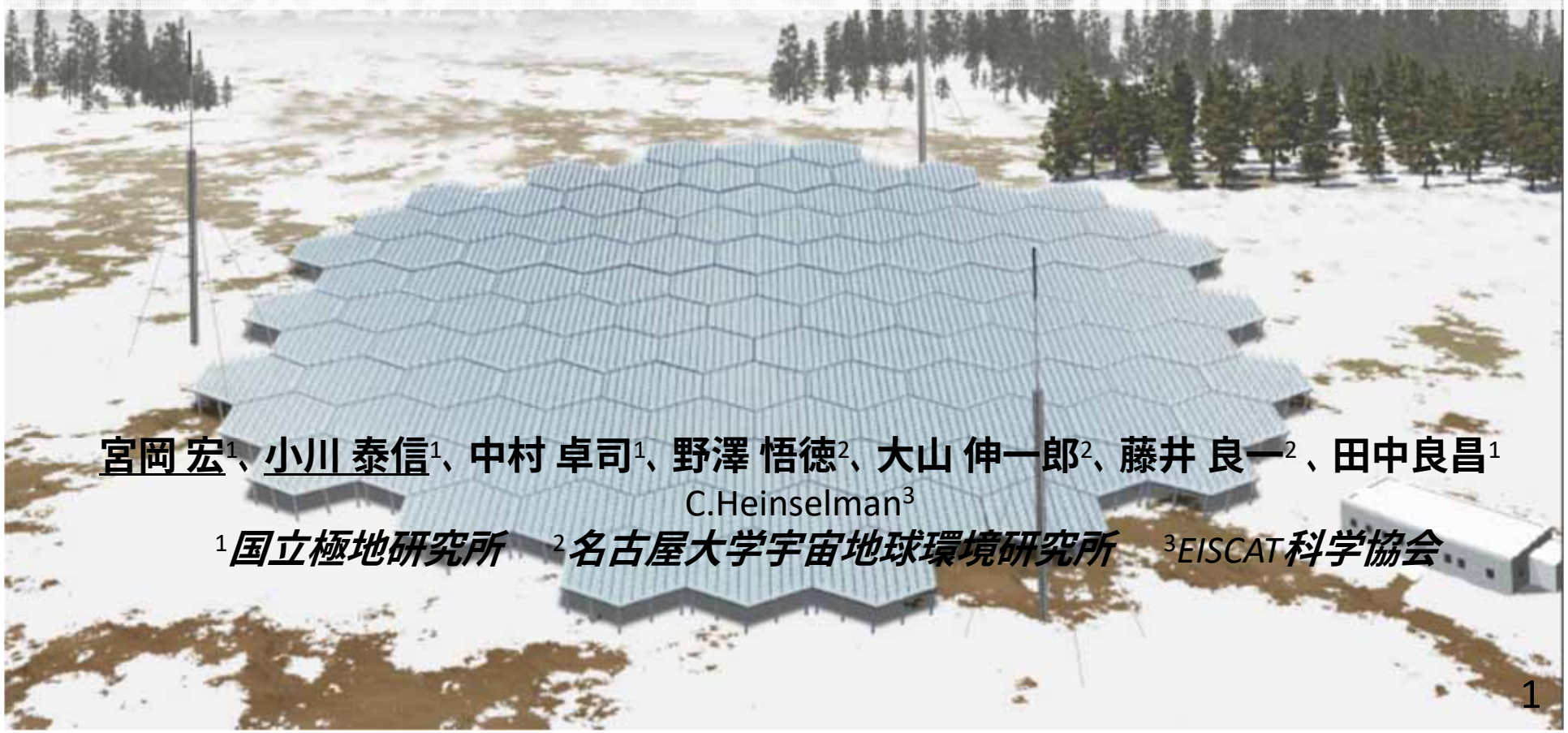
第3回IUGONET研究集会　2016年10月18-19日、国立極地研究所

EISCAT_3D計画の現状とデータ利用



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[1]国立極地研究所　[2]名古屋大学宇宙地球環境研究所　[3]EISCAT科学協会

『マスタープラン2014』

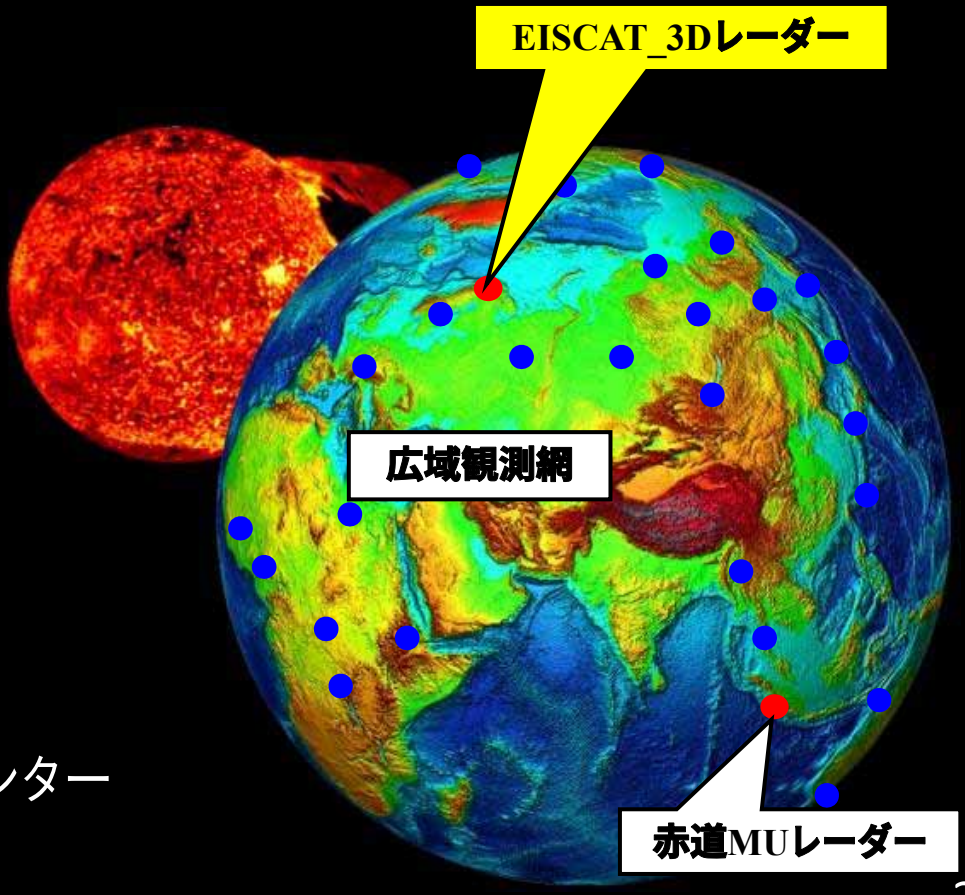
2014年3月に重点大型研究計画27件の1つに採択
2014年7月にロードマップ新規10件の1つに採択

太陽地球系結合過程の研究基盤形成

Study of Coupling Processes in the Solar-Terrestrial System

提案者　津田敏隆（京都大学生存圏研究所長・教授）

研究課題
- (1) 赤道ファウンテン
- (2) 極域エネルギー流入過程
- (3) グローバル結合過程



参画機関：
- 京都大学生存圏研究所
- 国立極地研究所
- 名古屋大学太陽地球環境研究所
- 九州大学国際宇宙天気科学・教育センター

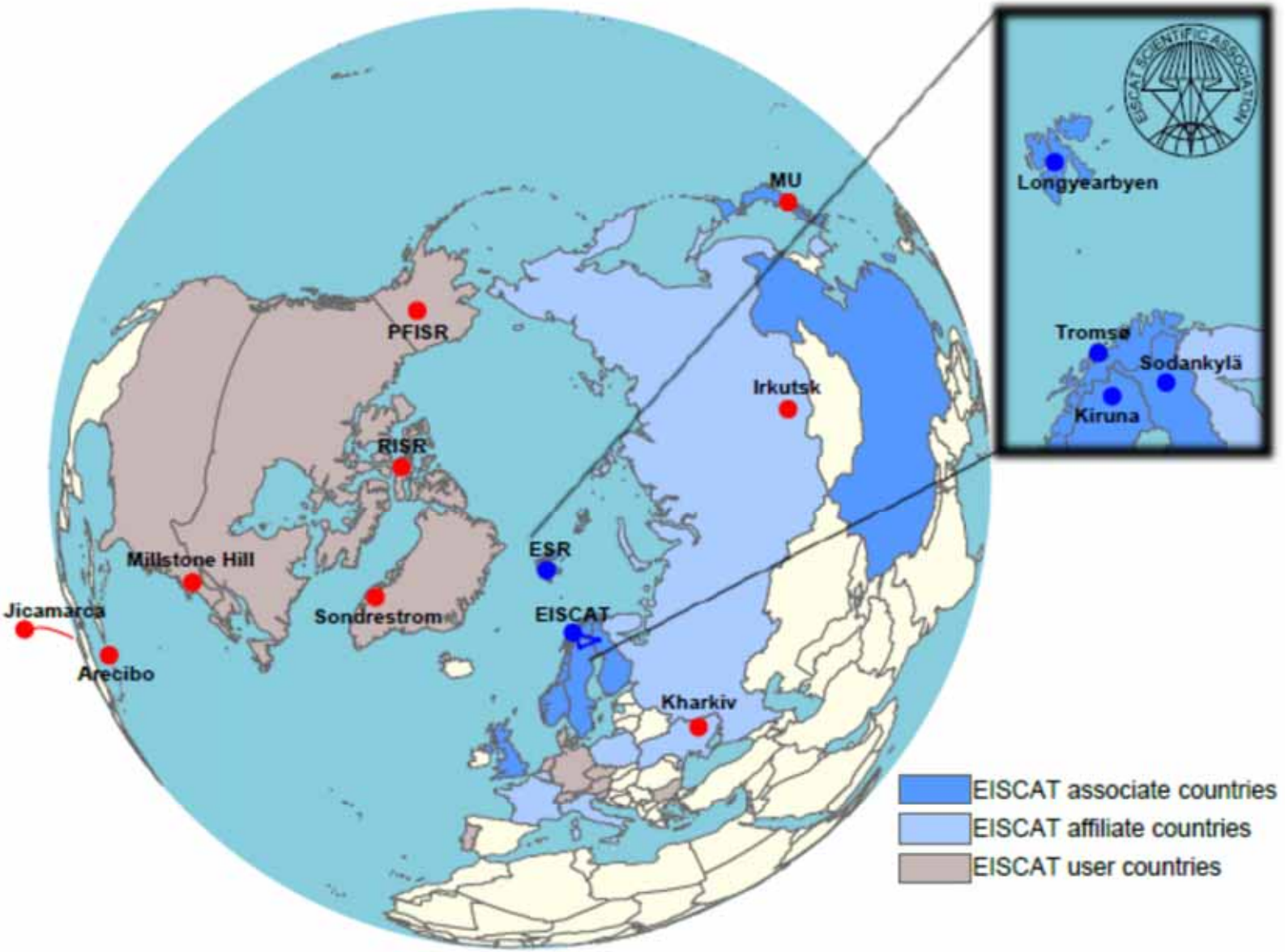
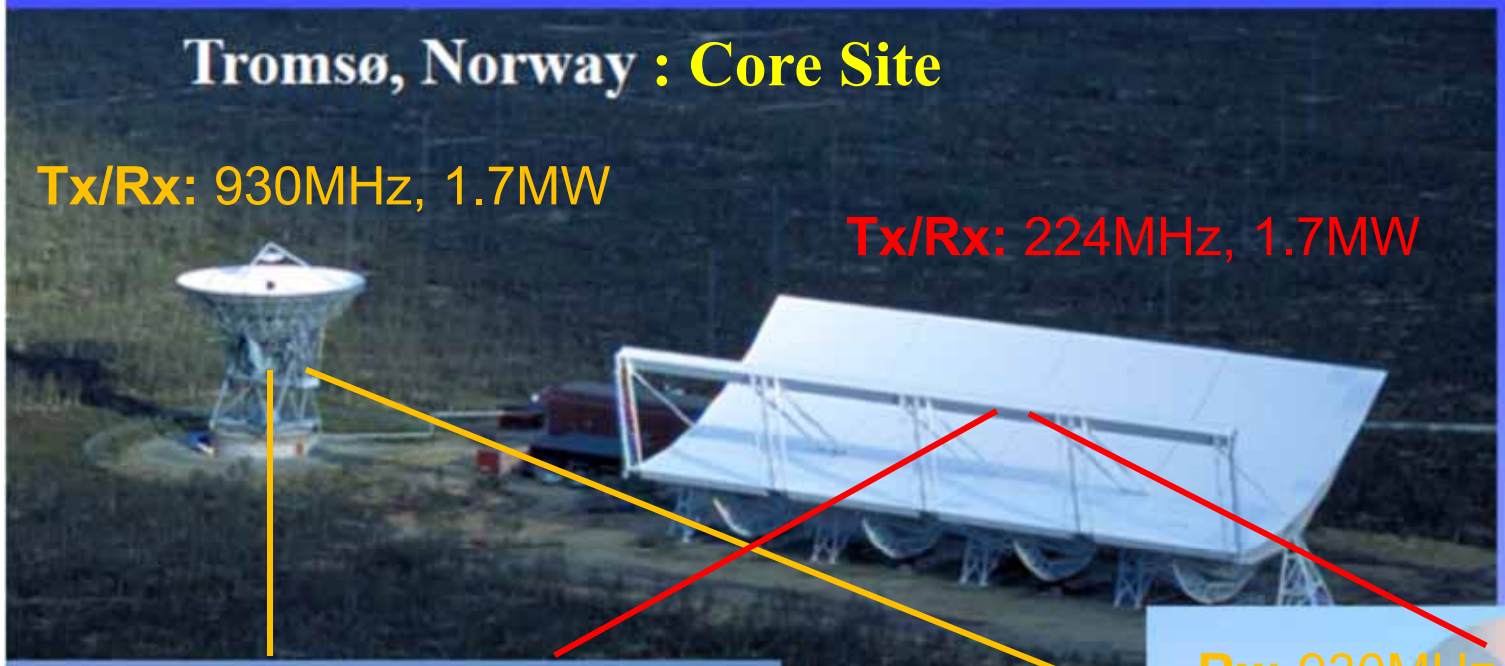


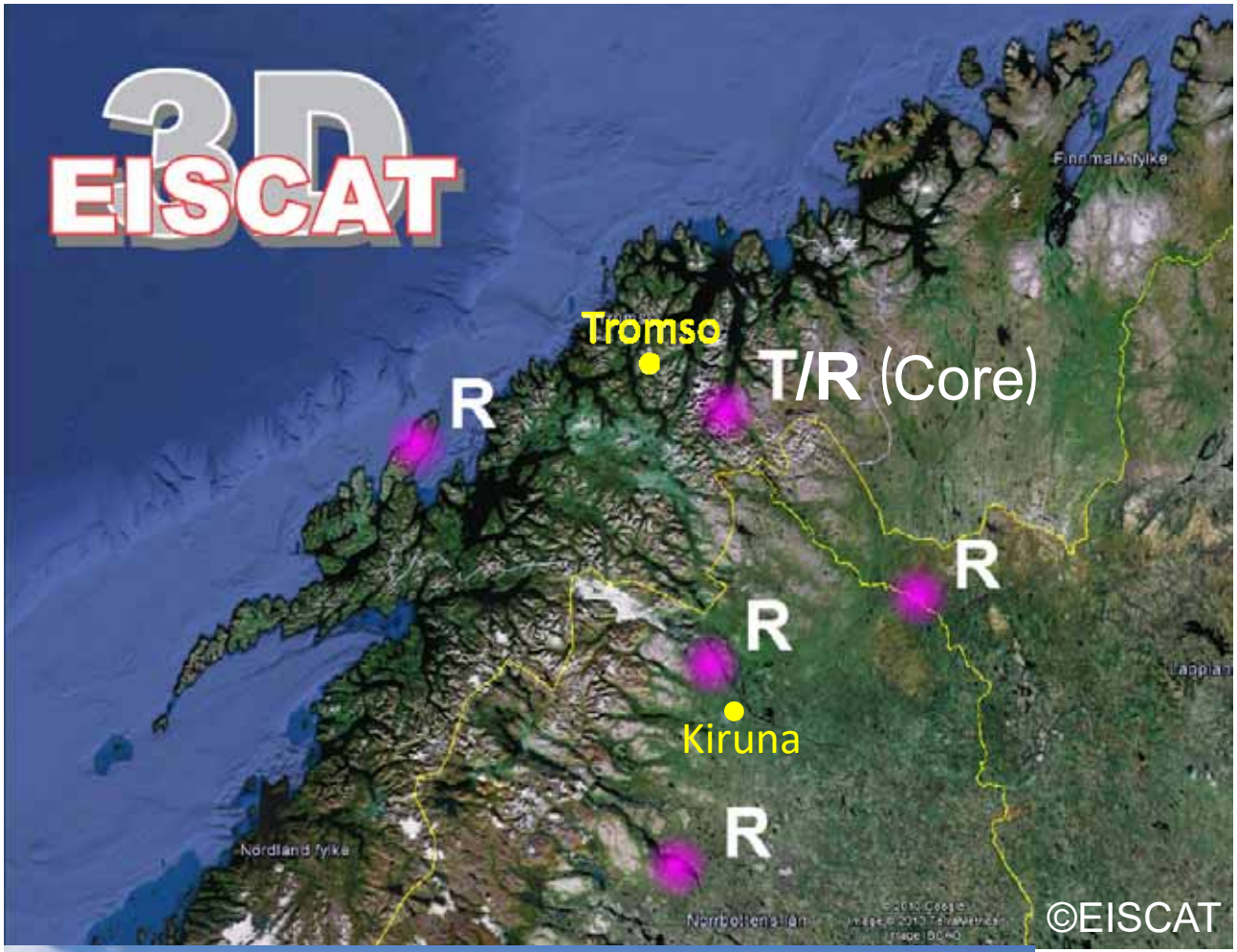
Figure 1: Existing incoherent scatter radars. The EISCAT associate countries, (prospective) affiliate countries and user countries are also marked on the map.

EISCAT Mainland Radars



Rx: 930MHz →224MHz

Rx: 930MHz →224MHz


3D
EISCAT
Tromso
T/R (Core)
R
R
R
R
Kiruna
Finnmark fylke
Lappland
Nordland fylke
Norrbottens län
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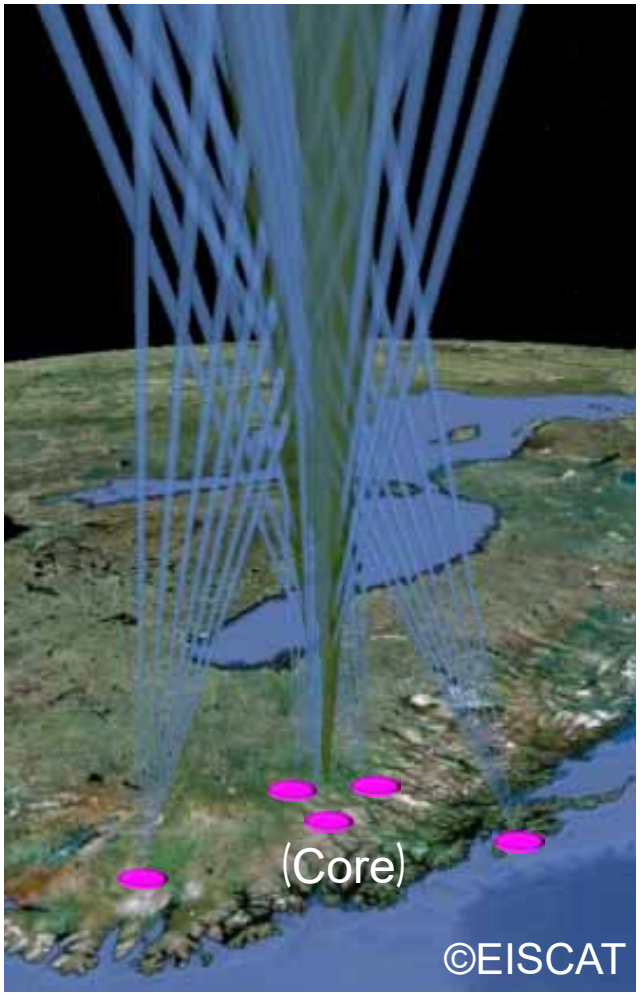
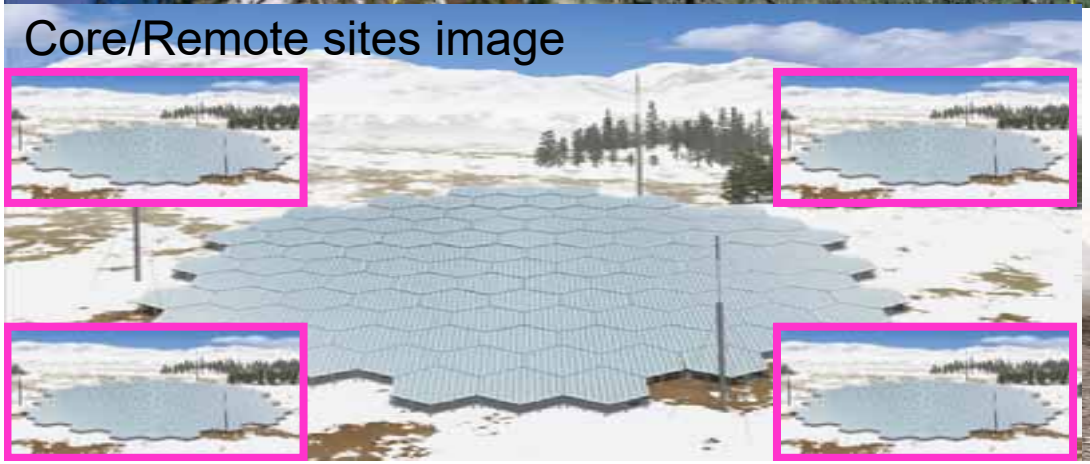
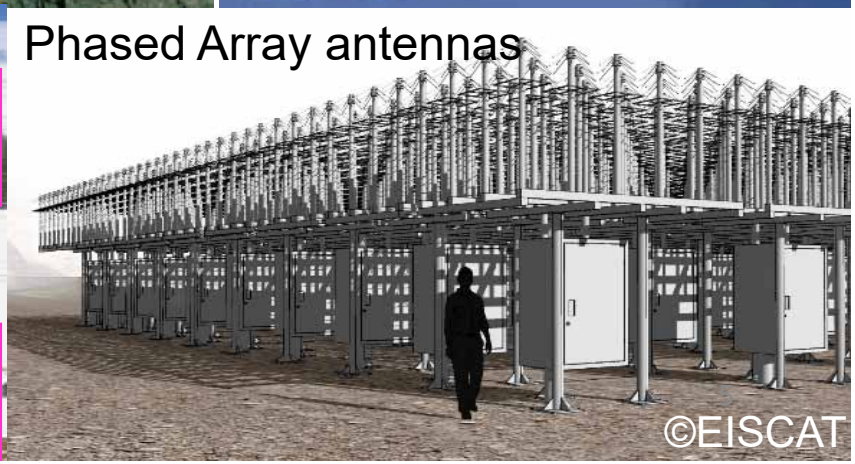
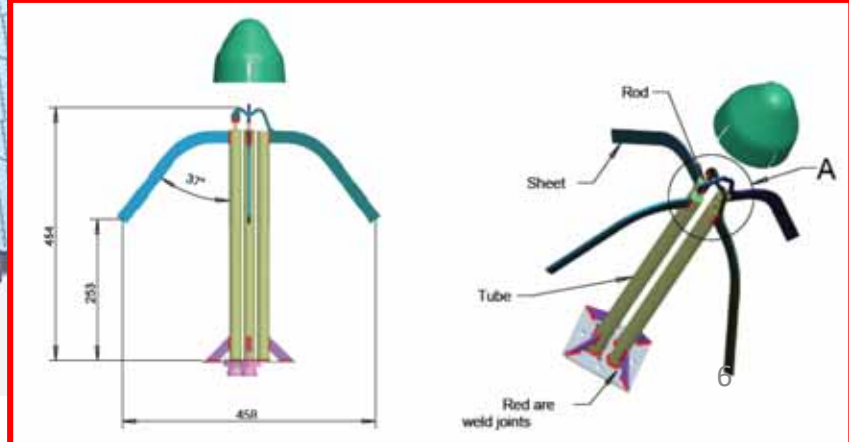

(Core)
©EISCAT

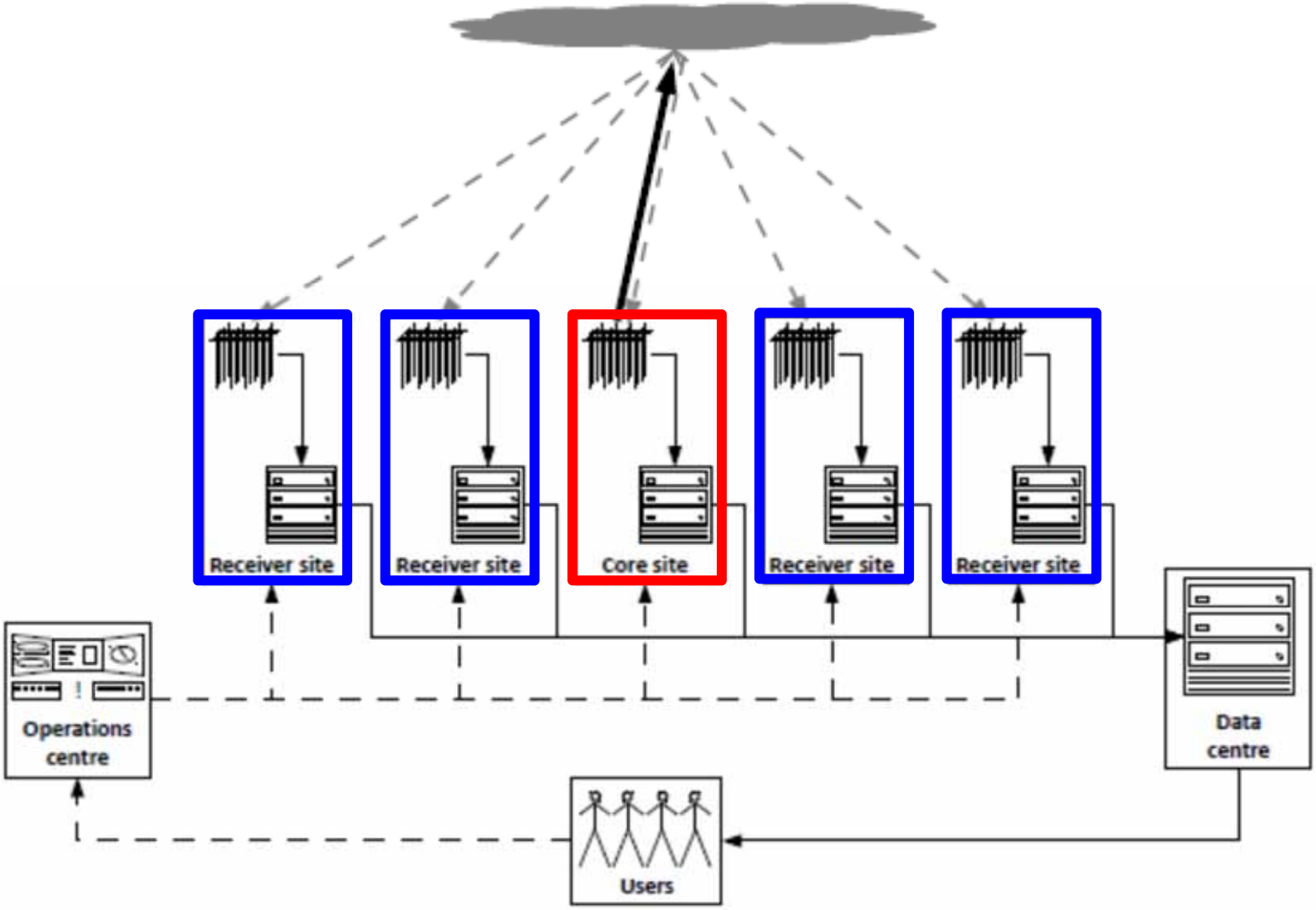

Core/Remote sites image


Phased Array antennas
©EISCAT

91elements ×109 sub-arrays
= 9,919 elements



An Overview of EISCAT_3D System



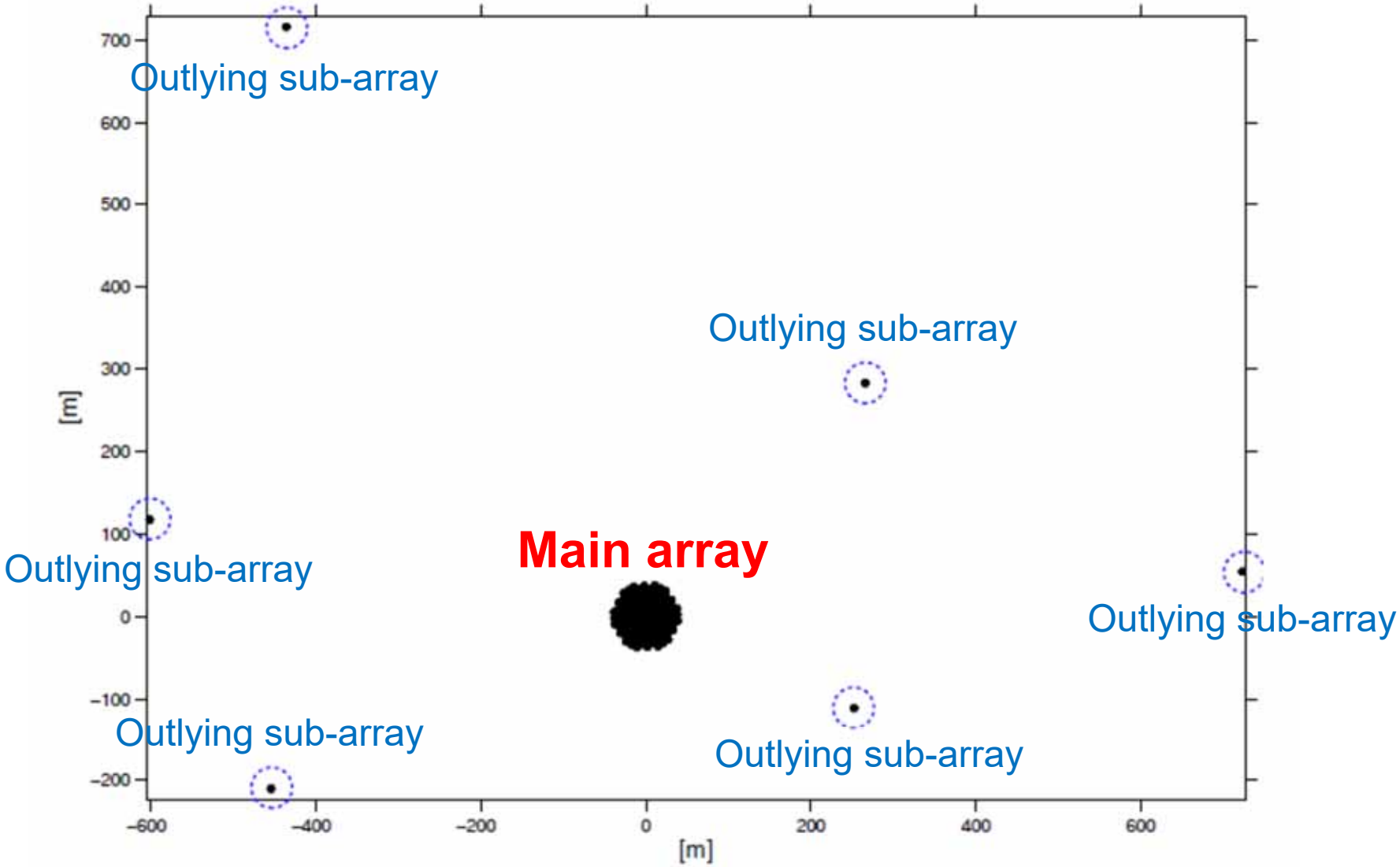
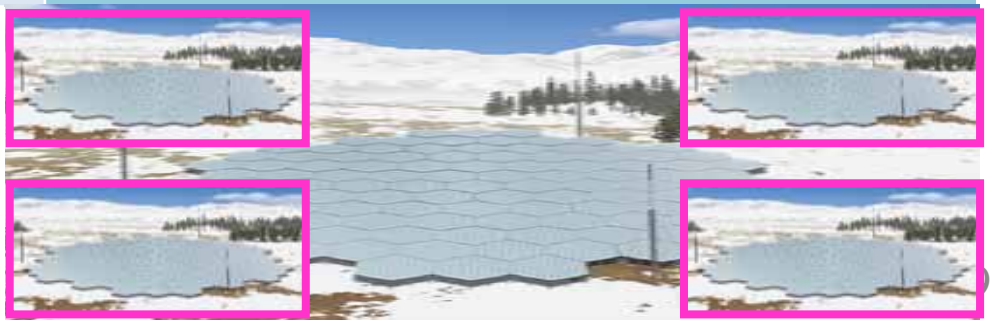


Figure 8: Example layout of the outlying sub-array receivers that will be deployed at each site to support aperture synthesis imaging applications. The centre point of the main array is at the origin, and the six outlying sub-arrays are spread out over the area. The final configuration of the outliers is determined by the local conditions at each site.

EISCAT vs EISCAT_3D

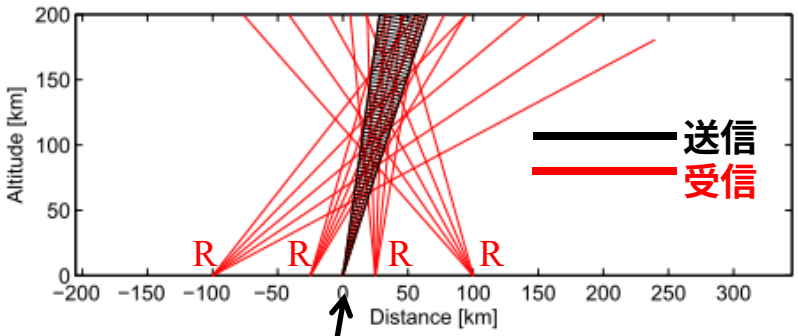
	EISCAT (KST)	EISCAT_3D
Radar System	**Tri-static parabola** (→1D vector) Core: 32m parabola Remote: 32m parabola x 2sites	**Multi-static phased array** (→3D volume-metric vector) Core：9,919 Cross-Yagis Array Remote: 9,919 Cross-Yagis Array x 4sites
Freq.	931MHz (～0.3 m)	233 MHz (～1.3 m)
Scan	Mechanical (2deg/sec)	Electrical (instantaneous)
Tx	**Peak Power: 1.7 MW** Duty Cycle: 12.5%	**Peak Power: 10MW** Duty Cycle : 0-25%
Data	10-40Mb/sec 100TB storage	53Gb/sec (Raw:1.6Tb/sec) 20PB storage



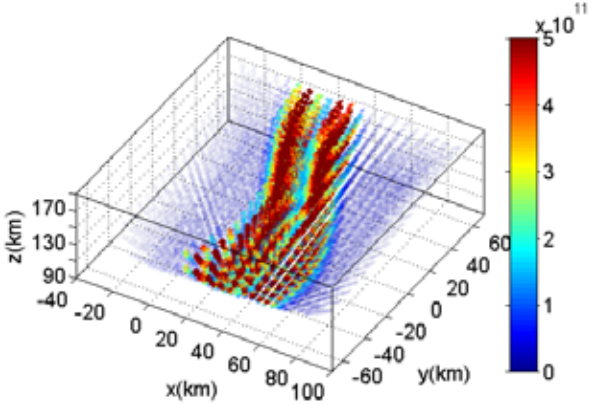
観測性能（時間分解能）が飛躍的に向上

送信機出力やアンテナ開口面積が増えることにより、1回（点）の観測に要する時間は1/100程度まで短縮され、時間分解能が飛躍的に向上する。（時間分解能＝1回の観測に要する時間）

大気の密度・温度・速度（観測高度）	EISCATの時間分解能	EISCAT_3Dの時間分解能	性能向上指数
電子密度・イオン温度・電子温度（110km）	5 秒	0.05 秒	100 倍
電子密度・イオン温度・電子温度（300km）	20 秒	0.3 秒	67 倍
3次元イオン速度（110km）	500 秒	10 秒	50 倍
3次元イオン速度（300km）	100 秒	1 秒	100 倍



送受信局
EISCAT_3D 観測



EISCAT_3D による3次元観測プロット

EISCAT_3D整備計画

	2015 (H27)	2016 (H28)	2017 (H29)	2018 (H30)	2019 (H31)	2020 (H32)	2021 (H33)	2022 (H34)	2023 (H35)	2024 (H36)
整備計画フェーズ	第1段階							第2段階	第3段階	第4段階
	＜技術実証＞期間			＜本格整備＞期間						
技術実証システム（トロムソ）										
主局（シーボトン）整備										
受信局（ベルグフォース）整備										
受信局（カレスバント）整備										
オペレーションセンター整備										
送信出力倍増（→10MW）										
受信局（アンドーヤ）整備										
受信局（ヨックモック）整備										

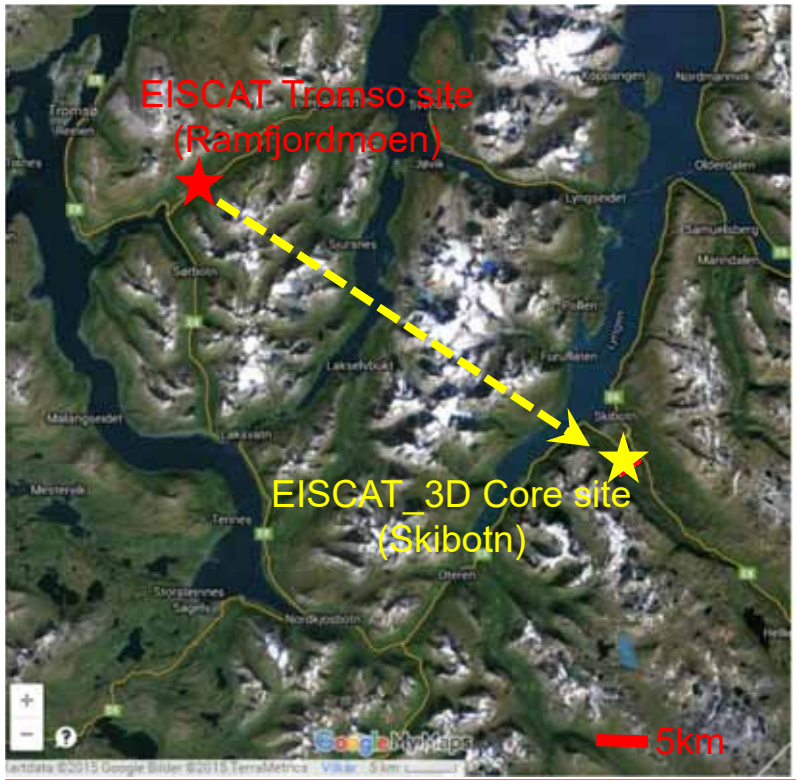
＜日本の貢献内容＞

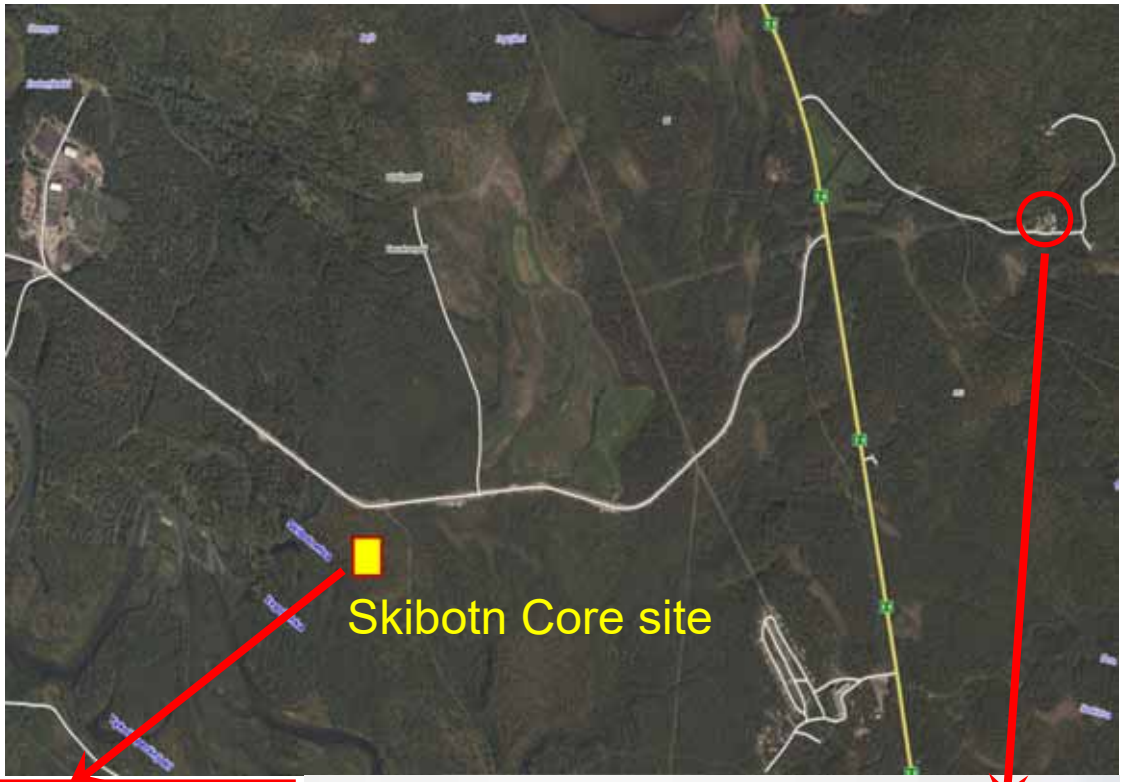
- 送信機開発
- 技術実証用送信機製造200台
- 電源ユニット1式
- 装置コンテナ開発・製造1基
- 現地設置調整（H29）

- 送信機および装置コンテナ製造年次計画（計10000台、110基）
  - H30　1000台、　11基
  - H31　3000台、　33基
  - H32　6000台、　66基
- 試験システム（1式、H30）
- 現地設置調整（H30-32）

＜計画全体の建設経費＞

第１段階	10,940百万円
第２段階	2,717百万円
第３段階	2,242百万円
第４段階	2,245百万円
合計	18,144百万円

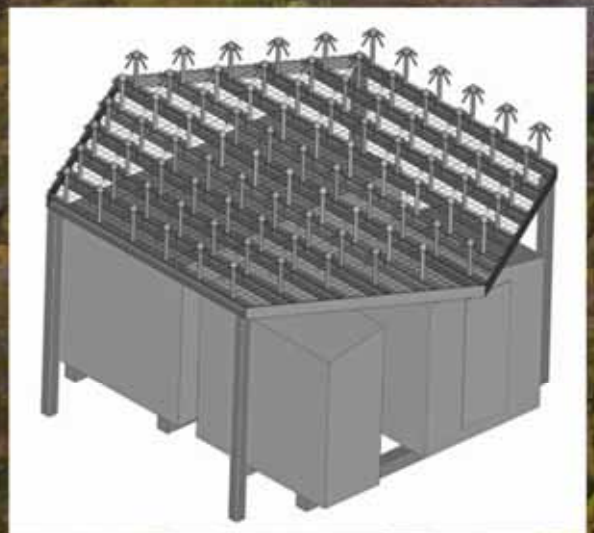

EISCAT Tromso site
(Ramfjordmoen)
EISCAT_3D Core site
(Skibotn)
5km


Skibotn Core site

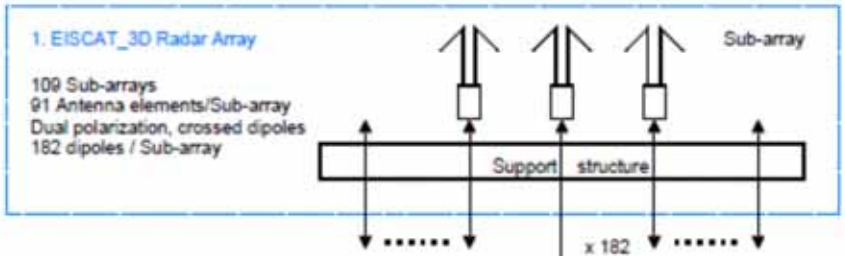

Skibotn Core site


UiT Fieldstation

Test Subarray Location

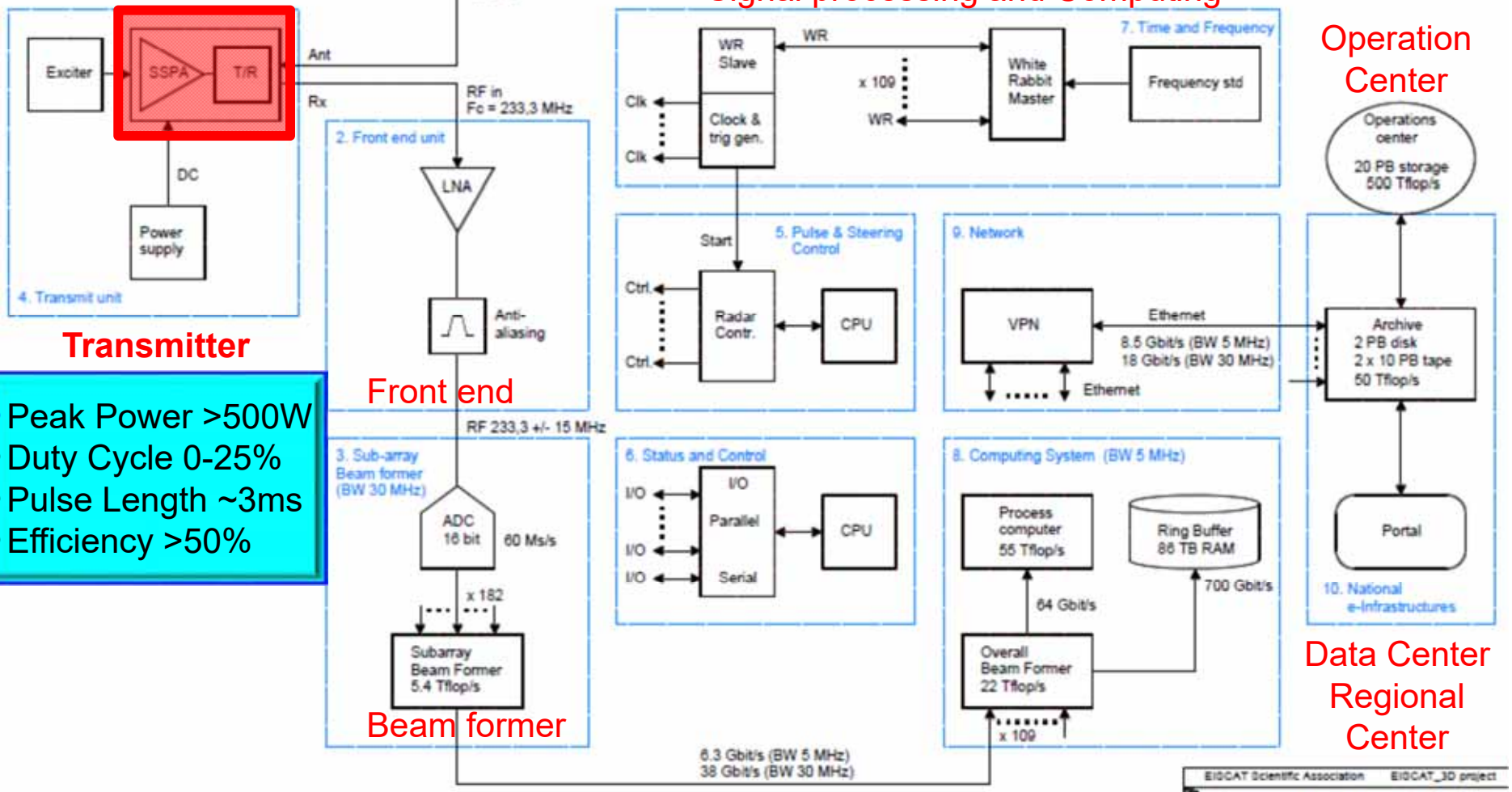


Antenna Array with support structure



91elements x 109 sub-arrays

Signal processing and Computing



Transmitter

- Peak Power >500W
- Duty Cycle 0-25%
- Pulse Length ~3ms
- Efficiency >50%

Front end

Beam former

EISCAT Scientific Association — EISCAT_3D project
EISCAT_3D Block diagram 0. top level
ver. 2014-02-20

Current Status on EISCAT_3D Project

1. Site Survey on-going

- Core: Skibotn (Norway) supported by UiT
- Remote: (1)Kaiseniemi (Sweden), (2)Karesuvanto (Finland) supported by U. Oulu

2. EISCAT3D_PfP (2015-2017: EU-funded) started

- Kick-off meeting 22-23 Oct 2015
- Project staffs: Dr. Sathyaveer Prasad, Chief Engineer and 3 dedicated staffs
- Manufacturing consultant: Consoden AB, Uppsala, Sweden
- Tenders open:
  (1) First Stage Receiver Unit, (2) Antenna Unit, (3)Pulse and Steering Control Unit
- Test sub-array system at Tromso site: Integration will start in July 2017

3. Funding Status

- **EC:** 3.1 Meuro for EISCAT3D_PfP
- **Finland:** 12.8MEuro allocated by Finnish Academy
- **Norway:** 228MNOK allocated by RCN conditionally by the end of 2016
- **Sweden:** 120MSEK allocated by VR conditionally
- **UK:** Identified on the Research Council capital roadmap
- **China:** Proposing for the next 5 year plan
- **Japan:** Development study is partially funded in 2016 to provide 19 Tx (SSPAs)
  Proposing for 2017 budget

EISCAT_3D計画のデータ利用

EISCAT_3Dデータに関する議論

（1）EISCAT_3Dユーザー会議（2009年より毎年1回、ウプサラ・スウェーデンで開催）

（2）NeIC（Nordic e-Infrastructure Collaboration）EISCAT_3D Support Project（2015年5月より実施）：EISCAT_3Dデータ生成や輸送、アーカイブ方法に関する文書作成

（3）EGI-Engage Competence Center：ユーザーアクセス用のポータルの製作

（4）EUDAT Pilot Project (proposal)：EISCATアーカイブ方法の検討

現行EISCATデータ：

- 約70TBをローカルストレージに記録（EISCAT本部、極地研、、、）
- プラズマ物理量データ（約100GB-1TB）をウェブ上で公開

EISCAT_3Dデータ：

- 約2TB/年のデータ生成。
- Non-localなストレージ及びデータ解析を検討
- ポータルを介したデータへのアクセス

NeIC: Nordic e-Infrastructure Collaboration
EISCAT_3D Support Project

Project goals

- Find workable and cost-efficient solutions for the EISCAT_3D computing, storage and archive
  （EISCAT_3Dの計算、ストレージ、アーカイブについて、実行可能かつ高効率な解を見つける。）
- Facilitate an effective dialogue on the implementation of EISCAT_3D with the stakeholders in the Nordic countries
  （北欧諸国の利害関係者と効果的な対話を促進する）
- Make best use of the existing expertise in the Nordic countries for implementing EISCAT_3D
  （北欧諸国の既存のノウハウを最大限に活用する）

- EISCAT_3Dシステムのデータハンドリングや ネットワークに関連した文書作成（合計12の文書作成を予定）

https://wiki.neic.no/wiki/EISCAT_3D_Support

Main page
Collaboration
Current events
Public documents
Projects
Training
Contact
Main areas
Recent changes
Random page
Help

Related Sites
NeIC
Internal Wiki

Tools
What links here
Related changes
Special pages
Printable version
Permanent link
Page information

EISCAT 3D Support

NeIC EISCAT_3D Support (E3DS) Public Page

Supporting EISCAT_3D

EISCAT_3D is an environmental research infrastructure on the European ESFRI roadmap. It is proposed as an international research infrastructure using the incoherent scatter technique to study the upper atmosphere above the Arctic in order to investigate how the Earth's atmosphere is coupled to space. EISCAT_3D is a multi-static phased array radar system that will be installed at remote locations in the most Northern parts of the Scandinavian peninsula. The system will be operated by and be an integral part of the EISCAT Scientific Association.

The e-infrastructure challenges for EISCAT_3D include finding cost-efficient state of the art solutions for on-site computing and establishing network connections between the different sites and with the data archive. The goal of the NeIC "Supporting EISCAT_3D" (E3DS) project is to support the preparation of the implementation of EISCAT_3D for those aspects concerning e-infrastructure. Particular goals also include to develop solutions for locating the data archive within existing national e-infrastructures and to support EISCAT in planning the recruitment of e-science experts.

Steering Group

- Craig Heinselman (EISCAT)
- Yasunobu Ogawa (EISCAT)
- Gudmund Høst (NeIC)

Project Manager

- John White (NeIC)

Project Members

- Carl-Fredrik Enell (EISCAT)
- Ingemar Haggstrom (EISCAT)
- Ingrid Mann (EISCAT)
- Anders Tjulin (EISCAT)
- Assar Westman (EISCAT)
- John White (NeIC)

Documents

- Project Plan
- MA-1: Requirements and their implications for EISCAT_3D data handling and processing at the operations centre
- MA-2: Requirements and their implications for EISCAT_3D data handling and processing at the data centre
- MA-3: EISCAT_3D Wide-Area Network Plan
- MB-1: On-site computing requirements for EISCAT_3D test sub-array
- MB-2: Consultation on selecting architecture/technology for the on-site computing related to a test-subarray
- MC-1: Test sub-array sub-systems and interfaces

EISCAT 3D data levels

Level	Type	Produced by	Storage	Format
1a	Ring buffer data	1st stage beam former	4 months*	TBD
1b	Beam-formed data	2nd stage beam former	4 months*	TBD
2	Time integrated correlated data	All sites	Archived	HDF5
3a	Physical parameters	All sites	Archived	HDF5
3b	3D-voxel parameters	Operations centre	Archived	HDF5
4	Derived geophysical parameters	Users	Users	Publications etc

Table 1: Summary of the EISCAT_3D data levels. The EISCAT_3D data centres will receive, serve and archive the data of levels 2 and 3. Users will be required to cite the used data by Persistent Identifiers or similar. (*) A 4 months period is selected as this is the estimated time to perform a "real-time" analysis on low-level data.

・アーカイブされるデータフォーマットは HDF5
・各サイトからオペレーションセンターへのデータレートは 8.5 Gb/s (at 5 MHz bandwidth) と 53 Gb/s (at 30 MHz bandwidth) を想定。

Milestone Document MA-1 & MA-2

EISCAT_3Dでターゲットとする科学対象と必要なデータ量等

優先順位高

R	Science case	Height	Bandwidth	Beams	Data rate
0	Atmosphere-ionosphere coupling (Global warming, winds)	0-400 km	100 kHz	30	192 Mb/s
0	D-region phenomena	70-90 km	1 MHz	10	640 Mb/s
1	Small scale (auroral) dynamics	70–500 km	30 MHz	30	58 Gb/s
1	Fine scale auroral structures	70-200 km	30 MHz	15	29 Gb/s
1	Topside composition	300-1500 km	10 kHz	100	64 Mb/s
1	Transition region composition	100-300 km	30 MHz	30	58 Gb/s
2	Meso-scale electrodynamics and flows (incl.BBFs)	85-400 km	100 kHz	30	200 Mb/s
2	Ion outflow (natural and heater-induced)	200-1500 km	10 kHz	100	64 Mb/s
2	NEIALs (aperture synthesis imaging)	100-1500 km	30 MHz	100	192 Gb/s
2	High energy particle events (SEPs etc.)	50-400 km	100 kHz	30	192 Mb/s
2	PMSE, PMWE	55-95 km	1 MHz	10	640 Mb/s
2	Heating experiments	100-2000 km	$10^5 \times 3$	100	1.92 Gb/s
2	Heating experiments aperture synthesis imaging	100-300 km	$10^5 \times 3$	30	576 Mb/s
3	Ionosphere irregularities	90-800 km	100 kHz	50	320 Mb/s
3	Meteoroids and their effects on the background (Es, PMSE etc), (Es, PMSE etc) high power mode	70-200 km	1 MHz	10	640 Mb/s
3	Meteoroid monitoring (piggy-back and low power mode)	70-200 km	1 MHz	10	640 Mb/s
4	Planets and asteroids	n/a	1 MHz	1	64 Mb/s
4	Interplanetary scintillation	n/a			
4	Space debris monitoring and satellite tracking	n/a	1 MHz	100	6.4 Gb/s

Table 2: The science cases and operational parameters for EISCAT_3D. The "R" value represents an estimation of the amount of time EISCAT_3D will operate for a particular science case. Higher "R" value is less likely.

Milestone Document MA-1

A proposed EISCAT 3D traffic matrix

To (below) \ From	Ops Centre	Data 1	Data 2	Skibotn	Bergfors	Karesuvanto	Jokkmokk	Andoya	Sum
Ops Centre	N/A	1	1	53	53	53	53	53	267
Data 1	2	N/A	0.5	0	0	0	0	0	3
Data 2	2	0.5	N/A	0	0	0	0	0	3
Skibotn	1	0	0	N/A	0	0	0	0	1
Bergfors	1	0	0	0	N/A	0	0	0	1
Karesuvanto	1	0	0	0	0	N/A	0	0	1
Jokkmokk	1	0	0	0	0	0	N/A	0	1
Andoya	1	0	0	0	0	0	0	N/A	1
UK (RAL)	0	1	1	0	0	0	0	0	2
Japan (NIPR)	0	1	1	0	0	0	0	0	2
Sum (Out)	9	3.5	3.5	53	53	53	53	53	

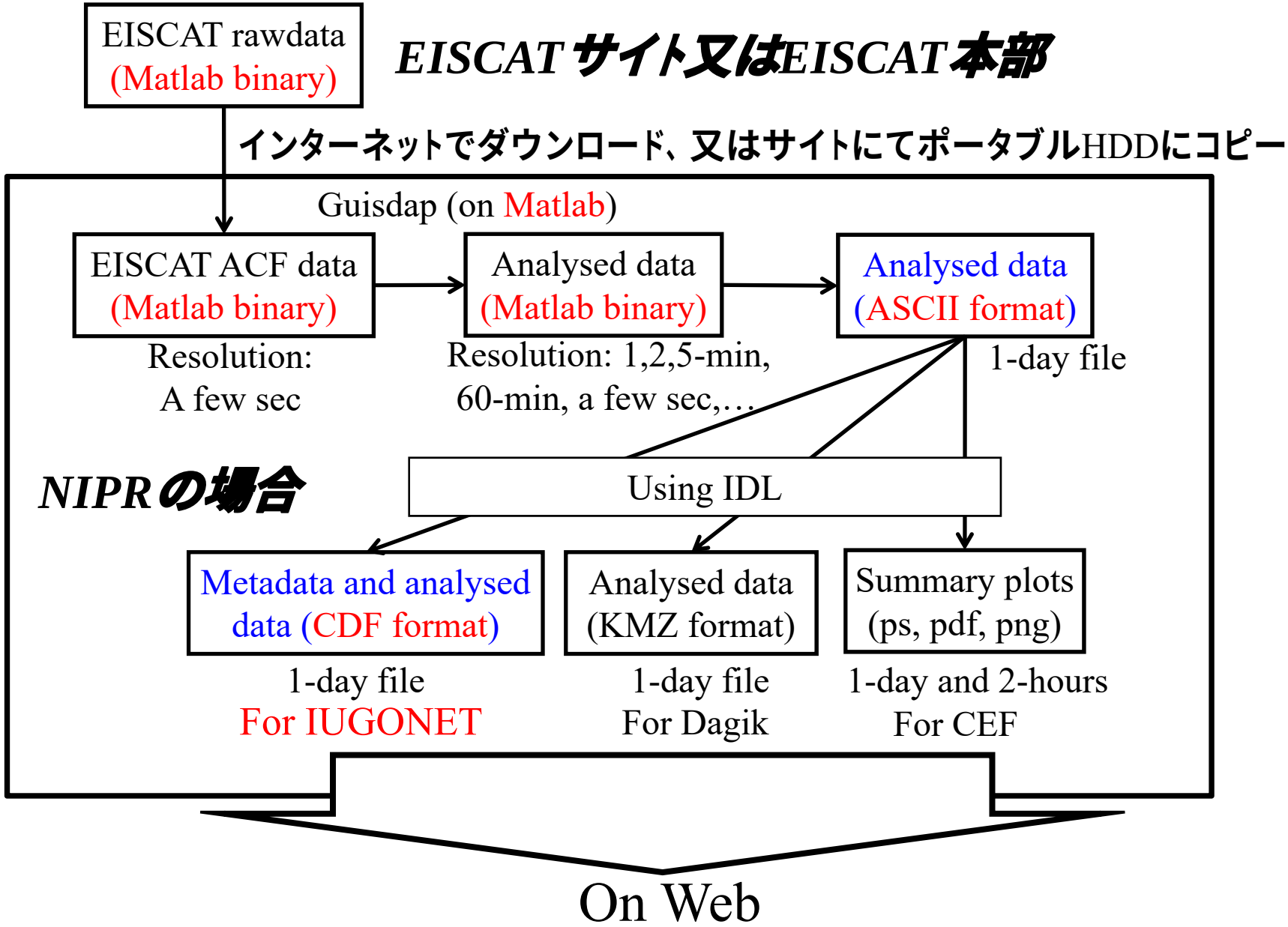
Figure 4: A proposed EISCAT_3D traffic matrix. All numeric values are in Gb/s. The network traffic shown in: A red (green) box indicates that the data flow must (does not need to) be routed over a redundant path. Orange denotes buffered data to be transferred outside the Nordic area.

From sites to operation centers: 53 Gb/s

→ Industry-standard 100 Gb/s service is sufficient

Milestone Document MA-3

現行EISCATのデータベース作成までの流れ



想定されるEISCAT_3Dデータベース作成

- データセンターから国内（極地研）にネットワーク（Level3,4データ）及び大容量テープ（Level2データ）を介してデータ転送。
- IUGONETとの連携により、メタデータの製作及びデータ可視化ツールの開発。HDF5フォーマットデータを直接読んで効率よくデータベース作成や解析を進めるように。

PFISR（AMISR）の多ビームデータ可視化の例

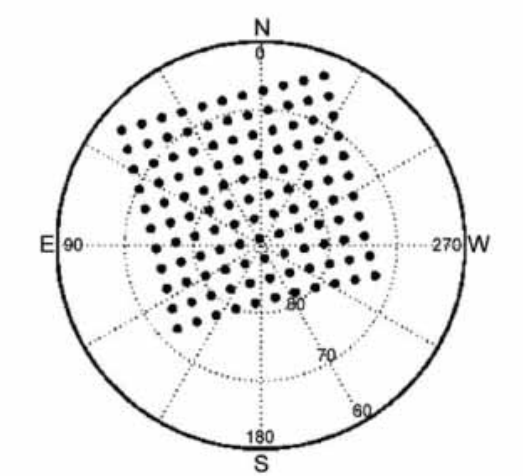


Fig. 1. (a) PFISR beam positions used in this experiment, depicted in a horizon-based polar coordinate system. (b) Beam positions superimposed on an image recorded with the collocated all-sky camera.

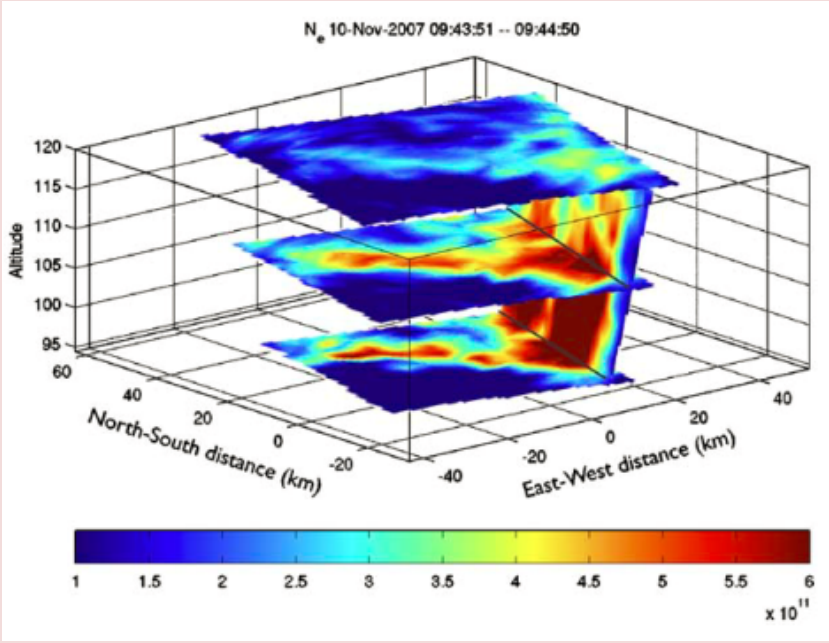


Fig. 2. Volumetric image of *E*-region on 10 November 2007, 09:43:51–09:44:50 UT. The image was produced by averaging 192 pulses-per-position. The horizontal cuts are at 100, 107, and 120 km. The structured density enhancement seen in the image was produced by auroral electron precipitation in the ~20 keV range.

Semeter et al., 2009

EISCAT_3D計画のデータ利用に関するまとめ

- EISCAT_3Dユーザー会議にて、将来のEISCAT_3Dデータ利用を議論。研究ターゲットにより、必要とされる観測範囲やデータ転送/蓄積量が大きく異なる。

- 主にNeIC EISCAT_3D Support Projectにて、Level 1-4データの転送やアーカイブ等を検討。各サイト、オペレーションセンター、データセンター、北欧外のRegionalセンター（極地研等）を想定。

- データフォーマットはHDF5を予定。

- IUGONETとの連携により、メタデータの製作及びデータ可視化ツールの開発。HDF5フォーマットデータを直接読んで効率よくデータベース作成や解析、可視化を進めるように。