EISCAT_3D

Craig Heinselman
EISCAT Scientific Association

EISCAT_3D Design Study

- 5 partners, 30 man years
  - EISCAT, University of Tromsø, Luleå University of Technology, Rutherford Appleton Laboratory, Swedish Institute of Space Physics
- Tl budgeted volume 2.8 MEUR
- EU FP6 support 2 ME

WP1: Project Management
WP2: Evaluation of design performance goals
WP3: Evaluation of options for the active element
WP4: Phased array receivers
WP5: Interferometric receivers
WP6: Active element
WP7: Distributed control and monitoring and Observation scheme
WP8: Data Archiving and Distribution
WP9: Signal Processing
WP10: New uses
WP11: Implementation Blueprint
WP12: Time and frequency distribution
WP13: Enabling procedures

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EISCAT_3D Preparatory Phase

14 work packages:

WP1: Management and reporting
WP2: Legal and logistical issues
WP3: Science planning
WP4: Outreach activities
WP5: Consortium building
WP6: Performance specification
WP7: Signal processing
WP8: Antenna, front end and timing
WP9: Transmitter development
WP10: Aperture synthesis imaging
WP11: Software theory & implementation
WP12: System control
WP13: Data handling & distribution
WP14: Mass-production & reliability

EISCAT_3D

A European Three-Dimensional Imaging Radar for Atmospheric and Geospace Research

ESFRI Roadmap Project

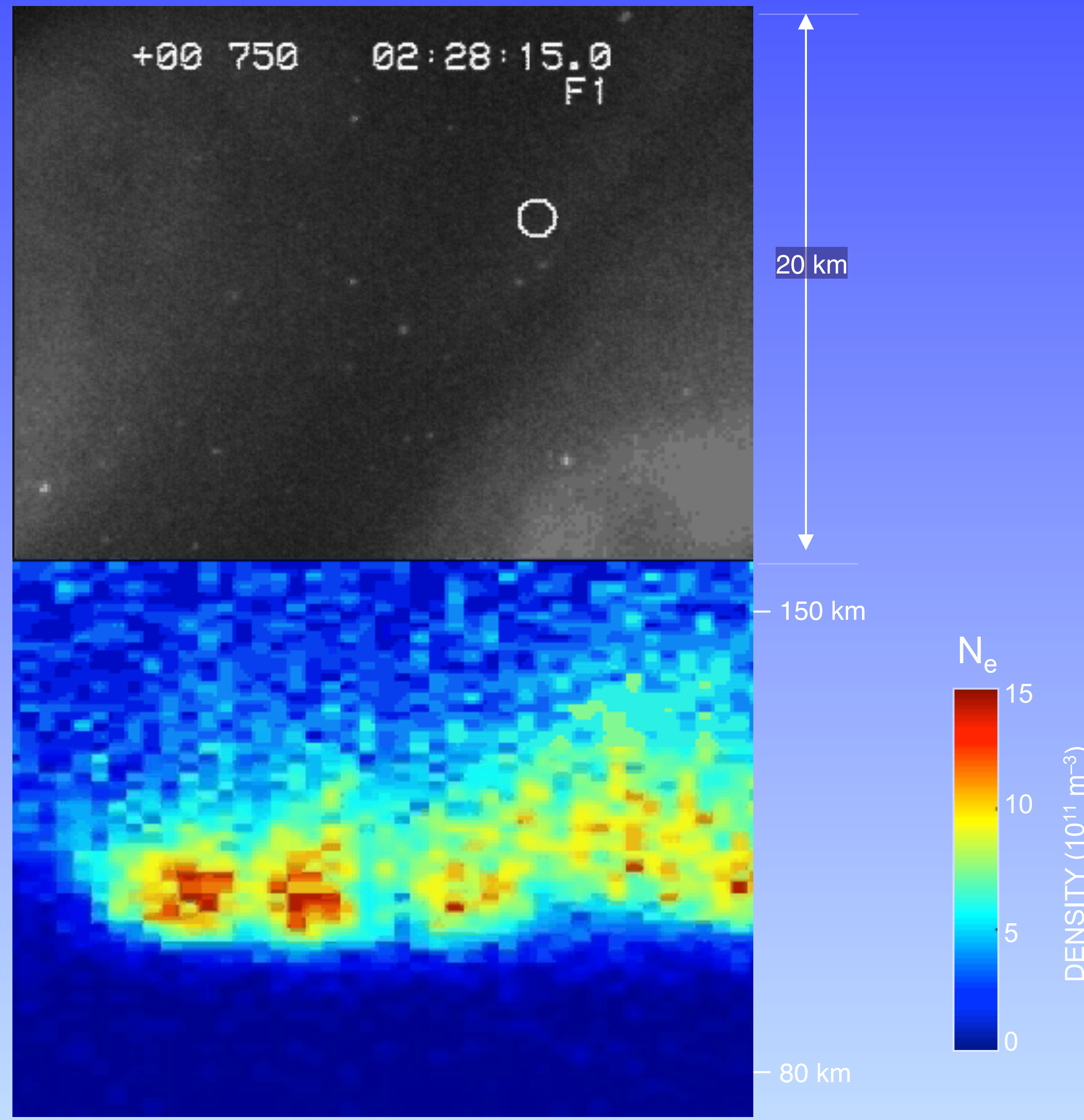
State of the art today: AMISR

Resolving Temporal/Spatial Ambiguities

High Speed Intensified Auroral Imaging

- **Narrow-field camera**
  25 frames/sec
  > 640 nm
  21 x 26 km at 110 km

- **Sondrestrom IS radar**
  Electron density
  1 km x 1.2 sec



J. Semeter

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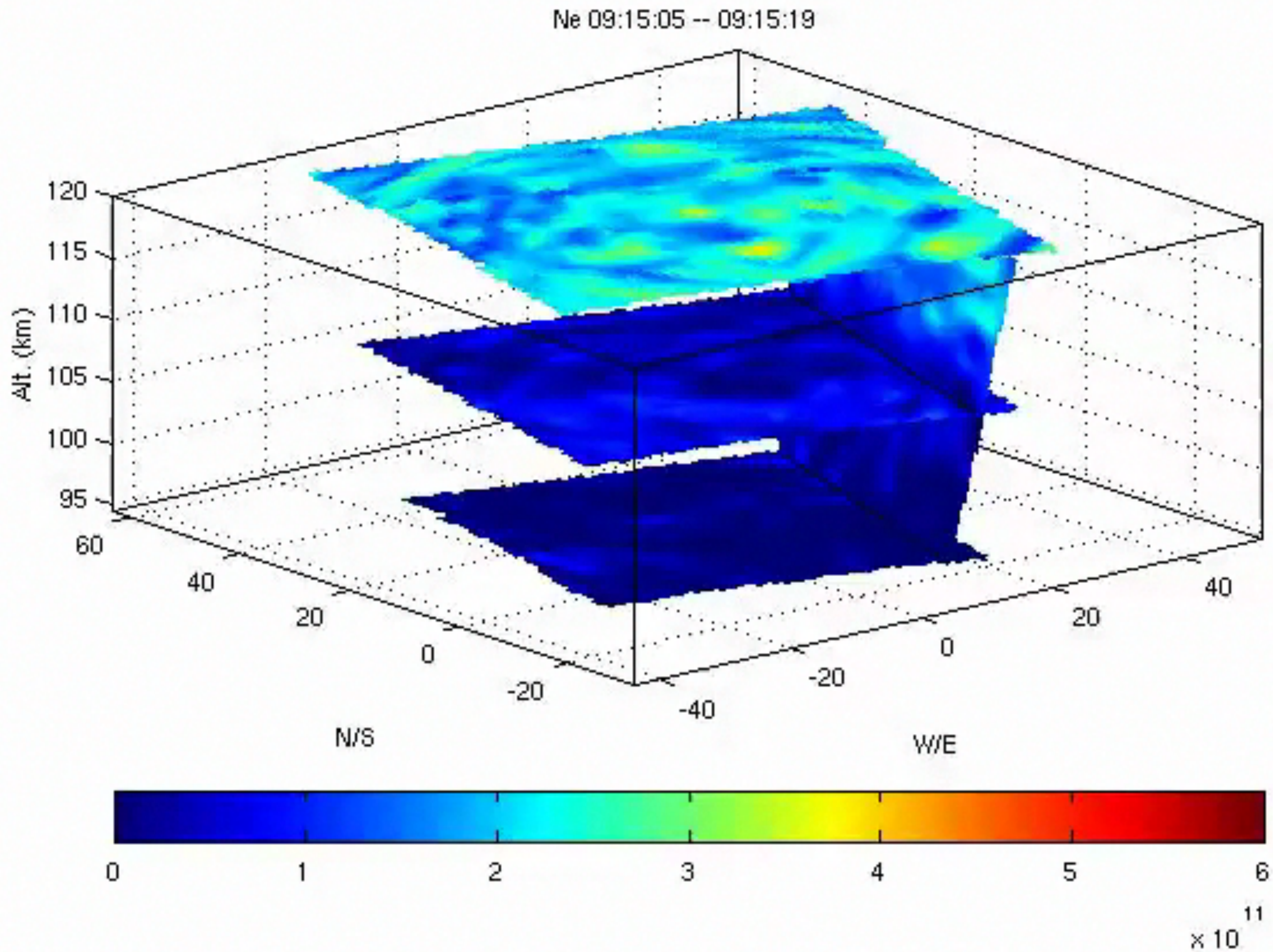
AMISR view of an aurora



Semeter et al.

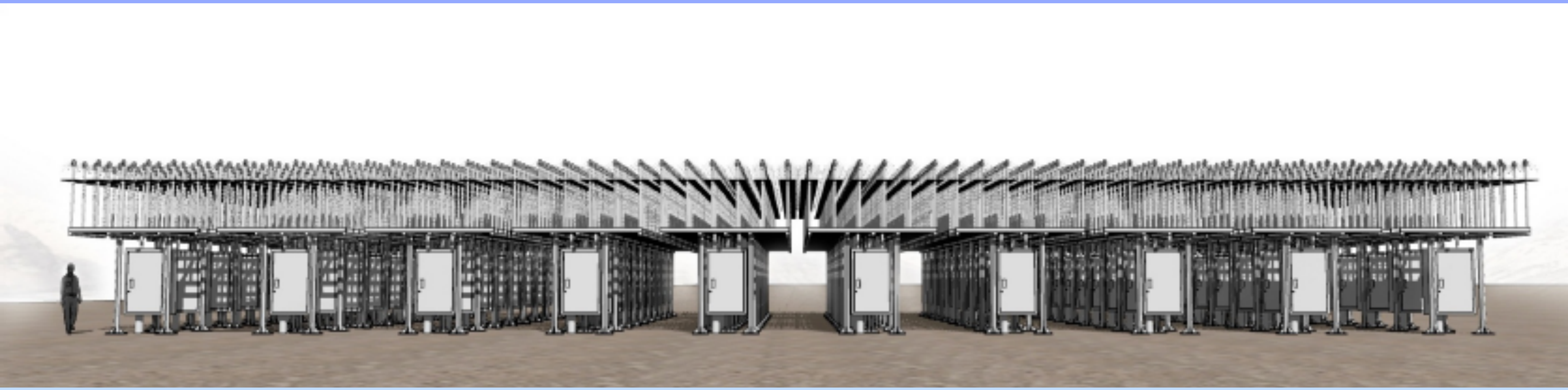
EISCAT_3D

EISCAT_3D will be a volumetric vector-imaging radar for studying the geospace environment

It represents a revolutionary upgrade to the existing EISCAT mainland facilities, utilizing multi-static, phased-array technologies

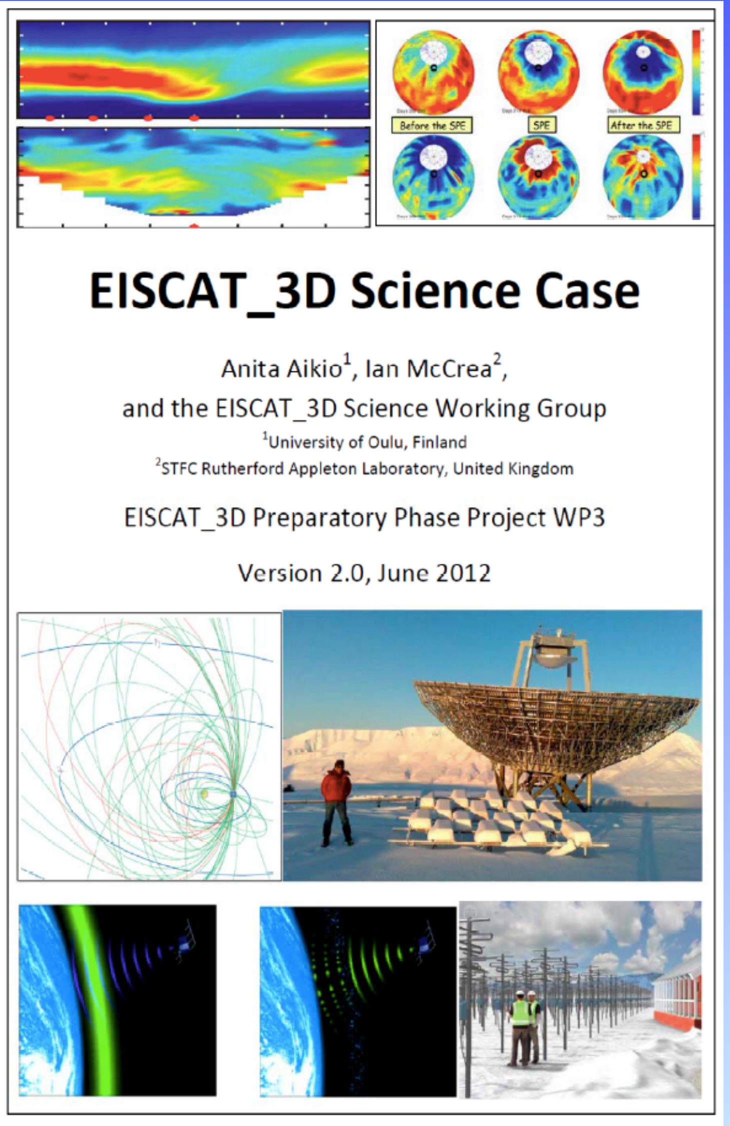
It will support continuous measurements of the space environment via unattended operations

EISCAT_3D will have the sensitivity needed for ionospheric measurements at better than 100 msec time scales and 50-100 meter spatial scales (order of magnitude improvements over current systems)



EISCAT_3D Science

- An extremely versatile and largely software-defined instrument
- Specific science plans are developed within national user communities
  - Norway's proposal poses 5 major questions
  - Sweden's proposal has 5 active areas for research
  - Finland's roadmap proposal has 5 active areas for research
- Easy expansion to new fields
- Easy inclusion of new nations



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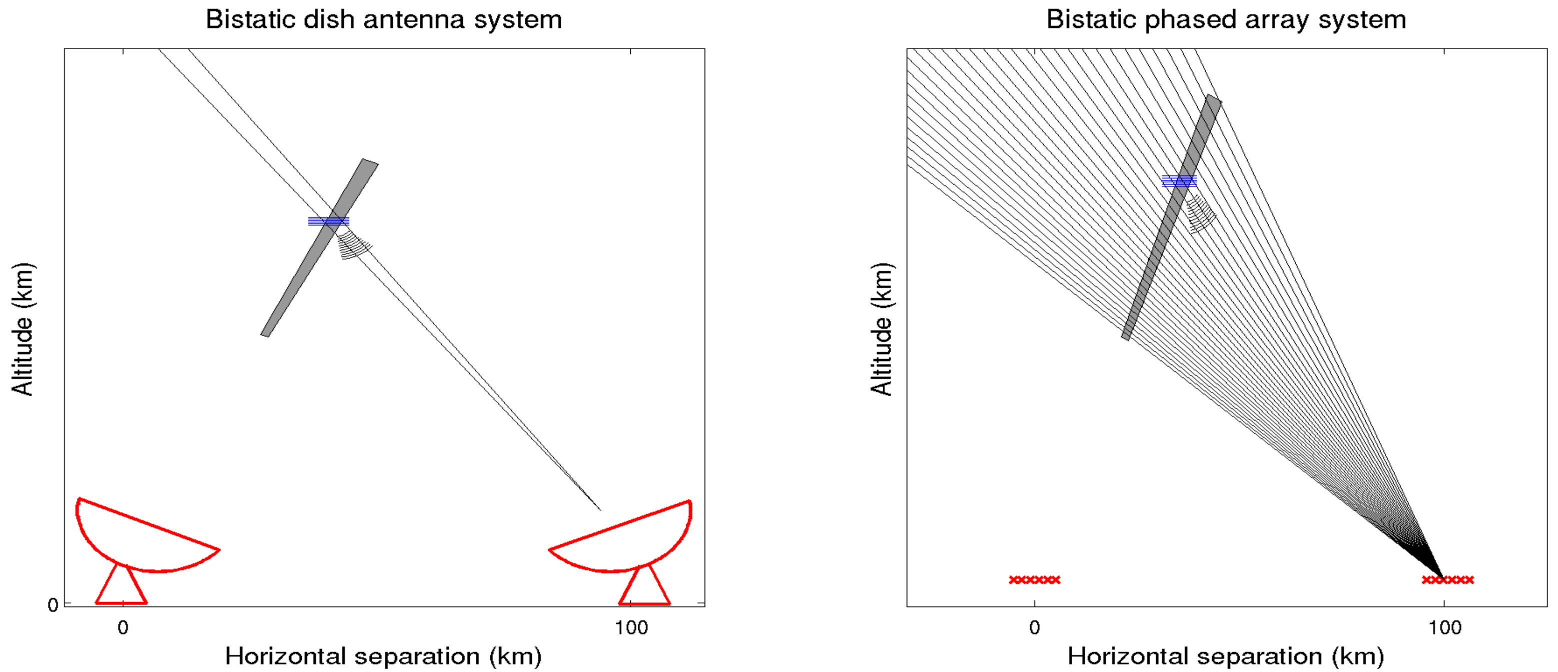
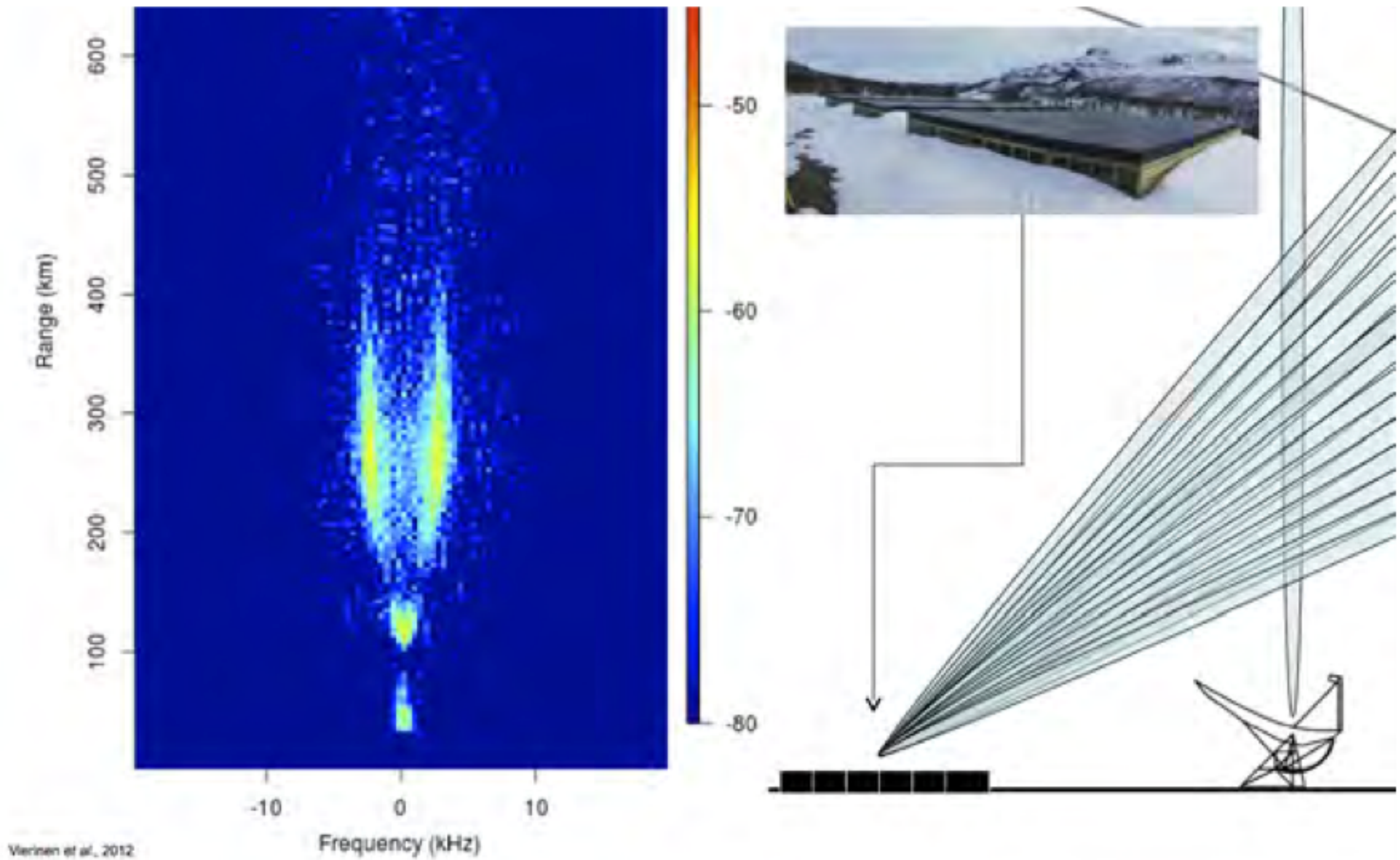
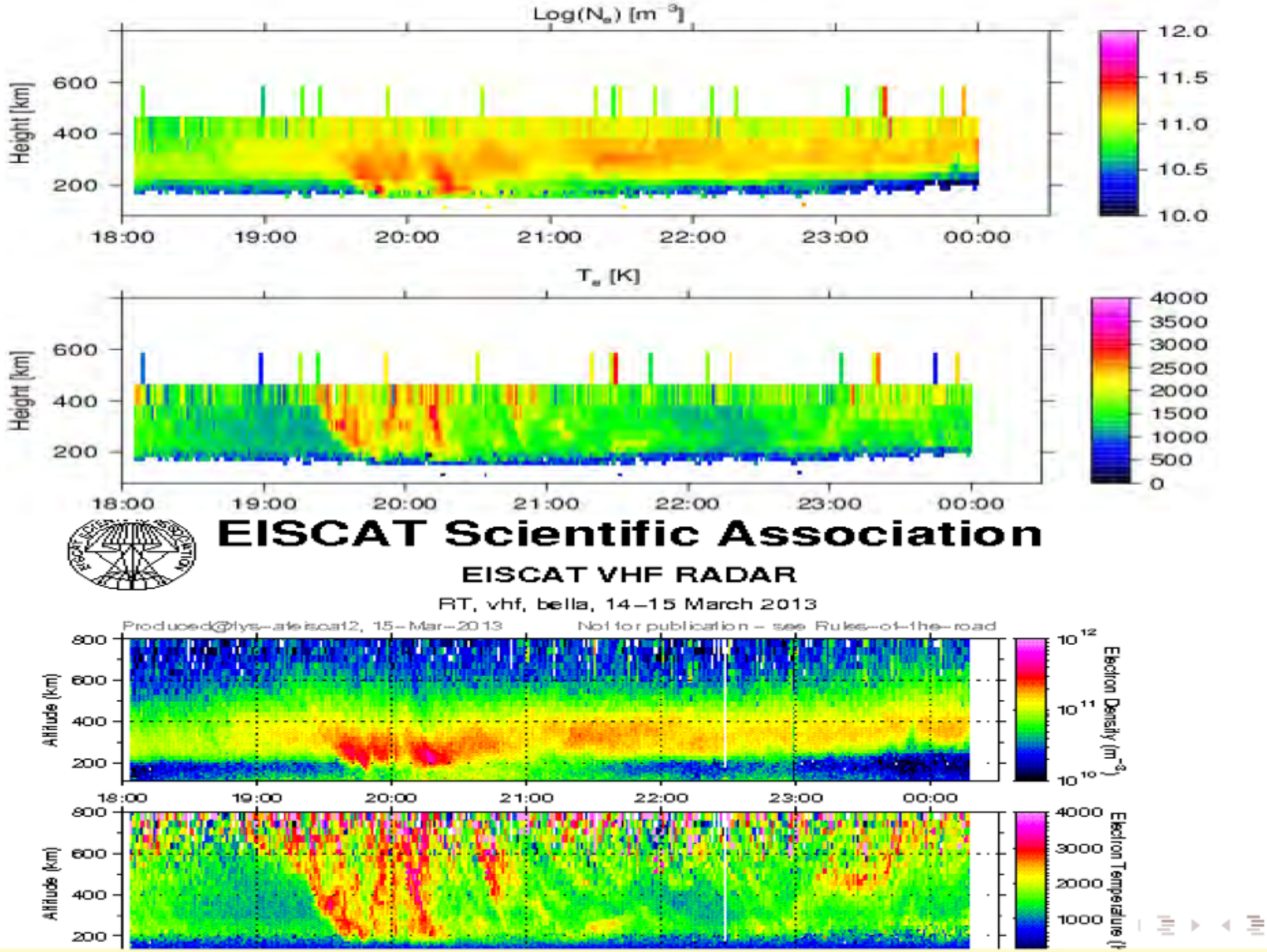
EISCAT 3D – the next generation ISR



First multibeam receiver data analysis, KAIRA receiving EISCAT VHF

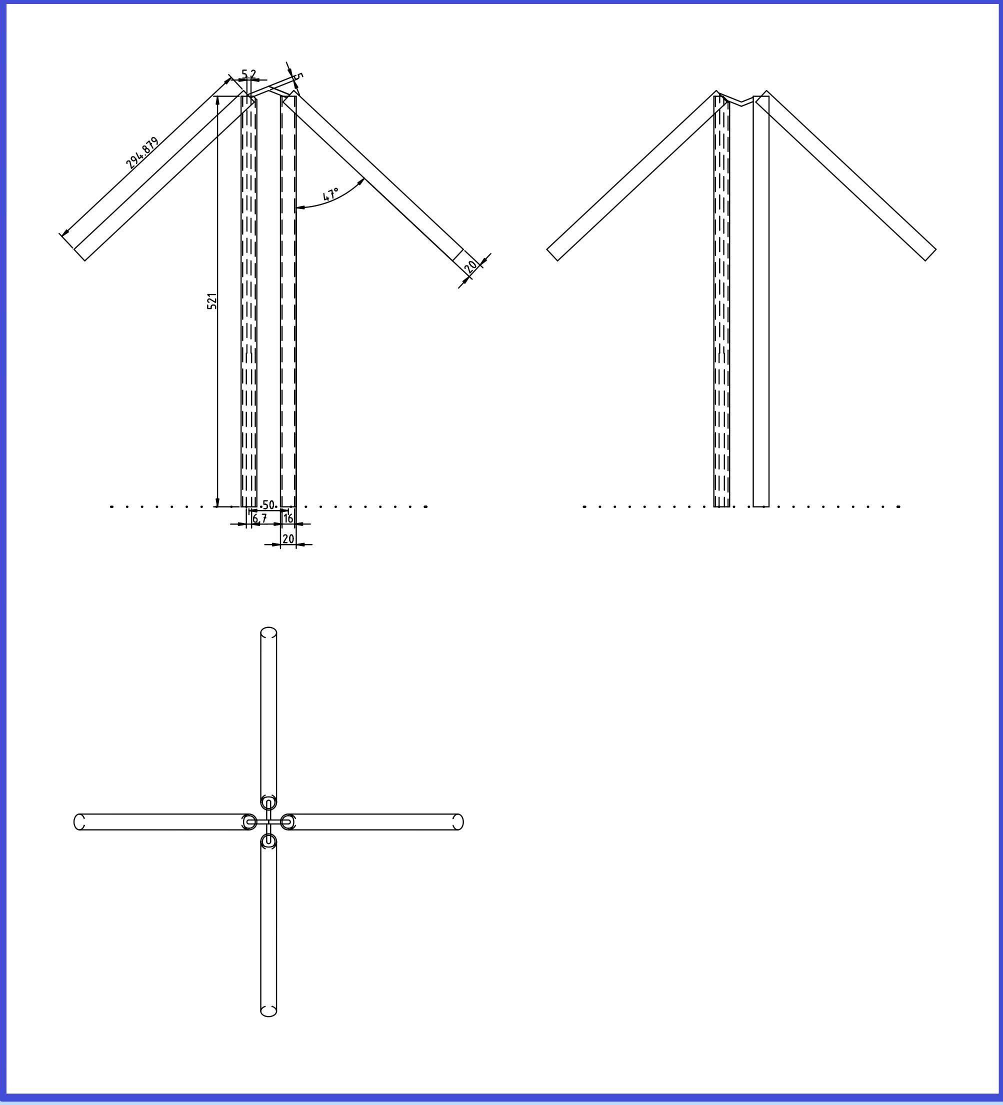


Bistatic KAIRA compared to monostatic EISCAT VHF



Vue graph from M. Lehtinen

Embedded Antenna Element



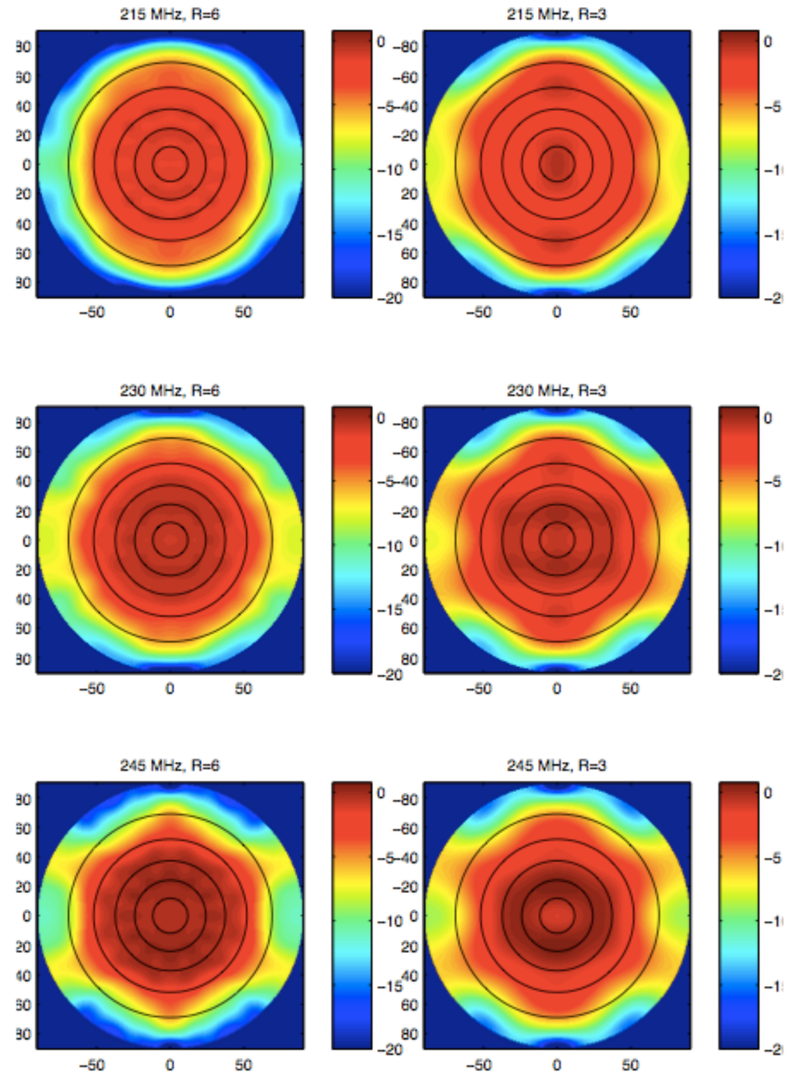


Figure 10: Gain of the selected antenna

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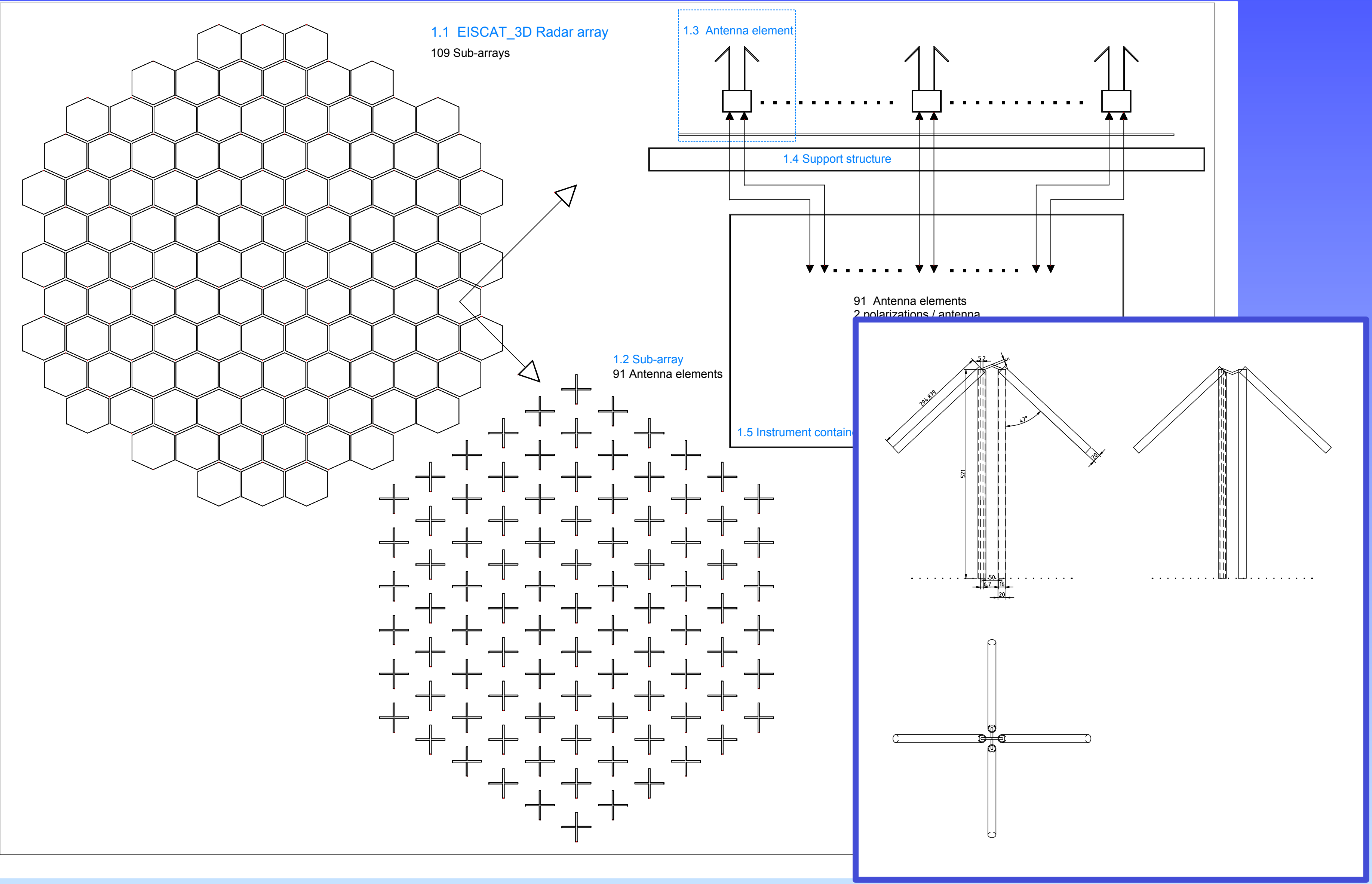
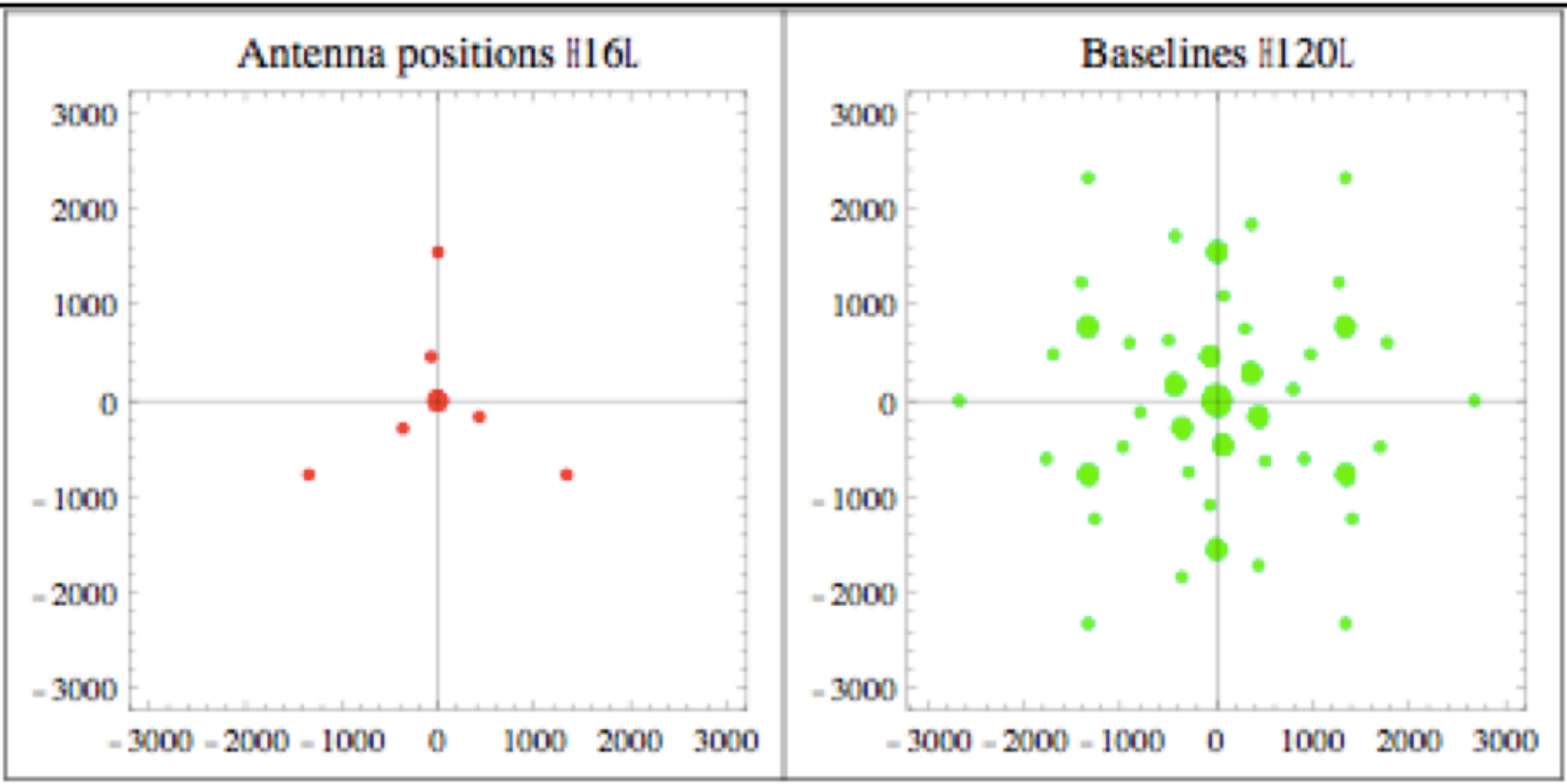
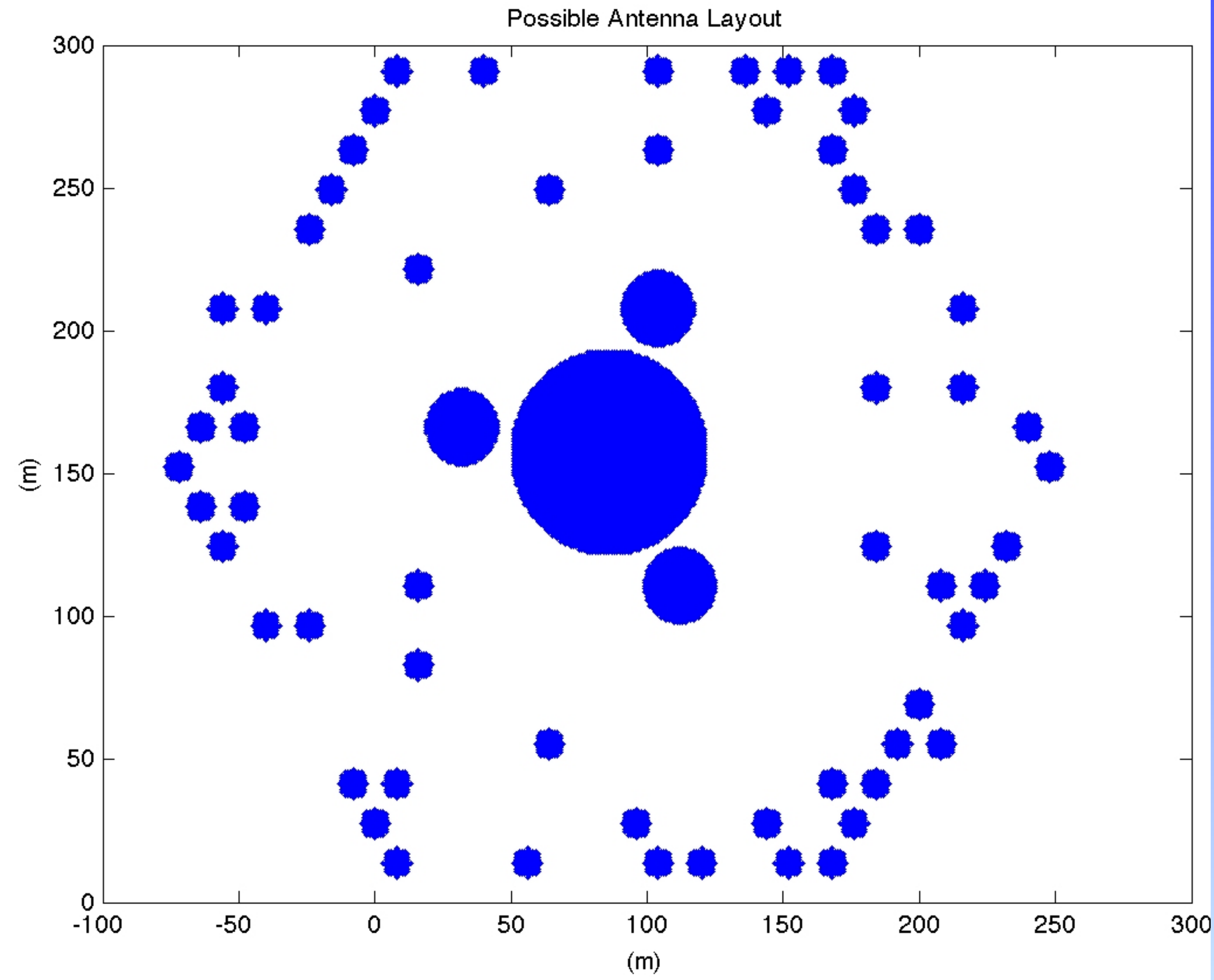
EISCAT_3D Site Dense Core



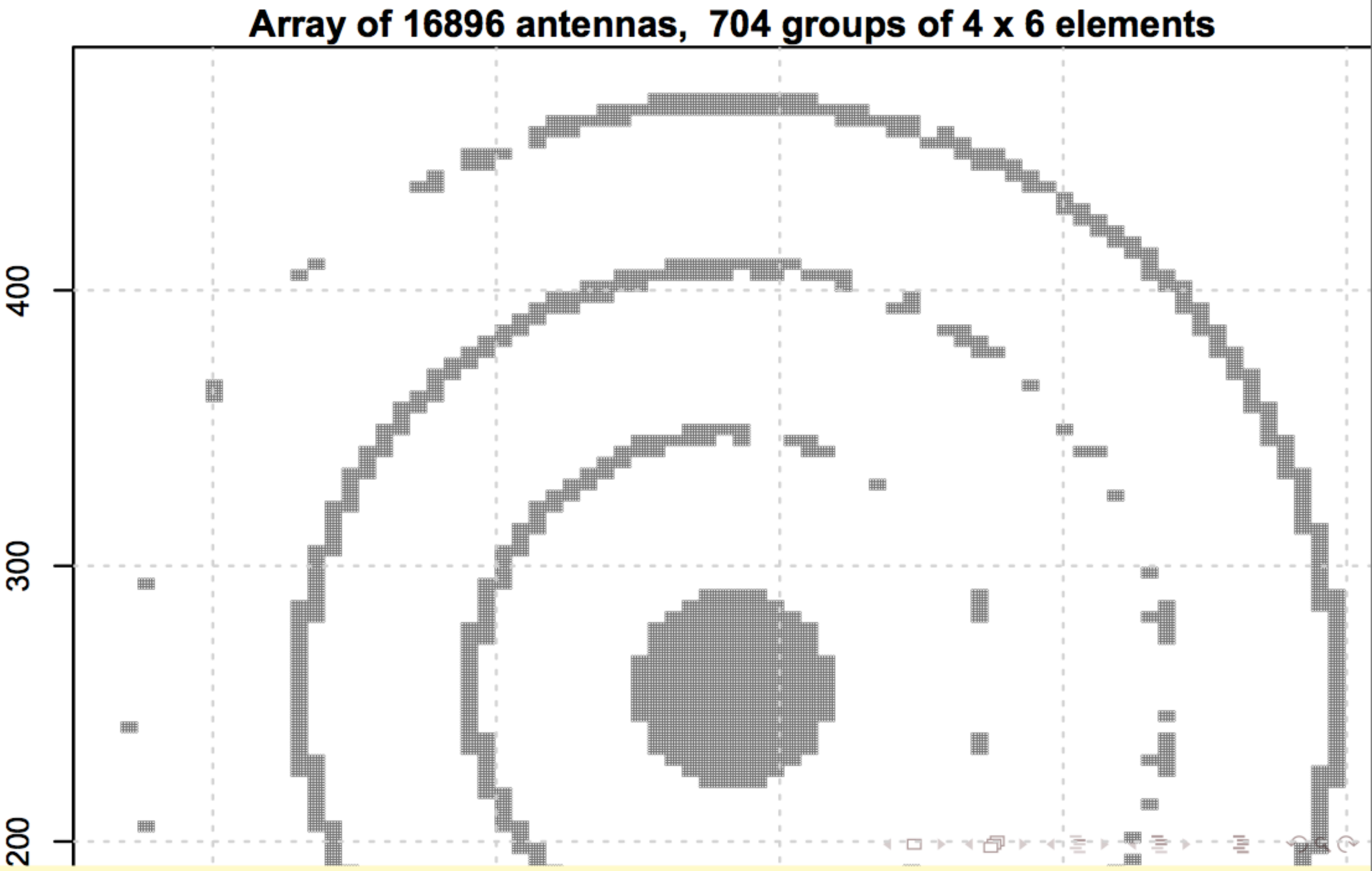
Aperture Synthesis Imaging



Another Possible Layout



Yet Another Possible Layout



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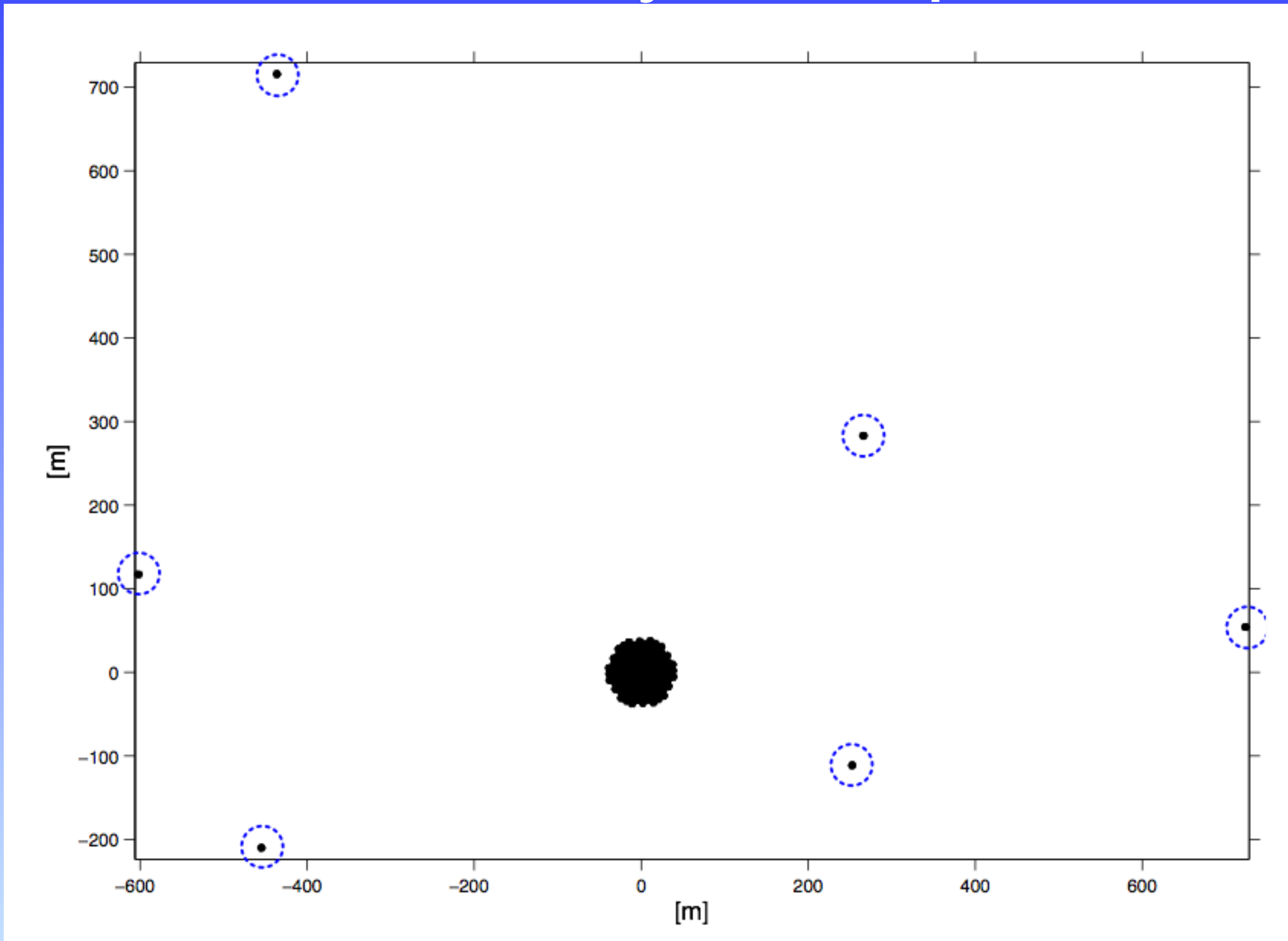
What we may end up with



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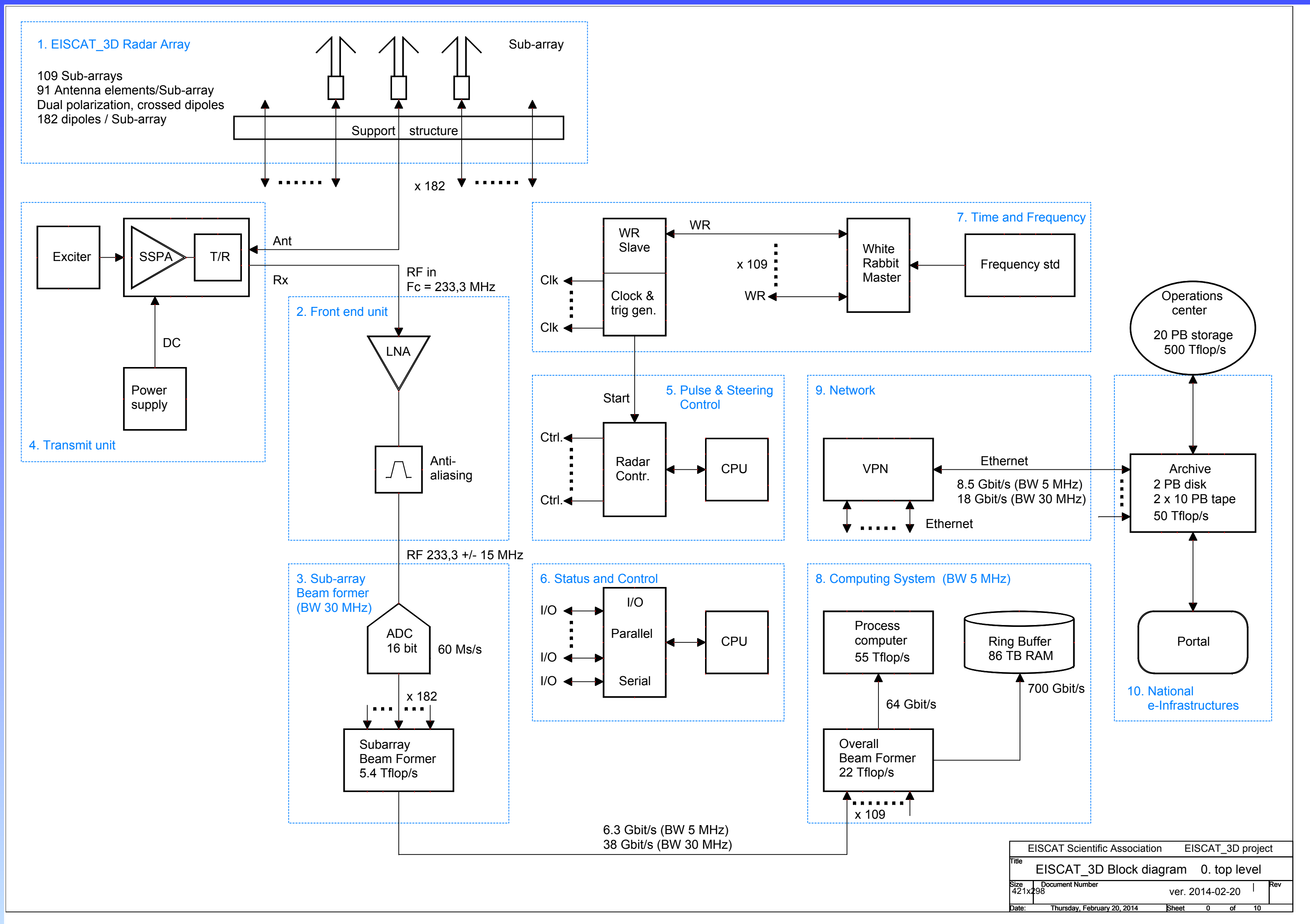
Component Modules



EISCAT_3D Instrument

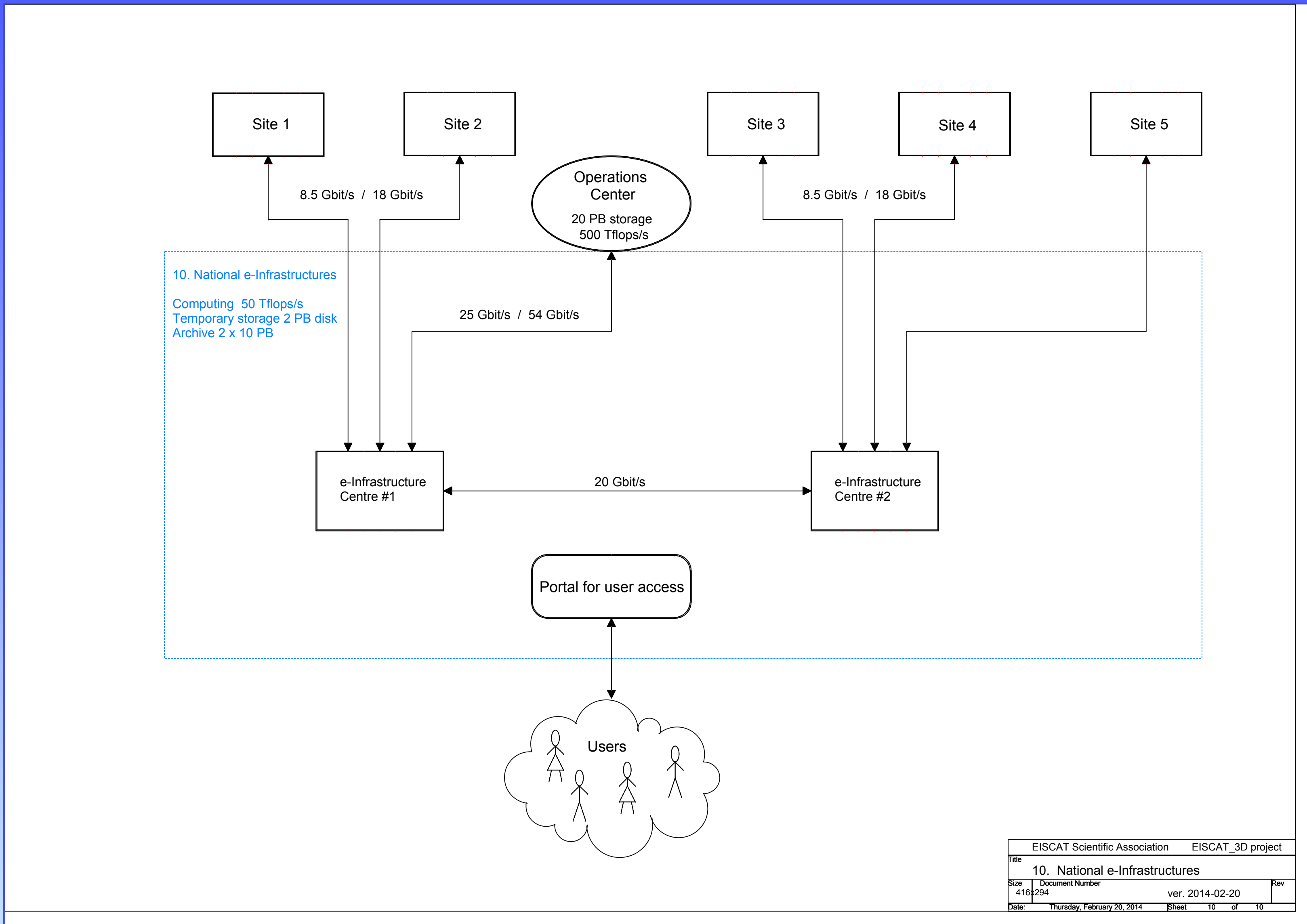


Table 1 EISCAT_3D Specifications

	Transmitter		
1	Type	Pulsed	-
2	Duty Cycle	25	%
3	Max Pulse Length	10	ms
4	Shortest Pulse Length	0.5 (75)	μs (m)
5	Peak Power	10	MW
6	Centre frequency	233	MHz
7	3 dB Bandwidth	$\pm$2.5	MHz
8	Modulation	Phase/Amp	-
9	Polarization	Arbitrary	-
	Antennas		
10	Type	Phased Array	-
11	Antennas per site	$\sim$10,000	-
12	3 dB Bandwidth	$\pm$15	MHz
13	Gain	$\sim$50	dBi
14	beam pointing resolution	0.625°	
15	Transverse resolution at 100 km better than	50	m
16	Grating-lobe free radiation pattern: zenith all azimuths	40°	
17	Power-aperture product	>100	GWm^2

	Features
1	3-dimensional vector and scalar imaging
2	Phase/Amp transmitter modulation
3	Arbitrary Tx/Rx polarisation
4	One Core Active site
5	4 Remote Passive sites
6	Remote active site with power $\sim$1 MW
7	Electronic scanning and beam-forming
8	5 phased steered array antennas
9	6-10 outlying antenna arrays at active site
10	Aperture synthesis imaging
11	High duty cycle
12	Better sensitivity by a factor > 20×
13	Unmanned operation
14	Remote operation via internet
15	Robust reliability in arctic environment
16	Uninterrupted continuous operations
17	Common Programs at low duty cycle
18	Special Programs to respond to pre-defined/unusual geophysical events
19	Validated archival database
20	Restricted real-time data

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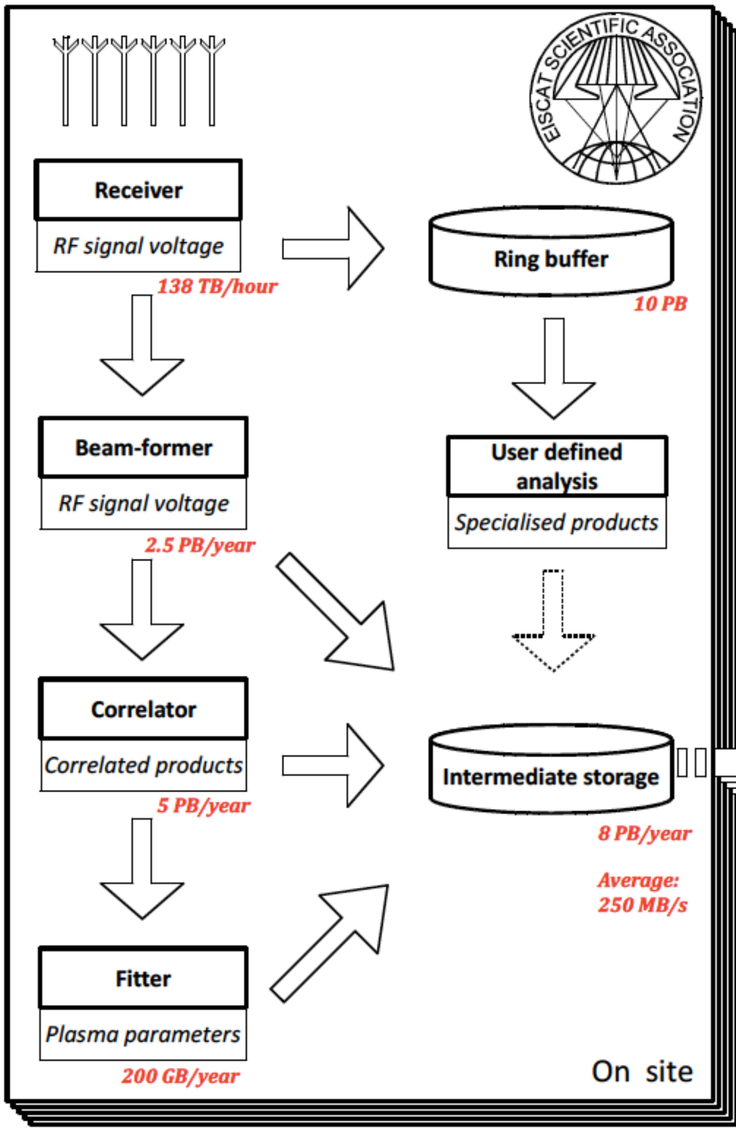
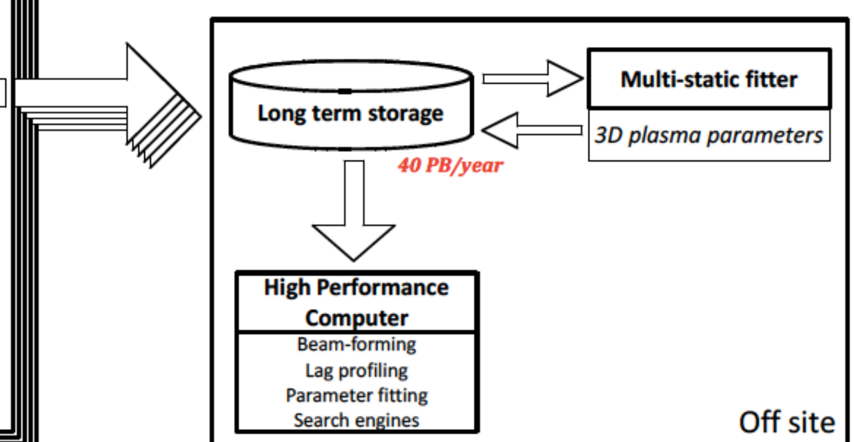
e-Infrastructure/e-Science

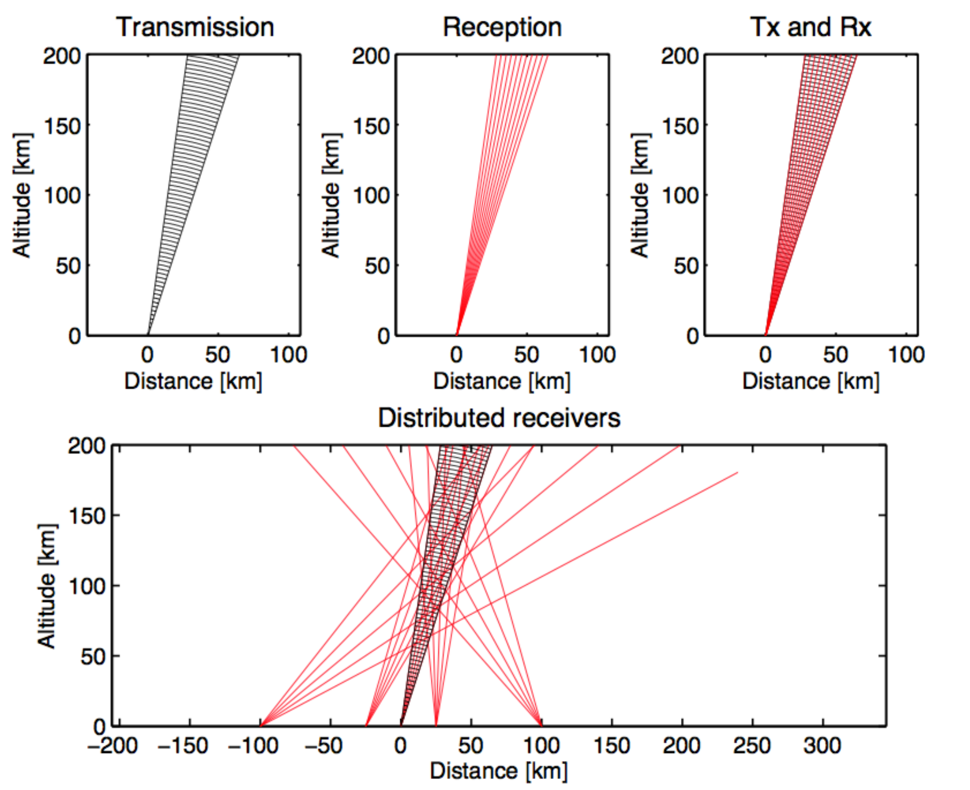
Data Flow EISCAT_3D

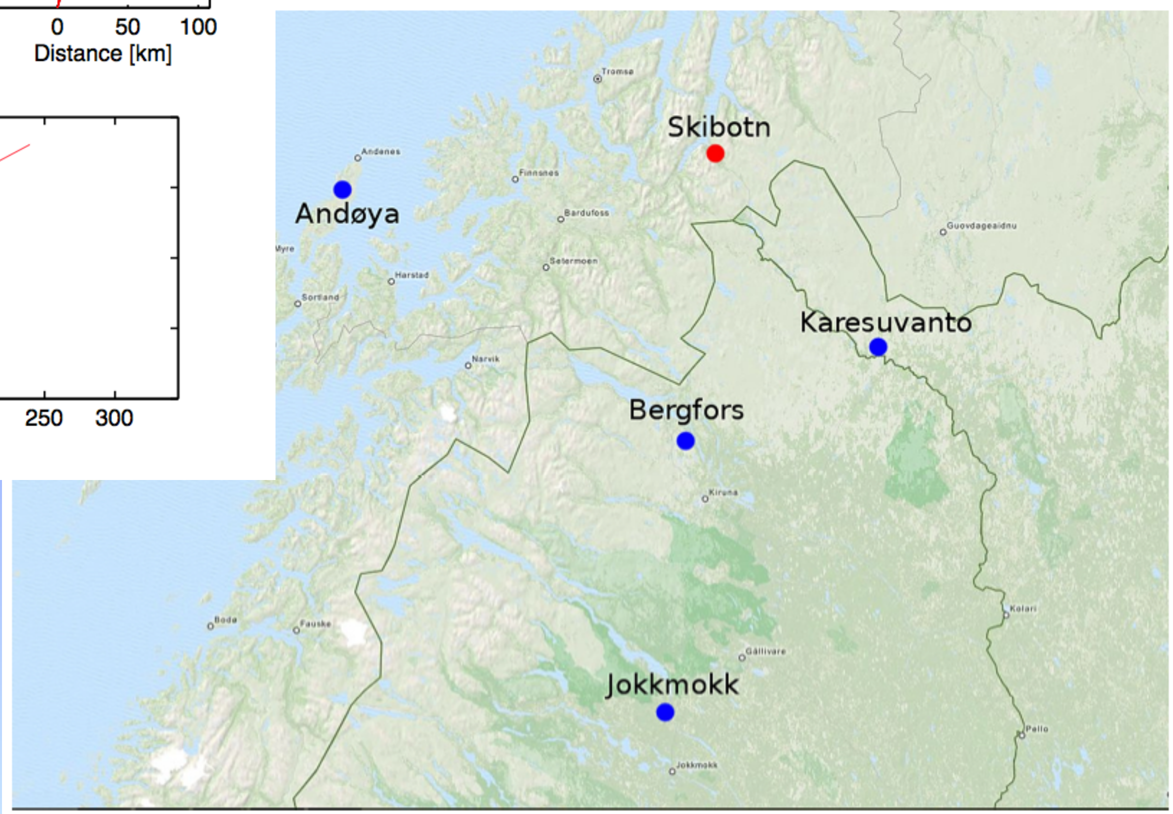


Antennas	Bandwidth from each antenna: 30 MHz Sampling from each antenna: 60 MS/s Data-production per antenna (2 Bytes per sample): 120 MB/s
Antenna groups	100 antennas per group forming beam with two polarisations (pol.) Data-production per group: 2 x120 MB/s = 240 MB/s Assuming 16,000 antennas on one site, there will be 160 groups Total data production: 160 x 240 MB/s = 38.4 GB/s = 138 TB/h Storage in ring buffer (up to three days of full time data): 10 PB
Beam-forming	Antenna groups on each site are combined into 100 beams Data decimated to 1 MHz Data per beam: 2 x 1 MHz x 2 B/sample x 2 pol. = 8 MB/s Total volume of beam-formed data: 100 x MB/s = 800 MB/s
Correlator	Correlated data is reduced by a factor 10 compared to raw data Correlated data use two bands with10 MHz bandwidth Beam: 2 bands x 2 x 10 MHz x 2 B/sample x 2 pol. /10 = 16 MB/s Total volume of correlated data: 100 x16 MB/s = 1.6 GB/s
Fitter	Data produced about 200 GB/yr
Data per year	Assume system running at 10% capacity over one year: Beam-formed data: 0.1 x 365 x 24 x 3600 x 800 MB = 2.5 PB/yr Correlated data: 0.1 x 365 x 24 x 3600 x 1.6 GB = 5 PB/yr Fitted data: 200 GB/yr. Total data to store for one site: 8 PB/yr



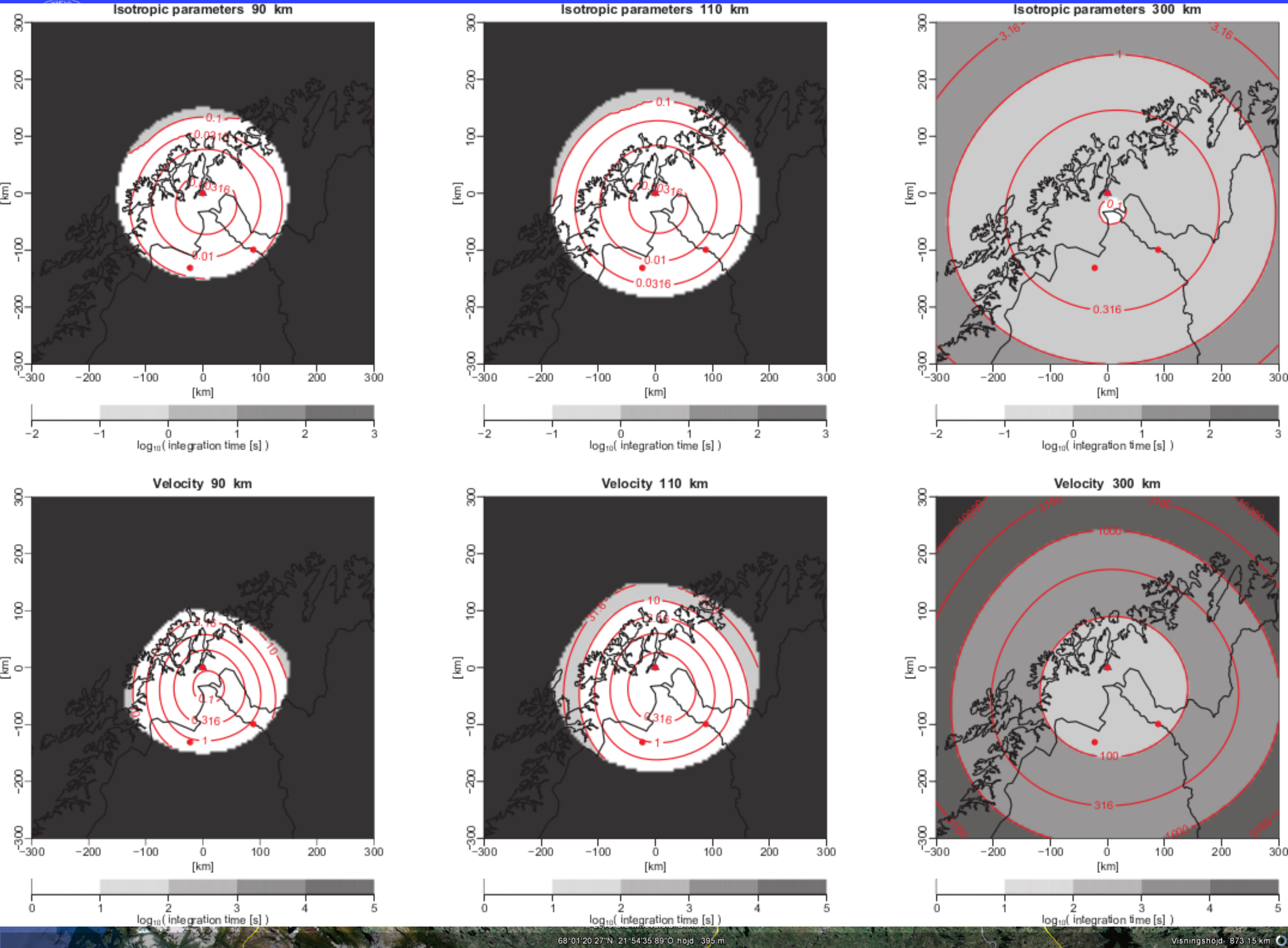
Multistatic Phased Array

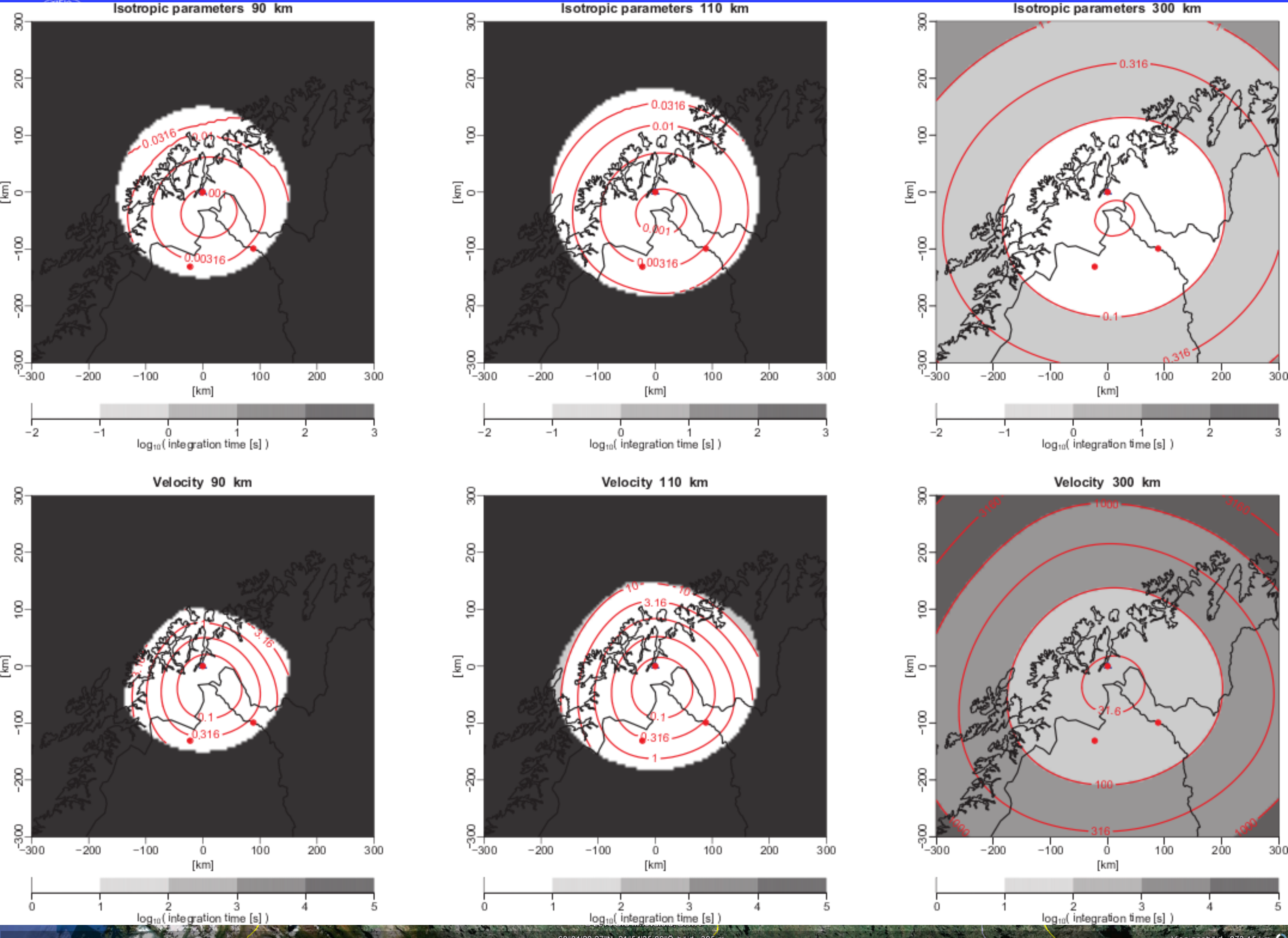




Staged Implementation

- After Stage 4, total of 5 sites
  - Core with 10 MW transmitter (Skibotn, Norway)
  - 4 receive-only (-mostly) sites: Berfgors, Sweden; Karesuvanto, Finalnd; Andøya, Norway; Jokkmokk, Sweden
- Construction plan ordered to provide useful capabilities at each stage


Isotropic parameters 90 km
Isotropic parameters 110 km
Isotropic parameters 300 km
Velocity 90 km
Velocity 110 km
Velocity 300 km
[km]
-300
-200
-100
0
100
200
300
log10(integration time [s])
-2
-1
0
1
2
3
4
5
0.1
0.0316
0.01
3.16
1
0.316
10
31.6
100
316
1000
3160
10000
68°01'20.27"N 21°54'35.89"O höjd 395 m
Visningshöjd 873.15 km



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0.01
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0.00316
0.316
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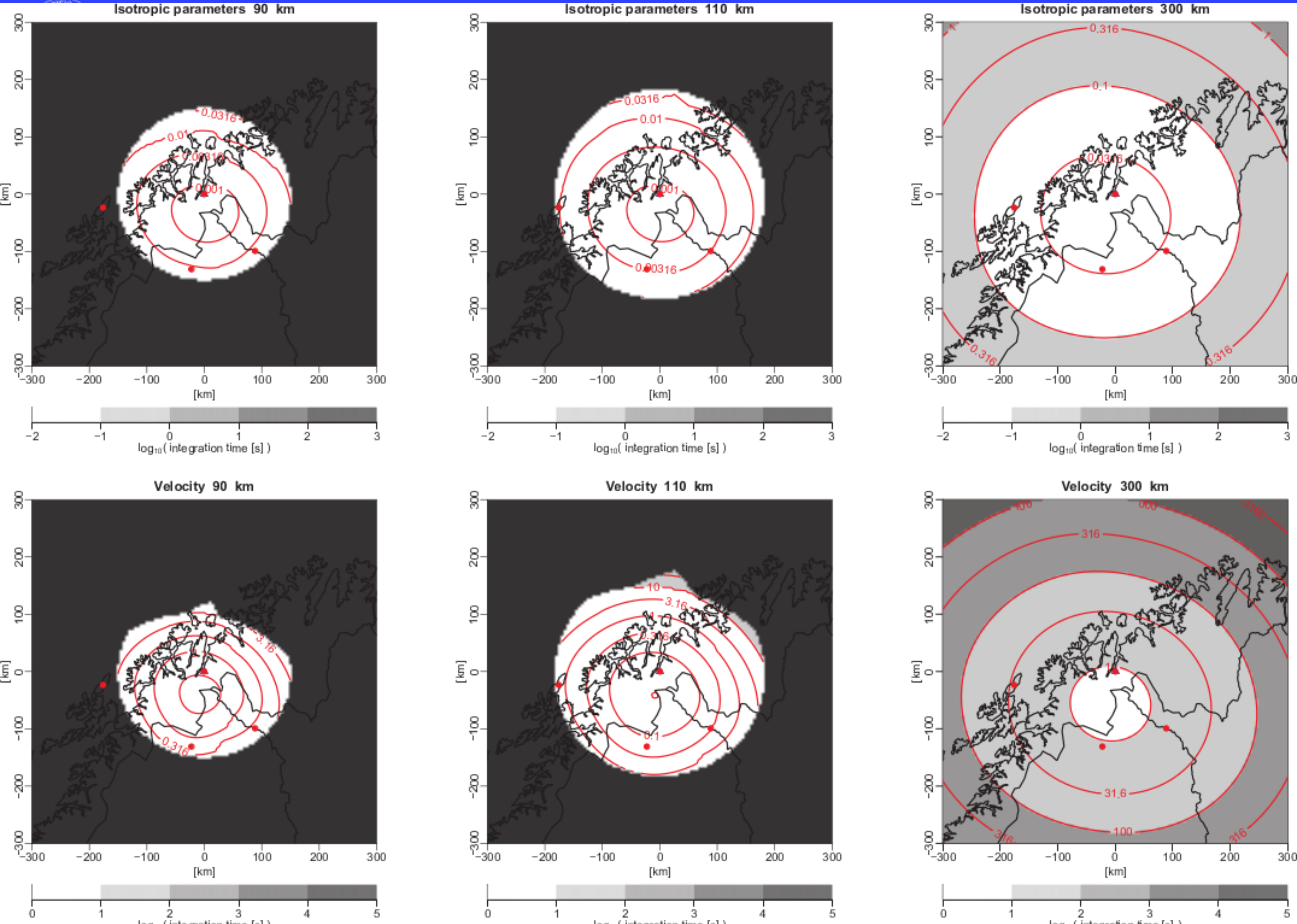

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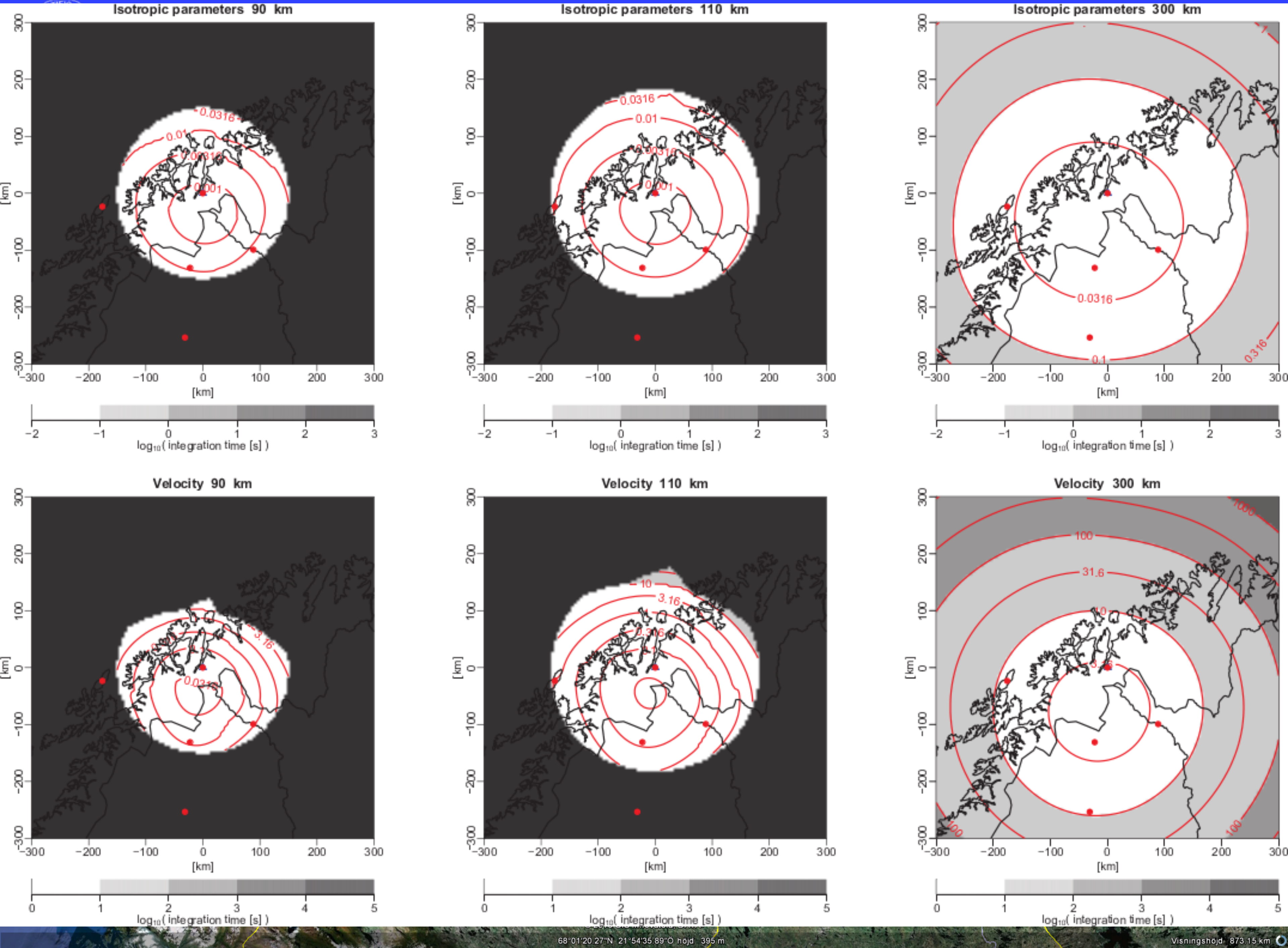

Isotropic parameters 90 km
Isotropic parameters 110 km
Isotropic parameters 300 km
0.0316
0.01
0.00316
0.001
0.1
0.316
1
[km]
-300 -200 -100 0 100 200 300
-2 -1 0 1 2 3
log10(integration time [s])
Velocity 90 km
Velocity 110 km
Velocity 300 km
3.16
10
31.6
100
1000
0.316
0.0316
0 1 2 3 4 5
log10(integration time [s])
68°01'20.27"N 21°54'35.89"O höjd 395 m
Visningshöjd 873.15 km

	Stage 1	Stage 2	Stage 3	Stage 4
1. Atmospheric physics and global change				
a. Vertical coupling between the atmospheric layers				
i. Troposphere	X	X	X	X
ii. Stratosphere	P	X	X	X
iii. Mesosphere	P	P	X	X
b. Turbulence and waves in the mesosphere and lower thermosphere				
i. Polar mesospheric summer echo (PMSE) interferometry	P	X	X	X
ii. MAARSY collaborations (Andøya, Norway)	P	P	X	X
iii. Polar mesospheric winter echo (PMWE) interferometry	P	X	X	X
2. Space and plasma physics				
a. Multiple scale interactions in ionosphere-magnetosphere plasmas				
i. Aurora (tens of meters, fractions of a second) density and velocity	P	X	X	X
ii. Magnetospheric-driven convection (localized & transient)		P	X	X
iii. Substorm processes over a large spatial region		P	P	X
b. Plasma turbulence and active experiments				
i. Naturally enhanced ion acoustic lines (NEIALs)	P	X	X	X
ii. Heating experiments (volumetric imaging of entire pump beam)	P	P	X	X
iii. Self heating in the EISCAT_3D beam		X	X	X
3. Inflow and outflow of matter in the Earth's atmosphere				
i. Meteoroid-atmosphere interactions	P	X	X	X
ii. Meteoric smoke particles (dusty plasmas)	P	X	X	X
iii. Ion upflow	P	X	X	X
4. Space debris, near-earth objects and space weather				
i. Space debris and meteoroid orbital parameters with wide coverage	P	P	X	X
ii. Near-earth objects (NEOs)	P	X	X	X
iii. Continuous measurements for space weather monitoring	P	P	P	X
5. Radio astronomy				
i. Epoch of reionization (EoR)	(P)	(P)	P	X
ii. Exoplanet detection via auroral kilometric radiation (AKR)-like emissions	(P)	(P)	P	X
iii. Trans-ionospheric imaging support	P	X	X	X

Blank – insufficient capabilities X – full capabilities P – partial capabilities (P) – partial capabilitie

EISCAT_3D Project Status

Fp6 Design Phase completed 2009

Fp7 Preparatory Phase on track for 2014 completion

Norway: application submitted Autumn 2012, revised August 2013, next submission Autumn 2014 (with clarifications)

Sweden: application submitted Spring 2013, clarifications submitted

Finland: on roadmap

Japan: on Master Plan 2014

U.K.: recently responded to a request for planning documents

Working to increase the size of the association (Affiliates)

Questions?

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Stages Timeline

Ver 2014-02-27 **EISCAT and EISCAT_3D combined, simulated price-level 2014 and thereafter inflat**

EISCAT	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024

Investment budget, EISCAT_3D system only

Assuming fixed price contracts. Contingency handles currency and inflation changes

Staged Implementation: First stage only (Core + two receive arrays: Bergfors Sweden (as originally planned) and Kaaresuvanto area (new location)

EISCAT_3D construction phases	Planning	Stage 1	Timing depends on funding, example only: Stage 2 / Stage 3 / Stage 4

Stage 1

Core array, Norway	Prep -> Site est	Build	Commissioning - operations		End of first stage
First receive array, Sweden	Site est	Build		Commissioning - operations	
Second receive array, Finland	Site est	Build		Commissioning - operations	
Op centre established, location to be decided		op centre in place - operations			

Stage 2

Core array - 5 -> 10 MW, Norway	Installation

Stage 3

Third receive array	Build

Stage 4

Fourth receive array	Build