

EISCAT 3D - The Next Generation European Incoherent Scatter Radar

A major new European research infrastructure, the EISCAT_3D incoherent scatter radar, will comprise a distributed network of next-generation instruments, planned to surpass all similar facilities, both existing and under construction. It will provide European researchers with access to the world's most advanced incoherent scatter radar. The design goal is ten times higher temporal and spatial resolution than the present radars have, a volumetric radar imaging capability in an extended spatial area with simultaneous full-vector drift velocities at all altitudes, having continuous remote-controlled operation modes, short baseline interferometry capability, real-time data access, automated data analysis and extensive data archiving facilities. The arrays are very large, in the scale of tens of thousands of individual antenna elements. Modular construction principle adds the possibility to improve the system according to available funds, as well as adding more active sites.

Summary of the EISCAT_3D Design Specification Document, 1st Nov, 2005:

System configuration:

- A central transmitting/receiving core facility, located at, or close to, the EISCAT Tromsø radar.
- At least two receiving facilities for the ionospheric F1, F2 and topside regions, located at distances of ~220-280 km south and east.
- At least two receiving facilities for the ionospheric D and E regions, at distances of ~90-120 km south and east
- Data storage and communication systems located at, or close to, each facility.
- Essentially unattended, continuous operation.
- System control, monitoring, data access via Internet.
- Relative time between sites better than 100 ns, absolute time maintained to GPS/Galileo standards.
- At central core beam-steering systems for transmission and reception and several (4–10) outlier, receive-only phased-array antennas for in-beam interferometry.
- At receiving facilities at least 5 beam formers

Spatial resolution:

- Along the transmitted beam better than 100 m.
- Horizontally (~3 dB) at 100 km better than 150 m.

Radar field-of-view (FOV):

- Central core steerable out to a maximum zenith angle of $\approx 40^\circ$ in all azimuth directions. At 300 km altitude, radius of FOV is approximately 250 km.
- Receiving facilities permit tri-static observations to be made at all altitudes up to 800 km.

Beam steering:

- Central core beam steerable into any of ≥ 12000 discrete pointing directions, separated by on average 0.625° in each of two orthogonal planes.
- System will operate on a $< 500 \mu\text{s}$ timescale.
- receive-only sites synchronised with the central core, simultaneous generation of independently steerable beams intersecting the central core beam at different altitudes.
- The D/E region receiving sites will provide 3D coverage from the mesosphere out to 250–300 km.
- The F/topside region receiving sites will provide 3D coverage over the range 200-800 km
- The transmit site will also provide continuing coverage into the topside to ~2000 km

Transmitter parameters:

- Centre frequency: between 220 – 250 MHz, subject to allocation
- Peak output power: ≥ 2 MW
- Instantaneous -1 dB power bandwidth: ≥ 5 MHz
- Pulse length: 0.5–2000 μs
- Pulse repetition frequency: 0–3000 Hz
- Modulation: Arbitrary waveforms, limited only by power bandwidth

Receiver parameters:

- Centre frequency: matching the transmitter cf.
- Instantaneous bandwidth: ± 15 MHz
- Overall noise temperature: ≤ 50 K referenced to input terminals
- Spurious-free dynamic range ≥ 70 dB

2.12 Sensor performance in incoherent scatter mode

The parameters of the different subsystems will be chosen such that, for each of the measurement scenarios tabulated below, the radar will generate estimates of incoherently scattered signal power (or equivalently, uncorrected electron density) with statistical accuracies of better than 10 % in the specified integration times:

Altitude [km]	Electron density [m^{-3}]	T_e/T_i	Ion composition	Height resolution [m]	Integration time [seconds]
80	1×10^{10}	1.0		≈ 100	30
100	3×10^{10}	1.0		100	1
150	1×10^{10}	1.0	50% NO^+ , 50% O^+	100	1
300	3×10^{10}	2.0	100% O^+	300	1
800	3×10^{10}	3.0	5% H^+ , 95% O^+	1000	10
1500	1×10^{10}	4.0	10% H^+ , 90% O^+		60

EISCAT 3D Design Specification Document
FP6-2003-Infrastructures-4: EISCAT 3D Proposal #011920

Appendix 1

Tentative EISCAT 3D System Layout



The figure shows one possible layout of the EISCAT 3D system. In this configuration, the central core (denoted by a green filled circle) is assumed to be located near the present Norwegian EISCAT site at Ramfjordmoen. The dashed circle with a radius of approximately 250 km indicates the approximate extent of the field-of-view of the central core at 300 km altitude. Phased-array receiving sites located near Porjus (Sweden) and Kaamanen (Finland) provide 3D coverage over the (250-800) km height range, while two additional receiving sites near Abisko (Sweden) and Masi (Norway) cover the (70-300) km height range.

The summary information given above is based on the EISCAT_3D Design Specification Document, dated 1st of November, 2005. The design specification document defined the task for the 4-year long EU FP6 - funded EISCAT 3D Design Study, scheduled to end on April 30, 2009. The current partners of the Design Study are EISCAT Scientific Association, University of Tromsø, Luleå University of Technology, Swedish Institute of Space Physics, and Rutherford Appleton Laboratory.

ESFRI Roadmap update, December 2008

ESFRI, the European Strategy Forum on Research Infrastructures, acts on issues related to the development of high scientific quality European research infrastructures. ESFRI's delegates are nominated and mandated by the Research Ministers of the Member States and Associated Countries, and include a representative of the European Commission. The Swedish Research Council proposed EISCAT_3D to be included on the ESFRI Roadmap of large European Research Infrastructures. ESFRI accepted the proposal in December 2008. The ESFRI EISCAT_3D proposal emphasises modular construction of a large distributed radar facility, with a possibility to have several active sites in the final concept. The timeline and rough cost estimate proposed for the ESFRI EISCAT_3D is given below:

Timeline:	Preparatory phase 2009-2011 Construction phase 2011-2015 Operation 2015-2045	Construction: 60 M€ one active site 250 M€ all sites
Estimated costs:	Preparation: 6 M€	Operation: 4-10 M€/year Decommissioning: 10-15% of construction
		Website: http://www.eiscat3d.se/

EISCAT_3D Science

These extremely large scale atmospheric and space environment radar arrays open up unprecedented science and technology application opportunities, well beyond the traditional ground-based ionospheric remote sensing role of the old incoherent scatter radars. The ground-based "window to geospace" provided by EISCAT_3D will naturally enhance research opportunities in studying the solar variability, development of solar wind and its interaction with Earth's environment, the coupling between the ionosphere and the magnetosphere, the physics of the aurora, the structure and coupling of the ionosphere and thermosphere, the coupling between the upper, middle and lower atmosphere, chemical effects of high ionisation on lower thermosphere, mesosphere and upper stratosphere, small-scale plasma physics, layered phenomena in the atmosphere, meteors, space debris and near-Earth objects, as well as it will provide better tools for long-term monitoring of global atmospheric change, monitoring the mesosphere and stratosphere, and for developing methods for special applications such as planetary and lunar radar, satellite navigation, heterodyne reflectometry and magnetotelluric soundings, and finally as a massive data provider it will serve as unique resource in assimilative modeling and virtual observatory work.

Preliminary results of the EISCAT_3D Design Study, status 2nd Feb 2009

The results of the Design Study are continuously published at the EISCAT web pages (http://e7.eiscat.se/groups/EISCAT_3D_info) and will be presented in final form to EISCAT users at a meeting in *Uppsala, 28th of May, 2009*. The current version of proposal by the Design Study for one option as the active element is given below:

- The Norwegian Telecommunication authority offers a spectrum allocation 229,928-236,632 MHz.
- Only a full-grown phased array system can approach the active element performance demanded by the scientific user community.
- A filled circular aperture with the array elements laid out on an equilateral triangular grid is proposed for the active element array. An element-element distance of 0.7λ will provide essentially grating-lobe free performance out to 40° zenith angle.
- The individual array element will comprise a radiator, a dual 300+300 watt linear RF power amplifier, a high performance direct-digitising receiver, a digital signal processing system and support electronics. The radiator is proposed to be a crossed Yagi antenna with a minimum directivity of about 7 dBi.
- The array will be physically subdivided into hexagonal groups of 49 elements. For practical reasons, all electronics for the group could be housed in a common equipment container and the radiators connected to the container by low-loss coax cable.
- The target is proposed to be a 16000-element, 120-m diameter array. This will have a half-power beamwidth of $\approx 0.75^\circ$, i.e. comparable to that of the EISCAT UHF. Its power-aperture product will be ≈ 100 GW m², i.e. about one order of magnitude greater than that of the EISCAT VHF when operated in single-beam, dual klystron mode (Mode 1).
- Modular construction could start minimally with a 5000-element, 70-m diameter array, which already would exceed the performance of the current VHF system, providing a 1.3° half-power beam-width, a power-aperture product of ≈ 10 GW m², and full steerability.
- A basic set of receive-only outlier arrays for interferometry should be put in place from the start to meet the horizontal resolution performance requirement.
- Relaxing the height resolution by a factor of 4-10 (from 100 m to 1 km at 150-km altitude and from 1 km to 4 km at 300-km altitude), would put the 16000-element array in a position to meet the PSD time resolution requirements.