The ESFRI Roadmap infrastructure facility EISCAT_3D - a new opportunity for ionospheric research

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EISCAT_3D is Europe's next-generation radar for the study of the high-latitude atmosphere and geospace, to be located in northern Fenno-Scandinavia. EISCAT_3D's capabilities go well beyond anything currently available to the international incoherent scatter research community. The facility consists of several very large active phased-array antenna transmitters/receivers and multiple passive sites located in three countries and comprising from tens of thousands to more than 100 000 individual antenna elements.

In December 2008, EISCAT_3D was placed on the updated ESFRI Roadmap of large research infrastructures, which are of strategic importance for the European research area for the next 20-30 years, by ESFRI, the European Strategy Forum for Research Infrastructures. During the years 2005-2009 the first 2.8 MEUR Design Study of EISCAT_3D was carried out. The Design Study received about 2 MEUR support from EU. In 2010 EU approved a 4.5 MEUR funding for the Preparatory Phase project of EISCAT_3D. The Preparatory Phase starts in October 2010 and is scheduled to be run for 4 years. Construction of EISCAT_3D is to be started in the end of the Preparatory Phase project, provided that international funding commitments are in place by that time. In Finland University of Oulu and Regional Development Funds of Lapland are currently funding a 1 MEUR development project for prototyping EISCAT_3D technology, and a larger project for EISCAT_3D receiver sites in Finland is currently under development.

EISCAT_3D combines several key attributes which have never before been available together in a single radar, such as volumetric imaging and tracking, interferometric imaging, multistatic configuration, improved sensitivity and transmitter flexibility. The use of advanced beam-forming technology allows the beam direction to be switched in milliseconds, rather than the minutes which it can take to re-position dish-based radars. This allows very wide spatial coverage to be obtained, by interleaving multiple beam directions to carry out quasi-simultaneous volumetric imaging. It also allows objects such as satellites and space debris to be tracked across the sky. At the passive sites, the early design allows for at least five simultaneous beams at full bandwidth, rising to at least over twenty beams if the bandwidth is limited to the ion line, allowing the whole range of the transmitted beam to be imaged from each passive site, using holographic radar techniques.

EISCAT_3D has a modular configuration, which allows an active array to be split into smaller elements to be used for aperture synthesis imaging. The result will be an entirely new data product, consisting of range-dependent images of small sub-beamwidth scale structures, with sizes down to 20m. EISCAT_3D will be the first phased array incoherent scatter radar to use a multistatic configuration. A minimum of five radar sites, consisting of two pairs located around 120km and 250km from the active site respectively, on baselines running East and South from the active core, is envisaged in the Design Study. This would provide an optimal geometry for calculation of vector velocities in the middle and upper atmosphere. However no decisions on the locations of the EISCAT_3D sites have yet been made. The currently starting Preparatory Phase project will define the site locations in an early phase, based on optimization of science merits and the use of nationally available and feasible infrastructure possibly still to be developed.

The gain of the EISCAT_3D antennas and the large size of the active site arrays will deliver an enormous increase in the figure-of-merit relative to any of EISCAT's existing radars. An active site of 5,000 elements would already exceed the performance of the current EISCAT VHF system, while a active site comprising 16,000 elements, as suggested in the Design Study during the years 2005-2009, will exceed the sensitivity of the present VHF radar by at least an order of magnitude. Each transmitter unit will have its own signal generator, allowing the generation and transmission of arbitrary waveforms, limited only by the available transmission bandwidth and spectrum mask as allocated by the respective frequency management authorities. This allows the implementation of all currently used and envisaged modulation schemes and antenna codings (such as polyphase alternating codes, array tapering, orbital angular momentum beams) and also provides the possibility to adopt any kind of future code. In addition, it will allow advanced clutter mitigation strategies such as adaptive null steering and null shaping.

In Finland, a recent new proposal of developing a software radio solution for EISCAT_3D signal processing, based on the use of clustered general purpose computers, instead of dedicated hardware for the second level beam forming, may lead to significant reduction in the costs estimated during the Design Study. Most importantly, with the proposed solution a more flexible use of methods based on inversion mathematics is envisaged. This proposal will be prototyped and evaluated during the nationally funded Finnish project which supports the Preparatory Phase, using a test receiver based on the industrially produced LOFAR antennas for radio astronomy.

In this talk the concept solutions proposed for EISCAT_3D and the upper atmosphere and geospace science case for EISCAT_3D are reviewed. Studies of atmospheric energy budget, space plasma physics with both small-scale structures and large-scale processes, as well as geospace environment monitoring and possible service applications are reviewed by showing the recent highlights by the current EISCAT incoherent scatter radars for comparison.