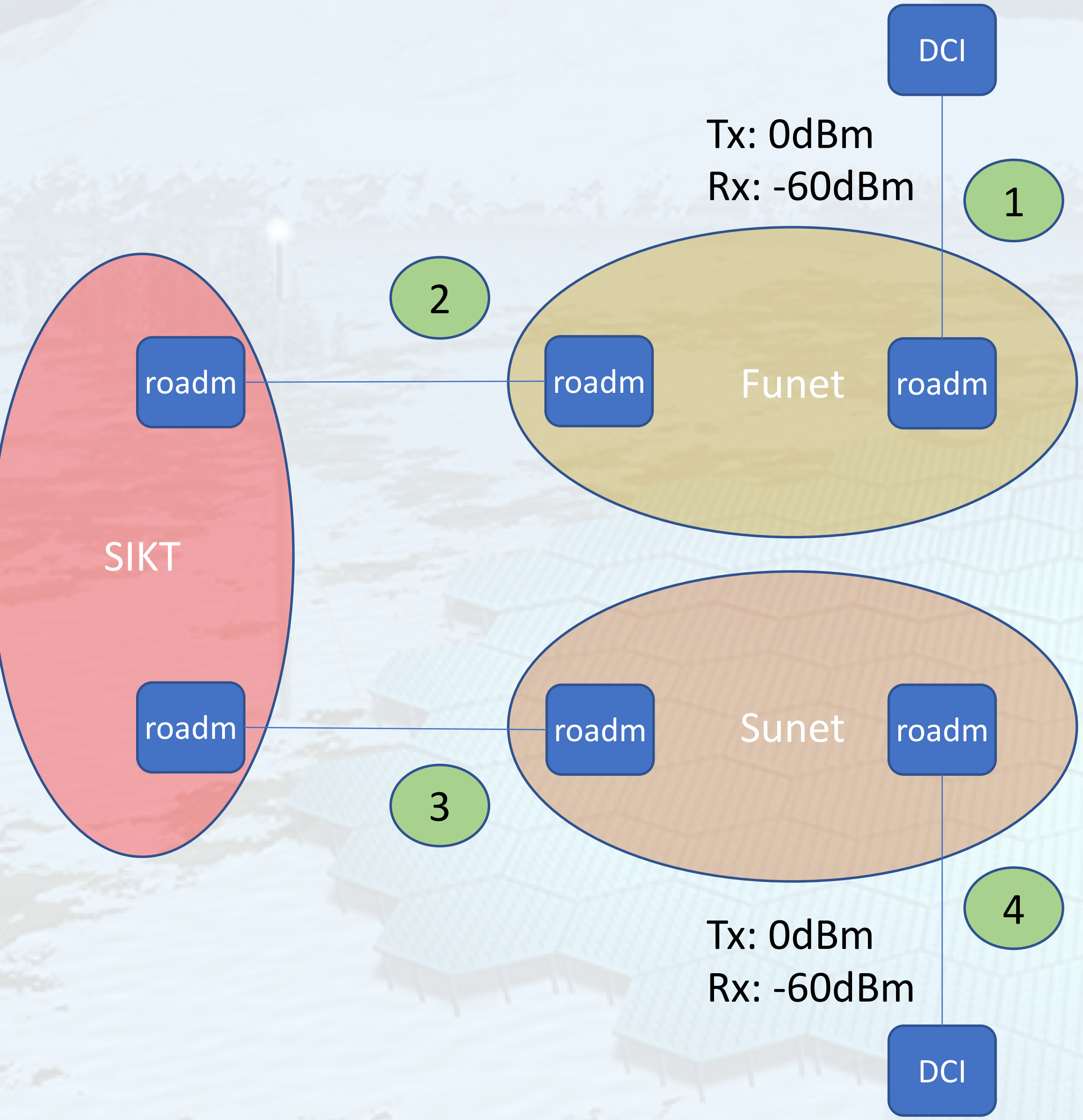
Extra slides

Turn up and balance



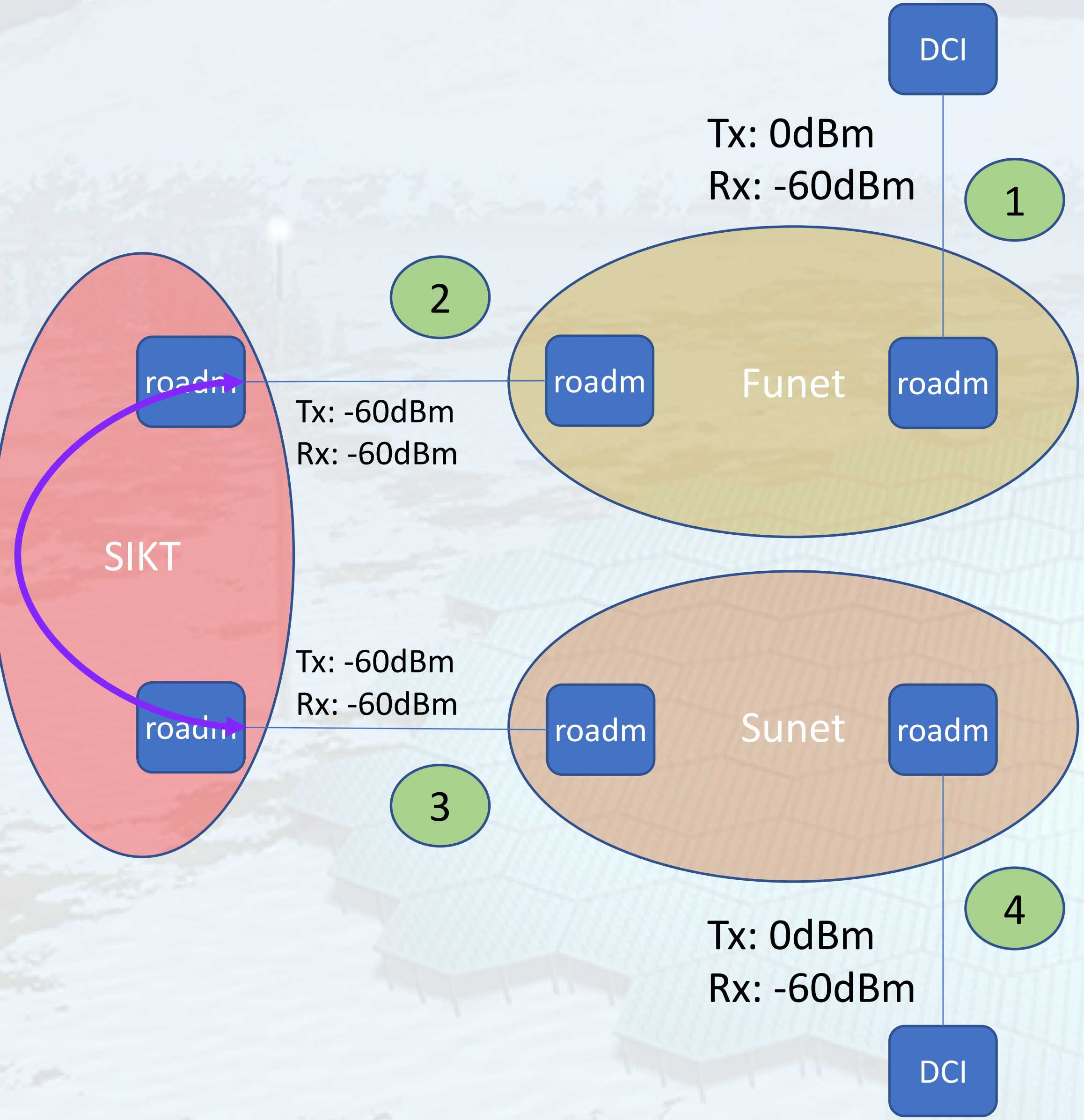
- 1: Decide on a frequency/channel

Turn up and balance



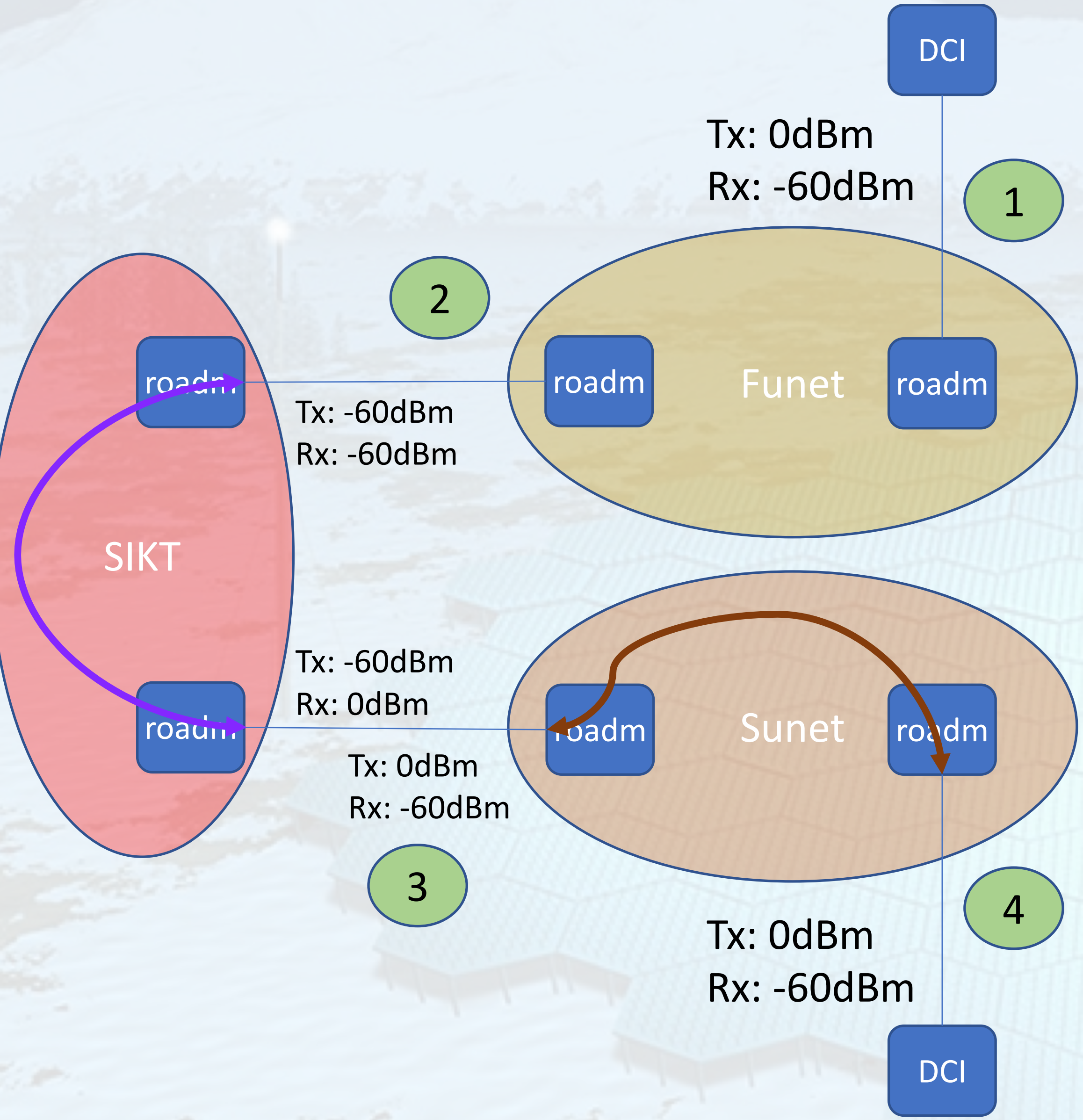
- 1: Decide on a frequency/channel
  - 193.100 THz
  - DCI transmits power
  - DWDM networks unconfigured
- 2: Build tunnels
  - SIKT goes first

Turn up and balance



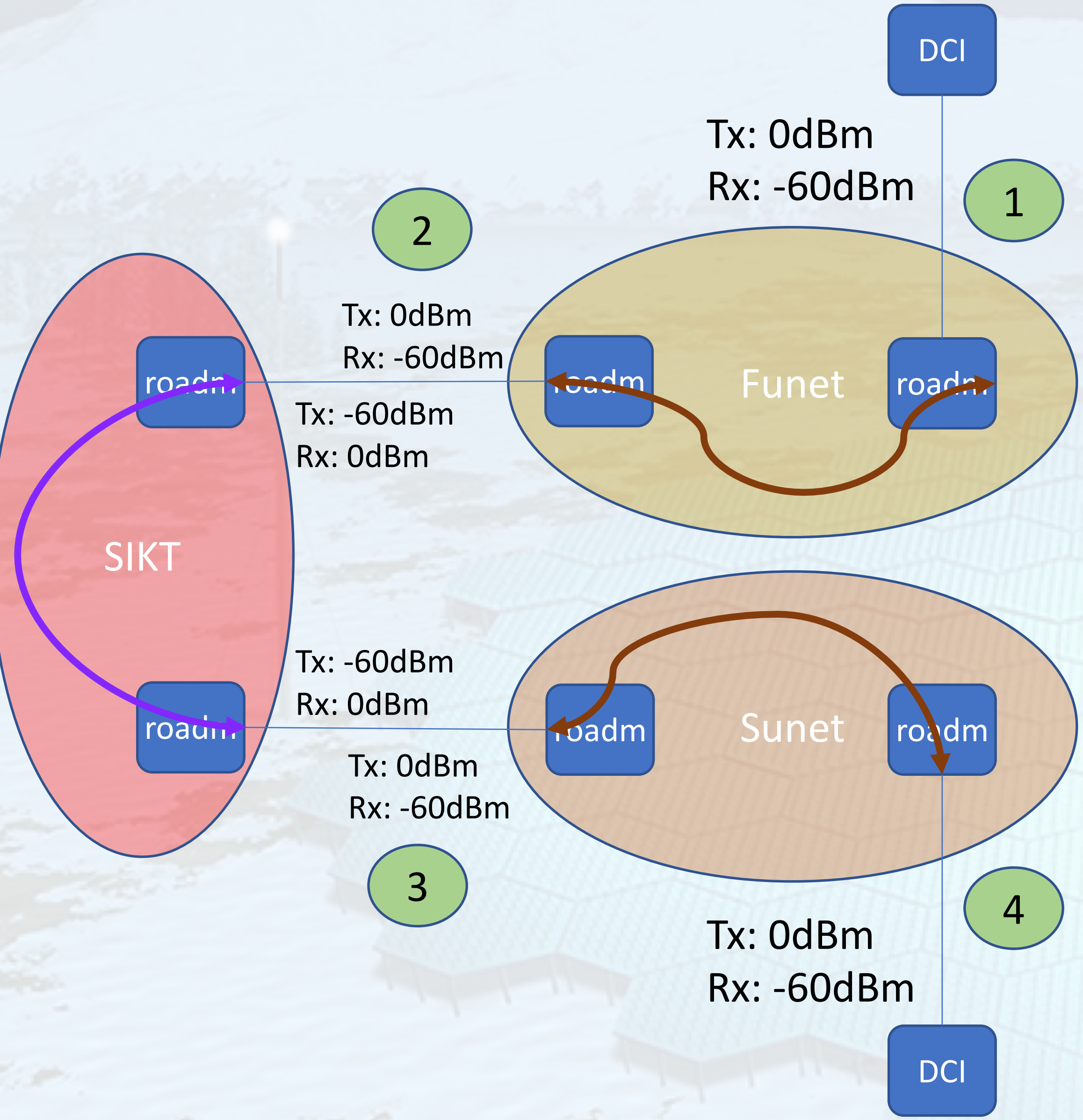
- 1: Decide on a frequency/channel
  - 193.100 THz
  - DCI transmits power
  - DWDM networks unconfigured
- 2: Build tunnels
  - SIKT goes first
    - Dark in on 2 and 3
  - Sunet goes next

Turn up and balance



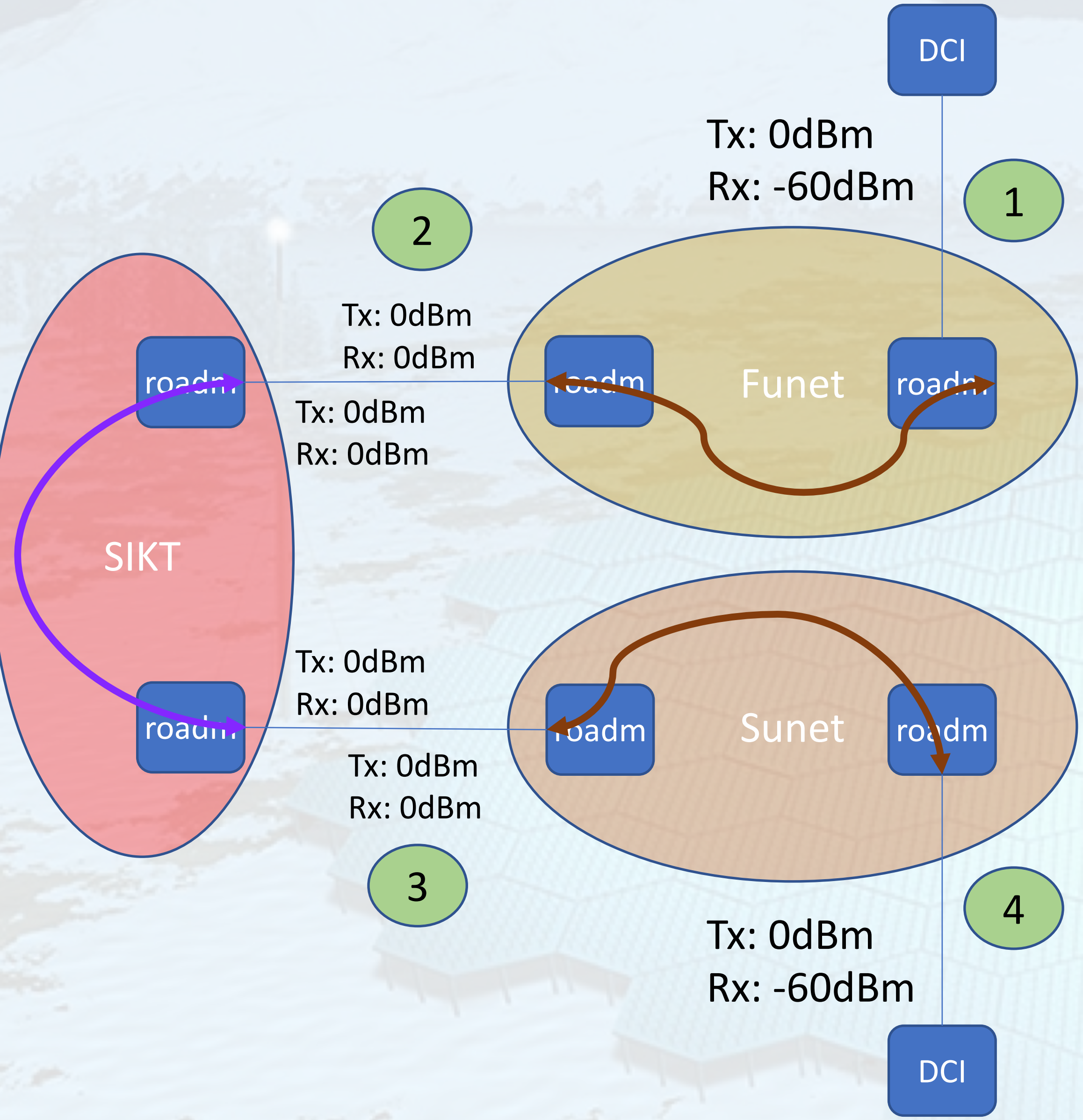
- 1: Decide on a frequency/channel
  - 193.100 THz
  - DCI transmits power
  - DWDM networks unconfigured
- 2: Build tunnels
  - SIKT goes first
    - Dark in on 2 and 3
  - Sunet goes next
    - Light in on 4, Light out on 3
    - Dark in on 3, Dark out on 4
  - Funet goes next

Turn up and balance



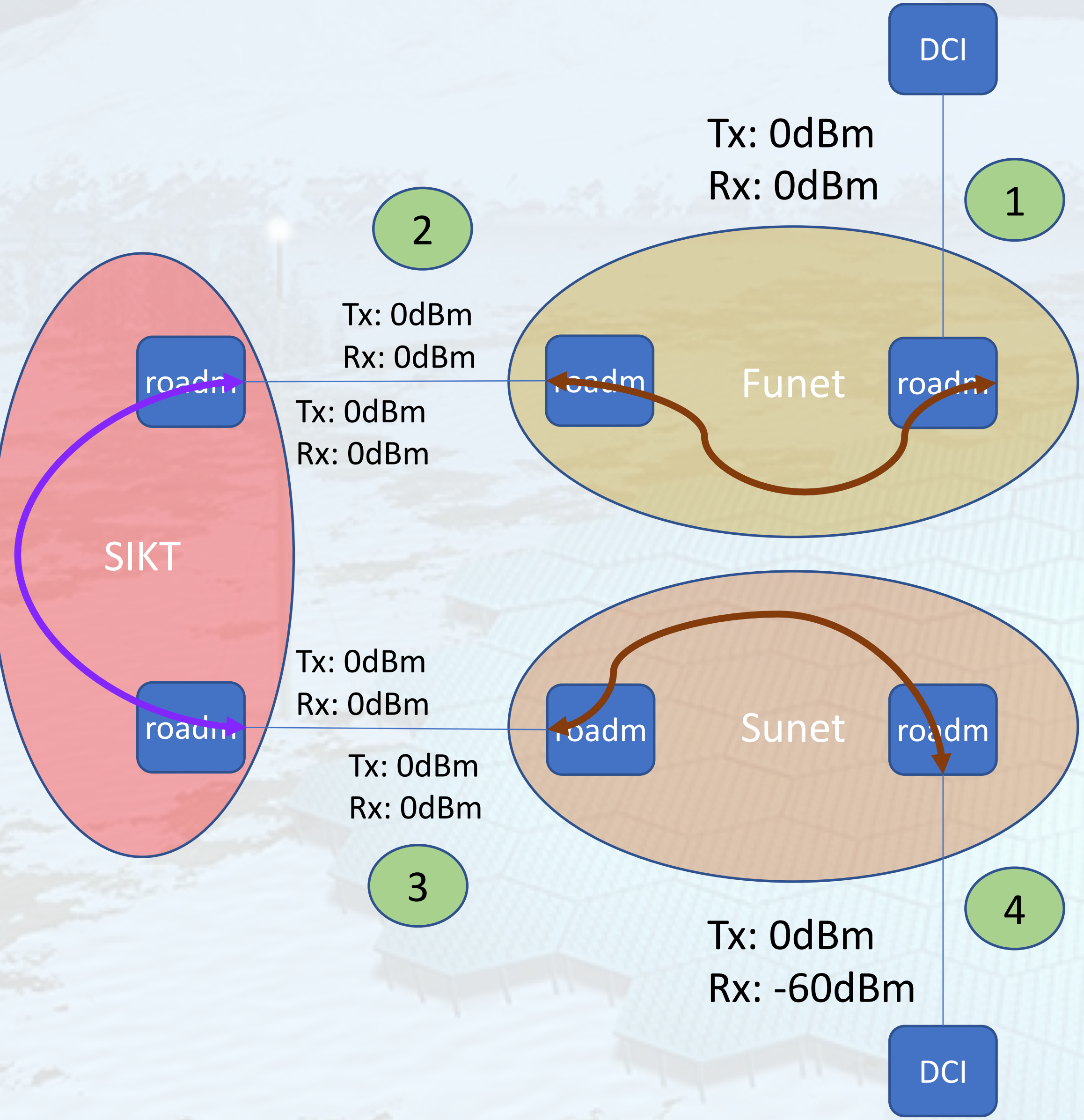
- 1: Decide on a frequency/channel
  - 193.100 THz
  - DCI transmits power
  - DWDM networks unconfigured
- 2: Build tunnels
  - SIKT goes first
    - Dark in on 2 and 3
  - Sunet goes next
    - Light in on 4, Light out on 3
    - Dark in on 3, Dark out on 4
  - Funet goes next
    - Light in on 1, Light out on 2
    - Dark in on 2, Dark out on 1

Turn up and balance



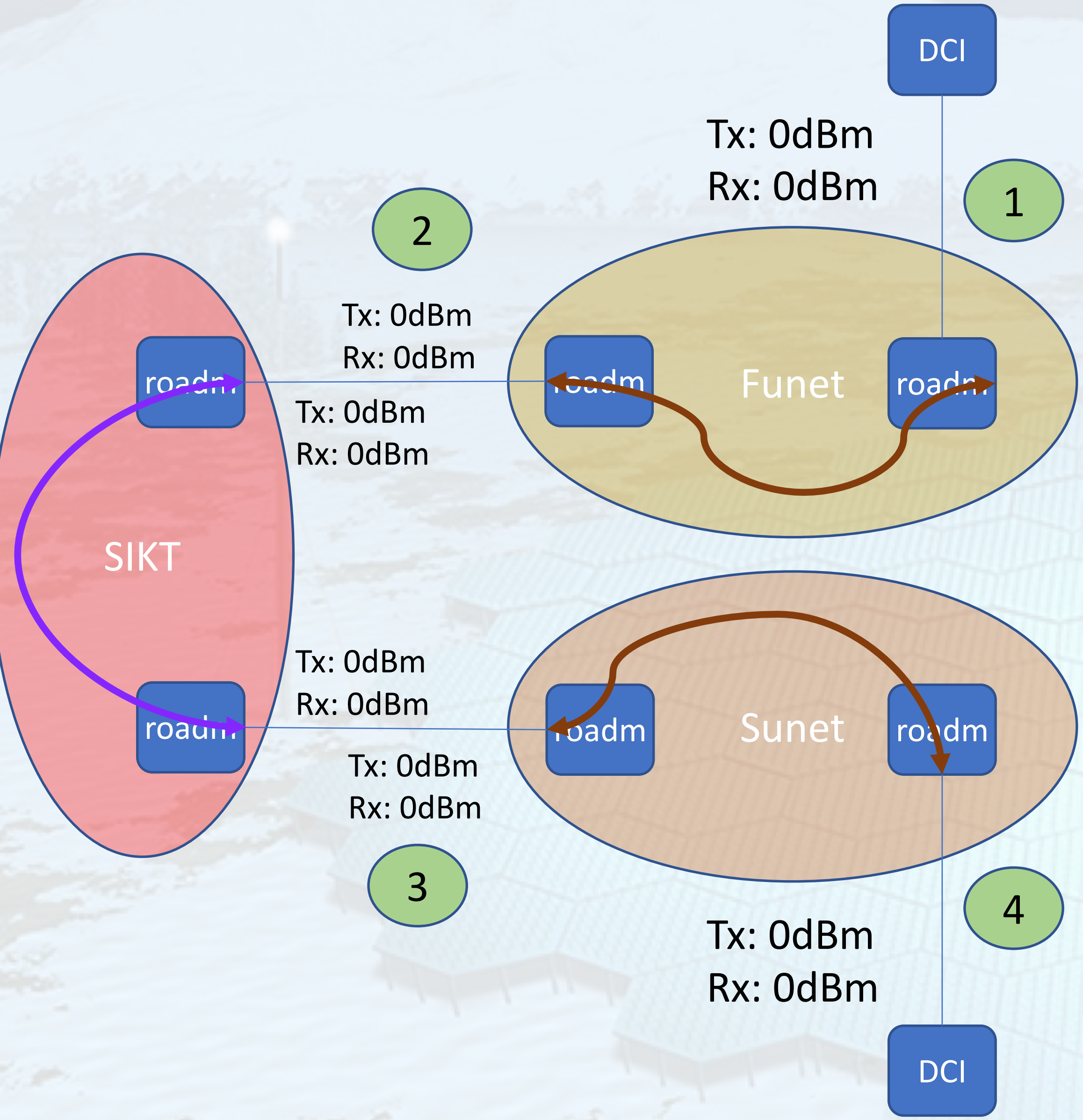
- 3: Sikt Re-balance their tunnel
  - Light in on 2, Light out on 3
  - Light in on 3, Light out on 2

Turn up and balance



- 3: Sikt Re-balance their tunnel
  - Light in on 2, Light out on 3
  - Light in on 3, Light out on 2
- 4: Funet Re-balance their tunnel
  - Light in on 2, Light out on 1

Turn up and balance

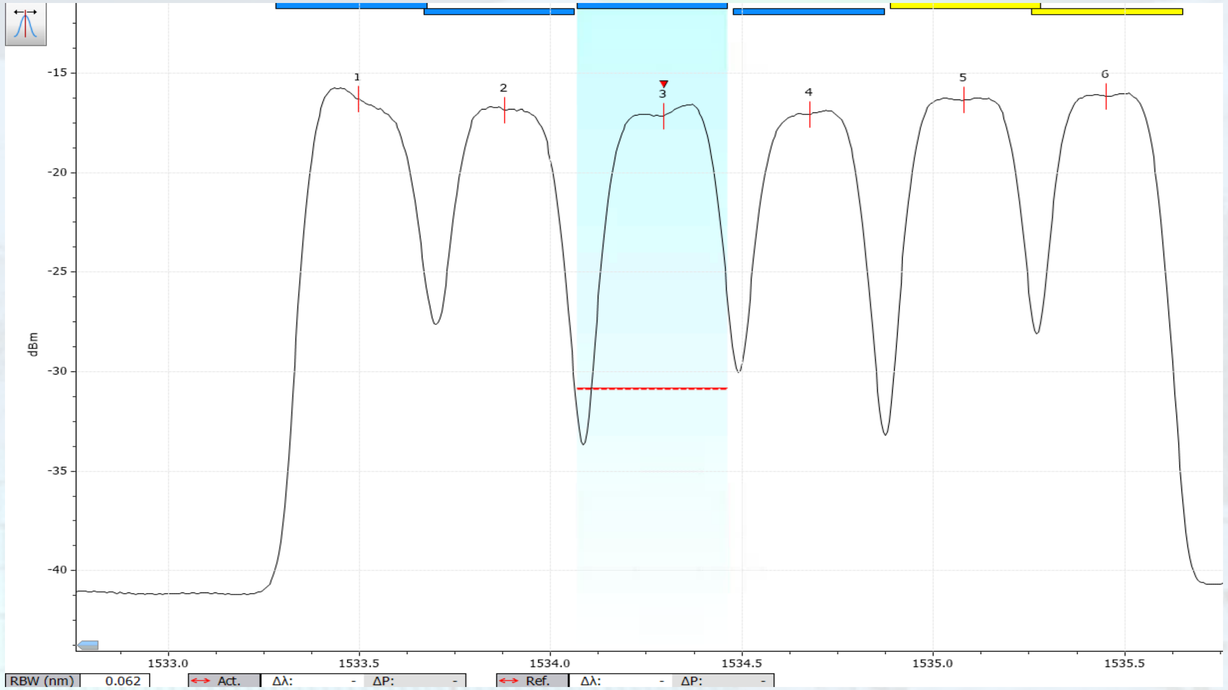


- 3: Sikt Re-balance their tunnel
  - Light in on 2, Light out on 3
  - Light in on 3, Light out on 2
- 4: Funet Re-balance their tunnel
  - Light in on 2, Light out on 1
- 5: Sunet Re-balance their tunnel
  - Light in on 3, Light out on 4

- Dance between the organizations.
  - All need to wait for light and manually rebalance twice.
  - Needs to be done for 10 channels in primary and backup direction per site.

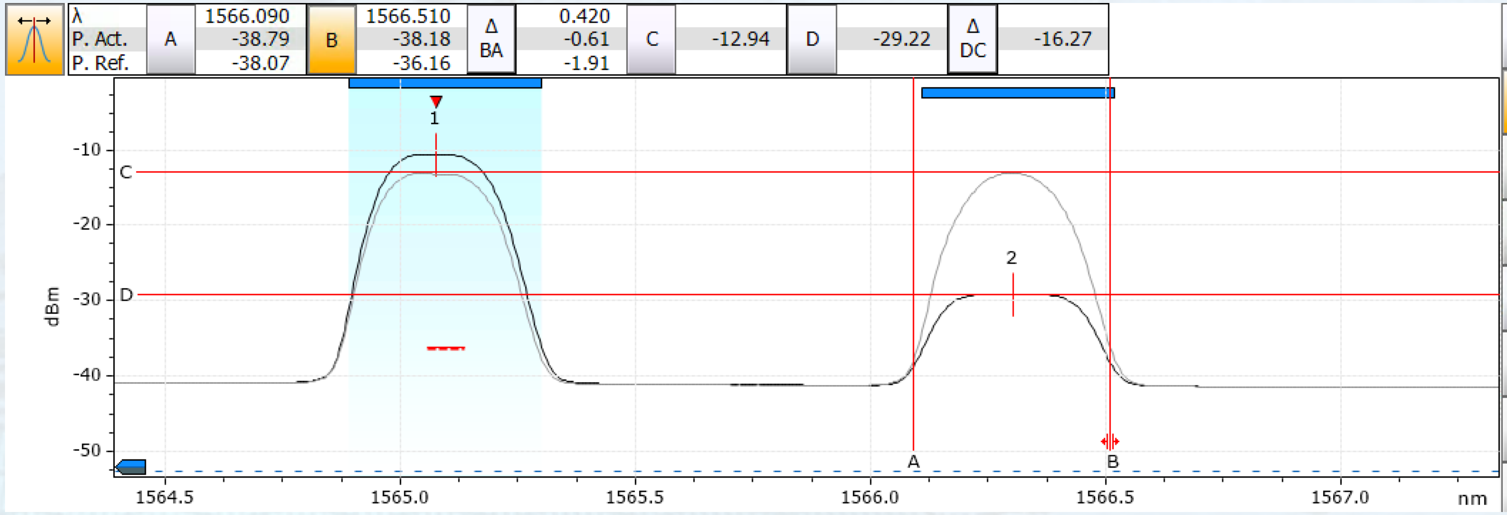
Super-channels

- The optical spectrum from each site will occupate 10 channels of minimum 75 GHz spectrum
- It could in theory be setup as a super-channel of 400 GHz. The ROADMs will the power balance them as one channel. This could lead to unbalance spectrum at the receiver.
- Better to use narrower spectrum blocks that can be power balanced in each ROADM

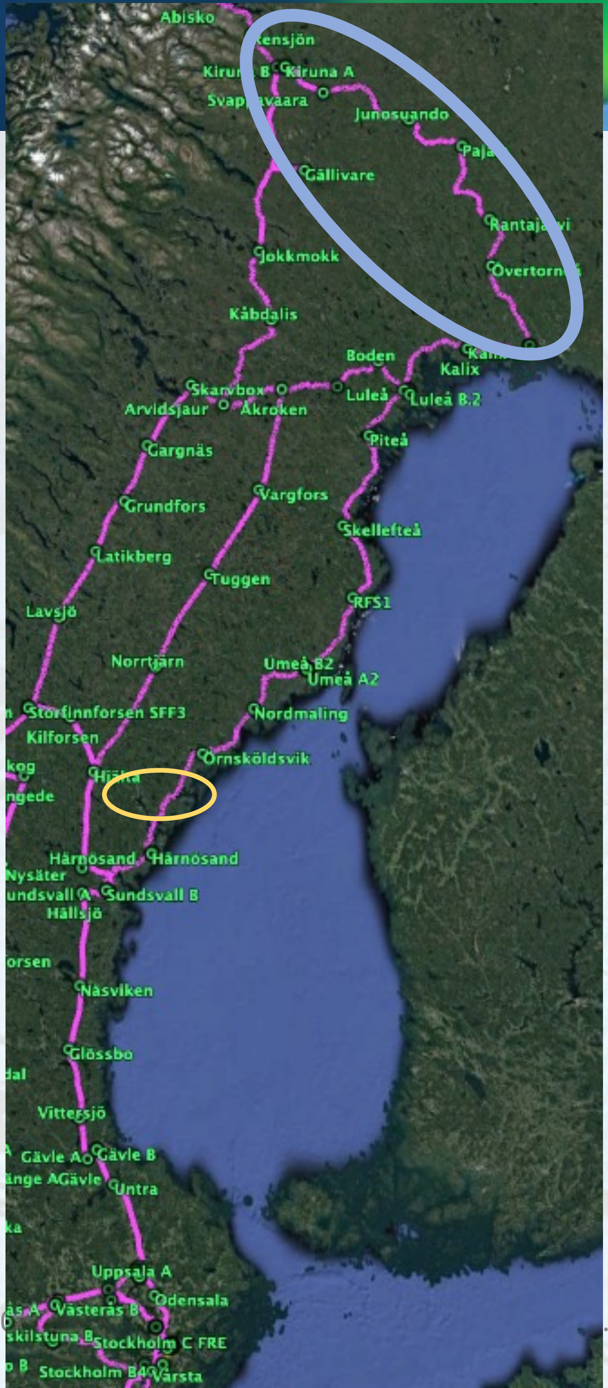


Noise is also a signal

- If a channel is turned off, could be fiberbreak or issue at the DCI, the signal will go away from the DWDM system.
- As all the ROADM filters are open the background noise will be amplified in each node. (OSA 2)
- At the domain interconnect the signal power could now be 20 dB lower. The other domain will now slowly compensate and add gain to get the signal up to the correct level.
- If the signal gets restored there will be a 20 dB gain and that DWDM system will be overloaded and neighbor channels will be interrupted until the channel is rebalanced



OSA 2



Line power changes

- Removing a large amount of power from the optical line will affect the amps. Tested in Sunet by removing large amount of test noise and the other channels got a short outage
- Raman effect in the DWDM spectrum, normally compensated with tilt in the EDFA.