A new model of radar technology

After 30 years in operation, incoherent scatter radars are receiving a major upgrade. **Dr Esa Turunen** and **Dr Jonny Johansson** discuss their current research activities and reveal the technology behind the rejuvenation of these radars which will allow scientists to monitor geospace in detail

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Can you summarise the overarching aims and objectives of the EISCAT_3D project?

Addressing the interactions between geospace and the atmosphere, as well as between the atmospheric layers themselves, EISCAT_3D offers a unique research opportunity to study the atmospheric energy budget and solar system influences, such as the effects of solar wind, meteors, dust, energetic particles and cosmic rays in the atmosphere.

EISCAT_3D will be the next-generation incoherent scatter radar (ISR) for the study of the atmosphere and geospace. It will be a distributed phased-array facility with up to 100,000 individual antenna elements. EISCAT_3D will be capable of making continuous measurements from the middle atmosphere to the magnetosphere. Some capacity for tropospheric measurements is also envisaged.

In what sense do EISCAT_3D's capabilities go beyond equipment currently available to the international research community?

EISCAT_3D will provide a 30 year update to EISCAT's existing mainland facilities, exploiting recent advances in state-of-the-art electronics, networking, storage and computing. In doing so, it will outstrip the capabilities of any such radar operating in the world and become the centrepiece of the international network of instruments monitoring the Earth's upper atmosphere and space environment.

In summary, EISCAT_3D will go beyond anything currently available in ISR technology, with multiple large phased-array antenna transmitters/receivers and multiple receiver sites, direct-sampling receivers and digital beam-forming and beam-steering.

What progress has been made in surveying and selecting specific sites for the new multiple antenna array instruments?

During the EISCAT_3D Design Study 2005–2009 a complete site survey for one core transmitter/receiver site and four candidate receiver sites was carried out. The survey included identifying suitable land areas for construction, measuring possible radio interference present at the sites, mapping the existing infrastructure in the neighbourhood of the proposed site and assessing the need to upgrade the supporting infrastructure. This site survey was optimised for multiple site measurement geometry when considering the core site to be located at the same area as the current UHF and VHF transmitters. Final locations of the sites will be selected according to the science needs, suitability of the land and availability of supporting infrastructure.

The 15th EISCAT International Workshop is set to take place from 5-9 September this year in Qingdao, China. What will this event facilitate, and can you at this stage anticipate the key issues that will be reported?

In 2011 we will have the celebration of 30 years of incoherent scatter measurements by the EISCAT radars. But we will not only be looking back, we will emphasise the outlook for the future with two sessions: one on the status of EISCAT_3D itself and another one on the global use of incoherent scatter radars. There is a new era of ISR measurements starting globally at the moment, and we anticipate a vast amount of new results being published at the Qingdao workshop.

What steps are being taken to ensure the project receives adequate exposure and publicity, both within the research community and to society at large? In what ways is the project capitalising on social media in this regard?

The younger generation in the EISCAT user community has initiated full use of modern social media. The purpose here is to ensure a living and vivid communication among the user community, enhancing their coherence as well as providing easy access to new users. In addition to a separate web page area for the EISCAT_3D project, there are blog pages, a Facebook page and a Twitter feed. Last year we produced an introductory video of the EISCAT_3D concept. In addition to the physical DVD, this is available to watch and download on YouTube and from our own webpages. The video was also broadcast on one national TV channel last year.

In which ways does Luleå Technical University contribute to the EISCAT_3D project, and what are the benefits of participating?

Luleå University of Technology (LTU) is located in northern Sweden, in fairly close proximity to the planned EISCAT_3D radar. As a university, LTU holds responsibilities within education, research, and interaction with the surrounding society. The involvement in EISCAT_3D contributes to all of these. The development in itself involves a number of research questions which, when dealt with, will also propagate to regular education and project courses. When built, the EISCAT_3D system will be a major instalment in northern Scandinavia and as such contribute to growth as well as to employment possibilities, both of which are desired outcomes for the work performed at LTU. The main LTU responsibilities in the project are the antenna front end electronics and antenna/array design, which are areas coupling closely to well established research areas within LTU.

Constructing an atmosphere watchdog

EISCAT_3D, a next-generation phased array technology radar, marks a major advance for environmental scientists by establishing five new radar sites which could transform the way we measure changes in the Earth's atmosphere

A KEY OBJECTIVE for environmental scientists for years and even decades to come will be measuring and understanding the effects of manmade change on the Earth. Most of the changes cannot be seen with the naked eye or as one goes about daily life; they must be studied from above the Earth's surface in what is known as 'geospace' – the Earth's upper atmosphere and the region of interplanetary space surrounding the Earth.

This region has been studied previously using incoherent scatter radars (ISR) for ground-based remote sensing of geospace. The European Incoherent Scatter Scientific Association (EISCAT) currently has ISRs in operation in mainland Scandinavia and on Svalbard, however technology has advanced significantly since their construction in the late 1970s, and the radar has become out of date. Therefore, EISCAT are currently working on developing a new and improved model of their previous radar called EISCAT_3D. The model will work at a new frequency and exploit 21st Century phased array technology to provide observations which have not been possible with existing EISCAT radar.

Dr Esa Turunen, Director of the EISCAT Scientific Association, notes that the radar stretches the traditional mindset and capabilities traditionally associated with ISR: "EISCAT_3D represents new thinking about the available tools for environmental science. We should understand where we live in the universe as a wider concept through the needs of our modern society. These needs include understanding the whole geospace environment as a system and being able to forecast and mitigate effects caused by space weather variations".

NEXT-GENERATION TECHNOLOGY

EISCAT_3D is an improvement on traditional incoherent scatter radars (ISR) which were unable to be operated as continuously measuring geophysical instruments, as Turunen remarks: "Traditional ISRs, using klystron-based transmitters, performed campaign-based operations; the new continuous operation capability with distributed solid-state power amplifiers is a major change in the philosophy of the ISR method".

The new radar system will house several large fields of antennas, known as phased arrays, some of which will be equipped to both transmit and receive signals, whilst others will remain passive receivers. The project currently plans to design at least five radar sites, one of which will be the central site and include a transmitter. Depending upon funding, the sites may be enlarged or given additional transmitting capabilities.

Furthermore, the new model will be a 'software radar' meaning, unlike its predecessor, EISCAT_3D can easily be improved and updated simply by changing the software and necessary parts of the hardware as new technologies and solutions arise.

The sites will be spread across the northern regions of Norway, Sweden and Finland, situated just under the auroral oval. These locations offer unique research opportunities since, as Turunen describes: "The couplings in geospace, from the solar wind to the magnetosphere, ionosphere and atmosphere are strongest here, as a result of the geometry of the Earth's intrinsic magnetic field. This is manifested by the visual phenomenon of the Northern Lights, or Aurora Borealis". The penetration into the atmosphere of the charged particles to which Turunen refers is strongly reduced at lower latitudes by the Earth's magnetic field, and is therefore more difficult to gather measurements.

PHASES TO COMPLETION

The project has now entered the Preparatory Phase, scheduled to run until 2014. The team is working to resolving any issues blocking the path to beginning construction on the radar. There will also be talks to finalise the site selections and frequency allocations, in order to secure the required land once funding falls into place. Any remaining design issues will be cleared up and the assembly of prototypes of key system elements will take place in order to determine their reliability and cost-effectiveness.

Next, the team will commence the Construction Phase. This work is planned to finish in 2016 with the EISCAT_3D radar sites fully prepared and the new hardware assembled. All of the necessary computing, storage and networking facilities will be put into place and the system will go through strict testing to ensure the functional reliability of the radar.

The culmination of all the work in the previous three phases will result in the project entering its Operational Phase, in which the radar will run continuously and largely autonomously for a 30 year lifespan.

INTERNATIONAL COLLABORATION

The project benefits from a tradition of collaboration within the community of incoherent scatter radars. For many years

AN EXAMPLE OF HOW AN ACTIVE SITE (A SITE WITH BOTH TRANSMITTERS AND RECEIVERS) MAY LOOK

the sector has organised and coordinated a World Day Programme, where certain science goals are selected to be taken into account in a global effort. Turunen expands on this work remarking: "The incoherent scatter community is thus prepared to take these actions further, for example, as part of possible globally coordinated targeted science tasks, where model development, data assimilation and access to globally relevant information is brought to practical science programme level".

EISCAT_3D follow in this tradition of global collaboration, as is evident by their strong ties with the U.S. "In the future, we would like to regard our radars, and also any other new-generation incoherent scatter radars, as a joint global instrument, which then finally would have a joint science programme directed to the most relevant science questions," says Turunen. The joint instrument and programme mentioned would require possible modifications to the training regimen for future radar scientists, as it requires them to work on a more global scale and with global data. With this in mind, Turunen and his partners are already looking towards organising global incoherent scatter radar schools along with colleagues from the U.S.

Because of EISCAT_3D's dedication to international collaboration, the project has been invited to participate in science and political discussions by the EU and the National Science Foundation. The two organisations are currently in talks to determine ways to jointly advance and finance the development, operation and use of large-scale research infrastructures. EISCAT_3D will contribute their experience in operating a joint database standard with open access to ISR data.

LONG LASTING BENEFITS

EISCAT_3D will be able to make important contributions to identifying and monitoring environmental problems. The radar will make significant contributions to understanding the impact climate change has on the upper layers of the atmosphere by measuring any changes. The radar will also be able to aid satellite observations of the ice and snow in polar areas, which are also feeling the effects of changing climate conditions.

An emerging type of environmental problem which EISCAT_3D will be able to observe is space junk also known as space debris. The term refers to all of the manmade objects that are left in orbit around the Earth after they can no longer fulfil any purpose. Observing these objects allows ISR to play a role in risk management since they pose a threat to space missions and satellites which could enter their path. Since EISCAT_3D will be 10 times more sensitive than any radar currently available, the accuracy in detecting space junk will be greatly increased.

Another major benefit of this new model is that it will be designed to allow for upgrades: "It is important to note that since the EISCAT_3D facility will be constructed for an operational period of several decades, the software radar concept allows the upgrading and enhancement of the measurement capability according to new solutions in computing and data storage". So while these are many relevant contemporary benefits of creating EISCAT_3D, there will be new applications emerging as both technology and our planet evolve.

EISCAT_3D

A EUROPEAN THREE-DIMENSIONAL IMAGING RADAR FOR ATMOSPHERIC AND GEOSPACE RESEARCH

OBJECTIVES

To build a next generation incoherent scatter radar system for high-latitude atmosphere and geospace studies in northern Fenno-Scandinavia.

PARTNERS

Institutet för Rymdfysik, Sweden
National Instruments Belgium Nv, Belgium
Vetenskapsrådet – Swedish Research Council, Sweden
Luleå Tekniska Universitet, Sweden
Universitetet i Tromsø, Norway
Oulun Yliopisto, Finland
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DR ESA TURUNEN has been the director EISCAT Scientific Association since 2009. He finished his PhD at the University Of Oulu, Finland in 1993 on interpreting ionospheric D-region measurements, using a detailed theoretical ion-chemistry model. He worked as the Head of Aeronomy Division of Sodankylä Geophysical Observatory until 2009. During his time in Finland he acted as the principal investigator during Finnish radar and rocket campaigns.

DR JONNY JOHANSSON was born in 1968. After receiving his MSc degree he worked from 1992 to 1999 for ABB with development of high-voltage measurement systems. In 1999 he joined EISLAB at Luleå University of Technology, from which he received a PhD degree in 2004. He is currently a Senior Lecturer, with research interests including low-power mixed-mode design for sensor systems.